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RESEARCH ARTICLE

Changes occurring over time in commercially exploited fish assemblages in lowland dam reservoirs

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Abstract. Changes in the ichthyofauna assemblages of three shallow dam reservoirs located in central and eastern Poland are presented based on long-term records of commercial fish catches. As the reservoirs age the evolution in the sizes of the shares of exploited fish species is depicted by temporal trend lines described with regression functions. The species targeted by commercial fishing are assigned to one of four ecological groups – predatory, eutrophying cyprinid, rheophilic, and others, depending on the role they play in the reservoir. Catches of cyprinid fishes from the eutrophying group increased in each of the reservoirs studied as the years passed. This was most notable in the Siemianówka Reservoir since in the period immediately following inundation the slope factor b trend line was 7.25 at $r^2 = 0.9$. The population of predatory fish was also noted to increase continually in this reservoir, and this was linked to intense stocking with pike, *Esox lucius* L. The shares of predatory fish in the other reservoirs decreased from inundation onwards, only to stabilize in recent years at minimal levels with slight increasing trends. As time passed from the inundation of the reservoirs the general dependency between the average shares of fish groups in catches was highly significant for all of fish groups identified.

Keywords: lowland dam reservoirs, fish, assemblages, long-term changes

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Introduction

Dam reservoirs usually fulfill a number of functions. Although fisheries are not the main aim in constructing dam reservoirs, they can, along with recreation, be important aspects of reservoir exploitation. In water supply reservoirs fisheries can be one of the factors that determines the possibilities of even their basic exploitation (Starmach 1958, Klupp 1994), but fisheries can also be restricted by the main aims of reservoir exploitation (Steiner 1992, Nusch 1993, Miranda 2001).

The species composition and abundance of fish stocks in dam reservoirs depends on many factors including environmental conditions, the trophic conditions of the water, pollution, fluctuations in water level, food base, intensity of commercial and recreational fisheries exploitation, and stocking (Wiśniewolski 2002a, Irz et al. 2002, Freeman et al. 2005). On the other hand, fish assemblages with high abundance and biomass have a strong impact on, among other things, water quality (Frankiewicz 1998, Matthews et al. 2004).

The succession of fish species that occurs in oligotrophic lakes as the productivity of the water increases is described by the model developed by Colby et al. (1972), and later confirmed by Hartmann (1977, 1979) in European alpine lakes. Attempts to describe species succession in dam reservoirs as they aged were published by Wajdowicz (1964, 1979), Volodin (1992), Vostradovský and Tichý (1999), and

Wiśniewolski (2002b). About two decades years after inundation, several herbivorous and benthivorous cyprinids species including common bream, *Abramis brama* (L.), white bream, *Abramis bjoerkna* (L.), and roach, *Rutilus rutilus* (L.), are noted to dominate lowland dam reservoirs. This is accompanied by a decrease in predatory fish. These species participate in the so-called ichthyoeutrophication process in which the trophic status of a reservoir increases as a result of fish feeding activities (Opuszyński 1987). Attempts are currently being made to counteract these processes by manipulating the composition of fish assemblages (Zalewski et al. 1990, Kajak 1998, Drenner and Hambright 1999, Starmach and Jelonek 2000).

Fisheries management, including strategies such as commercial and recreational catches and stocking, can affect changes in the course of species succession described above through selective catches of cyprinids combined with intense stocking with predatory fish species and implementing protection measures for them to create more stable, varied fish assemblages (Horppila and Peltonen 1994, Starmach and Jelonek 2000). Fisheries management can also reinforce negative processes occurring in the formation of fish assemblages through excessive exploitation of predatory species and ill-conceived stocking with various cyprinid species. Strategies such as these can have a strong, negative impact on the functioning of aquatic ecosystems, and they can accellerate eutrophication by releasing excessive nutrients from the bottom, eliminating the zooplankton that can limit blooms of algae, and destroying both emerged and submerged aquatic vegetation (Opuszyński 1987, Kajak 1998, Starmach and Jelonek 2000, Bremigan and Stein 2001, Matyas et al. 2003). The aim of this study was to identify the course of changes in characteristic groups of ichthyofauna in lowland dam reservoirs over time based on the results of commercial fish catches.

Study area

Fisheries analysis was performed in three shallow, lowland dam reservoirs: the Zegrzyński and Włocławski reservoirs located in the Mazovian Lowlands and the Siemianówka Reservoir in eastern Poland (Fig. 1). The largest and deepest of these is the Włocławski Reservoir which is dammed at km 674 of the Vistula River. The other two reservoirs are twice as small in surface area. Both are located on the Narew River; the Siemianówka Reservoir at km 432 and the Zegrzyński Reservoir at km 21.

Since their inundations, these reservoirs have been subjected to hydrobiological studies, and their hydrological and trophic conditions and invertebrate assemblages have been described in numerous

Table 1

Descriptions of selected morphological and environmental characters of the Siemianówka, Włocławski, and Zegrzyński reservoirs (Giziński et al. 1989, Kajak and Prus 2003, Górniak 2006)

Typical characters	Zegrzyński Reservoir	Włocławski Reservoir	Siemianówka Reservoir
Year inundated	1964	1969	1989
Dam location (river km)	Narew 21.60	Vistula 674.85	Narew 432.28
Maximum surface area (ha)	3300	7040	3210
Maximum water level (m a.s.l.)	79.10	57.30	145.00
Length (km)	60.0	56.9	13.7
Width (km)	0.5-3.0	0.5-2.5	0.8-4.5
Mean depth (m)	3.5	5.5	2.5
Maximum depth (m)	9.0	15.0	7.0
Water exchange time (days)	1-15	4.5	~120
Reservoir type	short-term retention	short-term retention	long-term retention
Daily fluctuations in water level (m)	0.1-0.5	0.5	~ 0.1

Table 2
Characteristics of selected trophic and production characters of dam reservoirs (Kajak 1990, Górniak 2006, authors' own data)

Trophic and production characters	Zegrzyński Reservoir	Włocławski Reservoir	Siemianówka Reservoir
Phytoplankton biomass (mg dm^{-3})	3.9 - 40.0	4.8 - 12.7	0.31 - 198.10
Zooplankton biomass (mg dm^{-3})	0.001 - 14.780	0.145 - 1.377	2.6 - 5.5
Benthos biomass (g m^{-2})	57.4 - 733.1	2.8 - 112.3	4.5 - 17.4
Surface area covered with macrophytes	small	small	small
Range of total annual fish catches (kg)	26482 - 99145	6621 - 240116	6787 - 57745
Range of catches per surface area unit (kg ha^{-1})	8.02 - 30.04	0.94 - 34.11	2.11 - 17.99

publications (Dusoge et al. 1985, Kajak and Dusoge 1989, Kajak, 1990, Sych 1997, Wiśniewolski 2000, Szlakowski and Wiśniewolski 2001, Górniak 2006). The basic morphological and hydrological parameters of the three reservoirs are described in Table 1.

Located in the upper course of the Narew River, the Siemianówka Reservoir has a long water retention time, while the Zegrzyński and Włocławski reservoirs, located in the lower courses of the Narew and Vistula rivers, respectively, have shorter water retention times. The morphological parameters particular to each reservoir, especially water retention times, impact the trophic conditions and thus fisheries production capabilities. Siemianówka is the youngest of the reservoirs and is rich in phytoplankton and zooplankton but is poor in benthos. The mean biomass of phytoplankton and zooplankton in Włocławski Reservoir, with its shorter water retention time, is lower than in the others. Zegrzyński Reservoir is the oldest of the reservoirs, and has the richest resources of benthic fauna with a biomass reaching 733.1 g m^{-2}. Table 2 presents the characteristics of selected trophic and production features of the individual reservoirs.

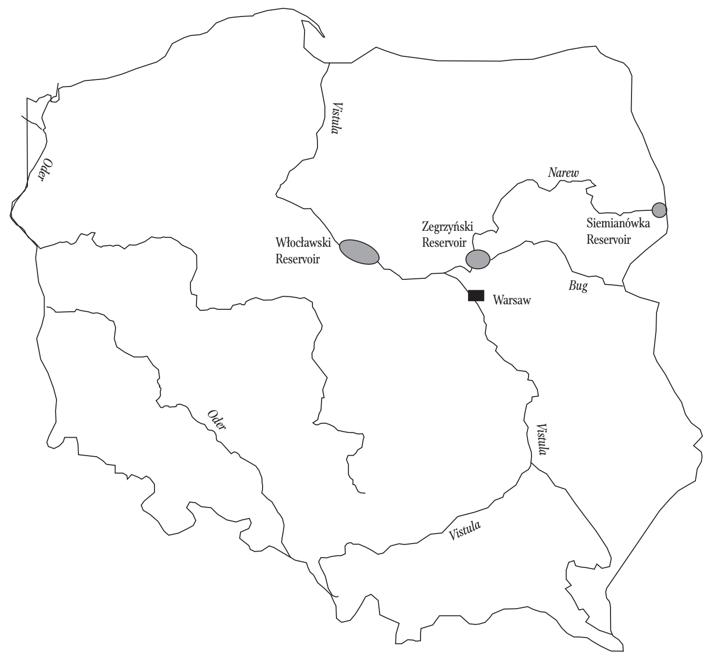

Figure 1. Location of the studied dam reservoirs.

