Stable isotope proxies for evaluating biodiversity in stream biota

Mayumi Yoshimura *

Forest Biodiversity Group, Kansai Research Centre, Forestry and Forest Products Research Institute, Nagaikyutaro 68, Momoyama, Fushimi, Kyoto 612-0855, Japan

ARTICLE INFO

ABSTRACT

Differences in $\delta^{13}C$ and $\delta^{15}N$ values in stream biota are caused by several environmental conditions. Variations in abundance, species richness and the assemblage structure of stream biota are also caused by several environmental conditions. Hence, abundance, species richness and the assemblage structure of stream biota are expected to be strongly correlated with the differences in value of stable isotopes. In this study, the gaps in $\delta^{13}C$ and $\delta^{15}N$ between periphyton and charr are discussed in terms of the abundance, genus richness, and assemblage of benthic invertebrates at each site. Gaps in $\delta^{13}C$ between periphyton and charr were strongly correlated with some aspects of mountainous area and the genus richness of benthic invertebrates at each site. The gaps in $\delta^{15}N$ between periphyton and charr were strongly correlated with the abundance and assemblage structure of benthic invertebrates at the location tested. The $\delta^{13}C$ values of predators were correlated with some aspects of mountainous area and the assemblage structure of the benthic invertebrates. The $\delta^{15}N$ values of predators were correlated with genus richness and the assemblage structure of the benthic invertebrates. These results suggest that the value gaps in $\delta^{13}C$ and $\delta^{15}N$ can be used to assess biodiversity and could provide indices for estimating the biodiversity in a stream.

1. Introduction

Diet is a main factor in isotope assimilation, and the stable isotope ratio of carbon and nitrogen ($\delta^{13}C$ and $\delta^{15}N$) differs depending on what the consumer eats. The degree of similarity in $\delta^{13}C$ between diet and consumer is indicative of the dietary sources (DeNiro and Epstein, 1978) and increased $\delta^{15}N$ indicates the trophic position of an animal in a food web (DeNiro and Epstein, 1981; Minagawa and Wada, 1984; Post, 2002). Therefore, differences in the stable isotope ratio in insects can explain their movement (Hobson et al., 1999; Dockx et al., 2004) because $\delta^{13}C$ and $\delta^{15}N$ in the diet differ depending on their habitats. These differences can also reflect the nutritional stress (fasting) of birds (Hobson et al., 1993). Differences in stable isotopes in bears consuming fish can explain the energy and nutrient flow from streams to terrestrial environments (Ballinger and Lake, 2006), and can track the movements of fish and aquatic invertebrates in a river (Rasmussen et al., 2009; Myers et al., 2012).

The variations in $\delta^{13}C$ and $\delta^{15}N$ in stream biota such as algae and aquatic insects are caused by various environmental conditions such as differences in watershed areas (Finlay, 2001; Finlay et al., 2010), surrounding vegetation (Robinson et al., 2008; Göthe et al., 2009) and water velocity (Rasmussen and Trudeau, 2007, 2010; Finlay et al., 2010). Abundances, species richness and assemblage structures that comprise abundance data of every species such as algae and aquatic insects in streams are also different depending on the same environmental conditions (Jenkins et al., 1984; Brönmark et al., 1984; Ward, 1992; Friberg et al., 1997; Piccolo and Wipfli, 2002; Yoshimura, 2006, 2007). Thus, the differences in abundance, species richness and assemblage structure of biota in a stream appear to be strongly correlated with the values of $\delta^{13}C$ and $\delta^{15}N$. For example, the biomass of periphytic algae increases where light is strong, causing a reduction in CO_2 in that specific area. So, ^{12}C is used first for light synthesis, and ^{13}C is used when a shortage of carbon dioxide (CO_2) occurs in the streams, leading to an increase in the value of $\delta^{13}C$ where biomass is higher and intense photosynthesis occurs (Rasmussen and Trudeau, 2007, 2010; Ishikawa et al., 2013). Abundance, species richness and assemblage structure are the main factors considered when constructing a food web. Layman et al. (2007) suggest the values of $\delta^{13}C$ and $\delta^{15}N$ could be used to understand the extent of trophic diversity. However, numerous biota do not play a role in specific food webs; trophic diversity that Layman et al. (2007) suggest. To evaluate streams and rivers, it is necessary to focus on all fauna and flora in the stream habitat not only trophic diversity.

