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MAIN CHANGES IN THE KONIN LAKE SYSTEM (POLAND) UNDER THE EFFECT OF HEATED-WATER DISCHARGE POLLUTION AND FISHERY

ABSTRACT: The location and limnological characteristics are described of five lakes near Konin, and the range and intensity of the impacts of heated waters on the whole lake system in relation to the period and mode of power-plant operation. The average level is characterized of the heating of lake waters, their inorganic and organic pollution, and the main fishery practices and catches. The loading of the lakes with P and Ca is estimated.

KEY WORDS: Lakes, heated waters, pollution, eutrophication.

1. INTRODUCTION

The lake system found near Konin, is used from 1958 as a through-flow cooling system at first of one and then of two power-plants. It offers possibilities of carrying out studies along all the lines of researches, described in Hillbricht-Ilkowska and Zdanowski (1988), on the impact of power- and heat-generating plants on the structure and functioning of the lake ecosystems.

Presented in the following description are the main limnological features of the above lake system and some general data on the effect of the cooling system on the retention time of water in the lakes, and degree of their waters heating, pollution sources and effects, and the main fishery practices. The above three kinds of human impact determine changes in the structure and functioning of the lakes, described in the further papers.

2. STUDY AREA, LOCATION AND BASIC MORPHOMETRICAL DATA ON THE LAKES

The Konin lakes are part of the Great-Polish Lakeland and include five separate water bodies corresponding to the lakes: Gosławskie, Pątnowskie, Licheńskie, Ślesińskie and Wąsosko-Mikorzyńskie[1] (Fig. 1). They cover the area of the following

Table 1. Basic limnological

Lake	Area (A) ha	Maximum depth $(z_{max.})$ m	Average depth $(\bar{z})$ m	Volume (V) 10^3 m^3	Shore-line development index (L)	Trophic type
Gosławskie before and after rising the water level	378.9 (438.0)[2]	3.0 (3.5)	1.3 (2.1)	4.865 (13.1) (9.1)[2]	1.35	eutrophic (pond like)
Pątnowskie	307.4 277.0[2]	5.4 5.8	2.6	8.143 7.1	1.72	eutrophic (pond like)
Licheńskie	153.6 146.0[2]	13.3 13.8	4.9 5.7	7.47 8.3	2.98	eutrophic
Mikorzyńskie	245.3 222.0[2]	38.0	11.9	29.29 28.9	2.52	b-meso-trophic, eutrophic
Ślesińskie	148.1 152.0[2]	25.7	7.5	11.072 12.7	2.52	eutrophic

[1] Morphometric data acc. to bathymetric maps of Inland Fisheries Institute and Zdanowski and and Backiel (1972). [4] State of 1960, acc. to data from Inland Fisheries Institute. [5] For the period ichthyofauna including the silver carp.

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[1] Hereafter referred to as L. Mikorzyńskie.

geographical coordinates: latitude 52°18' to 52°23', longitude 18°14' to 18°20'. According to hydrographical map of Poland („Podział hydrograficzny Polski" 1983) they are part of the Odra-Warta drainage area (Watershed no. 118C) and represent a watershed referred to as the Warta-Gopło Ślesiński canal watershed (also called Morzysławski canal). It is a waterway linking the Warta and Noteć rivers. Most of the water from this system is carried by the Morzysławski canal to the Warta r. (via L.

data [1] on the Konin lakes

Mictic type	Higher vegetation, per cent of lake area [4]	Year of inclusion in the cooling system	Main sources of sewage	Fishery practices	Average fish catches kg·ha⁻¹ [5]
polymictic	emergent 5.3%	1969 (continuous water uptake and discharge)	mine waters	introduction of silver carp (1971–76) – slight; 1977–79 intensive [6]	78.0 (34.9) [7]
polymictic		1958 (continuous water uptake and discharge)	sugar-mill effluents	introduction of grass carp and silver carp 1966–1968 [3]	30.0
dimictic (with a tendency towards slight stratification in summer)	emergent 5.7%	1958 (continuous discharge)		introduction of grass carp and silver carp 1966–1968 [3]	21.9
dimictic	emergent 3.9%	southern part – 1958 (continuous discharge), northern part – 1970 (periodical discharge via (L. Ślesińskie)		no stocking	13.1
dimictic	emergent 1.1%	1970 (periodical discharge)		no stocking	26.1

Korycka (1976). [2] Acc. to Widomski (1971) and/or Gadkowski (1977). [3] Zawisza 1976–1982, acc. to data from Inland Fisheries Institute. [6] Wilkońska (1988). [7] Total catch of native

Pątnowskie), some of it by a canal, known under the same name, to L. Gopło and the Noteć river via L. Ślesińskie (Fig. 1). L. Gosławskie receives also the water from a watercourse (so-called Struga Biskupia), draining an area of about 250 km^2 and

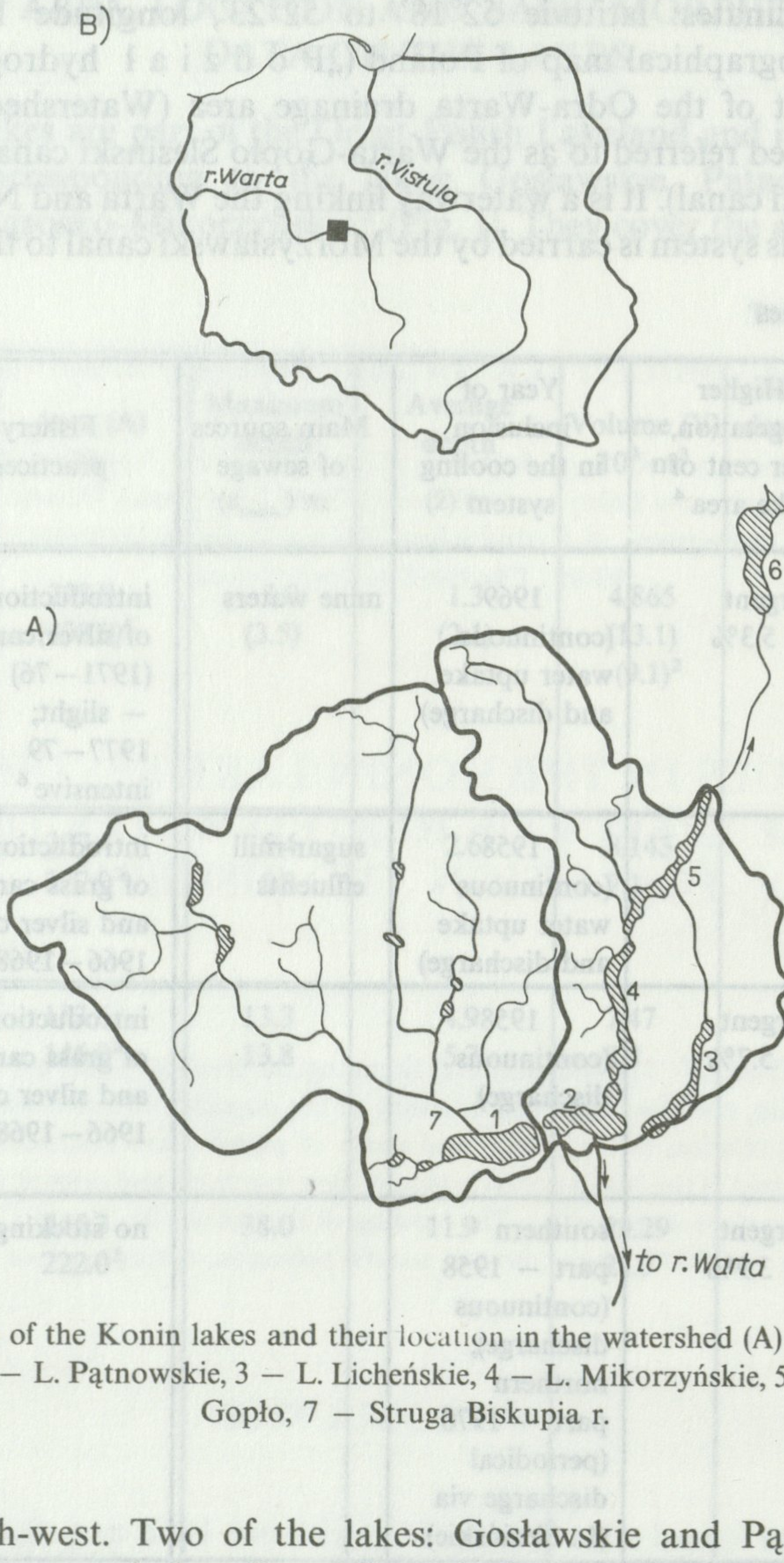

Fig. 1. A sketch-map of the Konin lakes and their location in the watershed (A) and in the country (B) 1 — L. Gosławskie, 2 — L. Pątnowskie, 3 — L. Licheńskie, 4 — L. Mikorzyńskie, 5 — L. Ślesińskie, 6 — L. Gopło, 7 — Struga Biskupia r.

situated on south-west. Two of the lakes: Gosławskie and Pątnowskie are large (shoreline development index, L < 1.7) and shallow ($\bar{z} = 2.6 - 1.3$ m) eutrophic, polymictic water bodies that have formed in front of a terminal moraine. L. Licheńskie is a eutrophic, deeper ($\bar{z} = 4.9$ m) water body (but with a tendency towards the polymixis) of an elongate shape (L — almost 3). The remaining two lakes: Mikorzyńskie and Ślesińskie are deep ($z_{max.} = 25 - 38$ m) lakes of an elongate form (L = 2.5) and with a number of distinct broader parts. L. Mikorzyńskie appears to be the least eutrophic of all the lakes of the above complex. Its trophic state is intermediate between mesotrophy and eutrophy (Table 1).

