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Isotopic Determination of Terrestrial Food Sources for a Brackish Water Clam *Corbicula japonica* PRIME in an Estuarine System of Youngil Bay, Korea

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The importance of terrestrial organic matter as a food source for a brackish water clam *Corbicula japonica* was evaluated using stable carbon isotope ratios ($\delta^{13}C$) in its tissues and potential food resources in an estuarine system of Youngil Bay, Korea. Suspended particulate organic matter (POM) had distinct $\delta^{13}C$ values from riverine (−31.8 to −27.2‰) to marine waters (−21.0 to −16.6‰). Estuarine macroalgae had a wide $\delta^{13}C$ range of −22.8 to −15.0‰. The $\delta^{13}C$ values of riverine POM were more negative than that of riverine phytoplankton (−26.5 to −24.2‰) but similar to that of freshmarsh plant species (−29.1 to −27.5‰ for *Phragmites communis* and −28.5 to −27.0‰ for *Salix gracilistyla*). These $\delta^{13}C$ values suggest that the POM transported by the Hyungsan River is predominantly of terrestrial origin rather than riverine autochthonous sources. The $\delta^{13}C$ values of *Corbicula japonica* tissues (−28.7 to −27.2‰) were most similar to values for riverine POM and freshmarsh plants. There was no significant difference in the isotopic composition of the clam individuals. The results indicate a predominant contribution of organic carbon derived from terrestrial and fresmarsh plant detritus to the diet of *Corbicula japonica.* Our results also confirm previous suggestion that terrestrial organic matter can be incorporated into estuarine food webs although its role is confined to the upper estuarine reaches.

INTRODUCTION

An estuary is one of the brackish areas characterized by high production (autochthonous) and allochthonous input of organic matter that is essential as trophic source for benthic animals. Knowledge of the relative importance of these two food sources is thus of importance for the understanding of benthic food web and energy flow within the estuarine ecosystem. The relative importance of organic matter of various origins to estuarine food webs can differ depending on the locality within the estuary (Deegan and Garritt, 1997), feeding mode, size and trophic position of the consumers (Peterson and Howarth, 1987; Riera, 1998), seasonal availability of a particular component (Riera and Richard, 1997) and sorts of vegestion in intertidal flat (see Créach *et al.*, 1997).

Marsh clams, *Corbicula japonica* PRIME, are typical brackish water species inhabiting estuaries (Tanaka, 1984). This species is thus largely distributed at the sand, muddy sand and sandy mud sediments of estuarine systems from the eastern to southern coast of Korea. Little is known about the feeding ecology of *Corbicula japonica.* It has been however demonstrated that the freshwater clam, *Cobicula fluminea* which is similar species to *Corbicula japonica*, can make physiological adjustments to its filtration rate to achieve some optimal rate depending upon the available particle concentration (Way *et al.*, 1990). Several studies have reported that the *Corbicula* is able to ingest selectively phyto-plankton (Hill and Knight, 1981; Foe and Knight, 1985), as shown generally for suspension-feeding bivalves. However, several studies have shown that estuarine bivalves inhabiting the upper or mid-estuary can also utilize terrestrial detritus when food is limited to the terrestrial particulate matter during high river discharge (Incze *et al.*, 1982; Stephenson and Lyon, 1982; Conkright and Sackett, 1986; Riera and Richard, 1996, 1997).

It is hard to determine directly primary food sources for mollusks using a traditional method such as the analysis of gut contents because estuarine particulate matter includes a large quantity of plant-derived and

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terrestrial organic detritus that is not able to be easily identified under microscope. Gut contents may also reflect material which is not assimilated and some material is digested quickly, making identification of food material difficult (Michener and Schell, 1994). Stable carbon isotope has been recently used as a natural tracer for aquatic food web analysis because carbon isotopic compositions of animals reflect those of diet with only a slight enrichment in each trophic transfer (see Fry and Sherr, 1984; Michener and Schell, 1994). The carbon isotopic compositions of plants depend upon the metabolic pathway during photosynthetic fixation of carbon. Therefore, plants from various taxonomic groups differ distinctively in $\delta^{13}C$ values: C_3 versus C_4 plants (Bender, 1971; Smith and Epstein, 1971; Benedict, 1978). Many studies have demonstrated that, based on comparison of $\delta^{13}C$ value of consumer bivalve tissues, the stable carbon isotope ratios can define organic carbon sources and trophic levels where potential food sources are isotopically distinct (Haines, 1976; Fry and Parker, 1979; Incze *et al.*, 1982; Stephenson and Lyon, 1982; Riera and Richard, 1996). In addition, since the $\delta^{13}C$ value of plant detritus is the same as that of live plant (Haines, 1977; Gearing, 1984; Zieman *et al.*, 1984; Stephenson *et al.*, 1986; Fenton and Ritz, 1988), it may be possible to trace the origin of carbon in aquatic food chains, even when based on detrital food sources.