* Tel.: +81 756111201.
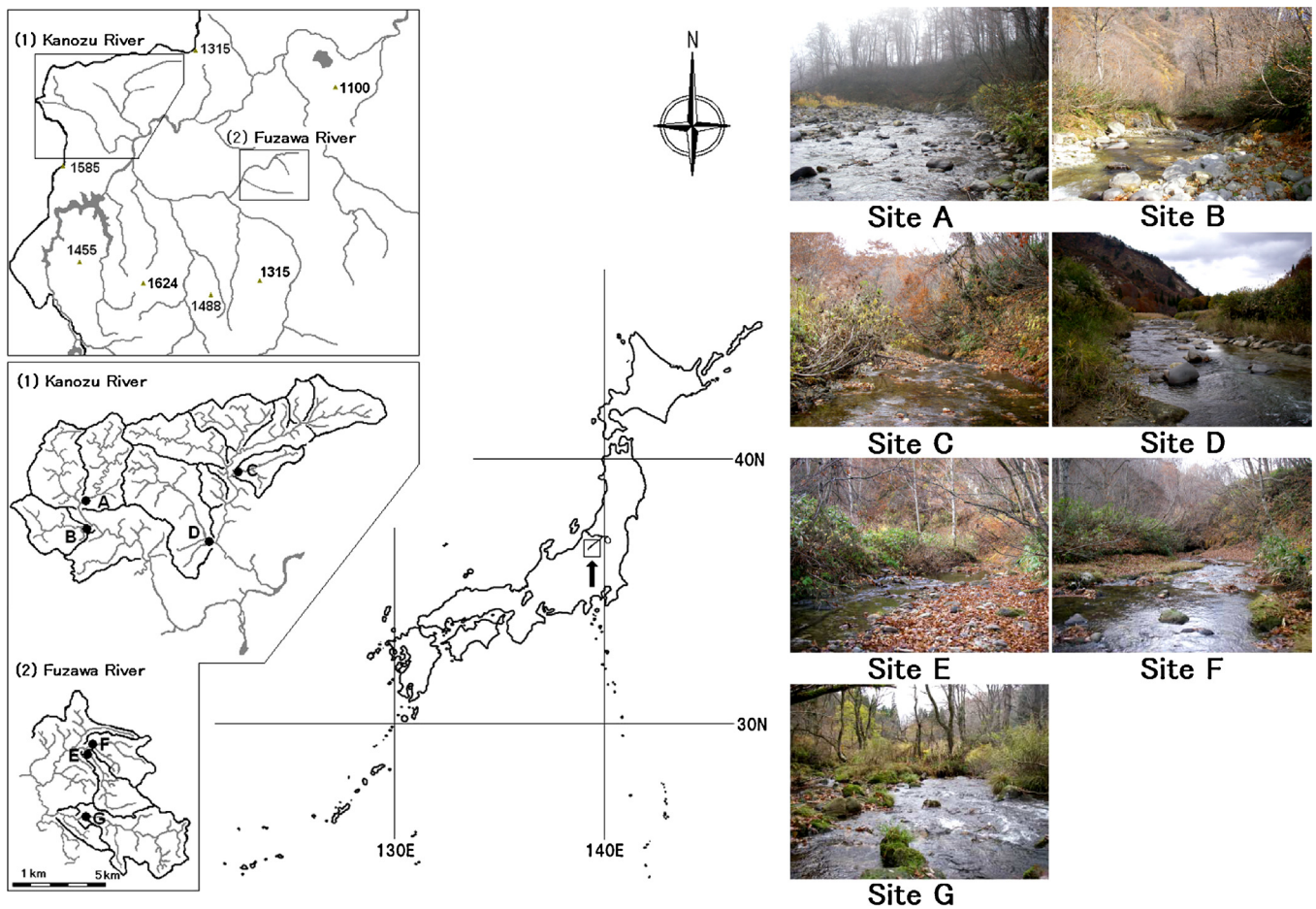*E-mail address:* yoshi887@ffpri.affrc.go.jp

