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Formation of bottom macrofauna in the Goczałkowice Reservoir (southern Poland) against the background of changing selected physico-chemical properties of the water

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Abstract – A tendency to an increase in electrolytes and nutrients (mineral nitrogen and total phosphorus) was found. The bottom macrofauna was not affected by human activity in the period from 1955 to 1982, when the degree of eutrophication was small. From 1983 the effect of human activity was revealed in both qualitative and quantitative changes in the composition of the macrofauna.

Key words: dam reservoirs, bottom macrofauna, ionic composition, nutrients

Formowanie się makrofauny dennej w Zbiorniku Goczałkowickim (południowa Polska) na tle zmieniających się wybranych fizyko-chemicznych właściwości jego wody. Stwierdzono tendencję wzrostu ilości elektrolitów i nutrientów (azotu mineralnego i fosforu ogólnego). Makrofauna denna w okresie od 1955 do 1982, kiedy stopień zeutrofizowania wody zbiornika był niewielki, nie podlegała wpływom antropopresji. Od 1983 roku wpływ ten uwidocznił się poprzez zmiany w jej składzie zarówno jakościowym jak i ilościowym.

1. Introduction

The regulation of rivers and building of dam reservoirs led to the necessity of carrying out hydrobiological investigations in them. There are 123 dam reservoirs in Poland (Głodek 1985), in some of which hydrobiological investigations, including those of bottom macrofauna, have been carried out (Giziński and Wolnomiejski 1966, 1982, Giziński and Paliwoda 1972, Grzybowska 1958, 1965, Kownacki 1963, Krzyżanek 1970, 1986, 1991, 1994, Paluch et al. 1975, Kajak 1990).

The present work comprises a synthetic description of the results of bottom macrofauna investigations carried out in the years 1955–1992 in the Goczałkowice Reservoir, against the background of certain physico-chemical properties of its water. Reports on the investigations have already been partly published (Kasza and Winohradnik 1986, Kasza 1992, Krzyżanek 1970, 1986, 1991, 1994, Kysela 1957, 1958, Zaćwilichowska 1965a, 1965b, 1965c). The aim of the work was to determine the interdependency between the changes in the selected physico-chemical parameters of the water and the forming of communities of bottom macrofauna.

2. Study area, material and methods

The Goczałkowice Reservoir (49°36' N, 18°56' E) was built in the period 1950–1955 as a barrage across the River Vistula at the 67th kilometre of its course. The reservoir is not deep (mean depth 5.2 m, large shallow areas), changing its water 2–3 times a year. At the maximum water level it can cover an area of 32 km^2 with a volume of 168 10^6 m^3. Its maximum length is 12 km, and width 5 km. The reservoir mainly serves for water supply.

Monitoring investigations of the bottom macrofauna and some physico-chemical parameters of the water have been carried out in the reservoir from the beginning of its existence, i.e. from 1955. Samples were taken and analysed by the same methods throughout. A precise description of them is presented in a general monography (Krzyżanek and Kownacki 1986). The results are presented as annual mean values.

3. Results

3.1. Changes in physico-chemical properties of the water

Data collected over the years concerning the ionic composition of the reservoir water showed a tendency to a gradual increase in abundance of macroelements and changes in the relative proportions of their occurrence (fig. 1a). Details are given in the work by Kasza (1992).

The dry residue and total fixed residue (indicators of the total content of substances in the water) also showed a rising trend (fig. 1b). The difference in value between the two indicators constitutes the loss after ignition, at the same time determining the approximate content of organic compounds and the degree of their pollution of the water. As the reservoir aged there was a tendency to a gradual and regular rise in such pollution of the water.

The concentration of biogenic compounds, i.e. mineral nitrogen (the sum of $N\text{-}NO_3$, $N\text{-}NH_4$, and $N\text{-}NO_2$) (fig. 1c) and total phosphorus (fig. 1d) also rose. The mean annual concentration of mineral nitrogen showed a tendency to increase clearly visible until the beginning of the eighties. In the following years the concentration of mineral forms of nitrogen did not in general evidence any increase and remained at a high level, leading to fertility of the water. The mean annual concentration of total phosphorus, studied from 1973, showed a rising trend with a rapid increase in total phosphorus concentration. The amount of total phosphorus, determined by the mean annual concentration between 1973 and 1992, i.e. over 20 years, increased 2.5 times.

The water transparency, measured by visibility of a Secchi disc, at the same time being an additional indicator of phytoplankton growth, shows a progressive rise in two trophic level of the reservoir water. The mean annual value of water transparency ranged from 1.1–1.3 m in the years 1956–1961, then rising to 1.5–2.0 m and from the beginning of the eighties varying from 1.0 to 1.4 m, and falling to 0.8–0.9 m in the nineties (fig. 1e).