Materials and Methods

The study materials comprised long-term fisheries statistics from the three dam reservoirs analyzed. The fishing gears used were gill-nets with mesh bar lengths of 40 to 90 mm that were deployed four to five times per week from spring until fall. Management catches were performed in the reservoirs since their inundation. This paper includs the results of the 1964-1998 and 2005-2008 periods in the Zegrzyński Reservoir; 1969-2009 in Włocławski Reservoir; and 1991-2008 in the Siemianówka Reservoir (Fig. 2). Since statistics for commercial fishing in Włocławski Reservoir were combined periodically with catches in free-flowing segments of the Vistula River, data for the reservoir only were analyzed from the 1969-1973, 1978-1984, 1986-1991, 1998-1999, and 2000-2009 periods. The composition of the river ichthyofauna upstream from the

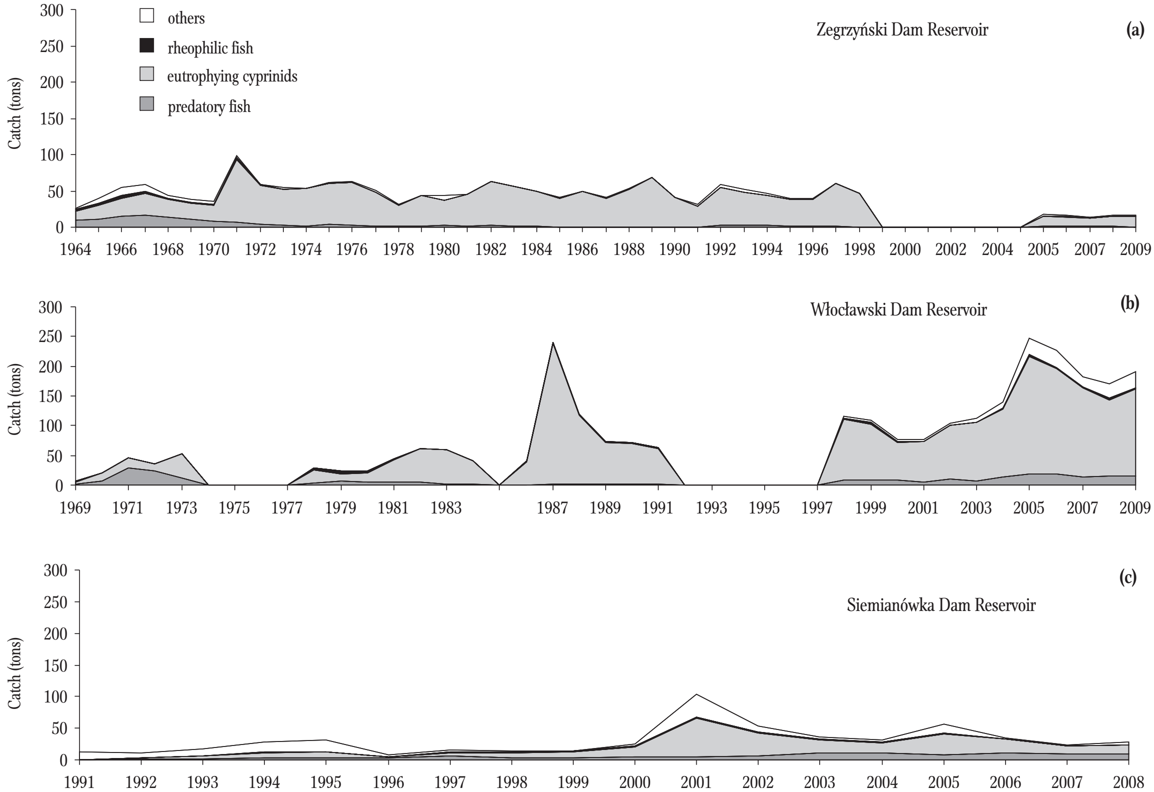

Figure 2. Total catch (tons) of the four fish categories: predatory, eutrophying cyprinids, rheophilic and others in subsequent years of analyzed dam reservoirs existence.

dams served as points of reference for ongoing changes, and this data was collected analogously to that from the reservoirs.

The initial data was used to calculate the share in percentages of weight of the various groups of fish in the overall weight of the catches. It was decided to abandon the analyses of absolute catches (fish weight in kg), because of the variability in fishing effort that stemmed from the fluctuating numbers of fishers, gears deployed, and numbers of fishing days in subsequent years and periods since this impacted the total overall weight of the fish caught. Under these circumstances, the catch structure presented as the percentage share of the weight of individual fish species in the overall weight of all catches was a good indicator of the changes occurring.

The results of management catches that have been conducted since the reservoirs were first inundated can be broken down into characteristic ecological groups formed by individual fish species. Predators include asp, *Aspius aspius* (L.); pikeperch, *Sander lucioperca* (L.); Wels catfish, *Silurus glanis* L.; pike, *Esox lucius* L.; and perch, *Perca fluviatilis* L. Rheophilic fish included barbel, *Barbus barbus* (L.); ide, *Leuciscus idus* (L.); chub, *Leuciscus cephalus* (L.); nase, *Chondrostoma nasus* (L.); and in the case of the Vistula and the Bug-Narew migratory sea trout, *Salmo trutta* L.; and vimba bream, *Vimba vimba* (L.). The third group comprised the cyprinids common bream, roach, white bream, and Prussian carp, *Carassius gibelio* (Bloch) (Wiśniewolski 2002b), and because of the role these species play in the process of ichthyoeutrophication, they are referred to as the eutrophying cyprinids. The last group of fish also includes other species of fish that are exploited commercially but which occur in catches sporadically or in small numbers such as Crucian carp, *Carassius carassius* (L.); tench, *Tinca tinca* (L.); bleak *Alburnus alburnus* (L.); dace, *Leuciscus leuciscus* (L.); as well as stocked species such as grass carp, *Ctenopharyngodon idella* (Val.); common carp; *Cyprinus carpio* L.; or eel, *Anguilla anguilla* (L.).

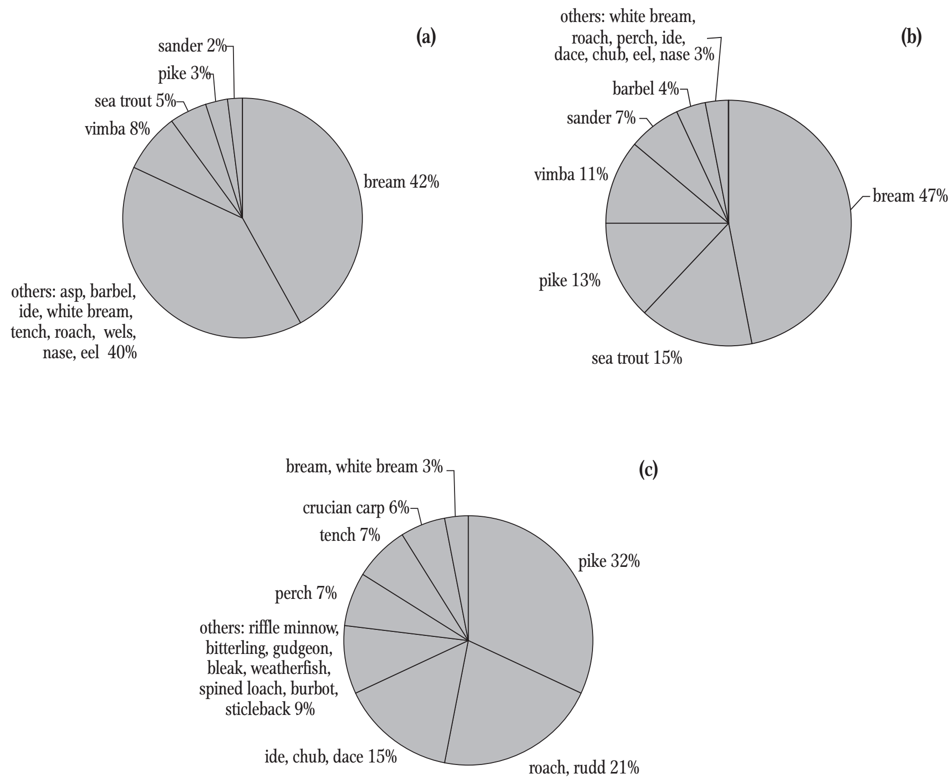

Figure 3. Fish assemblage species structure (% biomass) in the river before inundating reservoirs: a - the mouth of Bug River and lower Narew River, b – Vistula River – middle part, c – the upper Narew River (according to Wiśniewolski 2002 – adapted).

