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A regulated river ecosystem in a polluted section of the Upper Vistula*

9. Ichthyofauna

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Abstract — Catches of fish were made in the 1982 to 1984 period. The changes that have taken place in the ichthyofauna of the Upper Vistula during the last 100 years were compared. The constantly increasing pollution has contributed to the recession from the Vistula above Kraków not only of most predatory fish but also of species of the cyprinid family. The present conditions of the environment are distinctly leading to complete destruction of the fish.

Key words: regulated river, pollution, ichthyofauna, predators, forage fish, parasites, diseases.

1. Introduction

The ichthyofauna of the Vistula in the region of Kraków has for many years been the subject of investigations, whose results were nearly all published (Wałecki 1864, Nowicki 1880, 1882, 1883, 1889, Fiszer 1895, Rozwadowski 1900, Rychlicki 1933, Szymczuk 1934, Starmach 1948, Kołder 1964a, 1964b, Kołder et al. 1974, Żarnecki, Kołder 1956, Brzozowski, Tobiasz 1964, Tobiasz 1962, Bieniarz, Epler 1972, Epler, Bieniarz 1973, Backiel 1983, Kajak 1983). The studies of some authors from 1952 (Żelazny), 1956, 1960, and 1966 (Kołder), from 1960 (Kołder, Pałka), and from 1975 (Skóra et al.), in the form of unpublished manuscripts are valuable documents, housed in the Institute of Freshwater Biology of the Polish Academy of Sciences and at the Polish Anglers' Union in Kraków.

The aim of the present work was to make an assessment of the current

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state of the ichthyofauna in the region of the water stage on the Vistula at Łączany above Kraków, and to compare the changes that have taken place in the Upper Vistula near Kraków (in the barbel zone) over the last 100 years.

2. Study area

The investigations were carried out between kilometres 38 and 60 of the course of the Vistula, on the section between the water stage at Łączany (Station 3) and the mouth of the River Skawinka (fig. 1). A detailed description of the study area has been given by Dumnicka and Kownacki (1988). On the right hand bank of the Vistula, at the

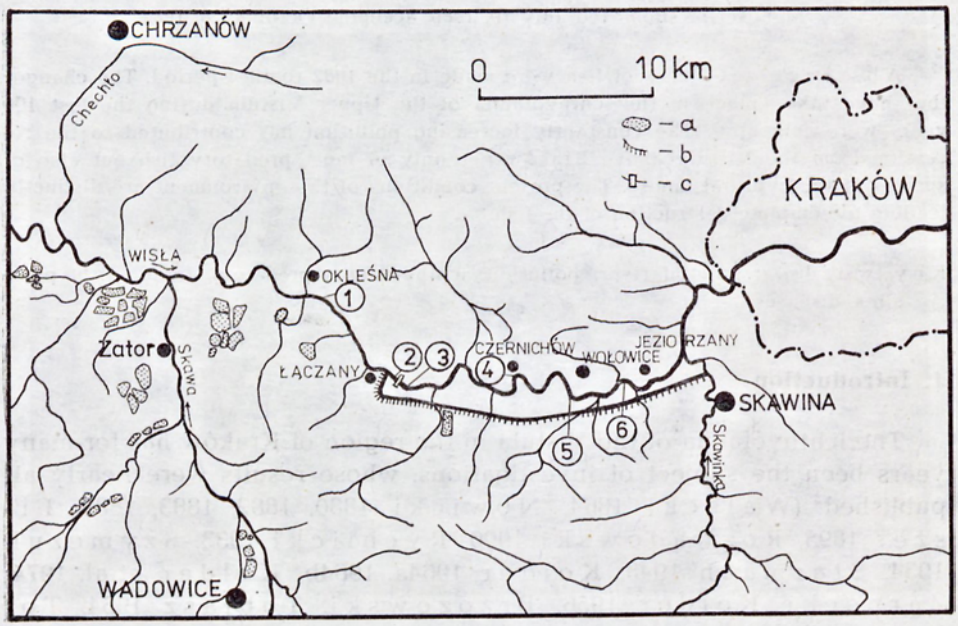

Fig. 1. Map of investigated area. 1—6 — sampling stations; a — ponds; b — canal; c — water stage

village of Brzeźnica, lies a fairly large complex of carp ponds, from which runs a millstream falling into the Vistula. Immediately above the water stage at Łączany, on the right hand bank, several millstreams run into the Vistula, draining large pond complexes belonging to the Inland Fisheries Institute, (formerly the Institute of Zootechnics) in Zator and the State Fish Farm in Kraków.

