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Stable carbon isotope variations in surface bloom scum and subsurface seston among shallow eutrophic lakes

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Abstract

Carbon stable isotope analysis of surface bloom scum and subsurface seston samples was conducted in shallow eutrophic lakes in China during warm seasons from 2003 to 2004. δ^{13}C values of bloom scum were always higher (averaged 5‰) than those of seston in this study, and the possible reasons were attributed to (i) direct use of atmospheric CO_2 at the air–water interface, (ii) decrease in ^{13}C fractionation due to higher carbon fixation, (iii) active CO_2 transport, and/or (iv) HCO_3^- accumulation. Negative correlation between $\delta^{13}C_{scum} - \delta^{13}C_{seston}$ and pH in the test lakes indicated that phytoplankton at the subsurface water column increased isotopic enrichment under the carbon limitation along with the increase of pH, which might in turn decreased the differences in δ^{13}C between the subsurface seston and the surface scums. Significant positive correlations of seston δ^{13}C with total concentrations of nitrogen and phosphorus in water column suggested that the increase in δ^{13}C of seston with trophic state was depending on nutrient (N or P, or both) supply. Our study showed that δ^{13}C of phytoplankton was indicative of carbon utilization, primary productivity, and nutrient supply among the eutrophic lakes.

Keywords: Bloom scum; Eutrophic lakes; Seston; Stable carbon isotope

1. Introduction

Eutrophication is a complex process whereby fresh and marine water bodies become enriched by nutrients (e.g. phosphorus and nitrogen) from both external and internal sources (Harper, 1992; ECOHAB, 1997). It is considered as one of the most pressing environmental problems in both the developed and the developing countries (Ryding and Rast, 1989; Harper, 1992). The main effect of eutrophication is the imbalance in the base of food web that results in high levels of phytoplankton biomass, which can lead to algal blooms depending upon environmental factors, e.g. nutrients, light, temperature and water movement (Jacoby et al., 2000). Cyanobacterial blooms are the most frequently observed and widely studied algal blooms in freshwater and estuarine ecosystems throughout the world. Cyanobacterial blooms are often regarded as an indication of accelerating nutrient enrichment of aquatic ecosystems (Sellner et al., 2003). Cyanobacterial blooms may cause a variety of water quality problems, including dissolved oxygen depletion and subsequent death of aquatic animals, aesthetic nuisances (e.g. odors, massive surface scum, fish tainting), cyanotoxin production (e.g. microcystins), and unpalatable and possibly unsafe drinking water (Welch, 1992; Xie, 2006). Such problems can severely limit

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aquatic habitat, recreational activities, fisheries, and use of a water body for drinking water.

Stable carbon isotope analysis is a powerful tool to study carbon biogeochemical cycle in aquatic ecosystems (e.g. Kendall et al., 2001; Lehmann et al., 2004a,b). Stable carbon isotope ratio ($\delta^{13}C$) of phytoplankton helps to gain substantial insights into sources and fate of carbon, primary productivity, and dissolved inorganic carbon (DIC) concentrations in the surface water (Kendall et al., 2001; Lehmann et al., 2004a,b). The $\delta^{13}C$ of phytoplankton in lacustrine systems varies over time and space (Gu et al., 1996; Lehmann et al., 2004b; Xu et al., 2005a), and these variations may be related to phytoplankton species composition, external nutrient input, and primary productivity, as well as sources and concentrations of DIC, their isotope signatures, and inherent isotope fractionations and kinetic mode of carbon fixation during photosynthesis (O'Leary, 1981; Rau et al., 1989; Falkowski, 1991; Grey and Jones, 2001). From the isotopic point of view, eutrophic lakes generally have a large potential to exhibit large spatial and temporal variations in $\delta^{13}C$ of phytoplankton due to dense algae blooms. Low DIC concentrations and high pH of lake water intensively affect the photosynthetic rate and imbalanced exchange between atmospheric CO_2 and aquatic carbon species (Zohary et al., 1994; Gu et al., 1996; Lehmann et al., 2004b; Xu et al., 2005a). For instance, phytoplankton fractionate against ^{13}C during carbon fixation, resulting in light isotopes in photosynthetic products and heavy isotopes in the DIC pool. However, when carbon demand is high and pool size is limited, phytoplankton incorporates all available C with little isotopic discrimination. Hence, during an algae bloom when primary production is increased and the pool size is reduced, $\delta^{13}C$ of phytoplankton may increase (Zohary et al., 1994; Gu et al., 1996; Xu et al., 2005a).

Many of the numerous shallow lakes in the middle and lower reaches of the Yangtze River area in subtropical China undergo severe eutrophication (Jin, 2003). Some of these lakes present cyanobacterial blooms (mainly composed of *Anabaena* and *Microcystis*) in warm seasons due to high nutrient levels and high water temperature, and surface scum is common in these eutrophic freshwaters (Wu et al., 2006). In this study, $\delta^{13}C$ of bloom scum ($\delta^{13}C_{scum}$) and seston ($\delta^{13}C_{seston}$) were investigated in 10 lakes, dominated by cyanobacterial bloom species, 9 of which were located in the middle and lower reaches of the Yangtze River, and 1 in Yunnan Plateau, in warm seasons between 2003 and 2004. The primary objectives were (i) to determine whether there are differences in $\delta^{13}C$ between bloom scums and seston, (ii) to evaluate relationships between environmental factors (e.g. nutrients, temperature, pH, etc.) and stable carbon isotopic compositions of scum and seston, and (iii) to discuss possible mechanisms underlying these observations in these shallow eutrophic lakes.

2. Material and methods

2.1. Study site

According to OECD (1982), the lakes were all in eutrophic and hypereutrophic states in terms of TP concentrations (Fig. 1). Phytoplankton biomass was high and consisted largely of cyanobacteria (mainly *Anabaena* and *Microcystis*). Aquatic macrophytes were scarce in these lakes, possibly because of nutrient stress, e.g. elevated NH_4^+, and light limitation (Cao et al., submitted to Marine and Freshwater Research). Lake Eastdongting is the only one connected with the Yangtze River throughout the year, and Lake Xingyun is the only exception which located in Yunnan Plateau, southwest China (Xu et al., 2005b). Limnological characteristics of these lakes were summarized in Table 1 (data from Wu et al., 2006; Xu et al., 2005a,b; Zhou et al., submitted to Ecological Engineering; Yang Hong, unpublished data).

2.2. Field sampling

One to four bloom scum samples were collected by scraping foam of phytoplankton from the surface of the

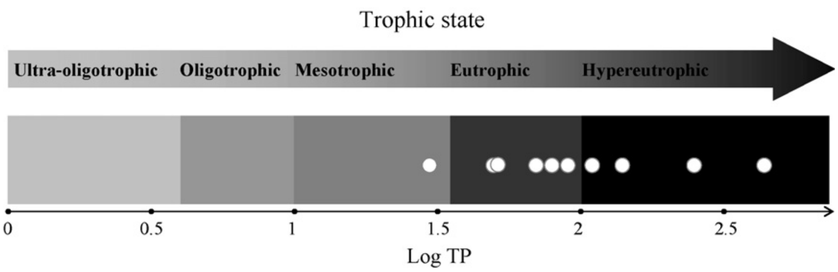

Fig. 1. Trophic states of the investigated lakes in this study classified according to total phosphorus concentration (OECD, 1982).