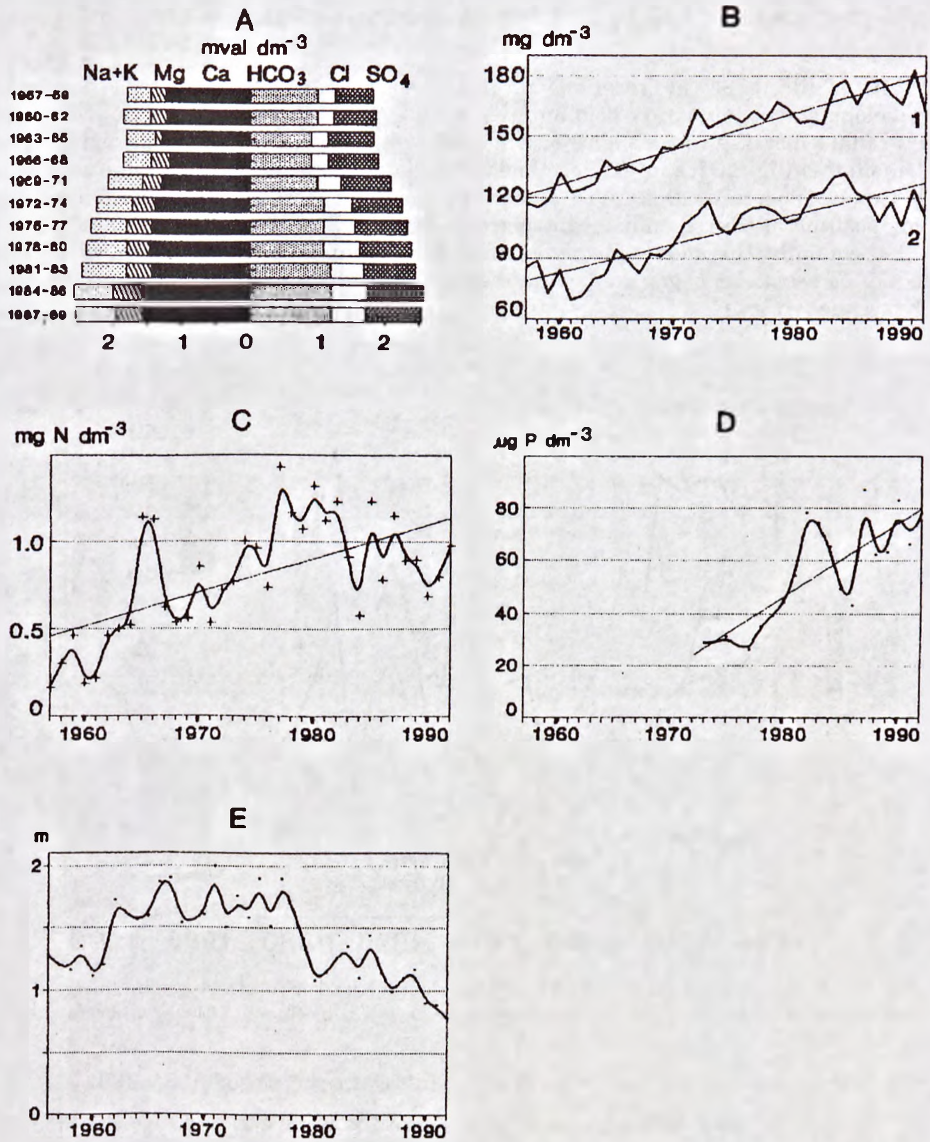

Fig. 1. Mean values of selected physico-chemical parameters of the Goczałkowice reservoir water and calculated trends of their changes: A — ionic composition, B — residue (1 — dry residue, 2 — total fixed residue), C — mineral nitrogen, D — total phosphorus, E — water transparency.

3.2. The process of formation of bottom macrofaunal communities in the period 1955–1982.

After filling of the reservoir in the period 1955–1963 there took place the development of temporary communities with a mass growth of Chironomidae and a gradual increase in the share of Oligochaeta and Bivalvia (first Sphaeridae, then Unionidae) (fig. 2, 3 and 4). Permanent communities were formed in the reservoir between 1964 and 1982. A characteristic feature was the stabilization in the composition of Chironomidae (the share of *Procladius* sp. amounted to 60%; fig. 3). Of the family Unionidae (Bivalvia) after the domination of *Anodonta cygnea* (L.) *Unio pictorum* (L.) began to dominate (fig. 4). The details are given in the work by Krzyżanek (1986).