The objective of the present study was to determine the composition of food actually assimilated by an estuarine bivalve *Corbicula japonica* from the Hyungsan river estuarine system of Youngil Bay (Korea). Our hypothesis was that the estuarine clam could utilize organic matter of terrestrial origin as its food. This hypothesis was tested by comparing the stable carbon isotope ratio ($\delta^{13}C$) of the clam and its potential food resources in the watershed.

Many studies on the biology of *Corbicula japonica* have been conducted for its distribution, spawning and growth in Korean estuarine systems (Jung, 1977; Cho *et al.*, 1997, 1998). The spawning of this species takes place from March to October and its main spawning has been observed in June. Clam spats newly settled down in early summer grow rapidly during mid-summer season and stop growing from autumn to winter. The growth maximum of juvenile (young individual of the second year) and adult clams has been found between May and September.

A distinctive postmetamorphic alteration of feeding behavior has been observed in many bivalve species (Reid 1991). *Corbicula fluminea* undergoes postmetamorphic alteration for food particle collection by foot in an adult stage of its life cycle (Reid *et al.*, 1992). Thus, we have studied the variation of tissue carbon isotopic composition with size (age) of *Corbicula japonica* during its main growing and spawning seasons.

MARERIALS AND METHODS

Study area

The Youngil Bay is an estuarine bay located on the southeastern coast of Korea (Fig. 1). The bay has an area of approximately 120 km^2, an average depth of 20 m and a tidal range of 7.6 cm. Marine waters enter through the northeastern enterance and move anticlockwise. Accordingly, marine particulate organic matter was sampled at the northerntrance (Juckchon) of the mouth of Youngil Bay. Freshwater flows into the bay from the Hyungsan River (mean discharge 17.4 m^3 s^{-1}) that drains a 1,167 km^2 agricultural and forested catchment. Clams are distributed near the lower reach of the Hyoungsan River. A brackish water species *Corbicula japonica* is concentrated and transplanted to this site from Kwangwon Province in mid-eastern part of Korea (Cho *et al.*, 1998). This species has been commercially exploited for a long time. Clam sampling site is dominated by coarse sand sediments and is very shallow (depth $\leq$2 m) (Fig. 1). Salinity of the site ranged from 3 to 21 psu depending on the tidal motion. Although both sides of the Hyungsan River are covered by diverse vegetation, two dominant species occupy most of the

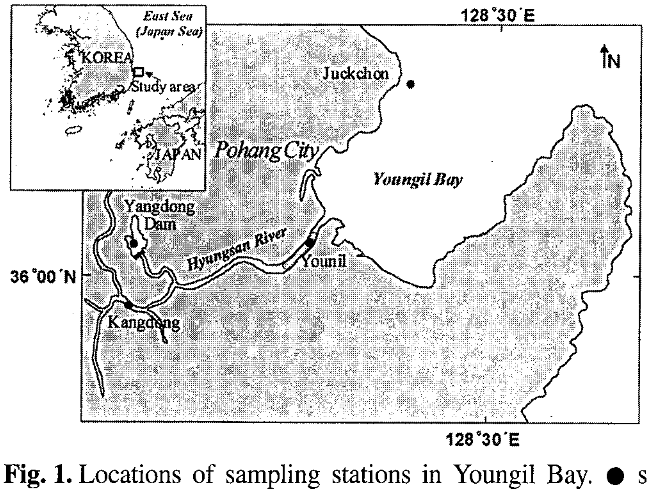

Fig. 1. Locations of sampling stations in Youngil Bay. ● s indicate the stations for particulate organic matter; ash-colored site indicates the habitat of *Corbicula japonica.*

plant biomass: *Phragmites communis* TRIN and *Salix gracilistyla* MIQUEL. To characterize the terrestrial inputs, particulate organic matter (POM) was sampled 15 km upstream from the mouth of the Hyungsan River, in a human lake of Yangdong where a dam prevents any tidal effects. Seston of the site is likely to contain all kinds of POM derived from upland and fresh water. Autochthonous algal community in the running water of the river was also sampled near the Kangdong bridge where the water is nearly stagnant.