Classification difficulties are encountered with species such as perch, since their feeding structure is linked to size; small specimens feed on benthic fauna and large specimens feed on fish. Information on perch from fisheries statistics usually refers to this species without size divisions. However, the perch usually caught in nets are larger; for example, those recorded in the Siemianówka Reservoir documentation referred to as "large" comprised 88-90% of the total weight of perch caught. This is why the total catch of this species is classified along with the predatory group of fish. The second classification challenge was encountered with regard to rudd, *Scardinius erythrophthalmus* (L.), which is a common, although not abundant, cyprinid species. This fish is herbivorous, but because the weight of this species in the fisheries statistics is usually marginal, it is included with roach, and in the present work it was included in the group of eutrophying cyprinids. Eel, and some other species with low shares in the catches such as Crucian carp, tench, bleak, and grass carp were usually included in the category of other species. In the present work, this group of fish was only taken into consideration in the final analysis of the data accumulated from the three reservoirs.

Linear correlation was used to describe the changes occurring over time in the composition of catches in each of the reservoirs analyzed. A trend line was created for each group of fish that illustrated the dependence between each group's share in the catch structure and the period of reservoir existence as described by the regression function that characterizes a given determination coefficient value (r^2) and correlation coefficient (r). Next, the shares of particular fish groups in overall catches in all three reservoirs in subsequent years were averaged beginning with the first year following inundation (1, 2, 3, 4.....). Thus, general trend lines were obtained that described changes occurring in ichthyofauna assemblages in large lowland reservoirs as they age. The dependencies between the shares of the designated fish groups in the catches and the period of reservoir

Table 3

Parameters of regression function for selected fish groups during the existence of the studied reservoirs. a – directional coefficient, b – slope factor

Years since inundation	Fish group	Zegrzyński Reservoir	Włocławski Reservoir	Siemianówka Reservoir
5-7	Predatory	a = 31.266	a = 35.742	a = 6.599
		b = -0.572	b = 2.062	b = -1.243
	Eutrophying cyprinids	a = 46.201	a = 52.890	a = -3.042
		b = 1.5403	b = 0.125	b =7.254
	Rheophilic	a = 8.962	a = 9.548	a = 0.515
		b = -1.244	b = -2.323	b = -0.007
8-20	Predatory	a = 22.997	a = 39.810	a = 16.812
		b = -1.246	b = -2.093	b =0.841
	Eutrophying cyprinids	a = 62.996	a = 31.999	a = 37.646
		b = 1.946	b = 3.623	b = 1.326
	Rheophilic	a = 4.666	a = 27.874	a = 6.684
		b = -0.289	b = -1.518	b = -0.292
>20	Predatory	a = -5.160	a = -3.687	
		b = 0.263	b = 0.328	
	Eutrophying cyprinids	a = 112.4	a = 117.990	
		b = -0.629	b = -0.989	
	Rheophilic	a = -0.363	a = 1.836	
		b = 0.020	b = -0.017	
Entire period	Predatory	a = 17.559	a = 29.099	a = 8.493
		b = -0.455	b = -0.716	b = 1.453
	Eutrophying cyprinids	a = 71.837	a = 67.181	a = 15.526
		b = 0.643	b = 0.596	b = 2.985
	Rheophilic	a = 3.164	a = 5.647	a = 1.765
		b = -0.095	b = -0.127	b = 0.070

existence were significant since, at a level of significance of 0.05, the critical value of the F distribution was smaller than the value of the regression function F_{emp}. Statistical analysis was performed with Statistica PL 5.0 for Windows (StatSoft Inc. Tulsa, USA).

Results

Fish catches made for management purposes in the Vistula River and the lower courses of the Narew and Bug rivers prior to the inundation of the Włocławski and Zegrzyński reservoirs were dominated by bream, which comprised 47 and 42%, respectively, of the total biomass of fisheries catches. One of the characteristic features of the catch structure in the upper course of the Narew was the distinct domination of pike (32%). Roach and a small number of rudd comprised 21% of the catch weight, while 15% was rheophilic species. Bream dominated in the lower courses of the Narew and Bug and in the Vistula near the future Włocławski Reservoir, but in the upper course of the Narew, this species, along with white bream, comprised barely 3% of the catches (Fig. 3). In the first 5-7 years following the inundation of the Zegrzyński Reservoir, the share of the predatory fish group exhibited a decreasing trend with a regression function (Fig. 4), given by the equation:

$$y = -0.572x + 31.266 \ (r^2 = 0.07)$$

In the subsequent two decades catches of predatory fish continued to decrease with a regression function, given by the equation:

$$y = -1.246x + 22.997 \ (r^2 = 0.45)$$

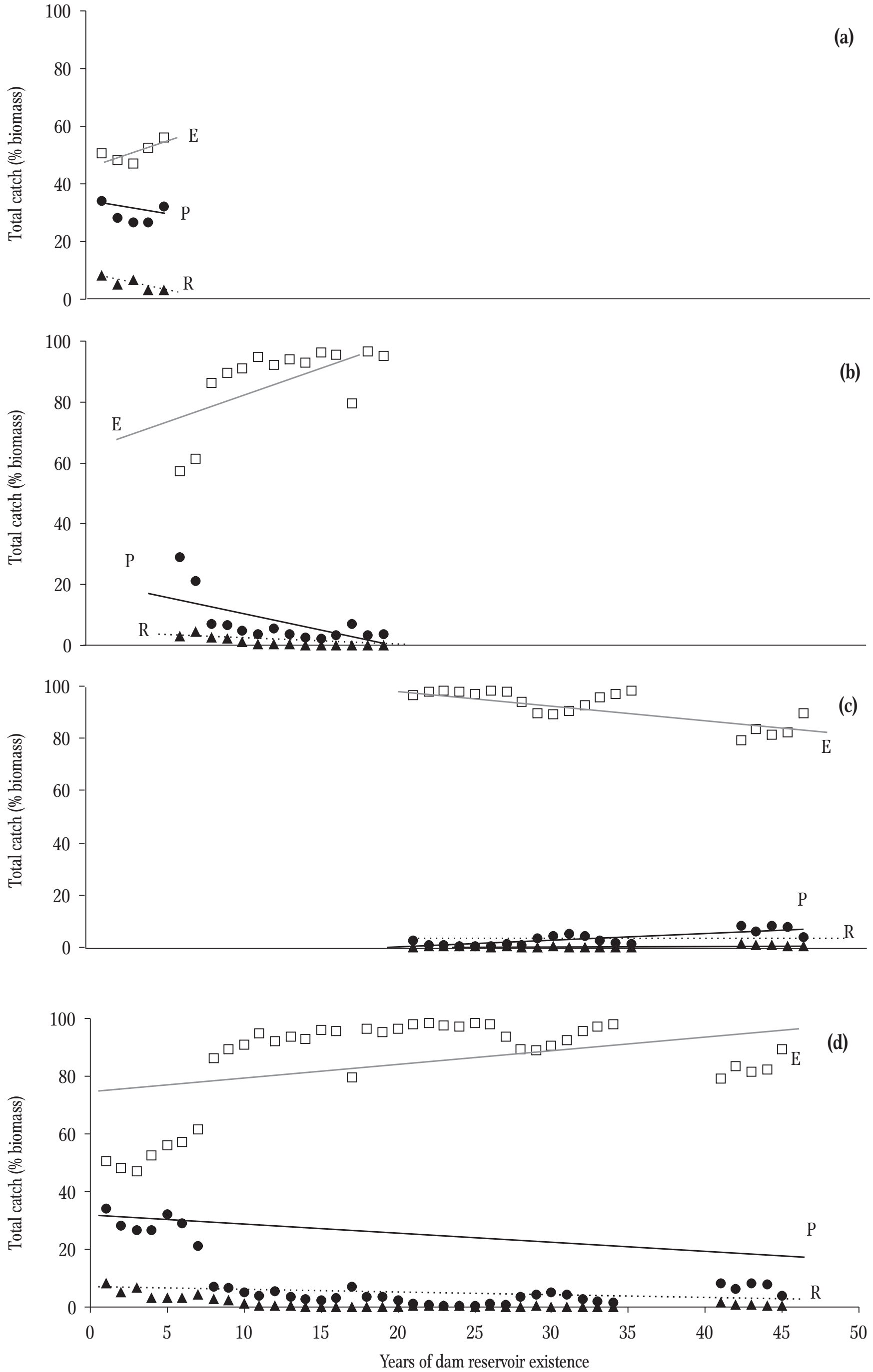

Figure 4. Trends in shares (% biomass) of predatory – P, eutrophying cyprinids – E, rheophilic – R in the structure of the ichthyofauna of Zegrzyński Reservoir in the first 7 years (a), the next 20 years (b), subsequent years (c), and for the entire period of the reservoir's existence (d).

