| ACTA HYDROBIOL. | 35 | 1 | 109—119 | KRAKÓW 1993 |
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# The production and destruction of organic matter in the water and surface layer of bottom sediments on the stream - estuary - Dobczyce Dam Reservoir line (southern Poland)

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Manuscript submitted April 14, 1993, accepted June 28, 1993

A b s t r a c t – The values of biological parameters calculated per 1 g C-org. were generally 0.5 to 2 orders of magnitude higher in the water than in the sediments. The exceptions were biomass (Ba), production (P), and respiration (Ra) of algae, approximately 0.5 to 1 order of magnitude higher in the sediments of the stream and respiration of bacteria (Rb) to their biomass (Bb) 0.7 order of magnitude higher in sediments of the dam reservoir.

K e y w o r d s: water, sediments, bacteria, algae, biomass, respiration, primary production, stream, estuary, reservoir.

## 1. Introduction

The metabolism of autotrophs in the water column and in the surface layer of bottom sediments is mainly connected with fixing of energy, the production of organic matter, and the release of oxygen. This link supplies other organisms, both in the water column and in the bottom sediments, with energy and organic carbon, utilized by them. In theory, the photosynthetic activity can be attributed to algae because photosynthesizing bacteria (with the exception of Cyanobacteria often regarded as blue-green algae) function under strictly anaerobic conditions (E l l i s, S t a n f o r d 1982).

Many investigations have demonstrated that 10-60 % of dissolved organic matter derived from phytoplankton production is channelled through the heterotrophic link, chiefly bacterioplankton (C o l e 1982; F u h r m a n, A z a m 1982; B e r m a n 1988; R a i, K r a m b e c k 1992; R o g e r s o n, L a y b o u r n - P a r r y 1992).

The sediments are important sites for the mineralization of organic matter and the recirculation of nutrients to the water mass (N i x o n 1981; J e n s e n et al. 1990), in which the role of bacteria is significant (S c a v i a, L a i r d 1987). Other authors investigating the influence of microphytobenthos, bacteria and protozoa on the flux of oxygen and inorganic nutrients in the sediment-water interface suggest that this part of the bottom sediments plays an important role in the oxygen and nutrientflux between the sediments and the water column (H a r g r a v e 1969; S u n d b ä c k et al. 1991; M o r a n, H o d s o n 1992).

The aim of the present study was to determine the metabolic activity of organisms with special regard to algae and bacteria both in the water column and in the surface layer of bottom sediments.

## 2. Study area, material, and methods

The investigations covered one of the streams, with a catchment of agricultural character, which flows into the Dobczyce Dam Reservoir in the region of the Wolnica creek (fig. 1). A detailed description of the area is given by the authors in a previous paper (S t a r z e c k a, B e d n a r z 1993).

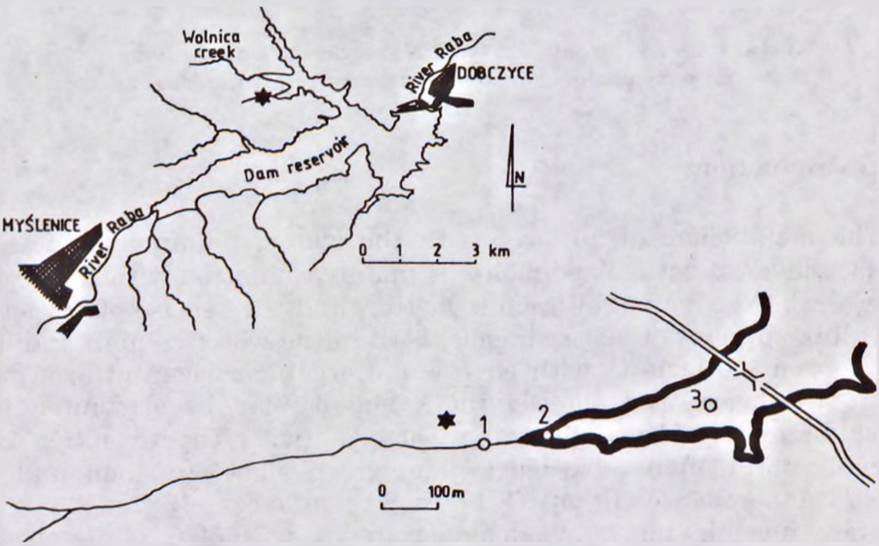


Fig. 1. Situation plan of the study area and sampling stations: 1a, 1b, 1c, - stream; 2a, 2b, 2c, - estuary; 3a, 3b, 3c, - dam reservoir