Fig. 1. Seven sampling sites (A–G) in the Tadami River system.

Considering the facts described above, the assemblage structure of stream biota seems to be strongly correlated with the values of $\delta^{13}C$ and $\delta^{15}N$ for each species. However, few studies have investigated the relationship between the abundance, species richness and assemblage structure of stream animals and the values of the stable isotope ratios of carbon (C) and nitrogen (N). A report by Layman et al. (2007) is restricted by the assemblage of food web, and not the assemblage of biota inhabiting it. The abundance, species richness and assemblage structure of stream animals have been used as indicators of biodiversity in stream biota (Yoshimura, 2007), but obtaining these indices requires the identification of a broad range of species by numerous specialists. Therefore, non-specialists such as assessment groups and executives, cannot directly determine the biodiversity in the stream. The objective of this study is to make clear the relationships between the abundance, richness and assemblage structures of benthic invertebrates and their stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$), and to evaluate the utility of the stable isotope ratio as a biodiversity indicator for streams.

2. Methods

2.1. Study site

The study was conducted in tributary streams in the upstream section of Tadami River in the northern part of the main island of Japan (37°32′ N 139°52′ E–37°43′ N 139°24′ E, Fig. 1). The Tadami River flows into the Japan Sea and has a total length of 145 km. The river basins of the upstream Tadami River are covered with lowland and hill forests [up to 1600 m above sea level] composed primarily of secondary forests and old-growth forest with no historical record of clearance. Above 1100 m a.s.l., the forests are dominated by deciduous broad-leaved trees (e.g. *Fagus crenata*, *Acer tschonoskii*, *Clethra barbinervis*) and conifers (e.g. *Pinus parviflora* var. *pentaphylla*, *P. parviflora*, *Pinus densiflora*, *Thuja standishii*). At approximately 1100 m a.s.l., broad-leaved trees are gradually replaced by a variety of vegetation (e.g. *F. crenata*, *Acer japonicum*, *Acer sieboldianum*). The lowland forests are dominated by diverse broad-leaved trees (e.g. *Quercus serrata*, *Quercus crispula*, *Magnolia obovata*, *A. sieboldianum*, *Sorbus alnifolia*). The annual mean temperature from 1996 to 2010 was 10.3 °C and the annual temperature range was 9.1 °C. The monthly mean precipitation from 1996 to 2010 was 203.1 mm. The snow season is from December to April. Snowfall measured 1.5–2.5 m in January and February even in the residence area. This area is composed of volcanic rock.

Seven sampling sites [Yoshizawa (A), Kinonesawa (B), Ojirosawa (C), Managawa (D), Otakisawa (E), Fuzawa (F), Tazawasawa (G)] were selected in the upstream Tadami River basin. Four (A–D) sites were in the Kanozu river basin and three sites (E–G) were in the Fuzawa river basin (Fig. 1). The sampling sites were chosen to have equivalent substrate conditions and slope.

The vegetation in each sampling basin was determined using a 1/20,000 vegetation map (National Forest Map for the 1996 Management Plan) and field surveys. The vegetation was divided into nine categories based on forest age (>100 years, 75–100 years, 50–75 years, 25–50 years, <25 years) and forest type (broad-leaved forest, planted coniferous forest). Each sampling basin was divided into 100 × 100-m grids, and the number of grids containing each