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Environmental characteristics of affluents of the Dobczyce Reservoir (Southern Poland) in the preimpoundment period (1983—1985)*

3. Ichthyofauna

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Abstract — The investigation concerned the species composition, density, and biomass of fish in the River Raba and its tributaries in the area of the Dobczyce Reservoir under construction. The effect of these factors on the development of a natural ichthyofauna in the future reservoir was analysed. In the zone affected by the reservoir 23 fish species were found with numbers varying from 851—4135 indiv. ha^{-1} and biomass from 6980—93.720 g ha^{-1}. Of these species 8 are adapted to life both in flowing and stagnant waters.

Key words: preimpoundment studies, streams, fish community, density, biomass.

1. Introduction

The damning up of the River Raba at kilometre 60.1 of its course in the locality of Dobczyce, planned for the years 1986—1987, will create a water supply reservoir of a damning ordinate of 269.90 m above sea level and an area of 970 ha. The project necessitated preimpoundment ichthyological studies in the River Raba and its tributaries in the region of the reservoir under construction. The last fishery investigations of the Raba catchment basin were carried out in 1966—1971 by Kołder et al. (1974) and in 1979—1980 by Starmach and Jelonek (unpubl. results). Since that time the quality of the water in the River Raba and its tributaries has considerably deteriorated (Wróbel 1980) owing to the development of the town of Myślenice and to the intensification of agriculture.

The aim of the present study, based on the current species composition, number, and biomass of fish, was to determine possible changes in the ichthyofauna of the affluents of the reservoir. According to earlier

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studies, they were chiefly settled by species adapted to life and reproduction in pure or slightly eutrophicated waters. The changes will decisively affect the formation of a natural ichthyofauna in the reservoir under construction and in the mouth sectors of its feeders.

2. Study area, material and method

A description of stations and of the catchment basin of the River Raba has been given by Mazurkiewicz (1988). The investigation was carried out in 1983—1985 in the summer at 8 catching stations: in the River Raba in the vicinity of Myślenice (Station 5) and Osieczany (Station 5a), in a small inundation below Brzączowice (Station 5b), below the dam at Dobczyce (Station 5c), and in the streams Brzezówka (Station 1), Trzemeśnia (Station 3), Bulinka (Station 4), and Wolnica (Station 8) (fig. 1). Three small feeders of the future reservoir (Ratanica, Dębnik, and Zakliczanka) were not taken into account since, as earlier studies had shown, the scanty populations of minnow (*Phoxinus phoxinus* (L.)) and stone loach (*Noemacheilus barbatulus* (L.)) would not affect the development of ichthyofauna in the Dobczyce Reservoir.

In the area included in the future reservoir, on the right side of the River Raba below Osieczany and above Dobczyce, there occur some small inundations utilized for fish rearing by State Farms and the Polish Angling Union. The species reared there were carp (*Cyprinus carpio* (L.)), tench (*Tinca tinca* (L.)), crucian carp (*Carassius carassius* (L.)), pikeperch (*Stizostedion lucioperca* (L.)), and grass carp (*Ctenopharyngodon idella* (Val.)).

Catches were made in rivers and streams in 200-metre netting-enclosed sectors, using a IUP-12 catch arrangement with a voltage and initial intensity of 350 V and 3.5 A and a frequency control from 20—100 Hz.

In order to estimate the number of fish at Stations 5 and 3 the two--catch method (Seber, LeCren 1967) was applied:

$$\check{n} = C_1^2/(C_1 - C_2) \tag{1}$$
$$\check{p} = (C_1 - C_2) / C_1 \tag{2}$$

where:

C_1 and C_2 — numbers in the successive catches.

The variation for number „n" and catch efficiency „p" was calculated according to the formulas:

$$\mathrm{var}\,[\check{n}] = \check{n} q^2 \, (1+q) \, / \, \check{p}^3 \tag{3}$$
$$\mathrm{var}\,[\check{p}] = q \, (1+q) \, / \, \check{n}\check{p} \tag{4}$$

where:
$q = 1 - \check{p}$.

