Arch. Pol. Fish.	Archives of Polish Fisheries	Vol. 15	Fasc. 2	141-156	2007

IMPACT OF THE WŁOCŁAWEK DAM ON MIGRATORY FISH IN THE VISTULA RIVER

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ABSTRACT. The aim of this paper is to summarize knowledge concerning the decline of vimba, *Vimba vimba* (L.) and sea trout, *Salmo trutta* m. *trutta* L. populations in the Vistula River following damming and the effectiveness of measures undertaken to counteract this and rebuild fish stocks. The assessment of the fish pass at the Włocławek Dam was done using both the conventional method of counting all the fish entering the fish pass and a new one based on data obtained with a special trap that permitted counting only the fish that had reached the top chamber of the fish pass (i.e., those that actually passed through it). Completed in 1968, the Włocławek Dam on the Vistula is located 266 km from the river mouth. A conventional pool fish pass was constructed in the dam in 1970. However, this measure was ineffective, and the dam prevented the upstream migration of vimba and sea trout. In order to minimize the negative effects of damming on the vimba population, the unconventional method of transporting spawners was applied in the 1970s and early 1980s. Despite promising results, this experiment of transporting spawners was discontinued in 1982 due to a lack of funding. The results of this experiment are summarized in the present paper, and similar methods are proposed for the future restoration of the vimba population in the Vistula River. Restoration programs for salmon, *Salmo salar* L. sea trout, vimba, and sturgeon, *Acipenser oxyrinchus* Mitchill, are currently in development in Poland. On the Vistula River the Włocławek Dam is the main obstacle that prevents them from being fully successful.

Key words: VISTULA RIVER, MIGRATORY FISH, FISH PASS, DAMMING, SEA TROUT, VIMBA

INTRODUCTION

The structure of ichthyofauna communities inhabiting rivers depends on various factors (Bless 1978, Wiśniewolski 2002). On a long-term scale, river damming has been revealed to have a particularly drastic impact on these ecosystems as it disrupts their ecological continuum (Backiel 1983, Wiśniewolski 1985, 1992, Bartel 2002). The basic foundation for the successful implementation of increasingly common measures undertaken to restore migratory fish to their former areas of distribution is the reconstruction of migration routes and free access to spawning grounds (Sych 1998).

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The construction of fish passes and other means facilitating fish migration has permitted realizing this task (Gebler 1991, Krüger et al. 1993, Wiśniewolski 2003). One of the ways to restore populations is to intensify the protection of extant wild spawning populations, spawning grounds, and rearing habitats as well as to strengthen such populations or rebuild them by stocking with fish reared under controlled conditions. Such work has been ongoing in Poland since the 1970s with regard to sea trout, *Salmo trutta* m. *trutta* L., and since 1994 with regard to salmon, *Salmo salar* L. and is presently being conducted within the framework of the "Program for the restoration of migratory fish in Poland" (Sych 1998, Bartel 2002). The aim of this program is to rebuild and protect populations of sturgeon, *Acipenser oxyrinchus* Mitchill, migratory trout, salmon, and migratory vimba, *Vimba vimba* (L.) in Poland.

Formerly, these species undertook spawning migrations to the tributaries of the upper Vistula (Dunajec, Raba, Soła, Skawa, Wisłok, San) as well as to the tributaries of the lower and middle Vistula (Drwęca, Brda, Wierzyca, Bug, Narew; Fig. 1). These same species also undertook spawning migrations in the Oder River basin to the following tributaries, among others, the Warta, Noteć, Gwda, Wełna, Bukówka, and Drawa. They were also noted in Pomeranian rivers. There were some distinct differences in species distribution in particular rivers, but these were most often related to the existence of convenient spawning grounds for a given species.

Human activities such as excessive forest exploitation, the utilization of rivers as sewage collectors, land reclamation projects, and regulatory works, which often have harmful effects on the environment and can include river regulation, the elimination of river bends, backwaters, dredging, gravel and sand excavation in river beds and, in particular, river damming, have all contributed to the creation of very unfavorable environmental changes. These activities combined with excessive fish exploitation have caused unfavorable changes in ichthyofauna communities. The effect of these transformations in the environment is reflected in the shortening of spawning migration routes, limited access to spawning grounds, and even the destruction of spawning grounds and rearing habitats for juvenile fish. Catches of migratory fish in rivers as well as the number of spawners reaching spawning grounds have decreased. Limiting natural reproduction has caused entire populations to disappear or has led to drastic decreases in their sizes. In consequence, the existence of these populations depends on continued stocking.

Fig. 1. Migration routes to the main spawning grounds of sea trout, vimba and salmon in the Vistula River system. Solid thick line – open section below the Włocławek dam, dashed lines – section disconnected by the dam.

