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# Effect of carp ponds on the nutrient composition of riverine water supplying the Goczałkowice Reservoir*

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**Abstract** – A large amount of the water feeding the Goczałkowice Reservoir on the River Vistula, storing drinking water for the Upper Silesia region flows through carp ponds. The water feeding the ponds contains mainly nitrate nitrogen and phosphates, and below the outflow of pond waters ammonia nitrogen and organic forms of phosphorus and nitrogen. Fishponds eliminate 30–60% of nitrogen and phosphorus from river water in the vegetation season.

**Key words:** ponds, dam reservoir, elimination of nutrients.

**Wpływ stawów karpiowych na skład biogenów w wodzie rzecznej zasilającej Zbiornik Goczałkowicki.** Duża część wody zasilającej zbiornik zaporowy Goczałkowice na rzece Wiśle, magazynujący wodę pitną dla Górnego Śląska, przepływa przez stawy karpiowe. Woda zasilająca stawy zawiera głównie azot azotanowy i fosforany, natomiast poniżej zrzutu wód stawowych azot amonowy i organiczne formy azotu i fosforu. Stawy rybne w czasie sezonu wegetacyjnego eliminują z wody rzecznej 30–60% azotu i fosforu.

## 1. Introduction

The dam reservoir on the River Vistula at Goczałkowice is one of the main sources of drinking water for the Upper Silesia region. More than 900 ha of fishponds are situated in the reservoir catchment. As a result of biological, physical, and chemical processes and farming operations the water in the ponds significantly changes its chemical composition as concerns both inorganic and organic compounds. The effect of intensive fishery management on the environment is the subject of many publications, most of which concern the pollution of the water with organic and inorganic compounds with salmonid production or in marine aquaculture (Alabaster 1982, De Voe 1994, Piedrahita 1994). Contrary to flow-through ponds, in carp ponds, because of the long time of water retention, phytoplankton develops intensively, enriching the water with both living and dead organic matter. The mass growth of planktonic algae in the ponds changes the

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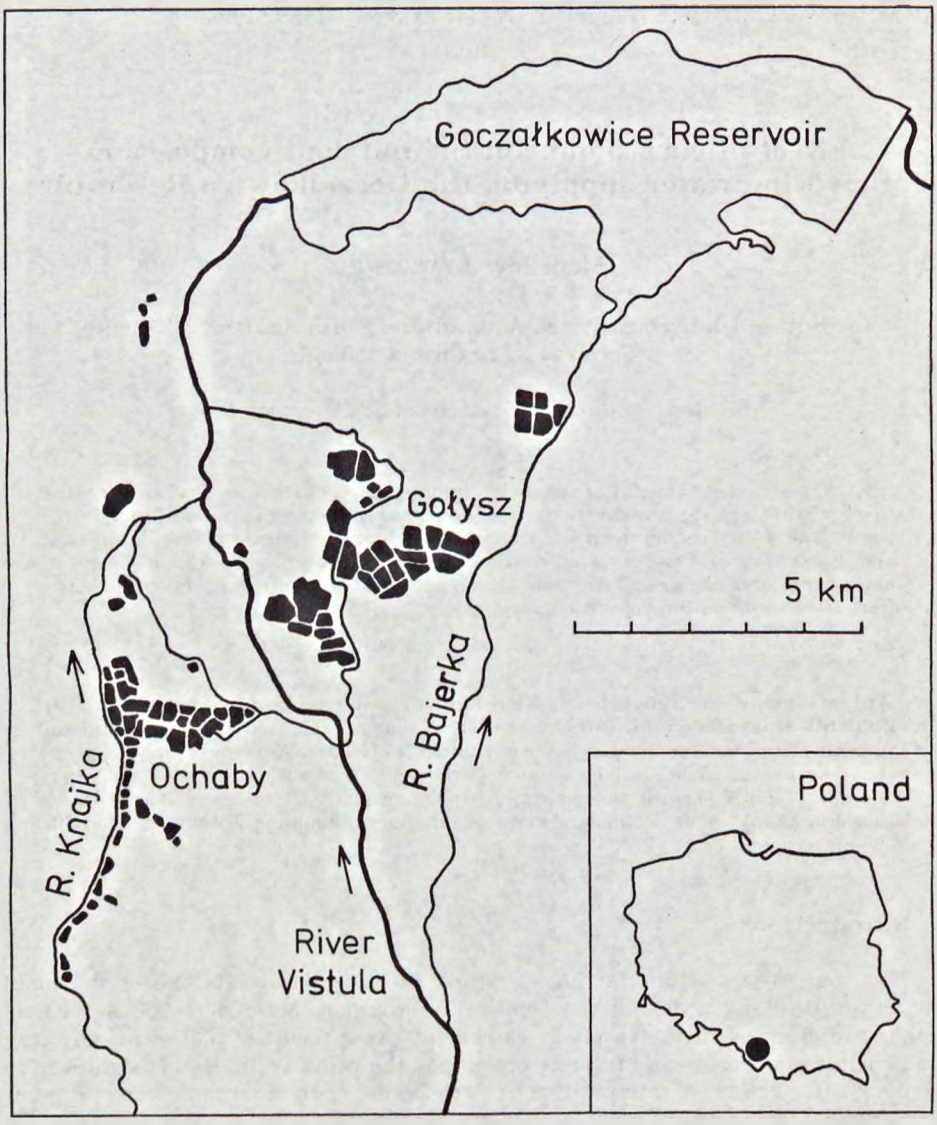