The area of the watershed of the Konin lakes is about 418 km^2, with cultivated land occupying most of it. The soils of the watershed have been formed of loamy sands, and clay sands. Originally, as little as 13% of the watershed area was wooded, and this proportion continues to decrease due to the growth of the industry. At present there is also a considerable percentage of urbanized areas connected with the mining (opencast mining of lignite) and power-producing industries. Generally, many factories are located in the drainage area, using considerable quantities of water. They include the "Aluminium" Works and the "Gosławice" Sugar Mill.

3. RESULTS

3.1. THE SCHEME OF FUNCTIONING OF THE LAKES AS A THROUGH-FLOW COOLING SYSTEM AND CHANGES IN THE LAKE WATER RETENTION TIME

The above lake complex functions as a through-flow system of water cooling the equipment of two power- and heat-generating plants: Konin and Pątnów. The operation of the former was started in 1958, and that of the latter in 1969, at first using L. Gosławskie waters, and from 1970 on also waters from the other lakes of the complex. The original system of links and water flow between the lakes has been changed significantly and adjusted for cooling the heated waters discharged by both power plants. The lakes have been interlinked by a number of canals (Figs. 2, 3), the total length of which comes up to about 26 km. Water retention in each of the lakes has changed. Its seasonal and diurnal variation were strongly related to the intensity of power plant operations.

Depending on whether one or both power plants are working, two periods are distinguished in the functioning of the lakes as the cooling system. The two periods significantly differ in the range and intensity of the impact of heated waters.

1st period (Fig. 2) corresponds to the years 1958 – 1969. The cooling system of the "Konin" power plant began to work (following the adaptation period 1958 – 1961), and has been using the waters from L. Pątnowskie (also as the source of water), L. Licheńskie and from the southern part of L. Mikorzyńskie. Heated waters were carried and pumped through open canals to the latter two lakes, whence, after cooling, they flowed down to L. Pątnowskie. This is the so-called small cycle. In that period L. Gosławskie (heated since 1969 by the "Pątnów" power plant whose operation then started), the northern part of L. Mikorzyńskie and L. Ślesińskie were not affected by heated waters.

2nd period (Fig. 3) corresponds to the years from 1970 to date. In this period the full operation has begun of the second power plant, "Pątnów", located on L. Gosławskie. The cooling system was enlarged by the inclusion of L. Gosławskie [2] (also as a water source), and another cycle (the second small cycle) thus arose. From 1970 on also this cooling system has been extended by including L. Ślesińskie into it (between May and September) (so-called great cycle). As a result, for 5 – 6 months a year the whole lake

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[2] Due to water discharges, the water level in this lake has been raised by about 80 cm, and a strip of land close to its edge has been permanently flooded.

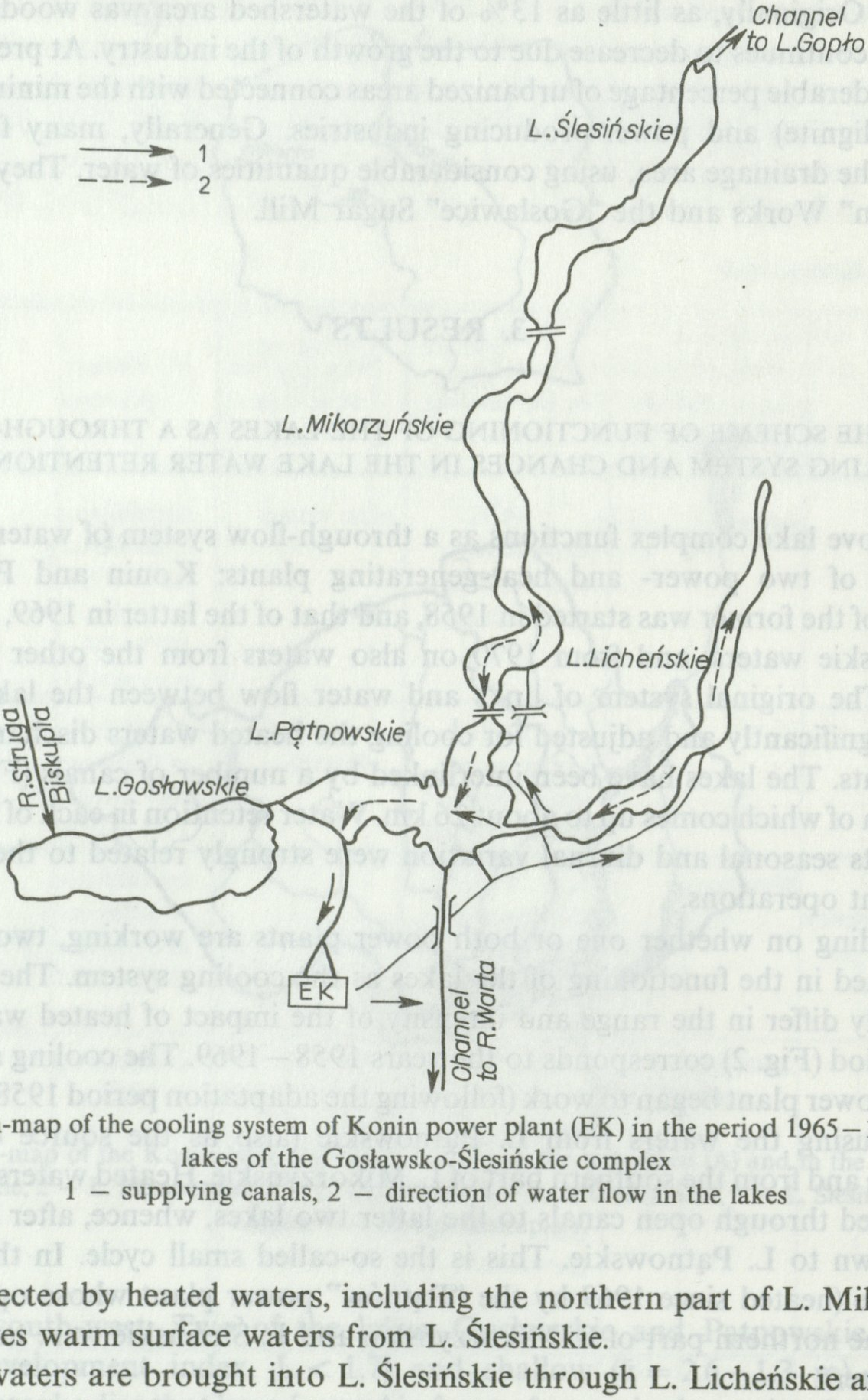

Fig. 2. A sketch-map of the cooling system of Konin power plant (EK) in the period 1965–1969 based on lakes of the Gosławsko-Ślesińskie complex
1 – supplying canals, 2 – direction of water flow in the lakes

system is affected by heated waters, including the northern part of L. Mikorzyńskie, which receives warm surface waters from L. Ślesińskie.

Heated waters are brought into L. Ślesińskie through L. Licheńskie and a canal, and the actual discharging is done by means of the so-called "springboard" (waterfall). In other periods (including winter) L. Ślesińskie is disconnected from the cycle, and the system of supplying and cooling the waters is based on L. Licheńskie, Pątnowskie and Mikorzyńskie. Waters from L. Gosławskie flow to the Pątnów power plant in canals and are discharged into the lake by several spillways. In the Pątnów power plant the condensers are cooled with water taken from L. Pątnowskie. The same amounts of water are afterwards returned through a discharge canal via L. Licheńskie (Widomski 1971, Gadkowski 1977).

