International Journal of Sedimentation Research 31 (2016) 173–180

Contents lists available at ScienceDirect

International Journal of Sediment Research

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

Original Research

Dynamics of algae growth and nutrients in experimental enclosures culturing bighead carp and common carp: Phosphorus dynamics

Suiliang Huang [a,*], Min Wu [a], Changjuan Zang [a], Shenglan Du [a], Joseph Domagalski [b], Magdalena Gajewska [c], Feng Gao [d], Chao Lin [e], Yong Guo [e], Baoyan Liu [d], Shaoming Wang [d], Yang Luo [e], Adam Szymkiewicz [c], Romuald Szymkiewicz [c]

[a] Key Laboratory of Pollution Processes and Environmental Criteria of Ministry of Education, Numerical Simulation Group for Water Environment, Tianjin Key Laboratory of Environmental Remediation and Pollution Control, College of Environmental Science and Engineering, Nankai University, Tianjin, China
[b] U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819, United States
[c] Faculty of Civil and Environmental Engineering, Gdańsk University of Technology (GUT), Poland
[d] Water Transfer Sub-Division from Luanhe River of Water Environment Monitoring Center, Haihe River Water Conservancy Commission, Tianjin 300170, China
[e] Haihe Water Resources Protection Bureau, Haihe River Water Conservancy Commission, Tianjin 300170, China

ARTICLE INFO

Article history:
Received 25 July 2014
Received in revised form
11 January 2016
Accepted 12 January 2016
Available online 22 January 2016

Keywords:
Fish food
Bighead carp
Common carp
Phosphorus flux
Enclosure experiment

ABSTRACT

This is the third paper of the series about "Dynamics of algae growth and nutrients in experimental enclosures culturing bighead carp and common carp". In this paper, phosphorus dynamics were investigated under the condition of culturing bighead carp and common carp with added fish food (nitrogen dynamics is discussed in the second paper because their behaviors are so different from each other). Nearly fifty days' observation results indicated that the reservoir water was typical of "phosphorus limited" water, and soluble reactive phosphorus (SRP) was the main constituent of measured total phosphorus (TP). The presence of fish food resulted in significantly higher SRP, dissolved total phosphorus (DTP) and TP concentrations in contrast with the reservoir water. Moreover, continuous supply of fish food led to the decline of total nitrogen to total phosphorus (TN:TP) from more than 100 to less than 5. Variations in the ratio of TN to TP favored the growth of blue-green algae. Fish species affected phosphorus concentrations, and culturing bait-eating common carp contributed more to reducing the SRP, DTP and TP concentrations than culturing planktivorous bighead carp. 0.5%, 4.1% and 3.1% TP can be removed in enclosures with culturing bighead carp, common carp and mixed bighead carp and common carp, respectively. Abundant phosphorus in the fish culturing activities may be present as the uneaten food, algae cells, and within the water column and sediment, which should be taken into serious consideration for the target of future water eutrophication prevention and safety of the drinking water supply.

1. Introduction

With the increasing demands of fishery products, cage aquaculture activities have developed rapidly in marine water bodies as well as in the inland fresh water bodies including lakes, rivers and reservoirs since 1990s (Anderson et al., 2002; Guo & Li, 2003; Guo et al., 2009; Islam, 2005; Tovar et al., 1999). As mentioned in the previous paper of this series, there are large quantities of researches about the effect of marine aquaculture on aquatic environments (Buschmann et al., 2006; Karakassis et al., 2000; Lee et al., 2003). The products of aquaculture are beneficial to society, however, environmental degradation and ecological damage caused by effluents can be a limiting factor for the sustainability of aquaculture industry development (Domagalski et al., 2007; Yucel-Gier et al., 2007). In general, aquaculture effluents include uneaten food, and feces and urine, which are released directly into receiving water during the fish cage-culturing process (Piedrahita, 2003; Sugiura et al., 2006; Wu et al., 2012). Anderson et al. (2002) demonstrated that nutrients released from fish culture sites can affect an area at least 3 times the size of the aquaculture zone. Once nutrient accumulation in the receiving water bodies exceeds the tolerant threshold of the aquatic ecosystem, the systems may experience the adverse effects of water quality deterioration, algae

* Corresponding author.
E-mail address: slhuang@nankai.edu.cn (S. Huang).

http://dx.doi.org/10.1016/j.ijsrc.2016.01.003
1001-6279/

blooms, and reduction in fishery productivity (Guo et al., 2009; Hargreaves, 1998; Yucel-Gier et al., 2007).

Previous research on phosphorus (P) cycling in shallow aquatic ecosystems conducted in estuarine or lacustrine environments (Felsing et al., 2006; Howarth & Marino, 1988; Schaus et al., 1997) indicates that release and accumulation of phosphorus during the culturing activities was the greatest contributor to the water quality deterioration in areas where culturing takes place. For instance, in China most intensive aquatic species are fed with formulated diets containing phosphorus (inorganic and organic) added in dietary pre-mixes for the best growth of the aquatic animal (Wu & Yang, 2010). Results from different fishery culture systems demonstrated that only 30% of phosphorus added as feed or other nutrient input was utilized by the target organisms (Liu et al., 1997). In general, nutrients including phosphorus released from the fish culturing industry may promote harmful algae growth not previously detected in the source water (Anderson et al., 2002). Phosphorus is a vital and essential mineral for phytoplankton growth. It is a major constituent for energy transformations and maintenance of the cell membrane integrity and genetic coding, as well as in lipid and carbohydrate metabolism, and synthesis of key enzymes, deoxyribonucleic acid, nucleic acids, phospholipids etc. (Nwanna et al., 2010; Paytan & McLaughlin, 2007). Understanding phosphorus dynamics therefore is critical for proper management of reservoirs.