Damming disrupts the ecological continuum of rivers and is the main threat to migratory fish. Dams either hinder or prevent anadromous fish from reaching spawning grounds. These constructions also cause changes in the characteristics of rivers and pose an additional risk to fish progeny as they swim downstream. The turbine channels of hydroelectric power stations constitute a particular threat to juvenile and adult fish as they pass through them while swimming downstream. A great number of the fish that pass through these channels are either damaged or killed by the turbines. These fish losses depend on the height of the dam, the turbine type, and the engine rotor speed (Chrzan 1947, Bartel et al. 2002).

The problem of insufficient natural spawning and, in consequence, decreased numbers of salmon and sea trout was identified over a century ago, and the first stocking attempts were undertaken with salmon smolts as early as 1879 and with sea trout in 1880 (Kołder 1958). The importance of this procedure increased together with the ongoing process of river damming and the continued decrease in the effectiveness of natural spawning. In 1940, the construction of the Rożnów Reservoir on the Dunajec River in the upper Vistula system resulted in limited access to spawning grounds located 22 kilometers upstream. The situation was not improved by the construction of the fish pass in 1942 (Chrzan 1947, Juszczyk 1949). In subsequent years, several other spawning grounds located in other tributaries of the upper Vistula were affected in the same way; nevertheless, some did remain accessible to the fish. The damming of the Vistula on the 675 km in Włocławek in 1968 prevented fish from migrating to the upper reaches of the Vistula system despite the pool fish pass constructed in 1970.

Catches of sea trout and vimba illustrate the negative effects the Włocławek Dam has on the populations of these fish. Prior to damming the Vistula River, the average annual catches in the lower run of the river from Włocławek to the mouth were 33.3 tons of sea trout and 94.7 tons of vimba, and upstream the Vistula from Włocławek catches were 14.7 and 16.4 tons, respectively. After the construction of the Włocławek Dam, catches of sea trout and vimba in the lower reach of the river below the dam decreased to an average annual of 12.9 and 20.1 tons, while above the dam sea trout catches fell to almost zero while only 0.1 tons of vimba were caught (Fig. 2, Wiśniewolski 1987, 1992).

The aim of this paper is to summarize the knowledge regarding the decline of the vimba and sea trout populations in the Vistula River following damming and the effectiveness of measures undertaken to counteract the decline and to rebuild these fish stocks.

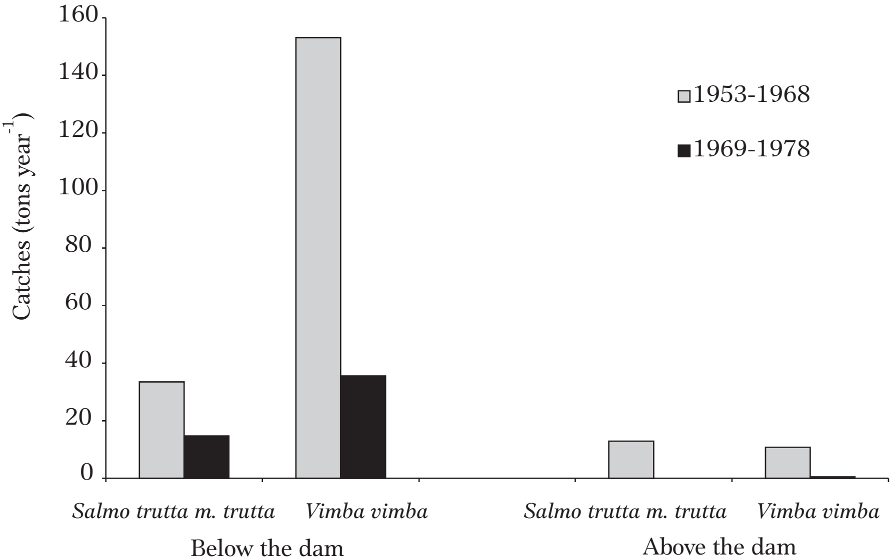

Fig. 2. Mean annual catches of sea trout and vimba in the Vistula River before (1953-1968) and after (1969-1978) the construction of the Włocławek Dam in 1968.

MATERIAL AND METHODS

This study was conducted based on information from the literature, multi-annual statistical data on commercial catches of migratory fish, data on the protection and restoration measures undertaken to preserve or rebuild the populations, and the archival resources of the Inland Fisheries Institute in Olsztyn.

From 1973 to 1982, an experiment was conducted annually that entailed deploying floating nets to catch the vimba spawners that had gathered at the base of the dam in the Vistula River (the weight of the fish ranged from less than 1 ton to approximately 20 tons), transporting them live to a location above the dam, and releasing them back into the Vistula River to allow them to continue their migration (Backiel 1983, Wiśniewolski 1985, 1992). Continual records were kept of commercial catches made along the entire length of the Vistula system (Wiśniewolski 1987).

