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Note

Use of Stable Carbon Isotope Ratios ($\delta^{13}C$) for Identification of the Origin of Organic Carbon in Benthic Food Webs in Youngil Bay, Korea

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The analysis of stable carbon isotope ratios for benthic fauna was applied to identify the source of carbon in benthic food webs in Youngil Bay, Korea. The $\delta^{13}C$ values of 9 invertebrate species collected in this area showed a narrow range between −20.5 and −16.3‰ with a mean of −18.1 (±1.1)‰. The results suggest that the major source of organic carbon for the benthic fauna of the lower estuarine reaches and the oceanic sites is autochthonous marine particulate organic matter. The contribution of organic matter from terrestrial and riverine sources to the diet of the benthic fauna in this area appears to be minor, despite the considerable inflow of riverine waters.

INTRODUCTION

Carbon is the main tracer in tracking the transformation of organic matter in the ecosystem food webs. The biochemical composition can not provide any more information about the origin of carbon after the chemical and metabolic processes have ended, while the isotopic compositions are generally preserved and thus animal $\delta^{13}C$ values reflect the carbon isotope composition of their diet with only a slight enrichment of about 1‰ (DeNiro and Epstein, 1978). Such an isotopic characteristic can provide a useful information on the source of organic carbon and energy flows in food webs of aquatic ecosystems (Fry and Sherr, 1984; Gearing, 1991; Michener and Schell, 1994). Therefore, since diverse photosynthetic plant groups from terrestrial to marine ecosystems differ distinctively in the $\delta^{13}C$ value, the origin of carbon actually assimilated by animals can be assessed from their $\delta^{13}C$ values.

Recent studies for the application of stable carbon isotope ratio in the coastal environments of the Korean peninsula are focused upon seasonal variation of particulate organic matter (Kim *et al.*, 1994), upon paleoceanographic investigation from the fossil mollusk shells (Woo *et al.*, 1994, 1995a, b), upon mollusk shells and the temperature of ambient seawater (Khim, 1997; Ji and Woo, 1998a, b), and upon foraminifera and present oceanographic environments (Park and Lee, 1994). To our knowledge, the first application of stable carbon isotope ratio to investigate carbon sources in marine and/or estuarine ecosystems of the Korean peninsula was conducted for an estuarine clam *Corbicula japonica* PRIME near the mouth of the Hyungsan river in Youngil Bay (Kang *et al.*, 2000).

Youngil Bay is an estuarine type bay where freshwater is pulsed through the Hyungsan river (mean discharge 17.4 $m^3 \cdot s^{-1}$) which drains a 1167 km^2 agricultural and forested catchments (Yi, 1994). Oceanic waters enter through the northeastern entrance and move anticlockwise. Thus, riverine water influences the southern part of the bay. The species composition of benthic polychaete community is also different depending on the location and sediment type within the bay (Shin *et al.*, 1992). Kang *et al.* (2000) showed that suspended particulate organic matter (POM) in marine waters is enriched in ^{13}C by about 11.3‰ compared to riverine POM in the bay. They concluded that the observed difference in $\delta^{13}C$ between marine POM and terrestrial detritus can be substantial enough to be reflected by differences in the $\delta^{13}C$ signatures of benthic consumers and the carbon incorporated into the estuarine clam *Corbicula* tissues originated from terrestrial organic detritus including freshmarsh plants.

The purpose of the present study was to investigate the $\delta^{13}C$ values of the benthic consumers in the lower estuarine reaches and the oceanic sites of Youngil Bay, and to determine whether they utilize the same source

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of carbon as found previously for an estuarine clam in the upper and middle reaches of the Hyungsan river estuary within the bay.