This was accompanied by a similar, distinct decrease in rheophilic fish that developed over time (r^2=0.72). Significant decreasing tendencies in the catches of the groups mentioned above meant that they were of marginal significance to the overall catch weight within 7 to 10 years following inundation. They were also accompanied by a permanent increase in the catch share of eutrophying cyprinids, given by the equation:

$$y = 1.946x + 62.996\ (r^2 = 0.41)$$

Table 4

Regression function parameters of the mean shares in catches of fish groups in the four periods of reservoir existence and the dependency on how long the reservoir has existed. a – directional coefficient, b – slope factor, r^2 – determination coefficient, F_{emp} – the values calculated for regression function and the critical values of F at a level of significance of 0.05 are taken from the Snedecor F-table

Years since inundation	Regression function parameters	Predatory species	Eutrophying species	Rheophilic species	Other species
1-7 $F_{0.05;1;5}$ = 6.61	a	30.308	37.33	4.377	27.985
	b	-0.292	2.441	-0.252	-1.897
	r^2	0.01	0.5	0.08	0.7
	F_{emp}	0.062	5.013	0.457	11.8
8-20 $F_{0.05;1;18}$ = 4.41	a	17.570	65.693	4.62	12.117
	b	-0.635	1.273	-0.182	-0.457
	r^2	0.48	0.6	0.66	0.29
	F_{emp}	16.401	26.539	35.671	7.494
>20 $F_{0.05;1;18}$ = 4.45	a	1.071	106.327	0.356	-7.754
	b	0.153	-0.585	0.013	0.419
	r^2	0.15	0.36	0.01	0.38
	F_{emp}	2.986	9.478	0.208	10.41
Entire period $F_{0.05:1;46}$ = 4.08	a	32.235	-12.244	31.872	28.555
	b	-0.8717	0.445	-5.624	-0.624
	r^2	0.36	0.29	0.37	0.11
	F_{emp}	25.00	18.09	26.01	5.34

This was approximately 90% of the overall catch weight (Fig. 4). In Zegrzyński Reservoir these trends fluctuated in subsequent years with the shares of predatory and rheophilic fishes increasing slightly and those of eutrophying cyprinids decreasing (Fig. 4). However, the regression function calculated for the entire period of the reservoir's existence clearly confirms the tendency for the fish assemblage of common bream, roach, and white bream to dominate the decreasing shares of rheophilic and predatory fishes (Table 3).

Following a brief period of increase, the share of predatory fish in the catches decreased in the subsequent period of the Reservoir Włocławski existence (Fig. 5). After about 20 years, catches of predatory fish were at a low level, and exhibited a weak increasing trend in subsequent years (Fig. 5). This was accompanied by quickly increasing shares in the catches of common bream, roach, and white bream, or the group of eutrophying cyprinids (Fig. 5). In the next period of reservoir aging, the population of eutrophying species stabilized and exhibited a tendency to decrease slightly (Fig. 5). It is noteworthy that in the reservoir with the shortest water retention period the process of change lasted longer, and the fish assemblages did not stabilize to Predatory < 5% and Eutrophying Cyprinids > 80% until about 12 years after inundation (Fig. 5c). The value of the slope factor at b = -2.323 that was noted for the group of rheophilic fish species indicated the rapid decrease of their shares in the overall catches from the inundation of the reservoirs (Fig. 5). This tendency held in subsequent years and was noted throughout the existence of the reservoir.

Throughout the entire period analyzed, the share of predatory fish in the Siemianówka Reservoir increased slightly, and in 18 years from inundation, the share of predatory species in the catches remained at about 10-15%, with the exception of the short-term increase in the share of this species to about 30% 6 and 7 years following inundation (Fig. 6). The increase in the share of eutrophying cyprinids was

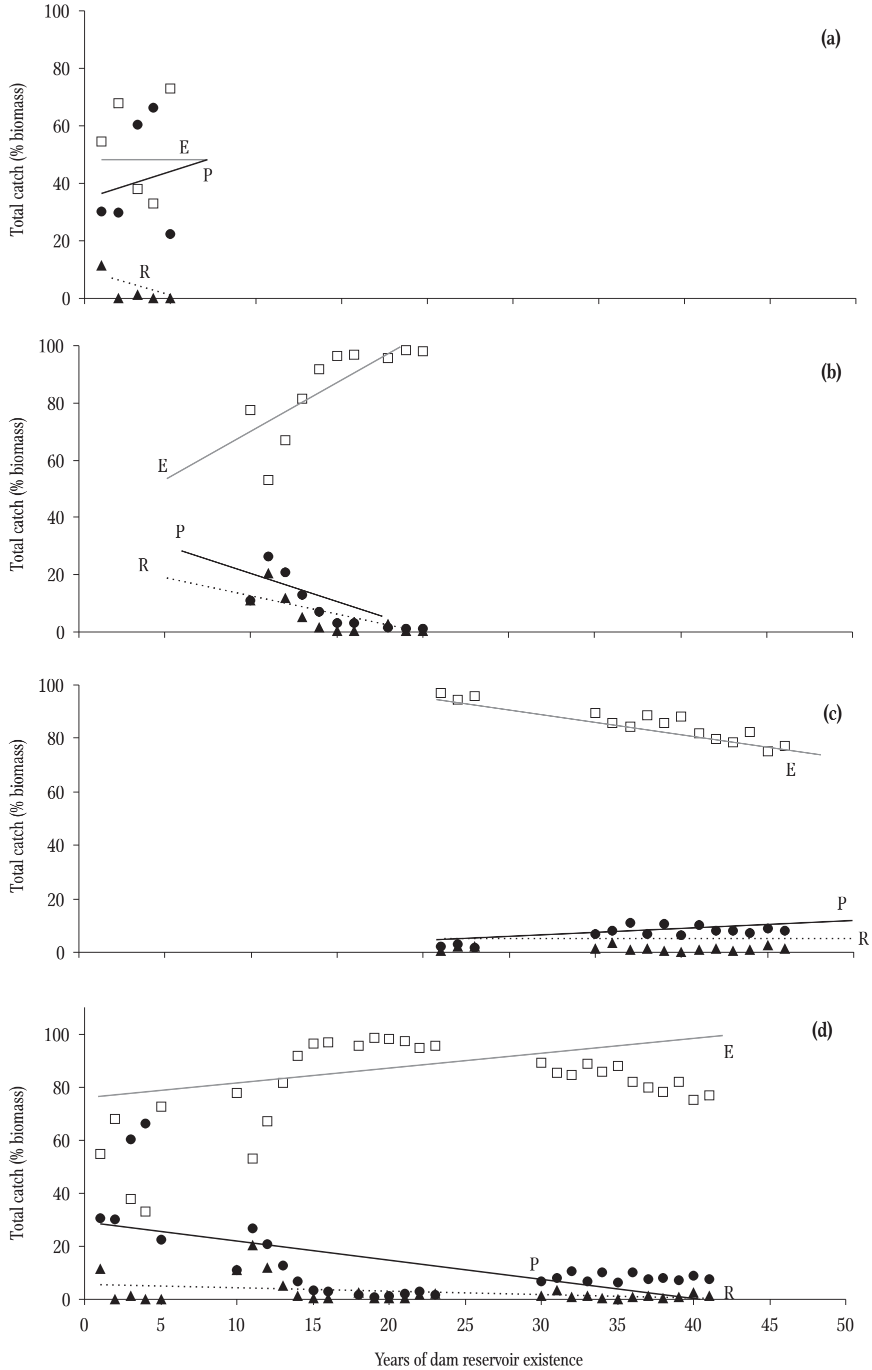

Figure 5. Trends in shares (% biomass) of predatory – P, eutrophying cyprinids – E, rheophilic – R in the structure of the ichthyofauna of the Włocławski Reservoir in the first 7 years (a), the next 20 years (b), subsequent years (c), and for the entire period of the reservoir's existence (d).

highly significant in the initial stages of the existence of the reservoir, and the trend line ran according to the following function (Fig. 6):

$$y = 7.254x - 3.042,\ r^2 = 0.91$$

After eight years, they comprised 70% of the overall catch weight. In the next period the share in the catches stabilized with an increasing trend (Fig. 6). Rheophilic species comprised only a small percentage of the catches in Siemianówka Reservoir,