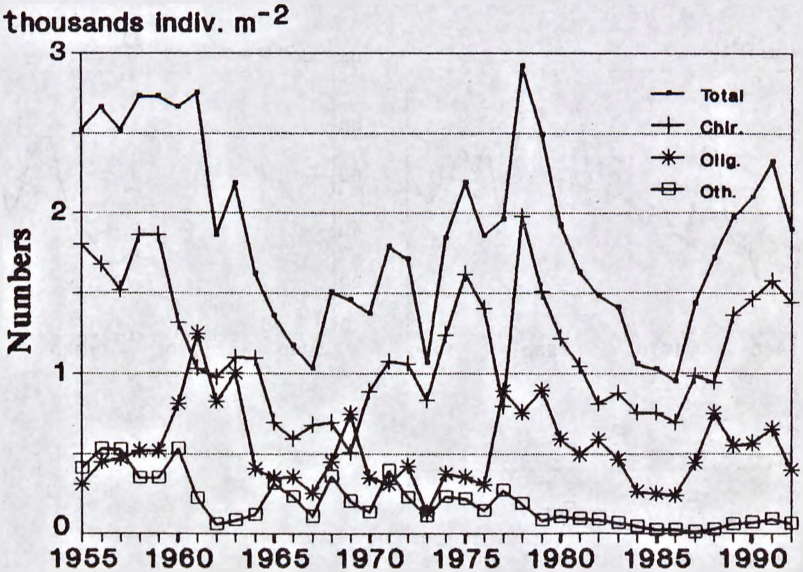

Fig. 2. Course of changes in annual mean values of bottom macrofauna numbers in the Goczałkowice Reservoir: Chir. — Chironomidae, Olig. — Oligochaeta, Oth. — others.

3.3. Changes in bottom macrofauna communities in the period 1983–1992

From 1981 until 1986 a gradual decrease in the numbers, and also the biomass of bottom macrofauna was observed. While in the period 1976–1980 the average number (for the whole five-year-period) amounted to 1681 ind. m^{-2}, and the biomass to 7.8 g m^{-2}, in the subsequent six years they were in 1981 — 1601 and 6.3; in 1982 — 1461 and 5.9; in 1983 — 1412 and 6.9; in 1984 — 1063 and 3.7; in 1985 — 1029 and 4.3; in 1986 — 952 ind. m^{-2} and 4.0 g m^{-2} respectively. This decrease was distinctly marked both in the Chironomidae group and in that of Oligochaeta (fig. 2) and occurred mainly in the littoral zone. Some groups of bottom macrofauna did not occur at all at the stations where the vegetation died out in 1986–1987. This especially concerns Gastropoda. The average number of these animals amounted to 20 ind. m^{-2} in the period 1976–1980, in 1981–1984 varying

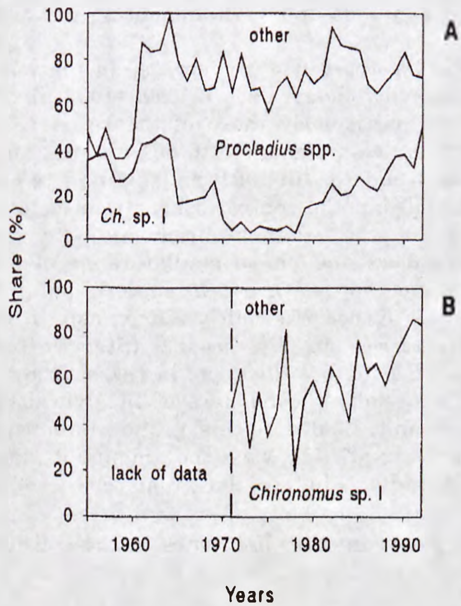

Fig. 3. Changes in the number (A) and biomass (B) structure of Chironomidae in the Goczałkowice Reservoir.