The results of studies from 1998 to 2004 on the effective use of the fish pass in the Włocławek Dam by different species were also used. Observations were performed once monthly from April to November or December. The number of fish that entered the pass and the number that reached the highest pool, thus successfully passing the dam, was determined. In order to determine the number of fish entering the pass, the exit to the upper waters was closed off with bars and after an average of 24 hours, the entrance in the lower part of the pass was closed off with bars. After water flow into the fish pass had been cut off, the fish remaining in it were counted and the species identified.

In order to determine the passage of fish through the pass, special funnel-shaped traps were installed in the flow and the bypass openings of the highest resting pool. Thanks to this shape water could easily flow through the fish pass and fish migrating upstream could reach the chamber without any obstacles. However, they could not leave the pool, because the construction of the gate prevented them from finding the exit and swimming down the pass, whereas the upper exit was closed with bars. The fish that reached the second to the last chamber of the pass gathered there because they could neither swim to the reservoir nor return to the chambers located below. After an average of 24 hours, the water flow into the pass was cut off and the number of fish in the upper chamber was counted, and the fish were segregated by species.

RESULTS

EXPERIMENTAL TRANSPORT OF VIMBA SPAWNERS ABOVE THE WŁOCŁAWEK DAM

Seven years after initiating the transport of vimba spawners, a ten fold increase in catches of this species was observed in the Vistula River system. This was connected with the life cycle of vimba, which return in large numbers from the sea to spawn in their home river at age 6 or 7 (Bontemps 1969, Wiśniewolski 1992). The results of the actual catches were slightly lower from the results estimated from spawners transport; however, in subsequent years catches remained at a constant proportion to the estimated catches (Fig. 3). This indicates that the experimental transport of spawners had a distinct and considerable impact on catch results, and, in consequence, on the size of the vimba population in the Vistula River. This effect was confirmed by the gradual decrease in vimba catches after the spawners transport program was discontinued in 1982. Seven years following the end of the experiment (1989), catches of vimba again fell to the level registered before the program was initiated.

This historical example of the effectiveness of the active protection of the migratory vimba population is a guideline for undertaking similar measures within the framework of the proposed restoration program aimed at increasing natural reproduction. The effectiveness of spawners transport also indirectly highlights the insufficiencies of the Włocławek Dam fish pass, which does not permit sufficient numbers of spawners to migrate upstream. This is confirmed by the decrease in catches after the spawners transportation program was discontinued.

EVALUATION OF THE PASSAGE OF FISH THROUGH THE FISH PASS IN WŁOCŁAWEK

The studies on the effectiveness of the Włocławek Dam fish pass indicated considerable differences in the numbers of fish entering the pass and the number which reached the highest pool and effectively pass through the facility. In 1998-2001, an average of 693 fish entered the fish pass per day (Fig. 4). A total of 19 species was noted. The most numerous were eel, *Anguilla anguilla* (L.), white bream, *Abramis bjoerkna* (L.), roach, *Rutilus rutilus* (L.), bream, *Abramis brama* (L.) and bleak, *Alburnus alburnus* (L.), which

