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The participation of bacteria, algae and the remaining organisms in the total oxygen respiration of bottom sediments on the stream - Dobczyce dam reservoir line (southern Poland)

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Abstract - The primary production of algae (Pr) 717.56 J and their respiration (Ra) 154.60 J were highest in the estuary. The greatest respiration of bacteria (Rb) 45.96 J was in the reservoir. The total oxygen respiration (RO) 1036.78 J and the respiration of the remaining organisms (Rr) 1000.82 J g^{-1} C 24 h^{-1} were greatest in the stream. The values of algae (Ba) and bacteria (Bb) biomass, and Rb, Ra and Rb/Bb increased, and those of Rr and RO decreased on the stream - reservoir line.

Key words: streams, estuaries, reservoirs, sediments, biomass, bacteria, algae, respiration, primary production.

1. Introduction

The metabolism of organisms in the bottom sediments of water ecosystems is mainly connected with the decomposition of organic matter and carbon released from the environment. Only in the interface of bottom sediments, apart from respiration, can carbon fixation and oxygen production also occur owing to the availability of light.

The measurement of aerobic activity of epibenthic communities, especially that of bacteria, in the upper aerobic strata of sediments is one of the keys to understanding the rates of degradation in aquatic ecosystems. Little is known about the aerobic and anaerobic microbial community metabolism in this section of aquatic ecosystems (Höfle et al. 1984).

The aim of the present work was therefore to evaluate the destruction (and production) of organic matter in the surface layer of bottom sediments on the stream - its mouth (estuary) - dam reservoir line.

2. Study area, material, and methods

The investigations were carried out in the direct catchment area of the dam reservoir at the 60th kilometre of the River Raba, in the vicinity of Dobczyce, about 25 kilometres south of Cracow.

The catchment and the reservoir are situated within the Wieliczka Plateau range, built of Silesian flysch of different age and mosaic distribution. In a large part of the catchment area soils are formed of fine-grained sands, originating from flysch rocks (P a s t e r n a k 1969).

The reservoir is chiefly fed by the River Raba, which brings in 88.6% of the total water inflow. The rest is supplied directly by the catchment (8.8%) and by atmospheric precipitation on the surface of the reservoir (2.6%) (M a z u r k i e w i c z 1988).

The investigations covered one of the streams with a catchment of agricultural character, which flows into the reservoir in the region of the Wolnica creek (fig. 1).

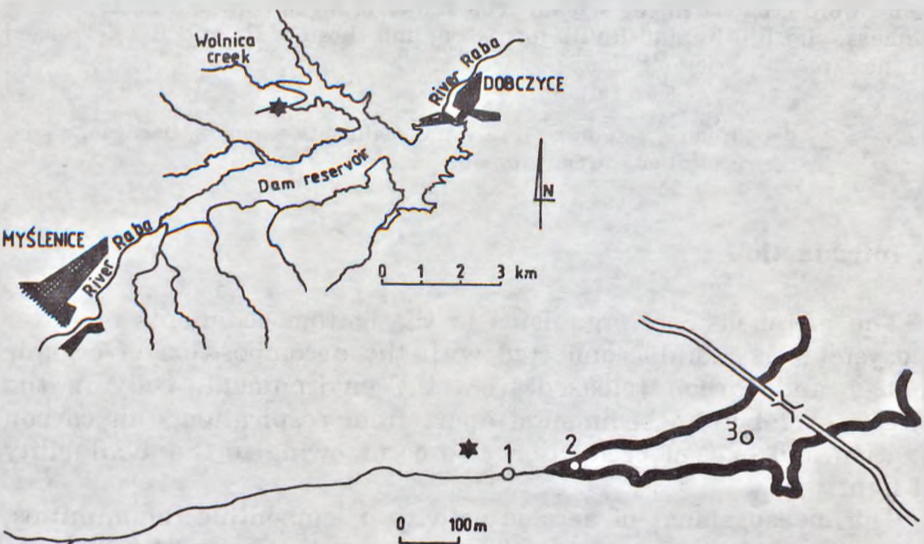

Fig. 1. Situation plan of the study area and sampling stations: 1 - stream; 2 - estuary; 3 - dam reservoir

