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Benthic primary production, respiration and remineralisation: in situ measurements in the soft-bottom *Abra alba* community of the western English Channel (North Brittany)

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Abstract

In situ measurements of ammonium and carbon dioxide fluxes were performed using benthic chambers at the end of spring and the end of summer in two soft-bottom *Abra alba* communities of the western English Channel (North Brittany): the muddy sand community (5 m, about 10% of surface irradiance) and the fine-sand community (19 m, about 1% of surface irradiance). High rates of ammonium regeneration were measured in the two communities at the end of summer (296.03±40.07 and 201.7±62.74 μmolN m^{-2} h^{-1}, respectively) as well as high respiration rates (2.60±0.94 and 2.23±0.59 mmolC m^{-2} h^{-1}, respectively). Significant benthic gross primary production (up to 6.11 mmolC m^{-2} h^{-1}) was measured in the muddy sand community but no benthic primary production was measured in the fine-sand community. It suggests that microphytobenthic production values used in simulations previously published for these two communities were overestimated while values of community respiration were underestimated. The study confirms that this benthic system is heterotrophic and strengthens the idea that an important pelagic-benthic coupling is required for the functioning in such coastal ecosystems.

Keywords: Sediment-water interface; Carbon dioxide exchange; Ammonia; Benthic; Respiration rates; Primary production; English Channel

1. Introduction

Generic models of the benthic system have been used to study the role of coastal marine ecosystems within the global carbon cycling of the ocean. Such an approach has been developed in the western English Channel (Chardy, 1987; Chardy and Dauvin, 1992; Chardy et al., 1993; Améziane et al., 1996) to understand the energy source of benthic ecosystems in temperate megatidal seas. Inputs of autochthonous carbon were estimated in two *Abra alba* communities

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characterised by different sediment grain sizes and depths: a fine-sand community (FS, 20 m deep) at Pierre Noire off the Bay of Morlaix (Chardy and Dauvin, 1992) and a muddy sand community (MS, 5 m deep), at the entrance of the river of Morlaix (Améziane et al., 1996). Modelling output of the annual secondary production (including micro- meio- and macrofauna) has been estimated at 182 gC m^{-2} in the FS and 473 gC m^{-2} in the MS community (Améziane et al., 1996). Benthic primary production was estimated to be 10 gC m^{-2} y^{-1} for the FS (Chardy and Dauvin, 1992) and 77 gC m^{-2} y^{-1} for the MS (Améziane et al., 1996). These estimations are in the range of values of annual benthic microalgal production reported in the literature and summarised (mean$\pm$sd) by Cahoon (1999) for temperate areas (62$\pm$116 gC m^{-2} y^{-1} for the depth range 5–20 m, n=12). In the *Abra alba* communities of the western English Channel, simulations were restricted to carbon flows related to secondary production. Furthermore, fluxes calculated by the model were based on a series of hypotheses and values found in the literature for other temperate areas. They were never validated because no measurements were available for the English Channel.

The aim of the present study was to provide actual primary production and respiration as well as ammonium exchange values to improve future simulation studies in two of the most dominant communities of the coastal zone of the English Channel. In situ experiments were conducted when the highest biological activity could be expected, to obtain actual values of maximum fluxes of ammonium and carbon dioxide.

2. Materials and methods

Experiments were carried out at two sites, Morlet cove (48°33′30″ N; 1°99′15″ W), inside the Rance estuary, and Pierre Noire (48°42′30″ N; 3°51′58″ W) off the Bay of Morlaix representative of muddy sand (MS) and fine sand (FS) of the *Abra alba* community in the western English Channel (Fig. 1). Series of enclosure experiments were performed by SCUBA diving in June 1999 and September 2000 in the Rance estuary and in September 1999 and May 2000 in the Bay of Morlaix.

Ammonium and carbon dioxide fluxes at the water-sediment interface were simultaneously measured according to procedures described in Boucher et al. (1994). Three replicated PVC cores (0.2 m^2) were pushed by hand ca 10 cm into the sediment. The openings of the cores were then sealed with clear (for net community production measurements) or dark (for community respiration measurements) acrylic hemispheres to trap a known volume of bottom water (varying from 48 to 65 l according to core insertion into the sediment). Pumps ensured a gentle closed-circuit flow, allowing good mixing of the water in the incubation chambers without particulate resuspension. Temperature of the near-bottom water was continuously monitored (Thermistance, $\pm$0.1 °C), as well as incident photosynthetically active radiation (400–700 nm, PAR in μmolquanta m^{-2} s^{-1}) at the sediment surface (quantum sensor LiCor Li-192 SA inside one of the three benthic chambers) and at the sea surface (quantum sensor LiCor Li-190 SA on board). Incubations lasted from 66 to 176 min. pH was measured every second, averaged and recorded every minute (data logger LiCor Li-1400). The pH electrodes (Radiometer GK 2401C, $\pm$0.001 pH unit), fitted in pressure-compensating devices, were calibrated daily against two N.B.S. buffers (Radiometer, $\pm$0.002 pH unit). Incubation water was collected with hand syringes at the beginning and at the end of the incubation to measure total alkalinity and ammonium concentration. Samples of 100 ml were filtered on cellulose acetate membranes (0.8 μm) and spiked with $HgCl_2$ pending potentiometric determination of total alkalinity (Millero et al., 1993) on 3 subsamples of 20 ml. Ammonium concentration was measured on 3 samples of 100 ml according to the colorimetric indophenol method (Koroleff, 1970). The total CO_2 concentration was calculated according to Strickland and Parsons (1972) using the formula given in Oviatt et al. (1986), taking into account ambient pH, alkalinity, temperature and salinity. Gross community primary production was calculated by correcting fluxes measured in the light by fluxes measured in the dark (GCP=$|\Delta CO_{2\ light}-\Delta CO_{2\ dark}|$).

Sediment was collected (to a depth of about 10 cm) at the two sites in the two periods for grain-size analyses by weighing dry sediment passed through a series of sieves (0.05 to 20 mm). Microphyte biomass was measured as chlorophyll-a content. At the end of