Giercuszkiewicz-Bajtlik and Jabłoński (1977) estimated

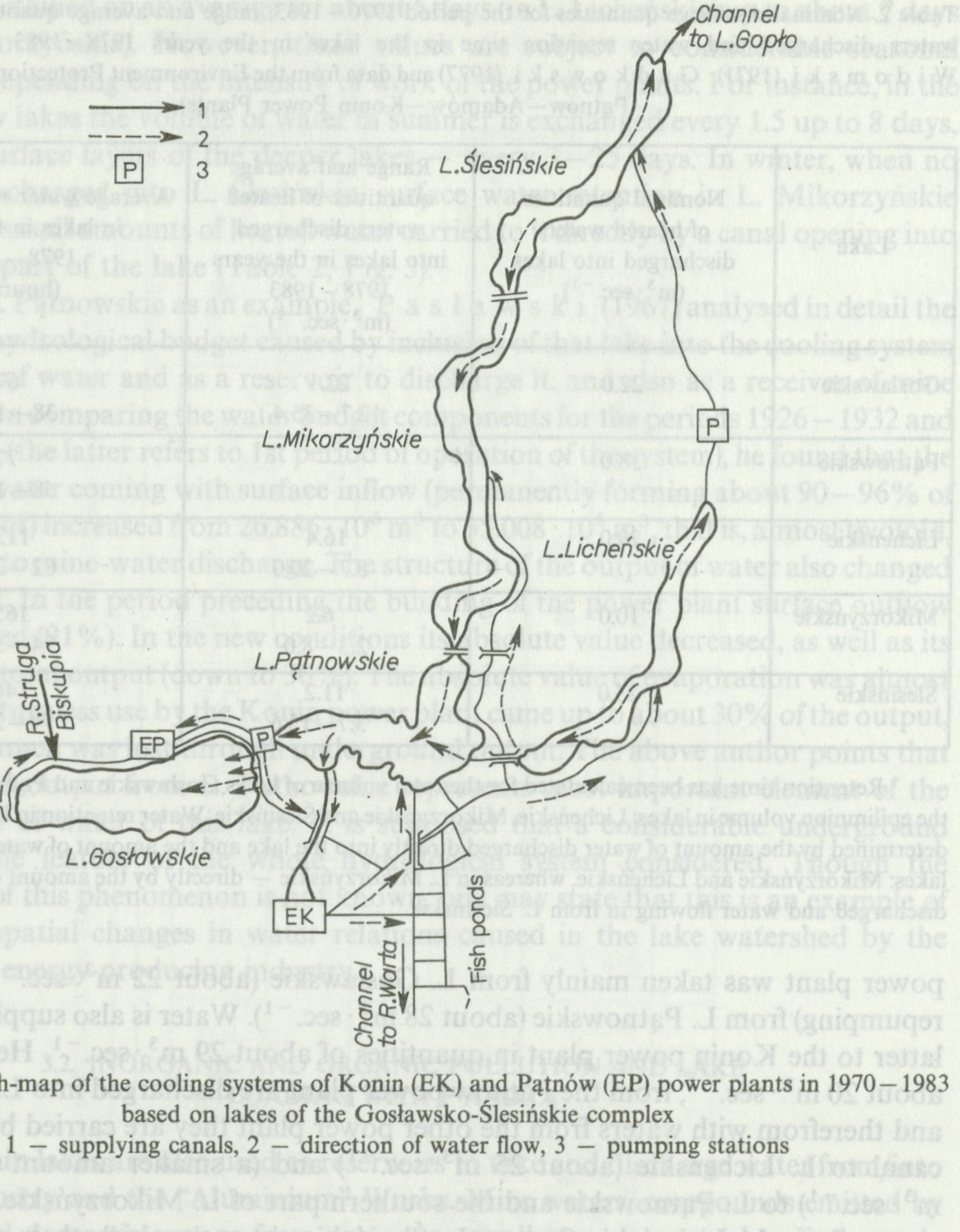

Fig. 3. A sketch-map of the cooling systems of Konin (EK) and Pątnów (EP) power plants in 1970 – 1983 based on lakes of the Gosławsko-Ślesińskie complex
1 — supplying canals, 2 — direction of water flow, 3 — pumping stations

the amount of heated waters discharged into the Konin lakes by both the power plants via lakes Gosławskie and Pątnowskie at 7387440 $m^3 \cdot day^{-1}$.

Obviously, the quantities of the cooling-system waters that get to particular lakes of the Konin system vary considerably.

In the 1st period of functioning of the system (1960 – 1965, stabilization phase) the total amount of heated waters discharged into the lakes was 17 $m^3 \cdot sec.^{-1}$ in winter, up to 33 $m^3 \cdot sec.^{-1}$ in summer. Most of this amount (about 50%) was discharged into L. Licheńskie which had beed used in the cooling system for the longest time, since 1958 (also in the phase of preliminary adaptation of the system). Most of the water used was taken from L. Pątnowskie.

In the 2nd period of functioning (Table 2) of the system water needed in the Pątnów

Table 2. Nominal discharge quantities for the period 1970–1983, range and average quantities of heated waters discharged and water retention time in the lakes in the years 1978–1983 (data acc. to Widomski (1971), Gadkowski (1977) and data from the Environment Protection Section of the Pątnów–Adamów–Konin Power Plants)

Lake	Nominal quantities of heated waters discharged into lakes ($m^3 \cdot sec.^{-1}$)	Range and average quantities of heated waters discharged into lakes in the years 1978–1983 ($m^3 \cdot sec.^{-1}$)	Average water retention time in lakes in the years 1978–1983 (hours)[1]
Gosławskie	22.0	22.1 12.7–35.4	67 38–173
Pątnowskie	18.0	–	77 58–197
Licheńskie	29.0	16.4 5.7–20.0	113 82–281
Mikorzyńskie	10.0	6.2 2.3–8.0	165 94–598
Ślesińskie	23.0	11.2 3.7–15.6	146 74–274

[1] Retention time has been calculated for the total volume of lakes Gosławskie and Pątnowskie and for the epilimnion volume in lakes: Licheńskie, Mikorzyńskie and Ślesińskie. Water retention in L. Pątnowskie is determined by the amount of water discharged directly into the lake and the amount of water drained from lakes: Mikorzyńskie and Licheńskie, whereas in L. Mikorzyńskie – directly by the amount of heated water discharged and water flowing in from L. Ślesińskie.

power plant was taken mainly from L. Gosławskie (about 22 $m^3 \cdot sec.^{-1}$) and (after repumping) from L. Pątnowskie (about 28 $m^3 \cdot sec.^{-1}$). Water is also supplied from the latter to the Konin power plant in quantities of about 29 $m^3 \cdot sec.^{-1}$. Heated waters, about 20 $m^3 \cdot sec.^{-1}$, from the Pątnów power plant are discharged into L. Gosławskie and therefrom with waters from the other power plant they are carried by a common canal to L. Licheńskie (about 25 $m^3 \cdot sec.^{-1}$) and (a smaller amount of about 10 $m^3 \cdot sec.^{-1}$) to L. Pątnowskie and the southern part of L. Mikorzyńskie. In summer, waters from L. Licheńskie flow to L. Ślesińskie through which they also heat the northern part of L. Mikorzyńskie. In this way in the 2nd period of the functioning of the system the amount of heated waters introduced into the cycle increases (summer periods) from 30 $m^3 \cdot sec.^{-1}$ to about 80 $m^3 \cdot sec.^{-1}$, and all the lakes are included in the cooling system.

Significant changes are brought in the water retention time in each of the lakes (Widomski 1971, Gadkowski 1977).

According to the data made available by the Environment Protection Section of the Konin-Pątnów Power Plants in the full-operation period of both power plants the lowest average annual retention time, i.e., 3 days, was recorded for the two shallow lakes: Gosławskie and Pątnowskie (Table 2). In the remaining lakes the waters (surface layers) are retained on an average for about 5 days (in L. Licheńskie) up to about 7 days (in L. Mikorzyńskie). However, these values are subject to considerable seasonal variation, depending on the intensity of work of the power plants. For instance, in the two shallow lakes the volume of water in summer is exchanged every 1.5 up to 8 days, while the surface layers of the deeper lakes – every 3–25 days. In winter, when no water is discharged into L. Ślesińskie, surface water retention in L. Mikorzyńskie depends on small amounts of heated water carried to it directly by a canal opening into the central part of the lake (Table 2, Fig. 3).

Using L. Pątnowskie as an example, Pasławski (1967) analysed in detail the changes of hydrological budget caused by inclusion of that lake into the cooling system as a source of water and as a reservoir to discharge it, and also as a receiver of mine waters. When comparing the water budget components for the periods 1926–1932 and 1963–1964 (the latter refers to 1st period of operation of the system), he found that the amount of water coming with surface inflow (permanently forming about 90–96% of the total input) increased from $26.886 \cdot 10^6$ m^3 to $55.008 \cdot 10^6$ m^3, that is, almost twofold, mainly due to mine-water discharge. The structure of the output of water also changed significantly. In the period preceding the building of the power plant surface outflow predominated (91%). In the new conditions its absolute value decreased, as well as its share in the total output (down to 30%). The absolute value of evaporation was almost doubled. Returnless use by the Konin power plant came up to about 30% of the output, and just as much was lost through underground output. The above author points that underground output from L. Pątnowskie represents most important element of the total output of water of this lake. It is supposed that a considerable underground output is the feature of the whole hydrological system considered. Though the magnitude of this phenomenon is not known, one may state that this is an example of large-scale spatial changes in water relations caused in the lake watershed by the mining and energy-producing industry.

3.2. INORGANIC AND ORGANIC POLLUTION AND LAKE LOADING WITH P AND Ca

The Konin lakes are also used as reservoirs to take and discharge water from/into by food industry and the "Aluminium" Works. Mine waters, compounds emitted by industry, and domestic sewage from numerous smaller sources are also discharged.

The inorganic compounds are the main components of the pollution. During sugar-mill operation periods organic pollutants (in BOD$_5$ quantities) did not exceed 506 kg $0_2 \cdot 24$ hours^{-1} for L. Gosławskie, and 415.3 kg $O_2 \cdot 24$ hours^{-1} for L. Pątnowskie (Gierczuszkiewicz-Bajtlik and Jabłoński 1977).

It must be pointed, however, that the amounts of sewage discharged into the lakes from various dispersed point and non-point sources like resident houses, holiday centres, agricultural and fish farms are not recorded, so the quantity of domestic and farm sewage permanently getting into the lakes should be much higher than that from the above sources.

