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Changes in the bivalve groups (Bivalvia - Unionidae) in the Goczałkowice Reservoir (southern Poland) in the period 1983-1992

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A b s t r a c t - The greatest development of bivalves in the Goczałkowice Reservoir occurred at the turn of the 1960s. In 1983 and 1992 detailed investigations of the exposed bottom of the reservoir were conducted. In 1983, in the north-eastern zone of the reservoir 2.23 individuals with a biomass of 26.9 per 1 m^2 were recorded, while in the south-eastern zone there were 0.77 individuals with a biomass of 20.2 g per m^2 . In 1992, in the north-eastern zone of the reservoir there were 1.68 individuals with a biomass of 37.6 g per m^2. The population of bivalves, when compared with that in the year 1983, had diminished there by about 30%.

K e y w o r d s: dam reservoirs, bivalves communities, population, biomass, domination.

1. Introduction

Bivalves play an important role in water bodies, especially in dam reservoirs which are utilized for drinking water. It is for this reason that investigations of such reservoirs are important.

The Goczałkowice Reservoir is inhabited by numerous communities of bivalves (Bivalvia) from the family Unionidae, comprising *Unio tumidus* P h i l., *U. pictorum* L., *Anodonta piscinalis* N i l s s, and *A. cygnea* L. These animals are nature's greatest filtrator organisms. The amount of water they filter is very high, amounting on the average to 0.5 dm^3 per hour.

The population of bivalves in the Goczałkowice Reservoir was greatest at the end of the 1960s and the beginning of the 1970s (K r z y ż a n e k 1986, 1991). In 1972 detailed investigations were carried out which showed that the entire surface of the bottom was inhabited by 106 million bivalves with a biomass of more than 5000 tons (K r z y ż a n e k 1976). This tremendous mass of animals was capable of filtering all the water of the reservoir 2-3 times a year. Bivalves accumulate in their bodies great amounts of nutrients (nitrogen and phosphorus). It has been calculated that during the period of their maximum development these bivalves accumulated about 5 tons of phosphorus, i.e. 2 tons in the mass of their bodies and 3 tons in their shells (K r z y ż a n e k 1989).

During monitoring investigations of bottom macrofauna in the period 1983-1992 a diminution of the population and of the biomass of bivalves as well as changes in the structure of domination were observed.

The aim of the present study was to carry out a more detailed examination of bivalves, taking advantage of the fall in the water level in this period and the exposure of considerable areas of the bottom in the Goczałkowice Reservoir.

2. Study area, material and methods

The Goczałkowice Reservoir is situated on the River Vistula, 67 km from the river sources, in flat territory (average longitudinal gradient is 0.5 - 0.8‰, the transverse gradient is 1-4‰), its area is 32 km^2, length 12 km, width 5 km, capacity 165 mln m^3 (at the maximum water level). In type it is a shallow flooded, limnic reservoir (maximum depth is 13 m, mean depth 5 m) whose water is exchanged 2-3 times a year (K r z y ż a n e k 1986).

Throughout the period from January to April 1983 the water level was high, and the damming ordinate exceeded 255.00 m above sea level. In March it was 255.59 m above sea level. In the following period a continuous fall of the water level was observed, the ordinate at the beginning of August amounting to 254.76 m, towards the end of September it was 253.66 m, and in November it fell to 252.32 m above sea level. Taking advantage of the fact that a large area of the bottom had become exposed (by the end of September 8 km^2 and by the end of the year a further 8 km^2), detailed investigations of bivalves were conducted at two stations from 26th-28th September 1983 (fig. 1).