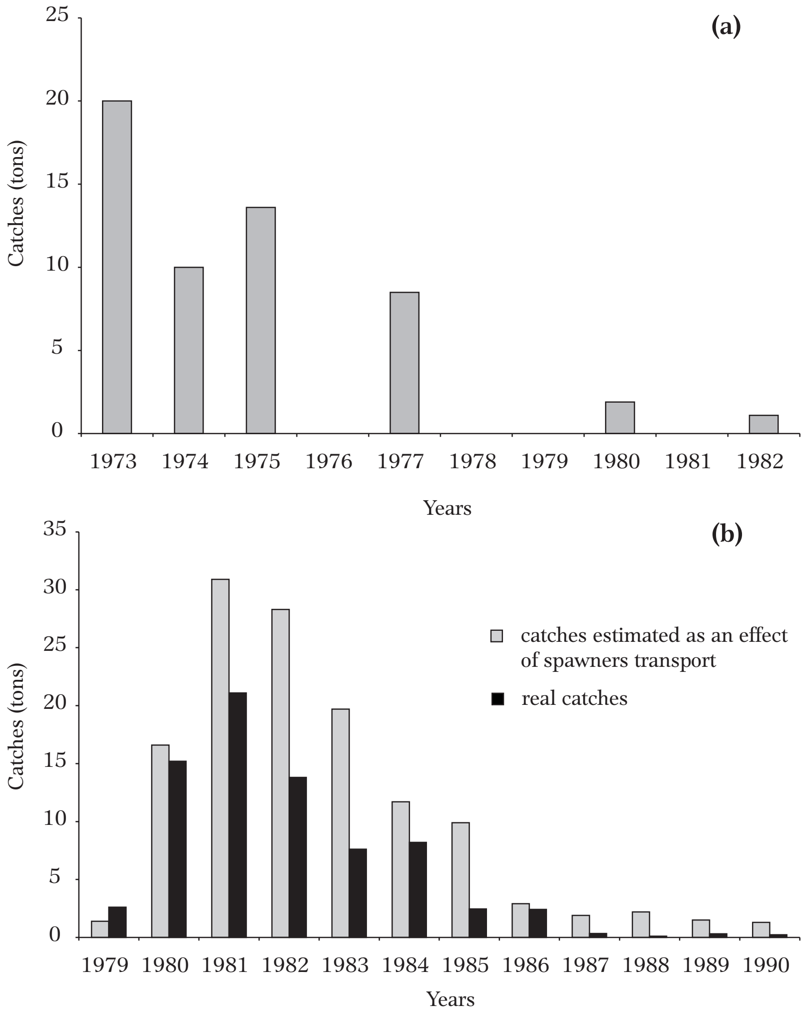

Fig. 3. Fishery practices in 1973-1982 in order to protect the migratory vimba population in the Vistula River. a – Catching vimba spawners below and transporting them above the Włocławek Dam, b – Estimated and actual vimba catches in the Vistula River.

constituted 86% of all the fish observed (Fig. 5). The share of vimba was significant (7%), but the share of sea trout was low at approximately 1%.

Observations conducted in 2002-2004 indicated that an average of 34 fish per day reached the highest pool (Fig. 6), which means that the number of fish actually crossing the pass is 26 times lower than the number of entering it. Sixteen species successfully crossed the fish pass; the most numerous were roach and bream that constituted a total

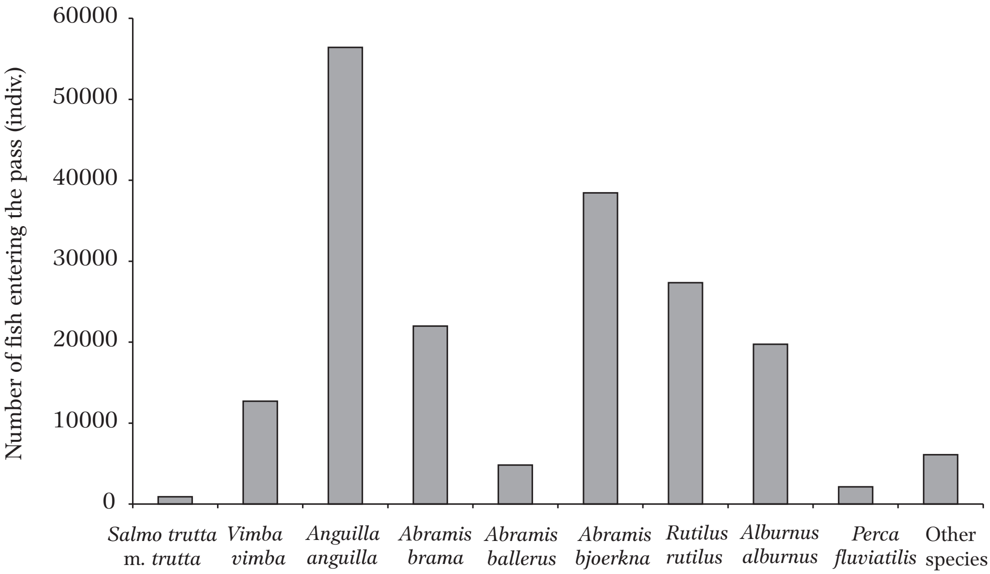

Fig. 4. Estimated number of fish entering the fish pass in the Włocławek Dam during observation seasons (275 days in April-December). Mean for seasons 1998-2001.

