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# Occurrence and role of bivalves of the family *Unionidae* (*Mollusca, Bivalvia*) in the eutrophic Lake Zbęchy (Wielkopolska — Kujawy Lowland) and its outflow canal

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Abstract — The density of *Unionidae*, their biomass, respiration, water filtration intensity, seston consumption, and content of accumulated phosphorus were evaluated in a eutrophic polymictic lake and in its outflow canal lying in agricultural terrain. The biomass of *Unionidae* in the lake was 1777 kg ha$^{-1}$ (production 638 kg ha$^{-1}$), and in the canal 30 kg ha$^{-1}$ (production 11.5 kg ha$^{-1}$). During the vegetation season *Unionidae* in the lake catch from the water 11.5 t dry weight of seston, assimilating about 36 kg of phosphorus, while in the canal they catch 6.8 kg of seston and assimilate 0.02 kg of phosphorus.

Key words: agricultural land, lake, outflow canal, ecology of bivalves, *Unionidae*, *Sphaeriidae*.

## 1. Introduction

In many aquatic ecosystems in agricultural terrain bivalves of the *Unionidae* family are among the most common molluscs. With regard to their great individual biomass and occurrence, as a rule in considerable density, they sometimes constitute up to 99 per cent of the biomass of the total benthos of lakes (Ökland 1963). The main role of *Unionidae* in an aquatic ecosystem is their role of great filtrators which in stagnant waters and flows participate significantly in catching and destroying seston. Estimation of the filtration ability of bivalve associations is one of the functional characteristics of bivalve associations in aquatic ecosystems. It permits the role of these animals in the circulation of matter in aquatic ecosystems to be assessed by measuring the amount of seston acquired from the water by filtration and sedimentation. The aim of this work was to present information concerning density, biomass, production, and respiration of *Unionidae* occurring in surface waters in agricultural terrain; to give estimated values of the intensity of water filtration by these bivalves and the consuption of seston in such a type of aquatic ecosystem; and to show the participation of *Unionidae* in rotation of the phosphorus.

## 2. Study area and methods

The investigation material of *Unionidae* was collected in the years 1977/78 in the eutrophic polymictic Lake Zbęchy (area 108.9 ha, mean depth 4.2 m, volume $4636.6 \cdot 10^3$ $m^3$) located in the Krzywin Lake District (southern part of the Wielkopolska — Kujawy Lowland) and in its outflow canal (Banaszak, Kasprzak 1980). The littoral zone (to a depth of 1.5 m) where *Unionidae* occur, covers an area of 19.3 ha. During the vegetation season (180 days) $1749.6 \cdot 10^3$ $m^3$ water pass through the examined sector of the canal (1063 m). According to the author's own laboratory analysis, the estimated annual mean amount of seston in the water of the lake is 450 mg dry weight $dm^{-3}$, this corresponding to 2086.2 t dry weight of seston suspended in the total volume of the lake water. In the investigated sector of the canal, with a mean flow of 0.3 m $sec^{-1}$ during the vegetation season, the mean amount of seston in the water is 350 mg $dm^{-3}$, this corresponding to 817.3 t dry weight of seston suspended in the water flowing during the vegetation season over 1 $m^2$ of the bottom of the canal. The estimation was made on the basis of analyses of water samples of 10 $dm^3$ volume each, taken once a month at various depths of the lake from its surface layer to the bottom at a depth of 4.5 m (total volume of the monthly sample was 60 $dm^3$); in the canal water collected in 30 $dm^3$ samples from the surface layer. The mean annual production of phytoplankton in the lake and canal was 11 000 kJ $m^{-2}$ $year^{-1}$ and 30 kJ $m^{-2}$ $year^{-1}$ respectively (J. Jurkowska unpublished results). *Dreissena polymorpha* Pall. did not occur either in the lake or in the canal. The investigation material of *Unionidae* was collected during a period of 8 months (from April to November) at 8 and 3 stations in the lake and canal respectively; these were distributed around the lake and along the investigated sector of the canal in cross--sections of its bed.

The water sampled in the lake at depths of 0.5 m, 1.0 m, and 1.5 m. A single sample of 0.25 $m^2$ bottom surface was taken; this was searched for bivalves manually and with a cog dredge. At each station 5 to 10 samples were examined. This amounted to a total number of 1450 examined samples. All bivalve individuals caught from the water were measured (length of shell) with accuracy to ± 0.1 mm. The biomass of *Unionidae*, constituting the function of shell length, and the age of individuals were determined on the basis of regression equations introduced by Lewandowski and Stańczykowska (1975): for *Anodonta piscinalis* Nilss. $y_1 = 0.0013 \cdot x^{2.39}$, $y_2 = 0.0000019 \cdot x^{3.3366}$, $y_3 = 0.00000052 \cdot x^{3.1425}$; for *Unio tumidus* Philip. $y_4 = 0.0018 \cdot x^{2.3086}$, $y_5 = 0.0001 \cdot x^{2.77}$, $y_6 = 0.0000016 \cdot x^{2.9650}$ (where x — length of the individual in the shell in mm; $y_1$, $y_4$ — live weight with the shell in g; $y_2$, $y_5$ — dry weight of the shell in g; $y_3$, $y_6$ — dry weight of the body without the shell in g). Equations valid for *Unio tumidus* Philip. ($y_4$, $y_5$, $y_6$) were also applied in calculations of biomass of *Unio pictorum* L. The mean respiration value was calculated using equations of the expotential function according to Alimov (1981) (Table I). The mean caloric value of *Unionidae* (1 g dry weight of the body = 4.43 kcal = 18.54 kJ) was adopted after Alimov (1981), taking into account corrections based upon the outhor's own measurements concerning temperature and length of the vegetation season (180 days) and investigation period (8 months), applying conversion into energy units (1 g $O_2$ = 3.51 kcal = 14.69 kJ); according to results given by Alimov (1981), the value $Q_{10} = 2.51$ was adopted for *Unionidae* for the temperature interval 15 to 20 centigrade. The annual production of *Unionidae* was calculated according to the method described by Greze (1965), applied for estimation of biomass production of various benthic invertebrates (Kajak 1972), including *Unionidae* (Negus 1966, Tudorancea, Florescu 1968a, b, Tudorancea 1968, 1969, Magnin, Stańczykowska 1971, Lewandowski, Stańczykowska 1975). In calculating biomass production for individuals belonging to the youngest age groups a density equalling the greatest density of individuals belonging to older age groups was theoretically adopted. This calculation, which in reality gives an approximate estimation of the size of the biomass production, is necessary since with the applied method of sampling a relatively low density of young individuals of *Unionidae* is obtained. For comparison and to check the reliability of results obtained by Greze's method (1965), for calculating the annual biomass production of *Unionidae* the author used regression equations describing the relation between production (P) and respiration (R) in molluscs (Humphreys 1979): log P=1.033 log R—