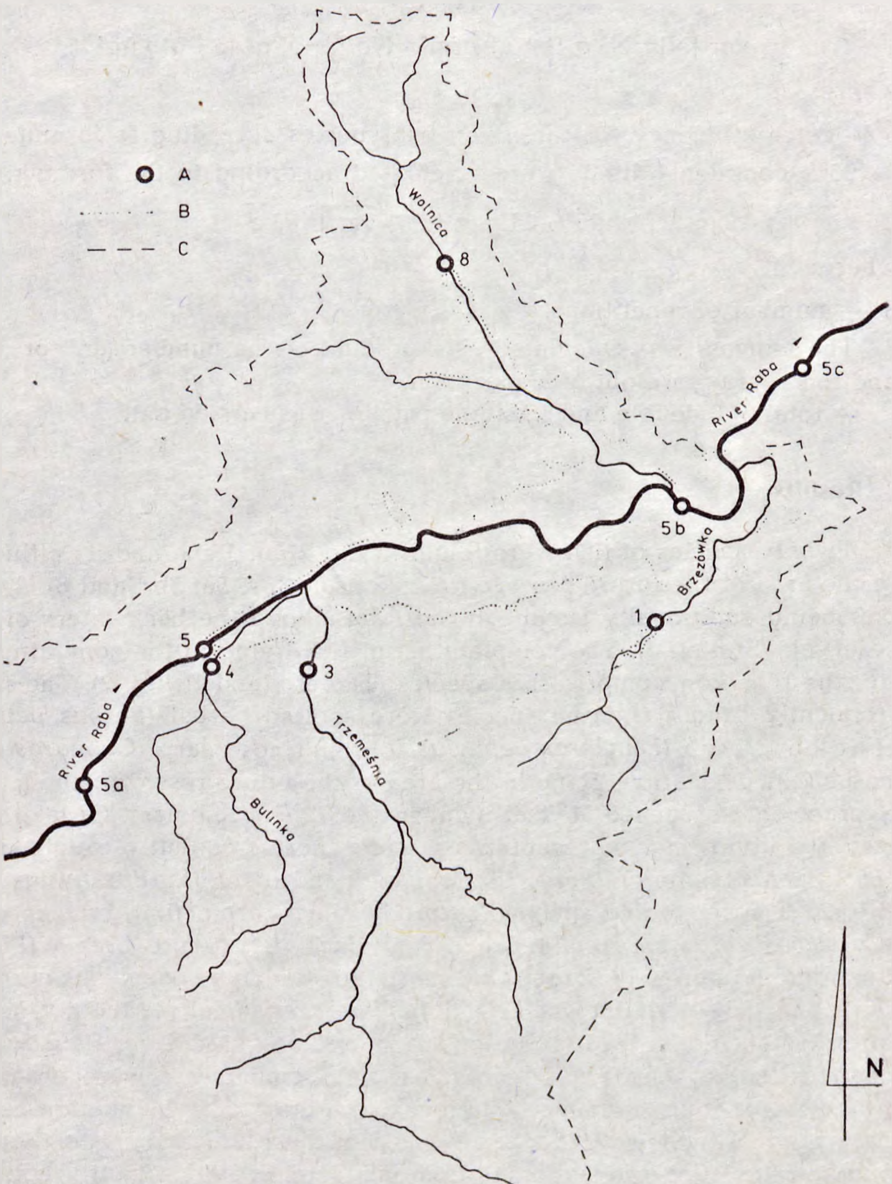

Fig. 1. Catchment basin of the Dobczyce Reservoir. A — fishing stations; B — range of the reservoir; C — borderline of the catchment basin of the reservoir

At the remaining stations the number of fish „N" was estimated using a complementary single-catch method (S e b e r, L e C r e n 1967):

$$\check{N}=C_1/\check{p} \tag{5}$$

$$\mathrm{var}\ [\check{N}]=\check{N}^2\ q\ (1+q)\ /\ \check{n}\check{p}^3+\check{N}q/\check{p}+\check{N}\ q^2\ (5+q)\ /\ \check{n}\check{p}^4 \tag{6}$$

where:

$\check{p}$ — catch efficiency for the given fish species according to formula (2)

95% confidence limits were calculated according to the formula:

$$95\%\ CL=\pm 1.96\sqrt{\mathrm{var}\ [n]}/\sqrt{S}$$

where:

S — number of repetitions.

The biomass was calculated as a product of the number („n" or „N") and the average weight of a specimen.