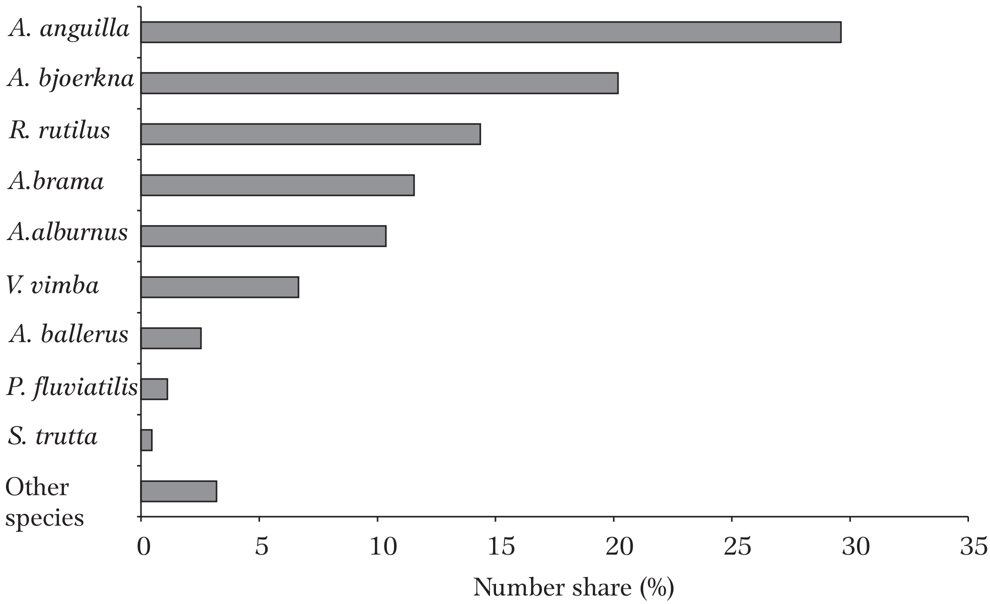

Fig. 5. Share of fish species registered in all pools of the fish pass (entering the pass) at Włocławek Dam on the Vistula River (mean for seasons 1998-2001).

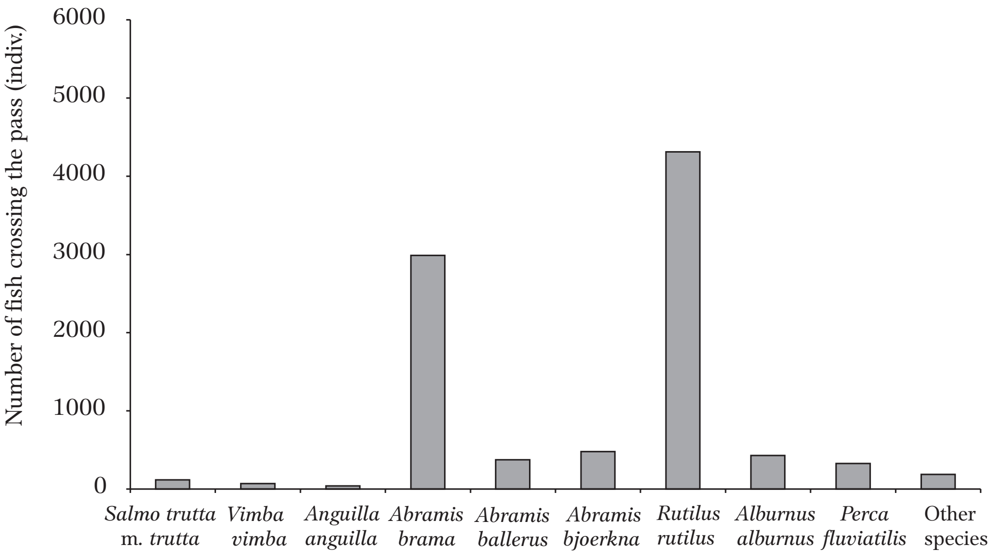

Fig. 6. Estimated number of fish crossing the fish pass in Włocławek Dam during observation seasons (275 days, April-December). Mean for seasons 2002-2004.