Sample collection and preparation

Clams were collected during a spring-summer period 1999 (April, June and July). Specimens were taken with 1 mm mesh seive sampler and kept alive overnight in filtered water from the sampling site 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 10 to 20 individuals by size. They were then freeze-dried, ground into fine powder using mortar and pestle, and kept frozen (–40°C) until analysis.

POM samplings were conducted 4 times at the spring-summer period 1999 (March, April, June and July) at four stations. About 5 to 10 l of water were pumped from about 30 cm under the water surface and prefiltered with a 63-μm screen to remove any zooplankton and large particles. POM was then filtered on precombusted Whatman GF/F glass fiber filters and the filterates were rinsed three times with Milli-Q water. A subsample for chlorophyll *a* determination was filtered on Whatman GF/F filters following Holm-Hansen *et al.* (1965). A subsample was also fixed with Lugol's solution and examined qualitatively for algal species composition. Dominant plants and macroalgae were collected manually during the same period and cleaned with Milli-Q water. Some freshmarsh plants were separated into live and dead blades. All POM and vegetation samples were then prepared in the same way as clam tissues.

Stable isotope analysis

All organic samples for isotope analyses were combusted using a CNS analyzer and the evolved CO_2 gas was purified. Its stable isotopic composition was analyzed on a stable isotope mass spectrometer (PRISM II, Micromass) of Korea Basic Science Institute. 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‰.

RESULTS

Carbon isotope composition of POM and primary producers

Five origins of organic carbon were determined as potentially available food sources to the clam population within the estuarine system studied: marine POM, detritus from land producers, freshmarsh plant species, phytoplankton in the running water, and estuarine macroalgae.

The 2 species of freshmarsh plants, which were analyzed in the study, were typical species of marsh of the Hyungsan River. The marsh plant blades had the quite constant $\delta^{13}C$ values of –28.5±0.6‰ (*Phragmites communis*) and –27.7±0.7‰ (*Salix gracilistyla*), respectively (Table 1). No significant isotopic difference was found between living and dead blades of *phragmites communis* at each sampling date

Table 1. $\delta^{13}C$ values (‰) of plant leaves and macroalgae in the Hyungsan river estuarine system of Youngil Bay at different periods

Species	Stations	25 March	20 April	8 June	28 July	Mean (±SD)
Live *Phragmites communis*	Kangdong bridge	–28.6	–29.6	–27.5	–29.4	–28.8 (±1.0)
Dead *Phragmites communis*	Kangdong bridge	–28.8	–28.0	–29.1	–29.3	–28.8 (±0.6)
Live *Phragmites communis*	Younil	–28.6	–28.2	–29.1	–27.9	–28.5 (±0.5)
Dead *Phragmites communis*	Younil	–28.2	–28.8	–28.0	–28.2	–28.3 (±0.3)
Salix gracilistyla	Kangdong bridge	–28.5	–27.0	–28.0	–27.4	–27.7 (±0.7)
Urospora penicilliformis	Younil	–23.3	–22.8	-	-	–23.1 (±0.7)
Ulva lactuca	Younil	-	-	–15.0	-	–15.0
Enteromorpha compressa	Younil	-	-	–20.9	-	–20.9

(t-test, df=14, p>0.8). This means that microbial decomposition is not likely to alter the isotopic composition of original primary plants. There were no significant differences for the δ^{13}C values of *phragmites communis* between the sampling stations and among the sampling dates (two-way ANOVA, p>0.2 for all factors).

The δ^{13}C values of macroalgae varied with the wider range from −23.3‰ for *Urospora penicilliformis* to −15.0‰ for *Ulva lactuca* (Table 1). Their mean δ^{13}C value was −20.5‰ (±3.8). Such a wide variability in the carbon isotope composition of macroalgae has been found in the literature (see Currin *et al.*, 1995). Though these macroalgae were attached on the gravels of the estuarine substrates, their biomasses were relatively low.