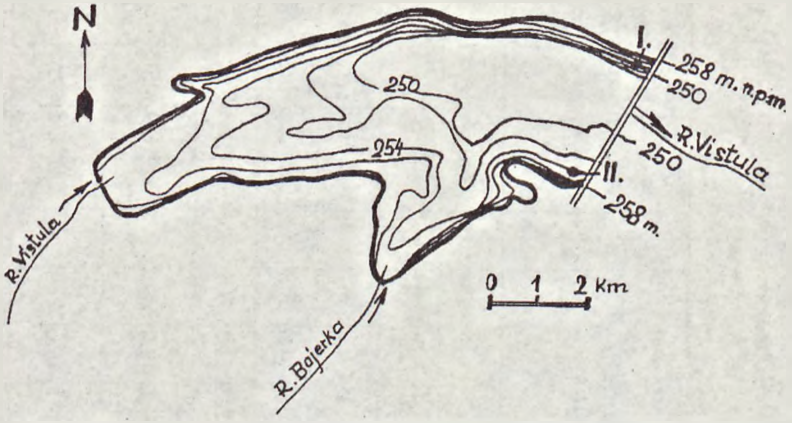

Fig. 1. Goczałkowice reservoir. The distribution of sampling stations (I, II)

In the north-eastern zone of the reservoir (Station I) which, according to the accepted data from 1972 (K r z y ż a n e k 1976), occupies 5% of the reservoir bottom, there emerged an area measuring 0.2 km^2. In the south-eastern zone (Station II) comprising 12% of the bottom there emerged 0.5 km^2.

From an area of exposed bottom measuring 100 m^2, which was just below the water surface, all the bivalves were collected. Their species composition, numbers, biomass (with and without the shell), age structure, as well as length, width, and thickness of the particular individuals were determined.

In 1992, in the period from April to October a constant fall in the water level was observed. The lowest water level was recorded on 17 October (252.05 m above sea level). Thereafter the level gradually rose. The difference between the level in April and that in October was 3.25 m. It follows that in that period 15 km^2 of the bottom became exposed.

In the north-eastern part of the reservoir, where the investigations were carried out (fig. 1), the area of the exposed bottom measured 0.75 km^2. At the same time, there occurred repeated water blooms caused by blue-green algae.

3. Results

3.1. Bivalve groups in 1983

At Station I (Table I) on 100 m^2 there were 223 bivalves with a biomass of 2696 g with, and 1410 g without shells. In the entire zone 446 thousand individuals were found with a biomass of 5.38 tons. *Unio tumidus* was dominant, mainly 4-year-old individuals.

Table I. Species composition, numbers, biomass, age structure, and parameters of size of bivalves (mean values) taken from 100 m^2 at Station I in 1983

Species / Parameter	*Unio tumidus*						Total indiv.	*Unio pictorum*			Total indiv.	*Anodonta piscinalis*						Total indiv.	*Anodonta cygnea*			Total indiv.
Age (years)	2	3	4	5	6	7		2	4	8		2	3	4	5	6	7		2	3	7	
Numbers (indiv.)	12	26	53	23	11	1	126	1	4	2	7	1	15	22	27	12	1	78	2	9	1	12
Lenght (cm)	2.1	3.0	4.3	5.2	6.1	6.2		1.6	5.5	7.5		2.5	4.3	6.0	6.6	8.0	8.7		4.3	4.9	7.1	
Width (cm)	1.1	1.7	2.4	2.7	3.0	3.1		0.7	2.8	3.2		1.8	2.8	3.9	4.3	4.9	5.3		2.4	2.8	4.0	
Thickness (cm)	0.7	1.0	1.6	1.8	2.0	2.1		0.5	1.9	2.3		0.6	1.4	2.0	2.2	2.8	3.3		1.2	1.3	2.4	
Mean biomass with shell (g)	0.8	3.4	8.7	11.8	19.2	19.2		0.4	10.8	26.7		1.3	6.9	16.0	26.1	40.3	57.2		5.5	6.9	45.5	
Mean biomass without shell (g)	0.4	1.6	4.3	5.4	7.2	7.2		0.2	4.3	9.8		0.8	3.8	8.4	13.1	19.6	28.6		2.2	2.8	26.2	

Table II. Species composition, numbers, biomass, age structure, and parameters of size of bivalves (mean values) taken from 100 m^2 at Station II in 1983