Fig. 1. Localization of investigated fishpond complexes in the catchment area of the Goczałkowice Reservoir.

physico-chemical conditions of the environment, chiefly as a result of the elimination of nutrients, the change in aerobic conditions, pH, and an intensive vertical stratification of some physical and chemical factors in the pond water. On the other hand, intensive fishery management causes loading of the ponds with a large amount of nutrients, originating from their mineral fertilization and from feed for fish. The concentration of inorganic and organic forms of phosphorus and nitrogen in the pond water undergoes intensive fluctuations in the course of the

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vegetation season and depends mainly on its loading pond with these elements and on their elimination resulting from biological and physico-chemical sorption. Wróbel and Włodek (1991) paid special attention to the possibilities of the effect of the ponds on the quality of water feeding the Goczałkowice Reservoir. According to them, the processes occurring in the ponds can both contribute to the pollution of the reservoir and reduce the concentration of the nutrients.

The aim of the present investigations was to find the effect of pond complexes with intensive fishery management on the amount of nutrients in the water feeding the Goczałkowice Reservoir.

## 2. Investigation area

The catchment of the Goczałkowice Reservoir is 532 $km^2$, of which 328 $km^2$ is of montane character, and the remainder of a submontane one (Kasza 1980). Arable lands constitute 46%, and forests 40% of the catchment (Kasza 1987). The main rivers of this catchment are the Vistula, Bajerka, and Knajka (fig. 1). On the border of the montane and submontane zones on the River Vistula, a weir is situated from which water for the ponds situated on the right and left banks of the river is carried by canals. The Bajerka is an artificial river, starting in the River Vistula above Skoczów. The River Knajka reaches the Vistula about 3 km above the backwaters of the reservoir, and the water of the river is many times used by fishponds in its catchment. The pond water is discharged to the same rivers and canals, from which it is taken, with the exception of the left-bank canal of the river Vistula, from which the water is discharged mainly to the River Knajka after passing through pond complexes.

## 3. Material and methods

The investigations were carried out in the years 1992–1994, water samples for analysis being taken from spring to autumn at two week intervals. Water for physico-chemical analysis was taken from affluents of the rivers to the fishponds and from the investigated rivers below the discharge of pond waters. The physico-chemical analyses of water were carried out according to standard methods (Hermanowicz 1976, APHA 1985).