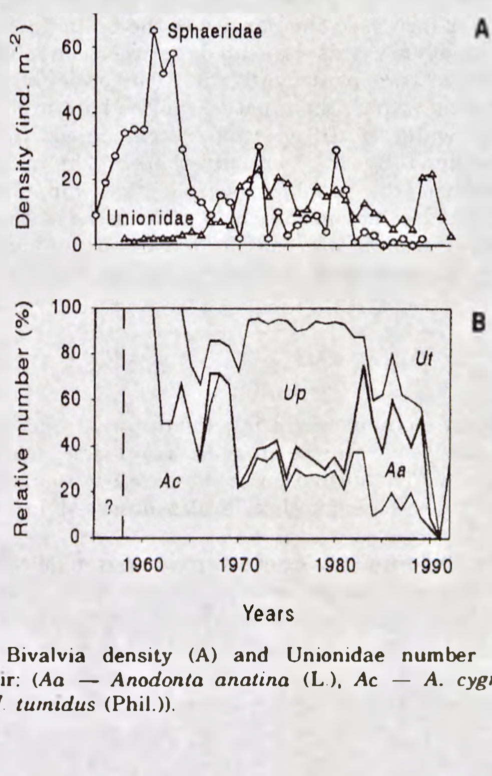

Fig. 4. Changes in Bivalvia density (A) and Unionidae number structure (B) in the Goczałkowice Reservoir: (*Aa* — *Anodonta anatina* (L.), *Ac* — *A. cygnea* (L.), *Up* — *Unio pictorum* (L.), *Ut* — *U. tumidus* (Phil.)).

from 5 to 9 ind. m^{-2}, and in 1985 and 1986 amounting to 1 ind. m^{-2} (E. Krzyżanek unpubl.).

In the period 1987–1992 there was an increase in the number and biomass of bottom macrofauna, especially clearly seen in 1990–1992 (fig. 2 and 3). It was due to Chironomidae larvae, particularly those of the taxon *Chironomus* sp. I. The mean annual value of this taxon amounted to 551 ind. m^{-2}, and the mean biomass to 10.4 g m^{-2} in 1990, 511 and 13.7 in 1991, and 737 and 14.6 respectively in 1992. At some stations, especially in the central zone, its mean number exceeded 1000 ind. m^{-2} and biomass 20 g m^{-2}. Other chironomid taxa, about 50 in number appeared in similar numbers and had a similar range of distribution as in the previous years. *Procladius* spp., *Micro- chironomus* sp. (*M. tener* K. ?), and *Cryptochironomus defectus* K. occurred fairly numerously in the central zone, and *Procladius* spp., *Dicrotendipes* sp. (*D. nervosus* (Staeg.) ?), *Polypedilum* sp. (*P. nubeculosum* (Mg.) ?), and *Psectrocladius* spp. in the littoral zone.

The numbers, and especially the biomass of Bivalvia decreased year by year (exceptions being 1989 and 1990). In this group there was also a change in dominance. *Anodonta anatina* (L.) was the dominant species in the period 1983–1989, and *Unio tumidus* (Phil.) in that from 1990–1992 (fig. 4).

3.4. Interdependency between the properties of the water and the bottom macrofauna

Among the forms of total phosphorus, organic phosphorus showed an increasing trend (fig. 5a). When taking together the rising tendency of this form of phosphorus and that of the bottom macrofauna biomass it appeared that there was an interdependency between these parameters. As the abundance in particulate phosphorus in the water increased the density of the bottom macrofauna also rose. However, an interdependency was indicated between an abundance of bottom macrofauna and the water transparency (fig. 5b). The lower the transparency (more seston and detritus in the water), the greater was the bottom macrofauna biomass.

The increase in water fertility was accompanied by an increase in phytoplankton, determined by the concentration of chlorophyll in the water. Parallelly to the rise in the trophic level of the water and phytoplankton abundance, a fall in the assemblage numbers of bivalves of the family Unionidae (fig. 5c) was observed. A gradual decrease in density of the bivalves of this family coincided in time with that in water transparency (fig. 5d).

4. Discussion

From the foundation of dam reservoirs, quantitative and qualitative changes take place in their ecosystems, which, after a certain time, lead to the creation of a relatively stable system. The formation of the dam reservoir ecosystem occurs in the process of ecological succession, that is also observed in the communities of bottom macrofauna.

A relative biological balance in the reservoir was established in the period from 1955–1982. The investigations carried out within this time allowed three stages of bottom macrofauna to be distinguished: the pioneer one, that of temporary communities, and that of permanent communities (Krzyżanek 1986). However, such a division into stages is schematic and simplified, and the limits of the periods (stages) are not sharply defined. A similar process was observed in many reservoirs