The samples of bottom sediments and water were collected in July 1991 (midsummer), at Stations 1 - the stream (sandy bottom), 2 - the mouth section of the stream, so-called estuary (muddy-sandy bottom), and 3 - the reservoir near the Wolnica creek (muddy bottom). From each station the samples of sediments were taken from the 0.5 cm surface layer while the samples of water were collected 10 cm above the bottom.

Photosynthesis and oxygen respiration were determined applying the method of light and dark bottles. The bottles were filled either with water or with a water suspension of sediments. After 12-16 h exposure of samples in darkness and in light, the oxygen concentration was measured by means of a Clark electrode and calculated in mg $O_2$ 24 $h^{-1}$ in the case of respiration and per 12 h for photosynthesis. A detailed description of the method mentioned above has been given by Starzecka and Bednarz (1993).

The total respiration of sediments (RT) was determined using the method based on measurement of $CO_2$ release by means of an infrared gas analyser (Infralyt IV) (Starzecka, Bednarz in press), and calculated per 24 h. Dry weight and organic matter content in the water and in the bottom sediments were estimated after evaporation of the water in a water bath at 60°C, and then drying at 105°C and calcination at 550°C. According to Jørgensen (1979), it was accepted that 1 g of ash-free organic matter corresponds to 50% of organic carbon.

The method of determination of bacteria biomass (Bb) and chlorophyll *a* has been given by Starzecka and Bednarz (1993).

The bacteria fraction was isolated from the water by means of filtration of the water samples or of water sediment suspension through Whatman glass microfibre filters GF/C. A detailed description of the preparation of water sediment suspension has been given by Starzecka and Bednarz (1993). Oxygen losses in the filtrate and respiration of bacteria (Rb) were calculated as in the work by Starzecka and Bednarz (1993).

The respiration of algae (Ra) during the night was estimated as 20% of their photosynthesis during the day (Hargrave 1969, Hillbricht-Ilkowska 1977). The diel net production of algae (P), the oxygen respiration of organisms in the water, and the respiration of epibenthic communities (RO), and the respiration of remaining organisms per 24 h (Rr) were calculated as in the cited work by Starzecka and Bednarz (1993).

A logarithmic comparative coefficient (LCC) was applied to illustrate differences in the intensity of biological processes between the water and the bottom sediments. The coefficient determined the ratio of the logarithm of the parameters measured in the water to the logarithm of those in the bottom sediments. A positive value of LCC showed larger values of the parameters in the water and a negative one in the sediments.

The measurements were carried out in the laboratory at 21°C (±1°C) in 3 replications and the results were given as arithmetical means calculated per joules (J), 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 organic carbon (C) = 4.9 cal (Cummins 1967) = 20.53 J.

## 3. Results

The determination of organic carbon concentration in the water and in the surface layer of bottom sediments (Table I) indicated that 1 g C was contained in 12 to 29 kg of water and in 65 to 123 g of fresh sediments.

Table I. Concentration of organic carbon in the water (1000 g) and in fresh bottom sediments (1000 g) at various stations

| Station | Water | Sediment |
|---|---|---|
| stream | 0.0822 | 15.3 |
| estuary | 0.0337 | 8.1 |
| dam reservoir | 0.0578 | 10.1 |

The algal production of organic matter (P) in the water column was highest in the estuary (2770.73 J $g^{-1}$ C 24 $h^{-1}$). In the water of the reservoir the P value was approximately 57% lower than in the estuary, but in the stream P constituted only 0.20% of the value found in the estuary. In the bottom sediments the P value was also highest in the estuary (65.74 J $g^{-1}$ C 24 $h^{-1}$) while in the bottom sediments of the stream and of the reservoir it was approximately 70% and 54%, respectively lower (fig. 2.).