Table I. Values of the index of oxygen consumption rate a (in mg $O_2$ indiv $^{-1}h^{-1}$) for regression index b=0.75=constant ($R=aW^{0.75}$) for Unionidae and Sphaeriidae bivalves (re-calculated by the author according to Alimov's (1981) results for the temperature 20°C).
R - oxygen consumption (respiration); W - live body weight with shell in g

| T a x a | Index of oxygen consumption rate a |
|---|---|
| Unio | 0.057 |
| Anodonta | 0.082 |
| Unionidae | 0.069 |
| Sphaeriidae | 0.179 |

Table II. Relationship between filtration rate (F) and body biomass (W) for other species of Unionidae and Sphaeriidae according to Alimov's (1965, 1981) results for the temperature 20°C.
F - filtration rate (µl indiv.$^{-1}$ h$^{-1}$); W - wet biomass with shell (g m$^{-2}$).
For calculations concerning temperature, corrections according to Alimov's (1981) results - for 10-15°C $Q_{10}$=3.11 and for 20-25°C $Q_{10}$=2.78

| T a x a | Range of biomass (g) | Equations of filtration rate |
|---|---|---|
| Unionidae: Anodonta piscinalis | 1.25-65.00 | $F = 84.14\ W^{0.49}$ |
| Unio pictorum | 0.80-32.72 | $F = 90.36\ W^{0.58}$ |
| Unio tumidus | 0.80-32.72 | $F = 66.80\ W^{0.53}$ |
| Unionidae | 0.043-156.00 | $F = 85.50\ W^{0.605}$ |
| Sphaeriidae: Sphaerium | 0.0070-0.4030 | $F = 10.38\ W^{0.60}$ |
| Pisidium | 0.0016-0.2610 | $F = 16.07\ W^{0.60}$ |

− 0.717 (in cal m$^{-2}$ year$^{-1}$) and poikilothermic animals (McNeil, Lawton 1970): log P = 0.8233 log R − 0.2367 (in kcal m$^{-2}$ year$^{-1}$). Taking into account differentiation in the biomass of individuals belonging to various taxa or age groups and corrections for temperature of the environment in the investigated period, as well as the length of the vegetation season, the rate of water filtration by bivalves was calculated on the basis of equations of the exponential function describing the relation between the biomass of individuals and volume of filtered water in the time unit (Table II). For quantitative estimation of water filtration the index of filtration intensity ($F_I$) was used; this gives the relation of the value of water filtered by these animals in the time unit to the total volume of water ($V_t/V_o$) in the reservoir or outflow. In estimating the participation of *Unionidae* in the process of phosphorus rotation by accumulating this element in the body it was assumed that phosphorus constitutes 1.0 per cent in the body (without the shell) of these bivalves (Stańczykowska 1983) and 0.02 per cent in the bivalve shell (Kuenzler 1961).

For comparison analogous values were adopted also for *Sphaeriidae*, making use of the author's unpublished or only partially published results (Banaszak, Kasprzak 1980, Kasprzak 1986) concerning the density and biomass of the population of these bivalves occurring in the investigated ecosystems. Respiration was also calculated on the basis of these results. The size of the biomass of *Sphaeriidae* was estimated according to the author's own weight measurements and by applying the equation given by Alimov (1965) and Desjatnik (1968): $W = 0.0002 \cdot L^3$, determining the relation between shell length (L in mm) and body weight (W in g); it was assumed that dry body weight equals 4 per cent of live weight. In estimating seston consumption it was assumed that for *Unionidae* the mean diel food ration is on the average 20.6 mg dry weight of seston and 4.2 mg dry weight of faecal water per individual.

Food assimilation in the summer is 79.6 per cent in relation to food filtration from the water (Lewandowski, Stańczykowska 1975). Taking into account the amount filtered by *Sphaeriidae*, the quantity of seston in the waters of the investigated ecosystems, and assuming consumption of the whole food ration filtered, it was found that the daily food ration for *Sphaerium corneum* (L.) is on the average 10.7 mg dry weight and for species of the genus *Pisidium* 4.5 dry weight of seston per individual; it was assumed that food assimilation in the summer was 80 per cent in relation to the food filtered from the water.

In this work use was made of the unpublished results of A. Karabin (Institute of Ecology of the Polish Academy of Sciences, Dziekanów Leśny) concerning zooplankton biomass in Lake Zbęchy and in its outflow canal.

## 3. Results

### 3.1. Species composition, density, biomass, and age structure

Both in the lake and in the outflow canal three species of *Unionidae* were found — *Anodonta piscinalis* Nilss., *Unio tumidus* Philip., and *U. pictorum* L. A comparison of the *Unionidae* fauna of the lake and canal indicated a considerable differentiation in the density, biomass, and dominance structure of communities of these bivalves (fig. 1). The mean density of *Unionidae* was seven times greater on an average m² of the lake bottom than in the canal, whereas the mean dry weight of these bivalves without the shell was about eight times greater (Table III). The greatest number of *Unionidae* was found in the lake in April but in the canal in October. Both in the lake and in the canal *Unio tumidus,* which also dominated in the canal as far as biomass was concerned (46 per cent), showed the largest share in the total density (lake 69 per cent, canal 71 per cent) of *Unionidae* communities. As for biomass, *Anodonta piscinalis* (60 per cent) dominated in the lake (fig. 1). A comparison based upon estimations of the total number and biomass of all *Unionidae* living in the investigated ecosystems (Table IV) showed considerable differences in the resources of *Unionidae* fauna in the lake and canal. Individuals of *Unionidae* of various age groups and different biomass and number were found in these two ecosystems (fig. 2A). In the case of the dominating *Unio tumidus*, 3 to 6-year-old individuals were the most numerous participants in the lake with regard to biomass, while in the canal 2 to 5 year olds dominated.

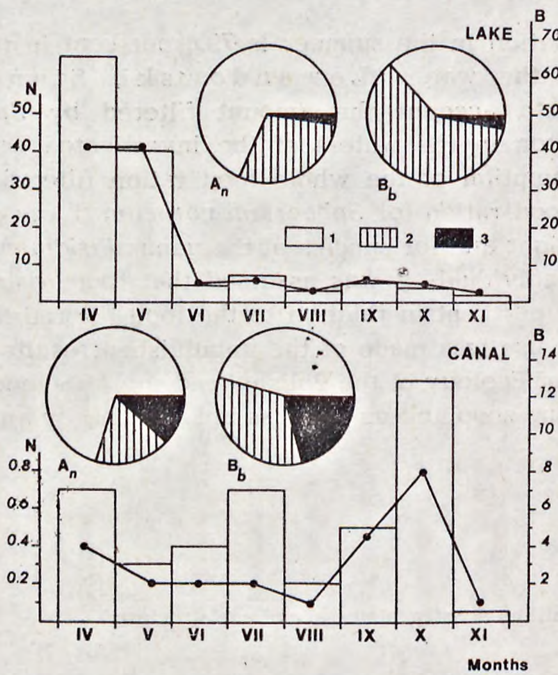


Fig. 1. Domination structure and changes of density and biomass of the *Unionidae* community in Lake Zbęchy and its cutflow canal during the vegetation season. N — numbers (individuals $m^{-2}$); B — wet biomass with shell (g $m^{-2}$); $A_n$ — domination structure with regard to numbers; $B_b$ — domination structure with regard to biomass. 1 — *Unio tumidus;* 2 — *Anodonta piscinalis;* 3 — *Unio pictorum*