A total of 6 double and 12 single catches was carried out.

3. Results

Twenty species of fish were found in the River Raba and its affluents in the area of the future reservoir (Stations 1, 3, 4, 5a, 5b, and 8), 3 species being additionally caught in the Raba above the backwaters of the reservoir (Station 5). The complete list of fish living in the zone affected by the reservoir comprises 23 species (Tables I and II, fig. 2). The most frequently caught riverine species were spotted barbel (*Barbus petenyi* H e c k e l), chub (*Leuciscus cephalus* (L)), and nose carp (*Chondrostoma nasus* (L.)). At stations lying in the area of the future reservoir their total average share reached 58% of number and 79% of biomass. Of lake species the following representatives were most frequently caught: pike (*Esox lucius* L.), perch (*Perca fluviatilis* L.), and roach (*Rutilus rutilus* (L.)) (fig. 2). The remaining species: carp (*Cyprinus carpio* (L.)), crucian carp (*Carassius carassius* (L.)), tench (*Tinca tinca* (L.)), white bream (*Blicca bjoercna* (L.)), bream (*Abramis brama* (L.)), ruffe (*Gymnocephalus cernuus* (L.)), and eel (*Anguilla anguilla* (L.)) were sporadically caught. Special attention should be paid to Stations 5, 5a, and 5b in the River Raba where changes in the structure of ecological fish communities were observed in the sector from Myślenice (Station 5) to a temporary inundation below Brzączowice, built in 1971 for the needs of the Municipal Water Supply and Sewage Plant in Kraków (Station 5b). Here, in a 8-kilometre sector of the river, the number of stagnophile species increased, while among rheophile species the nose carp (*Chondrostoma nasus* (L.)) occurred much more frequently (fig. 3).

In the investigated affluents of the reservoir the number of fish varied from 851—4135 indiv. ha^{-1} (Tables I and II) and the biomass from 6980—

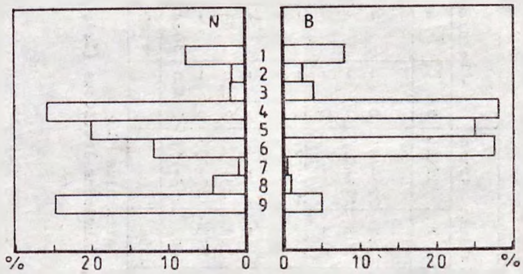

Fig. 2. Mean number (N) and biomass (B) of fish in the area of the Dobczyce Reservoir (Stations 1, 3, 4, 5—5c). 1 — trout; 2 — pike; 3 — barbel; 4 — spotted barbel; 5 — chub; 6 — nose carp; 7 — roach; 8 — perch; 9 — other species

Table I. Number of fish (n ha^{-1}) in the River Raba and in the Trzemesnia stream

Species	5 - River Raba							3 - Trzemesnia stream						
Species	S	$\bar{C}_1$	$\bar{C}_2$	$\bar{n}$	95% CL	$\bar{p}$	95% CL	S	$\bar{C}_1$	$\bar{C}_2$	$\bar{n}$	95% CL	$\bar{p}$	95% CL
Salmo trutta m. fario L.	3	32	14	57	46-68	0.56	0.40-0.72	3	28	12	49	40-58	0.57	0.40-0.74
Esox lucius L.	3	7	2	10	8-12	0.71	0.45-0.97	3	16	[illegible]	26	21-31	0.62	0.42-0.82
Barbus barbus (L.)	3	32	13	54	45-63	0.59	0.44-0.74	0	-	-	-	-	-	-
Barbus petenyi Heckel	3	290	191	849	708-990	0.34	0.27-0.41	3	136	57	234	214-254	0.58	0.51-0.65
Leuciscus cephalus (L.)	3	177	45	237	229-245	0.74	0.69-0.79	3	889	249	1235	1214-1256	0.72	0.70-0.74
Chondrostoma nasus (L.)	3	11	6	20	9-31	0.45	0.10-0.80	0	-	-	-	-	-	-
Rutilus rutilus (L.)	0	-	-	-	-	-	-	3	87	40	161	142-180	0.54	0.44-0.64
Perca fluviatilis L.	3	12	5	21	15-27	0.58	0.33-0.83	3	314	125	522	496-548	0.60	0.55-0.65
Other species+	3	109	60	198	171-225	0.45	0.34-0.56	3	878	474	1908	1802-2014	0.46	0.43-0.49
Total				1446							4135			

+Station 5: Thymallus thymallus (L.), Gobio gobio (L.), Leuciscus leuciscus (L.), Phoxinus phoxinus (L.), Alburnus alburnus (L.), Noemacheilus barbatulus (L.), Cottus gobio L., Cottus poecilopus L.

