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Response of freshwater algae to water quality in Qinshan Lake within Taihu Watershed, China

Jianying Zhang [a,*], Wanmin Ni [a], Yang Luo [a], R. Jan Stevenson [b], Jiaguo Qi [c]

[a] Environment and Ecology Research Center, College of Environmental and Resource Sciences, Zhejiang University, Hangzhou 310028, China
[b] Center for Water Sciences, Michigan State University, East Lansing, MI 48824, USA
[c] Center for Global Change & Earth Observations, Michigan State University, East Lansing, MI 48824, USA

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ABSTRACT

Although frequent algal blooms in Taihu Lake in China have become major environmental problems and have drawn national and international attention, little is understood about the relationship between algal blooms and water quality. The goal of this study was to assess the growth and species responses of freshwater algae to variation in water quality in Qinshan Lake, located in headwaters of the Taihu watershed. Water samples were collected monthly from ten study sites in the Qinshan Lake and were analyzed for species distribution of freshwater algae and physiochemical parameters such as total nitrogen (TN), NH_4^+–N, NO_3^-–N, total phosphorus (TP), chemical oxygen demand (COD_{Mn}) and Chl-a. The results showed that average TN was 4.47 mg/L, with 92.2% of values greater than the TN standard set by the Chinese Environmental Protection Agency; average TP was 0.051 mg/L, with 37.9% of values above the TP national standard; and average trophic level index (TLI) was 53, the lower end of eutrophic condition. Average Chl-a concentration was 12.83 mg/m^3. Green algae and diatom far outweighed other freshwater algae and were dominant most time of the year, with the highest relative abundances of 96% and 99%, respectively. Blue-green algae, composed mainly toxic strains like *Microcystis* sp., *Nostoc* sp. and *Oscillatoria* sp., became most dominant in the summer with the maximum relative abundance of 69%. The blue-green algae sank to the lake bottom to overwinter, and then dinoflagellates became the dominant species in the winter, with highest relative abundance of 89%. Analysis indicated that nutrients, especially control of ammonia and co-varying nutrients were the major restrictive factor of population growth of blue-green algae, suggesting that control in nutrient enrichments is the major preventive measure of algal blooms in Qinshan Lake.

1. Introduction

Large scale algal bloom, primarily caused by eutrophication due to nutrient enrichment from agricultural non-point sources, has been one of the most serious water environmental problems (Vasconcelos and Pereira, 2001; Mohamed et al., 2006; Vareli et al., 2009; Prakash et al., 2009). Algae blooms caused by eutrophication in freshwater lakes in China are increasingly serious, such as those intensive and large scale algal blooms in Taihu Lake, Dianchi Lake and Chaohu Lake (Xu et al., 2005; Liu et al., 2006a,b; Ye et al., 2008; Zhang et al., 2009). Recently some streams and reservoirs have also evidenced various levels of eutrophication (Shi and Qu, 2005; Dai et al., 2008a,b). Studies have concluded that the frequent algae blooms in Taihu Lake in summers were related to nutrient enrichment, primarily in nitrogen and phosphorus, from primarily agriculture non-point pollution (Wang et al., 2004). Microcystis was widely distributed worldwide among the algae species (Oliver and Ganf, 2000) and perhaps was the most studied genus of toxin-producing cyanobacteria, which lead to the production of microcystins harmful in drinking water. The outbreak of algae bloom requires then nutrients to reach a certain level, or threshold, under suitable environmental conditions. In this study, we analyzed the relationship between nutrients levels and algae species and concentration in order to better understand the thresholds of nutrients in freshwater lakes in China, thus providing science-based information for developing algal blooms prevention policies.

2. Materials and methods

2.1. Study area and experimental design

The study site (Fig. 1) is the Qinshan Lake (119°45′42.06″E–119°48′00.32″E, 30°13′32.56″N–30°15′18.64″N) with a total area of about 10 km^2 and is located in the Taihu watershed in Lin'an county, just about 100 km west of Hangzhou city in China. The lake

* Corresponding author. Tel./fax: +86 571 88273099.
E-mail address: zjy@zju.edu.cn (J. Zhang).