### 3.2. Respiration

During the 8 months investigation period oxygen consumption by *Unionidae* in the lake was fourty times greater than in the canal (fig. 2B). In the lake *Anodonta piscinalis,* especially 4-, 5-, and 7-year-old

Table III. Comparison of average density and biomass of Unionidae in Lake Zbęchy and its outflow canal. A - density (indiv. $m^{-2}$); B - wet biomass without shell ($g\ m^{-2}$); C - shell weight ($g\ m^{-2}$); D - dry biomass without shell ($g\ m^{-2}$). x-Average density and biomass of the Unionidae investigated in various lake zones during the season are presented as constant arithmetic means (in brackets). The value was calculated by multiplying the density and biomass values by the constants (weights) reflecting the ratio of the zonal surface between isobaths to the total lake area. Such a calculation allowed the obtained densities in the lake to be compared with those in the canal

| Species | Lake x | | | | Canal | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A | B | C | D |
| Anodonta piscinalis Nilss. | 4.8 (0.9) | 106.62 (18.90) | 14.19 (2.51) | 1.24 (0.22) | 0.07 | 1.06 | 0.15 | 0.02 |
| Unio tumidus Philip. | 11.3 (2.0) | 64.88 (11.50) | 42.31 (7.50) | 1.93 (0.34) | 0.27 | 1.39 | 0.75 | 0.04 |
| Unio pictorum L. | 0.04 (0.01) | 6.27 (1.11) | 0.13 (0.02) | 0.004 (0.0007) | 0.04 | 0.53 | 0.37 | 0.01 |
| Total | 16.1 (2.9) | 177.77 (31.51) | 56.63 (10.03) | 3.17 (0.56) | 0.38 | 2.98 | 1.27 | 0.07 |

Table IV. Comparison of the total number of individuals and biomass of the Unionidae living in Lake Zbęchy and its outflow canal. A, A' - number of individuals (A - indiv. $10^6$, A' - indiv. $10^3$), B, B' - wet biomass with shell (B - t, B' - kg); C, C' - dry biomass without shell (C - t, C' - kg); D, D' - shell weight (D - t, D' - kg)

| Species | Lake | | | | Canal | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A' | B' | C' | D' |
| Anodonta piscinalis Nilss. | 0.9 | 23.3 | 0.2 | 0.72 | 0.3 | 5.79 | 0.09 | 2.7 |
| Unio tumidus Philip. | 2.2 | 20.7 | 0.4 | 3.59 | 1.3 | 10.24 | 0.19 | 8.2 |
| Unio pictorum L. | 0.008 | 1.2 | 0.0008 | 1.77 | 0.2 | 4.31 | 0.05 | 0.03 |
| Total | 3.1 | 45.2 | 0.6 | 6.08 | 1.8 | 20.34 | 0.33 | 10.9 |

individuals, were the main oxygen consumers, whereas in the canal *Unio tumidus*, chiefly 5- and 6-year-olds, were. A comparison of the oxygen consumption of the population of *Unionidae* with that of populations of *Sphaeriidae* indicated that in the lake consumption by *Sphaeriidae* (40.5 kJ $m^{-2}$ $year^{-1}$, *Sphaerium corneum* 55 per cent, species of the genus *Pisidium* 45 per cent) was more than ten times smaller than that by *Unionidae*, while in the canal the reverse was true, oxygen consumption by *Sphaeriidae* ($47 \cdot 10^3$ kJ $m^{-2}$ $year^{-1}$, *Sph. corneum* 95 per cent, species of the genus *Pisidium* 5 per cent) being $3.6 \cdot 10^3$ times greater than that by *Unionidae*.

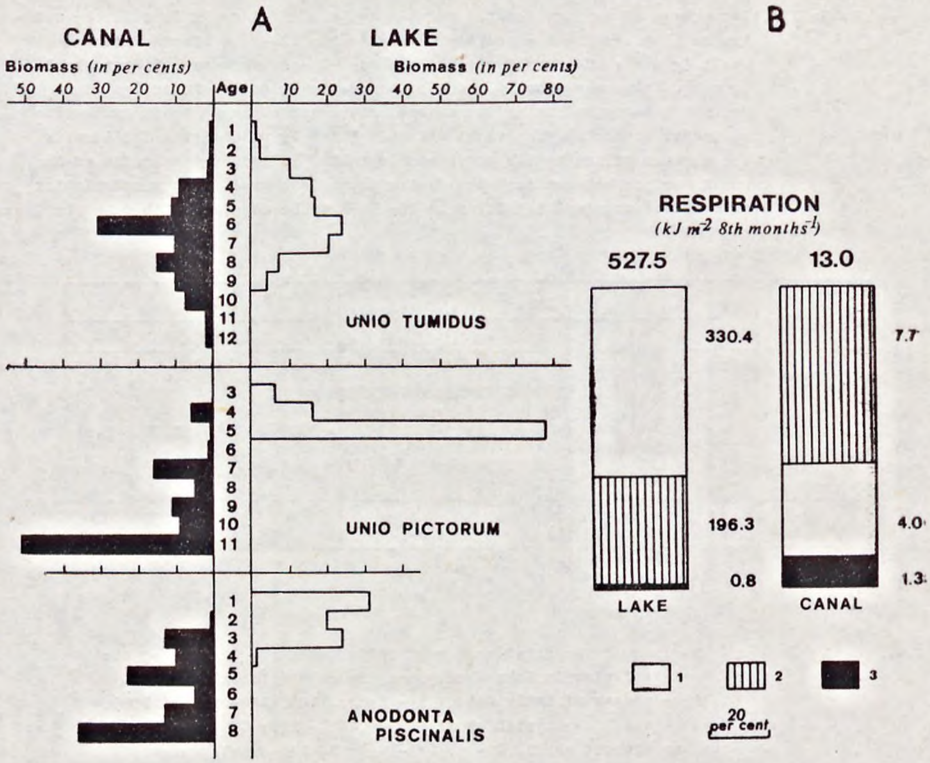


Fig. 2. Comparison of the A — age structure with regard to biomass and B — respiration of the *Unionidae* community in Lake Zbęchy and its outflow canal. 1 — *Anodonta piscinalis*; 2 — *Unio tumidus*; 3 — *Unio pictorum*

### 3.3. Production

Calculations of production (Table V) carried out by G r e z e's method (1965) showed that the annual production of biomass of all *Unionidae* (*Anodonta piscinalis* 71.0 per cent, *Unio tumidus* 28.9 per cent, *U. pictorum* 0.1 per cent) in the investigated lake was 638 kg ha$^{-1}$, while in the canal it was 11.5 kg ha$^{-1}$ (*A. piscinalis* 50.9 per cent, *U. tumidus* 36.0 per cent. *U. pictorum* 13.1 per cent). The ratio P/$\bar{B}$ was on the average in the lake 0.45 (*A. piscinalis* 0.46, *U. tumidus* 0.37, *U. pictorum* 0.51) and in the canal 0.34 (*A. piscinalis* 0.44, *U. tumidus* 0.33, *U. pictorum* 0.26) being considerably higher for younger than for older individuals. Calculations made on the basis of equations presenting the dependence of production on respiration showed the occurrence of much higher values of production (Table VI).