Station 3: Thymallus thymallus (L.), Gobio gobio (L.), Leuciscus leucisus (L.), Phoxinus phoxinus (L.), Noemacheilus barbatulus (L.)

—98 720 g ha^{-1} (Table III). The largest number of fish was found in the Trzemeśnia stream (Station 3), followed by the Bulinka (Station 4), Brzezówka (Station 1), and Wolnica (Station 8). The River Raba with the largest resources of water fed by its affluents appears as low as the fifth place (Tables I—III). Table IV presents a prognosis concerning the share of the particular affluents in the formation of numbers and biomass of fish in the reservoir.

4. Discussion

Direct estimates of density and biomass of fish in rivers are chiefly based on the results of electrofishing. Methods of repeated catches (2—7 repetitions) in netting-enclosed sectors of the river are most frequently used (Leslie, Davis 1939, De Lury 1947, Zippin 1956, Seber, Le Cren 1967, Ricker 1975). Apart from detailed conditions for the

Table II. Number of fish ($N\ ha^{-1}$) in the River Raba and in the Brzezówka, Bulinka, and Wolnica streams

Stations / Species	5a - River Raba				5b - River Raba				5c - River Raba				1 - Brzezówka stream				4 - Bulinka stream				8 - Wolnica stream			
	S	$\bar{C}_1$	N	95% CL	S	$\bar{C}_1$	N	95% CL	S	$\bar{C}_1$	N	95% CL	S	$\bar{C}_1$	N	95% CL	S	$\bar{C}_1$	N	95% CL	S	$\bar{C}_1$	N	95% CL
Salmo trutta m. fario L.	0	-	-	-	0	-	-	-	0	-	-	-	2	528	927	590-1264	2	201	352	223-481	0	-	-	-
Esox lucius L.	2	9	13	6-20	2	28	39	10-58	2	8	11	5-17	0	-	-	-	2	179	289	171-407	0	-	-	-
Barbus barbus (L.)	2	10	17	10-24	2	9	15	8-22	2	6	10	5-15	0	-	-	-	0	-	-	-	0	-	-	-
Barbus petenyi Heckel	2	91	268	193-343	2	22	65	40-90	2	104	306	206-406	0	-	-	-	2	130	244	181-267	0	-	-	-
Leuciscus cephalus (L.)	2	227	307	278-336	2	100	135	121-149	2	310	419	381-457	0	-	-	-	2	327	454	429-479	0	-	-	-
Chondrostoma nasus (L.)	2	38	85	2-168	2	216	481	22-940	2	16	36	0-73	0	-	-	-	0	-	-	-	0	-	-	-
Rutilus rutilus (L.)	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	2	33	61	45-77	2	30	56	41-71
Perca fluviatilis L.	2	14	24	9-33	2	21	36	15-57	2	16	27	11-43	0	-	-	-	2	128	213	187-239	0	-	-	-
Other species[+]	2	89	198	134-262	2	36	80	52-108	2	114	253	172-334	2	142	308	269-347	2	489	1063	953-1173	2	480	1044	936-1152
Total			912				851				1044				1235				2556				1100	

[+]Station 5a: Gobio gobio (L.), Leuciscus leuciscus (L.), Phoxinus phoxinus (L.), Alburnus alburnus (L.), Noemacheilus barbatulus (L.)

Station 5b: **Gobio gobio (L.), Cyprinus carpio L., Carassius carassius (L.), Abramis brama (L.), Blicca bjoerkna (L.), Leuciscus leuciscus (L.), Phoxinus phoxinus (L.), Alburnus alburnus (L.), Gymnocephalus cernua (L.), Anguilla anguilla (L.)**

Station 5c: Gobio gobio (L.), Leuciscus leuciscus (L.), Noemacheilus barbatulus (L.)