Species / Parameter	*Unio tumidus*				Total indiv.	*Anodonta piscinalis*						Total indiv.	*Anodonta cygnea*					Total indiv.
Age (years)	2	4	5	6		3	4	5	6	7	8		4	5	6	7	8	
Numbers (indiv.)	1	8	1	5	15	7	16	15	7	3	1	49	1	1	1	9	1	13
Lenght (cm)	1.9	4.2	5.1	6.2		4.4	5.5	7.4	8.5	8.4	9.0		7.2	7.1	7.0	7.6	8.6	
Width (cm)	1.0	2.2	2.6	3.3		2.7	4.0	4.0	5.1	5.3	5.5		4.6	4.5	4.6	4.2	5.0	
Thickness (cm)	0.7	1.5	1.8	2.1		1.5	1.8	2.3	2.9	3.1	3.3		2.4	2.3	2.4	2.1	2.1	
Mean biomass with shell (g)	0.8	5.3	11.2	18.6		7.6	15.2	27.2	42.8	52.8	59.2		36.2	32.2	38.8	54.2	59.2	
Mean biomass without shell (g)	0.4	2.6	5.1	7.4		4.2	8.3	13.6	21.4	26.4	29.5		13.1	12.6	13.6	18.2	19.1	

At Station II (Table II), on 100 m^2, the occurrence of 77 individuals, with a biomass of 2019 g with shells, and 910 g without was recorded. *Anodonta piscinalis* was the dominant species, mainly 4-5-year-old individuals.

3.2. Bivalve groups in 1992

Investigations carried out on 29 July revealed that only 20-40% of bivalves took refuge in the water. These animals showed little mobility, didnot make their characteristic circular movements, and their shells were slightly opened. This was associated with the water blooms caused by the blue-green algae (*Aphanizomenon flos aquae*). The investigations conducted on 18 October did not reveal such behaviour of these animals.

On 29 July (Table III) the occurrence of 163 bivalves with a biomass of 2552 g (including shells) was recorded on a 100 m^2 area. Thus, in the entire exposed zone there were 1 275 000 individuals with a total biomass of 28.2 tons. The dominant species were *Unio tumidus, Anodonta piscinalis*; in the case of the first species 6-year-old individuals prevailed, while in that of the second species most individuals were 7 years old. The percentage of bivalves aged 2-3 years was also high.

Investigations carried out on 18 October (Table III) revealed similar numbers (173 individuals per 100 m^2), but with a slightly greater biomass (4969 g including shells). *Unio tumidus* and *Anodonta piscinalis* occurred in the same numbers, but the biomass values of *A. piscinalis* were higher. This increased biomass was due to a greater number of older individuals. This mainly concerned *A. piscinalis* in which 8-year-old individuals prevailed. In comparison with 1983, a decrease in the bivalve population and an increase in their biomass (increased number of older individuals) were observed. The dominance of *Unio tumidus* and of *Anodonta piscinalis* remained on a similar level.

3.3. Changes in the bivalve groups during the whole period of the reservoir's existence

The Goczałkowice Reservoir came into being 1955 and the investigations on the bottom macrofauna, including bivalves, were begun in the same year. The first bivalves already appeared in the following year, i.e. 1956. They were small species from the genus *Pisidium* (Sphaeridae). Their population constantly increased, reaching in 1958, on average 66 individuals m^{-2}. Higher density was observed in the central zone, where *Pisidium amnicum* M ü l. and *P. casertanum* P o l i. dominated.

Table III. Species composition, numbers, biomass, age structure, and parameters of size of bivalves (mean values) taken from 100 m^2 at Station I on 29 July, 1992 and 18 October, 1992