Table V. Biomass and annual production of Unio tumidus Philip. in Lake Zbęchy.
A - age (years); n - density (indiv. $m^{-2}$); b - biomass of one individual (wet weight without shell in g); $\Delta b$ - increase in the biomass of one individual per year in g; $\bar{B}$ - average biomass (g $m^{-2}$); P - production per year (g $m^{-2}$); * Theoretical numbers (=numbers of the $3^{th}$ and $4^{th}$ age classes)

| A | n | b | $\Delta b$ | $\bar{B}$=n.b | P=n.$\Delta b$ | P/$\bar{B}$ |
|---|---|---|---|---|---|---|
| 1 | 2.05 * | 0.59 | 0.59 | 1.21 | 1.21 | 1.00 |
| 2 | 2.05 * | 1.68 | 1.09 | 3.44 | 2.23 | 0.64 |
| 3 | 2.05 | 3.58 | 1.90 | 7.34 | 3.89 | 0.53 |
| 4 | 2.05 | 5.51 | 1.93 | 11.29 | 3.96 | 0.35 |
| 5 | 1.58 | 6.55 | 1.04 | 10.35 | 1.64 | 0.16 |
| 6 | 2.03 | 7.11 | 0.56 | 14.43 | 1.14 | 0.08 |
| 7 | 1.34 | 9.52 | 2.41 | 12.76 | 3.23 | 0.25 |
| 8 | 0.36 | 12.13 | 2.61 | 4.37 | 0.94 | 0.22 |
| 9 | 0.17 | 13.11 | 0.98 | 2.23 | 0.17 | 0.08 |
| Total | 13.68 | - | - | 67.43 | 18.41 | - |

Table VI. Comparison of the production of biomass (in kJ $m^{-2}$) of the populations of Unionidae in the vegetation season in Lake Zbęchy and its outflow canal calculated according to the methods of Greze (1965) (A), McNeil and Lawton (1970) (B), and Humphreys (1979) (C)

| Ecosystems | Method: | | |
|---|---|---|---|
| | A | B | C |
| Lake | 47.3 | 139.4 | 162.8 |
| Canal | 0.8 | 6.2 | 3.2 |

### 3.4. Intensity of water filtration by *Unionidae* as an estimation of the degree of seston destruction

Data from the literature and the author's own investigation results show that the filtration intensity of *Bivalvia* varies greatly in water bodies and flows of various type. The value of the index of filtration intensity varies from 0.001 to 1.10 (Table VII). The results of the author's own investigations in the lake and canal indicate a distinct relation between the filtration intensity ($V_t/V_o$) and biomass ($\bar{B}$) of *Unionidae* and *Sphaeriidae* occurring there (Table VIII). This is shown by the regression equation (fig. 3A). The described relation elaborated on the basis of the author's own materials is clearly consistent with various data in the literature concerning the intensity of filtration by *Bivalvia* mainly in eutrophic lakes and dam reservoirs. Calculation of this intensity permitted formulation of the regression equation (fig. 3B). The few data in the literature also indicated that in the case of *Unionidae* there is an evident relation between filtration intensity and production as far as these bivalves are concerned (fig. 4). Estimation of the

Table VII. Comparison of the biomass of bivalves (mainly Unionidae) and intensity filtration rate in the vegetation season in various types of water bodies with various productivity.
P - primary production (kJ $10^3$ $m^{-2}$); $\bar{B}$ - average wet biomass (g $m^{-2}$); $F_I$ - index of intensity filtration rate $F_I = \frac{V_t}{V_o}$ ($V_t$ - volume of filtered water, $V_o$ - volume of water in lake or canal)

| Ecosystems | P | $\bar{B}$ | $F_I$ | Authors |
|---|---|---|---|---|
| Lake Krasnoe | 6.2 | 1315.0 | 0.30 | Andronnikova, Drabkova 1976; Kuz'menko 1976 |
| Lake Mikołajskie | 13.0 | 3102.5 | 1.10 | Lewandowski, Stańczykowska 1975 |
| Lake Drivjaty | 7.4 | 61.0 | 0.80 | Gavrilov 1970 |
| Lake Krugloe | 0.2 | 15.8 | 0.21 | Alimov 1981 |
| Lake Zeleneckoe | 0.1 | 0.1 | 0.01 | Alimov 1981 |
| Lake Zbęchy | 11.0 | 177.8 | 0.79 | Kasprzak unpublished data |
| Wołgograd man-made lake | 4.7 | 50.9 | 0.32 | Kondratev 1970 |
| Outflow canal | 0.03 | 2.9 | 0.001 | Kasprzak unpublished data |

Table VIII. Comparison of the intensity filtration rate of populations of Unionidae and Sphaeriidae in Lake Zbęchy and its outflow canal.
$\bar{B}$ - average wet biomass without shell (g $m^{-2}$);
$F_I$ - index of the intensity filtration rate $F_I = \frac{V_t}{V_o}$

| Eco-systems | Taxa | $\bar{B}$ | $F_I$ |
|---|---|---|---|
| Lake | Unionidae: | 177.8 | 0.79 |
| | Anodonta piscinalis | 106.6 | 0.37 |
| | Unio tumidus | 64.9 | 0.43 |
| | Unio pictorum | 6.3 | 0.03 |
| | Sphaeriidae: | 0.10 | 0.0059 |
| | Sphaerium corneum | 0.03 | 0.0001 |
| | Pisidium species | 0.07 | 0.0059 |
| Canal | Unionidae: | 2.98 | 0.001 |
| | Anodonta piscinalis | 1.06 | 0.0003 |
| | Unio tumidus | 1.39 | 0.0006 |
| | Unio pictorum | 0.53 | 0.0003 |
| | Sphaeriidae: | 57.8 | 0.049 |
| | Sphaerium corneum | 42.1 | 0.015 |
| | Pisidium species | 15.7 | 0.034 |

filtration intensity of *Unionidae* and *Sphaeriidae* in the lake and canal showed that during the vegetation season these bivalves in the lake altogether filter 80 per cent of the total lake volume of water. 4- to 6-year-old individuals of *Unio tumidus* and *Anodonta piscinalis* have the greatest share in this process, whereas 7-year-old ones (fig. 5), which constitute approximately half of the population of *Unionidae* in the lake, are less engaged. Altogether the *Unionidae* (about $3 \cdot 10^6$ individuals) occurring in the lake (almost exclusively the littoral zone down to a depth of 1.5 m) can, during the vegetation season, filter 79 per cent of the total volume of the lake water (fig. 6) catching from