Samples of bottom sediments were collected during the vegetation season April-October 1991 at monthly intervals, from a 0.5 cm surface layer, at Stations 1 - the stream (sandy bottom), 2 - the mouth section of the stream, the so-called estuary (muddy-sandy bottom), and 3 - the reservoir near the Wolnica creek (muddy bottom). At each site nine subsamples were taken and mixed, yielding a mean sample for the given station.

Oxygen respiration was determined on the basis of losses of oxygen dissolved in the water suspension of sediments, after 12-16 h exposition of samples in darkness, by means of Clark electrode and calculated in mg O_2 24 h^{-1}. A detailed description of this method is given by S t a r z e c k a and B e d n a r z (in press). Dry weight and organic matter content in the bottom sediments were determined at 105°C and 550°C, respectively. According to J ø r g e n s e n (1979), it was accepted that 1 g of ash-free organic matter corresponds to 50% of organic carbon.

The biomass of bacteria was determined using the total number of heterotrophic bacteria in sediments estimated by the agar plate method, assuming that 1 bacterial cell contains 6.05 x 10^{-8} μg C (W a t s o n et al. 1977). The biomass of algae was estimated on the assumption that 1 μg of chlorophyll *a* corresponds to 0.05 mg C (J ø r g e n s e n 1979). Chlorophyll *a* was determined by ethanol extraction (S a r t o r y 1982).

The bacterial fraction was isolated from bottom sediments in the following way: fresh sediments (100 g) were suspended in sterile water (900 g) from each station and shaken for 30 minutes. After 5 minutes of settling the supernatant was decanted and filtered through Whatman glass GF/C microfibre filters. Oxygen losses in the filtrate were determined applying a Clark electrode after 12-16 h exposure of the cultures in the dark. Taking into account the number of bacteria in the culture and the amount of oxygen they consumed, the respiration of one bacterial cell was calculated in mg O_2 24 h^{-1}. Then, using the number of bacteria in fresh sediments, their respiration (Rb) in the sediments was calculated.

In order to determine the photosynthesis and respiration of algae (Ra), the suspension of sediments (prepared as described above) was exposed for 12-16 h in the light and in the dark. Rises and falls in oxygen concentration were measured using a Clark electrode and calculated in mg O_2 12 h^{-1}. The net production of algae (Pr) was calculated as the difference between their photosynthesis and respiration. It is assumed that the respiration of algae in the dark constitutes 20% of their photosynthesis (H a r g r a v e 1969, H i l l b r i c h t - I l k o w s k a 1977).

The total respiration of epibenthic communities (RO) in bottom sediments was calculated as the difference between oxygen respiration during 24 h and the photosynthesis of algae during 12 h. The respiration of the remaining organisms (Rr) in the sediments was calculated from the equation: Rr = RO - (Rb+Ra).

The measurements were carried out at 21°C (± 1°C) in 3 replications and the results given as arithmetical means calculated per joules (J) per 12 or 24 hours and 1 g C_{org}. According to the equation of photosynthesis, in the calculations concerning respiration the assumption was 1 mg O_2 = 14.78 J. On the other hand, it was assumed that 1 mg C = 4.9 cal (C u m m i n s 1967) = 20.53 J.

3. Results

The greatest respiration estimated for bacteria was in the bottom sediments of the reservoir (45.96 J g^{-1} C 24 h^{-1}) and 3-4 times exceeded the bacterial oxygen uptake in the bottom sediments of the estuary and the stream (fig. 2). However, the greatest algal respiration was observed in the estuary (154.60 J g^{-1} C 24 h^{-1}), that of the bottom sediments of the stream and the reservoir being 6 and 2 times smaller, respectively (fig. 2).