3. Material and methods

The investigations on the ichthyofauna inhabiting the studied section of the River Vistula were carried out from 1982 to 1984. During this period fish were caught three times in the fish pass located in the water stage at Łączany (in 1982, on 30 Jul., 17 Sept., and 11 Oct.) and nine times in the river (in 1982 on 11 Oct., 21 Oct., 22 Oct., in 1983 on 8 Jul., 29 Sept., 30 Sept., 1 Oct., and 2 Oct. and in 1984 on 13 Apr.). The length of the sector of every catch was about 3 km. Catches in the river were made from a boat using a direct current generator of about 220 V, 4—6 A, while for those in the pass the generator was positioned beside it. 100% of the fish were caught in the chambers of the fish pass. The fish caught were counted, identified down to species, after which their total length and body length were measured, and the body weight of each was determined. In order to assess their age and rate of growth, several scales were taken from each fish. Some of those caught were preserved in formalin, their alimentary tracts were removed and the contents examined. The health of the fish was also assessed. The measurements obtained were subjected to statistical analysis (Kołder et al. 1974, Włodek 1975). Moreover, for the whole population of fish caught, the coefficients of condition were calculated according to Fulton's formula:

$$K = \frac{g \times 100}{L^3}$$

where: g — the body weight of the fish, L — its total length.
The coefficients of the filling of the alimentary tracts were calculated according to the formula:

$$W = \frac{p \times 100}{P}$$

where: p — the weight of the fish's food, P — the body weight of the fish.

In the alimentary tracts the taxonomic composition of the diet was determined and the percentage of its particular components estimated.

In the investigations on the structure of the ichthyofauna the limits of dominance were arbitrarily assumed as follows: 10—25% — ordinary dominance, a share of a given species over 25% both in numbers and weight — prime dominance.

4. Results

4.1. Structure of the ichthyofauna

A haul of 53 fish with a total weight of 12.7 kg was obtained from the fish pass, and one of 701 fish with a total weight of 68.5 kg from the

Table I. Number (N) and percentage share of fish caught in Vistula and in the fish pass at the Łączany water stage in the period 1982–1984

Species	River										Fish pass	
Period of catches	1982		1983				1984		1982–1984		1982	
	Autumn		Summer		Autumn		Spring		Total		Summer	
	N	%	N	%	N	%	N	%	N	%	N	%
Cyprinus carpio L.	2	2.82	2	1.14	–	–	2	1.53	6	0.86	–	–
Carassius auratus gibelio Bloch	1	1.41	33	18.75	13	4.04	9	6.87	56	8.00	–	–
Barbus barbus L.	2	2.82	7	3.98	18	5.59	–	–	27	3.86	11	28.95
Gobio gobio L.	38	53.52	10	5.68	–	–	13	9.92	61	8.71	1	2.63
Abramis brama L.	1	1.41	8	4.55	–	–	–	–	9	1.29	4	10.53
Blicca björkna L.	–	–	6	3.41	–	–	–	–	6	0.86	2	5.26
Leucaspius delineatus Heckel	–	–	–	–	–	–	1	0.76	1	0.14	–	–
Alburnus alburnus L.	4	5.63	46	26.14	89	27.64	15	11.45	154	22.00	9	23.69
Leuciscus leuciscus L.	2	2.82	4	2.27	27	8.39	7	5.34	40	5.71	–	–
Leuciscus cephalus L.	7	9.86	18	10.23	106	32.92	11	8.40	142	20.29	1	2.63
Scardinius erythrophtalmus L.	4	5.63	3	1.70	–	–	–	–	7	1.00	–	–
Rutilus rutilus L.	7	9.86	14	7.95	9	2.80	4	3.05	34	4.86	10	26.32
Phoxinus phoxinus L.	–	–	–	–	6	1.86	–	–	6	0.86	–	–
Chondrostoma nasus L.	–	–	2	1.14	34	10.56	–	–	36	5.14	–	–
Total of Cyprinidae	68	95.77	153	86.93	302	93.79	62	47.33	585	83.58	38	100.00
Nemachilus barbatulus L.	3	4.23	22	12.50	20	6.21	56	42.75	101	14.43	–	–
Anguilla anguilla L.	–	–	1	0.57	–	–	–	–	1	0.14	–	–
Perca fluviatilis L.	–	–	–	–	–	–	13	9.92	13	1.86	–	–
Total of other fish	3	4.23	23	13.07	20	6.21	69	52.67	115	16.43	–	–
Total	71	100.00	176	100.00	322	100.00	131	100.00	700	100.00	38	100.00