The main load of inorganic pollutants in the lakes cames from the Struga Biskupia

Table 3. Chemical composition of the water of the Struga Biskupia river (tributary of L. Gosławskie) in the years 1976–1984

Parameters		Mean and range
T°C		10.3 1.2–21.0
O_2 ($mg \cdot dm^{-3}$)		9.2 4.4–12.0
Oxygen saturation (%)		84.6 46.9–118.9
pH	$mg \cdot dm^{-3}$	8.2 7.9–8.6
NH_4—N		0.09 0.00–0.28
NO_3—N		0.27 0.02–1.36
PO_4—P		0.118 0.016–0.229
SO_4^{-2}		34.8 8.6–73.7
Cl^{-1}		12.2 6.5–24.0
Tot. Fe		0.45 0.10–1.60
Ca^{+2}		97 77–117
Mg^{+2}		24.5 11.7–91.0
HCO_3^{-1}		387 317–445
CO_3^{+2}		0.15 0.0–15.0
Conductivity of water ($\mu S \cdot cm^{-1}$)		594 324–702

(Figs. 2, 3) receiving water from lignite opencast mines. The waters from that stream were characterized by high concentrations of nitrates, phosphates, iron, calcium, carbonates and total suspension, considerable concentrations of sulphates and magnesium, but low quantities of organic pollutants as expressed by the BOD_5 and oxidability (Table 3). Sediment pools did not remove nutrients, inorganic compounds or slowly-sedimenting loamy material from the mine waters before their being discharged into the Struga Biskupia. In L. Gosławskie the rate of their precipitation and sedimentation was significantly high, which contributed to the shallowing of this water body at the opening of the watercourse (Figura 1972, Szarfenberg 1972). Due to the forced water movement, considerable amounts of inorganic

Table 4. Indicators of water pollution in the lakes of the Gosławskie-Ślesińskie complex in the years 1976–1984

Lakes and canals	T°C	pH	O_2		BOD_5 ($mg\ O_2 \cdot dm^{-3}$)	Oxidability ($mg\ O_2 \cdot dm^{-3}$)	Dry residue			Suspension ($mg \cdot dm^{-3}$)
			$mg \cdot dm^{-3}$	%			total	volatile parts	solid parts	
Struga Biskupia	10.3 1.2–21.0	8.2 7.9–8.6	9.2 4.4–12.0	84.6 46.9–118.9	3.0 0.2–5.7	7.7 3.5–14.5	418 213–680	142 60–201	276 114–494	26.5 2.0–142.4
Suppliers of water to power plants	14.0 0.4–26.6	8.4 7.9–8.8	8.7 4.6–15.0	86.2 68.4–113.5	2.4 0.1–7.6	7.1 3.3–11.0	358 215–570	128 29–410	230 89–399	10.8 0.2–62.2
Canals for discharging heated water	20.2 6.6–34.9	8.4 7.9–8.8	8.4 5.7–12.4	96.0 77.4–114.0	2.4 0.4–5.8	7.1 4.4–10.6	366 232–542	117 46–271	249 102–383	12.2 0.3–55.0
L. Gosławskie	14.6 0.4–26.0	8.4 8.0–8.8	9.0 4.6–14.7	89.9 73.8–112.4	2.5 0.4–7.7	7.1 4.5–14.0	370 278–487	132 56–222	238 132–347	12.5 0.6–50.4
L. Licheńskie L. Pątnowskie L. Mikorzyńskie L. Ślesińskie	14.3 0.6–30.5	8.4 7.7–8.8	9.2 4.6–16.9	92.8 68.4–124.4	2.4 0.1–12.6	6.8 4.0–11.2	337 211–552	128 47–225	209 118–336	8.9 0.4–29.0

pollutants were spread throughout the whole lake complex, and the chemical composition of water in lakes and canals became similar in this way (Table 4). A low water retention time in L. Gosławskie and a high water flow rate in the canals may have favoured the resedimentation of fine-particle suspension. This is indicated by slightly higher quantities of total suspension and dry residue (Table 4).

The lakes are also contaminated with sulphur oxides and dust emitted to the atmosphere by both the power plants, as well as fluorine compounds emitted by the aluminium works (Figiel 1972, Gostyńska 1972, Twardowska 1978). The range of the impact of these sources on the lakes varied considerably during the season, depending on the local weather conditions (wind direction, air humidity, precipitation, etc.). Winds from west and south-west, prevailing in this region, may carry the gases emitted over long distances, sometimes beyond the boundaries of the region where the lakes are located. However, the range of dustfall was far narrower, over a radius of 4—11 km, but sufficient to cover the lakes Gosławskie, Pątnowskie, Licheńskie and the southern part of L. Mikorzyńskie.

The dust emitted by the power plants contains large amounts of silicates (23%), calcium and magnesium oxides (32.18%), sulphur trioxides (18%), slightly lower quantities of iron oxides (6%) and aluminium oxides (3%). These compounds are very readily leached and are able to cause water alkalization. This applies particularly to sulphates and calcium hydroxides. As a result of their high solubility, about 41% of these compounds can be leached (including about 63% of calcium). Their high sorptive capability may contribute to their precipitation as insoluble compounds containing phosphorus and fluorine (Figiel 1972, Matyjaszek 1975, Twardowska 1978).

The highest concentrations of emitted pollutants were found near the power plants. They did not exceed the allowable levels established for protected areas: 0.130 mg $\cdot$ m^{-3} air for sulphur oxides, and 200 t $\cdot$ km^{-2} a year for dust. The largest dust quantities fell on the western part of L. Pątnowskie and the southern part of L. Gosławskie (up to 140 t $\cdot$ km^{-2} a year). The lowest recorded dustfall per lake was about 10 t $\cdot$ km^{-2} a year.

A continuous dust emission in even small amounts not exceeding the allowable levels but for a long time can be a significant source of a slow enrichment of the lake waters with inorganic compounds. This process can maintain a constant, high water pH, and high concentrations of some compounds in the epilimnion. Concentrations of calcium, silicates and other compounds were fairly often slightly higher in the surface layers than in deeper layers (Korycka and Zdanowski 1976). This inorganic input from the air may activate the process of binding the considerable amounts of calcium, carbonates and phosphorus which are transported in the surface input into the lakes.

Dumped ashes and waste effluents from the two power plants can also become the source of input of inorganic compounds into the lakes. In the early 1970s the dumping was started in opencast pits near the lakes under study. To these pits large amounts are transported by floatation methods of dust from lignite burning, dust from electrofilters, and wastes arising in the process of water treatment in the power plants, i.e., decarbonization, demineralization, and maintenance of the power plant equipment.

These waste waters contain considerable amounts of heavy metals (Pacyna and Lisowski 1981).

The inorganic load from the dump pits to the lakes has not been calculated. Mine waters discharge into the lakes decrease of underground watertable over a large watershed area, higher rates of water exchange in the lakes, changes in the proportions of the water-budget components, runoff through the lake floor (Pasławski 1967) are the main symptoms of disturbances in hydrological relations which favour the migration of chemical substances within the watershed, to and from the lakes.

On the basis of available sources the annual values have been calculated of the loading of the lakes with phosphorus and calcium[3] (Table 5). In the period 1976–1983, Lake Gosławskie received on an average about 2.9 $g\ P \cdot m^{-2}$ and 2.421 $g\ Ca \cdot m^{-2}$ a year. During the functioning of the small cooling cycle (about 6 months) lakes Pątnowskie and Licheńskie received about 0.69 $g\ P \cdot m^{-2}$ and 547 $g\ Ca \cdot m^{-2}$, whereas the whole lake complex 0.44 $g\ P \cdot m^{-2}$ and 372 $g\ Ca \cdot m^{-2}$ received during the 6 months of the growing season when the great cycle is functioning. The phosphorus and calcium input to the lakes with dustfall were on an average about 0.09 $g\ P \cdot m^{-2}$ and 76 $g\ Ca \cdot m^{-2}$, representing about 9% of the total loading of the lakes with these elements.

Table 5. An estimate of the mean annual loading of lakes with P[1] and Ca from controlled sources (mine-water discharge, sugar-mill effluents, emissions) for the period 1976–1983 in $g \cdot m^{-2}$ lake surface area

Lake	P	Ca
L. Gosławskie	2.9	2.421
L. Pątnowskie L. Licheńskie[2]	0.69	547.0
Whole lake complex	0.44[3] 0.06[4]	372.0[3] 16.0[4]

[1] Without organic phosphorus. [2] For 6 months' functioning period of the small cycle (see the text). [3] For 6 months' functioning period of the great cycle (see the text). [4] Assuming a 7 days' retention time.

Loading with phosphorus is no doubt very high, several times higher than the critical levels allowable for lakes according to Vollenweider's (1968) criteria. A factor that may alleviate the effects and prevent a fast eutrophication of the lakes is the very short time of water retention in them, and the export of inorganic compounds (difficult to calculate) to the Warta river and L. Gopło, as well as output with underground water. Assuming that the average time of water retention in whole lake

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[3] Loading with phosphorus has been calculated on the basis of determination of phosphates in the Struga Biskupia and the amount of P emittet in the dust. The result is probably too low because a number of unchecked small point sources (farms, recreation centres) and input from the watershed have been left out.

complex is 7 days, the annual loading of phosphorus and calcium has been estimated at 0.06 $g \cdot m^{-2}$, and 16 $g \cdot m^{-2}$, respectively.