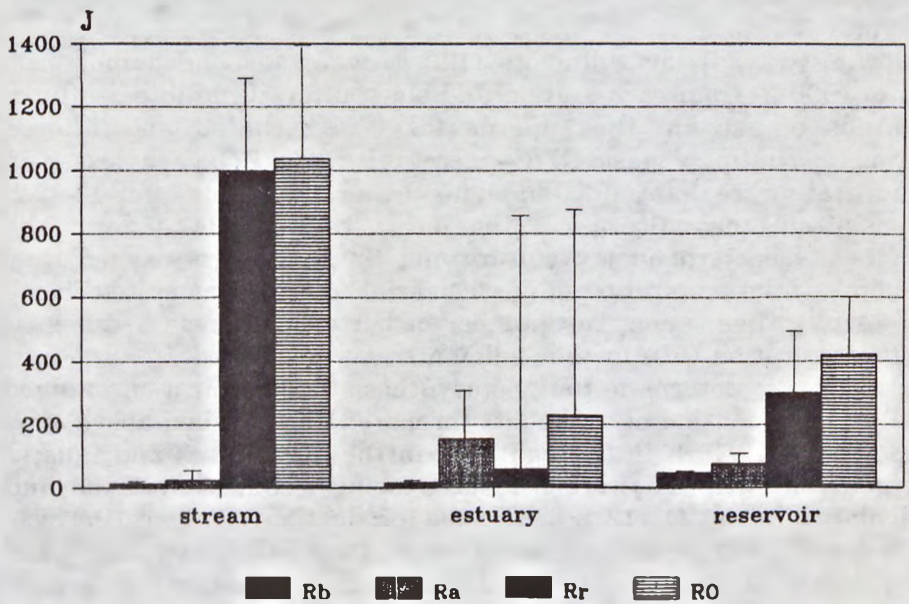

Fig. 2. Respiration of bacteria (Rb), algae (Ra), remaining organisms (Rr) and total respiration of epibenthic communities (RO) in J g^{-1} C 24 h^{-1} ± 1SE

In the surface layer of bottom sediments on the stream - dam reservoir line there was a clear tendency to a decrease in the respiration of the remaining epibenthic organisms and also in the total respiration, from 1000.82 J to 299.49 J g^{-1} C 24 h^{-1} in the case of Rr and from 1036.78 J to 419.59 J g^{-1} C 24 h^{-1} in that of RO (fig. 2). The lowest values of Rr, amounting to 57.41 J, and of RO amounting to 227.21 J g^{-1} C 24 h^{-1}, were recorded in the estuary (fig. 2).

The net primary production in the estuary amounted to 617.56 J g^{-1} C 24 h^{-1}. It was over 6 and 2 times higher than that recorded in the stream and the reservoir, respectively (fig. 3).