Station 1: Phoxinus phoxinus (L.), Noemacheilus barbatulus (L.)

Station 4: Tinca tinca (L.), Phoxinus phoxinus (L.), Noemacheilus barbatulus (L.)

Station 8: Gobio gobio (L.), Phoxinus phoxinus (L.), Noemacheilus barbatulus (L.)

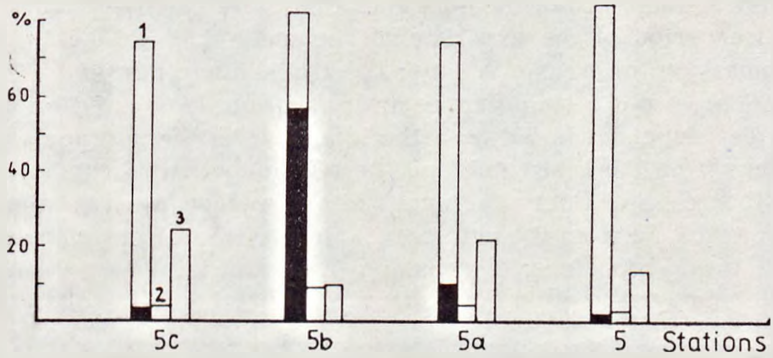

Fig. 3. Percentage share of ecological fish communities in the River Raba at Stations 5—5c. 1 — rheophile species; 2 — stagnophile species; 3 — other species. Black denotes the percentage share of the nose carp (*Chondrostoma nasus* (L.))

Table III. Mean biomass of fish in the affluents of the Dobczyce Reservoir (g ha^{-1}) from the period 1983 - 1985

Stations / Species	River Raba				Streams			
	5	5a	5b	5c	Brzezówka 1	Trzemesnia 3	Bulinka 4	Wolnica 8
Salmo trutta m. fario L.	2785	-	-	-	53250	3140	14810	-
Esox lucius L.	780	1290	3290	880	-	2010	9520	-
Barbarus barbarus (L.)	6380	1270	1670	1090	-	-	-	-
Barbarus petenyi Heckel	47980	15310	2620	12360	-	9320	7880	-
Leuciscus cephalus (L.)	16780	21780	9330	29560	-	64720	22740	-
Chondrostoma nasus (L.)	2180	6670	52260	3870	-	-	-	-
Rutilus rutilus (L.)	-	-	-	-	-	1980	690	560
Perca fluviatilis L.	190	300	530	440	-	5040	1960	-
Other species	2450	3170	1470	3380	2460	12510	7320	6420
Total	79565	50380	77100	51470	55710	98720	64920	6980

Table IV. Total number and biomass of fish in the sectors of the river and the streams on the territory of the future Dobczyce Reservoir

Stations / Factor		River Raba 5b	Brzezówka 1	Trzemesnia 3	Bulinka 4	Wolnica 8
Area of the river:	ha	11.70	1.08	0.72	0.170	0.50
	%	77.10	7.10	4.70	1.10	3.30
Number of fish:	N ha^{-1}	10947	1334	2997	434	550
	%	64.70	8.21	18.83	2.67	3.39
Biomass of fish:	g ha^{-1}	807475	60167	71078	11036	3490
	%	84.70	6.31	7.46	1.16	0.37

particular methods, all of them assume a constant catch efficiency during the entire period of the experiment. The method of estimating density and biomass on the basis of a single electrofishing, proposed by Z a l e w-s k i (1986a) is to a certain degree an innovation. It is based on a highly correlated dependence between the logarithm of the average weight of specimens from the first catch and the efficiency of this catch, found by that author. The distinct advantages of the method are: the elimination of error resulting from the active avoidance of the electromagnetic field by fish during repeated electrofishing (Z a l e w s k i, P ę c z a k 1981), reduced labour consumption, and improved reliability of results (Z a l e w-s k i 1986a).

The results of electrofishing and hence the reliability of results are affected by three groups of factors (Z a l e w s k i 1986b):

— biotic, depending upon the structure of the fish community, the structure of the population, and the characters of the species,

— abiotic, related to water quality, habitat, season of the year, and weather conditions,

— technical, related to the staff, fishing equipment, and organization of catches.

