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Short communications

FISH PASSING THROUGH THE TURBINES OF POMERANIAN RIVER HYDROELECTRIC PLANTS

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ABSTRACT. The rate of losses resulting from fish (rainbow trout of a total length of 12 – 23 cm, the same size as sea trout smolts) passing through turbines was estimated. The fish were provided with 3 x 4 cm Styrofoam floats tied to their backs under the dorsal fin. The tagged fish were immersed in covered buckets into the inlet of the turbine canal before switching on the turbines. The bucket lids were removed by a special line, and the fish were drawn into the turbine canal with the water flow. After passing through the canal, the fish, which had a limited area to move in at a greater depth and were easily identified due to the styrofoam floats, were recaptured manually with nets from boats.
Fish losses at the hydroelectric power plants situated on Pomeranian rivers ranged from 0.0 to 60% and depended on the differences between water levels upstream and downstream from the hydroelectric power plants and on the turbine's rotation speed per minute.

Key words: RAINBOW TROUT (*ONCORHYNCHUS MYKISS*), SMOLT, SEA TROUT (*SALMO TRUTTA* M. *TRUTTA*), TURBINES, FISH PASSING

Stocking rivers and streams is currently one of the primary methods of maintaining the abundance of fish populations. The stocked segments of rivers and streams are often separated from other parts by valley dams which have hydroelectric power plants. When this is the case, the only way the fish can swim downstream is through the canals of working hydroelectric turbines. Fish can sustain injuries while making the passage; thus the issue was raised if stocking above valley dams is sensible and profitable. In order to answer this question, it must be ascertained how much loss is sustained as the fish pass through the turbine canals of hydroelectric power plants located in dams. This has been the subject of study for many years now; the first papers dedicated to this issue were published by Alm (1927, 1929). Bieniarz and Epler (1973) published a review of relevant literature, and since this time one of the most significant papers to be published in this field is the work by Larinier and Dartiguelongue (1989). In the papers cited above, the greatest challenge to the studies was devising a method for recapturing fish which had passed through the canals of working turbines, as most authors were only able to capture several percent of the initially released fish.

It would appear that the most reliable method to date for capturing the majority of fish, irregardless of the degree of injury, which are released for experimental purposes into the canals of working turbines was developed in the Department of Ichthyobiology and Fisheries at the Agricultural Academy in Cracow.

It was decided to attempt to use this method to determine the loss magnitude of sea trout smolt following their passage through turbine canals in hydroelectric power plants located on Pomeranian rivers.

The studies were financed by the Headquarters of the Polish Anglers' Association in Warsaw and were conducted from 1989 to 1997. The results were published in five works (Bieniarz et al. 1992, Bartel et al. 1993, 1994, 1996 and 1998), and this communication is the summation of the results of the studies described in the preceding publications.

Rainbow trout *Oncorhynchus mykiss* (Wal.) and sea trout *Salmo trutta* m. *trutta* L. smolts with total lengths of 12 – 23 cm (average 18 cm) were used. The studies involved releasing fish with a 3 × 4 cm styrofoam cork attached with thick nylon twine to their backs into the turbine inlets and then recapturing them below the dam. The difference between the number of fish released into the turbine inlet and the number of undamaged fish which were recaptured constituted the number of fish which were either injured or killed while passing through the turbine canal.

Bieniarz and Epler (1973) demonstrated that the attached cork increases the body height of the fish and may increase losses during passage through working turbines by 12 to 24%. They also proved that the stress experienced by the fish during the cork attaching operation can contribute an additional 11% to losses. This means that losses confirmed using this method are from 23 to 35% too high. To compensate for this, the numbers of injured and killed fish were multiplied by coefficients of 0.77 or 0.65 (the difference between 100 and 23 or 35%, respectively, expressed as a decimal fraction) to obtain loss figures closer to the actual ones. The numbers thus obtained were expressed as percentages, with 100% representing the fish released into the turbine inlets.