3.3. AVERAGE DEGREE OF HEATING OF KONIN LAKE WATERS BY HEATED-WATER DISCHARGE

Data from Korycka and Zdanowski (1976) and those from the Environment Protection Section of the Konin-Pątnów Power Plants indicate that the average yearly temperature difference (Table 6) between the lake water taken by the power plants and that discharged by them (2nd period of functioning) is 7–9°C in summer, and 11–14°C in winter. The average difference between the temperature of the heated water discharged (after passing through the canal) into the lakes and the temperature of their surface waters ranges from 2.8 to 5.7°C (data for three lakes: Licheńskie, Ślesińskie and Mikorzyńskie), but nearly 9°C in winter (Table 6). In L. Mikorzyńskie the temperature difference between the water discharged through a canal and the surface lake water is the highest one: the average value for the 1st period of functioning is 8.6°C, but comes over 12°C in winter periods. In the canals in the immediate vicinity of the points of discharging from the power plants and at different points along their course the temperature of the water is much higher, about 30°C, sometimes (instantaneous values) up to 40°C at the point of discharge (Gadkowski 1977).

Table 6. Mean values and temperature difference (°C) between study stations in the Gosławskie-Ślesińskie lake complex in the years 1965–1969 and 1970–1983 (calculated according to data from Zdanowski and Korycka (1976) and from the Environment Protection Section of the Pątnów-Adamów-Konin Power Plants)

Period	1965–1969	1970–1983
Average degree of water heating by Pątnów power plant	–	9.0 7.0–11.0
Average degree of water heating by Konin power plant	7.4 2.6–14.4	7.0 5.1–9.1
Mean water temperature difference between the discharge canal and L. Licheńskie	4.4 0.5–6.7	3.6 1.2–7.3
Mean water temperature difference between the discharge canal and L. Ślesińskie	–	2.8 0.2–5.7
Mean water temperature difference between the discharge canal and L. Mikorzyńskie	8.6 5.2–12.2	5.7 3.2–8.7

A comparison of the average seasonal temperature fluctuations for functioning periods 1st and 2nd (Fig. 4) shows that the shallow L. Gosławskie attains the highest water temperature and for the longest period in the year. The difference between the average natural temperature (prior to the inclusion in the cycle, 1st period) and the temperature resulting from heating is about 5–7°C in the winter-spring period (constantly without ice cover), and about 3–4°C in summer (Fig. 4). In spring, the

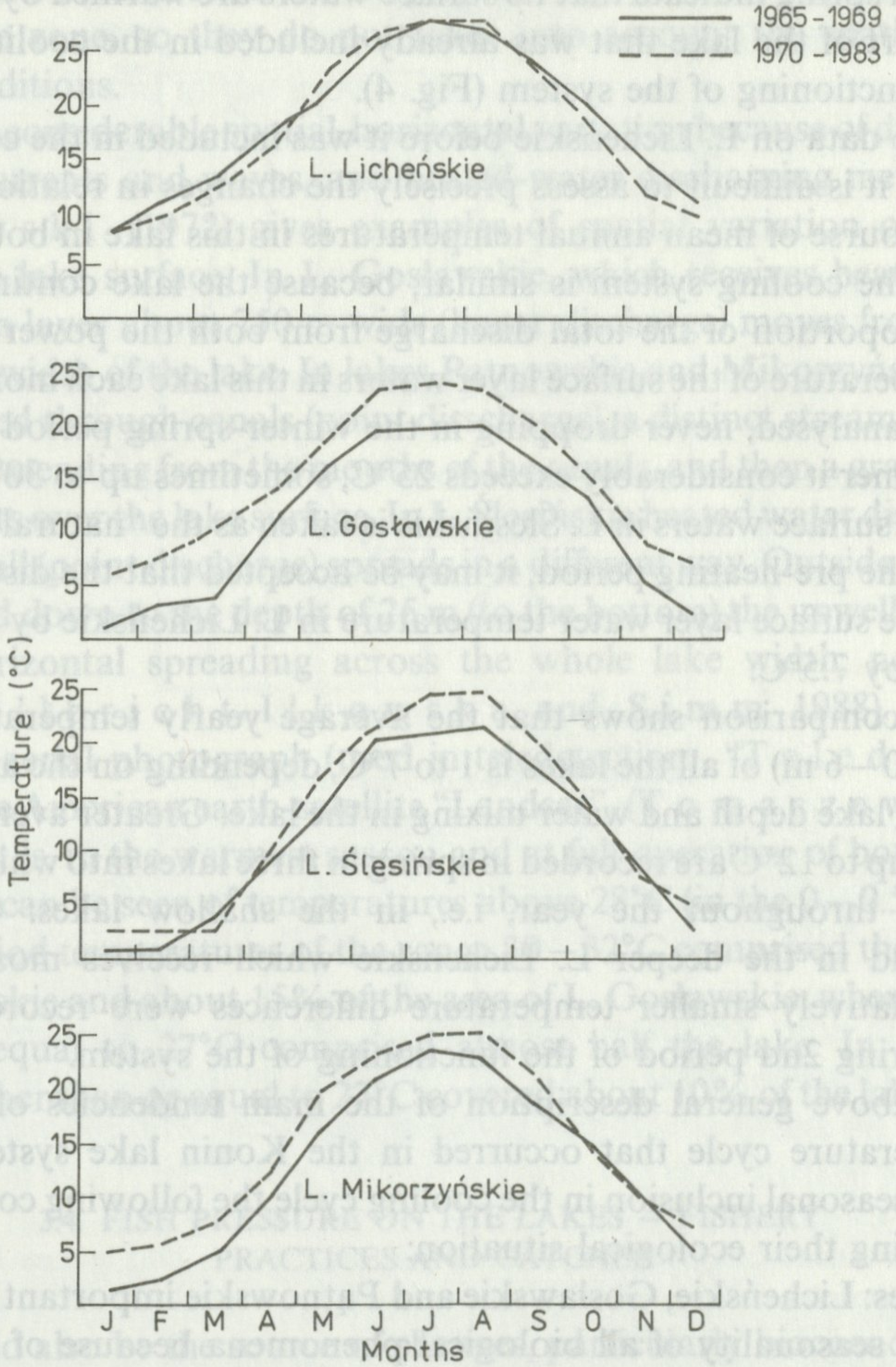

Fig. 4. Mean seasonal surface water temperature in lakes: Licheńskie, Gosławskie, Ślesińskie and Mikorzyńskie in 1965–1969 (1st period) and 1970–1983 (2nd period of the functioning of the cooling system) (data acc. to Zdanowski and Korycka 1976, unpubl. data of Inland Fisheries Institute, unpubl. data of Environment Protection Section of the Pątnów-Adamów-Konin Power Plants)

heating is also followed by a reduced rate of temperature rise in comparison to the rate of this change in a natural situation. A similar level of variation was found by Pasławski (1967) and Chojnowski (1972) for L. Pątnowskie.

In both of the deep lakes which receive heated waters for 5–6 months each year in the 2nd period of the functioning of the cooling cycle the effects of the heating are seen primarily during the warmest season. In this period the temperature difference is about 3–4°C in L. Ślesińskie which is heated directly by waters discharged in a waterfall mode, and about 1–2°C in the northern part of L. Mikorzyńskie where heated waters from L. Ślesińskie warm the surface layer of this lake (Fig. 4). Both of these lakes not often freeze over in winter. However, temperature changes in the northern part of L.

Mikorzyńskie in spring indicate that its surface waters are warmed by the waters from the southern part of the lake that was already included in the cooling system in 1st period of the functioning of the system (Fig. 4).

There are no data on L. Licheńskie before it was included in the cooling cycle (i.e., before 1958), so it is difficult to assess precisely the changes in relation to the natural situation. The course of mean annual temperatures in this lake in both periods of the functioning of the cooling system is similar, because the lake continually receives a considerable proportion of the total discharge from both the power plants. For this reason, the temperature of the surface layer waters in this lake each month is the highest of all the lakes analysed, never dropping in the winter-spring period below 8 – 10°C, whereas in summer it considerably exceeds 25°C, sometimes up to 30°C (Fig. 4). If the temperatures of surface waters in L. Ślesińskie is taken as the "natural" situation for L. Licheńskie for the pre-heating period, it may be accepted that the discharge of heated waters raised the surface layer water temperature in L. Licheńskie by 5.2 up to 12.9°C, on an average by 7.5°C.

The above comparison shows that the average yearly temperature rise for the surface waters (0 – 6 m) of all the lakes is 1 to 7°C, depending on the amount of heated waters received, lake depth and water mixing in the lake. Greater average temperature differences of 5 up to 12°C are recorded in spring in three lakes into which heated waters are discharged throughout the year, i.e., in the shallow lakes: Gosławskie and Pątnowskie, and in the deeper L. Licheńskie which receives most of the waters discharged. Relatively smaller temperature differences were recorded in summer, particularly during 2nd period of the functioning of the system.