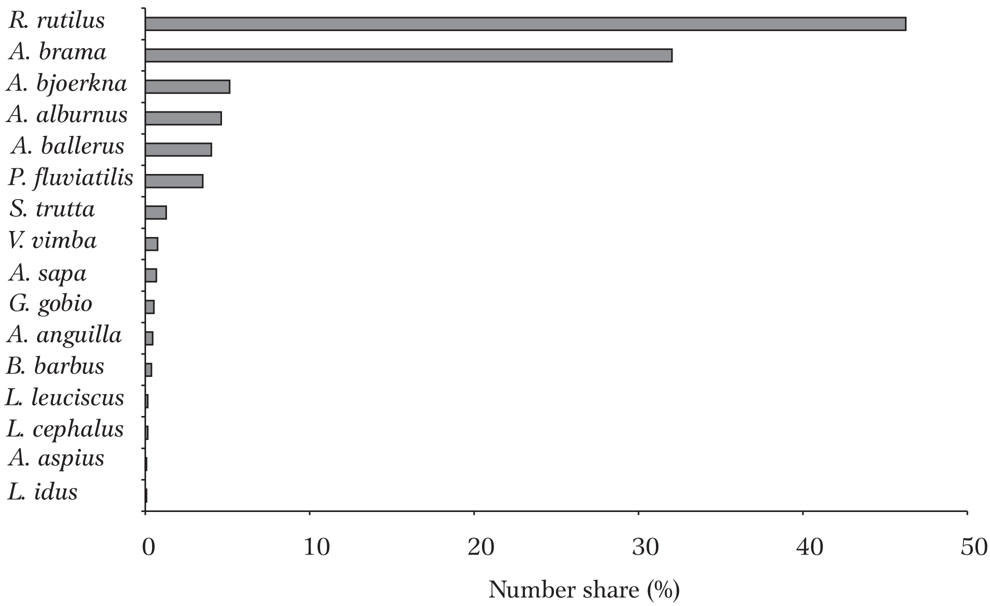

Fig 7. Share of fish species registered in the top pool of the fish pass (crossing the pass) at the Włocławek Dam on the Vistula River (mean for seasons 2002-2004).

of 79% of all the fish (Fig. 7). The share of sea trout and vimba was approximately 1%, while ascending eel was less than 1%. The total number of sea trout and vimba spawners that crossed the pass during one year was estimated to be approximately 100 individuals of each; this number is insufficient for preserving either of the two populations throughout the Vistula River basin.

The 16 species that used the fish pass successfully represented less than half of the number of species that inhabit the Vistula River below the Włocławek Reservoir. This indicates just how ineffective and unimportant the fish pass is for migrating fish in the Vistula River system (Table 1).

TABLE 1

Fish species found in the Vistula River below the Włocławek Dam (in commercial and experimental catches) and the species noted in the top pool of the fish pass at Włocławek Dam (trap method, 2002-2004)

Species group					
Migratory behavior	Current velocity preference	Origin	Body size	Fish species	Observed crossing the fish pass
anadromous	reophilous	native	large	*Salmo trutta* m. *trutta* L.	+
			medium	*Vimba vimba* (L.)	+
catadromous		native	small /large*	*Anguilla anguilla* (L.)	+
potamodromous/ stationary	eurytopic/ stagnophilous	native	large	*Silurus glanis* L.	-
			large	*Esox lucius* L.	-
			large	*Sander lucioperca* (L.)	-
			medium	*Perca fluviatilis* L.	++
			large	*Abramis brama* (L.)	+++
			medium	*Abramis bjoerkna* (L.)	++
			medium	*Abramis ballerus* (L.)	++
			medium	*Rutilus rutilus* (L.)	+++
			small	*Alburnus alburnus* (L.)	++
			medium	*Scardinius erythrophthalmus* (L.)	-
			medium	*Carassius carassius* (L.)	-
			large	*Tinca tinca* (L.)	-

cont. Table 1

Species group				Fish species	Observed crossing the fish pass
Migratory behavior	Current velocity preference	Origin	Body size		
potamodromous/ stationary	eurytopic / stagnophilous	native	small	*Gymnocephalus cernuus* (L.)	-
			small	*Cobitis taenia* L.	-
			small	*Alburnoides bipunctatus* (Bloch)	-
			small	*Rhodeus sericeus* (Pallas)	-
			small	*Leucaspius delineatus* (Heckel)	-
			small	*Barbatula barbatula* (L.)	-
			small	*Gasterosteus aculeatus* L.	-
potamodromous/ stationary	stagnophilous	alien	small	*Carassius auratus gibelio* (Bloch)	-
	reophilous		medium	*Abramis sapa* (Pallas)	+
	stagnophilous		large	*Cyprinus carpio* L.	-
	stagnophilous		large	*Hypophthalmichthys molitrix* (Valanciennes)	-
	reophilous		small	*Perccottus glenii* Dybowski	-
potamodromous	reophilous	native	large	*Aspius aspius* (L.)	+
			large	*Barbus barbus* (L.)	+
			medium	*Lota lota* (L.)	-
			small	*Gobio gobio* (L.)	+
			large	*Leuciscus leuciscus* (L.)	+
			large	*Leuciscus cephalus* (L.)	+
			large	*Leuciscus idus* (L.)	+

+++ – dominant (> 30%), ++ – frequent (3-5%), + – sporadic (<2%)
**small – when migrating upstream; large – when migrating downstream*
- – species did not cross the fishpass

DISCUSSION

The impact the Vistula River's Włocławek Dam has had historically and presently on the distribution range of migratory sea trout and vimba is well documented by the fluctuations in catch size based on statistical data from commercial catches mentioned previously in this study (Wiśniewolski 1987). Statistical data on commercial catches are a good measure of changes occurring in ichthyofauna communities that result from various factors. The description of fishing practices and changes in fish assemblages that occurred in the Elba River after it was dammed (Schiemenz and Köthke 1956) and the collapse in professional fishing on the Rein (Denzer 1966, Kuhn 1976) and Vistula Rivers (Wiśniewolski 1987) are all examples. A comprehensive description of the factors that led to considerable transformations in the ichthyofauna of German rivers was published by Bless (1978). These were confirmed in a paper written by Jungwirth (1998), who considers the maintenance of the ecological continuum of river ecosystems to be the decisive criteria in ensuring the preservation of migratory fish populations. It is also of fundamental importance for the success of their restoration (Bartel 1993, 1997, 2002, Sych 1998).