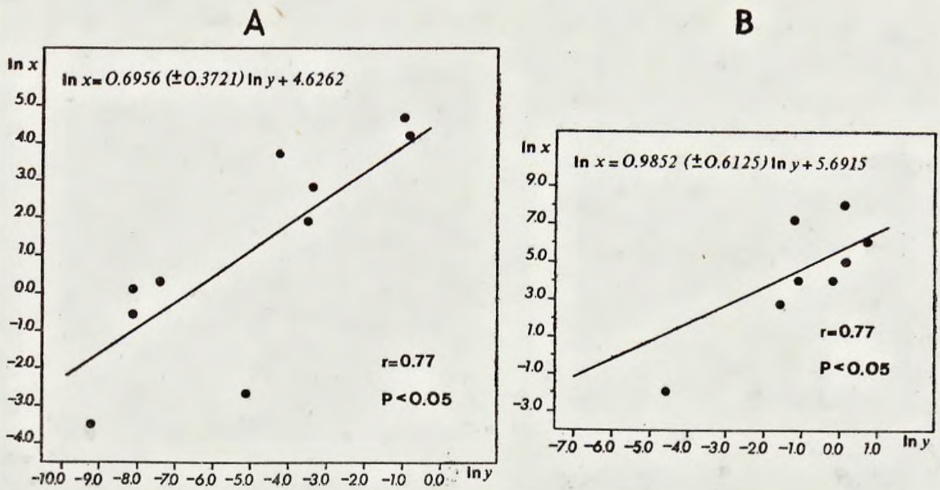


Fig. 3. Regression line of relationship between biomass and intensity of filtration rate for: A — various species of *Unionidae* and *Sphaeriidae* communities in Lake Zbęchy and its outflow canal; B — *Bivalvia* (mainly *Unionidae*) in eutrophic and artificial lakes according to various literature data. x — mean annual wet biomass without shell (g $m^{-2}$); y — index of the intensity filtration rate $F_I = \frac{V_t}{V_o}$

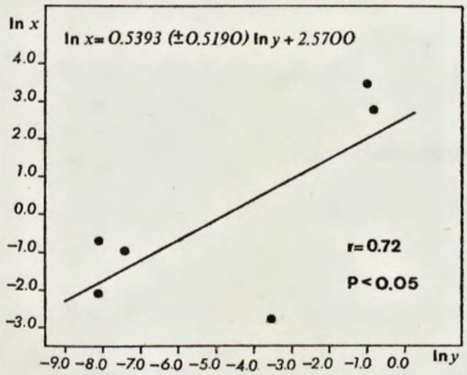


Fig. 4. Regression line of relationship between biomass production and intensity filtration rate for the species of *Unionidae* community in Lake Zbęchy and its outflow canal. x — mean biomass production in the vegetation season (g $m^{-2}$); y — index of intensity filtration rate $F_I = \frac{V_t}{V_o}$

it 11.5 t dry weight of seston of which 9.1 t dry weight is assimilated. At the same time, *Unionidae* living in the canal take from the water only 6.81 kg dry weight of seston of which 5.42 kg dry weight is assimilated (Table IX). The amount of seston assimilated by *Unionidae* in the lake during the vegetation season constitutes 0.44 per cent of the amount

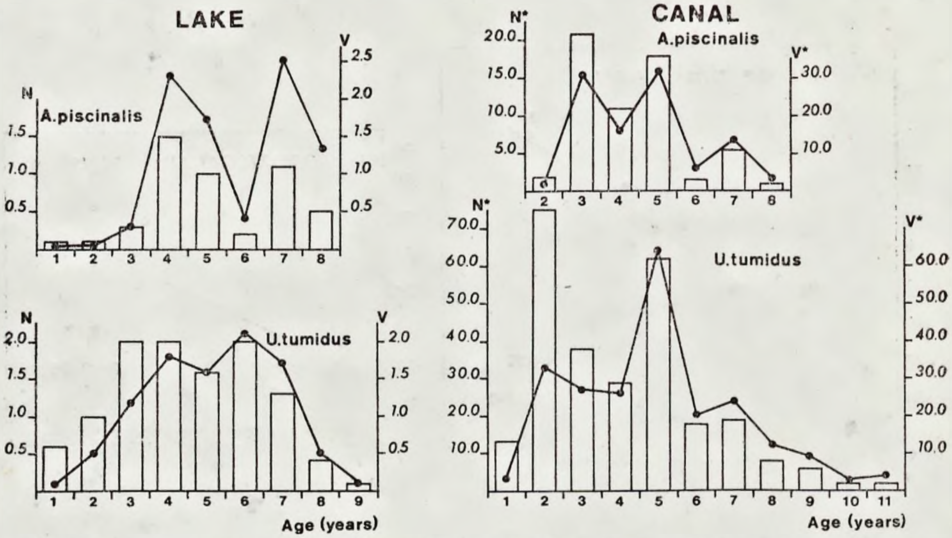


Fig. 5. Comparison of changes of density and volume of filtration of water in the vegetation season by members of various age classes (years) of *Anodonta piscinalis* and *Unio tumidus* in Lake Zbęchy and its outflow canal. N — numbers (N — individuals $m^{-2}$; N* — individuals $10^{-3}$ $m^{-2}$); V — volume of water filtered by bivalves (V — $dm^3$ $10^3$; V* — $dm^3$)

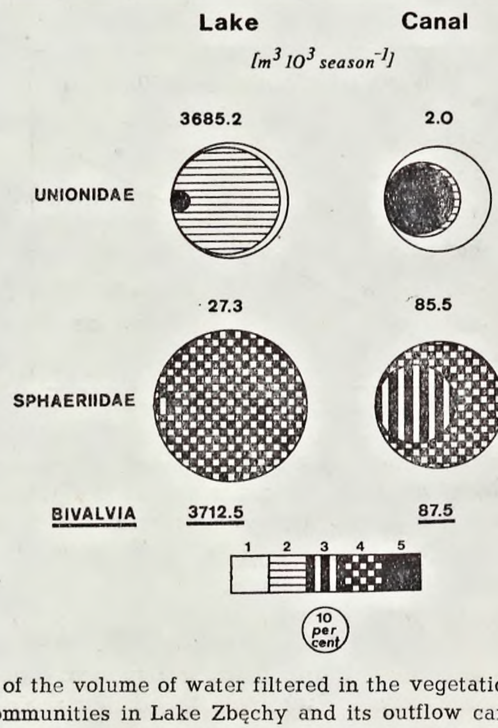


Fig. 6. Comparison of the volume of water filtered in the vegetation season by *Unionidae* and *Sphaeriidae* communities in Lake Zbęchy and its outflow canal. 1 — *Unio tumidus*; 2 — *Anodonta piscinalis*; 3 — *Sphaerium corneum*; 4 — *Pisidium species*; 5 — *Unio pictorum*