From the above general description of the main tendencies of changes in the seasonal temperature cycle that occurred in the Konin lake system due to their successive and seasonal inclusion in the cooling cycle the following conclusions can be drawn concerning their ecological situation:

In three lakes: Licheńskie, Gosławskie and Pątnowskie important changes must be expected in the seasonality of all biological phenomena because of the permanently high water temperatures in spring and permanent absence of ice cover in winter. However, there is no rapid temperature rise in this period due to the discharging of heated waters, and, conversely, the spring temperature rise is slower than that observed in natural situations in temperate lakes. In summer, the average temperature rise, due to heating, in the surface water layers of all the lakes under observation is moderate in the sense that it is equal to 1 up to 7°C (the highest in lakes Licheńskie and Gosławskie), and there is no tendency in this period of temperatures above 25°C to occur for a longer time. An exception from this is L. Licheńskie in which higher temperatures, about 25°C, occur fairly regularly in the June-August period (Chojnowski 1972, Zdanowski and Korycka 1976). It must be mentioned, however, that the above conclusions concern the mean temperature of the surface water layers, that is, from 0 to 5 – 6 m, and the average long-term trends illustrated in Figure 4. In particular years and lakes, particularly in lakes Gosławskie, Pątnowskie and Licheńskie temperatures of the order of 25 – 28°C occur fairly often, especially in the top 0 – 2 m water layer. Moreover, all the data used in the analysis of long-term changes have been obtained from measurements at fixed stations. They do not apply to the temperature conditions in the near-shore zone, so they do not take into account the spatial variation in temperature conditions.

There may be considerable spatial-horizontal variation because of differences in the distribution of currents and waves, and heated-water discharging method.

Chojnowski (1972) gives examples of spatial variation of heated-water spreading on the lake surface. In L. Gosławskie, which receives heated water from spillways, a warm layer about 750 m wide (linear discharge) moves from east to west across the whole width of the lake. In lakes Pątnowskie and Mikorzyńskie, into which water is discharged through canals (point dirscharge), a distinct stream of warm water can be observed extending from the mouths of the canals, and then a gradual spreading of the warm waters over the lake surface. In L. Ślesińskie heated water discharged into it through a waterfall (point discharge) spreads in a different way. Outside the zone where the water is mixed down to the depth of 25 m (to the bottom) the upwelling can be seen and then its horizontal spreading across the whole lake width, northwards and southwards (Hillbricht-Ilkowska and Simm 1988).

In a thermal aerial photograph (used in teledetection, "Teledetekcja..." 1980) taken by the American earth-satellite "Landsat" (Tomaszewski 1978) in August 1975, that is, in the warmest season and at full operation of both of the power plants, the range can be seen of temperatures above 28°C (in the 0 – 0.5 m layer) in all lakes. In that period temperatures of the range 30 – 32°C comprised the whole surface area of L. Licheńskie and about 15% of the area of L. Gosławskie, where temperatures higher than or equal to 27°C comprised almost half the lake. In L. Pątnowskie temperatures higher than or equal to 27°C covered about 10% of the lake surface area.

3.4. FISH PRESSURE ON THE LAKES – FISHERY PRACTICES AND CATCHES

Fishery should also be the source of changes, particularly biocoenotic changes, in the lakes of Konin.

In the years 1966 – 1968 the grass carp (*Ctenopharyngodon idella* Val.) and the silver carp (*Hypophthalmichthys molitrix* Val.) were introduced into lakes Licheńskie and Pątnowskie (Zawisza and Backiel 1972), and the introduction of the eel was continued. The introduction of about 3.5 thous. grass carp individuals, each about 0.5 kg in body-weight, resulted in the destruction of higher vegetation in L. Licheńskie (Zawisza and Backiel 1972) and thereby the spawning grounds for other fish species.

There have also occurred changes in the fish productivity of the lakes. In 1st period of the use of the lakes in the cooling system an increase in fish catches was reported, followed by a decline that has continued to date. According to data from the Inland Fisheries Institute (Fig. 5), in the period 1958 – 1970 catches in L. Licheńskie increased from 17.4 to 46.4 kg · ha^{-1} (as the result of the introduction of herbivorous fish), and in the years 1971 – 1982 they decreased down to 21.9 kg · ha^{-1}. The corresponding data for L. Ślesińskie were 32.3 vs. 26.1 and for L. Mikorzyńskie 43.5 vs. 13.1 kg · ha^{-1}. In the

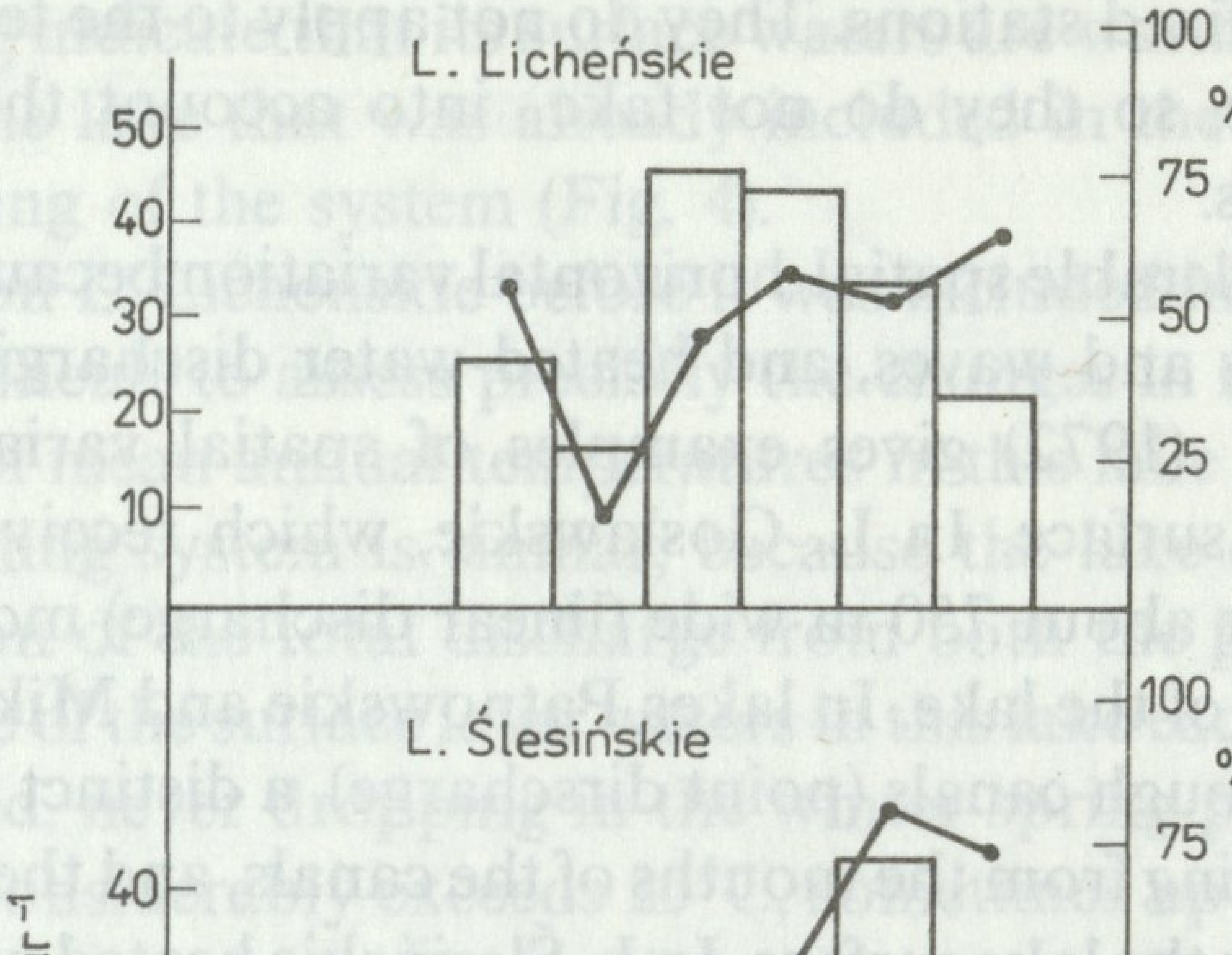

Fig. 5. Average fish catches (in kg · ha⁻¹) for different periods in 1951 – 1982 in three lakes near Konin with indication of the percentage of low-value fish catches (mainly young individuals of the roach, bream, white bream)

years 1967 – 1976 the average catch of native fish in L. Gosławskie was about 58 kg · ha^{-1}. Following the period of intensive stocking with the silver carp in 1976 the catches almost trebled (with a maximum of 177 kg · ha^{-1} in 1977) mainly owing to the catching of the latter fish species. In the last period (1980 – 1983) catches of native ichthyofauna practically dropped to 20 kg · ha^{-1}, and of the silver carp to about 10 kg · ha^{-1} (Wilkońska 1988).