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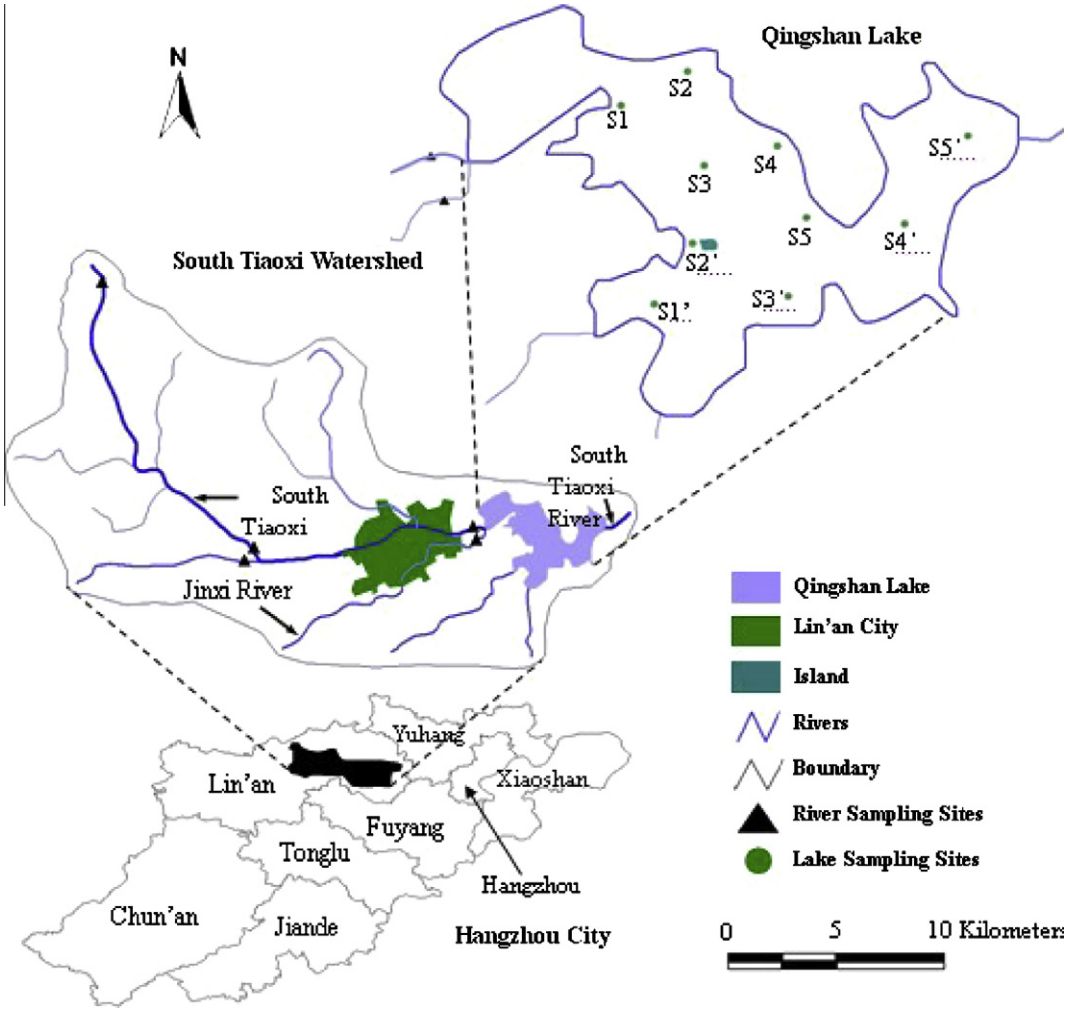

Fig. 1. Map for study area and sampling site.

serves as the major drinking water sources, but wastewater from industry upstream and residential sewage the lake have caused severe eutrophication, a major cause of frequent algal blooms.

Water samples (Table 1) were collected monthly from the Qinshan Lake and were analyzed for species distribution of freshwater algae and physiochemical parameters such as total nitrogen (TN), NH_4^+–N, NO_3^-–N, total phosphorus (TP), chemical oxygen demand (COD_{Mn}) and Chl-a from January 2008 through March 2009. Water quality and algae data were obtained from ten sites in the lake, with one site (site 3) located in the western inlet one at the outlet dam (site 7). *In-situ* temperature, dissolved oxygen, turbidity, conductivity, salinity and pH were measured using multi-parameter water quality metrical equipment (YSI 556MPS) (Table 2). Lake water depth was measured by sonar only from October through December 2008. Water samples were collected and brought to the laboratory for algae species analysis. All samples were analyzed using optical microscopy for presence of harmful cyanobacterial such as *Microcystis* spp., *Nostoc* spp. and *Oscillatoria* spp.

Annual average water temperature in Qinshan Lake was 19.10 °C, DO concentration was 5.68–9.34 mg/L, annual average conductivity was about 0.34 mS/cm, and turbidity was 32–115 NTU, which was affected by human activities such as touring boats and dredges (see Table 3).

Table 1
Sample stations and their locations in Qingshan Lake.

Samples	Lat/long	Samples	Lat/long
Site 1	30°14.36 N, 119°46.33E	Site 6	30°14.55 N, 119°47.03E
Site 2	30°14.99 N, 119°45.99E	Site 7	30°14.72 N, 119°47.56E
Site 3	30°15.24 N, 119°45.69E	Site 8	30°14.19 N, 119°47.46E
Site 4	30°14.84 N, 119°46.85E	Site 9	30°14.10 N, 119°46.94E
Site 5	30°15.22 N, 119°46.34E	Site 10	30°14.20 N, 119°46.09E

2.2. Algal biomass

Samples were collected for pigment determination. Chlorophyll-a was measured using hot-ethanol as extraction solvent (Jespersen and Christofersen, 1987). To measure pigments, 250 mL aliquots were filtered through Whatman AH glass fiber filters, and were held frozen over desiccant until analysis.

2.3. Analysis methods

For the analysis of TN, a water sample of 10 mL was autoclaved at 120–124 °C for 30 min after alkalinc $K_2S_2O_8$ was added, and then cooled before 10% hydrochloric acid of 1 mL was added, and the sample was measured by alkaline potassium persulfate digestion-UV spectrophotometric method (GB11894-89, PR China) at 220 nm and 275 nm (Shimadze UV2450, Japan). TP was measured as the sum of dissolved P and particulate P by ammonium molybdate spectrometric method (GB11893-89, PR China). A water