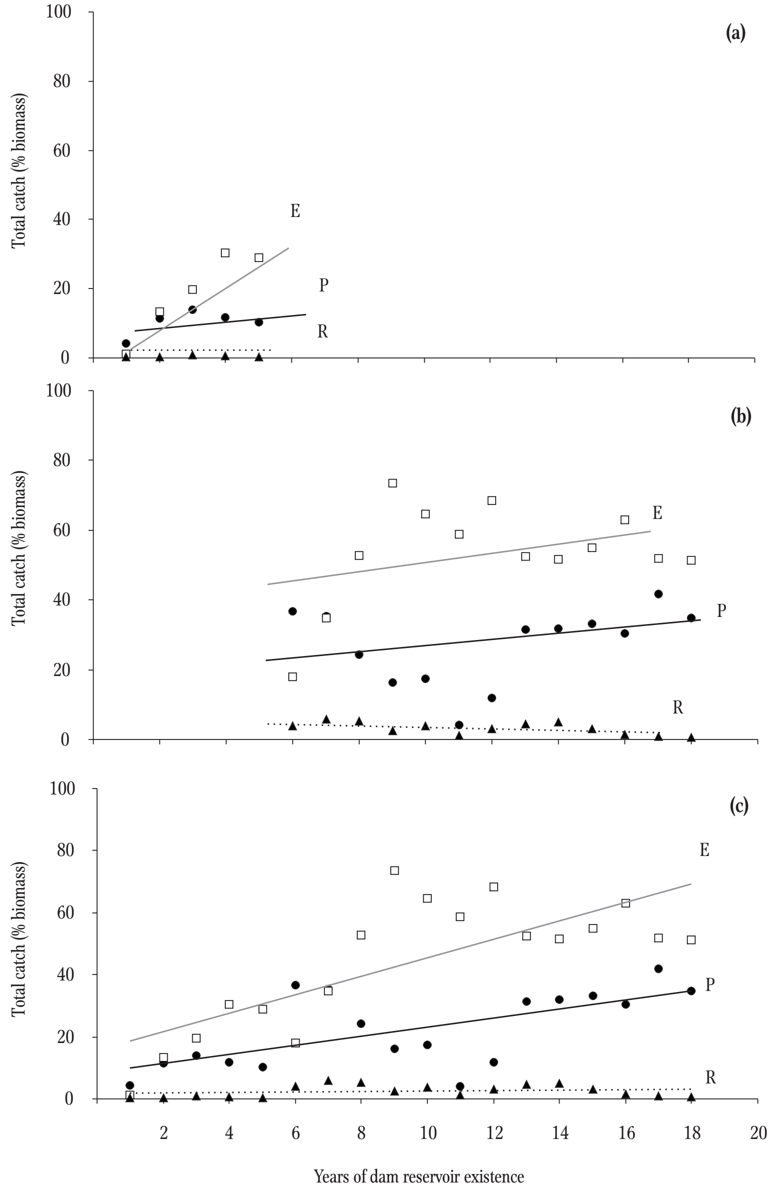

Figure 6. Trends in shares (% biomass) of predatory – P, eutrophying cyprinids – E, rheophilic – R in the structure of the ichthyofauna of the Siemianówka Reservoir in the first 7 years (a), in subsequent years (b), and for the entire period of the reservoir's existence (c).

and they exhibited a weak tendency to decrease that was not linked with reservoir age (Fig. 6). The trend line plotted for the shares of designated groups in the first 7, and the subsequent years following reservoir inundation and designated for the entire period of the existence of the reservoir is presented in Table 3.

The mean size of the shares in catches of the groups of fish analyzed in subsequent years of reservoir existence illustrates the general trend of changes in the composition of fish assemblages as lowland dam reservoirs age (Fig. 7). The trend line plotted for predatory species in the first 5 to 7 years after the river was dammed indicates a slight decline, while there was a slight increase in eutrophying species. However, the dependency between the length of reservoir existence and the shares of these two fish groups in the catches was not significant since the critical value of the F distribution at a level of significance of 0.05 was lower than the calculated value of the function F_{emp} (Table 4). The first 5 to 7 years after

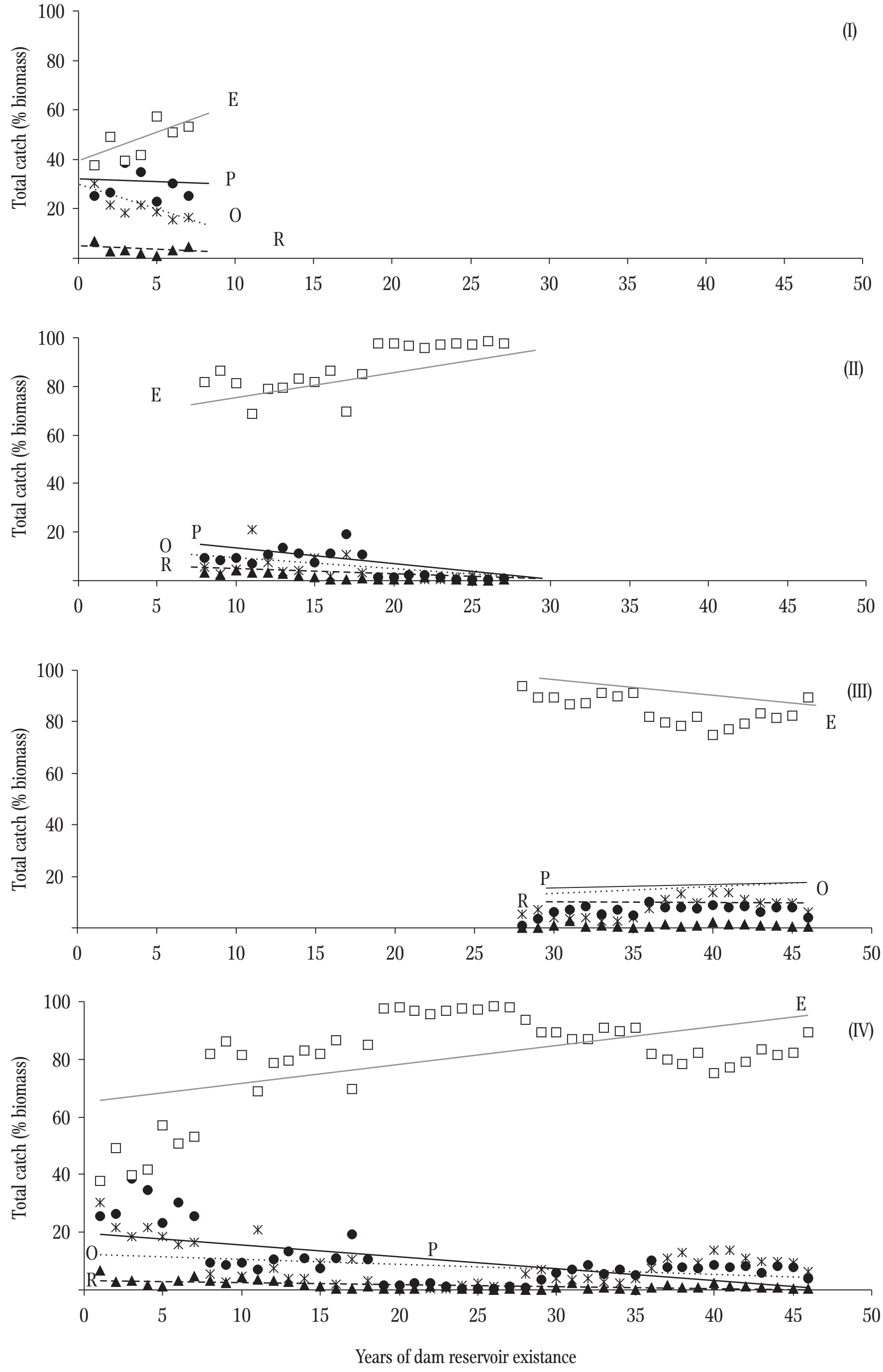

Figure 7. Trend lines created for the mean shares of the biomass of the four fish groups: predatory (P), eutrophying cyprinids (E), rheophilic (R), and others (O) in the total biomass of commercial catches in the dam reservoirs studied in four periods of their existence. I – the first 7 years, II – the next 20 years, III – subsequent years, IV – and for the entire period of the reservoir's existence.

a river is dammed do not have a significant impact on decreasing catches of rheophilic species despite the trend illustrating a weak decreasing trend for the share of this group. The values calculated for regression function F_{emp} are lower than the critical value of the function (Table 4). The picture of changes in fish assemblages in the following years after inundation is different (Fig. 7). The trend line

Table 5

General model of the regression equation obtained based on the abundance share in fish catches for each fish group in a lowland dam reservoir. a – directional coefficient, b – slope factor, r^2 – determination coefficient, F_{emp} – the critical values of F are taken from the Snedecor F-table