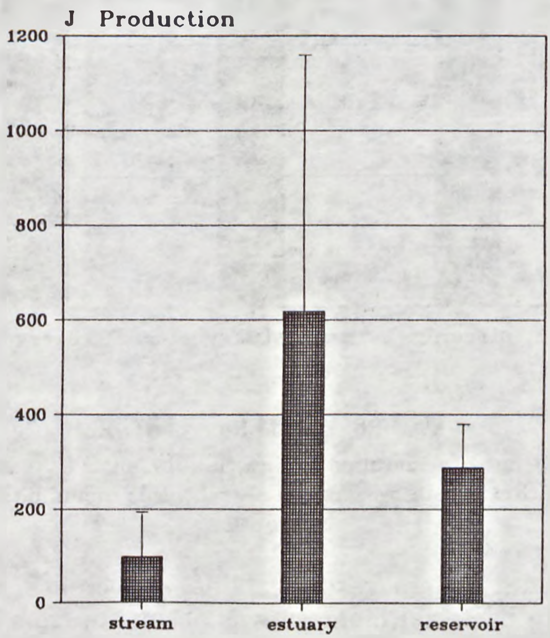

Fig. 3. Production of algae in J g^{-1} C 24 h^{-1}; ± 1SE

Taking into account the percentage share of the respiration of bacteria, algae, and the remaining organisms in the total respiration of epibenthic communities, it was found that in the stream sediments only 3% of oxygen was taken up by bacteria and algae altogether, and 97% by other organisms. In the estuary and the reservoir the share of bacterial and algal respiration in RO clearly increased (fig. 4). The highest percentage share of Rb in RO was found in the bottom sediments of the reservoir (11%), and that of Ra in RO in the estuary (68%) where, as was mentioned above, the highest algal production took place (fig. 3, 4).

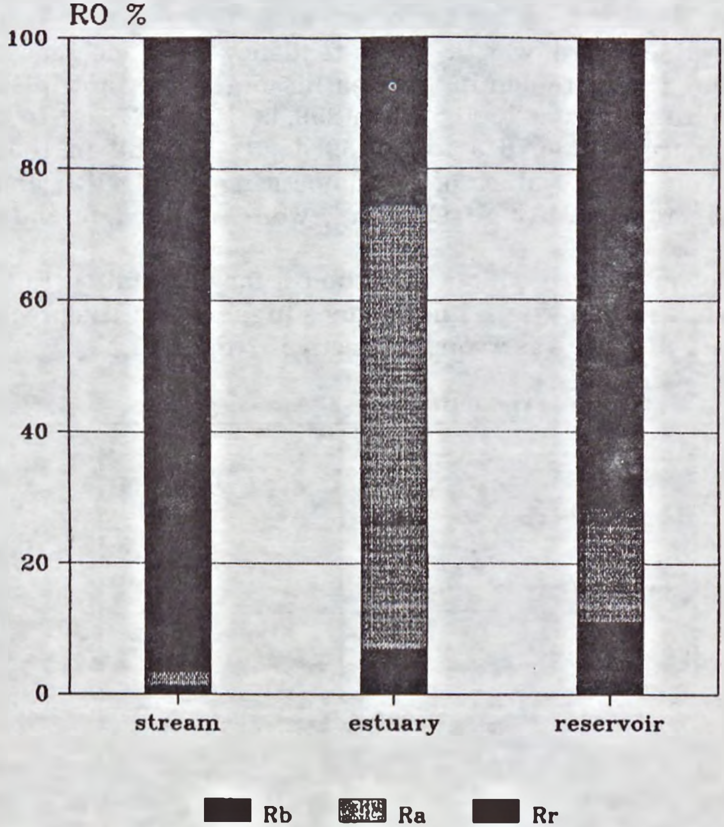

Fig. 4. Percentage share of respiration of bacteria (Rb), algae (Ra), and the remaining organisms (Rr) in total respiration of epibenthic communities (RO)

On the stream - dam reservoir line a decrease in the energy accumulation in bacterial biomass was observed, from 7.41 to 4.98 J g^{-1} C 24 h^{-1}, and a rise in algal biomass, from 436.64 to 1342.87 J g^{-1} C 24 h^{-1} (fig. 5).

In the bottom sediments of the stream bacterial bioaccumulation constituted 0.04% of the energy value of 1 g C. It was 4 and 2 times higher than that in the bottom sediments of the estuary and of the dam reservoir. On the other hand, algal bioaccumulation rose from 2% in the stream to 7% in the reservoir (fig. 6).

The ratio of the amount of energy released as a result of bacterial respiration to the amount of energy accumulated in their biomass indicated that in the bottom sediments of the estuary and of the reservoir "the cost of maintenance" of bacteria was 4.6 and 6 times higher than that in the stream (fig. 7).