Table IX. Comparison of the quantity of filtered seston (in kg dry seston weight) in the vegetation season by 4-, 5-, and 6- year — old individuals of Unionidae and populations of Sphaeriidae in Lake Zbęchy and its outflow canal.
$S_f$ - filtered seston; $S_a$ - assimilated seston;
Fa - faeces

| Eco-system | Taxa | $S_f$ | $S_a$ | Fa |
|---|---|---|---|---|
| Lake | Unionidae: | 11476.6 | 9135.4 | 2341.2 |
| | Anodonta piscinalis | 3402.0 | 2708.0 | 694.0 |
| | Unio tumidus | 8046.0 | 6404.6 | 1641.4 |
| | Unio pictorum | 28.6 | 22.8 | 5.8 |
| | Sphaeriidae: | 12213.3 | 9769.1 | 2442.2 |
| | Sphaerium corneum | 308.2 | 246.6 | 61.6 |
| | Pisidium species | 11903.1 | 9522.5 | 2380.6 |
| Total | Bivalvia | 23689.9 | 18904.5 | 4783.4 |
| Canal | Unionidae: | 6.8 | 5.4 | 1.5 |
| | Anodonta piscinalis | 1.2 | 1.0 | 0.3 |
| | Unio tumidus | 4.8 | 3.8 | 1.0 |
| | Unio pictorum | 0.8 | 0.6 | 0.2 |
| | Sphaeriidae: | 34425.8 | 27540.6 | 6885.1 |
| | Sphaerium corneum | 5546.2 | 4436.9 | 1109.2 |
| | Pisidium species | 28879.6 | 23103.7 | 5775.9 |
| Total | Bivalvia | 34432.6 | 27546.0 | 6886.6 |

suspended in the water. In the canal the amount of seston assimilated by *Unionidae* during the vegetation season is, however $1.6 \cdot 10^3$ times smaller, constituting 0.00066 per cent of that suspended in the water flowing over a $m^2$ of the canal bottom. A comparison with the results concerning *Sphaeriidae* showed that in the lake *Sphaeriidae* altogether filter only 1 per cent of the total lake volume of water (fig. 6), catching from it 12.2 t dry weight of seston. In the same period, however, the population of *Sphaeriidae* occurring in the outflow canal take up 34.4 t dry weight of seston i.e. over $5 \cdot 10^3$ times more than *Unionidae* living in the canal. The amount of seston assimilated by *Sphaeriidae* from the lake during the vegetation season is similar to that of *Unionidae* (0.46 per cent of the seston suspended in the depth of the water). In the canal the amount of seston assimilated by *Sphaeriidae* during the vegetation season is almost three times greater than in the lake and equals 3.4 per cent of the seston suspended in the water flowing over a $m^2$ of the canal bottom.

### 3.5. Participation of *Unionidae* in phosphorus rotation

With regard to the content of phosphorus in the body and shell of *Unionidae* and assuming the mean number 16.1 individuals $m^{-2}$ and biomass 59.8 g $m^{-2}$ (dry weight of body and shell) in the zone of

Table X. Comparison of the quantity of total phosphorus (in g) accumulation in populations of Unionidae and Sphaeriidae on the bottom and (in kg) assimilated by these populations filtrating and feeding on seston in Lake Zbęchy and its outflow canal

| Taxa | Lake | Canal | Lake | Canal |
|---|---|---|---|---|
| | ($g\ P_{total} m^{-2}$) | | ($kg\ P_{total}$) | |
| Unionidae | 0.04 | 0.001 | 36 | 0.02 |
| Sphaeriidae | 0.000004 | 0.002 | 39 | 110.00 |
| Total | 0.040004 | 0.003 | 75 | 110.02 |

occurrence, it was calculated that in these bivalves on a m² of surface there are about 0.04 g P (Table X). Taking it that the bottom surface of the lake inhabited by *Unionidae* is about 19.3 ha, then the total amount of phosphorus accumulated in the population of these bivalves is about 8 kg P. Assuming, however, a greater concentration, e.g., the maximum concentration found of 41.2 individuals $m^{-2}$, i.e. 156 g dry weight $m^{-2}$, the total amount of phosphorus accumulated in the population of *Unionidae* in the lake can reach 18 kg P. In the investigated sector of the canal the amount of phosphorus accumulated in these bivalves is about 5 g P at a concentration of 0.4 individuals $m^{-2}$ (1.34 g dry weight $m^{-2}$) and is 40 times lower on a m² of bottom surface than in the lake (Table X). It results from a similar calculation for the population of *Sphaeriidae*, carried out for comparison, that with a number of 32.8 individuals $m^{-2}$ and biomass 0.004 g dry weight $m^{-2}$ in the lake, about 4 g P is accumulated in these bivalves, whereas in the canal, with a number of 7453.5 individuals $m^{-2}$ and biomass 2.3 g dry weight $m^{-2}$ there is 10 g P. Assuming, however, a greater concentration of *Sphaeriidae*, e.g., 207 individuals $m^{-2}$ (0.008 g dry weight $m^{-2}$), i.e. the maximum number found in the lake, and 11 850 individuals $m^{-2}$ (2.7 g dry weight $m^{-2}$) in the canal the amount of phosphorus accumulated in populations of *Sphaeriidae* can reach in the lake and in the canal about 77 g P and 11 g P respectively. In comparison with populations of *Unionidae* the amount of phosphorus accumulated in populations of *Sphaeriidae* on a m² of bottom area is, on the other hand, in the lake $10^4$ times smaller and in the canal twice as large (Table X). On the basis of results concerning the intensity of water filtration by bivalves and estimations of the amounts of phosphorus taken from the water it may be reckoned that the whole population of *Unionidae* in the lake, at a mean concentration of 16.1 individuals $m^{-2}$, assimilates about 9.1 t dry weight of seston, including 36 kg of phosphorus (Table X) with the assumption that phosphorus constitutes 0.4 per cent of the seston. The amount of phosphorus assimilated through the seston taken up by *Unionidae* in the investigated sector of the canal is on the other hand,

$1.8 \cdot 10^3$ times smaller (Table X). The whole population of *Sphaeriidae* in the lake, with a density twice as high as that of *Unionidae* on a $m^2$ of the bottom surface, assimilates a very similar amount of phosphorus, whereas in the canal *Sphaeriidae*, with a several thousand times greater density than that of *Unionidae*, assimilate over $5 \cdot 10^3$ times more phosphorus (Table X).

