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Substrate degradation and nutrient enrichment structuring macroinvertebrate assemblages in agriculturally dominated Lake Chaohu Basins, China

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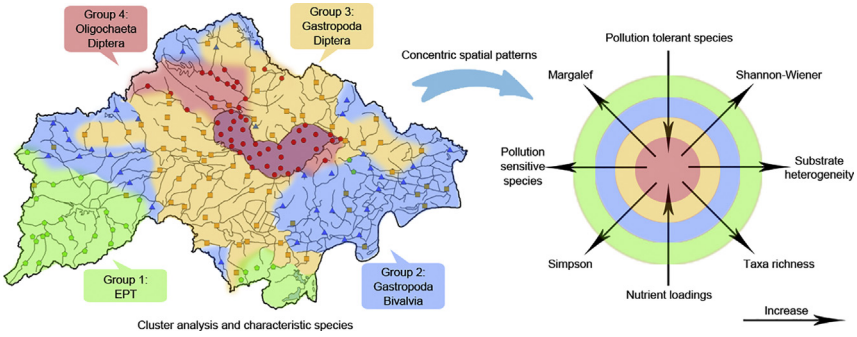
HIGHLIGHTS

- Macroinvertebrate assemblages showed concentric spatial distribution patterns.
- Sensitive species reduced while the tolerant species increased.
- Taxonomic diversity decreased with increased human disturbance.
- Substrate heterogeneity and nutrient enrichment regulated benthic fauna.
- Distribution of major taxa were more closely correlated with nitrogen than phosphorus.

GRAPHICAL ABSTRACT



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ABSTRACT

Rapid agricultural development has induced severe environmental problems to freshwater ecosystems. In this study, we aimed to examine the structure and environmental determinants of macroinvertebrate assemblages in an agriculture dominated Lake Chaohu Basin, China. A cluster analysis of the macroinvertebrate communities identified four groups of sites that were characterized by significantly different macroinvertebrate species. These four groups of sites had concentric spatial distribution patterns that followed the variation in the environmental conditions from the less anthropogenically disturbed headwaters towards the more anthropogenically disturbed lower reaches of the rivers and the Lake Chaohu. Moreover, taxa richness decreased from the headwaters towards the Lake Chaohu. The increasing practice of agriculture has reduced the abundances and richness of pollution sensitive species while opposite effects on pollution tolerant species. The study identified substrate heterogeneity and nutrient concentrations as the key environmental factors regulating the changes in the macroinvertebrate communities. We propose that particular attentions should be paid to reduce the nutrient enrichment and habitat degradation in the Lake Chaohu Basin and similar agriculture dominated basins.

1. Introduction

Rapid agricultural development has induced severe environmental problems to freshwater ecosystems worldwide (Allan, 2004; Fierro

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et al., 2017), particularly in China (Fang et al., 2006; Liu et al., 2003), where many areas are experiencing serious agricultural non-point source pollution (Sun et al., 2012). For example, in some areas as much as 53% of the total nitrogen load and 85% of the total phosphorus load in rivers originate from agriculture runoff (Ongley et al., 2010), which have serious negative impacts on the freshwater ecosystems (Allan, 2004; Cui et al., 2017; Moore and Palmer, 2005; Riseng et al., 2011).

Benthic macroinvertebrates are important components of freshwater ecosystems, providing crucial ecosystem services through nutrient cycling and decomposition of organic matter (Covich et al., 2004). However, macroinvertebrate communities are in many ways extremely sensitive to agricultural stressors which affect the biological integrity of freshwater ecosystems through changes in species abundances, biomass, and diversity (Chará-Serna et al., 2015; Matthaei et al., 2010). This sensitivity to environmental changes makes macroinvertebrates good indicators of environmental degradation. For instance, changes in the abundances and richness of pollution sensitive taxa such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies; EPT species) are commonly used to assess changes in water and habitat quality in freshwaters (Herman and Nejadhashemi, 2015; Koperski, 2011).

Ecosystem health of rivers and lakes in China are gaining increasing attention, and new researches have been initiated to assess the health status of freshwaters (Huang et al., 2015; Jun et al., 2012). Currently, most of the assessments are based on physicochemical factors, although methods based on macroinvertebrates are becoming increasingly more popular (Cai et al., 2017; Huang et al., 2015; Jun et al., 2012). However, the lack of knowledge of the environmental factors that currently structure the macroinvertebrate communities in many of the regions hinders the development of bioassessment methods based on macroinvertebrates. Knowledge is especially lacking from agricultural areas (Gao et al., 2014) as the new researches have mainly focused on economically more developed urban regions (Wang et al., 2012; Zhang et al., 2014). Hence, the environmental determinants of the macroinvertebrate communities in agriculture dominated landscapes are limited, leading to lack of basis for management programs based on macroinvertebrates in these areas.