## 4. Results

In the water feeding the ponds nitrogen occurred mainly in the inorganic form (Table I). The water feeding the ponds contained a small amount of organic nitrogen because of a low concentration of organic matter in the feeding water — BOD did not exceed 2 mg $O_2$ $dm^{-3}$. The water of the Vistula contained distinctly more ammonia nitrogen than that of the Knajka. The concentration of $N\text{-}NH_4$ in the Vistula water varied in the range 0.25–3.7 mg N $dm^{-3}$, and in the water of the Knajka from 0.15–1.05 mg N $dm^{-3}$. Periodically high concentrations of ammonia nitrogen in the water of the Vistula could have been about by malfunctioning of the biological treatment plants in the catchment of this river.

Below the discharge of pond waters into the Knajka the concentration of particular nitrogen forms varied significantly in comparison with the concentration

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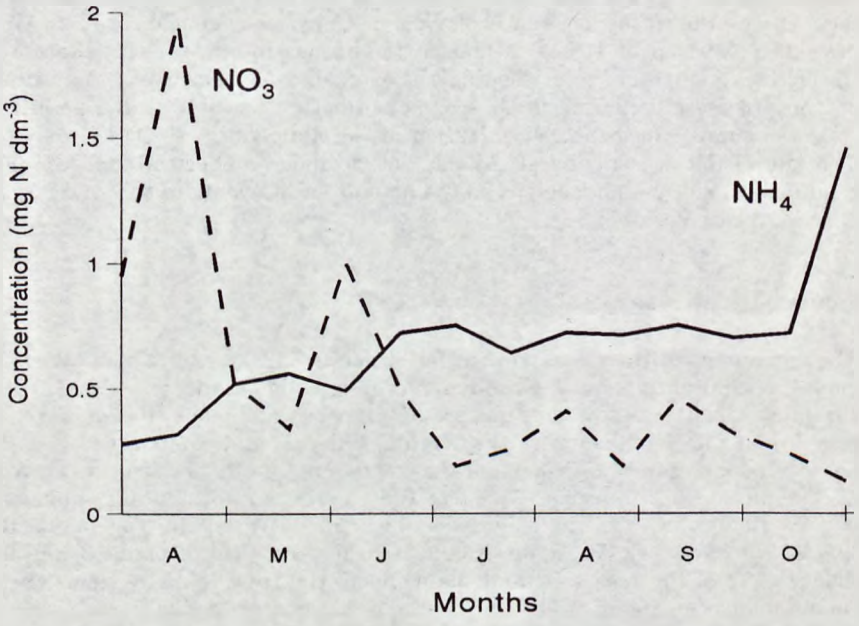


Fig. 2. Concentration of nitrate and ammonia nitrogen in the water of the River Vistula below the discharge of the fishpond waters.

of these compounds in the water feeding the ponds. In the Knajka water below the discharge of pond waters a significant increase in ammonia and organic nitrogen concentration took place with a dramatic fall in the nitrate concentration.

The ponds situated on the right bank of the Vistula are fed with water from the river Bajerka and the right bank canal of the Vistula. The Bajerka water contains much less inorganic nitrogen than that of the right-bank canal of the Vistula (Table I). Such a great difference in the nitrate concentration in the water of the investigated canals is mainly caused by two factors. The Bajerka is fed with water from the Vistula above Skoczów, the largest industrial centre in the catchment; wastes, after biological treatment, are periodically discharged from the treatment plant from Skoczów to the right-bank canal of the Vistula, effecting occasional high concentrations of inorganic nitrogen in the water, especially of nitrates. There is an increase in concentration of organic and ammonia nitrogen and a reduced of nitrate concentration below the discharge of pond waters into the right-bank canal of the Vistula and in the Bajerka. Comparatively high concentration of nitrates in the water of the right-bank canal of the Vistula below the discharge of pond waters was the result of using trout ponds in the Experimental Centre of the Polish Academy of Sciences at Gołysz. A large part of the water from this canal flowed through trout ponds with a short retention time, hence the reduction of nitrates was smaller than that in the remaining pond complexes with a dominating carp (*Cyprinus carpio* L.) stock.