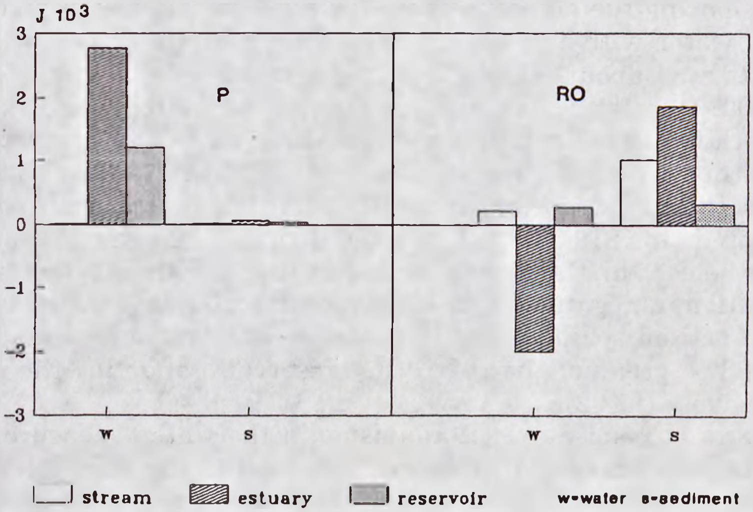


Fig. 2. Algal production (P) and oxygen respiration of organisms (RO), in J, calculated per 1 g C per 24 h

The respiration of bacteria (Rb) rose on the stream-reservoir line from 341.28 to 729.60 J $g^{-1}$ C 24 $h^{-1}$in the water and from 9.33 to 47.84 J in the bottom sediments. In the case of algae, the highest respiration (Ra) was found in the estuary, both in the water (692.68 J) and in the bottom sediments (16.43 J), and the lowest in the water and in the sediments of the stream (1.44 and 4.96 J $g^{-1}$ C 24 $h^{-1}$, respectively) (fig. 3).

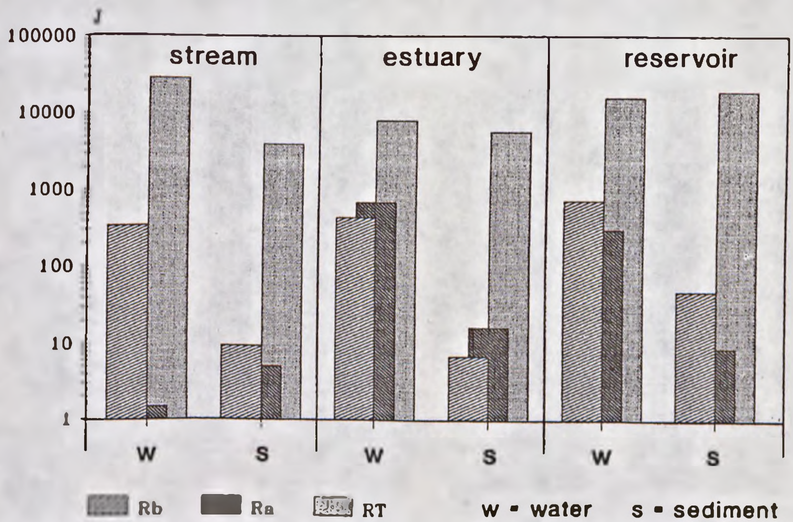


Fig. 3. Oxygen respiration of: bacteria (Rb), algae (Ra), and total respiration of organisms (RT) measured by $CO_2$ released, calculated in J per 1 g C per 24 h

Comparing the amounts of energy fixed in primary production (P) in the water with the those released by bacteria (Rb) it was found that Rb was about 6000% P in the stream, 16% P in the estuary, and 60% P in the reservoir. However, in the bottom sediments from each station these values were 47%, 10%, and 135%, respectively.

In the water of the stream and of the reservoir the data concerning oxygen respiration (RO) were similar to each other and amounted to 219.36 and 274.00 J $g^{-1}$ C 24 $h^{-1}$, respectively. Nevertheless, in the water of the estuary, with the highest algal production, a negative value of RO occurred (-2006.26 J $g^{-1}$ C 24 $h^{-1}$). In the bottom sediments of the estuary RO was approximately 46% and 83% greater than in the reservoir and in the stream, respectively (fig. 2).