One way of protecting migratory fish populations when migratory routes are obstructed is to catch the fish gathered below the dam and transfer them to a location above the dam thus permitting them to continue their spawning migration and to reach the spawning grounds. This was demonstrated feasible by the results of an experiment in transporting vimba spawners above the Włocławek Dam (Backiel 1983, Wiśniewolski 1985, 1992). This unique experiment, which is not cited frequently in the literature, describes this method of safeguarding threatened populations. Transporting spawners must be continued consequently until the obstacle preventing fish migration to spawning grounds is made passable, as the positive effects of this undertaking depends on it. This was confirmed by the decrease in Vistula River vimba catches to the level noted before the experiment that occurred seven years following its completion.

An effective preservation method for migratory sea trout and salmon populations is to perform stocking with material reared under controlled conditions. This permits the commercial exploitation of the population in the event of limited or even the lack of access to natural spawning grounds (Wiśniewolski 1987, 1992, Bartel 1993, 1997, 2002). The smolt development stage, during which descending migrations from the river to the sea are made, is a particularly effective stocking material for this method. The fact that these smolts return as adult fish to the places of their release should be emphasized. This has been confirmed by the results of tagging studies of sea trout smolts released into the Vistula River; the fish returned to the river despite long feeding migrations throughout the Baltic Sea (Bartel 1987, 2002, Dębowski and Bartel 1995).

The lack of tag returns from the part of the Vistula River basin above Włocławek confirms the negative impact of this dam on the migratory fish populations in this river. The success of stocking is not equivalent to species restoration because this can only be considered when a population is capable of sustaining itself as a result of self-reliant, natural reproduction (Sych 1998, Wiśniewolski et al. 2006). Nevertheless, the stocking method is an extremely important element in protecting migratory fish as well as the fishery economy.

Preserving open migration routes is of key importance for the protection and successful restoration of migratory fish. This is possible to attain by constructing functional fish passes, which reinstate in rivers the ecological continuum that is lost when a transverse construction is built. There are many examples of effectively functioning fish passes (Sakowicz and Żarnecki 1954, Gebler 1991, Adam et al. 1996, Eberstaller et al. 1998, Mader et al. 1998, Steiner 1998). There are also examples of badly functioning passes (Sakowicz and Żarnecki 1954, Pelz 1985, Wiśniewolski 1992). This may not just be the result of design faults, it could also be a consequence of the deteriorating ecological continuum of rivers.

Examples of poorly functioning fish passes may lead to the erroneous conclusion that constructing such facilities is futile. One such example was published by Pelz (1985), who studied the effectiveness of fish passes in the Mosel River system, specifically cascades of water steps that only preserved the river in some sections. One of the arguments raised is that after negotiating the pass, the fish did not encounter better conditions because those in the upper, dammed parts of the river are the same. This view was evaluated critically by Gebler (1991) and Eberstaller et al. (1998), who both draw attention to the fact that the above mentioned conclusion ignores the existence of a river continuum in the river ecosystem and the role played by non-dammed sections of the river and even its smallest tributaries entering the main river in preserving the biodiversity of river fauna assemblages, especially reophilous species. Justifications questioning the conclusion on the futility of constructing fish passes are given by the observations of the functioning of two modern fish passes (“ecological”) located on the Marchfeldkanal, which constitutes a by-pass to one of the dams in the Austrian section of the Danube River. In 1995, 31,335 and 57,278 fish belonging to 34 species passed through this fishpass (Mader et al. 1998).

Observations of fish negotiating the fish pass in the Włocławek Dam indicated that the appropriate construction of the facility is of enormous importance. The barrage in Włocławek with its improperly functioning fish pass closes off the entire Vistula River system located above the dam. This is confirmed by the statistical data on commercial catches in the Vistula River system (Wiśniewolski 1987), the results of stocking of this river with tagged sea trout smolts (Bartel 2002), as well as the experiment of transporting migrating spawners above the dam in Włocławek (Backiel 1983, Wiśniewolski 1985, 1992). The results show that solving of the problem of the migration of migratory fish and the success of their restitution in the Vistula River system requires building a new fish pass in the Włocławek Dam that conforms to the current state-of-the-art. It should not only provide free access for migratory fish to spawning grounds in the tributaries of the Vistula River located in the Carpathian region, but also the safe by-passing of the hydroelectric power station in the Włocławek Dam by descending smolts and adult fish. However, this extremely important issue is not the subject of the present work.

