Benthic energy dynamics in a southern Baltic ecosystem

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Abstract. Benthic components and metabolic activity at two stations in the Darss-Zingst estuary (eastern German Baltic coast) were investigated over a seasonal cycle from April 1985 to August 1986. As has been established for temperate and boreal ecosystems, peaks in the biomass of benthic microphytes occurred in the spring and late autumn to winter, presumably caused by settling phytoplankton blooms. Metabolic activity of the benthos did not increase with rising ambient temperatures. Rather, the highest values of oxygen consumption were recorded during the cooler months (spring and winter), when increased numbers of organisms were also observed. This may be a response to a greater food supply to the sediment in the form of settling phytoplankton during these times of year.

Introduction

This work reports an investigation of ecosystem response over a seasonal cycle in terms of oxygen metabolism and how this might relate to the abundance of benthic organisms at particular times. It considers the question of food supply as a major regulatory mechanism of benthic energy dynamics, specifically with respect to the shallow-water boreal estuary of the present study. Preliminary findings have been presented in Yap and Oertzen (1989).

The simultaneous measurement of benthic components (commonly in terms of abundance and biomass) and community metabolism has a relatively long history. One of the important early studies is that of Pamatmat (1968). Methods employed from that time up to the present have not changed substantially (Zeitzschel 1981, Herndl et al. 1989). Despite the number of studies carried out in this field, there remains a lack of information on broad-scale production and consumption patterns (Schwinghamer et al. 1986).

The Darss-Zingst estuary, or “Boddenkette”, a chain of shallow-water bodies on the northern coast of the former German Democratic Republic, has been previously investigated in terms of its separate benthic components. These include the microphytes (Wasmund 1983), ciliates (Scharf 1979), meiofauna (Arlt 1984) and macrofauna (Möller 1984).

The combination of abundance and/or biomass measurements of benthic-community component organisms with some measures of total function is one approach to the description and evaluation of ecosystem dynamics (Pamatmat 1968, Dale 1978, Bergstroem and Sarvala 1986). This method, as any other, has limitations (Kremer and Nixon 1978), but these do not detract from its general usefulness. In the present study, the most likely ecological factors influencing ecosystem activity were also determined.

Materials and methods

Study site

The Darss-Zingst estuary has a total area of ca. 197 km², a maximum depth of 12 m and an average depth of 2 m. Salinity ranges from 1 to 12‰. For purposes of sampling, two stations were chosen (Fig. 1). Kleine Wieck (KW), being subject to influence from the open Baltic Sea, was considered representative of healthier or more normal conditions, particularly with respect to water clarity, circulation, salinity, organic matter levels in the sediment, and abundance of organisms. Average salinity was ca. 5‰. Sediment in this and the other station was predominantly medium sand. The second station, Kirr (Ki), was located ca. 10 km northwest of KW. It was similar to KW in its broad environmental regimes, general sediment characteristics, and associated flora and fauna; it differed from the other station mainly in its exposure conditions, being situated in a relatively sheltered embayment termed the “Kirr Bucht”. An important characteristic of both stations was the significant influence of wind and water turbulence due to shallow depths, causing frequent sediment resuspension and mixing (author’s unpublished data).

Sampling

Sampling for routine measurements of seasonal trends was conducted once a month from April 1985 to August 1986 at both
stations. Sediment was collected from patches devoid of macrophytic growth, at depths ranging from 20 to 40 cm. Only the upper 2 cm layer was retrieved, to minimize the portion characterized by reduced conditions. The sediment always had a relatively light color, indicating that it was generally oxidized. This justified the use of oxygen measurements to quantify energy flow (Parsons et al. 1984).

The sampling device used was a Plexiglas corer (inner diameter 4.8 cm), which also served as a watertight chamber which could be directly attached to a respirometer in the laboratory, thus avoiding transferring and disturbing the sediment. Sampling was carried out carefully by hand. After retrieval, cores were sealed with enough overlying water and immediately taken to the laboratory (within 0.5 to 1 h) while immersed in water obtained from the biotope to prevent mechanical disturbance. A total of seven cores spaced ca. 0.5 to 1 m apart were collected from each station.

The following environmental parameters were monitored with each sampling: light intensity, temperature, pH and salinity. Dissolved oxygen content of the water was checked occasionally, and was always found to be at saturation.

Sediment analysis

Organic matter content of the sediment was measured by drying to constant weight at 105°C, and then combusting at 550°C to constant weight (Holme and McIntyre 1984). Total phosphorus was analyzed following Andersen (1976). Nitrogen in the sediment was quantified as the component that reacted with potassium peroxidisulphate, as modified from Grasshoff (1976).

Metabolic measurements

Immediately after sampling, a total of six sediment cores were analyzed for oxygen production and uptake, the latter being partitioned into respiration and chemical oxygen demand (COD).

Two cores at a time were measured for oxygen turnover using a polarographic flow-through respirometer, while the remainder were maintained in a flow-through system in original biotope water. Details of the respirometer, which utilized Clarke microelectrodes, may be obtained from Dr. Jörg-Andreas von Oertzen (Department of Biology, University of Rostock, Rostock, Germany; see also Oertzen 1984).

Primary production was quantified as release of oxygen while the cores were illuminated at 40 W m⁻², roughly the average for in situ conditions over the whole year in the extremely turbid estuary. The entire measurement chamber was then covered with a black mantle to measure oxygen uptake. Oxygen uptake was later partitioned into respiration and COD by poisoning two cores with 10% buffered formalin. The limitations of this method of COD determination are discussed in Dale (1978).

During all measurements, salinity was maintained at 5% and temperature at a fixed value corresponding to seasonal ambient conditions, viz. 1 or 5°C for winter, 10 or 15°C for spring, 20°C for summer, and 10°C for autumn. The pH was fixed at 8, which was typical for the estuary. Flow rate in the respirometer was set to a constant value of 170 ml h⁻¹, which was considered optimal for accurate measurements under steady-state conditions. All readings were recorded by a pen recorder.

Benthic components

Biota were quantified by subsampling four cores (those not treated with formalin) after the metabolic measurements. The same sediment used for oxygen measurements was analyzed for abundance of organisms, because only those groups that contributed to observed metabolic trends were of interest in this study. The corer adequately sampled only the following groups, and these were considered in subsequent analyses: microphytes, bacteria, microfauna, and meiofauna.

Microalgae were quantified by means of their chlorophyll a (chl a) content, following the procedure of Lorentzen [1967, in Wasmund (1983); see also Wasmund (1984), Sundbäck and Jönsson (1988)]. Bacteria were preserved in 2% buffered formalin and then