The studies were conducted on the following rivers in northern Poland (Fig. 1):

- Słupia – at dams in Konradowo (studies in 1989, 1990 and 1992), Krzynia (studies in 1989, 1990, 1992), Gałęźna Mała (1992), Soszyca (1992);

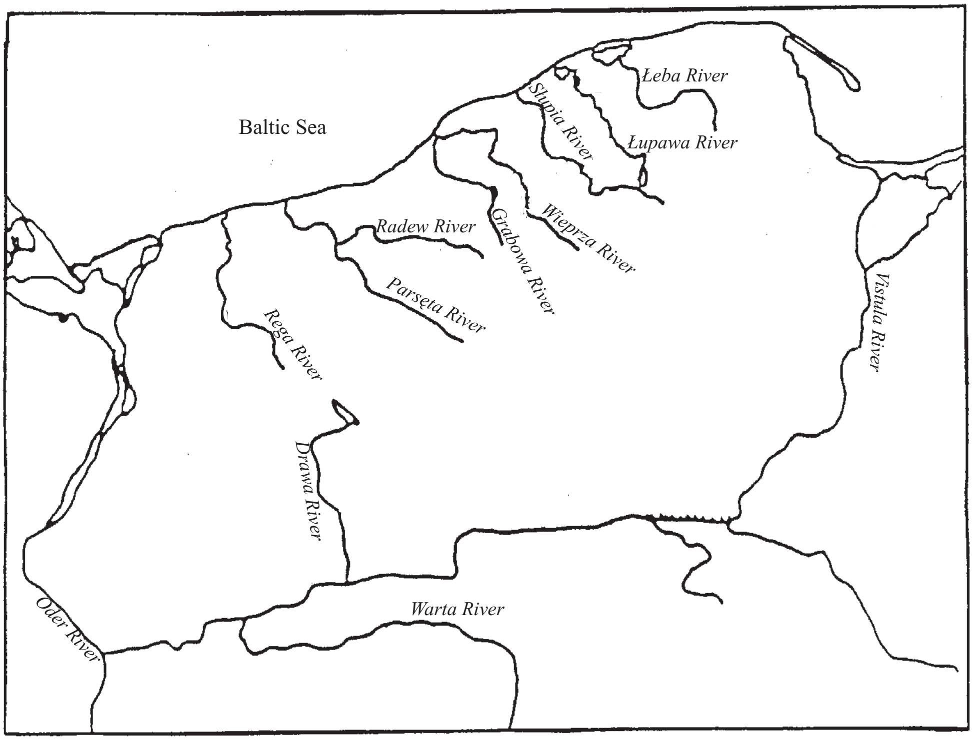

Fig. 1. Sites of the hydroelectric power plants on the Drawa River and the Pomeranian rivers Łupawa, Słupia, Wieprza, Grabowa and Rega.

- Łupawa – at dams in Drzeżewo (1990 and 1994), Łabień (1990, 1994), Łupawa (1994), Żelkowo (1994), Smołdzino (1994);
- Wieprza – at dams in Biesowice (1990), Kępice (1990), Darłowo (1997);
- Grabowa – at the dam in Nowy Żytnik (1990);
- Rega – at dams in Płoty (large and small turbines 1994), Gryfice-Rejowiec (1994), Trzebiatów (1994);
- Drawa – at the dam in Kamienna in 1995.

From 34 to 100 fish (most often 100) were released into the turbine canal inlet. Horizontal or vertical Francis turbines were in operation at all of the hydroelectric power plants. The water flow ranged from 2 m^3 (the Soszyca hydroelectric power plant, Słupia River) to 15 m^3 (the Gryfice-Rejowiec hydroelectric power plant, Rega River). The differences between the upper and lower water levels varied from 1.8 m (the Płoty hydroelectric power plant, Rega River) to 38 m (the Gałęźna Mała hydroelectric power plant, Słupia River), and the number of revolutions per minute varied from 43 (the Łabień hydroelectric power plant, Łubawa River) to 375 (Kondradowo and Gałęźna Mała hydroelectric power plants, Słupia River).

