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Detritus derived from eelgrass and macroalgae as potential carbon source for *Mytilus edulis* in Kiel Fjord, Germany: a preliminary carbon isotopic study

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ABSTRACT: Stable carbon isotope ratios were measured for the muscle tissue of blue mussel *Mytilus edulis*, eelgrass *Zostera marina*, macroalgae *Fucus vesiculosus*, and phytoplankton in two areas in Kiel Fjord, Germany. Carbon isotope evidence is presented to show the predominance of phytoplanktonic production as a carbon source for *M. edulis* tissue carbon. Via decomposition processes for both eelgrass and macroalgal primary production, each contributed 0.5–6.5 % to mussel carbon.

INTRODUCTION

Stable isotope studies have been shown to be useful to define the contribution of different primary producers to given consumer chains. They are also very useful as a method of research on detritus-based trophic systems. The main carbon source for filter feeding bivalves has generally been assumed to be the phytoplanktonic production. However, carbon isotopic studies show that terrigenous detritus significantly contributes to the food range of filter feeding bivalves (Conkright & Sackett, 1986; Haines & Montague, 1979; Incze et al., 1982). Some bivalve species also feed on symbiotic bacteria (Schmaljohann, 1991). Carbon isotope ratios could not be used to estimate the consumption of kelp carbon in coastal food chains off the Aleutian Islands of subarctic Alaska (Simenstad et al., 1993). *Mytilus edulis* L. tissue had carbon isotope ratios close to marine plankton values (between −20 ‰ PDB and −18 ‰ PDB), but interpretation of those values with regard to trophic relationships was impossible due to a wide range of kelp $\delta^{13}C$ values (between −13 ‰ PDB and −28 ‰ PDB). Low CO_2 availability, resulting from high kelp density off the Aleutian Islands, induced this high $\delta^{13}C$ variability in kelp tissue. For the Itamaracá estuarine system in Brazil, carbon isotope measurements indicated that detritus derived from mangrove leaves constituted a significant fraction (up to 59 %) of the food range of *Crassostrea rhizophorae* (Schwamborn, unpubl.). Isotope evidence showed that the teredinid bivalve *Zachsia zenkewitschi* directly feeds on eelgrass rhizomes (Kiyashko, 1986). Thus filter feeding bivalves may as well feed on detritus originating from eelgrass and macroalgae. The provenience of organic matter in detritus based food chains is difficult to estimate from stomach content analyses (Odum & Heald, 1972). As a consequence, the present study uses the differences in carbon isotopic composition between primary carbon sources to determine the contributions of carbon

from the different primary carbon sources to bivalve tissue carbon. The mussel *M. edulis* has been chosen as a target species because of its well known association to eelgrass in Kiel Fjord, Germany (Reusch et al., 1994). The present study is the first preliminary attempt to quantify the fraction of *M. edulis* carbon derived from eelgrass and macroalgal decomposition.

MATERIAL AND METHODS

Samples of *Mytilus edulis* and its potential food sources were taken during June 1993. On 2nd June, 13 specimens were randomly collected from a 50 m^2 area in the inner Kiel Fjord near Düsternbrook (Fig. 1, Area B). The benthic community of this area was conspicuously dominated by the brown alga *Fucus vesiculosus*. Shell lengths of the bivalves ranged from 32 to 53 mm, and the average shell length was 41 mm (SD = 7 mm). Algal samples were collected by cutting small pieces (3–5 mm in length) from randomly chosen disparate plants. On 4th June, mussels and eelgrass *Zostera marina* were collected with a Van Veen grab sampler within Area A (Fig. 1) at a depth of 11 m. These samples contained muddy bottom substrate, eelgrass and 6 specimens of *M. edulis*. Shell lengths of the bivalves ranged from15 to 36 mm and showed an average of 27 mm (SD = 8). No *F. vesiculosus* strands were found in Area A. Plankton samples were collected by hand-towing a 55-µm plankton net. Biochemical activity of the plankton samples was terminated by adding $MgCl_2$ (concentration in the sample: 1 %). The samples were kept in darkness at 6 °C until further analysis.

All samples were instantly transported to the laboratory, where the shell lengths were measured, and then the bivalves were dissected. Feet tissue was cut out and separated from the byssus glands and the adjacent adhesive bands. Algal and eelgrass material were manually cleaned and rinsed under freshwater. Using a vacuum pump, the plankton samples were then filtered through silicate filters with 1- to 3-µm diameter pores. Prior to filtration, the filters had been combusted at 500 °C to remove adhesive organic material. After drying the samples at 85 °C for 24 hours, the material from each probe type was ground to a maximum particle diameter of 0.02 mm. Material from each sample of the bivalves, eelgrass and algae was separately homogenised. Finally, subsamples of 0.0123 to 0.0237 g dry weight were analysed for their $^{13}C/^{12}C$ ratio using a double-inlet mass spectrometer (Type: Kordt).

The contributions of carbon to consumer tissue were calculated by inserting the $\delta^{13}C$ values into the following equation:

$$F_{K;\,PS_2} = \frac{\delta^{13}C_K - \delta^{13}C_{PS_1}}{\delta^{13}C_{PS_2} - \delta^{13}C_{PS_1}}$$

where K is consumer; PS_1 is primary source 1 (e.g. phytoplankton); PS_2 is primary source 2 (e.g. eelgrass); and $F_{K;\,PS_2}$ is the fraction of carbon in consumer K tissue derived from primary carbon source 2.