Table II. Biomass of fish caught in the Vistula and in the fish pass at the Łączany water stage in the period 1982–1984

Species	River										Fish pass	
Period of catches	1982		1983				1984		1982–1984		1982	
	Autumn		Summer		Autumn		Spring		Total		Summer	
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
Cyprinus carpio L.	0.14	6.92	0.22	1.45	–	–	0.86	20.25	1.22	2.19	–	–
Carassius auratus gibelio Bloch	0.04	1.96	2.48	16.46	3.27	9.55	0.70	16.35	6.49	11.68	–	–
Barbus barbus L.	0.15	7.63	2.80	18.58	8.10	23.65	–	–	11.05	19.89	6.30	78.60
Gobio gobio L.	0.34	17.44	0.15	1.02	–	–	0.13	3.14	0.63	1.13	0.01	0.16
Abramis brama L.	0.13	6.56	0.95	6.32	–	–	–	–	1.08	1.95	0.38	4.79
Blicca björkna L.	–	–	1.19	7.90	–	–	–	–	1.19	2.14	0.48	6.00
Leucaspius delineatus Heckel	–	–	–	–	–	–	0.00	0.02	0.00	0.00	–	–
Alburnus alburnus L.	0.05	2.80	0.90	5.99	1.44	4.21	0.43	9.97	2.83	5.09	0.14	1.68
Leuciscus leuciscus L.	0.02	1.07	0.13	0.88	0.43	1.25	0.36	8.40	0.94	1.69	–	–
Leuciscus cephalus L.	0.65	33.16	4.27	28.35	18.81	54.93	0.55	12.86	24.29	43.72	0.17	2.12
Scardinius erythrophtalmus L.	0.09	4.58	0.18	1.20	–	–	–	–	0.27	0.49	–	–
Rutilus rutilus L.	0.34	17.04	0.50	3.34	0.48	1.40	0.16	3.68	1.47	2.65	0.53	6.65
Phoxinus phoxinus L.	–	–	–	–	0.02	0.05	–	–	0.02	0.03	–	–
Chondrostoma nasus L.	–	–	0.16	1.07	1.51	4.42	–	–	1.68	3.02	–	–
Total of Cyprinidae	1.95	99.14	13.95	92.56	34.06	99.46	3.18	74.68	53.14	95.67	8.01	99.99
Nemachilus barbatulus L.	0.02	0.86	0.27	1.77	0.18	0.54	0.67	15.79	1.14	2.05	–	–
Anguilla anguilla L.	–	–	0.85	5.67	–	–	–	–	0.85	1.55	–	–
Perca fluviatilis L.	–	–	–	–	–	–	0.41	9.53	0.41	0.73	–	–
Total of other fish	0.02	0.86	1.12	7.44	0.18	0.54	1.08	25.32	2.40	4.33	–	–
Total	1.97	100.00	15.07	100.00	34.24	100.00	4.26	100.00	55.54	100.00	8.01	99.99

river. Altogether during the period of study 17 species belonging to 4 families — Cyprinidae, Percidae, Cobitidae, and Anguilidae — were caught. The cyprinid family, to which 14 species belonged (Tables I, II) was the most numerously represented. Predatory species were not particularly important.

The barbel (*Barbus barbus L.*) should be the indicator species for the river section investigated. In the present catches it occurred in fairly small quantities, numerically comprising 3.9% of all the fish caught, but dominating in terms of weight, at 19.9%. Most specimens of the species

were caught in the chambers of the fish pass, where in July 1982 it was the prime dominant both with respect to numbers (28.9%) and to weight (78.6%) (Tables I, II).

The chief, prime dominant of the ichthyofauna was the chub (*Leuciscus cephalus*). It dominated both numerically and in weight, replacing the barbel as the indicator species.