The water is supplied to the turbines at the Gałęźna Mała and Soszyca hydroelectric power plants (both on the Słupia River) through a pipeline 120 cm in diameter. Its length in Gałęźna Mała is 800 m and 50 m in Soszyca. Table 1 presents a detailed description of all the turbines.

TABLE 1

Rivers, hydroelectric plant location, turbine characteristics and magnitude of losses during trout passage through the turbines of hydroelectric plants on some Pomeranian rivers

	Rivers	Locality	Year	Type	Water flow ($m^3 s^{-1}$)	Differ-ences betweenw ater levels (m)	Revo-lution per minute	Number of relased fish	Losses (%)	Note
1.	Słupia	Konradowo	1989	Francis twin	9.0	12.0	375.0	95	51.3-60.8	
2.	Słupia	Konradowo	1990	Francis twin	9.0	12.0	375.0	100	50.0-59.3	
3.	Słupia	Konradowo	1992	Francis twin	9.0	12.0	375.0	100	38.3-45.4	
4.	Słupia	Krzynia	1989	Francis twin	8.5	7.5	250.0	99	36.1-42.8	
5.	Słupia	Krzynia	1990	Francis twin	8.5	7.5	250.0	95	37.6-44.6	
6.	Słupia	Krzynia	1992	Francis twin	8.5	7.5	250.0	100	19.1-37.0	
7.	Słupia	Gałęźna Mała	1992	Francis horizontal	2.5	38.0	375.0	100	40.9-48.5	1
8.	Słupia	Soszyca	1992	Francis horizontal	2.0	14.0	200.0	100	45.5-53.9	2
9.	Łupawa	Drzeżewo	1990	Francis vertical	3.2	2.4	60.0	57	0.0	
10.	Łupawa	Drzeżewo	1994	Francis vertical	3.2	2.4	60.0	100	5.2-6.2	
11.	Łupawa	Łabień	1990	Francis vertical	3.2	2.3	43.5	83	7.8-9.3	
12.	Łupawa	Łabień	1994	Francis vertical	3.2	2.3	43.5	100	5.2-6.2	
13.	Łupawa	Łupawa	1994	Francis vertical	4.0	2.0	7.0	100	6.5-7.7	
14.	Łupawa	Żelkowo	1994	Francis horizontal	4.4	6.0	250.0	100	39.0-46.2	
15.	Łupawa	Smołdzino	1994	Francis horizontal	4.25	2.5	125.0	100	91-10.8	
16.	Wieprza	Biesowice	1990	Francis horizontal	2.5	5.0	250.0	96	29.3-24.7	
17.	Wieprza	Kępice	1990	Francis vertical	2.7	3.5	75.0	72	17.7-14.9	
18.	Wieprza	Darłowo	1997	Francis vertical	12.0	2.2	12.0	100	7.1-8.5	
19.	Grabowa	Nowy Żytnik	1990	Francis vertical	2.8	3.2	81	34	7.6-9.1	
20.	Rega	Płoty	1994	Francis vertical Big turbine	4.7	1.8	60.0	100	5.4-6.4	
21.	Rega	Płoty	1994	Francis turbine Small turbine	1.8	1.8	60.0	100	0.0	
22.	Rega	Gryfice-Rejowiec	1994	Francis horizontal	15.0	7.0	210.0	100	47.2-55.4	
23.	Rega	Trzebiatów	1994	Francis horizontal	8.1	2.2	82.0	100	48.6-56.8	
24.	Drawa	Kamienna	1995	Francis twin	9.7	8.0	100.0	100	24.0-28.5	

[1] *Pipeline - 120 cm diameter, 800 m long*
[2] *Pipeline - 120 cm diameter, 50 m long*

