IMPACT OF RIVERINE WATER QUALITY ON FISH POND ECOSYSTEMS

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Abstract

The ponds situated in the area of the upper Vistula river (Poland) are affected by some pollutant loads coming from surrounding industrial centres, numerous towns and villages as well as from agricultural activity. The distinct differences in water quality supplied to the ponds from three rivers result from differences in the geological character and human activity in the drainage basins of the rivers. However, the biogenic salt concentration has increased several times in all three rivers since the 1930's and even since the 1950's. Their rapid increase in the Vistula river in the 1970's resulted from the development of recreation centres. The high nutrient concentration in the riverine and the precipitation waters and a lack of mineral carbon in ponds in the first part of the farming season caused significant reduction in mineral fertilization of the ponds, replaced by organic-mineral fertilization. Of the heavy metals considered, only zinc reached high concentrations, but it did not limit carp development and growth. The high uptake of nutrients and accumulation of zinc in ponds indicates their positive effect on water quality in the catchment.

Augustyn, D., S. Lewkowicz & M. A. Szumiec: **Einfluß der Wasserqualität von Fließgewässern auf Fischteich-Ökosysteme.**

Die Teiche an der oberen Weichsel (Polen) sind von Schadstofffrachten betroffen, die aus den umgebenden Industriezentren, den zahlreichen Städten und Dörfern und der landwirtschaftlichen Tätigkeit stammen. Die deutlichen Unterschiede in der Wasserqualität der drei Flüsse, welche die Fischteiche versorgen, resultieren aus dem geologischen Character und der menschlichen Aktivität im Einzugsgebiet der Flüsse. In allen drei Flüssen hat die Konzentration biogener Salze seit den 30er und sogar seit den 50er Jahren um ein Mehrfaches zugenommen. Der rasche Anstieg in der Weichsel während der 70er Jahre geht auf die Entstehung von Erholungszentren zurück. Die hohe Nährstoffkonzentration im Fluß- und Niederschlagswasser und das Fehlen von mineralisierten Kohlenstoffen in den Teichen während des ersten Teiles der Wirtschaftssaison verursachte einen signifikanten Rückgang der mineralischen Teichdüngung, die durch eine organisch-mineralische Düngung ersetzt wurde. Von einigen Schwermetallen ergaben sich nur bei Zink hohe Konzentrationen, die aber Karpfenentwicklung und -wachstum nicht begrenzten. Die hohe Nutzung von Nährstoffen und die Anreicherung von Zink in Teichen wies auf deren positiven Einfluß auf das Einzugsgebiet hin.

Augustyn, D., S. Lewkowicz & M. A. Szumiec: **Vliv kvality říční vody na rybniční ekosystémy.**

Rybníky situované v oblasti horního toku Vistuly (Polsko) jsou znečišťovány přísunem odpadních vod z okolních průmyslových středisek, komunálních vod mnoha měst a vesnic, a v neposlední řadě zemědělským hospodařením v krajině. Značné rozdíly v kvalitě vody tří řek zásobujících zmíněnou rybniční soustavu jsou vysvětleny rozdílným geologickým charakterem a činností člověka v povodí těchto řek. Nicméně, ve všech třech řekách vzrostla několikanásobně od třicátých a také padesátých let koncentrace biogenních solí. Příčinou prudkého zvýšení koncentrace těchto solí v řece Vistule v sedmdesátých letech byla výstavba rekreačních středisek. Vysoké koncentrace živin v říční i dešťové vodě a nedostatek anorganického uhlíku v rybnících na počátku zemědělské sezony vedly k výraznému snížení hnojení rybníků minerálními hnojivy a používání organo-minerálních hnojiv. Z těžkých kovů pouze zinek dosahoval vysokých koncentrací, což ovšem neovlivnilo vývoj ani růst kapra. Vysoké využití živin a akumulace zinku v rybnících má pozitivní vliv na kvalitu vody v povodí.

INTRODUCTION

In many European countries, ponds play a significant role in fish production, water retention, flood control and catchment management. In Poland, for example, the pond fish production, mainly carp, reaches about 16,000 tons/year, and ponds also retain about 500 x 10^6 m^3 water. As habitats of freshwater flora and fauna, ponds help to sustain biodiversity.