The dace (*Leuciscus leuciscus* L.) occurred in fairly small quantities and did not achieve dominance. The gudgeon (*Gobio gobio L.*) dominated only once (in the autumn of 1982). The bream (*Abramis brama* L.) also played no great role in the ichthyofauna caught. Only in the fish pass in the summer of 1982 did it occur somewhat more numerously, comprising 10.3% of the numbers of the haul. In the autumn of 1983 and spring of 1984 there were no bream at all in the catches; nor did the white bream (*Blicca björkna* L.), carp (*Cyprinus carpio* L.), roach (*Rutilus rutilus* L.), rudd (*Scardinius erythrophtalmus* L.), nose carp (*Chondrostoma nassus* L.), minnow (*Phoxinus phoxinus* L.), sunbleak (*Leucaspius delineatus* Heckel), or eel (*Anguilla anguilla* L.) play any important role in the numbers or weight. These species did not achieve dominance except incidentally such as, for instance, the carp, which in the spring of 1984 became dominant in terms of weight. Also the roach in the autumn catches of 1982 occurred as an ordinary dominant in numbers and weight. The carp had escaped from neighbouring fish ponds and found its way into the Vistula from the millestreams draining the fish farms. The perch (*Perca fluviatilis* L.), which was initially totally absent in the catches, in the spring of 1984 became an ordinary dominant in numbers and biomass. Interestingly enough, the giebel carp (*Carassius auratus gibelio* Bloch) and the groundling (*Nemachilus barbatulus* L.), especially the latter, previously absent in the barbel zone, began to form quite high dominances in terms of numbers and biomass in the currently heavily polluted waters of the Vistula. The numbers of these species increased during the period of study.

4.2. Growth, variation in body weight and length, and condition of the fish

In terms of body weight, the largest fish caught below the water stage in Łączany were the barbel, eel, carp, and chub (Table III). At present, the barbel and chub are indicator species of the studied section of the river while the carp and eel should be considered as accidental taxa. The statistically average fish in the Vistula above Kraków weighed 108.5 g in the 1982—1984 period.

The range of variation in body length and weight (Table III) is evidence of the adaptation of particular populations of fish to the conditions of the environment — the greater the variety, the better is the

Table III. Comparison of mean body length and mean body weight, their coefficients of variability (V%) and of condition (K) in the period 1982–1984

Species	Number of fish N	Mean body length cm	Body weight mean g	Body weight max. g	V% body length	V% body weight	K
Cyprinus carpio L.	6	16.4	203.0	648.0	34.9	67.6	2.12
Carassius auratus gibelio Bloch	56	13.3	133.3	324.0	26.1	85.0	2.06
Barbus barbus L.	38	37.4	373.8	861.0	33.0	79.4	1.57
Gobio gobio L.	62	8.8	11.9	26.0	8.6	46.7	1.05
Abramis brama L.	13	16.6	114.7	204.0	5.0	31.2	1.38
Blicca björkna L.	8	19.1	219.5	305.0	7.9	42.5	1.60
Leucaspius delineatus Heckel	1	3.9	1.0	1.0	-	-	1.03
Alburnus alburnus L.	163	10.0	18.6	53.0	11.2	68.8	1.07
Leuciscus leuciscus L.	40	10.8	27.6	35.0	18.9	44.6	1.13
Leuciscus cephalus L.	143	16.2	115.0	589.0	28.9	73.9	1.21
Scardinius erythropthalmus L.	7	11.2	41.4	121.0	19.0	62.6	1.55
Rutilus rutilus L.	44	11.8	45.9	125.0	9.5	79.6	1.67
Phoxinus phoxinus L.	6	5.1	2.8	4.0	22.0	26.6	1.37
Chondrostoma nasus L.	36	15.0	62.8	85.0	19.1	49.4	1.01
Nemachilus barbatulus L.	101	8.7	9.7	29.0	10.7	47.5	1.08
Anguilla anguilla L.	1	80.0	854.0	854.0	-	-	-
Perca fluviatilis L.	13	12.0	31.2	46.0	25.4	50.3	1.17

adaptation of the species. It is a characteristic feature that the range of variation in body weight does not strictly correspond with that of body length. The relationship between the two variables was investigated and it was found that there is a positive and statistically significant coefficient of correlation ($r = 0.558$). It is not high, however, hence the correlation is inconspicuous.

The giebel carp showed the greatest relative changes in body weight; in the waters investigated it occurred in considerable quantities and began to dominate in the weight of the fish. The roach had the second place but, though occurring constantly, did not dominate. The barbel came third; however, despite its high variation, this species is unable to adapt to the considerably polluted environment. The chub and bleak, species dominating numerically and in weight, also showed a very high variation in weight. The rudd, a species accompanying the roach, also showed a high variation in weight. This fish, however, is on the decline in the investigated section of the Vistula, or is difficult to catch, owing to its small numbers. With respect to body weight, the perch was on the verge of high variation (over 50%). It occurred in small numbers, being caught only in the spring of 1984. The remaining species for which coefficients of variation were calculated (Table III) showed lower variation (under 50%). The minnow showed the smallest variations in body weight, followed by the bream, which is receding from the environment. Also the nose carp, with a low variation in body weight, seems to be unadapted to the strongly polluted environment. The gudgeon survives in the environment. The groundling, which was initially not observed owing to small numbers, in 1984 became a prime dominant in numbers and an ordinary one in biomass. The dace acompanying the chub did not become dominant. Its variation served rather as confirmation of the observed rule of adaptation to the new conditions of high pollution.