The total respiration of organisms in the water, measured as the amount of released $CO_2$ (RT), distinctly fell in the direction from the stream to the reservoir (28578.68 - 15965.44 J $g^{-1}$ C 24 $h^{-1}$), contrary to the bottom sediments, where a distinct increase in RT value was observed, from 3980.17 J $g^{-1}$ C 24 $h^{-1}$ in the stream to 19185.56 J in the reservoir (fig. 3).

The biomass of bacteria (Ba) in the water was maintained on a uniform level on the stream (134.14 J $g^{-1}$ C) - estuary (156.50 J) - reservoir (141.60 J) line. However, in the bottom sediments a pronounced decrease in bacterial biomass was found in the direction from the stream (13.66 J $g^{-1}$ C) to the reservoir (1.74 J) (fig. 4).

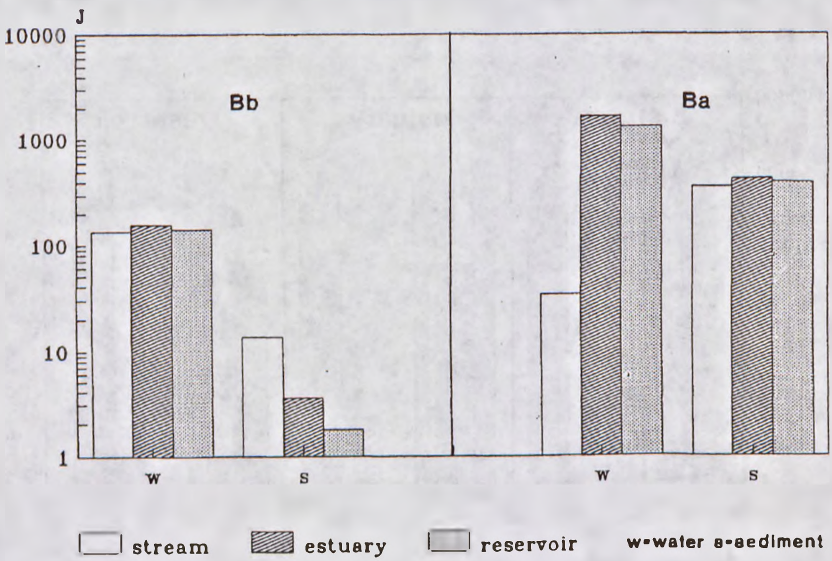


Fig. 4. Biomass of bacteria (Bb) and algae (Ba) in J per 1 g C

In the water very distinct differences between the algal biomass (Ba) in the stream (33.82 J $g^{-1}$ C) and that at two other stations (1645.16 J in the estuary and 1314.50 J in the reservoir) occurred. In the bottom sediments on the stream- reservoir line the biomass of algae was maintained on an uniform level in the range of 359.15 J $g^{-1}$ C in the stream, 422.80 J in the estuary, and 389.87 J in the reservoir. It should be emphasized that the greatest biomass of algae was observed in the estuary, both in the water and in the bottom sediments (fig. 4).

The expense of energy per a biomass unit of bacteria (Rb/Bb) increased on the stream - reservoir line from 2.54 to 5.15 in the water and from 0.68 to 27.51 in the sediments. The values of Rb/Bb in the water were higher than in the sediments - 3.7 times in the stream and 1.4 times in the estuary. In contrast, in the reservoir Rb/Bb was 5.3 times higher in the sediments than in the water (fig. 5).