All this causes our attention to be drawn to these ecosystems which are endangered by excessive loads of biogenic and toxic substances in rivers and precipitation. The specific objective of the present work is to determine the extent to which the chemical and physical composition of the riverine water feeding the ponds has changed since the first half of this century, and how these changes affect the pond ecosystem.

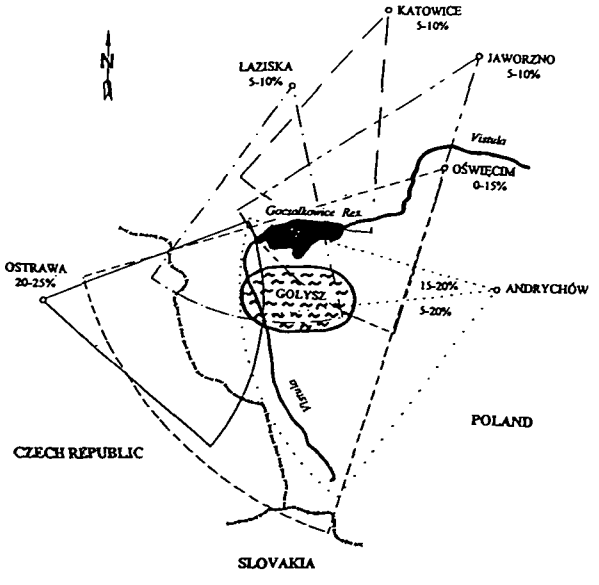

Fig. 1: Extension and duration (in percentages of days/year) of the aerosol trails emitted by the industrial centres surrounding the Gołysz ponds. Taken by "Landsat", November 2, 1973 and October 10, 1978, analyzed by Prof. Dr. J. Walczewski

STUDY AREA AND METHODS

Monitoring of water quality was carried out in 1986-1990 at Gołysz Institute, situated in the south-western part of Poland. The total surface area of the ponds considered is about 800 ha. Ponds are fed by water supplied from the Vistula river - polluted mostly by local industries, communal wastes and partly by agriculture - and from the Iłownica and Bajerka rivers - containing mostly pollution loads from agriculture and forestry. All the rivers originate in the Beskidy Mountains (western part of the Carpathian Mountains). The installations for water supply for the ponds are situated in the rivers 20-30 km downstream from their springs. The whole region is affected by the contamination advecting with the air masses above the surrounding largest Polish and Czech industrial centres (Fig. 1).

The riverine and pond water samples were taken each month. The concentrations of the chemical components were measured by standard methods, heavy metals by atomic absorption spectrometry. The pollutant loads were calculated by multiplying concentrations with the water discharge volumes. Only a few physical and chemical components chosen from over a score that were measured are presented here, and only the data obtained in the warm season of the year, i.e. from May until September, are discussed.

To compute the loads entering and leaving the ponds it was necessary to register all the components of the pond water budget. The water entering and leaving the ponds was measured by calibrated hydrological containers, precipitation water by ombrometer, and evaporation by a floating container with a surface area of 3000 cm^2 (RICHTER 1969, SZUMIEC 1972).

The differentiation among the riverine water qualities was statistically evaluated using principal components analysis (JEFFERS 1978).

RESULTS

The pollutant concentrations in the considered rivers did not show any distinct changes during the five years of monitoring but individual sample values varied enormously. A comparison of the results obtained in the 1950s and the 1960s showed, however, a distinct increase in the biogenic salt concentrations in all the considered rivers (Tab. 1) as well as in precipitation (SZUMIEC et al. 1993). The highest PO_4-P concentration in the Vistula river found by Stangenberg in the 1930s amounted to 0.02 mg dm^{-3} (STANGENBERG-OPOROWSKA 1962). The pollutant concentrations generally decreased with the increasing water table, but in the Iłownica river they sometimes increased due to heavy rainfall leaching the nutrients from the adjacent agricultural terrain.