Fish group	a	b	F_{emp}
Predatory species	33.305	-0.936	31.62
Eutrophying species	-11.356	0.442	24.59
Rheophilic species	30.208	-4.186	20.61
Other species	29.609	-0.673	10.56

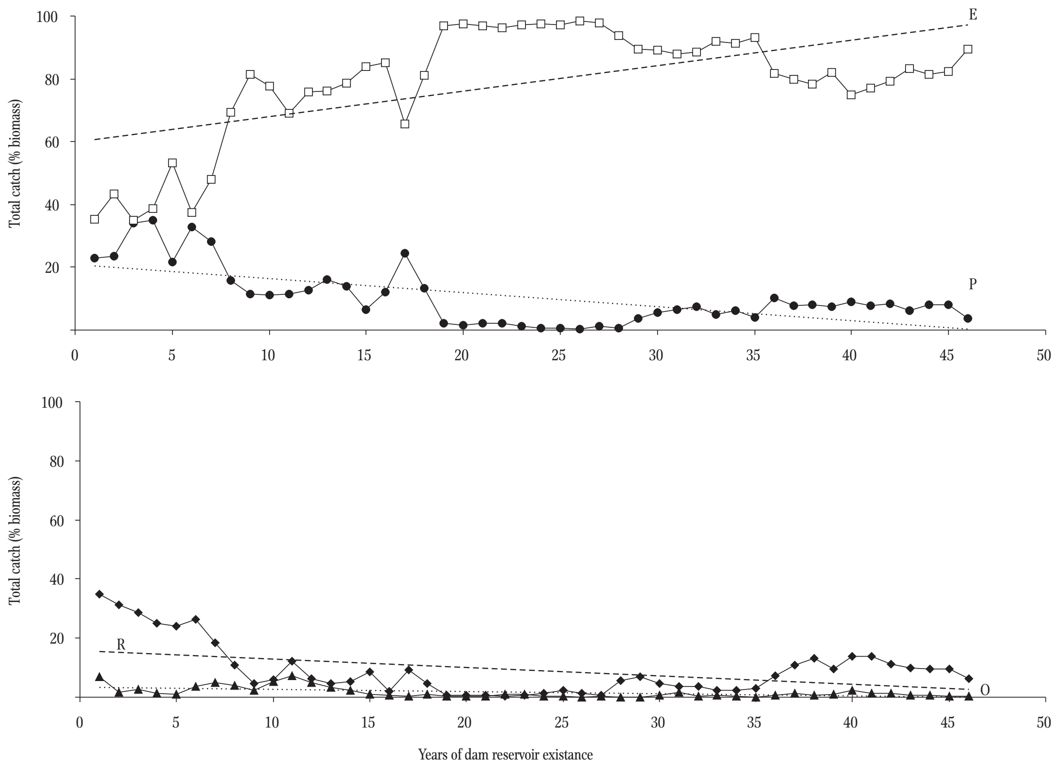

Figure 8. Overall tendencies for changes in the composition of the fish assemblages in lowland dam reservoirs based on the mean share of the fish species groups of predatory, eutrophying cyprinids, rheophilic, and others in the total catch biomass in subsequent years of reservoir existence.

plotted for the predatory fish group falls, and this tendency is highly significantly dependent on the period of time the reservoir has existed (Table 4). The increase in catches of eutrophying fish is also statistically significant: $F_{0.05;1;18} < F_{emp}$. The aging of the reservoir has the greatest impact on changes of the rheophilic fish component of the fish assemblage. The share of this group decreases successively from the moment the river is dammed, and it is highly significantly dependent on the length of time the reservoir has existed (Table 4). As the reservoir ages, the dependence between the catch structure and reservoir age becomes insignificant for the predatory and marginal rheophilic groups of species. Catches of these two groups stabilize and exhibit slight increasing trends. The share of eutrophying cyprinids, despite a small decline at y = -0.585x + 106.327, still exhibit significant dependencies with reservoir age. A significant link also exists with the size of the share of the other species group (Table 4).

The mean share of the designated groups of fish species in the catch weight of all the reservoirs analyzed permit drawing a general trend line that describes changes in the composition of fish assemblages during a specific period of reservoir existence. The general tendencies of the process of shaping fish assemblages in lowland dam reservoirs as they age is presented in Fig. 8. The proportions of all eutrophying cyprinids (common bream, roach, white bream, Prussian carp) increases while the shares of all other species groups decrease. This phenomenon is highly statistically significantly dependent on the length of time reservoirs have existed, $F_{0.05;1;44} < F_{emp}$ (Table 5).

Discussion

The description of the results of management catches conducted before the river was dammed indicate that the fish assemblages were represented by species that differed with regard to feeding, reproduction, habitat, and ecological group. The catches comprised spieces that were rheophilic and limnophilic, predatory and passive feeders, nectonic and benthic with varied feeding preferences, as well as threatened diadromous species. Despite the dominant position of common beam, the share of which ranged from 42-47% of the total catches in the Bug–Narew and Vistula rivers, a large share of catches comprised rheophilic, predatory, and diadromous species that are valuable in river ecosystems. The share of diadromous species in the Vistula was as high as 26%. Pike and roach dominated in the upper Narew with a total share of more than 50%, and the share of rheophilic species was also comparable. Common bream made a slight contribution of about 3%, and this reflected the character of the upper course of the Narew. This ichthyofauna structure reflects the environmental conditions of a freely flowing river close to its natural state.

Mikulski and Tarwid (1951) reported on the variability of habitat conditions on various segments of the Vistula River ecosystem and their value for ichthyofauna. Backiel (1993) developed this concept further and published a diagram of varied habitats and feeding grounds within the ecosystem of a moderately regulated segment of a large river on which the following were marked: current zones, vast sandy bottoms swept clean by water currents, gravel beds and rocky bottoms essential for the habitation and reproduction of rheophilic fish species, distributaries, oxbow lakes, calm areas downstream from lakes or dams required by limnophilic species for breeding, rearing young, and feeding, as well as washed out hollows beneath the banks of rivers. This rich habitat variety explains the occurrence of rich fish assemblages represented by species with varied ecological requirements (Balon 1964, Morawska 1968). The condition is guaranteeing the fish uninhibited passage between these micro-habitats (Bless 1978, Schiemer 1985). The abundance of ichthyofauna is not determined only by the values of single habitats that guarantee optimum conditions for the development of species with different environmental requirements, but, above all else, the variety and availability of habitats (Jungwirth 1998, Wiśniewolski 2002a).

The river system prior to damming is disturbed by dam construction that causes radical changes in environmental conditions (water flow, temperature, chemistry) in the flooded area (Starmach 1958, Hannan and Young 1974). This is reflected in the species structure and abundance of ichthyofauna developing in dam reservoirs (Jelonek and Amirowicz 1987a, 1987b, Steiner 1992, Volodin 1992, Mheen 1993).

The dynamic process of changes in the species structure of fish assemblages developing in dam reservoirs is an important biological indicator that provides information about subsequent stages that occur as time passes in aging reservoirs. This process occurs quickly since just a few years are required for the basic ichthyofauna assemblage to form (Wundsch 1949, Backiel et al. 1956, Wajdowicz 1964, 1979, Vostradovský and Tichý 1999, Wiśniewolski 2002b). The basic ichthyofauna assemblage is unstable and vulnerable to various kinds of influences (Kuznecov 1980, Sych 1997, Frankiewicz 2000). This means that in similar types of reservoirs it is possible that significant changes or disturbances within the species structure of the developing ichthyofauna stock can be similar. Examples of this are the lowland Zegrzyński, Włocławski, and Siemianówka reservoirs with their short or long water retention periods that are analyzed in the present work, and in which the ichthyofauna assemblage formation processes exhibited great similarity. In the 5 to 7 years following inundation, the share of predatory fish decreased to about 10%, while after the subsequent 7 years it stabilized at barely 5%. This tendency also refers to rheophilic fish since the conditions in reservoirs are different from those in river environments. As the reservoirs age, the share of other fishes in the catches also decreases to levels ranging from just several to about 15%. The group of fish that benefits following the inundation of dams is the cyprinids, especially common bream, roach, and white bream (eutrophying cyprinids). In the first decade after a reservoir is inundated, the share of cyprinids increases from about 40-50% to 80%, and this tendency intensifies as reservoirs age. The distinct increase in the share of eutrophying cyprinids in catches along with decreases and the marginalization of the other groups of fish analyzed in these reservoirs indicate the direction of ongoing changes, and this is a characteristic feature of large lowland reservoirs. Additionally, it is significant that the succession processes of the three basic fish groups–eutrophying cyprinids, predatory, and rheophilic, that were observed in the reservoirs analyzed could be described with linear regressions characterized by significant values of the coefficients r^2 and r. The direction of changes in fish assemblage composition in lowland dam reservoirs exhibit a consistent pattern: just a few years following inundation, reservoirs become totally dominated by common bream, roach, and white bream along with a consistently decreasing share of other fish species. This indicates that ichthyofauna change which continues as reservoirs age is a pattern which can generally refer to other large lowland dam reservoirs in similar geographical locations. The index of increasing productivity is the increasing dominance of fish species such as common bream, roach, white bream, and small perch that feed on zooplankton and benthic fauna, and thus accelerate the increasing trophic status of reservoirs.