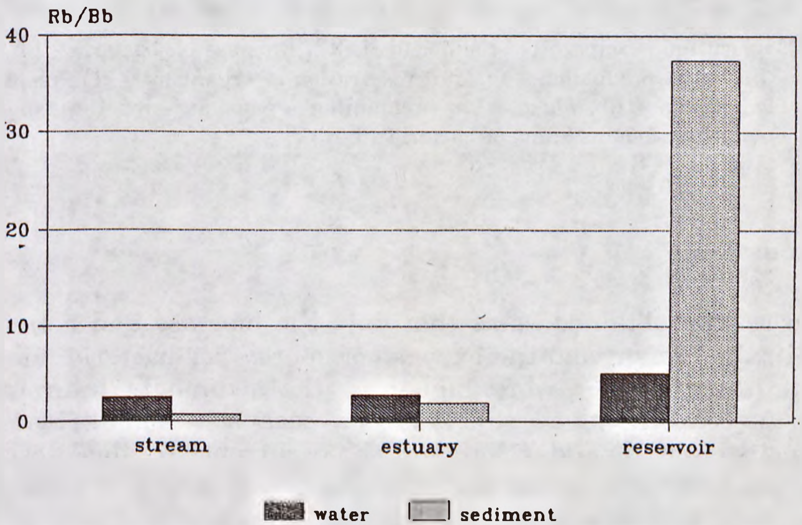


Fig. 5. Coefficient Rb/Bb illustrating the expense of energy per bacterial biomass unit

Applying a logarithmic comparison coefficient (LCC), it was found that the values of the determined biological parameters in the water were approximately 0.5 to 2 orders of magnitude higher than in the bottom sediments of the same stations. The exceptions were Ba, P, and Ra which were approximately 0.5 to 1 order of magnitude higher in the bottom sediments of the stream, and Rb/Bb which was approximately 0.7 order of magnitude higher in the bottom sediments of the reservoir. However, Rr and RT in the bottom sediments of the reservoir prevailed only slightly over the values obtained for the water (fig. 6).

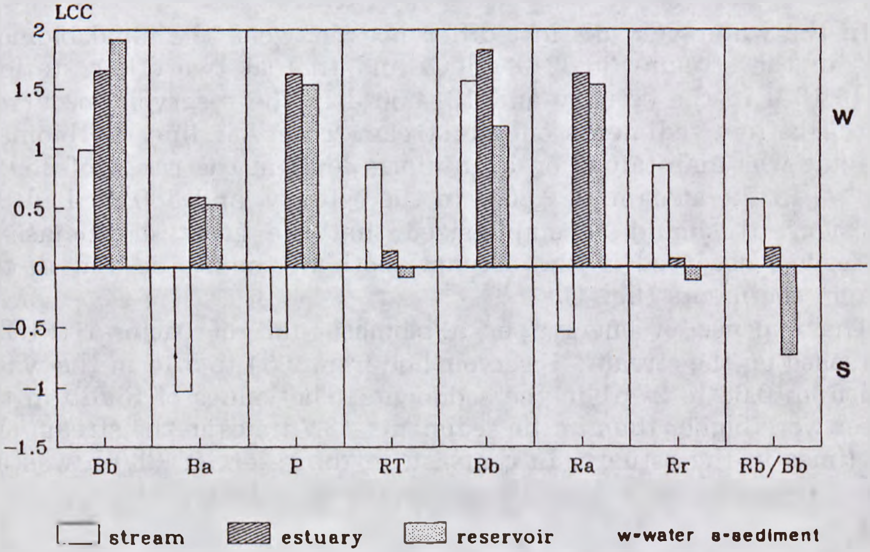


Fig. 6. Logarithmic comparative coefficient (LCC). Biomass of: bacteria - Bb, algae - Ba; algal production - P; total respiration of organisms - RT; respiration of: bacteria - Rb, algae - Ra, remaining organisms - Rr; the expense of energy per biomass unit of bacteria Rb/Bb

## 4. Discussion

The results obtained show that only the biomass and activity of algae in the stream and the expense of energy per bacterial biomass unit in the reservoir were higher in the sediments than in the water. As concerns algae, this is clearly because in small rivers and streams, sessile algae develop, and the occurrence of algal seston is a secondary event. The expense of energy per bacterial biomass unit, higher in the bottom sediments than in the water of the reservoir, indicated a greater content of organic matter more easily degradable in the water and more refractory in the bottom sediments of the reservoir.

The rise in the Rb/Bb coefficient value on the stream - reservoir line in both the investigated subsystems, was evidence of a decline in the concentration of organic matter easily degradable by bacteria in the direction from the stream to the reservoir.