A distinct differentiation in the water quality of the considered rivers, despite the small distance between them, results from their different geology, and differences in human activity in their drainage basins. The limy ground of the valley raises the ion concentrations in the Iłownica river (Fig. 2a). It also caused the average electrical conductivity in Iłownica to reach 308 $\mu S\ cm^{-1}$, while in Bajerka and on the right- and left banks of the Vistula river it only amounted to 175, 253 and 234 $\mu S\ cm^{-1}$, respectively. The numerous towns, villages and factories stimulate the increase in the biogenic salt concentrations in the Vistula river (Fig. 2b, Tab. 1).

The higher concentrations of some biogenic salts on the right bank of the Vistula river resulted from the treatment plant (without the biological purification) situated on this river bank. The agriculture and forestry in the drainage basin raise the concentration of organic matter in the Iłownica and Bajerka rivers (Fig. 2c), where the turbidity was equal to 99 and 89 while in Vistula only to 27, respectively.

The average precipitation input during the farming season amounts only to about 25% of the riverine input but it supplies over 50% of ammonium-nitrogen (NH_4-N) and zinc loads, although less than 10% of the total sulphate and phosphate-phosphorus (PO_4-P) (Fig. 3). The nitrogen load amounts to about 30% nitrogen supplied with mineral fertilizers, yet it does not cause any biogenic effects because of the very low phosphorus concentration in the rain.

River	Years	pH	Alcalinity meq dm^{-3}	Hardness n	K mg dm^{-3}	NO_2-N mg dm^{-3}	NO_3-N mg dm^{-3}	NH_4-N mg dm^{-3}	PO_4-P mg dm^{-3}
Vistula-left bank	1954*	7.0	0.8-1.2	2.8-3.7	1.4-3.3	0.007	0.06-0.08	0.03	0.003-0.050
	1960-65**	7.2-7.4	0.8-1.3	3.8-4.3	1.9-2.1	0.020-0.040	0.60-1.20	0.02-0.28	/
	1986-90	7.0-8.1	0.5-2.0	3.2-8.5	1.5-5.0	0.013-0.360	1.50-5.90	0.03-2.15	0.004-0.320
Vistula-right bank	1954*	7.0	0.7-1.1	2.4-3.8	1.4-3.3	0.007-0.125	0.06-0.14	0.09	0.01
	1960-65**	7.2-7.4	0.8-1.3	3.2-5.1	1.7-2.7	0.002-0.030	0.20-1.00	0.02-0.28	0.01
	1986-90	7.1-7.9	0.5-1.8	3.0-7.2	1.6-5.0	0.014-0.500	1.22-6.20	0.10-2.50	0.100-0.378
Iłownica	1954*	7.1	1.2-2.0	4.2-8.0	2.1-3.0	0.001-0.025	0.04-0.20	0.03-0.16	0.010
	1986-90	7.1-8.0	1.5-2.8	6.2-10.6	2.2-5.0	0.007-0.048	0.15-5.10	0.04-1.02	0.010-0.209

* K. Starmach
** K. Pasternak

Tab. 1: Limits of the concentration of some chemical components in the riverine water