## 4. Discussion

The biomass of *Unionidae* in the examined ecosystems is relatively great, being in the lake 1777 kg $ha^{-1}$, and in the canal 30 kg $ha^{-1}$ (live weight without the shell). For example the biomass of *Unionidae* in Lake Mikołajki was 62.6 kg $ha^{-1}$ (84 per cent *Anodonta piscinalis*), whereas production was 22.4 kg $ha^{-1}$ (81 per cent *A. piscinalis*) (Lewandowski, Stańczykowska 1975). In Lake Crapina in the delta of the Danube the biomass of *A. piscinalis* was 161.7 kg $ha^{-1}$ and the annual production of this species 50.9 kg $ha^{-1}$ (Tudorancea, Florescu 1969). The biomass of *Unio tumidus* in that lake was, on the other hand, 116.9 kg $ha^{-1}$ and the annual production of this species 29.9 kg $ha^{-1}$ (Tudorancea, Florescu 1968b). The values of the ratio $P/\bar{B}$ in the examined lake are very similar to those obtained in the investigation of Lake Mikołajki (the mean for all *Unionidae* 0.34) (Lewandowski, Stańczykowska 1975) or Lake Crapina (the mean for *Anodonta piscinalis* 0.32) (Tudorancea, Florescu 1969). The ratio $P/\bar{B}$ for *Unio tumidus* was on average 0.25, being similar to that of *A. piscinalis*, higher for younger individuals (0.71) than for older ones (sexually adult) (0.17) (Tudorancea, Florescu 1968b). In Lake Zbęchy the ratio $P/\bar{B}$ was 0.26 for older (5 to 8 years) individuals of *A. piscinalis* and for younger ones (1 to 4 years) 0.67; for *Unio tumidus* it was 0.18 and 0.63 respectively. Analysing all values of $P/\bar{B}$ it follows that populations of *Unionidae* are as a rule characterized by a very low production per unit of biomass. Investigations carried out so far also indicate that the production per year of the population of moluscs does not exceed 2.4 per cent of the amount of primary production in the given reservoir, usually constituting, however, a tenth or hundredth part of one per cent of primary production (Alimov 1981). In Lake Zbęchy the production of *Unionidae* constitutes 0.43 per cent of the primary production of the phytoplankton of the lake.

In the lake and in the canal *Unionidae* in middle age, i.e. 4- to 6-year--olds, occur most frequently. Since, in consequence of the applied method of collecting material in field conditions, young individuals were relatively rarely found, a greater number of younger age classes than that actually found were adopted for further estimations of production. Data concerning production of *Unionidae* obtained by means of equations describing relations between oxygen consumption and production are overstated. This probably results from, among other factors, the adopted calculation method where mean respiration values were applied. It does not take into account, however, the fairly great variations in respiration of individuals of particular species of *Unionidae*, belonging to various age classes, during the course of the year. A comparison of production (P) and respiration (R) of *Unionidae* in the examined lake and canal, based only on estimations, shows that the energy costs of respiration exceed 11 to 16 times those in the production of body tissue of these bivalves. Similar values of the respiration index R/P for *Uniotumidus* P = 7.0, R = 97.8; in kJ $m^{-2}$ $year^{-1}$) and for *U. pictorum* (P = 7.8, R = 127.2; in kJ $m^{-2}$ $year^{-1}$) were given by Tudorancea and Florescu (1968a, b).

Estimations of the density of biomass and filtration of *Unionidae* and *Sphaeriidae* made in the canal showed that in the event of a decrease in the biomass of *Unionidae, Sphaeriidae* play a decisive role in compensation of the whole biomass of bivalves and filtration intensity; their participation in the total biomass of all benthos invertebrates of the

Table XI. Comparison of the biomass and consumption of various filtrators together with their pressure on the seston in Lake Zbęchy and its outflow canal

| Eco-systems | Groups (species) | Biomass of filtrators | | Seston consumption |
|---|---|---|---|---|
| | | (g $m^{-2}$) | (g $m^{-3}$) | (g $m^{-3}$ 24 $h^{-1}$) |
| Lake | Non-predatory zooplankton: | 8.7439 | 1.9431 | 2.9498 |
| | Planktonic crustaceans | 8.7088 | 1.9535 | 2.9303 |
| | Planktonic rotifers | 0.0351 | 0.0078 | 0.0195 |
| | Unionidae: | 50.9468 | 11.3215 | 0.013704 |
| | Anodonta piscinalis | 34.4160 | 7.6480 | 0.00407 |
| | Unio tumidus | 16.4700 | 3.6600 | 0.0096 |
| | Unio pictorum | 0.0608 | 0.0135 | 0.000034 |
| | Sphaeriidae: | 0.1013 | 0.0225 | 0.0145 |
| | Sphaerium corneum | 0.0301 | 0.0067 | 0.0003 |
| | Pisidium species | 0.0712 | 0.0158 | 0.0142 |
| Canal | Non-predatory zooplankton: | 0.0123 | 0.0816 | 0.1237 |
| | Planktonic crustaceans | 0.0121 | 0.0803 | 0.1204 |
| | Planktonic rotifers | 0.0002 | 0.0013 | 0.0033 |
| | Unionidae: | 0.9973 | 1.9946 | 0.0000592 |
| | Anodonta piscinalis | 0.4960 | 0.9920 | 0.0000014 |
| | Unio tumidus | 0.3750 | 0.7500 | 0.000057 |
| | Unio pictorum | 0.1263 | 0.2526 | 0.0000008 |
| | Sphaeriidae: | 57.8692 | 115.7384 | 79.9659 |
| | Sphaerium corneum | 42.1234 | 84.2468 | 12.8830 |
| | Pisidium species | 15.7458 | 31.4916 | 67.0829 |

Notes:
1) In a lake situation concerning the epilimnion zone (mean depth 4.5 m).
2) For comparison received consumption of whole seston by all filtrators. For valuation of the quantity of consumed seston through zooplankton assuming that food ration for crustaceans is equal 150 per cent and for rotifers 250 per cent of consumers biomass

canal is also high (K a s p r z a k, unpublished results). The volume of water filtered by *Sphaeriidae* in the canal during the investigation period was 50 times higher (Table VIII) than that filtered by *Unionidae*, and the amount of seston caught was almost $5 \cdot 10^3$ times higher (Table IX). In comparison with associations of non-predatory zooplankton, the amount of seston caught by *Unionidae* was in the lake $2 \cdot 10^2$ and in the canal $2 \cdot 10^3$ times lower than that consumed by the zooplankton, though the biomass of *Unionidae* was in these two ecosystems much higher (Table XI). Compared with the non-predatory zooplankton, *Sphaeriidae* in the lake consumed also about $2 \cdot 10^2$ times less seston, whereas in the canal the amount of seston consumed by *Sphaeriidae* was more than $6 \cdot 10^2$ times greater than that by non-predatory zooplankton (Table XI). However, it should be stressed that in comparison with non-predatory zooplankton *Unionidae* catch from the water also large fractions of seston (including phytoplankton) over 30 µm in size, which are not used up by zooplankton, whose quantity in the water of a eutrophic lake constitutes about 70 per cent of all seston particles suspended in the water (H i l l b r i c h t - I l k o w s k a 1977). Because of the various size structure of phytoplankton, non-predatory zooplankton and bacterioplankton as well as other heterotrophs (among others *Unionidae*) are alternative consumers of the biomass produced by phytoplankton.