A detailed analysis of these factors shows that their effects cover all the methods of electrofishing applied so far. It may therefore be supposed that those of them whose action does not change during the experiment, such as the structure of the fish community, transparency and conductivity of the water, the state of the fishing equipment etc., cannot be taken into account in repeated catches where the basic condition is the constant catch efficiency of the species. However, in single catches they do have to be considered. It seems that if the Z a l e w s k i method (1986a) is used each of the factors mentioned above should be quantified, this making possible the introduction of corrections increasing the accuracy of results. The lack of such corrections seriously limits the application of the method. Therefore, in the present work it was decided to use the S e b e r and L e C r e n method (1967) which considerably reduces labour consumption, gives quite good and comparable results, and permits calculation of the variation of each catch. This method is particularly useful in studies whose chief aim is not the exact estimate of number and biomass of fish.

The fishery studies carried out from 1983—1985 gave a general picture of the state of the ichthyofauna in the affluents of the Dobczyce Reservoir before its filling. An analysis of results and their comparison with data obtained in the period 1966—1971 by K o ł d e r et al. (1974) and 1979—1980 by S t a r m a c h and J e l o n e k (unpubl. data) showed changes in the structure of fish communities in the investigated sectors of the rivers. These chiefly concerned:

— the withdrawal of Salmonidae and Cottidae from the sector of the

River Raba from Osieczany to Dobczyce,

— an increase in the percentage share of the pike (15 times), the nose carp (4 times), and the perch (40 times) in the affluents of the reservoir under construction,

— the appearance of species not previously found in this part of the Raba, such as the carp, crucian carp, bream, white bream, tench, and ruffe.

The changes occurring in the years 1971—1985 in the composition of the ichthyofauna of the River Raba and its affluents in the area of the future reservoir were brought about by the construction and exploitation of a small inundation for purposes of water supply, by building an earth dam and preparing the bowl of the reservoir, and also by accompanying constructions. The range of these works included the exploitation of crushed stone aggregates, resulting in the formation of stagnant water and old riverbeds; the repeated relocation of the Raba riverbed; dismantling of bridges, etc. These enterprises, changing the water environment, affected particular fish species by modifying their food base, spawning grounds, and places of rearing their young. It seems that in the case of the Dobczyce reservoir one should speak about a three-stage process of formation of the ichthyofauna. Stage I covers the years of constructing the reservoir when, under the pressure of the transformed environment, the ichthyofauna began to „modify" the species composition of the fish community. Stage II includes changes in the composition of the ichthyofauna from the beginning of the filling of the reservoir to the point when rheophile fish species originating from the river before its obstruction retreated from the biocenosis. Stage III comprises the formation and stabilization proper of the ichthyofauna composition chiefly on the basis of the community of stagnophile species with a certain share of introduced ones. According to the division proposed above, it may be accepted that the present paper documents the state of the ichthyofauna after stage I of its development, constituting a starting-point for prognosing the succession of fish in stages II and III.

Fish living in the River Raba and the Trzemeśnia and Bulinka streams will decisively affect the species composition of the ichthyofauna in the future reservoir since, apart from rheophile species, the ichthyofauna of these rivers contains species adapted to life both in rivers and in dam reservoirs, such as the pike, crucian carp, bream, white bream, roach, tench, perch, and ruffe. Fish from the remaining affluents, the Brzezówka and Wolnica streams, will be quite unimportant. Quantitative relations in the projected fish community, especially at stage II, will develop under the impact of the ichthyofauna of the River Raba. In the part included in the future impoundment this largest affluent of the reservoir under construction contains 67% of the number and 85% of the biomass of all fish living in these affluents. When the Dobczyce reservoir is filled, fish communities of the feeders will be strongly affected by the new environment. The instruction of the first filling of the reservoir prescribes the alternate raising and lowering of the water level for inspection and control of the technical state of the construction. During the long period of impoudment flooded fields will contribute to a remarkable inflow of allochtonous food, this creating excellent conditions of growth for all age-groups of fish. In consequence, the rate of natural mortality of specimens will fall and the new environment will be rapidly settled.