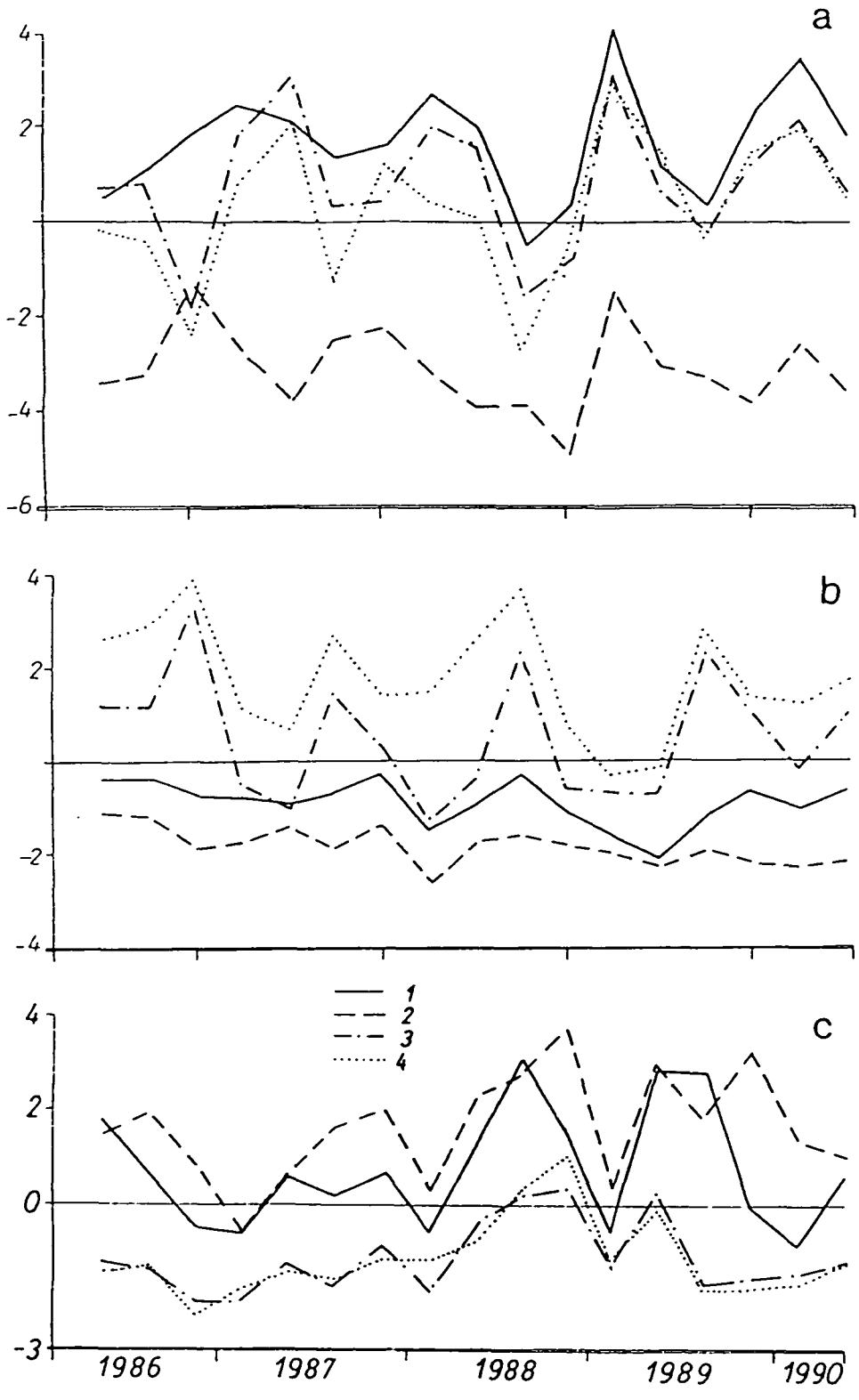

Fig. 2: Principal component analysis of:

a) (PC1) - ions composition (Ca, Mg, HCO_3, Fe, K, hardness and conductivity) in the three rivers: 1. Bajerka, 2. Iłownica, 3. Left- and 4. right bank Vistula river. All the components are unipolar grouped on the negative pole.
b) (PC2) - biogenic salts (NH_4, PO_4, Na, K and Fe), all the components unipolar positive.
c) (PC3) - organic matter exponents (BODs, COD, turbidity, organic nitrogen), all the components unipolar positive.