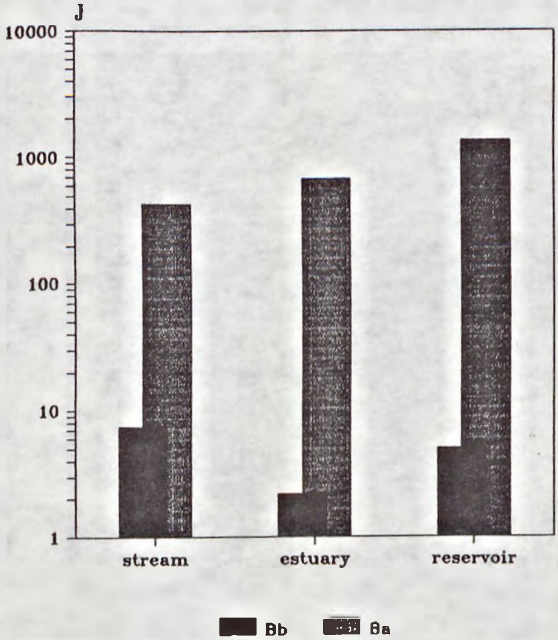

Fig. 5. Biomass of bacteria (Bb) and algae (Ba) in J g^{-1} C

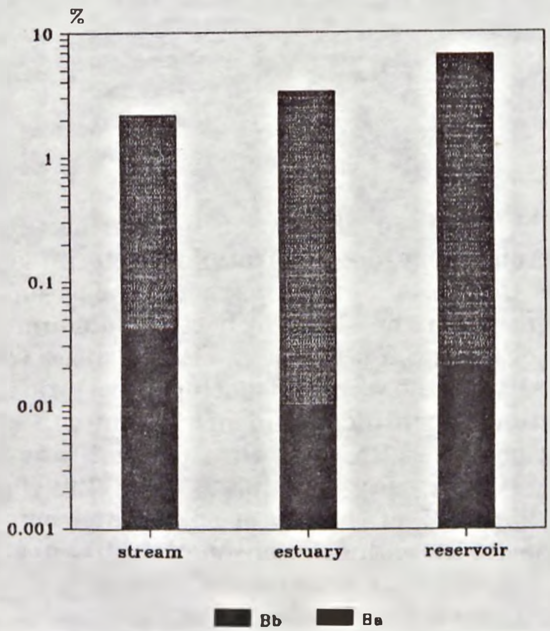

Fig. 6. Percentage share of energy accumulated in the biomass of bacteria (Bb) and algae (Ba) per 1 g C = 20530 J

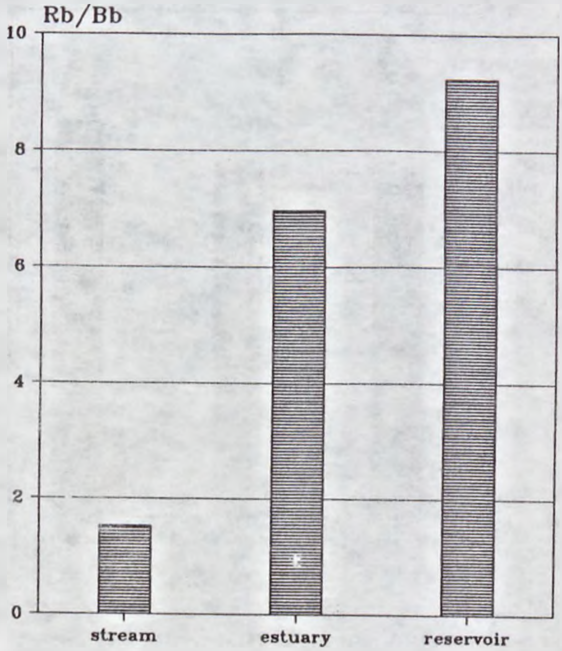

Fig. 7. Ratio of energy released by bacteria (Rb) to energy accumulated in their biomass (Bb)

4. Discussion

According to Hargrave (1969), in the surface layer of bottom sediments microbial oxygen respiration (bacteria, algae, protozoa) can constitute 67% of the total oxygen respiration of epibenthic communities (in which the share of bacteria amounted to 30%, and that of algae to 23%). S a u n d e r s (1976), after W e t z e l et al. (1972), reported that the share of bacterial respiration in the total oxygen respiration of benthic organisms amounts to 25% and that of algal respiration to 11%. In the present investigations Rb constituted 1 - 11%, Ra 2 - 68%, and Rr (fungi, protozoa, invertebrates) 25 - 97% of the RO of epibenthic communities.