The δ^{13}C values of POM from the purely riverine station (Yangdong Dam) ranged from −31.8 to −27.2 ‰ with a mean of −29.9‰ (±2.3) (Table 2), while the values from the marine station (Juckchon coast) were much more positive with a range of 21.0 to −16.6‰ and a mean of −18.6‰ (±2.2). The estuarine station (Younil) exhibited intermediate δ^{13}C values from −26.6 to −24.4‰. There was a strikingly clear separation of fresh-water and marine species in the distribution of phytoplankton (Table 3). Phytoplankton from the marine station were dominated by typical marine taxa (*Chaetoceros* spp., *Prorocentrum minimum* and *Thalassiothrix flanenfeldii*), while in the riverine stations they consisted mainly of typical fresh water taxa (*Anabaina* sp., *Aphanocapsa* sp., *Asterionella formosa* and *Microsystics rivularis*). In the estuarine station, phytoplankton assemblage comprised a mixture of these two groups. This result indicates that the δ^{13}C values of estuarine POM may reflect the mixing of materials from terrestrial and marine sources.

Riverine phytoplankton were sampled from the surface water of a riverine station near the Kangdong bridge because of difficulties in separation of pure phytoplankton assemblage from the filtration of natural waters. In this station, the water was stagnant and chlorophyll *a* concentration of the surface water reached 19.6 μg·l^{-1} in May and June, about 9 times higher than those of the other three stations. Also, phytoplankton were composed of typical fresh water taxa (Table 3) and reached greatest abundance in the studied stations. The riverine phytoplankton showed a narrow range of δ^{13}C values from −26.5 to −24.2‰, with a mean of −25.3‰ (±1.2) (Table 2). In July, the value reached −29.0‰ owing to the increase of river discharge and thereby high turbidity by a large amount of yellow clay materials. Thus, this value was not considered riverine phytoplankton end-member.

Carbon isotope composition of Corbicula japonica

Carbon isotope ratios of clams sorted and pooled by shell size from an estuarine station of Youngil Bay during three sampling periods are presented in Figure 2 and Table 4. Average δ^{13}C values of clams ranged from −28.7‰ (±0.8) (April 1999) to −27.3‰ (±0.6) (June 1999) for the total sampling period (mean −28.0± 0.9‰). Although they showed statistically significant difference (one-way ANOVA, p<0.001) among the sampling dates, the difference between the dates was less than 1.4‰. No tendency was found in the δ^{13}C values depending on the clam size on each sampling date (Fig. 2). Intraspecific difference in δ^{13}C values was not significant (t-test, df= 30, p>0.1) between natural individuals (mean −27.9± 0.8‰) and transplanted ones (mean −28.3±0.6‰) (Table 4).

DISCUSSION AND CONCLUSIONS

Carbon isotope composition of potential food sources

Because of little influence of anthropogenic activities, origins of POM in the Hyungsan River are expected to be POM from *in situ* production of phytoplankton and terrestrial organic matter from the catchment. In the present study, the δ^{13}C value of riverine phytoplankton ranged from −26.5 to −24.3

Table 2. δ^{13}C values (‰) of sestonic particulate organic carbon from the sampling stations in the Hyungsan river estuarine system of Youngil Bay at different periods

Stations	25 March	20 April	8 June	28 July	Mean (±SD)
Yangdong dam	−31.8	−28.6	−27.2	−31.8	−29.9 (±2.3)
Kangdong bridge	−24.2	−26.5	−25.2	−29.0	−26.2 (±2.1)
Younil	−24.4	−25.4	−26.6	−27.9	−26.1 (±1.5)
Juckchon coast	−21.0	−20.0	−16.6	−16.9	−18.6 (±2.2)