This equation requires that the $\delta^{13}C$ value of a given consumer tissue is identical to the $\delta^{13}C$ value of its food. Several studies have shown the existence of an additional $\delta^{13}C$ shift during assimilation processes which leads to slightly (~1 ‰) higher $\delta^{13}C$ values in the consumer tissue (Teeri & Schoeller, 1979). In case this assimilatory $\delta^{13}C$ shift can not be quantified, the fraction calculated by the equation represents the maximum contribution of primary source 2 to consumer tissue. During the present study, a hypothetical shift

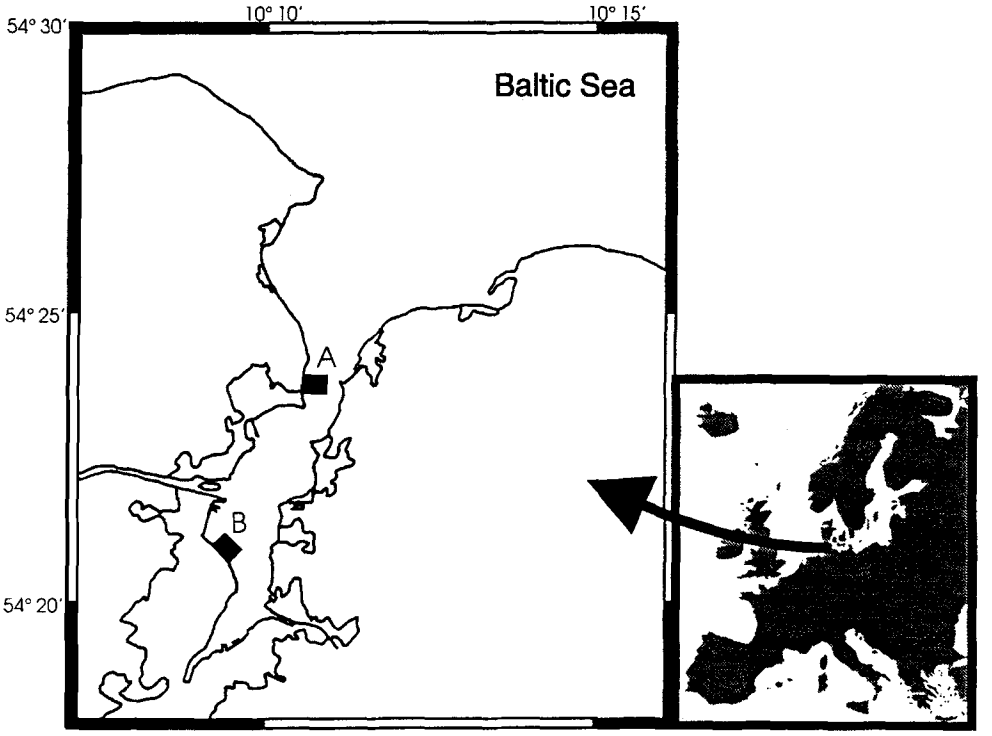

Fig. 1. Map of the Kiel Fjord, Germany, showing the sampling areas A (Falkenstein) and B (Düsternbrook)

of 1‰ was subtracted from the measured $\delta^{13}C_K$ values in order to approximate the minimum contribution of primary source 2 to consumer K tissue.

RESULTS AND DISCUSSION

The carbon isotope values for the mussel tissue from the two sampling areas do not show distinct differences (Table 1). The values remain close (± 1‰) to $\delta^{13}C$ values measured in phytoplankton samples. *Zostera marina* and *Fucus vesiculosus* show higher $\delta^{13}C$ values ($\Delta > 4.9$‰) than phytoplankton and mussel tissue. The phytoplankton contribution to mussel carbon is clearly predominant in both areas (Table 2). Eelgrass-derived carbon contributes a maximum of 8 % to mussel tissue carbon in the eelgrass meadow off Falkenstein beach (Area A). The macroalga *F. vesiculosus* has a maximum input of 21 % to mussel tissue carbon in the macroalgal assemblage off Düsternbrook (Area B). Benthic primary carbon sources have an estimated overall maximum contribution of 13 % to Kiel Fjord mussels. As the significance of the trophic $\delta^{13}C$ shift during assimilation by *Mytilus edulis* is not yet precisely known, it is difficult to quantify the contribution minimum for the benthic primary producers. The assumption that an assimilatory shift of 1‰ exists leads to a minimum carbon contribution for benthic sources that is between 0 % and 4 %.

Table 1. Mean $\delta^{13}C$ values measured in samples collected from two distinct areas in Kiel Fjord, Germany from 2nd June to 4th June 1993

Compartment specification	Mean $\delta^{13}C$ PDB [‰]
Phytoplankton	−20.8
Zostera marina (Area A)	−10.5
Fucus vesiculosus (Area B)	−14.6
Mytilus edulis (Area A)	−19.9
Mytilus edulis (Area B)	−19.5

Table 2. Percent contributions of specific primary carbon sources to *Mytilus edulis* carbon in Kiel Fjord, Germany

Area	Phytoplankton	*Zostera marina*	*Fucus vesiculosus*
A*	92–100	0 –8.0	0
B*	79– 96	0	4.0–21.0
Average**	87– 99	0.5–6.5	0.5– 6.5

* Values based on the assumption that there is only one benthic primary carbon source.
** Values based on the assumption that *Z. marina* and *F. vesiculosus* equally contribute to *M. edulis* carbon in Kiel Fjord.

The carbon isotopic relationships between phytoplankton and *Mytilus edulis* tissue clearly show that planktonic production was the main carbon source for those bivalves during the summer of 1993. The benthic primary producers considered in this study provided a minor fraction of carbon to bivalve tissue. Further studies, considering particularly seasonal effects and the assimilatory $\delta^{13}C$ shift, are necessary to quantify the processes supporting the secondary production of *M. edulis*. In addition to the primary sources presented in this study, benthic diatoms and detritus derived from epiphytic algae may be important carbon sources to be quantified as well.

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