The decrease in RO value found on the stream - dam reservoir line, and the rise in total respiration, determined as CO_2 release (S t a r z e c k a, B e d n a r z in press), indicated an increasing share of anaerobic processes in the metabolism of epibenthic communities on this line.

According to the data given by H o f m a n et al. (1991), oxygen production by epibenthic algae in Oosterschelde (SW Netherlands) wholly compensated for oxygen consumption by the communities of epibenthic organisms. H a r g r a v e (1969) found that in the surface layer of the bottom sediments of Marion Lake 30% of carbon was supplied by epibenthic algal production. However, in the present studies it was evidenced that the mean seasonal algal primary production was the source of 4% of organic carbon in the stream. The most intensive fixation of energy in the estuary was accompanied by its smallest release, suggesting that the energy fixed in the process of photosynthesis was directly used by organisms living in that environment.

The rise in "the cost of maintenance" of bacteria in the bottom sediments on the stream - dam reservoir line provided evidence of the presence of more easily degradable organic matter in the bottom sediments of the stream, and of that less easily degradable in its mouth section and in the reservoir.

5. Polish summary

Udział bakterii, glonów i innych organizmów w ogólnej tlenowej respiracji osadów dennych na linii potok - zbiornik zaporowy w Dobczycach (Polska południowa)

Badania przeprowadzono w potoku o rolniczym typie zlewni, jego ujściu (estuarium) i sublitoralu zbiornika zaporowego w Dobczycach, w rejonie Zatoki Wolnica (ryc. 1). W wierzchniej, 0,5 cm warstwie osadów dennych określono produkcję i destrukcję materii organicznej.

Respiracja bakterii (Rb) była największa w osadach zbiornika, a glonow (Ra) w estuarium (ryc. 2). Na linii potok - zbiornik stwierdzono wyraźną tendencję spadkową respiracji pozostałych organizmów (Rr) i ogólnej respiracji tlenowej (RO) (ryc. 2).

W potoku, 97% skonsumowanego tlenu przypadało na Rr, a tylko 3% na Ra i Rb łącznie. W osadach estuarium i zbiornika procentowy udział Rb i Ra w RO wyraźnie wzrastał i osiągał 7 i 11% dla bakterii oraz 68 i 18% dla glonów (ryc. 4).

Największa produkcja glonowa netto (Pr) wystąpiła w osadach estuarium (ryc. 3). Na linii potok - zbiornik stwierdzono spadek akumulacji energii w biomasie bakterii (Bb) i wzrost akumulacji energii w biomasie glonów (Ba) (ryc. 5). W osadach potoku Bb stanowiła 0.04% wartości energetycznej 1 g $C_{org.}$ i była 4 i 2 krotnie większa niż w osadach estuarium i zbiornika. Natomiast Ba wzrastala od 2% w potoku, do 3% w estuarium i 7% w zbiorniku (ryc. 6). Wydatki energetyczne na jednostkę biomasy bakterii (Rb/Bb) w osadach zbiornika i estuarium były 4,6 i 6 krotnie większe niż w osadach potoku (ryc. 7).

W osadach na linii potok - zbiornik stwierdzono zwiększający się udział procesów beztlenowych w metabolizmie zbiorowisk epibentosowych, a także wzrost ilości materii organicznej bardziej opornej na rozkład bakteryjny.

6. References

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