Table 3. List of phytoplankton species in the present study

Site	Yangdong Dam		Kangdong Bridge		Younil		Juckchon coast	
Date	June	July	June	July	June	July	June	July
Anabaina sp.	C					C		
Aphanocapsa sp.		C		C	C	C		
Asterionella formosa			R	R		R		
Bateriastrum sp.								R
Ceratium furca							R	R
Ceratium fusus								R
Chaetoceros spp.					R	R	R	C
Chroococus sp.						C		
Cocconeis sp.			R	R				
Dictyoceis fibula								R
Eutreptiella gymnastica			R	R				
Fragilaria construeus			R					
Fragilaria sp.	R					R		
Guinaardia flaccida						R		R
Gymnodinium sp.								R
Melosira granulata				C		C		
Melosira sp.		R		C	R	C		R
Microsystics virrdis	C	C	C					
Navicula sp.	R		R	C	R	C	C	
Nitzschia longissima								R
Nitzchia sigma	R		R	R				
Nitzchia sp.				R			C	
Nostoc sp.				C	C			
Oscillatoria sp.					C			
Prorocentrum dentatum								R
Prorocentrum minimam								C
Scenedesmus sp.		R			R	C		
Schroedenia spiralis	R							R
Scrippsiella trochodea								R
Skletonema costatum					R	R	R	R
Stauroneis anceps					R			
Synedra sp.				R		R		
Thalassiosira sp.					R	R		R
Thalassiothrix flauenfeldii								C
Ulorhrox aequalis			R					

C, common; R, rare

‰. These values may not represent the value of pure algal material since it is very difficult to separate completely algal cells from the rest organic debris and microbes. The isotopic composition of phytoplankton could be indirectly estimated from the $\delta^{13}C$ value of dissolved inorganic carbon (DIC) (Tan and Strain, 1983). Unfortunately, we have no isotopic data of DIC. Our isotope data set for riverine phytoplankton was therefore obtained from the samples with the "cleanest" algal community as reported by Junger and Planas (1994). Chlorophyll *a* concentrations in the samples were relatively high (about 20 $\mu g \cdot l^{-1}$) and microscopic examination confirmed that a significant part of particles consisted of algal cells. The resulted values were very close to the range reported for riverine phytoplankton by Tan and Strain (1983) in the St. Lawrence Estuary, and Junger and Planas (1994) in a boreal forest lotic system in Québec.

POM in the upper reach of the Hyungsan River had

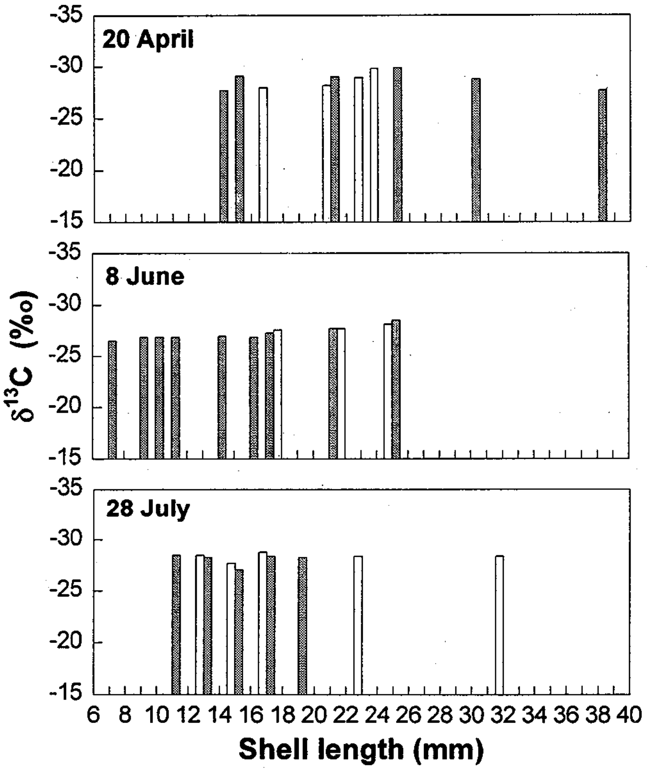

Fig. 2. Variaton of $\delta^{13}C$ with size for *Corbicula japonica* collected in the Hyungsan river estuary. Dotted bar, natural individuals; empty bar, transplanted ones.

more negative $\delta^{13}C$ values (mean −29.9±2.3‰) than that of the riverine phytoplankton. These values fall within the typical range of upland C_3 plants (Sternberg *et al.*, 1984; Conkright and Sackett, 1986; Peterson and Howarth, 1987; Cai *et al.*, 1988). In the present study, the $\delta^{13}C$ values (mean −28.5±0.6‰ and −27.7±0.7‰) of dominant freshmarsh plants, *Phragmites* and *Salix*, were also close to the upriver POM value. The relative importance of two potential sources for riverine POM can be evaluated using the $\delta^{13}C$ data (Cai *et al.*, 1988; Riera and Richard, 1996). If the POM had been predominantly contributed by riverine autochthonous phytoplankton, the POM $\delta^{13}C$ values would have been much less negative. The present $\delta^{13}C$ values of riverine POM thus strongly suggest that the POM transported by the Hyungsan River is predominantly of terrestrial origin rather than riverine autochthonous source.