The concentration of inorganic and organic forms of phosphorus in the rivers feeding the ponds situated in the catchment of the Goczałkowice Reservoir was very diversified (Table I). In the water feeding the ponds, that of the Knajka, into

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Table I. Mean concentraton of nutrients (mg $dm^{-3}$) in the waters supplying and flowing out from ponds complexes at Gołysz in 1992–1994 (from spring to autumn).

| Localization of the ponds | Nitrogen | | | Phosphorus | |
|---|---|---|---|---|---|
| | $N\text{-}NO_3$ | $N\text{-}NH_4$ | Norg. | $P\text{-}PO_4$ | Porg. |
| Left bank of the River Vistula | | | | | |
| inflow: Vistula (1993) | 1.24 | 1.11 | 0.31 | 0.230 | 0.033 |
| Knajka | 1.04 | 0.53 | 0.31 | 0.579 | 0.091 |
| outflow | 0.37 | 0.88 | 0.58 | 0.121 | 0.100 |
| Right bank of the River Vistula | | | | | |
| Vistula: inflow (1992) | 2.15 | 0.57 | 0.27 | 0.274 | 0.065 |
| outflow | 0.96 | 0.77 | 0.89 | 0.206 | 0.146 |
| Bajerka: inflow | 1.25 | 0.39 | 0.35 | 0.176 | 0.053 |
| outflow | 0.33 | 1.06 | 0.56 | 0.079 | 0.116 |
| Inflow of Vistula into Goczałkowice Reservoir | | | | | |
| 1992 | 0.77 | 0.58 | 0.28 | 0.090 | 0.070 |
| 1993 | 0.53 | 0.67 | 0.35 | 0.110 | 0.082 |

which after biological treatment wastes from a dairy are discharged, contained the most phosphates. The water of the right-bank canal of the Vistula, affected by the treatment plant in Skoczów, also had a high concentration of phosphorus, and the smallest amount of this element being found the water of the Bajerka, which is slightly polluted with industrial and municipal wastes. In all the investigated rivers the concentration of organic phosphorus increased and the concentration of phosphates decreased to a significant degree below the discharge of pond waters. The smallest elimination of phosphates occurred in the right-bank canal of the Vistula, where the trout complex is situated.

The lowest concentration of phosphorus was found in the water in the sections of the Vistula near its inflow into the reservoir, below the water discharge from the ponds situated in the catchment area of this river (Table I). Similarly as on the concentration of phosphorus, the ponds affect the concentration of inorganic forms of nitrogen contained in the water in the section of the Vistula near its inflow into the reservoir (fig. 2). The nitrate form prevails in spring, while in summer and autumn there is more ammonia nitrogen, this being the dominant form of inorganic nitrogen in the ponds, in this period of the vegetation season. The highest concentration of ammonia nitrogen in the section of the river close to its inflow into the reservoir was found in October at the time of catching in the ponds.

## 5. Discussion

The River Vistula, being the main tributary of the Goczałkowice Reservoir is characterized by great fluctuations in its current 0.1–715 $m^3 s^{-1}$, on average 7.8 $m^3 s^{-1}$ (Winohradnik 1986). In periods of low water level almost all the water feeding the Goczałkowice Reservoir flows through fishponds. Low water levels in the rivers coincide with a decreased need of water exchange in the ponds, which occurs mainly in the summer months, when the accumulation of organic matter in the

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pond water threatens the death of fish as a result of the oxygen deficiency. Carp ponds are charged with a high concentration of nutrients, originating from three main sources — with the water feeding the ponds, from mineral fertilization, and from feed for the fish.

The concentration of biogenic compounds in the water feeding the ponds of the catchment area of the Goczałkowice Reservoir has changed considerably during the last fifty years. The first results given by Stangenberg (1938) more than half a century ago showed a very low level of biogenic elements in the water of the pond affluents. The concentration of phosphorus was most often below 0.02 mg P $dm^{-3}$, and of inorganic nitrogen below 1 mg $dm^{-3}$. In the years a constant rise in nutrients in the water feeding the fishponds was observed (Sowa 1959, Pasternak 1962, Wróbel 1965, Lewkowicz et al. 1977). At present, the concentration of nutrients in the water feeding the ponds, and especially that of phosphorus many times exceeds the values given by authors in past years.