The percentage share of the amount of energy released by bacteria in the amount of energy fixed in primary production clearly showed that the main nutrient source for bacteria in the water of the stream was allochtonous organic matter.

The negative value of oxygen respiration (RO) found for the water in the estuary was connected with the highest biomass and production of algae. Consequently, oxygen saturation of the water in the estuary was higher than the oxygen demand of all the organisms. H o f f m a n et al. (1991) described a similar situation in Lake Oosterschelde (SW Netherlands), where epibenthic algae oxygen production entirely compensated for the oxygen consumption by the communities of epibenthic organisms.

The intensity of biological processes, found to be distinctly higher in the water than in the bottom sediments was unexpected. It is generally accepted that the place of the most intensive processes is the water-sediment interface (J a n s s o n 1967; M i l b r i n k 1968; M o s s 1968; P a m a t m a t 1968; H o f m a n et al. 1991; S u n d b ä c k et al. 1991; M o r a n, H o d s o n 1992). The calculation of results per 1 g of C, applied in the present work, permitted a comparison of the processes taking place in the water and in the bottom sediments, independently of the density of organic matter in situ. It should be remarked that the microbiological processes described by here referred to a large mass of water (12-29 kg) and a comparative small mass of bottom sediments (65-123 g). Nevertheless, referring the results to the square measure most often applied by other authors can indicate a greater intensity of biological processes in the water-sediment interface because the concentration of carbon in this layer is higher than in the water.

## 5. Polish summary


### Produkcja i destrukcja materii organicznej w wodzie i wierzchniej warstwie osadow dennych na linii potok - zbiornik zaporowy w Dobczycach (Polska południowa)

Badania przeprowadzono w potoku o rolniczym typie zlewni, jego ujęciu (estuarium) i sublitoralu zbiornika zaporowego w Dobczycach, w rejonie zatoki Wolnica (ryc. 1.). W wodzie i wierzchniej 0,5 cm warstwie osadów dennych określono zawartość węgla organicznego (C) (tabela I), produkcję glonów i destrukcję materii organicznej.

Produkcja glonowa (P) była największa w estuarium zarówno w wodzie jak i w osadach (ryc. 2). Respiracja tlenowa organizmów (RO) utrzymywała się na wyrównanym poziomie w wodzie potoku i zbiornika. Natomiast w estuarium stwierdzono ujemną wartość RO. W osadach estuarium wartość RO była ok. 46% i 83% większa niż odpowiednio w zbiorniku i potoku (ryc. 2). Respiracja bakterii (Rb) wzrastała na linii potok - zbiornik w wodzie i osadach. Respiracja glonów (Ra) zarówno w wodzie jak i osadach była największa w estuarium, a najmniejsza

w potoku (ryc. 3). Całkowita respiracja organizmów, mierzona ilością wydzielonego $CO_2$ (RT) obniżała się na linii potok - zbiornik w wodzie, a w osadach wyraźnie wzrastała w kierunku od potoku do zbiornika (ryc. 3). Biomasa bakterii (Bb) na linii potok - zbiornik utrzymywała się na wyrównanym poziomie w wodzie, a w osadach wyraźnie obniżała się w kierunku od potoku do zbiornika (ryc. 4). Biomasa glonów (Ba) w wodzie była najmniejsza w potoku i znacznie większa w estuarium oraz zbiorniku. Natomiast w osadach wartość Ba utrzymywała się na wyrównanym poziomie na linni potok - zbiornik, z tendencją wzrostu w estuarium (ryc. 4). Wydatki energetyczne na jednostkę biomasy bakterii (Rb/Bb) wzrastały w kierunku od potoku do zbiornika zarówno w wodzie jak i osadach (ryc. 5).

Wartości oznaczanych parametrów biologicznych na ogół były od 0,5 do 2 rzędów wielkości większe w wodzie niż w osadach. Wyjątek stanowiły Ba, P i Ra w potoku oraz Rb/Bb w zbiorniku, których wartości były 0,5 do 1 rzędu wielkości większe w osadach niż w wodzie (ryc. 6).

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