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Stable Isotope Variations in Particulate Organic Matter and a Planktivorous Fish in the Yangtze River

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ABSTRACT

Temporal and spatial changes in $\delta^{13}C$ and $\delta^{15}N$ of particulate organic matter (POM) and *Hemiculter leucisculus* were studied in the Yangtze River of China. Isotopic signatures of POM showed seasonal variations, which was assumed to be associated with allochthonous organic input and autochthonous phytoplankton growth. $\delta^{13}C$ of *H. leucisculus* was 1.1% higher than that of POM, which suggested that the food source of *H. leucisculus* was mostly from the POM. A mass balance model indicated the trophic position of *H. leucisculus* in the food web of Yangtze River was estimated to be 2.0 - 2.1, indicating that this fish mainly feeds on planktonic organic matter, which agreed with previous gut content analysis.

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INTRODUCTION

Stable isotope analysis is increasingly used in freshwater ecological studies (e.g., France 1995, Vander Zanden et al. 1997, Post, 2002, Xu et al. 2005a), and the $\delta^{15}N$ and $\delta^{13}C$ isotopic signatures of producers and consumers are reflections of their trophic position and carbon sources, respectively (Vander Zanden et al. 1997, Post 2002). Stable isotope analysis can also provide a powerful tool for studying the variation of particulate organic matter (POM) in rivers (Hedges et al. 1986, Angradi 1993, Kendall et al. 2001).

POM is composed of allochthonous and autochthonous organic materials (Meybeck 1982) and it can provide a detailed, integrated record of natural and anthropogenic activities in rivers (Hedges et al. 1986, Barth et al. 1998, Kendall et al. 2001). For higher trophic level consumers, isotopic signatures of primary producers are generally conserved in consumers along the food chain because it has been documented that modification of $\delta^{15}N$ and $\delta^{13}C$ during the feeding process is relatively constant (France 1995, Vander Zanden et al. 1997, Post 2002).

The present study was conducted in the Three Gorges region of the Yangtze River during January through November of 2005. The aim of this study was to describe the temporal and spatial variations of stable carbon and nitrogen isotopes in POM and *Hemiculter leucisculus*, a common planktivorous fish in the Yangtze River.

MATERIALS AND METHODS

Samples were collected from three sites (Zigui, Sandouping, Yichang; upstream to downstream) along the upper Yangtze River, where the Three Gorges Dam and Gezhouba Dam are located. In the field, water was filtered onto precombusted Whatman GF/C glass fiber filters (1.2 μm) for the sampling of POM. The filters were transported on ice to the laboratory where they were acidified with 1N HCl to dissolve calcium carbonate and then rinsed with distilled water. Ten replicate filters were analyzed each sampling month at

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each site. Each month, about 10-12 age-2 *H. leucisculus* were collected by casting nets and/or from fishermen. White dorsal muscle was taken for analysis. All samples were dried to a constant weight at 50°C, ground and homogenized to a fine powder with mortar and pestle, and then stored in a desiccator with silica gel for subsequent stable isotope analysis.

Stable carbon and nitrogen isotope ratios were analyzed with a Delta Plus (Finnigan) continuous flow isotope ratio mass spectrometer directly coupled to an NC 2500 elemental analyzer (Carlo Erba) for combustion. The samples were analyzed with two or more replicates. Isotope ratios were expressed as parts-per-thousand (‰) differences from a standard reference materials Vienna Pee Dee Belemnite and atmospheric nitrogen for carbon and nitrogen, respectively. International reference materials were IAEA-USGS25 and urea ($\delta^{13}C$ = -49.44‰ and $\delta^{15}N$ = -1.53‰). The standard deviations of $\delta^{13}C$ and $\delta^{15}N$ among replicates were less than 0.2‰ and 0.4‰, respectively.

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RESULTS AND DISCUSSION

Generally, the isotopic compositions of POM reflect the relative proportions of allochthonous terrestrial organic matter and autochthonous particles in river ecosystems (Angradi 1993, Barth et al. 1998, Kendall et al. 2001). Allochthonous organic matter often has higher $\delta^{13}C$ than that of autochthonous matter (Kendall et al. 2001). In this study, the $\delta^{13}C$ of POM in three sites ranged from -30.4‰ to -27.2‰ and had relative high values (-28.3‰ ± 0.54) in the flood season (June to November) of Yangtze River, and the low $\delta^{13}C$ (-29.9‰ ± 0.17) was in May (Fig. 1), the time of highest plankton biomass of the year (Kuang et al. 2005). One possible explanation is that seasonal variation of POM $\delta^{13}C$ in this region was mainly affected by both a large amont of the allochthonous terrestrial organic matter input in flood seasons and active growth of plankton in dry seasons (Hu and Cai 2006). The $\delta^{15}N$ of POM also showed a peak in May in all sites, followed by a remarkable decline to September and a gradual increase afterwards. This finding was similar to that reported by Barth et al. (1998) in their study of the upper St. Lawrence River of Canada. Our results, together with previous studies, suggest that isotopic variation of POM coupled with the seasonal or hydrological changes in large rivers is a common phenomenon and is associated with allochthonous organic input and autochthonous phytoplankton growth (Mariotti et al. 1991, Barth et al. 1998, Kendall et al. 2001).

