Comparison of primary production and pelagic community respiration rates in the coastal zone of the Gulf of Gdańsk

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Abstract

The organic matter production/respiration balance in the coastal water column was examined, both the primary production and community respiration being measured with the oxygen light-and-dark bottle method. Community respiration (CR) was always lower than the gross primary production (GPP) measured at a standard light intensity of 390 μE m^{-2} s^{-1}, which amounted, on average, to 30% of GPP. During most of the *in situ* sampling period, the coastal system (6–7 m depth) was found to be autotrophic, with depth-integrated GPP ranging from 6.7 mmoles O_2 m^{-2} d^{-1} in December to 214.2 mmoles O_2 m^{-2} d^{-1} in August, and CR ranging correspondingly from 6.0 to 177.7 mmoles O_2 m^{-2} d^{-1}. However, on some occasions heterotrophic conditions were recorded: depth-integrated GPP<CR. In summer (August) this was caused mainly by low water transparency, which repressed photosynthesis, while in winter (December) it was due to the short period of daylight.

1. Introduction

The coastal zone of the Gulf of Gdańsk is affected by municipal wastes from the Gdańsk–Gdynia agglomeration and by Vistula River discharges, which supply large quantities of both inorganic nutrients (250 t P y^{-1} and 2500 t N y^{-1} from urban sources and 4400 t P y^{-1} and 74 000 t N y^{-1} from the Vistula; HELCOM 1998) and organic carbon (no recent estimates, but approximately 300 000 tons C y^{-1} from the Vistula alone; Niemirycz et al. 1989). Inorganic nutrients enhance photosynthesis and stimulate oxygen production, while the decomposition of allochthonous organic matter raises oxygen consumption in the Gulf of Gdańsk. It is thus not surprising that both supersaturated and hypoxic oxygen conditions have been reported from the coastal zone (Falkowska et al. 1993). On the basis of indirect calculations, Witek et al. (1997) discovered signs of net heterotrophy in the coastal system, a situation where more organic matter is decomposed and more oxygen consumed than is produced. On the other hand, a positive trend in oxygen concentration has been observed over the last two decades in the inner part of the Gulf of Gdańsk (Łysiak-Pastuszak & Drgas 2000). The aim of the present study was to examine with direct methods the organic matter production/respiration balance in the coastal water column.

This study was carried out from March to December 1997 at one coastal station located at Gdynia–Orłowo 200 m offshore at a depth of 2.5 m, and additionally from August to December 1997 at two other stations located in Gdynia and in Sopot at distances of 500 and 800 m from the shore, and at depths of 6 and 7 m, respectively.

At the Gdynia-Orłowo sampling location, primary production was measured in an incubator under standard light conditions (390 μE m^{-2} s^{-1}) and ambient photoperiod and temperature, while at the Gdynia and Sopot sampling stations (from August to December), *in situ* primary production was measured at depths 0.5, 2.5 and 5.0 m. Community respiration was measured at all stations parallel to primary production. To avoid problems arising from the use of different methods and from the conversion of oxygen units to carbon, and vice versa, both primary production and community respiration were measured with the oxygen light-and-dark bottle method, with incubations lasting 24 h.

The dissolved oxygen content in the water was in most cases uniform throughout the water column, with saturation values between 90 and 110%, although periodically it was marked by strong vertical stratification, with supersaturation in the upper levels and subsaturation in deeper water.

This was correlated with temporary weak mixing in the water column (as demonstrated by the salinity stratification) and suggested that community respiration was greater than primary production, even at relatively shallow depths.

Community respiration (CR) was always lower than gross primary production (GPP) measured at standard light intensity (390 μE m^{-2} s^{-1}), and amounted, on average, to 30% of GPP (Fig. 1). In all *in situ* experiments except for one, net primary production (NPP) was positive at 0.5 and 2.5 m, but at 5.0 m (and probably lower) this value was close to zero or negative owing to light limitation (Table 1). The high light extinction was probably due to the large amount of suspended and dissolved matter in the water column.