Very significant changes in catch species composition have also been found. The proportion has risen of low-value fish, such as small individuals of the roach, bream and white bream (Fig. 5). Relative numbers have also changed of various fish species, e.g., there has been a tendency towards growing percentages of the roach, bleak, tench, carp and crucian carp, and of predaceous fish like the pike-perch and rheophilous chub, and at the same time a numerical decline has been recorded of the perch and pike (Wilkońska and Żuromska 1983a). Most of the changes can be interpreted as the results from the conflict between the thermal tolerance of fish and the habitat characterizing by the longer period of high temperature and the lack of ice cover (Frieske 1972, Zawisza and Backiel 1972). Very significant changes have been found in the growth rate of fish and fry (e.g., impeded growth at temperatures above 28°C) and in the starting and lasting of breeding seasons of fish (Rola... 1972, Zawisza and Backiel 1972, Marciak 1977, Wilkońska 1977, Wilkońska and Żuromska 1977a, 1977b, 1977c, 1978, 1983a, 1983b, Żuromska 1977). An increase in mortality, due to parasite infestation, has been recorded (Niewiadomska 1977). The effects resulted from the destruction of littoral vegetation by the grass carp have been also noted (Zawisza and Backiel 1972).

In general, it may be presumed that after an intensive temporary growth caused by the introduction of herbivorous species, fish pressure upon the biocoenose of the heated lakes became at present stabilized probably on a relatively lower level.

4. CONCLUSIONS

The above-presented results of the studies carried out so far, characterize the Konin lakes as particularly convenient sites for studying the multidirectional impact of the mining- and energy-producing industries, on account of the kind and range of the various causes of changes.

The results relating to changes in the water retention time and hydrological relations in general (underground output) of the Konin lakes indicate the magnitude of changes in the basic conditions of their habitat and possible effects on the biocoenosis. The lakes function as a river system, at least it applies to their surface water layers. The most affected of them is L. Licheńskie which has become a through-flow lake, and so have both of the shallow lakes: Gosławskie and Pątnowskie.

As a result of the velocity of flow between lakes (the total cycle time is 7 days), the chemical composition of the waters tends to become uniform, and local effects (e.g., waste effluents) spread across the whole system. In the new hydrological system new factors of selection of organisms should be expected. It must be emphasized that the average water retention time in the lakes (especially in the shallow ones), is close to several days, and thus is shorter than the average time of one generation in most plankton invertebrates.

An analysis of temperature changes in the Konin lakes indicates that a new thermal regime was formed. The natural seasonal cycle has been disturbed (particularly in three of the lakes). The spring temperatures are on average much higher (as compared with natural conditions), and occurr much longer. The summer temperatures are moderately higher and a significant and permanent thermal zonation in each of the lakes was formed. Apart from this, in summer in some of the lakes, notably in L. Licheńskie, temperatures above 28°C occur occasionally and thus critical situations arise for the organisms (Hillbricht-Ilkowska and Zdanowski 1988).

Finally, the Konin lakes constantly function as reservoirs for the discharging of considerable amounts of inorganic compounds, mainly Ca, Si and P (mine waters and emitted compounds).

High calcium inputs in a lake should favour a steady growth of its concentration in the lake water (which is the case, cf. Korycka and Zdanowski 1976) which in turn intensifies precipitation and deposition in bottom sediments. This process may in turn have led on to the binding of not only the phosphorus in inputs, but also of the standing stock of this element in the water bodies, thus reducing the fertility of the lakes. Calcium phosphate compounds may have accumulated particularly in the bottom sediments of the littoral and of the power-plant canals, especially in their off-flow zones. Fine fluoro-apatite particles were to a smaller extent subject to sedimentation in the profundal zone [4], the more so as the process was prevented by the high-rate water flow. The above data on the inorganic contaminants (from various sources: waste effluents, precipitation, emissions) in the lakes make one expect progressing desalination and alkalization of their waters, changes in their chemical composition and ion ratios, and a relatively inactivation of phosphorus loads.

An analysis of fishery practices (primarily the introduction of the grass carp which resulted in the extinction of higher vegetation in L. Licheńskie) and long-term changes in fish catches, as well as the trends in catch structure also indicate that the varying fish pressure on the habitat of heated lakes act as an equivalent cause of biocoenotic changes in them.

5. SUMMARY

The location, watershed relations and limnological characteristics have been described of five lakes near Konin (Fig. 1, Table 1). A detailed description is also given of their functioning as a through-flow system for cooling the heated waters discharged by two power plants (Figs. 2, 3).

The range and intensity of effects of heated waters varied in relation to the period of functioning of the whole system in the cooling process.

In 1st period (1958 – 1969) heated waters were discharged into three lakes, i.e., Licheńskie, Pątnowskie and the southern part of L. Mikorzyńskie.

In 2nd period (since 1970) the permanent cooling system has also included L. Gosławskie, and in summer also L. Ślesińskie is linked up so in summer all the Konin lakes take part in the cooling process. The quantities are given of water discharged and taken up, as well as estimates of water retention time in the lakes (Table 2). The average water retention time in 2nd period (since 1970) has diminished several – to over dozen-fold, amounting in summer to about 7 days for all the lakes, and 3 – 25 days in particular lakes.

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[4] Phosphate content was determined in unfiltered water samples by the colorimetric method with ammonium molybdate. In this method subsamples are acidified, which facilitates the solution of the inorganic fraction of particulate phosphorus. Considerable amounts of these compounds may have resulted in an overestimation of the absolute values of soluble reactive phosphorus concentrations in periods of a high-rate decalcification, especially in intensively mixed medium where a certain amount of a low-sedimentation-rate fraction of inorganic seston remains in suspension. This is confirmed by calcium determination with the EDTA titrimetric method (without filtration) and by flame photometry (filtered samples). Calcium quantities determined with the former method were usually larger.

The discharge of mine waters and underground output became significant in the hydrological budget of the lakes. The quantities of inorganic compounds brought with these waters (Table 3), particularly NO_3, PO_4, Fe, Ca, CO_3, SO_4 and gases are high. Together with chimney dustfalls they constitute the cause of a constant rise of the concentration of inorganic compounds, of the alkaline reaction of the lake waters (Table 4) and a very high annual loading of the lake waters with P and Ca (Table 5). It is pointed that this process can partially limit lake eutrophication by inactivating dissolved phosphorus (sorption) and depositing it (especially in the littoral) on sedimenting particles of calcium carbonate and loam.

Mean level of heating lake waters (Table 6, Fig. 4) in different periods of the cooling system functioning was also characterized.

In summer, temperature differences in relation to natural conditions are 1 to 7°C. Significant disturbances in the seasonal cycle have been demonstrated (lack of ice cover, slower temperature rise in spring), as well as a permanent presence of a thermal zonation in all the lakes. Fishery can also be the cause of changes in the lake biocoenose. The introduction of the grass carp (and extinction of higher vegetation in two lakes) and silver carp was followed at first by an increase and then by a decrease in fish catches. The permanent change in the species composition of the catches was noted (Fig. 5).

6. POLISH SUMMARY

Opisano położenie, stosunki w zlewni oraz cechy limnologiczne pięciu jezior konińskich (rys. 1, tab. 1) oraz opisano szczegółowo ich funkcjonowanie jako układu otwartego chłodzenia wód ciepłych zrzucanych przez dwie elektrownie (rys. 2, 3).

Zasięg i intensywność oddziaływania wód ciepłych jest różna zależnie od okresu funkcjonowania całego systemu.

W okresie I (1958 – 1969) trzy jeziora, tzn. J. Licheńskie, Pątnowskie i południowe ploso J. Mikorzyńskiego, objęte są zrzutem wód ciepłych.

W okresie II (od roku 1970) stały obieg chłodzenia obejmuje również J. Gosławskie, zaś w okresie letnim do układu chłodzenia wprowadzane jest również J. Ślesińskie, powodując, że w układzie tym funkcjonują wszystkie jeziora systemu. Podano ilości wody zrzucanej i pobieranej oraz oceny retencji wód w jeziorach, które mogą wtórnie kształtować funkcjonowanie całego jeziora (tab. 2).

Przeciętny czas retencji wód w II okresie (od 1970) zmniejszył się kilka-kilkunastokrotnie wynosząc około 7 dni dla całego systemu jezior w okresie letnim, zaś około 3 – 25 dni w poszczególnych akwenach.

W bilansie hydrologicznym jezior istotne znaczenie ma dopływ wód pokopalnianych oraz odpływ podziemny. Ilości związków mineralnych wprowadzanych z tymi wodami (tab. 3), zwłaszcza NO_3, PO_4, Fe, Ca, CO_3, SO_4 i gazów, są wysokie i razem z opadami pyłów kominowych stanowią źródło stałego wzrostu koncentracji soli mineralnych i alkalicznego odczynu wód jezior (tab. 4), jak też bardzo wysokiego rocznego obciążenia ładunkami P i Ca (tab. 5) ich powierzchni. Wskazano, że proces ten może częściowo ograniczać eutrofizację jezior poprzez inaktywację fosforu rozpuszczonego (sorpcja) i jego deponowanie w wodach (szczególnie litoralu) na sedymentujących cząstkach węglanu wapnia i ilastych.

Scharakteryzowano również przeciętny poziom podgrzania wód jezior (tab. 6, rys. 4) w różnych okresach funkcjonowania układu chłodzenia.

Różnice w stosunku do temperatur naturalnych w okresie letnim wynoszą od 1 do 7°C. Wskazano na zasadnicze odkształcenia cyklu sezonowego (brak zlodzenia, wolniejsze tempo wzrostu temperatury w okresie wiosennym) oraz na trwałe występowanie strefowości termicznej we wszystkich jeziorach.