MATERIALS AND METHODS

The sampling of macrobenthos was carried out at 4 stations in Youngil Bay in July 1999 (Fig. 1). General oceanographic features and benthic species composition of Youngil Bay were described by Shin *et al.* (1992) and Kang *et al.* (2000). Sediments were collected using a weighted 0.1 m^2 van Veen grab sampler and sieved through 1 mm mesh seive. After sorting, specimens were kept alive overnight in filtered water from the sampling station to evacuate gut contents. They were dissected carefully and the tissue was acidified in 10% V:V HCl to remove any carbonate debris from the shell, quickly rinsed with Milli-Q water and then pooled into each species. They were then freeze-dried, ground into fine powder using mortar and pestle, and kept frozen (−40°C) until analysis.

Animal tissues for isotope analyses were combusted using a CNS analyzer and the evolved CO_2 gas was purified. Their stable isotopic compositions were analyzed on a stable isotope mass spectrometer (PRISM II, Micromass) at Korea Basic Science Institute. The isotopic composition is expressed as a $\delta^{13}C$ value, defined the per mil (‰) deviation from the PeeDee Belemnite standard (PDB) following the method of Craig (1957) where $\delta^{13}C=[(R_{sample}/R_{PDB})-1]$, with $R=^{13}C/^{12}C$. Analytical precision of mass spectrometer measurements was ±0.1‰.

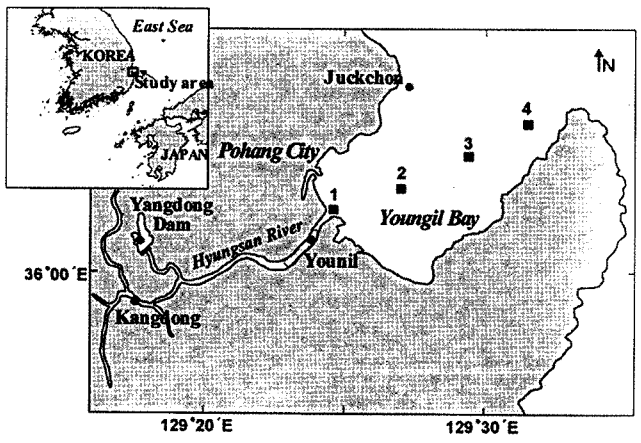

Fig. 1. Sampling stations (■) of benthic consumers in this study. Dots (●) indicate the stations for suspended particulate organic matter; ash-colored site, for the clam *Corbicula japonica* as previously reported by Kang *et al.* (2000).

RESULTS AND DISCUSSION

The $\delta^{13}C$ values of 9 invertebrate species (6 polychaetes and 3 bivalves) which were collected during a rainy season of this study are presented in Table 1. All fauna had a narrow $\delta^{13}C$ range of −20.5 to −16.3‰ and a mean of −18.1 (±1.1)‰ in the four sampling stations. There was no significant difference (Kruskal-Wallis test, H=4.71, df=3, p>0.19) among mean values for the fauna collected at the different stations. No clear tendency in inter- and intraspecific variations was found for deposit-feeder, suspension-feeder and carnivores. Available data on stable carbon isotope ratios of various organisms living in nearshore and estuarine systems are numerous (see Michener and Schell, 1994; Currin *et al.*, 1995; Page, 1997). However, no study has yet been conducted in temperate Korean coastal waters.

The use of stable carbon isotope compositions in tracing food webs in aquatic ecosystems is based upon two principal hypotheses: first, food sources must have large differences in $\delta^{13}C$ values and second, the transfer of carbon isotope compositions to the animal from the diet must be conserved (Fry and Sherr, 1984). Kang *et al.* (2000) already showed that different primary food sources of Youngil Bay are isotopically distinct. Figure 2 shows the percentage frequency distribution of $\delta^{13}C$ values for the fauna collected in this study, together with the various sources of organic matter reported by Kang *et al.* (2000). Although marine POM and freshmarsh plants have