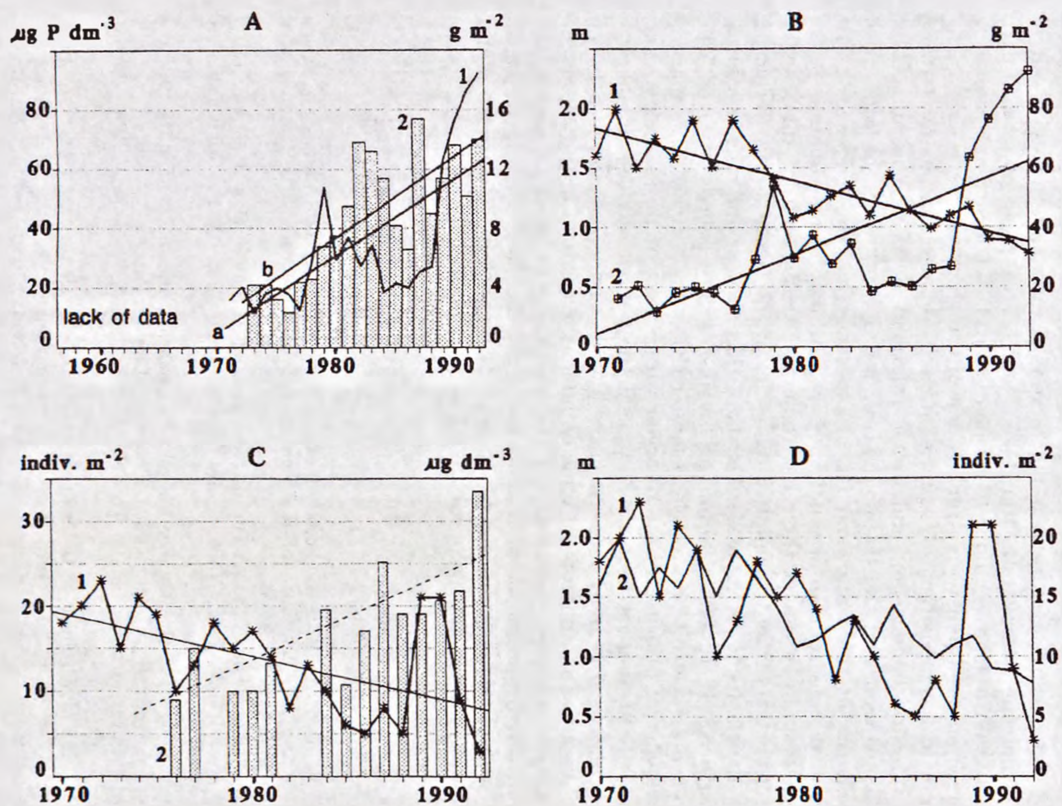

Fig. 5. Interdependency between the physico-chemical parameters of the water and bottom macrofauna in the Goczałkowice Reservoir: A — macrofauna biomass (1 — annual mean, a — trend) and organic phosphorus (2 — annual mean, b — trend), B — water transparency (1) and macrofauna biomass (2) (continuous lines — trends), C — Unionidae density (1 — annual mean, continuous line — trend) and chlorophyll a content (2 — annual mean, broken line — trend), D — Unionidae density (1) and water transparency (2).

(Jankovic 1972, Mordukhay-Boltovsky et al. 1972, Shilova 1976, Prat 1980) and is typical of relatively pure waters.

The existing ecosystem began to decline in the early eighties (in 1986–1987 almost all the submersed plants and a considerable part of the emergent ones died off), this also being seen in the communities of bottom macrofauna. The effects of human activity began to be noted in 1983 (or even in 1982) and lasted until 1992. This period was divided into two stages: the first one, from 1983 to 1986 (characterized by a scarcity of bottom macrofauna, caused by the dying off of macrophytes), and the second one, from 1987 to 1992 (a stage of quantitative increase, mainly that of Chironomidae (*Chironomus* sp. I — *Chironomus plumosus* L. ?), resulting from the intensive eutrophication of the reservoir water).

The taxonomical composition of aquatic animals depends on many factors, among which physico-chemical and nutritional relations play the most important role. A clear convergence of the bottom macrofauna density with the content of organic phosphorus in the water and its transparency may be evidence of the indirect effect of the environmental conditions upon its bottom macrofauna.

Animal organisms also affect their environment. An example of this can be communities of bivalves from the family Unionidae. In the Goczałkowice Reservoir the greatest development took place between the sixties and the seventies (Krzyżanek 1986, 1991). In 1972 106 million bivalves with a biomass of over 5000 tonnes lived on the surface of the whole reservoir (Krzyżanek 1976). This mass of animals was capable of filtering all the reservoir water twice or three times a year. The number of these animals decreased in the later period, but the numbers of phytoplankton increased year by year. Negative interdependence observed between the number of bivalves and phytoplanktonic organisms, contained in the water and the water transparency demonstrated that the bivalves were able to control the development of phytoplankton, and at the same time the purity of the water, in a significant way. Their filtering activity played an important role in the water self-purification and the processes of cycling of matter.

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