Our aim was to identify the key environmental factors that currently structure the macroinvertebrate communities in agriculture-dominated basins in China. The study was conducted in the Lake Chaohu Basin, located in the lower Yangtze River region, eastern China (Fig. 1). The basin provides an ideal site to examine the effects of agriculture and varying environmental factors on the macroinvertebrate communities as there is significant gradient in the environmental conditions within the basin from the headwaters to the Lake Chaohu (Fig. S1). The results can be used as a basis when planning new restoration and biomonitoring strategies for areas with similar ecological conditions.

2. Materials and methods

2.1. Study area

Lake Chaohu is the fifth largest freshwater lake in China (Fig. 1) and is part of the drainage system of the Yangtze River. The lake storage is 20.7×10^8 m^3. The maximum water depth is 3.77 m, with a mean depth of approximately 2.7 m. Lake Chaohu is a typical shallow lake, there is no stable temperature stratification. The residence time is approximately 168 days (Cai et al., 2017). The Lake Chaohu Basin covers an area of 13,400 km^2 extending from 116°23′59″ E to 118°22′5″ E and from 30°52′25″ N to 32°7′53″ N. Average elevation within the basin is approximately 65 m (Gao and Jiang, 2012). Hefei City is the only large city within the basin. The Chaohu Lake Basin lies in the transitional area between subtropical zone and warm temperate zone, with a mean annual rainfall of 1100 mm (Z Zhang et al., 2015). The landscape in Lake Chaohu basin consist mainly of agricultural area and forest land area, accounting for 60.08% and 21.61%, respectively (Z Zhang et al., 2015). There is a high-density river network with a total of 33 rivers draining into the lake Chaohu (Fig. 1). Most of the inflow is from the Hangbu River, Baishitian River, and Nanfei River. Yuxi River is the only channel linking Lake Chaohu to the Yangtze River. There is a clear gradient of increasing pollution from the headwaters towards the Lake Chaohu (L Zhang et al., 2015), and the lower reaches of the rivers and the Lake Chaohu are seriously degraded (Kong et al., 2015; Y Zhang et al., 2016). As a result, the Lake Chaohu is now one of the most

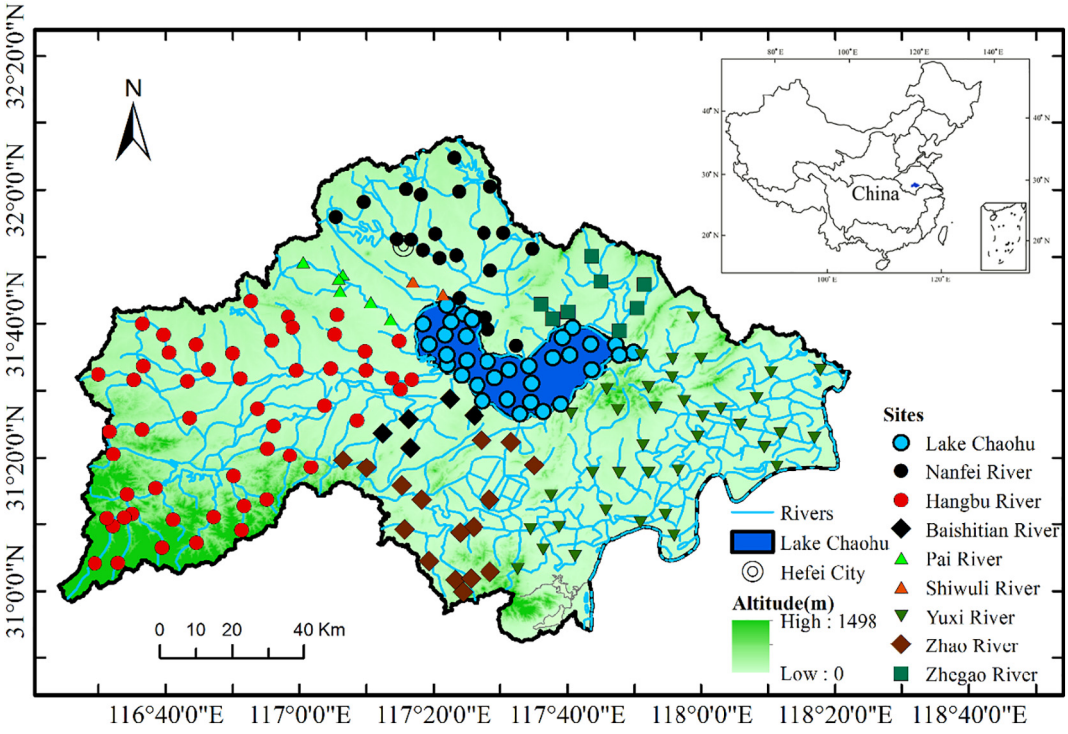

Fig. 1. Location of the sampling sites in the Lake Chaohu Basin, China.