The process of ichthyofauna succession in large lowland dam reservoirs is generally analogous to the processes of changes in ichthyofauna assemblages in lakes undergoing eutrophication (Colby et al. 1972, Hartmann 1977, 1979). Differences in the directions of and rates at which fish assemblages formed in the reservoirs analyzed stem from the varied environmental conditions of the dammed rivers, the reservoirs created by these dams, and the type of fisheries management practiced in them. However, they did not impact the overall process of shaping the ichthyofauna of lowland reservoirs. These differences can disrupt slightly or cause relative deceleration in the occurrence of succession processes. Confirmation of this can be found in the work by Kuznecov (1980), which indicates that environmental conditions are responsible for the effects of reproduction and fry survival. Zalewski et al. (1990) reported, based on the example of the Sulejowski Reservoir, that excessive perch and cyprinid reproductive success not only results in significant decreases in water quality, but also contributes to the elimination of predators such as pikeperch and asp, as well as to long-term disruptions in the population structures of fish inhabiting the reservoirs. Confirmation of this is seen in the differences in the structures of ichthyofauna assemblages forming in several Czech and Russian dam reservoirs with varied environmental conditions (Vostradovský and Křížek 1992, Tereshchenko et al. 2004).

In light of the differences noted among fish groups in the progressing changes of ichthyofauna composition in dam reservoirs, questions of whether or not it is possible to interfere with this process through fisheries management measures, and especially stocking programs, are raised. There is a significant dependency between reservoir age and changes in the share of the group of “other” fish comprising primarily introduced species, which underscores the role of stocking in the shaping of reservoir fish assemblages. Wiśniewolski (2002b) cites the example of stocking carp in the Siemianówka Reservoir, which, although it initially had a positive impact on the sizes of catches, was finally disadvantageous for water quality (Górniak 2006). However, pike stocking performed from the beginning of the reservoir's existence resulted in a small, but continual, increase in the share of predatory fish in the catches. In the case of the Zegrzyński Reservoir, stocking with common carp, bighead carp, and Prussian carp did not effect the anticipated results (Wiśniewolski 1992). The case with applying mass catches to reduce fish populations (Horppila and Peltonen 1994) indicates that, that although fisheries biomanipulation procedures in dam reservoirs are essential and they do contribute to maintaining appropriate quality in these systems, they are not easy to execute, and their effectiveness can vary (Paller 2005). Opuszyński (1987) demonstrated a mutual dependence between the process of eutrophication and changes in fish assemblages, and concluded that environmental changes in reservoirs impact ichthyofauna assemblages, while changing fish assemblages accelerate the course of environmental changes. The measures implemented by authorities managing reservoirs should, thus, focus as much as is feasible on the primary ichthyofauna structure and the protection of predatory species.

Eutrophying cyprinid species such as common bream, roach, white bream, and Prussian carp comprise the most quickly developing fish group in lowland dam reservoirs from their inundation, and they exhibit continually increasing trends in later years. The share of the other fish groups-predatory, rheophilic, and others, exhibited continually decreasing tendencies as the reservoirs aged. Permanent stocking of lowland reservoirs with predatory species resulted in increasing trends in their shares in catches, but without any dependency on the age of the reservoir. The linear regression functions created for the designated species groups indicate the character of change trends. The share of common bream, roach, white bream, and Prussian carp carp, which are cyprinids that all have a strong impact on the trophic status of reservoirs, exhibited a steady increasing trend that was linked significantly with the age of the reservoir.

References

Backiel T. 1993 – Ichthyofauna of large rivers - preservation trends and possibilities – In: Nature preservation and environmental protection in Polish lowland rivers (Ed) L. Tomiałojć, Wyd. Instytutu Ochrony Przyrody PAN Kraków: 39-48 (in Polish).

Backiel T., Kossakowski J., Rudnicki A. 1956 – Fisheries management in dam reservoirs – Rocz. Nauk Rol. B-71: 65-138 (in Polish).

Balon E.K. 1964 – Verzeichnis und ökologische Charakteristik der Fische in der Donau – Hydrobiologia 24: 441-451.

Bless R. 1978 – Bestandsändrungen der Fischfauna in der Bundesrepublik Deutschland – Ursachen, Zustand und Schutzmassnahmen. Kilda Verlag, Greven, Deutschland, 66 p.

Bremigan M.T., Stein R.A. 2001 – Variable gizzard shad recruitment with reservoir productivity: Causes and implications for classifying systems – Ecol. Appl. 11: 1425-1437.

Colby P.J., Spangler G.R., Hurley D.A., McCombie A.M. 1972 – Effects of Eutrophication on Salmonid Communities in Oligotrophic Lakes – J. Fish. Res. Bd. Can. 29: 975-983.

Drenner R.W., Hambright K. D. 1999 – Biomanipulation of fish assemblages as a lake restoration technique – Arch. Hydrobiol. 146: 129-165.

Dusoge K., Bownik-Dylińska L., Ejsmont-Karabin J., Spodniewska I., Węgleńska T. 1985 – Plankton and benthos of the artificial Lake Zegrzyńskie – Ekol. Pol. 33: 455-479 (in Polish).

Frankiewicz P. 1998 – Regulatory mechanisms within fish assemblages and their influence through the cascading effect on water quality in a lowland reservoir – Wyd. Uniwersytetu Łódzkiego, 126 p. (in Polish).

Frankiewicz P. 2000 – Impact of environmental conditions of biotic interactions on the dynamics of fish assemblages in the Sulejowski Dam Reservoir – In: Selected aspects of fisheries management in dam reservoirs (Eds) J. Szumiec, A. Pilarczyk, J. Mastyński. Proceedings from International Conference, Gołysz, 15-16 May 2000. Gołysz, Wyd. ZIiGR PAN: 46-63 (in Polish).

Freeman M.C., Irwin E.R., Burkhead N.M., Freeman B.J., Bart H.L. Jr. 2005 – Status and conservation of the Fish fauna of the Alabama River system – Am. Fish. Soc. Symp. 45: 557-585.

Giziński A., Błędzki L.A., Kontzner A., Wiśniewski R., Żytkowicz R. 1989 – Hydrobiological characteristic of the lowland, rheolimnic Włocławek Reservoir on the Vistula River – Ekol. Pol. 37: 359-403.

Górniak A. 2006 – Ecosystem of the Siemianówka Reservoir in 1990-2004 and its restoration – Department of Hydrobiology University of Białystok, 236 p. (in Polish).

Hannan H.H., Young W.J. 1974 – The influence of a deep-storage reservoir on the phisicochemical limnology of a central Texas river – Hydrobiologia 44: 177-207.

Hartmann J. 1977 – Fischereiliche Veränderungen in kulturbedingt eutrophierenden Seen – Schweiz. Z. Hydrol. 39: 243-254.

Hartmann J. 1979 – Unterschiedliche Adaptionsfähigkeit der Fische an Eutrophierung – Schweiz. Z. Hydrol. 41, 2: 374-382.

Horppila J., Peltonen H. 1994 – The fate of roach *Rutilus rutilus* stock under an extremely strong fishing pressure and its predicted development after the cessation of mass removal – J. Fish Biol. 45: 777-786.

Irz P., Laurent A., Messad S., Pronier O., Argillier C. 2002 – Influence of site characteristics on fish community patterns in French reservoirs – Ecol. Freshw. Fish 11: 123-136.

Jelonek M., Amirowicz A. 1987a – Composition, density and biomass of the ichthyofauna of the Goczałkowice Reservoir – Acta Hydrobiol. 29: 253-259.

Jelonek M., Amirowicz A. 1987b – Density and biomass of fish in the Rożnów Reservoir (Southern Poland) – Acta Hydrobiol. 29: 243-251.

Jungwirth M. 1998 – River continuum and fish migration – going beyond the longitudinal river corridor in understanding ecological integrity – Fish Migration and Fish Bypasses Fishing News Books: 19-32.

Kajak Z. 1998 – Hydrobiology - Limnology. Inland water ecosystems – Wyd. Nauk. PWN, Warszawa, 356 p. (in Polish).