At the beginning of stage II one should expect the settlement of the reservoir by fairly numerous populations of adult rheophile fish, such as the chub and nose carp. With the passage of time the limitation of suitable spawning grounds for these species and, hence, decreased possibilities of development of their populations, will bring about a gradual elimination of riverine fish from the ichthyofauna of the reservoir. As observations of the development of the ichthyofauna in dam reservoirs have shown (W a j d o w i c z 1964, M a s t y ń s k i 1985, S t a r m a c h 1986) in the first years after their filling the brown trout, minnow, stone loach, spotted barbel, barbel, dace, and, somewhat later, the chub will disappear from flooded areas, being replaced by the pike, roach, bream, white bream, crucian carp, bleak, perch, and ruffe. As in the Rożnów Reservoir, the rheophile nose carp will develop a population settling the backwaters of the reservoir and migrating for spawning up river (K o ł d e r 1968). At stage II the presence of predators: the pike (in 1983 30 000 fry were introduced to the River Raba) and the perch will be distinctly manifested. The marked development of the pike will be associated with the favourable conditions of flooded meadows. This state will continue for 2—5 years, depending on the rate of bottom sliming and decomposition of land vegetation which constitutes the spawning substrate. At that time the number of pike will decrease while at the same time that of the species constituting its food will increase (roach, bream, white bream, and bleak).

Stage III of development of the ichthyofauna in the reservoir will probably take much longer than stage II and will depend upon the fish culture management there. In this period controlled fishery exploitation, planned introduction of silver carp (*Hypophthalmichthys molitrix* (V a l.)), bighead carp (*Aristichthys nobilis* (R i c h.)), and stocking with pikeperch (*Stizostedion lucioperca.* (L)) and eel (*Anguilla anguilla* (L.)) may appear as important factors modifying the community of fish. The final development of the natural qualitative and quantitative composition of fish in the Dobczyce Reservoir will probably take about 10—15 years, similarly as was observed in the Goczałkowice Reservoir (S t a r m a c h 1986).

5. Polish summary

Środowiskowa charakterystyka dopływów zbiornika dobczyckiego (Polska Południowa) w okresie poprzedzającym jego zalanie (1983—1985)

3. Ichtiofauna

Badania nad ichtiofauną dopływów zostały podjęte w celu zbadania aktualnego stanu gatunkowego, liczebności i biomasy ryb żyjących w rzece Rabie i jej dopływach, w rejonie nowo budowanego zbiornika wody pitnej w Dobczycach. Ryby dopływów będą miały bowiem zasadniczy wpływ na kształtowanie się naturalnej ichtiofauny zbiornika.

Połowy ryb prowadzone były w latach 1983—1985 przy użyciu agregatu połowowego IUP-12 w rzece Rabie na stanowiskach 5—5c, ponadto w potokach: Brzezówce (st. 1), Trzemeśni (st. 3), Bulince (st. 4) i Wolnicy (st. 8) (ryc. 1).

Badania wykazały, że w strefie przyszłego zbiornika żyją 23 gatunki ryb, których liczebność i biomasa waha się od 851 do 4135 osobn. ha^{-1} (tabele I, II, ryc. 2) i od 6980 do 98 720 g ha^{-1} (tabela III).

Spośród dopływów zbiornika decydujący wpływ na ilościowy skład ichtiofauny będą miały Raba i Trzemeśnia (tabela IV), a na skład jakościowy dwa wspomniane już dopływy i dodatkowo Bulinka (tabela I, II), ponieważ żyją w nich gatunki ryb przystosowanych do życia zarówno w rzekach, jak i zbiornikach zaporowych (szczupak, płoć, leszcz, krąp, karaś, ukleja, okoń i jazgarz).

Ichtiofauna zbiornika będzie formować się trójetapowo. Etap I to okres budowy zapory i inwestycji towarzyszących. W czasie tym na skutek prac budowlanych, zmieniających warunki środowiskowe dopływów, nastąpiła modyfikacja zespołu ryb w kierunku gatunków jeziorowych. Etap II obejmuje okres od momentu rozpoczęcia pierwszego napełniania zbiornika do momentu ustąpienia z ichtiofauny zbiornika reofilnych gatunków ryb pochodzących z nie spiętrzonej rzeki. Etap III to właściwe formowanie i stabilizowanie się składu ichtiofauny pod wpływem eksploatacji rybackiej oraz planowanych introdukcji (tołpyga biała i tołpyga pstra) i zarybień (sandacz, węgorz).

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