Panjiakou Reservoir is the key hydraulic structure in northern China, and plays an irreplaceable role in transferring water from the Luanhe River (primary water source for the reservoir) to Tianjin City and Tangshan City for mitigating the crisis of water resources shortage. The available water of the Panjiakou Reservoir increases the irrigated area, and municipal and industrial water supply. In addition, significant improvements of the biological environment and economic development of North China can be attributed to the presence of this reservoir system. Thus, water quality of the Panjiakou Reservoir is of particular concern to the public, government agencies and researchers, as well as the river basin management agency.

Since the 1980s, fish cage culturing has gradually developed and has become the primary industry and major source of income to the local population who live in the Panjiakou Reservoir area. In order to investigate the impacts of fish cage culturing on water quality, Wang and Liu (2008) monitored the difference in water environmental parameters with and without aquaculture activities, and found that total phosphorus concentrations were 200% and 238% higher in the silver carp and common carp culturing water than those in the control reservoir water, respectively. It was implicated that fish cage culturing contributed much to the increase of phosphorus loads in the Panjiakou Reservoir.

The ratio of total nitrogen (TN) to total phosphorus (TP) is a useful tool for evaluating the potential of water eutrophication and managing reservoirs (Havens et al., 2003). For Panjiakou Reservoir, monitoring results indicated that TN:TP was 198 and 250 for the year of 2000 and corresponding flood season, respectively (Wang et al., 2001), and control of phosphorus is the preferred strategy to the prevention of reservoir water eutrophication. In order to ascertain the relationship between cage culturing and reservoir water eutrophication and guarantee the safety of the water supply, the Haihe River Conservancy Commission funded the present research to determine the impact of fish cage culturing on nutrients and algae growth dynamics in the Panjiakou Reservoir. In this study, two kinds of fish (bighead carp and common carp) were cultured in the five different enclosures installed in the Panjiakou Reservoir. The objectives of the research were:

- to investigate the variability in phosphorus fractions with different culturing designs;
- to explore the factors impacting phosphorus dynamics during the culturing period;
- to determine the contribution of fish culturing to the phosphorus load of the reservoir.

2. Materials and methods

2.1. Experimental set-up and operation

The Panjiakou Reservoir (118°15′E, 40°25′N) located in Qianxi County, Tangshan City, northern Hebei Province, China has a useable water surface area of approximately 40 km^2 and water storage of $2.93 \times 109\ m^3$ (Fig. 1). Situ enclosure experiments were conducted in the representative fish culturing water area of the Panjiakou Reservoir, about 15 m far from the reservoir bank (Fig. 1). Details of this reservoir and in-site experimental enclosures could be found in a previously companion paper (Huang et al., 2015).

2.2. Water sampling and analysis

Water samples for both enclosures and reservoir were collected at an interval of 2 days from 18th August 2009 to 6th October, 2009. Compared to enclosures, reservoir water samples determine the background values for algae biomass and water quality variables. All samples were analyzed on the same day. They were analyzed for the following parameters: COD, electric conductivity (EC), total dissolved solids (TDS), chlorophyll-a (Chl-a), dissolved oxygen (DO), SRP (soluble reactive phosphorus), DTP (dissolved total phosphorus), TP (total phosphorus), water temperature (*T*) and pH. Water quality parameters including COD, SRP, DTP and TP were determined according to standard methods (APHA, 1998) if not stated otherwise. PTN was the difference between TN and DTN. A YSI 6600 V2-2 Multi-Parameter Water Quality Sonde was used for DO, EC, TDS, Chl-a, *T* and pH analysis, respectively. Each variable test had parallel samples.

At the end of the experiment, both bighead carp and common carp were netted and weighed. Experimental fish were rinsed and then wiped with gauze to remove the mucus. Fish scale and fish skin were removed and the fish meat was dried to constant weight at 50 °C. Dried fish meat was subsequently powdered, and then 0.2000 g of it was weighed and digested with 3 ml sulfuric acid and 3 ml perchloric-nitric acid. The total phosphorus concentration in the digestion solution was analyzed by the ammonium molybdate spectrophotometric method (Cao et al., 2007). The results were expressed in terms of mg of phosphorus per gram of fresh fish meat (wet weight). Detailed information could also be found in a companion paper (Huang et al., 2015).

2.3. Fish netting and analysis

At the end of the experiment, both bighead carp and common carp were netted and weighed. Experimental fish were rinsed and then wiped with gauze to remove the mucus. Fish scale and fish skin were removed and the fish meat was dried to constant weight at 50 °C. Dried fish meat was subsequently powdered, and then 0.2000 g of it was weighed and digested with 3 ml sulfuric acid and 3 ml perchloric-nitric acid. The total phosphorus concentration in the digestion solution was analyzed by the ammonium molybdate spectrophotometric method (Cao et al., 2007). The results were expressed in terms of mg of phosphorus per gram of fresh fish meat (wet weight).