The highest coefficient of condition (Table III) was found for the carp and giebel carp. These, however, were accidental species in the ichthyofauna of the zone of the barbel on the River Vistula. The giebel carp adapts itself to the difficult conditions of the studied river section.

4.3. State of fish health

The changes in the internal organs of most of the fish investigated, especially in the hepato-pancreas, indicate the effect of an environment heavily polluted both by organic and inorganic compounds. The anatomical and pathological changes on the gills confirm this supposition. Clinical examination likewise showed the occurrence of ulcers and increased extravasation. The results of parasitological examination are also striking. External parasites on the skin and gills occurred with very low intensity and a small extent of infection. However, the intensity and extent of infection by internal parasites proved to be very high. This is observed chiefly in a heavily polluted environment. The internal parasites most frequently found were Acanthocephalia, flukes (*Diplostomum*), and Sporozoa of the *Myxobolus* genus, the external ones belonging to the genera *Trichodina, Glossatella, Actylogyrus,* and *Diplozoon.* Parasitological examination showed that in the overwhelming majority of the fish large degenerative changes in the organs, with features of fatty degeneration, had taken place, and internal parasites dominated absolutely. The intensity of infection with these was high, from under 10 or more to several tens in one fish. The extent of infection was likewise high, frequently reaching 100% of the fish examined. The present state of health of the fish is affected chiefly by the adverse environmental conditions.

4.4. Food of the fish

The sample taken for investigation of the food of the fish consisted of 131 individuals, among them 14 species, 12 of which belonged to the cyprinid family. It was found that the fish took little food and the filling coefficient of the alimentary tract seldom exceeded a value of 1 (Table IV), being greater than 1 for 2 species only (the carp and giebel carp). Detritus (the remains of higher plants) was the main food. Macrofauna took second place, midge larvae being the most common (Chironomidae). In the food of some of the fish large quantities of filamentous algae, chiefly *Cladophora glomerata,* were found while the remaining components such as, for instance, zooplankton, occurred sporadically and in small quantities.

It should be stressed that the groundling, a species not belonging to

Table IV. Coefficients of the filling of the alimentary tracts (F) and percentage of empty tracts in different fish species. N – number of fish

Species	N	F	%
Carassius auratus gibelio Bloch	13	1.14	31.3
Leuciscus cephalus L.	18	1.43	53.9
Alburnus alburnus L.	15	0.73	68.3
Rutilus rutilus L.	14	0.55	66.0
Nemachilus barbatulus L.	11	0.74	83.2
Gobio gobio L.	9	0.88	47.2
Abramis brama L.	8	0.46	70.0
Barbus barbus L.	7	0.21	75.7
Blicca björkna L.	6	0.42	74.2
Leuciscus leuciscus L.	4	0.65	91.3
Scardinius erythrophtalmus L.	3	0.81	65.0
Cyprinus carpio L.	2	1.93	50.0
Chondrostoma nasus L.	2	0.04	97.5
Anguilla anguilla L.	1	0.00	100.0
Total	131		

the cyprinid family, fed mainly on oligochaetes, which in the diet of cyprinids were very rare and occurred in small quantities.

In the alimentary tracts of the giebel carp, zooplankton was found (cladocerans and copepods), occurring chiefly in ponds, and also small, planktonic green algae.

A large number of the fishes' alimentary tracts were empty or poorly filled with food. The fish examined were mostly from the July catches, i.e. from the middle of the vegetation season. Broadly speaking, those taken from the strongly polluted section of the Vistula fed similarly to fish of the same species living in unpolluted waters. The high pollution of the Vistula did not lead to any changes in the quality of the diet. Depending on the kind of food consumed, two groups of fish may be distinguished: those feeding mainly on plant food (the barbel, rudd, bream, and roach) in whose diet micro — and macrophytes predominated, and a group preferring animal food (the gudgeon and chub).

