Science of the Total Environment xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

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

# Seasonal patterns of water quality and phytoplankton dynamics in surface waters in Guangzhou and Foshan, China

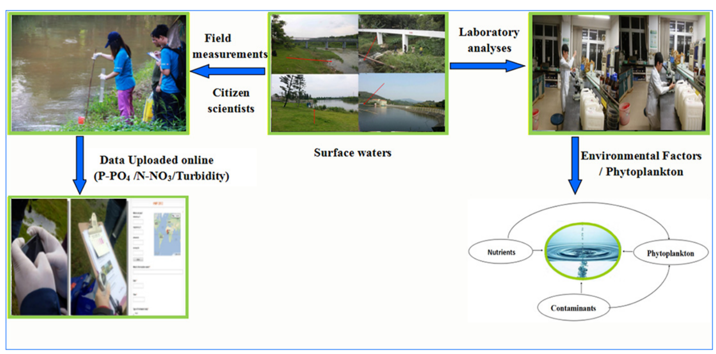
Yanggui Xu [a,b], Adela Jing Li [a,b], Junhao Qin [a,b], Qi Li [a,b], Jonathan G. Ho [c], Huashou Li [a,b,*]

[a] College of Natural Resources and Environment, South China Agricultural University, Guangzhou 510642, China
[b] Guangdong Engineering Research Center for Modern Eco-agriculture and Circular Agriculture/Key Laboratory of Agroecology and Rural Environment of Guangzhou Regular Higher Education Institutions, Guangzhou 510642, China
[c] Earthwatch Institute (Hong Kong), Room 1402 Breakthrough Centre, 191 Woosung Street, Kowloon, Jordan

## HIGHLIGHTS

- Trained citizen scientists can provide useful water quality monitoring data.
- Agricultural processes visibly influence nutrient levels and phytoplankton community.
- Nitrate concentrations peaked in late winter and early spring.
- Phosphate concentrations peaked during the winter, late summer and late autumn.

## GRAPHICAL ABSTRACT




## ARTICLE INFO

*Article history:*
Received 28 August 2016
Received in revised form 4 February 2017
Accepted 5 February 2017
Available online xxxx

*Keywords:*
Eutrophication
Phytoplankton
Seasonal variation
Citizen scientists

## ABSTRACT

During 2015, we studied the temporal patterns of nutrient concentrations and turbidity in water bodies with different degrees of agricultural and urban pressures across Guangzhou and Foshan (China). Data and observations were made by trained citizen scientists and professional researchers. Our study shows that all monitored water bodies, with the exception of Qiandeng Lake and Fengjiang River, had elevated $NO_3^-$-N concentrations, which ranged from 0.10 to 6.83 mg/L and peaked in late winter and early spring and reached a minimum in summer and mid-autumn. PO43-P concentrations ranged from 0.01 to 0.25 mg/L and peaked during the winter, late-summer and late autumn. Turbidity values were highest at sites with agricultural activities, with maximums in the late winter and autumn, and the highest frequency (16% and 25%) of algae presence occurred in the spring and autumn. To better understand the characteristics and drivers of the algae occurrences, measurements of phytoplankton composition and physicochemical characteristics were conducted in three key seasons in the agricultural process, fallow, sowing and rainy season in 2016. Our focused study found that the occurrence of *Bacillariophyta*, *Euglenophyta*, *Xanthophyta*, *Cryptophyta*, *Chrysophyta* were positively correlated with dissolved oxygen and phosphorus concentrations, while *Chlorophyta* and *Cyanophyta* had positive correlations with turbidity, oxygen demand and nitrogen concentrations. *Bacillariophyceae* counted for the highest proportion of phytoplankton during the fallow season, comprising up to 60+% of the phytoplankton among the sites. During the rainy season, *Chlorophyceae* species were the majority, comprising up to 90+% of phytoplankton among the sampled sites. Our results pointed to the complexity of nutrient and phytoplankton dynamics in water bodies under

* Corresponding author.
*E-mail address:* lihuashou@scau.edu.cn (H. Li).

http://dx.doi.org/10.1016/j.scitotenv.2017.02.032


Please cite this article as: Xu, Y., et al., Seasonal patterns of water quality and phytoplankton dynamics in surface waters in Guangzhou and Foshan, China, Sci Total Environ (2017), http://dx.doi.org/10.1016/j.scitotenv.2017.02.032

multiple pressures, and to the value of using citizen scientists to determine contextual information to benefit more focused studies.



## 1. Introduction

China's agricultural non-point source (NPS) pollution is currently the primary contributor to surface water eutrophication and ecosystem degradation, exceeding both residential and industrial inputs (Sun et al., 2012). Although China is becoming increasingly modernized and urbanized, a large number of farmers remain engaged in intensive agriculture with the industry providing food to 22% of the world's population, despite containing only 7% of the world's arable land. Since the demand for food continues to increase whilst arable land is decreasing, the application of fertilizer is widely used to increase crop yield with the goal of satisfying the overall demand for food. Since the 1980s, Chinese farmers have been encouraged to use chemical pesticides and fertilizers to boost crop production (Vitousek and Matson, 2014). By the 2000s, however, it became evident that intensive agricultural practices produced significant environmental pollution, degraded farmland and reduced agricultural productivity. The overuse of fertilizers and poor management of runoff from croplands have been associated to the most important environmental damage (Lu et al., 2015).