Źródłem przeobrażeń biocenozy jezior winna być również gospodarka rybacka – w wyniku introdukcji amura (i zaniku roślinności wyższej w dwóch jeziorach) i tołpygi, początkowo wzrosła, a następnie spadła wydajność rybacka z jednoczesną zmianą składu gatunkowego odłowów (rys. 5).

7. REFERENCES

1. Chojnowski S. 1972 — Wstępna charakterystyka zjawisk termicznych w jeziorach konińskich [A preliminary description of thermal phenomena in the Konin lakes] — Prace PIHM, 107: 99—118.
2. Figiel J. 1972 — Ochrona powietrza atmosferycznego przed szkodliwym działaniem elektrowni Pątnów i Konin [Air protection against the harmful effects of the Pątnów and Konin power plants] — Mat. Konf. "Ochrona środowiska konińskiego okręgu przemysłowego", kwiecień 1972, Konin, 53—75.
3. Figura K. 1972 — Badania fizyko-chemiczne jezior konińskich [Physico-chemical studies of the Konin lakes] — Mat. Konf. "Ochrona środowiska konińskiego okręgu przemysłowego", kwiecień 1972, Konin, 76—93.
4. Frieske Z. 1972 — Wpływ wód podgrzanych na eksploatację rybacką jezior pasma Gosławsko-Ślesińskiego [Impact of heated waters on the fishery of the Gosławsko-Ślesińskie lake chain] — Woj. Konf. naukowo-techniczna "Rola wód podgrzanych w produkcji rybackiej", 8—9 czerwiec 1972, Konin, 1—18.
5. Gadkowski M. 1977 — Zmiany termiczne w zbiornikowych obiegach chłodzenia [Temperature changes in lake cooling cycles] — Gosp. wodna, 12: 375—379.
6. Giercuszkiewicz-Bajtlik M., Jabłoński J. 1977 — Zagrożenie wód jeziornych Polski w wyniku ich zanieczyszczenia ściekami [Threat to lake waters in Poland as a result of their pollution with sewage] — Wyd. Inst. Kształ. Środ., Warszawa, 43 pp.
7. Gostyńska J. 1972 — Charakterystyka rozprzestrzeniania się zanieczyszczeń atmosfery w rejonie konińskiego okręgu przemysłowego na tle rzeźby terenu i warunków klimatyczno-meteorologicznych [Description of the spreading of air pollution in the Konin industrial region in relation to the relief and climatic-meteorological conditions] — Mat. konf.
8. Hillbricht-Ilkowska A., Simm A. T. 1988 — Spatial pattern of temperature, oxygen and nutrient concentration in two lakes of different heated-water discharge systems — Ekol. pol. 36: 165—182.
9. Hillbricht-Ilkowska A., Zdanowski B. 1988 — Changes in lake ecosystems connected with the power-generating industry (the outline of problem); the Konin lakes (Poland) as the study sites — Ekol. pol. 36: 5—21.
10. Korycka A., Zdanowski B. 1976 — Wpływ zrzutu wód podgrzanych na chemizm wody jezior konińskich [The influence of effluent waters on the water chemism of Konin lakes] — Rocz. Nauk. roln. 97, H-3: 89—107.
11. Marciak Z. 1977 — Wpływ podgrzania wody przez elektrownię cieplną na wzrost leszcza w jeziorach konińskich [Influence of the thermal effluents from an electric power plant on the growth of the bream in the Konin Lake Complex] — Rocz. Nauk roln. 97, H-4: 17—43.
12. Matyjaszek W. 1975 — Próba oceny wpływu zwałowania odpadów górnictwa węglowego na zasolenie wód [A trial for assessing the effect of coal-mine waste dumping on the salinity of waters] — Gosp. wodna, 9: 296—297.
13. Niewiadomska K. 1977 — Pasożyty wylęgu i narybku niektórych gatunków ryb z jezior konińskich [Parasites of hatchlings and of fry of some fish species from the Konin Lake Complex] — Rocz. Nauk roln. 97, H-4: 45—59.
14. Pacyna J., Lisowski A. 1981 — Wymywanie zanieczyszczeń z powietrza w zraszalnikach chłodni w elektrowniach [Leaching of pollutants from the air in the sprinklers of power-plant coolers] — Gosp. wodna, 11/12: 280—282.
15. Pasławski Z. 1967 — Stosunki termiczne i wodne jeziora Pątnowskiego [Thermal and water relations of the L. Pątnowskie] — Gosp. wodna, 4: 117—122.
16. Podział hydrograficzny Polski [A hydrographic map of Poland] — Wyd. Inst. Meteorologii i Gosp. Wodnej, 921 pp.
17. Rola wód podgrzanych w produkcji rybackiej [The role of heated waters in fishery] — Kraj. Konf. naukowo-techniczna, 8—9 czerwiec 1972, Konin (streszczenia referatów).
18. Szarfenberg M. 1972 — Badania biologiczne jezior konińskich [Biological studies of the Konin

lakes] – Mat. Konf. "Ochrona środowiska konińskiego okręgu przemysłowego", kwiecień 1972 – Konin, 94–115.

19. Teledetekcja w gospodarce narodowej (wybrane przykłady), 1980 [Teledetection in national economy (selected examples)] – Wyd. Głównego Urzędu Geodezji i Kartografii, Warszawa, 5 pp.
20. Tomaszewski S. 1978 – Obserwacje satelitarne w badaniach środowiska [Satellite observations in environmental studies] – Przyr. pol. 5: 6–8.
21. Twardowska J. 1978 – Zastosowanie pyłów dymnicowych do unieszkodliwiania odpadów hutnictwa aluminium [The use of smoke-box dust for the neutralization of wastes from aluminium metallurgy] – Gosp. wodna, 1: 13–17.
22. Vollenweider R. A. 1968 – Scientific fundamentals of the eutrophication of lakes and flowing waters with particular reference to nitrogen and phosphorus as factors in eutrophication – OECD. Directorate for Sci. Affairs, Paris, DAS (CSI), 68, 27: 1–182.
23. Widomski A. 1971 – Wyniki badań hydrotermicznego obiegu chłodzącego elektrowni Pątnów i Konin w lipcu 1970 [Results from studies of the hydrothermal cooling cycle of the Pątnów and Konin power plants in July 1970] – Gosp. wodna, 3: 96–103.
24. Wilkońska H. 1977 – Wzrost płoci (*Rutilus rutilus*) w podgrzanym jeziorze Licheńskim [Growth of roach (*Rutilus rutilus*) in heated Licheńskie Lake] – Rocz. Nauk roln. 97, H-4: 60–75.
25. Wilkońska H. 1988 – The effect of the introduction of herbivorous fish in the heated Lake Gosławskie (Poland) on the fry of local ichthyofauna – Ekol. pol. 36: 275–281.
26. Wilkońska H., Żuromska H. 1977a – Obserwacje rozrodu ryb w jeziorach konińskich podgrzewanych zrzutami ciepłych wód z elektrowni [Observation on reproduction of fish in Konin Lake Complex heated by effluent waters from a power plant] – Rocz. Nauk roln. 97, H-4: 77–89.
27. Wilkońska H., Żuromska H. 1977b – Wzrost narybku w podgrzewanych jeziorach konińskich [Growth of fry in the heated Konin Lake Complex] – Rocz. Nauk roln. 97, H-4: 91–111.
28. Wilkońska H., Żuromska H. 1977c – Zmiany w składzie gatunkowym narybku w płytkim litoralu podgrzewanych jezior konińskich [Changes in the species composition of fry in the shallow littoral of heated lakes of the Konin Lake Complex] – Rocz. Nauk roln. 97, H-4: 113–134.
29. Wilkońska H., Żuromska H. 1978 – Zmiany w składzie gatunkowym narybku w płytkim litoralu podgrzewanych jezior konińskich w ciągu 10 lat [Changes in the species composition of fry in the shallow littoral of heated Konin Lake Complex during a 10-year period] – Wyd. Inst. Ryb. Śródlądowego, Olsztyn, 27 pp.
30. Wilkońska H., Żuromska H. 1983a – Wzrost narybku w podgrzewanych jeziorach konińskich w latach 1966–1977 [Growth of fry in the heated Konin lakes in 1966–1977] – Rocz. Nauk roln. 100, H-7: 123–148.
31. Wilkońska H., Żuromska H. 1983b – Zmiany składu gatunkowego narybku w podgrzanych jeziorach konińskich w latach 1966–1975 [Changes in the species composition of fry in the heated Konin Lake Complex in 1966–1975] – Rocz. Nauk roln. 100, H-7: 149–165.
32. Zawisza J., Backiel T. 1972 – Some results of fishery biological investigation at heated lakes – Verh. int. Verein. Limnol. 18: 1100–1107.
33. Zdanowski B., Korycka A. 1976 – Wpływ zrzutu wód podgrzanych na stosunki termiczno-tlenowe i przezroczystość wody jezior konińskich [The influence of heated effluent waters on the thermal-oxygen relations and water transparency in the Konin Lake Complex] – Rocz. Nauk roln. 97, H-3: 141–164.
34. Żuromska H. 1977 – Wzrost wzdręgi (*Scardinius erythrophthalmus*) w jeziorze sztucznie podgrzanym [Growth of the rudd (*Scardinius erythrophthalmus*) in the artificially heated lake] – Rocz. Nauk roln. 97, H-4: 135–151.

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