Marine POM had the most positive $\delta^{13}C$ value (mean −18.6±2.2‰) in the potential food components and was similar to the range reported previously for marine phytoplankton (see Michener and Schell, 1994; Currin *et al.*, 1995). POM at the Juckchon coast may not include any terrestrial detritus because marine waters are introduced to Youngil Bay through the northeastern entrance from East Sea (Japan Sea). Microscopic examination indicated that the marine POM is strongly dominated by oceanic diatoms and dinoflagellates (Table 3). Its isotopic ratio was distinct from the opposite end-member (terrestrial POM). The range between these two end-members was 11.3‰. Such a broad range allows us to interpret the relative importance of these two sources to clam diet.

The isotopic composition of estuarine POM may reflect the mixture of the various sources such as terrestrial POM, estuarine phytoplankton, macroalgal debris and marine POM. Macroalgae and marine POM had the most positive $\delta^{13}C$ values in the present study. In general, the $\delta^{13}C$ value of DIC is much more positive in marine waters than in fresh waters (see Coffin *et al.*, 1994). Thus, taking a general isotopic fractionation in C_3 microalgae into consideration, estuarine plankton might have more positive $\delta^{13}C$ values than riverine plankton (mean −25.3±1.2‰, in the present study). This interpretation has been exemplified well in various estuarine systems (Tan and Strain, 1983; Cai *et al.*, 1988; Riera and Richard, 1996). As a result, the $\delta^{13}C$ value of POM in the Hyungsan river estuary (mean −26.1±1.5‰) was more negative than the latter three potential sources and tended to be shifted to that of riverine POM.

Identification of food sources of clams by carbon isotope composition

The $\delta^{13}C$ value of clams was very negative and similar to those of riverine POM and freshmarsh plants. The first possible explanation for such a negative

Table 4. Mean $\delta^{13}C$ values (± SD, ‰) of *Corbicula japonica* from the Hyungsan river estuary of Youngil Bay at different periods

Date	Natural individuals	Transplanted individuals	Average
20 April	−28.7±0.9 (n=6)	−28.7±0.8 (n=4)	−28.7±0.8 (n=10)
8 June	−27.2±0.6 (n=9)	−27.8±0.3 (n=3)	−27.3±0.6 (n=12)
28 July	−28.1±0.6 (n=5)	−28.4±0.4 (n=5)	−28.2±0.5 (n=10)
Mean	−27.9±0.9 (n=20)	−28.3±0.6 (n=12)	−28.0±0.9 (n=32)

δ^{13}C is that high lipid content during the high gamete production could have influence on the δ^{13}C value of the clams because the δ^{13}C value of lipids is much more negative than that of proteins and carbohydrates (DeNiro and Epstein, 1978). In the present study, adult clams spawned before June and clam spats were already settled down in June. Thus, after June, the reproductive phase of most adult clam individuals was the empty stage during which they have no gonads. However, no isotopic difference was found among the smapling periods. There was no tendancy in isotopic value between juvenile and adult clams either. *Cobicula japonica* is well known as a hypolipidemic food (Iritani *et al.*, 1979). These results indicate that the lipid content of clams would not be enough to explain the negative δ^{13}C value. Similarly, Kang *et al.* (1999) reported that tissue lipid of the cockle *Cerastoderma edule* have no great influence on the isotopic composition of its whole bodies because of low lipid content of the cockle tissue.

An alternative explanation is that the clams utilize the food components of which the δ^{13}C value is negative. Figure 3 shows the distribution of δ^{13}C of the clams, compared with the various sources of organic matter and POC. When two food sources that have distinctly different carbon isotope composition are present, carbon isotope values of consumers reflect the contribution of the two food sources to their diet (Fry and Sherr, 1984). If a considerable amount of marine POM and/or riverine phytoplankton had incorporated into the clam tissues, the δ^{13}C value of the clams would have been much more positive and occupied the range between those two food components. In the present study, the δ^{13}C value of the clams was very close to that of riverine POM and freshmarsh plants. Certainly, the δ^{13}C value of marine POM is far from that of clam tissues, indicating little contribution to clam diet. It is difficult to exclude completely the contribution of riverine phytoplankton because the isotopic difference between the phytoplankton and the clam tissues was relatively small on average 2.7‰. Since the metabolic ^{13}C enrichement occurs during the assimilation of food, the carbon isotope values of consumers are 0.7 to 1.5‰ more positive than their diets (DeNiro and Epstein, 1978; Rau *et al.*, 1983; Fry and Sherr, 1984). Therefore, the δ^{13}C value of actual food of clams must be slightly more negative than mean −28.0‰ (±0.9) for clams. Our results strongly suggest a predominant contribtion of terrestrial organic matter to clam diets.