The loss percentages ranged from 0.0% (small turbine at the Płoty hydroelectric power plant, Rega River) to 60.8% (Konradowo hydroelectric power plant, Słupia River, Table 1). The results obtained indicate that the magnitude of losses depended on the difference between the levels of high and low waters. The greater the difference, the greater observed fish losses were during their passage through the canals of the working turbines. However, losses confirmed at some hydroelectric power plants on Pomeranian rivers (Kondradowo, Gałęźna Małą, Soszyce) are about two times higher than those observed by Bieniarz and Epler (1973) at very high water (60 m) at the Solina dam on the San River in southeastern Poland. This is probably due to the differences in turbine sizes in Solina and on the Pomeranian rivers. The Francis turbines in Solina are much bigger and the space between turbine blades is greater, thus fish are not in as much danger of mechanical injury. This corresponds with results obtained by Cramer and Oligher (1960-1963), who reported that turbine construction plays a dominant role in the losses of fish passing through its canals. The difference between high and low water appears to have an impact on fish losses during their passage through turbines of similar construction and size. Additionally, the results of the study indicate that loss percentage increase (within a certain range) as turbine revolutions increase. When water is supplied to the turbine through a pipeline it also seems to increase losses, as is indicated by results obtained from two hydroelectric power plants (Gałęźna Mała and Soszyce, Słupia River). In these hydroelectric power plants, the fish were released into the pipeline inlet along which they had to swim for 800 m and 50 m, respectively, before reaching the turbines.

CONCLUSIONS

1. In hydroelectric power plants located on Pomeranian rivers the magnitude of fish losses during their passage through turbine canals depended on the difference between the upper and lower water levels, the number of turbine revolutions and the turbines being supplied with water directly from the dam reservoir or through a pipeline.
2. The greatest losses were observed in the hydroelectric power plants on the Słupia River (especially in Kondratowo, Gałęźna Mała and Soczyce) and in the hydroelectric power plants on the Rega River at Gryfice-Rejowiec and Trzebiatów.

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STRESZCZENIE

PRZECHODZENIE RYB PRZEZ TURBINY ELEKTROWNI WODNYCH NA RZEKACH POMORSKICH

Celem pracy było określenie strat jakie ponoszą ryby przechodzące przez turbiny elektrowni wodnych na rzekach pomorskich.

Badania prowadzono w latach 1989-1997 na rzekach pomorskich: Słupia, Łupawa, Wieprza, Grabowa, Rega, Drawa (rys. 1). Pstrągi tęczowe o długościach od 12 do 23 cm znakowano styropianowymi pływakami o wymiarach 3 × 4 cm przymocowanymi nylonową nicią pod przednią częścią płetwy grzbietowej. Pstrągi w liczbie od 34 do 100 ryb (najczęściej 100) wypuszczano do kanału turbinowego. Odławiano poniżej piętrzenia ryby znakowane nieuszkodzone i uszkodzone oraz zbierano oderwane pływaki. Do obliczenia procentów strat wprowadzono poprawki, gdyż znakowanie ryb zwiększało straty i dla otrzymania wyników odzwierciedlających faktyczne straty wprowadzono współczynniki (mnożniki) 0,77 lub 0,65. Elektrownie posiadały turbiny Francisa poziome lub pionowe, przepływ wody przez turbiny wynosił od 2 do 15 m^3/sek, różnice wysokości między górną i dolną wodą od 1,8 do 38 m, a liczba obrotów turbiny wahała się od 43 do 375/min (tab. 1).

Procent strat wahał się od 0,0 do 60,8 i zależał od różnicy poziomów między „górną" i „dolną" wodą (tab. 1). Procent ten był wyższy przy wyższych piętrzeniach i przy większych obrotach turbiny. Straty te były również uzależnione od sposobu dostarczania wody do turbiny. Wyższe występowały, gdy wodę na turbiny dostarczano rurociągami, a niższe gdy bezpośrednio ze zbiornika.

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