Quantitative calculations of phosphorus accumulated in populations of *Unionidae* and *Sphaeriidae* in the lake and canal showed that phosphorus is accumulated in these bivalves in amounts of the order of a few to 10 or more kg P. An analogous calculation made by S t a ń - c z y k o w s k a (1983) for the population of *Unionidae* in Lake Mikołajki showed that the maximum amount of phosphorus accumulated in these bivalves may reach even 55 kg P (on the average 3 kg P). A comparison of the above results with those given by K a j a k (1978) concerning phosphorus content in the main constituents of the ecosystem of Lake Mikołajki showed that these amounts are much smaller than those contained in, e.g., macrophytes (700 kg P, 1.3 per cent) or fish (800 kg P, 1.5 per cent) in this lake. *Unionidae*, however, accumulate phosphorus in such quantities that they should not be neglected in estimations of the general balance of phosphorus circulation in aquatic ecosystems. In comparison with other bivalves the role of *Unionidae* in phosphorus accumulation is, however, smaller than e.g., that of *Dreissena polymorpha* (S t a ń c z y k o w s k a 1983). The part played by *Unionidae* and *Sphaeriidae* in the process of phosphorus circulation in the investigated lake and effluent canal is not confined, however, to the accumulation of this element in the body and shell. Their importance, as has already been mentioned, consists mainly in their filtration activity. Phosphorus accumulated by *Unionidae* and *Sphaeriidae* in filtration processes constitutes in the lake 0.90 per cent (*Unionidae* 0.43 per cent) of phosphorus contained in the seston (8.3 t. P) suspended in the total volume of the water in the lake, assuming, however, that phosphorus constitutes 0.4 per cent of dry weight of seston (Stańczykowska 1983). On the other hand, phosphorus accumulated by these bivalves in the canal constitutes 3.4 per cent of that contained in the seston (3.3 t P) passing during the vegetation season over 1 $m^2$ of the bottom surface.

## 5. Polish summary


**Występowanie i rola małży z rodziny *Unionidae* (*Mollusca, Bivalvia*) w śródpolnym eutroficznym jeziorze Zbęchy (Nizina Wielkopolsko-Kujawska) i kanale odpływowym**

Materiał zbierano w eutroficznym polimiktycznym jeziorze i kanale odpływowym na terenach o intensywnej gospodarce rolnej. Średnie zagęszczenie *Unionidae* na przeciętny $m^2$ dna jeziora jest siedmiokrotnie wyższe niż w kanale (tabele III, IV; ryc. 1). W jeziorze i kanale przeważają osobniki 4—6-letnie (ryc. 2A). Biomasa jest stosunkowo wysoka i wynosi w jeziorze 1777 kg $ha^{-1}$, a w kanale 30 kg $ha^{-1}$ (biomasa mokra bez muszli). Produkcja biomasy oceniona metodą Grezego (tabela V) w sezonie wegetacyjnym wszystkich *Unionidae* w jeziorze wynosi 638 kg $ha^{-1}$ (*A. piscinalis* 71%), a w kanale 11,5 kg $ha^{-1}$ (*A. piscinalis* 51%). Dane dotyczące wielkości produkcji uzyskane przy zastosowaniu równań określających zależności występujące między respiracją i produkcją uznano za zawyżone (tabela VI). Respiracja *Unionidae* w jeziorze jest 40 razy większa niż w kanale (ryc. 2B). Respiracja *Sphaeriidae* w jeziorze jest kilkanaście razy mniejsza od respiracji *Unionidae* w tym samym okresie, natomiast w kanale respiracja *Sphaeriidae* jest $3{,}6 \cdot 10^3$ razy większa od respiracji *Unionidae*. Analizując intensywność filtracji wody przez małże (tabela VII), będącą m. in. oceną stopnia destrukcji sestonu, wykazano występowanie wyraźnych zależności między intensywnością filtracji i biomasą (tabela VIII; ryc. 3) oraz między intensywnością filtracji i wielkości produkcji (ryc. 4). W ciągu sezonu wegetacyjnego wszystkie osobniki *Unionidae* i *Sphaeriidae* w jeziorze filtrują wodę w ilości równej 80% objętości jeziora (ryc. 5). Wszystkie *Unionidae* filtrujące w ciągu sezonu wegetacyjnego wodę o objętości równej 79% objętości jeziora (ryc. 6) wychwytują jednocześnie z wody 11,5 t sm. sestonu, asymilując 9,1 t sm. W takim samym okresie w kanale *Unionidae* wychwytują z wody tylko 6,8 kg sestonu, asymilując 5,4 kg sm. (tabela IX). W jeziorze wszystkie *Sphaeriidae*, filtrując wodę w ilości tylko 1% całkowitej objętości jeziora (ryc. 6), wychwytują 12,2 t sm. sestonu, natomiast w takim samym okresie *Sphaeriidae* żyjące w kanale wychwytują 34,4 t sm. sestonu. Ilość sestonu zasymilowana przez *Sphaeriidae* w jeziorze jest podobna jak w przypadku *Unionidae* (0,46% ilości sestonu zawieszonego w toni wodnej), natomiast w kanale wynosi ona 3,4% ilości sestonu. Objętość filtrowanej przez *Sphaeriidae* wody w kanale w sezonie wegetacyjnym jest w porównaniu z *Unionidae* 50 razy większa (tabela VIII), a ilość odfiltrowanego sestonu $5 \cdot 10^3$ razy większa (tabela IX). W porównaniu ze zgrupowaniami zooplanktonu niedrapieżnego ilość konsumowanego sestonu przez *Unionidae* jest w jeziorze ponad $2 \cdot 10^2$, a w kanale $2 \cdot 10^3$ razy mniejsza od ilości sestonu konsumowanego przez zooplankton. Także w jeziorze *Sphaeriidae* konsumują w porównaniu z zooplanktonem niedrapieżnym około $2 \cdot 10^2$ razy mniej sestonu, natomiast w kanale ilość konsumowanego przez

*Sphaeriidae* sestonu jest w porównaniu z zooplanktonem ponad $6 \cdot 10^2$ razy większa (tabela XI). W jeziorze całkowita ilość fosforu zgromadzona w populacjach *Unionidae* wynosi średnio około 8 kg P, natomiast w kanale tylko około 5 g P. Ilość fosforu skumulowana w *Unionidae* w kanale jest w porównaniu z jeziorem 40 razy mniejsza na $m^2$ powierzchni dna (tabela X). W porównaniu z populacjami *Unionidae* ilości fosforu skumulowane w populacjach *Sphaeriidae* na $m^2$ powierzchni dna są natomiast w jeziorze $10^4$ razy mniejsze, a w kanale dwukrotnie większe (tabela X). Wszystkie *Unionidae* w jeziorze asymilują poprzez seston około 36 kg P, a w kanale 0,02 kg P (tabela X).

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