Characteristics of Lake Biwa from Stable Isotopic Viewpoints

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INTRODUCTION

Nitrogen is the most important biophilic element and consists of two stable isotopes: $^{14}$N and $^{15}$N. Although both physicochemical nature is quite similar, more precisely $^{14}$N and $^{15}$N undergo fractionation in every physical and chemical processes. Consequently, each nitrogen bearing substance has its own inherent isotopic composition depending upon its position in material cyclings in nature [1], [2], [3]. It has been recognized that $\delta^{15}$N of an animal is an useful indicator of its trophic level, while its carbon isotope ratio reflects $\delta^{13}$C of the food base and is an available source indicator of its carbon[4], [5]. Therefore, the SI ratio($^{15}$N/$^{14}$N) can be possible indicator to trace transport of organic matter and to reconstruct a food web structure of natural ecosystems [6], [7], [8], [9]. In this paper, preliminary surveys were performed on the distribution of nitrogen isotope ratio among biogenic substances involving nitrate, POM, plankton and fishes in Lake Biwa, Japan, with emphasis on the construction of a possible isotopic geochemical structure of the lake ecosystem.

MATERIALS AND METHODS

Study area

Lake Biwa is the largest lake locates in the central part of Honshu Island, Japan. Its surface area is 647 km$^2$. The lake is separated into two parts: the north basin and south basin. The north basin occupies the major parts of the lake with maximum depth of 108m and a water volume of 27 thousand million tonnages. In contrast, the south basin is small with average depth of 4m and water volume of 2 hundred million tonnages. The lake water is supplied from the surrounding mountain areas. An estimated exchange rate of the lake water is around 10 years[10]. The lake is monomictic and the depth of a thermocline in the north basin becomes deeper during spring through autumn from 15m to 40m. The thermocline disappears commonly in January.

Analytical method

POM, phytoplankton, zooplankton and fishes were collected from April through August in 1993, together with nitrate at the deepest points(water depths of 70 and 90m) in the north basin in August. Zooplankton samples were collected by horizontal towing a net (150 $\mu$m mesh size) and were sorted under a stereoscopic microscope into each species. Phytoplankton samples were collected by various kinds of nets, of which mesh sizes were 70, 40, 20 $\mu$m, respectively. POM
were collected on GF/D(2.7 μm) and GF/F(1.2 μm) glass fiber filters precombusted at 450 °C for 2 hours. Collected samples on the filter was washed with 0.05N hydrochloric acid and dried at 60 °C. Samples for nitrogen isotope analysis were combusted by the sealed quartz tube method to N₂ gas[11]. 1 to 10mg of dry sample materials were sealed into an evacuated quartz tube with 1.0g of copper oxide, and 0.5g of copper and silver wires. The tube was heated up to 500°C for 30 minutes and at 850°C for 2 hours and then cooled down overnight in the furnace. N₂ gas was separated and purified cryogenically by using liquid nitrogen and dry ice-ethanol traps. Purified gases were introduced into a Delta-S mass spectrometer for ratiometry. Isotope ratio was expressed as permil deviation from a standard as follows:

\[ \delta^{15}N(\text{‰}) = \left( \frac{R_{\text{sample}}}{R_{\text{stand}}}-1 \right) \times 1000, \]

where R donates $^{15}N/^{14}N$. L-alanine was used as a running standard for the isotope measurement.

RESULT AND DISCUSSION

*Silurus biwaensis, Plecoglossus altivelis altivelis*, zooplankton, phytoplankton, and POM had very high $\delta^{15}N$ values so far examined in the present lake. $\delta^{15}N$ value of POM and phytoplankton ranged 6 to 9‰. *Eodiaptomus japonicus* exhibited $\delta^{15}N$ value of 10 to 15‰. Temporal variation of $\delta^{15}N$ in *E. japonicus* showed similar with those of POM, and phytoplankton of which mesh size was from 2.7(GF/D) to 70 μm. Fishes exhibited rather high $\delta^{15}N$ value. For example, *Plecoglossus altivelis altivelis* had $\delta^{15}N$ values of 13 to 18‰ and *Silurus biwaensis*, ca.19‰. A relationship between an average $\delta^{15}N$ value of each organism collected during April to August in 1993 and its corresponding trophic level was summarized in Fig 1. A stepwise increase

![Graph showing relationship between δ¹⁵N and trophic level](image)

**Fig. 1** A relationship between δ¹⁵N of an organism and its corresponding trophic level. The straight line was obtained using the δ¹⁵N value of POM and
of $^{15}$N was clearly demonstrated along a food chain in the following manner: phytoplankton and POM, *E. japonicus*, *Plecoglossus altivelis altivelis*, and *Silurus biwaensis*. The fact strongly suggested that the stepwise enrichment of $\delta^{15}$N was also confirmed in Lake Biwa with an enrichment factor of 3.3‰/T.L. Therefore, the $\delta^{15}$N could be a very clear indicator of trophic level of an organism as has been shown in Lake Suwa, the estuaries, and marine environments[2], [4], [5], [8]. Rather high $\delta^{15}$N value of the whole food web in Lake Biwa(Fig. 1) coincided with high $\delta^{15}$N value of nitrate(5 to 6‰) in spite of the supply of nitrate with low $\delta^{15}$N(0 to 2 ‰) through precipitation onto the surrounding mountain areas.

In Lake Biwa, loss of ca.40% of nitrate was reported from a mass balance calculation of nitrogen[12]. If high $\delta^{15}$N value is caused by denitrification, the occurrence of denitrification with rather high fractionation factor of 1.009 was strongly suggested in Lake Biwa.

REFERENCES