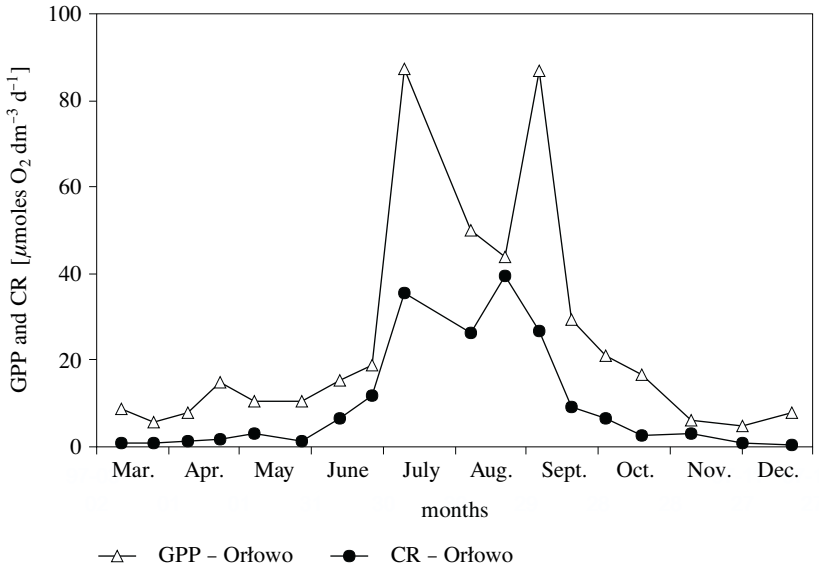

Fig. 1. Daily gross primary production (GPP) at standard light intensity (390 μE m^{-2} s^{-1}) and natural photoperiod and community respiration (CR). Samples taken from the surface layer at Gdynia–Orłowo

Integrating the production and respiration values over the entire water column allowed the trophic status of the system to be evaluated. During most of the *in situ* sampling period, the system was found to be autotrophic, but there was a tendency towards heterotrophy in August and December (Table 1). In August this was due primarily to low water transparency, which repressed photosynthesis, while in winter it was caused by the short period of daylight.

Table 1. Net primary production (NPP) at different depths, and depth-integrated gross primary production (GPP) and community respiration (CR) measured *in situ* at Sopot and Gdynia

Date	NPP [μmoles O_2 dm^{-3} d^{-1}] Depth: 0.5 m	2.5 m	5.0 m	GPP [mmoles O_2 m^{-2} d^{-1}] Depth-integrated	CR Depth-integrated
Sopot					
20 August 1997	36.17	–18.76	–17.86	121.47	136.56
23 September 1997	16.08	4.91	–1.79	77.26	32.19
6 October 1997	7.59	1.79	0.20	29.92	13.36
13 October 1997	3.57	2.23	0.20	23.22	8.97
25 November 1997	1.79	0.89	0.67	11.89	6.03
12 December 1997	1.03	0.31	–2.08	6.70	8.48
Gdynia					
20 August 1997	49.12	*25.01	**–6.25	214.19	177.66
2 September 1997	63.86	15.18	0.00	195.93	65.98
23 September 1997	14.74	10.27	–3.57	80.92	52.62
6 October 1997	3.13	1.34	1.34	31.64	19.54
13 October 1997	1.79	0.89	–0.89	16.51	15.48

*this measurement was taken at 1.5 m,
**this measurement was taken at 4.0 m.

The results of this study do not confirm the earlier assumptions of general net heterotrophy in the coastal zone of the Gulf of Gdańsk (Witek et al. 1997), an assumption formulated from a comparison of GPP measured by the isotope method (^{14}C) with CR measured by the oxygen method. The comparison was made in carbon units, with the RQ coefficient equal to 1. However, GPP determined by the isotope method may differ from GPP based on the oxygen method not only because of the PQ or RQ approximation, but also because each method measures slightly different fluxes. The isotope method measures GPP minus the amount of ^{14}C remineralized during sample incubation. To account for this process, an appropriate correction factor is used. However, the exact value of this factor is not generally known and is taken from references (e.g. 1.06; Aertebjerg Nielsen & Bresta 1984). In the oxygen method GPP may be underestimated owing to phytoplankton photorespiration (which does not occur in dark bottles). This process is not taken into account in GPP calculations; instead it is assumed that marine plankton photorespiration is almost entirely suppressed by an intercellular CO_2 concentration mechanism

(Beardall 1989). Used mainly for carbon budgeting, this assumption may not be appropriate with regard to oxygen. Therefore, the above-mentioned methodological differences could lead to contradictory conclusions about the trophic status of the coastal zone of the Gulf of Gdańsk, especially when differences between GPP and CR were minor, within the range of measurement error. In light of the present study, the most likely explanation for the negative balance between production and decomposition of organic matter obtained by Witek et al. (1997) seems to be the excessively low value of the correction factor for ^{14}C remineralization applied in the isotope method of GPP estimation.

Net heterotrophy on an annual basis was described by Hopkinson (1985) in the Georgia Bight, which receives organic matter from macrophyte marshes. In terms of the production/respiration budget, the coastal zone of the Gulf of Gdańsk seems similar to Waquoit Bay (Massachusetts), an N-loaded estuary, where on an annual basis community metabolism was in balance or slightly autotrophic (D'Avanzo et al. 1996).

However, even a temporary period during which more oxygen is consumed than produced can be detrimental to shallow benthic communities. In the near-bottom zone, if inadequate light, strong stratification precluding vertical mixing, and a high respiration rate appear simultaneously, the oxygen supply may become completely exhausted within a few days, with dramatic consequences for sessile bottom fauna. Such phenomena have been reported from other coastal Baltic regions (e.g. Powilleit & Kube 1999) and also from the Gulf of Gdańsk (J. Warzocha, personal communication).

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