The low concentration of nutrients in the water feeding the ponds necessitated mineral fertilization in order to increase fish production in previous years (Starmach 1958, Wróbel 1962).

The introduction of mineral fertilizers, both phosphorus and nitrogen, brought about an intensive development of phytoplankton, causing an increased efficiency of the ponds. At present in the fishery management of the upper Vistula region, mineral fertilization is occasionally applied, and there are rather problems with a surplus of nutrients in the pond water (Lewkowicz and Lewkowicz 1981).

An important source of nutrients in ponds with intensive carp production is fish feed (Avnimelech and Lacher 1979, Boyd 1982), most of which undergoes mineralization and constitutes a medium for planktonic algae or accumulates in the bottom sediments. Ponds are able to eliminate large amounts of nutrients from the water thanks to a mass development of planktonic algae. Low water hardness in most pond complexes in the catchment area of the Goczałkowice Reservoir leads to a water reaction often exceeding pH 10 during the mass growth of algae. Then occur biological deprivation of calcium in the water and precipitation of phosphates. The dominant form of nitrogen form in the water feeding the ponds are nitrates which in ponds are not only taken by phytoplankton but are also denitrified in the layers near the bottom. Ponds can eliminate over 400 kg of nitrate nitrogen calculated per 1 ha of the pond area (Pokorny at al. 1990). In spite of strong charging of the ponds with nutrients the accumulation of inorganic forms of nitrogen and phosphorus in the water is rarely observed (Müller 1990). The accumulation of inorganic forms of these elements occurs only in the period of mass algae decomposition, especially of blue-green algae or in the ponds where large amounts of high protein pellets in doses exceeding 10 t $ha^{-1}$ are applied. The water discharged from the ponds during the vegetation season (leaking and exchange) contains mainly organic forms of these elements or those contained in soil minerals, this leading to a possibility of rapid sedimentation of their suspensions in the bottom sediments of the section of the river at its entry to the reservoir. Along a 10 km section of the river course between the weir at Ochaby and the backwater of the reservoir at Strumień the concentration of total nitrogen in the water feeding the reservoir fell by 46%, and that of total phosphorus 56% in 1992, and in 1993 42% and 30%, respectively. Ponds are the third stage of purification of wastes in spite of a much higher charge of nutrients than in the water feeding them. The magnitude of nutrient reduction can be more effective when settling ponds are built below the pond complexes (Wróbel and Włodek 1991). Sedimentation of inorganic and organic suspensions in the section of the river near the entry to the reservoir facilitates washing out of

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the nutrients during a greater water flow. Another important factor precipitating the elimination of nutrients in the water of the rivers feeding the reservoir is the presence of a large number of planktonic algae below the discharge of pond waters. The numbers of algae is very low above the ponds, and species typical of montane streams predominate (W. Urbaniec-Brózda unpubl.). Below the discharge of pond waters, in the water of the Vistula and Bajerka planktonic species typical of ponds are dominant with a density several scores higher than 10 km above the backwaters of the Goczałkowice Reservoir. The phytoplankton in water discharged from the ponds has good development conditions in the backwaters of the Goczałkowice Reservoir. The slow water current and the environment rich in nutrients lead to the intensive development of planktonic algae, advancing the elimination of nutrients from the water environment to the sediments. The building of settling ponds for the waters discharged from the fishponds would limit the possibility of the nutrients discharged with the pond water being washed out into the rivers feeding the Goczałkowice Reservoir.

## References

Alabaster J.S. 1982. Report of the EIFAC workshop on fish-farm effluents. EIFAC Tech. Pap., 41, 1–166.

APHA 1985. Standard methods for the examination of water and wastewater (16th edn). Washington, American Public Health Association, 1268 pp.

Avnimelech Y. and Lacher M. 1979. A tentative nutrient budget intensive for fish ponds. Bamidgeh, 31, 3–8.