Kajak Z. 1990 – Main features of the Zegrzyński Reservoir ecosystem on the Narew – In: Aquatic ecosystem functioning and cultivation. Part I. Ecology of dam reservoirs and rivers (Ed.) Z. Kajak, Wyd. SGGW-Akademia Rolnicza, Warszawa: 188-199 (in Polish).

Kajak Z., Dusoge K. 1989 – Temporal and spatial diversity of trophy-indicators in a lowland dam reservoir – Ekol. Pol. 37: 211-233.

Kajak Z., Prus P. 2003 – Seasonal and year-to-year variation of numbers of *Chironomus plumosus* L. and *Tubificidae* in lowland reservoir: regularities, causes, mechanisms – Pol. J. Ecol. 51: 339-351.

Klupp R. 1994 – Biomanipulation - Entahme von zooplanktonfressenden Fischen - im Weissenstaedter See und Trebgast See – Fischer Teichwirt, 45: 258-260.

Kuznecov V.A. 1980 – Fluctuation in the abundance of commercial fishes influenced by regulated river discharge (as exemplified by Kuybyshev Reservoir) – Vopr. Ikhtiol. 20: 805-811 (in Russian).

Mheen H. 1993 – Assessment of fishing pressure in reservoirs – Alcom News 10: 17-22.

Matthews W.J., Gido K.B., Gelwick F.P. 2004 – Fish assemblages of reservoirs, illustrated by Lake Texoma (Oklahoma-Texas, USA) as a representative system – Lake Reser. Manage. 20: 219-239.

Matyas K., Oldal I., Korponai J., Tatrai I., Paulovits G. 2003 – Indirect effect of different fish communities on nutrient chlorophyll relationship in shallow hypertrophic water quality reservoirs – Hydrobiologia 504: 231-239.

Mikulski J., Tarwid K. 1951 – Possible impact of Vistula River regulation on some feeding grounds of benthic fish – Rocz. Nauk Rol. 57: 179-204 (in Polish).

Miranda L.E. 2001 – A review of guidance and criteria for managing reservoirs and associated riverine environments to benefit fish and fisheries – In: Dams, fish and fisheries. Opportunities, challenges and conflict resolution (Ed.) G. Marmulla, FAO fisheries technical paper 419: 91-137.

Morawska B. 1968 – Fish and fishing in the Vistula River near Włocławek – Zesz. Nauk. SGGW 7: 23-56 (in Polish).

Nusch E.A. 1993 – Water quantity and quality in lakes and reservoirs for human uses – Mem. Ist. Ital. Idrobiol. 52: 237-255.

Opuszyński K. 1987 – Feedback loop between the eutrophication process and changes in fish assemblages. Theory of ichthyoeutrophication – Wiad. Ekol. 33(1): 21-30 (in Polish).

Paller M.H. 2005 – The influence of biomanipulation on fish community development in a southeastern United States cooling reservoir – Hydrobiologia 539: 69-81.

Schiemer F. 1985 – Die Bedautung der Auegewässer als Schutzzonen für die Fischfauna – Österr. Wasserwirtschaft 37: 9-10.

Starmach K. 1958 – Hydrobiological foundations for water supply systems exploiting shallow river reservoirs – Pol. Arch. Hydrobiol. 4(17): 10-67 (in Polish).

Starmach J., Jelonek M. 2000 – Special fishery - one of several parameters of water quality protection – In: Dobczyce Dam Reservoir Ecology-Trophy-Protection (Eds) J. Starmach, G. Mazurkiewicz-Boroń, Zakład Biologii Wód im. Karola Starmacha PAN. Kraków: 233-240 (in Polish).

Steiner V. 1992 – Fischereiliche Nutzung von Kraftwerksspeichern – Öst. Fischerei 45: 58-69.

Sych R. 1997 – Some remarks on fish density, examples from dam-reservoirs – In: Angling in protection of waters and fish, Conference Materials, Łódź 1997, Wyd. Polskiego Związku Wędkarskiego, Materiały Uzupełniające Roczników Naukowych: 53-66 (in Polish).

Szlakowski J., Wiśniewolski W. 2001 – Fish biomass in Zegrzyński Reservoir as an aspect of exploitation using the silver bream, *Blicca bjoerkna* (Linnaeus, 1758), as an example – Suppl. Acta Hydrobiol. 1: 67-76 (in Polish).

Tereshchenko V.G., Trifonova O.V., Tereshchenko L.I. 2004 – Formation of the fish population structure in reservoir, from filling to present, with introduction of new fish species – J. Ichthyol. 44: 575-586.

Volodin V.M. 1992 – Some peculiarities of the population structure of bream *Abramis brama* in the Ivankovsk and Rybinsk dam reservoirs and factors conditioning them – Vopr. Ikhtiol. 32: 149-156 (in Russian).

Vostradovský J., Křížek J. 1992 – On conditions in ichthycenoses of some selected waters in Bohemia. I. Reservoirs Karchov, Lučina, Nýrsko, Staviště, Želivka and Žlutice – Bul. VÚRH Vodňany 3: 67-77.

Vostradovský J., Tichý J. 1999 – History of fish stock development, fishery management and research on the Lipno Reservoir – Bul. VÚRH Vodňany, 1/2: 48-65.

Wajdowicz Z. 1964 – Development of the ichthyofauna of dam reservoirs with little fluctuation in the state of the water – Acta Hydrobiol. 6: 61-79 (in Polish).

Wajdowicz Z. 1979 – Development of ichthyofauna in the San cascade – Acta Hydrobiol. 21: 73-90 (in Polish).

Wiśniewolski W. 1992 – Results of stocking the Zegrzyński Reservoir with marked bighead carp, carp, and Prussian carp – Rocz. Nauk. PZW 5: 105-118 (in Polish).

Wiśniewolski W. 2000 – Exploited fish assemblages in the Włocławski Reservoir prior to and following the ecological disaster – In: Selected aspects of fisheries management in dam reservoirs (Eds) J. Szumiec, A. Pilarczyk, J. Mastyński. Proceedings from International Conference, Gołysz, 15-16 May 2000. Gołysz, Wyd. ZIiGR PAN: 152-165 (in Polish).

Wiśniewolski W. 2002a – Advantageous and disadvantageous factors for the development and maintenance of fish populations in flowing waters – Suppl. Acta Hydrobiol. Kraków, 3: 1-28 (in Polish).

Wiśniewolski W. 2002b – Changes in ichthyofauna composition, biomass, and catches in selected dam reservoirs in Poland – Arch. Pol. Fish. 10(Suppl. 2): 5-73 (in Polish).

Wundsh H. H. 1949 – Grundlagen der Fischwirtschaft in den Grossstaubecken – Abhandl. Fisch. Hilfswiss. 42, 1: 17-186.

Zalewski M., Brewińska-Zaraś B., Frankiewicz P., Kalinowski S. 1990 – The potential for biomanipulating using fry communities in a lowland reservoir: concordance between water quality and optimal recruitment – Hydrobiologia 200/201: 549-556.

Streszczenie

Zmiany zachodzące z upływem czasu w eksploatowanych gospodarczo zespołach ryb nizinnych zbiorników zaporowych

Zmiany w ichtiofaunie trzech, płytkich zbiorników zaporowych położonych w centralnej i wschodniej Polsce przedstawiono na przykładzie wieloletnich połowów gospodarczych. Kształtowanie się wielkości udziałów eksploatowanych gatunków ryb w miarę starzenia się zbiorników zobrazowano liniami trendów czasowych opisanych funkcjami regresji. Gatunki będące przedmiotem połowów gospodarczych przyporządkowano, w zależności od roli, jaką pełnią w zbiorniku, do charakterystycznych grup ekologicznych: drapieżne, karpiowate eutrofizujące, rzeczne i inne. W każdym z badanych zbiorników z upływem lat obserwowano wzrost wielkości połowów ryb karpiowatych z grupy eutrofizujących. Najsilniej uwidocznił się on w Zbiorniku Siemianówka, w pierwszym okresie po utworzeniu zalewu: współczynnik nachylenia „b" linii trendu wyniósł 7,25 przy R^2 = 0,9. W zbiorniku tym obserwowano także stały wzrost populacji ryb drapieżnych, związany z intensywnym zarybianiem szczupakiem, *Esox lucius* L. Udziały gatunków ryb drapieżnych w pozostałych zbiornikach spadały od początku powstania zbiornika, by w ostatnich latach ustabilizować swoją wysokość na minimalnym poziomie, przy niewielkim wzrastającym trendzie. Wyprowadzona dla wszystkich zbiorników ogólna zależność między wielkością średnich udziałów grup ryb w połowach a czasem, jaki upłynął od powstania zbiornika, była w całym okresie istnienia zbiornika wysoce istotna dla wszystkich wyróżnionych grup.