Species / Parameter	*Unio tumidus*						*Unio pictorum*				*Anodonta piscinalis*							*Anodonta cygnea*	
	29 July																		
Age (years)	2	3	4	6	7	8	4	5	6	8	2	3	5	6	7	8	9	4	8
Numbers (indiv.)	16	22	15	25	4	1	2	4	3	3	11	6	7	12	16	9	4	1	2
Biomass (g)	12.8	74.8	130.5	480.0	68.8	20.2	18.6	49.2	48.9	80.4	14.3	39.0	182.7	483.6	915.2	514.8	249.6	32.6	120.0
Mean lenght (cm)	2.2	3.1	4.4	6.1	6.5	7.0	5.5	5.9	6.2	7.6	2.4	4.2	7.1	8.1	8.7	8.9	9.1	7.0	8.1
Mean mass (g)	0.8	3.4	8.7	19.2	17.2	20.2	9.3	12.3	16.3	26.8	1.3	6.5	26.1	40.3	57.2	59.1	62.4	32.6	60.2
Total numbers	83						12				65							3	
Total biomass	787.1						197.1				2399.2							153.0	
	18 October																		
Age (years)	3	4	6	7	8		5	6	8		4	5	6	7	8	9		5	
Numbers (indiv.)	23	26	15	4	10		6	4	9		12	2	16	6	20	18		2	
Biomass (g)	78.2	226.2	288.0	192.0	205.2		64.8	65.2	240.4		192.0	52.2	644.8	343.2	1184	1123		70.4	
Mean lenght (cm)	3.2	4.6	6.0	6.4	6.9		6.0	6.2	7.4		5.8	6.9	7.9	8.5	8.9	9.1		7.2	
Mean mass (g)	3.4	8.7	19.2	48.0	20.5		10.8	16.3	26.7		16.0	26.1	40.3	57.2	59.2	62.4		35.2	
Total numbers	78						19				74							2	
Total biomass	989.6						370.4				3539.4							70.1	

In 1958 the first representative of the family Unionidae (*Anodonta cygnea* L.) was caught. Since that time this species has been encountered more and more frequently, and its maximum population was recorded in the period 1966-1973.

Starting from 1970, the share of *Unio pictorum* L. in the bivalve communities gradually increased. Its first appearance had been observed in the year 1962.

In the period 1972-1982 a constant decrease in the population and in the biomass of bivalves was observed. While in 1972 their mean annual population was 53 indiv. m^{-2} and the biomass was 100 g m^{-2}, in 1976 these values were 16 indiv. m^{-2} and 120 g m^{-2} and in 1982 10 indiv. m^{-2} and 120 g m^{-2}. The dominant species also changed. After *Anodonta cygnea* (1964-1973) dominance was taken over by *Unio pictorum* (1974-1982).

Still taking as basis the results obtained in the investigations of the entire bottom macrofauna (by means of a bottom grab and scrapers) in the period 1983-1992, a decrease (except from 1989-1990) in the population of bivalves (Table IV) and a successive change in dominance were observed. On the basis of these results it was found that at present *Unio tumidus* and *Anodonta piscinalis* are the dominants in the reservoir, with a slightly greater share of the former.

4. Discussion

Investigations of the bottom macrofauna in the Goczałkowice Reservoir also took bivalves into consideration. When applying the same investigation methods (scrapers, bottom grabs) one cannot in the case of bivalve groups accept the findings as fully reliable. It is for this reason that advantage was taken of the periodical falls in the water level and exposure of large areas of the bottom in 1965, 1972, 1983, and 1992 to carry out detailed investigations of these animals (K r z y ż a n e k 1966, 1976). Taking as basis the results of all the investigations conducted so far, it was possible to trace the development of the bivalves, i.e. the qualitative and quantitative changes occurring in the groups as well as the succession of their species composition throughout the existence of the reservoir.

The greatest development of the bivalve family Unionidae was observed at the turn of the 1960s. In 1972, on the whole exposed area of the reservoir bottom (800 ha) the occurrence of 18 million bivalves with a biomass of 1114 tons was recorded, which when calculated per 1 m^2 gives 4 individuals with a biomass of 240 g.