5. Discussion

5.1. Changes in the composition of the ichthyofauna in the 1882—1984 period

The very first studies on the ichthyofauna of the Vistula were carried out by W a ł e c k i (1864). Their results, however, apply to the whole length of the Vistula, undivided into fish zones. The first to divide the Vistula into such zones was N o w i c k i (1880, 1882, 1883, 1889). He included the section of the Vistula from the mouth of the River Przemsza to Nowe Brzesko in the barbel zone, while the section below Nowe Brzesko, roughly from mouth of the River Raba, was counted as

Table V. Occurrence of fish species in the barbel zone of the Upper Vistula from the mouth of the Przemsza to that of the Raba in the period 1882-1984. f - frequency in percentage; g - weight in g; + - species recorded; — - species absent

Period of investigations	1882	1943	1951-1953	1952	1956	1964-1967		1964-1967		1982-1984	
Author / Species	Nowicki (1882)	Starmach (1948)	Kołder, Pałka (unpubl.)	Żelazny (unpubl.)	Kołder (unpubl.) fish pass at Przewóz	Bieniarz, Epler (1972)		Epler, Bieniarz (1973)	heated waters	Author's data	
		g	g	g	f	f	g			g	f
Cyprinus carpio L.	+	-	0.25	2.5	-	1.0	0.9	+	+	2.19	0.86
Carassius auratus gibelio Bloch	-	-	-	-	-	2.6	0.5	-	+	11.68	8.00
Carassius carassius L.	+	-	0.16	3.0	0.06	-	-	+	+	-	-
Tinca tinca L.	+	-	0.41	1.0	0.80	0.1	0.2	-	+	-	-
Barbus barbus L.	+	41.40	2.98	4.0	0.67	3.2	2.5	+	+	19.89	3.86
Barbus meridionalis petenyi Heckel	+	1.99	-	-	-	-	-	-	-	-	-
Gobio gobio L.	+	-	-	-	-	2.9	1.1	-	+	1.13	8.71
Abramis brama L.	+	0.50	8.64	16.0	1.59	7.0	2.8	+	+	1.95	1.29
Abramis balerus L.	+	-	-	-	-	-	-	-	-	-	-
Blicca björkna L.	+	8.44	-	-	3.56	0.6	0.7	+	+	2.14	0.86
Vimba vimba L.	+	0.50	0.85	2.0	6.85	-	-	+	-	-	-
Pelecus cultratus L.	+	-	-	-	-	-	-	-	-	-	-
Aspius aspius L.	+	0.17	2.43	-	0.24	-	-	-	-	-	-
Leucaspius delineatus Heckel	+	-	-	-	-	-	-	-	-	0.00	0.14
Alburnus alburnus L.	+	-	10.84	6.0	20.92	9.2	24.6	+	+	5.09	22.00
Alburnus bipunctatus Bloch	+	-	-	-	-	-	-	-	-	-	-
Rhodeus sericeus Pallas	+	-	-	-	-	0.0	0.2	-	+	-	-
Leuciscus leuciscus L.	+	0.99	-	-	2.69	1.2	1.1	+	+	1.69	5.71
Leuciscus idus L.	+	0.99	0.38	0.5	0.06	2.9	1.1	-	+	-	-
Leuciscus cephalus L.	+	9.93	3.02	3.0	20.30	35.5	40.7	+	+	43.72	20.29
Scardinius erythrophtalmus L.	+	-	-	-	-	0.2	0.2	-	+	0.49	1.00
Rutilus rutilus L.	+	2.15	-	5.0	4.59	7.8	14.3	+	+	2.65	4.86
Phoxinus phoxinus L.	+	-	-	-	-	-	-	-	-	0.03	0.86
Chondrostoma nasus L.	+	29.63	36.68	17.0	37.49	16.4	3.0	+	+	3.02	5.14
Little fish			26.88	10.0							
Average fish			1.51								
Total of Cyprinidae		96.69	94.83	70.0	99.82	90.6	93.9			95.67	83.58
Lampetra planeri Bloch	+	-	-	-	-	-	-	-	-	-	-
Acipenser sturio L.	+	-	-	-	-	-	-	-	-	-	-
Salmo salar L.	+	-	-	7.0	0.06	-	-	-	-	-	-
Salmo trutta L.	-	-	1.14	-	-	-	-	-	-	-	-
Salmo trutta m. fario L.	+	-	-	0.5	-	-	-	-	+	-	-
Salmo gairdnerii Richardson	-	-	-	-	0.06	-	-	-	-	-	-
Thymallus thymallus L.	+	-	-	-	-	-	-	-	-	-	-
Misgurnus fossilis L.	+	-	-	-	-	-	-	-	-	-	-
Nemachilus barbatulus L.	+	-	-	-	-	0.1	0.4	-	-	-	-
Cobitis taenia L.	+	-	-	-	-	-	-	-	-	2.05	14.43
Silurus glanis L.	+	-	0.94	1.5	-	-	-	-	-	-	-
Anguilla anguilla L.	+	-	+	4.0	0.06	-	-	-	-	-	-
Esox lucius L.	+	1.16	1.67	8.0	-	6.5	1.9	-	+	1.55	0.14
Perca fluviatilis L.	+	0.83	1.01	3.0	-	0.5	1.8	+	+	-	-
Acerina cernua L.	+	-	-	-	-	-	-	-	-	0.73	1.86
Lucioperca lucioperca L.	+	1.32	1.41	6.0	-	2.3	2.0	-	-	-	-
Cottus gobio L.	+	-	-	-	-	-	-	-	-	-	-
Cottus poecilopus Heckel	+	-	-	-	-	-	-	-	-	-	-
Gasterosteus aculeatus L.	+	-	-	-	-	-	-	-	-	-	-
Lota lota L.	+	-	-	-	-	-	-	-	+	-	-
Total of other fish		3.31	5.17	30.00	0.18	9.4	6.1			4.33	16.43
Total		100.00	100.00	100.00	100.00	100.00	100.00			100.00	100.00