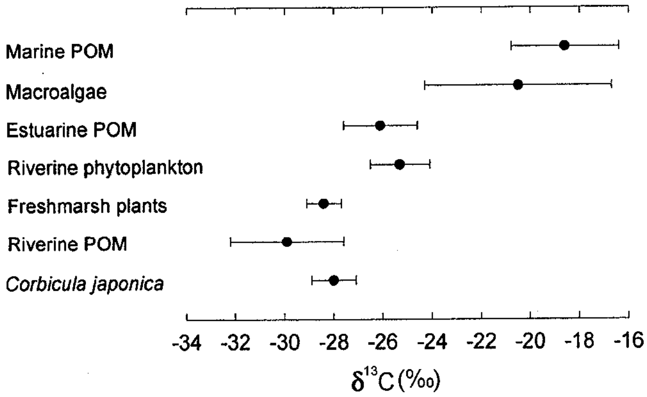

Fig. 3. Comparison of the δ^{13}C values (mean±SD) for *Corbicula japonica* and its potential food sources.

Hill and Knight (1981) showed that phytoplankton was selectively retained by *Corbicula fluminea* from the analysis of the ratio of algal pigment to total particulate matter in its stomach. However, Foe and Knight (1986) reported that although algae appears to be a superior food item for *Corbicula fluminea*, artificial diets (nine-grain cereal, rice flour, rye bran, denatured brewers yeast and *Ralston purina* trout chow) were of nutritional value. Several studies have elucidated the utilization of terrestrial organic matter by estuarine bivalves (see references in Introduction). These authers pointed out that the relative importance of terrestrial organic matter to their diets is determined by the position of bivalves within the estuary and local hydrography. They postulated that when high runoff from the upper estuary forces coastal waters furthur offshore, high nutritive food sources like marine and/or estuarine algae may become poorly available to the bivalves. High ratio (>400) in C:chlorophyll *a* from the Hyunsan river estuarine system (unpublished data, Korean East Sea Fisheries Research Institute) suggests that the proportion of non-living detritus of the riverine POM is much higher than that of live phytoplankton. The mechanisms by which such a high content of terrestrial organic matter is incorporated into bivalve tissues seem to be explained by the recent conclusion of Riera and Richard (1996) that although the carbon assimilated is generally only a few percent of the total POC, non-algal food such as terrestrial detritus can, when supporting a high bacterial biomass, be an important source of nutrition for bivalves in habitats receiving large inputs of terrestrial organic matter.

In Youngil Bay, *Corbicula japonica* is distributed in the upper and middle part of the Hyungsan river estuary. Other bivalve species (*Moerella pectinaria* and *Yoldia johanni*) from the lower estuarine reaches (the mouth of the Hyungsan river) to the oceanic sites displayed a narrow range of δ^{13}C values between −19.7‰ and −17.2‰ (own unpublished data). This range is overlapped to that of marine phytoplankton, indicating no contribution to diet from terrestrial organic matter. This fact supports that incorporation of terrestrial organic carbon by the bivalves in Youngil Bay may be also limited to the upper and middle reaches of the Hyungsan river estuary.

In conclusion, stable carbon isotope data from this study suggest that *Corbicula japonica* can utilize detritus of terrestrial origin including freshmarsh plants as its food. This seems to be attributed to the utilization of carbon originating from terrestrial detritus that is predominant in the POC pool (Riera and Richard, 1996), rather than the preferential ingestion of a particular food component that is a feeding characteristic typical of bivalves. Illustrated from a typical brackish water clam species, our results confirm previous suggestion that although its role is largely confined to the upper estuarine reaches, terrestrial organic matter can be incorporated into estuarine food webs.

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