Table IV. Changes in mean numbers (indiv. m^{-2}) of bivalves in the period 1970-1992

Year	Bivalvia	Sphaeridae	Unionidae	*Anodonta cygnea*	*Anodonta piscinalis*	*Unio pictorum*	*Unio tumidus*
1970	20	2	18	4	–	13	1
1971	36	16	20	5	1	13	1
1972	53	30	23	8	1	13	1
1973	17	2	15	5	1	8	1
1974	31	10	21	8	1	11	1
1975	22	3	19	4	1	13	1
1976	16	6	10	3	1	5	1
1977	19	6	13	3	3	6	1
1978	27	9	18	5	1	11	1
1979	19	4	15	4	1	9	1
1980	46	29	17	5	1	10	1
1981	31	17	14	3	1	9	1
1982	9	1	8	3	1	3	1
1983	17	4	13	3	3	1	6
1984	13	3	10	1	4	1	4
1985	8	2	6	2	0.5	0.5	3
1986	6	1	5	1	2	1	1
1987	10	2	8	1	3	1	3
1988	5	–	5	0.5	2	0.5	2
1989	23	2	21	2	9	1	9
1990	22	1	21	0.5	0.5	4	16
1991	9	–	9	–	–	–	9
1992	3	–	3	–	2	–	1

In the entire reservoir (investigations applying diving) 106 million individuals with a biomass of 5038 tons were obtained (Krzyżanek 1976).

In 1983, at Station I (in the north-eastern zone of the reservoir), there occurred on the average 2.23 individuals with a biomass of 26.9 g per 1 m^2, and their numbers being 10% higher than those in 1972.

At Station II (north-western zone - fig. 1) there occurred 0.77 individuals with a biomass of 20.2 g. When compared with 1972 the numbers of bivalves were 70% smaller.

In 1992 the population of bivalves was investigated only in the north-eastern zone. In July of that year their mean number per 1 m^2 was 1.6 indiv. with a biomass of 25.5 g, while in October there were 1.73 indiv. with a biomass of 49.7 g. When comparing the results obtained in 1983 and 1992 with those obtained for analogous zones in 1972, it was found that the number of bivalves had decreased on the average by 30%.

In water bodies these animals are exposed to various dangers. Too great numbers of predatory animals, such as crayfish are a threat to bivalves. Great numbers of bivalves often lead to an intensive invasion of sporocysts and cercaria, as these animals also play the role of indirect host to trematodes which cause serious disease in fish (C a s t a g n o l o et al. 1972). Too frequent changes in the water level, resulting in many bivalves being left on the exposed bottom and dying, are also dangerous. However, the greatest threat to these animals are sudden changes in the environmental conditions.

In the mid 1980s the amounts of nitrogen and phosphorus in the reservoir water increased, causing excessive development of algae, especially the blue-green ones. In 1992 there occurred repeated water blooms caused by the blue-green algae (*Gomphosphaeria naegeliana* and *Aphanizomenon flos-aquae*). Investigations carried out on 29 July showed that, besides the fall in the water level, the water blooms occurring there caused the death of about 60% of bivalves.

5. Polish summary

Zmiany w zgrupowaniach małży (Bivalva - Unionidae) w zbiorniku Goczałkowickim (Polska południowa) w latach 1983-1992

W latach 1983 i 1992 przeprowadzono szczgółowe badania małży na fragmencie wynurzonego dna zbiornika. W 1983 roku na dwóch stanowiskach (fig. 1 - stanowiska I i II), w 1992 na jednym stanowisku (I) dwukrotnie, w lipcu i październiku.

W 1983 roku na stanowisku I gdzie dominował *Unio tumidus* na $1m^2$ występowało średnio 2,23 okazy o biomasie 26,9 g (cały organizm z muszlą) na stanowisku II (dominacja *Anadonta piscinalis*), odpowiednio 0,77 i 20,2 (tabela I i II). W lipcu 1992 roku średnia liczebność na $1m^2$, wynosiła 1,6 osobn., a biomasa 25,5 g,

w październiku 1,73, biomasa 49,7 g. *Unio tumidus* i *Anodonta piscinalis* występowały w podobnych liczebnościach (tabela III). Porównując otrzymane wyniki z lat 1983 i 1992 z wynikami uzyskanymi z tych samych stref w 1972 roku stwierdzono średnio o 30% mniej małży. Obniżenie się liczebności małży potwierdzają wyniki badań monitoringowych całej makrofauny dennej w tym także zgrupowań małży (tabela IV).

6. References

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