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Received – 12 March 2007

Accepted – 28 June 2007

STRESZCZENIE

WPŁYW ZAPORY WE WŁOCŁAWKU NA RYBY WĘDROWNE W WIŚLE

Budowa zapory na Wiśle we Włocławku (266 km od ujścia) w 1968 r. spowodowała przerwanie szlaków wędrówek m.in. łososia, *Salmo salar* L., troci, *Salmo trutta* m. *trutta* L., certy, *Vimba vimba* (L.) i węgorza, *Anguilla anguilla* (L.) w systemie Wisły (rys. 1). Pomimo oddania do użytku w 1970 r. przepławki w stopniu wodnym Włocławek w kolejnych latach nastąpił drastyczny spadek połowów gospodarczych troci i certy w całym systemie Wisły (rys. 2). Powodzenie realizowanego obecnie programu restytucji ryb wędrownych w Polsce jest w znacznym stopniu uzależnione od odtworzenia ciągłości ekologicznej Wisły, przerwanej przez zaporę we Włocławku.

Pracę oparto na statystykach odłowów gospodarczych ryb gromadzonych w Instytucie Rybactwa Śródlądowego w Olsztynie, danych o działaniach ochronnych i restytucyjnych podejmowanych dla zachowania bądź odtworzenia populacji ryb wędrownych. Analizowano wpływ odłowu i transportu cert, wędrujących na tarło powyżej zapory we Włocławku w latach 1973-1982, a także wyniki badań nad możliwością pokonywania przepławki na zaporze we Włocławku przez różne gatunki ryb, prowadzone w latach 1998-2004.

W siedem lat po rozpoczęciu przenoszenia tarlaków certy zaobserwowano około 10-krotny wzrost odłowów gospodarczych tego gatunku w systemie Wisły. Wyniki rzeczywistych połowów były nieco niższe od estymowanych jako wynik przenoszenia tarlaków, jednak w kolejnych latach pozostawały w stałej proporcji do nich (rys. 3). Świadczy to o istotnym wpływie podjętych zabiegów na wyniki połowów, a co za tym idzie – na liczebność populacji certy w Wiśle. Potwierdzeniem tego efektu był stopniowy spadek połowów certy po zaniechaniu w 1982 r. przenoszenia tarlaków przez zaporę. W 7 lat po zakończeniu eksperymentu (1989 r.) odłowy certy osiągnęły ponownie poziom notowany przed jego podjęciem.

Badania funkcjonowania przepławki na zaporze we Włocławku wykazały znaczną różnicę między liczbą ryb wchodzących do niej i tych, które docierają do najwyższej komory, czyli faktycznie pokonują przepławkę. W latach 1998-2001 dziennie wchodziły do przepławki średnio 693 ryby (rys. 4). Zanotowano obecność 19 gatunków. Dominowały wśród nich węgorz, krąp, *Abramis bjoerkna* (L.), płoć, *Rutilus rutilus* (L.), leszcz, *Abramis brama* (L.) i ukleja, *Alburnus alburnus* (L.), stanowiące łącznie 86% wszystkich ryb. Udział certy był znaczący (7%), natomiast udział troci niski (około 1%) (rys. 5).

Obserwacje z lat 2002-2004 wykazały, że w ciągu doby do najwyższej komory docierały średnio 34 ryby (rys. 6). Liczebność ryb faktycznie pokonujących przepławkę była zatem 26 razy mniejsza niż wchodzących do przepławki. Wśród ryb pokonujących przepławkę stwierdzono przedstawicieli 16 gatunków, wśród których dominowały płoć i leszcz, stanowiące łącznie 79% wszystkich ryb (rys. 7). Udział troci i certy wynosił około 1%, a węgorza poniżej 1%. Całkowita liczba tarlaków troci i certy pokonujących przepławkę w ciągu roku może być szacowana na około 100 osobników każdego gatunku, co w skali dorzecza Wisły praktycznie nie ma znaczenia dla zachowania ich populacji.

Gatunki pokonujące przepławkę stanowią mniej niż połowę gatunków występujących w Wiśle poniżej Zbiornika Włocławskiego (tabela 1). Świadczy to o słabej efektywności funkcjonowania i małym znaczeniu przepławki dla przemieszczania się ryb w systemie Wisły. Dla zapewnienia powodzenia programu restytucji ryb wędrownych w Polsce niezbędna jest modernizacja istniejącej przepławki bądź budowa nowoczesnego przejścia dla ryb.