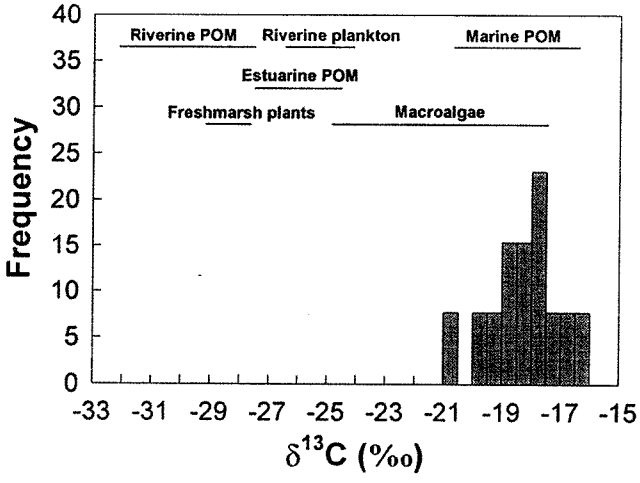

Fig. 2. Percentage frequency distribution of stable carbon isotope ratios found for individual consumer species from the Youngil Bay sampling stations. Data for suspended particulate organic matter (POM) and primary sources are taken from Kang *et al.* (2000).

Table 1. Mean $\delta^{13}C$ values and individual measurements of benthic consumers at each station on a transect of Youngil Bay

Species	$\delta^{13}C$, ‰				
	Station 1	Station 2	Station 3	Station 4	Mean
Glycera chirori	−18.0		−19.1		−18.6
Moerella jedoensis (Lischke)	−18.6	−17.2	−18.0		−17.9
Nepthys polybranchia	−17.8	−16.6	−16.3		−16.9
Nereis sp.				−16.9	−16.9
Pectinaria hyperborea auct.	−20.5				−20.5
Scoloplos amiger		−17.9			−17.9
Spiophanes bombyx		−18.6		−17.8	−18.2
Yoldia johanni Dall		−17.7			−17.7
Unknown bivalve spat	−19.7				−19.7
Mean	−18.9±1.2	−17.6±0.8	−17.8±1.4	−17.4±0.6	−18.1±1.1

$\delta^{13}C$ values as negative as −29‰, the consumers that approach that value were not collected in this study. Although ^{13}C enrichment of about 1‰ along food chains (DeNiro and Epstein, 1978) is taken into consideration, the $\delta^{13}C$ values for the fauna in this study are still far from those of riverine plankton or estuarine POM. The most striking conclusion of this study is that the $\delta^{13}C$ range of the fauna is overlapped to that of marine POM. This result clearly indicates that marine POM is predominantly used by the benthic fauna. The $\delta^{13}C$ values of the fauna are also similar to those of macroalgae. It may be thus difficult to eliminate the possibility of the use of macroalgae. However, since sediments of the bay largely consist of mud and sand, macroalgal biomass is expected to be relatively low.

Our isotopic data for the fauna from the lower estuarine reaches and the oceanic sites of Youngil Bay make an interesting comparison with the data for a bivalve species from the upper and middle reaches of the Hyungsan river estuary within the bay. Contrary to the result for the upper and middle estuarine sites, we found no evidence to suggest that organic matter from the terrestrial and riverine sources were incorporated into benthic food webs of the lower estuarine reaches and the oceanic sites. These results strongly suggest that an important role of terrestrial organic matter as a carbon source for benthic food webs in Youngil Bay can be limited to the upper and middle estuarine reaches. Similar results have been pronounced in many estuarine ecosystems (Incze *et al.*, 1982; Riera and Richard, 1996; Deegan and Garritt, 1997; Riera, 1998). We do not have seasonal data. However, taking it into consideration that sampling for the fauna was carried out during a rainy season of late July, the organic matter transported by the riverine waters is unlikely to be important food resource for the fauna over the course of the year.

Identifying the source of organic matter in the estuarine and coastal food webs is one of the most important considerations for the understanding and management of these ecosystems. The relative importance of food sources can be determined by the feeding mode of consumers. The 9 invertebrate species collected in this study include deposit-feeders, suspension-feeders, ominvores and carnivores. However, more research is needed to identify the source of carbon for all the common marine phyla, resentative of all the feeding modes including zooplankton, fish and other invertebrate species, and to determine seasonal variability in the isotopic composition of the potential food sources and the animals.

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