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Impacts of two biomanipulation fishes stocked in a large pen on the plankton abundance and water quality during a period of phytoplankton seasonal succession

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ARTICLE INFO

Article history:
Received 2 March 2007
Received in revised form
31 December 2007
Accepted 5 January 2008

Keywords:
Biomanipulation
Filter-feeding fish
Pen culture
Silver carp
Bighead carp
Microcystis

ABSTRACT

Silver and bighead carp were stocked in a large pen to control the nuisance cyanobacterial blooms in Meiliang Bay of Lake Taihu. Plankton abundance and water quality were investigated about once a week from 9 May to 7 July in 2005. Biomass of both total crustacean zooplankton and cladocerans was significantly suppressed by the predation of pen-cultured fishes. There was a significant negative correlation between the N:P weight ratio and phytoplankton biomass. The size-selective predation by the two carps had no effect on the biomass of green alga *Ulothrix* sp. It may be attributed to the low fish stocking density (less than 40 $g\,m^{-3}$) before June. When *Microcystis* dominated in the water of fish pen, the pen-cultured carps effectively suppressed the biomass of *Microcystis*, as indicated by the significant decline of chlorophyll *a* in the >38 μm fractions of the fish pen. Based on the results of our experiment and previous other studies, we conclude that silver and bighead carp are two efficient biomanipulation tools to control cyanobacterial (*Microcystis*) blooms in the tropical/subtropical eutrophic waters. Moreover, we should maintain an enough stocking density for an effective control of phytoplankton biomass.

1. Introduction

The trophic state of a lake is controlled not only by external nutrient load, but also by the structure of the food web. The use of food web manipulation as a method for the control of cyanobacterial blooms has been extensively studied for many years (McQueen et al., 1989; Horppila et al., 1998; Kasprzak et al., 2002).

Fish is a major factor determining the algal blooms, structuring the composition of both zooplankton and phytoplankton communities (Lazzaro et al., 2003). Fish predation strongly suppresses the zooplankton even during the winter (Jeppesen et al., 2004). The decline of phytoplankton biomass has been observed as a response of reductions or removal of planktivorous fish and this has been attributed to increased zooplankton grazing (Shapiro et al., 1975). Large-sized zooplankton are known to be highly efficient grazers and may be more important for the improvement of water quality. A 'clear water phase' in early summer may be attributed to the grazing of large crustacean zooplankton (Talling, 2003). Fish kills or low fish recruitment may lead to high grazing pressure on phytoplankton and clear water conditions throughout the summer (Hosper and Meijer, 1993; Jeppesen et al., 2004). However, most experiments are focused on zooplanktivorous fish that are dominant in temperate lakes (Kasprzak et al., 2002). In tropical or subtropical eutrophic lakes, the potential for controlling the

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doi:10.1016/j.ecoleng.2008.01.006

water quality with zooplankton grazing is often more questionable than in temperate lake, and the possible reasons are attributed to the uningestible size, grazing-resistant coverings and the toxicity associated with certain species of cyanobacteria (Horppila et al., 1998). Meanwhile, the top-down effect of zooplankton on phytoplankton is related to the tropic state of a lake (McQueen et al., 1989). It is unclear whether models developed for temperate systems, such as the trophic cascade hypothesis, are appropriate for the tropics (Lazzaro et al., 2003).

Silver carp (*Hypophthalmichthys molotrix*) and bighead carp (*Aristichthys nobilis*) are two native planktivorous fishes in China. There were many controversial reports on the effects of silver and bighead carp on phytoplankton communities. Some authors have thought that stocking of these carps may increase nannoplankton and reduce herbivorous zooplankton, or even increase total chlorophyll *a* and algal biomass (Lieberman, 1996; Domaizon and Devaux, 1999). But much research has indicated that stocking of silver and bighead carp for biomanipulation is appropriate in tropical or subtropical lakes that are highly productive and naturally lack large-sized cladoceran zooplankton (Starling et al., 1998; Radke and Kahl, 2002). Moreover, much N and P can be removed form the lake through harvesting the fish products (Li and Yang, 1995). In southern China, silver and bighead carp have been stocked in many lakes for the sake of controlling algal blooms (Xie, 2003).