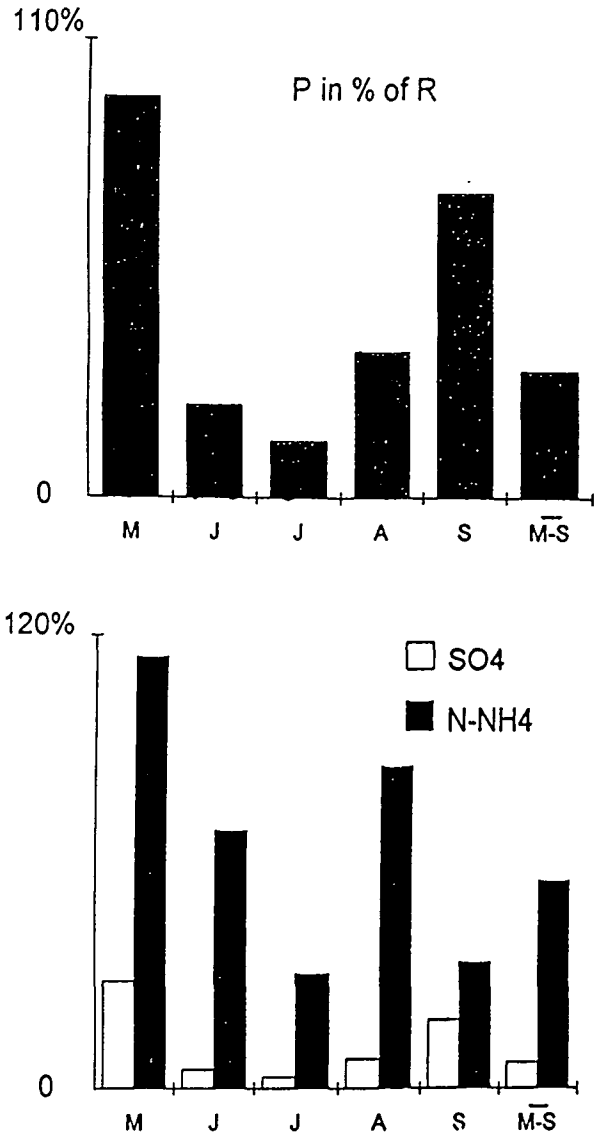

Fig. 3: Proportion of the average (1986-1990) monthly sums of the precipitation water P to the riverine water R, and of the sulphate and ammonia-nitrogen loads to the loads in R.

The low concentrations of mineral carbon, exhausted at the beginning of the farming season by the pond biotope, together with a high concentration of riverine nutrients induce a rapid increase in pH in the pond water, even up to 10.6, threatening fish survival (LEWKOWICZ 1987, SUMIEC 1987). The high nitrite concentration in the riverine waters has not been, as yet, dangerous for the pond ecosystem because of a very high chloride concentration which lowers the toxic impact of the NO_2 (EIFAC Technical Paper, 1984).

The computation of zinc and copper budgets indicated that the ponds are highly loaded with Zn, which accumulates in pond bottoms, while only to a minor degree with Cu, which is removed with fish and water (Tab. 2). This high Zn load in ponds results from a very high Zn concentration in the atmosphere and in the precipitation observed in this region (SZUMIEC et al. 1993). It also caused a high Zn concentration in the Vistula river, which stimulated the growth of filamentous algae in recent years. The concentrations of the other heavy metals considered, like Cr, Cd and Pb, usually did not surpass the limits inhibiting carp development and growth. The mercury concentration in the pond sediments, checked by Prof. Nuorteva, amounts to 0.09 ppm and is comparable with the values found in the river beds and lake sediments in southern Poland and in Finland (Prof. Nuorteva, personal communication, NUORTEVA et al. 1986).

	Inlet						Outlet				
	Water inlet in spring	Precipitation	Water inlet in summer	Fish stock	Feeds	Sum	Water outlet in autumn	Water outlet in summer	Harvesting	Sum	Accumulation in sediments
Cu	54	24	28	1	25	132	54	91	3	184	-16
Zn	1890	369	220	8	87	2574	486	287	23	778	+1796

Table 2: Copper and zinc (g ha^{-1}) budget in ponds

DISCUSSION

A rapid increase in the nutrient concentrations in all the considered rivers in the 1970s followed the construction of many recreation facilities in that region, as well as the intensified application of mineral fertilizers in agriculture. The treatment plants, initially constructed without biological purification, actually stimulate organic matter concentration in the Vistula river instead of limiting it. The high concentration of biogenic salts in the riverine waters caused a significant reduction in fish pond mineral fertilization, and its replacement by organic-mineral fertilization. It also contributed towards stimulation of the mineral carbon concentration in pond water, thus, also limiting pH increase (SZUMIEC 1987).

The high ammonia-nitrogen concentration observed in local precipitation may not only be a result of its emission from power stations and steel works, but also as a result of ammonia volatilization from pond water at high pH when the ratio of ammonia to ammonium increases (JØRGENSEN & GROMIEC 1989).

In autumn, i.e. after the season of fish growth, the pond water supplied back to the rivers and the Goczałkowice reservoir (the source of drinking water for Upper Silesia), contains lower concentrations of biogenic salts than riverine water. Moreover, ponds reduce zinc concentration, and in this way they contribute to the improvement of the water quality in their catchment.

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