Boyd C.E. 1982. Water quality management for pond fish culture. Development in aquaculture and fisheries science, 9, 1–318.

De Voe M.R. 1994. Aquaculture and the marine environment: policy and management issues and opportunities in the United States. Bull. Natl. Res. Inst. Aquaculture, suppl. 1, 111–123.

Hermanowicz W., Dożańska W., Dojlido J. and Koziorowski B. 1976. Fizyczno-chemiczne badanie wody i ścieków [Physico-chemical investigation of water and waste-waters]. Warszawa, Arkady, 847 pp. [in Polish].

Kasza H. 1980. The management of the catchment area of the Goczałkowice reservoir and its effect on the amount of nitrogen and phosphorus migration from it. Acta Hydrobiol., 22, 35–37.

Kasza H. 1987. Development and structure of the Goczałkowice reservoir ecosystem. 2. Characteristics of the catchment area. Ekol. pol., 34, 313–322.

Lewkowicz M. and Lewkowicz S. 1981. Efficiency of zooplankton consumption and production in ponds with large loads of allochtonous organic matter. Acta Hydrobiol., 23, 297–317.

Lewkowicz S., Golachowska J., Moczek T., Nowak M. and Skoczeń I. 1977. Nawożenie azotowo-fosforowe odgrodzonych części stawów. 2. Elementy fizyczne i chemiczne środowiska [Fertilization of enclosed parts of ponds with nitrogen and phosphorus. 2. Physical and chemical characteristics of the environment]. Roczn. Nauk Roln., H, 98, 25–51.

Müller W. 1990. Aspects of pond fertilization in high-intensive carp culture. Proc. FAO-EIFAC Symp. "Production enhancement in still-water pond culture", Prague, 1990. 207–211.

Milstein A., Alkon A. and Karplus I. 1995. Combined effects of fertilizations rate, manuring and feed pellet application on fish performance and water quality in polyculture ponds. Aquacult. Res., 26, 55–65.

Pasternak K. 1966. Pond soils arising from heavy loam and clay formations. Acta Hydrobiol., 8, 131–155 [in Polish with English summary].

Piedrahita R. H. 1994. Managing environmental impacts in aquaculture. Bull. Natl. Res. Inst. Aquaculture, suppl. 1, 13–20.

Pokorny J., Tomanova J. and Nemcova Z. 1990. Decline in nitrate contents in carp ponds during the growing season. Proc. FAO-EIFAC Symp. "Production enhancement in still-water pond culture", Prague, 1990, 64–67.

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Rakocy J.E. 1994. Waste management in integrated recirculating systems. Bull. Natl. Res. Inst. Aquaculture, suppl. 1, 75–80.

Sowa R. 1959. Syrton of stream Bajerka. Acta Hydrobiol., 1, 197–213 [in Polish with English summary].

Starmach K. 1958. Ergebnisse der Teichdungung in der Versuchsteichwirtschaft Ochaby. Biul. Zakł. Biol. Stawów PAN, 6, 81–95.

Winohradnik J. 1986. Development and structure of the Goczałkowice reservoir ecosystem. 2. Characteristics of the reservoir and its usefulness to water-supply system. Ekol. pol., 34, 323–341.

Wróbel S. 1962. Einfluss der Stickstoff-Phosphordüngung auf die chemische Zuzammensetzung des Wassers, auf die Primärproduktion des Phytoplanktons und auf der Fischzuwachs in Teichen. Acta Hydrobiol., 4, 151–204 [in Polish with German summary].

Wróbel S. 1965. Die chemische Zusammensetzung des Wasser in den Teichen Südpolens. Acta Hydrobiol., 7, 303–316 [in Polish with German summary].

Wróbel S. and Włodek J.M. 1991. Gospodarka stawowa w dorzeczu Górnej Wisły [Pond management in the Upper Vistula catchment area]. In: Dynowska I. and Maciejewski M. (eds) Dorzecze Górnej Wisły [The Upper Vistula catchment area]. Warszawa-Kraków, PWN, vol. 2, 96–105 [in Polish].

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