China's agricultural activities release up to 2.7 million tons of nitrogen into the environment annually, of which 57.2% of the discharge enter into water bodies (National Bureau of Statistics, 2000; Ministry of Environmental Protection of China, 2010; Ministry of Agriculture of the People's Republic of China, 2010). Nevertheless, China's total agricultural fertilizer application has continued to increase with particularly high loads being applied to vegetable and fruit crops. In the province of Guangdong, intensive agriculture is especially prominent. In 2013, Guangdong ranked as the province with the highest application of agricultural chemicals in China, with fertilizer application of 963 $kg/hm^2$ and pesticide application of 45 $kg/hm^2$ (National Bureau of Statistics, 2013). Similarly, production of fertilizer in Guangdong has increased by 0.58 million tons from 2013 to 2014; a 27.3% increase (Guangdong Agricultural non-point source pollution control project management office, 2016).

Urbanization is also a major pressure to aquatic ecosystems. Urbanization has resulted in extensive water quality problems in multiple cities in the region (Sim and Balamurugan, 1991). Increases in impermeable surfaces, as well as vehicular traffic related to the flow of people and material in the growing regional economy can increase pollution loads and runoff to urban and periruban waterbodies (Lebel, 2005). Overall, the urbanization-related conditions of increased transportation intensity, industrial intensity and residential density have been shown to have important impacts on surface water quality (He et al., 2007).

As a result of agricultural activities and urbanization, the potential number of non-point, diffuse pollution sources have increased dramatically, as reflected in the trends of chemical oxygen demand, total nitrogen, and total phosphorous levels in the country's surface waters. In 2012, the chemical oxygen demand, total nitrogen, and total phosphorous were 22.9%, 17.2%, and 12% higher respectively, compared to 2000 levels. (Rural Energy & Agency, Ministry of Agriculture, 2016). Water pollution is among the most severe and pressing environmental issues in Guangdong, and several previous studies have highlighted a strong link to the province's agricultural practices (Zhu et al., 2002; Zhou et al., 2003). Both heavy utilization of fertilizers and resultant nutrients have severely compromised most freshwater systems (Zhang et al., 2004; Sun, 2014; Zhong, 2008). Such practices, along with the impacts of urbanization, lead to an increased sediment load and NPS pollutants into water bodies, leading to decreased water quality in ponds, streams, reservoirs and potable supply (Jain, 2002; Jiao et al., 2014). Not only does water pollution decrease the quality of water resources, but it subsequently reduces the supply of clean freshwater (Wernand, 2007). In 2005, around 20% of streams and rivers in Guangdong were ranked as category "Below V" water quality (Table 1), whereas only 7% of the rivers were in the same category in the 1990s (GDEPB, 2006).

The integration of trained citizen scientists to make regular monitoring of water bodies is a new tool to help agencies and research institutions acquire important background information on chemical and biological conditions of urban, periurban and, where possible, agricultural environments (Conrad and Hilchey, 2011; Lévesque et al., 2017; Striner and Preece, 2016). More focused studies on the impacts of poor water quality on biodiversity, potable water supplies and other important ecosystem services benefit from the increased spatial and temporal coverage of information as well as from the creation of a more knowledgeable community (Thornhill et al., 2016).

Guangzhou and Foshan are two major cities in Guangdong province, undergoing rapid urbanization as well as major pressure from surrounding agricultural activities (Zhang et al., 2004; Sun, 2014; Zhong, 2008). In such a rapidly changing environment and given the random, intermittent, and the diffuse nature of NPS pollution (Yu and Liu, 2009), it is very important to gain a better understanding of the distribution, in both time and space, of NPS pollutants and their possible impacts. In the present study, we utilize information obtained by trained citizen scientists to determine the conditions of nutrient concentrations, turbidity levels, and dynamics of algae occurrences for a range of water bodies in Guangdong province. We build on this information by focusing field measurements to explore changes in chemical and physical conditions of these water bodies over three typical agricultural periods.

## 2. Methods

### *2.1. Field measurements*

Between June 2013 and April 2016, trained citizen scientists regularly collected $NO_3$–-N, $PO4^{3-}$-P and turbidity data and recorded observations of the presence of algae from reservoirs, rivers and farmland drains in urban, periurban and agricultural areas in Guangdong province every month (Fig. 1), as part of the FreshWater Watch (FWW) program. Here, we use 2015 (January to December, inclusive) FWW data from eight assigned sampling sites (Table 2). Measurements were taken monthly in these sites and were uploaded onto a global online database (freshwaterwatch.thewaterhub.org/content/data-map).

The sampling sites consisted of one farmland, two reservoirs, two lakes, and three rivers in Guangzhou and Foshan (Fig. 1). The South China Agricultural University (SCAU) farmland, located within the SCAU campus, primarily undergoes regular farming of rice, maize and soybean. The Muqiang and Jinkeng Reservoirs are water storage reservoirs managed and maintained by the government. Muqiang Reservoir

**Table 1**
Water quality category and some of their intended use, according to the China environmental quality standards for surface water.

| Category | Some intended use |
|---|---|
| I | Headwater, State nature reserves |
| II | Drinking water source, habitats for rare and precious aquatic organisms, fish nursery grounds |
| III | Drinking water source, aquaculture, swimming |
| IV | Industrial, recreation with direct contact of water |
| V | Agricultural, amenity uses |
| Below V | Unusable |

Please cite this article as: Xu, Y., et al., Seasonal patterns of water quality and phytoplankton dynamics in surface waters in Guangzhou and Foshan, China, Sci Total Environ (2017), http://dx.doi.org/10.1016/j.scitotenv.2017.02.032