that of the bream. Nowicki investigated the fauna of the Vistula using a questionnaire method and found that in the barbel zone 40 species occurred, of which 23 were from the cyprinid family. He also found that

in 1882 13 species of predatory fish occurred in this section of the river. The investigations of Nowicki (1882) are a point of reference in relation to the present ones.

Table V makes apparent the magnitude of the changes that have taken place in the ichthyofauna of the River Vistula in the barbel zone in the region of Kraków during the last 100 years. In 1943, Starmach (1948) undertook investigations on the indicator species, the barbel, and used the opportunity to study the whole state of the ichthyofauna. He demonstrated that an association of fish species typical of this zone still existed here. He also found that despite the disappearance of species of predatory fish, the main indicator species of this zone, the barbel, was still the prime dominant in the ichthyofauna (42.4% of the ichthyofauna). Of the species of predatory fish only three occurred — the perch, pike-perch, and pike. The investigations of Starmach (1948) were based chiefly on the results of fishermen's catches. In three fishing districts in the region he recorded only 14 species of fish from the cyprinid family and three from other families.

The recession of predatory fish from the barbel of the Vistula began a long time ago. It is known, for instance, that the sturgeon (*Acipenser sturio* L.) and the salmon (*Salmo salar* L.) had already receded from the Vistula before 1939. Next to recede were the grayling (*Thymallus thymallus* L.), the stone perch (*Acerina cernua* L.), and the stickleback (*Gastrosteus aculeatus* L.), not recorded since Nowicki's times (1882). The sheat-fish (*Silurus glanis* L.) together with six other species were last recorded in the Vistula in the region of Kraków by Żelazny (unpubl.) during a mass death of fish in May 1952. The sea trout (*Salmo trutta* L.), pike (*Esox lucius* L.), and burbot (*Lota lota* L.) last occurred in the section of heated waters below the mouth of the River Skawinka in the catches of Bieniarz and Epler (1972) and Epler and Bieniarz (1973). In the present studies, only once were small numbers of perch (*Perca fluviatilis* L.) obtained, and only one specimen of eel (*Anguilla anguilla* L.). From this it is evident that all the species of predatory fish from the barbel zone of the River Vistula have receded en masse, and only a few specimens still live there.

It may be supposed that the effluent from a plant producing synthetic petrol, built in Dwory-Oświęcim in 1940—1942, contributed to the recession of most of the species of predatory fish recorded by Nowicki in 1882.

Of the predatory fish, species of the percid family remained the longest. In the catches their ichthyomass was greater in 1982—1984 than in 1943—1953. Nevertheless, in the catches made by the present authors the pike-perch was not recorded but the perch was, in quantities similar to those in the investigations of Bieniarz and Epler (1972) from 1964—1967.

5.2. Stages of changes in the ichthyofauna

On the basis of investigations of the ichthyofauna of the Vistula in the barbel zone over the last 100 years, four basic stages of change in its composition caused by increasing pollution can be distinguished.

The first stage consisted in the disappearance of most species of predatory fish, which took place before 1943.

The second stage was the recession from domination of the indicator species, the barbel, in the 1950's. The nose carp took its place, the bleak and chub accompanying it as co-dominants. Species of predatory fish continued to disappear from the environment.