In Meiliang Bay of Lake Taihu, silver and bighead carp were cultured in pens for the control of *Microcystis* blooms in drinking water resource. The main objective of the present study was to evaluate the influence of silver and bighead carp on the plankton communities and water quality during a period of phytoplankton seasonal succession from late spring to early summer with emphasis on the applicability of stocking filter-feeding fishes in large fish pens to control *Microcystis* blooms.

2. Materials and methods

Lake Taihu, the third largest freshwater lake in China, is located in the south of the Yangtze River delta. The total area of the lake is 2338 km^2, with an average depth of 2 m, and a total volume of 47.6×10^8 m^3. It is very important of the urban water supply and irrigation. Because of a large population increase and rapid industrial and agricultural pollution in the lake's drainage basin, Lake Taihu has undergone rapid eutrophication (Pu et al., 1998; Qin et al., 2004).

A large fish pen (total surface area 1.08 km^2 and mesh size 2 cm × 2 cm) was built in Meiliang Bay of Lake Taihu. Silver and bighead carp were stocked in the pen in order to reduce the dense *Microcystis* blooms in the bay in the warm months. The fish pen experiment was a part of the Lake Taihu restoration program. Field sampling was conducted between 9 May and 7 July in 2005 when the fish biomass was estimated to be 35–70 g m^{-3} in the pen. Four sampling stations were set up: Stations 1 and 2 were in the center of the fish pen, and Stations 3 and 4 were located in just outside the fish pen (Fig. 1).

Sampling was carried out approximately once a week. Integrated water column samples were collected with the Patalas-Schindler trap. Surface water temperature was measured with a thermometer. pH and conductivity were measured by a pHB-4pH meter (Leici Instrument Co., Shanghai, China) and a DDB-303A meter (Leici Instrument Co., Shanghai, China), respectively. Water transparency was measured with a 20-cm diameter black and white Secchi disk. Orthophosphate (PO_4–P) was analyzed by the ascorbic acid method. Total phosphorus (TP) and total dissolved phosphorus (TDP) were measured by the same method after persulphate digestion in disposable polycarbonate bottles in an autoclave at 120 °C for 45 min. Total nitrogen (TN) and total dissolved nitrogen (TDN) were determined by the kjeldahl method. Nitrate (NO_3–N) was analyzed using the automated

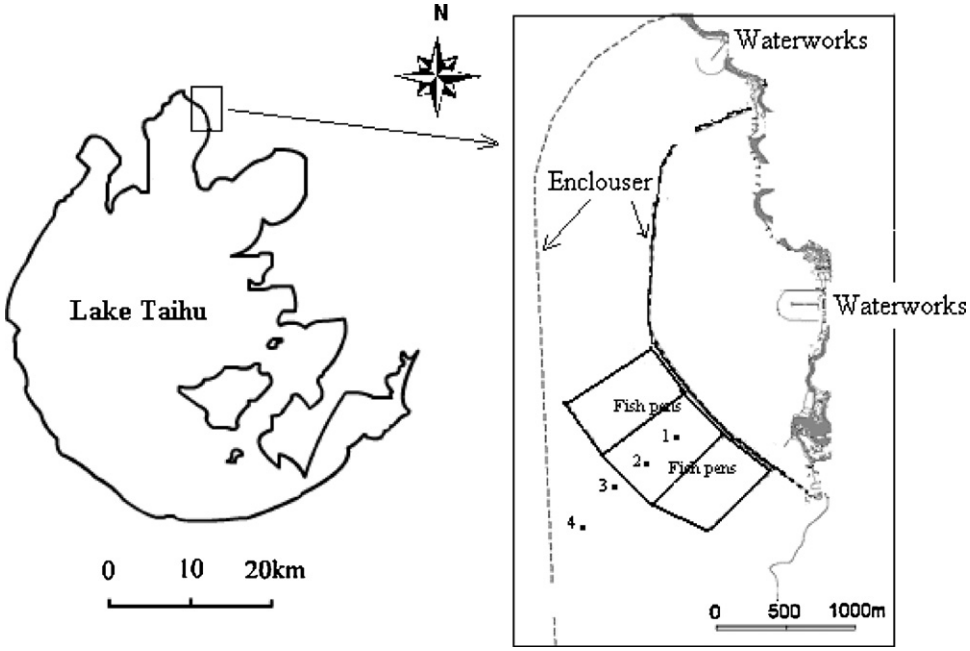

Fig. 1 – Map of Lake Taihu and the location of sampling stations in Meiliang Bay.