The $\delta^{13}C$ of *H. leucisculus* at the three sites ranged from -28.9‰ to -24.2‰, had the lowest values in March, reached a peak in September (Fig. 1), and showed a significant positive correlation with that of POM (ANOVA $P<0.05$). The annual average $\delta^{13}C$ of *H. leucisculus* was significantly higher than the $\delta^{13}C$ of POM (1.1±0.2‰), which suggests that the food source of *H. leucisculus* was mostly POM, because the $\delta^{13}C$ of a consumer usually has 1‰ enrichment relative to its food source (Vander Zanden et al. 1997, Post 2002). The $\delta^{15}N$ of *H. leucisculus* ranged from 6.2‰ to 12.1‰ and showed much less temporal variability than that of POM (1.7‰ to 11.7‰). In general, the $\delta^{15}N$ of *H. leucisculus* in three sites had a significant positive correlation with that of POM (ANOVA $P<0.05$), and the average difference of $\delta^{15}N$ between them ranged from 3.5‰ to 3.7‰. The trophic level can be calculated as $\lambda + (\delta^{15}N_{consumer} + \delta^{15}N_{baseline})/\Delta$, where λ is the trophic position of the organism used to estimate $\delta^{15}N_{baseline}$ (e.g., $\lambda=1$ for primary producers), $\delta^{15}N_{consumer}$ is measured directly, $\delta^{15}N_{baseline}$ is the corresponding value at the base of the food web, and Δ is the enrichment of $\delta^{15}N$ per trophic level (Vander Zanden et al. 1999, Post 2002, Xu et al. 2005b). Using 3.4‰ as the $\delta^{15}N$ enrichment factor per trophic level (Post 2002) and $\delta^{15}N$ of POM as baseline, the trophic position of *H. leucisculus* in the food web of Yangtze River was estimated to be 2.0 - 2.1, indicating that the fish mainly fed on the planktonic organic matter. Our estimation is consistent with previous gut content observation that revealed the main ingested items of *H. leucisculus* were planktonic material, including phytoplankton, zooplankton, and detritus (Fish Laboratory of Institute Hydrobiology of Hubei Province 1976).

In natural systems, $\delta^{13}C$ and $\delta^{15}N$ of POM always increase with movement downstream in rivers, as much more allochthonous organic matter is imported into the downriver section (Angradi 1993, Thorp et al. 1998, Kendall et al. 2001). However, the annual mean isotopic signatures of POM and *H. leucisculus* in this study consistently declined along with the direction of flow in the Yangtze River. After the impoundment by the dams, much upriver anthropogenical sewage was stored in the reservoir (Hu and Cai 2006), and the biomass of phytoplankton was much higher than before (Kuang et al. 2005). Thus, enriched isotopic compositions of carbon and nitrogen sources from the sewage and active photosynthesis and growth of phytoplankton in the reservoirs were expected to result in the enriched $\delta^{13}C$ and $\delta^{15}N$ of POM (Kendall et al. 2001, Xu et al. 2005a), which could be partially responsible for the higher $\delta^{13}C$ and $\delta^{15}N$ of POM and *H. leucisculus* from upriver reaches versus those downstream.

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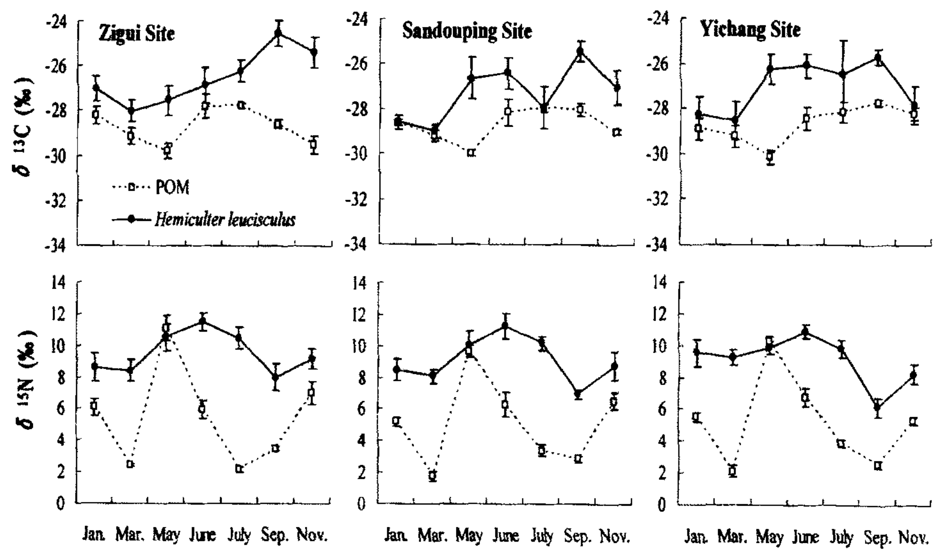

Figure 1. Variation in stable isotope signatures of POM and *H. leucisculus* (means±1 SD).

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