The third stage was reached in the 1960's. The nose carp was replaced by a new prime dominant, the chub. The number of nose carp in the ichthyofauna distinctly decreased, its share in the catches being only a few per cent. The bleak remained at the level of an ordinary dominant. Predatory fish disappeared almost entirely and there was a catastrophic fall in the numbers of forage ones. River sections in which fish did not occur at all began to appear.

The fourth stage was recorded in the late 1970's. The loads of pollution were constantly increasing and causing further destruction of the ichthyofauna, and also bringing about qualitative changes. The bleak took first place in the dominance, moving the chub down to second place, but neither of these species achieved prime dominance. This might indicate that they are unable to adapt to the constantly deteriorating and changing conditions of the environment. However, new co-dominants such as the giebel carp and groundling have appeared, in greatly reduced numbers. Of the predatory fish the perch occurred from time to time. The present conditions of the aquatic environment in the Vistula are clearly leading to complete destruction of the fish.

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6. Polish summary

Ekosystem uregulowanego i zanieczyszczonego odcinka Górnej Wisły

9. Ichtiofauna

Celem pracy była ocena aktualnego stanu ichtiofauny oraz porównanie zmian, jakie w niej zaszły w ciągu ostatnich 100 lat. Odłowy przeprowadzono w latach 1982—1984 za pomocą agregatu prądotwórczego na prąd stały. W 1982 r. ryby łowiono trzykrotnie w przepławce usytuowanej w stopniu wodnym w Łączanach, a w latach 1982—1984 dziewięciokrotnie w Wiśle na odcinku o długości ok. 22 km pomiędzy stop-

niem wodnym w Łączanach a ujściem rzeki Skawinki do Wisły (ryc. 1). Z przepławki pozyskano 53 ryby o łącznym ciężarze 12,7 kg, a z rzeki 701 okazów o ciężarze 68,5 kg. Ogółem w okresie badań złowiono 17 gatunków ryb należących do 4 rodzin: karpiowatych, okoniowatych, piskorzowatych i węgorzowatych. Najliczniej była reprezentowana rodzina karpiowatych, do której należało 14 gatunków (tabele I i II). Gatunki drapieżne nie miały większego znaczenia.

Głównym dominantem w pozyskanej ichtiofaunie był kleń. Dominował on zarówno liczebnie, jak i ciężarowo i zajął miejsce brzany jako gatunku wskaźnikowego.

Największą zmiennością długości i ciężaru ciała odznaczały się: karaś srebrzysty (*Carassius auratus gibelio* Bloch), płoć (*Rutilus rutilus* L.), brzana (*Barbus barbus* L.) kleń (*Leuciscus cephalus* L.) i ukleja (*Alburnus alburnus* L.) (tabela III). Świadczy to o dużych możliwościach adaptacyjnych tych gatunków do zmieniających się warunków środowiska.

Badania parazytologiczne wykazały, że u większości ryb występowały w dużym stopniu zmiany degeneracyjne narządów o cechach zwyrodnień tłuszczowych oraz bezwzględnie dominowały pasożyty wewnętrzne. Na obecny bardzo zły stan zdrowotności rybostanu wpływają w głównej mierze niekorzystne warunki środowiska.

Ryby pobierały mało pokarmu: współczynnik napełnienia przewodów pokarmowych rzadko przekraczał 1 (tabela IV). Podstawowym pokarmem był detritus (w nim szczątki roślin wyższych), a następnie larwy ochotkowatych (Chironomidae). Pozostałe składniki (np. zooplankton) występowały w małych ilościach.

W krainie brzany rzeki Wisły w okolicy Krakowa w ciągu ostatnich 100 lat można wyróżnić kilka zasadniczych etapów zmian w składzie ichtiofauny Wisły pod wpływem wzrostu zanieczyszczeń (tabela IV). Pierwszy etap — zanik większości ryb drapieżnych nastąpił przed rokiem 1943. Drugi to lata 50, w których ustąpiła z dominacji przewodniej brzana. Miejsce brzany zajęła świnka, a towarzyszyły jej jako współdominanty ukleja i kleń. Trzeci etap nastąpił w latach 60. — był to katastrofalny spadek liczebności ryb spokojnego żeru i prawie zupełny zanik ryb drapieżnych. Czwarty etap w końcu lat 70. to dalsze wyniszczenie ichtiofauny i zmiany jakościowe pod wpływem stale zwiększających się zanieczyszczeń. Obecne warunki środowiska wyraźnie zmierzają do całkowitego zaniku ryb w Wiśle.

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