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Do Beaver Dams on Small Streams Influence the Effects of Trout (*Salmo trutta trutta*) Stocking?

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1. Introduction

The influence of beaver dams on the state of ichthyofauna in water courses has been, studied for many years [6, 9, 17, 18, 20, 22]. Up to now no definite answer has been given to the question on whether the influence of beaver dams on the qualitative and quantitative composition of ichthyofauna is positive or negative. According to some authors beaver dams increase the biodiversity of the ichthyofauna as they provide an increased number of hiding places and increase the production of food [6, 12, 20], while others claim that the beavers dam have negative influence as they induce drastic changes in water temperature, physicochemical parameters, hydrological and morphological conditions in the watercourse [5, 10]. The effects of beaver dams on particular species of fish have also been studied. The Cyprynidae, preferring limnetic waters respond positively to beaver ponds but the salmonids show a rather negative response [7], although their response depends on the landscape and climatic conditions.

At present the occurrence of the salmonids in watercourses depends exclusively on man management, mainly by stocking with juveniles. The effects of such stocking depend on the environmental conditions in a given watercourse. In Pomerania region many watercourses

have lost their natural worth because of negative anthropogenic effect such as drainage, pollution, hydrotechnological structures and others. The earlier present there valuable species of salmonids have disappeared having found no typical conditions needed for living and reproduction [3]. A similar situation was observed in two small watercourses Sitna and Pokrętna, in which the number of salmonids has decreased [2]. In these two rivers this phenomenon could have been caused not only by the anthropogenic effect but also by beaver dams. To establish this an attempt was made at determination of the direct and indirect influence of beaver ponds on the number of salmonids in selected sections of the Sitna and Pokrętna rivers, which was the aim of the study presented.

2. Material and Methods

The hatchery-reared fry sea trout (*Salmo trutta trutta* L.) fry were used for the stocking. The larvae were reared for 10 weeks in tanks and then were released into the wild. The rearing was performed in a recirculation system. Larvae were fed on live zooplankton and prepared pellet feed (Skretting, Perla Larva Proactive 4.0, contents: 62% protein and 11% fat, pellet size 0.3–0.8 mm). The feed was given *ad libitum*. The final results of the reared fry used in the stocking are shown in Table 1 and 2.

The fry were marked using fluorescence immersion on the second day following the completion of hatching. This was done by immersion for 3 hours in an alizarin red pigment solution at a concentration of 100 ppm. This method is effective and safe for fish growth and survival [15, 23]. All the fish were killed by an overdose of MS-222. Otoliths of each captured fish were observed using a UV-light microscope, in order to check to which captured fry were the hatchery-reared fry.

After 10 weeks of rearing (in April) the fish were released into the stream. For stocking, the Sitna and Pokrętna streams were chosen (NW Poland, both are the tributaries of River Drawa). These streams are ca. 7 km long. In the years 2007 and 2008 in the Sitna stream and in 2007 in the Pokrętna stream, selected sections of the streams were checked for the effects of stocking with salmonids fry hatched and reared in tanks and fed with different type of food. However, in 2009 in the lower course of the Sitna stream some beaver dams appeared. Therefore, we decided to check also the influence of beaver ponds on the effects of stockings with trout fry.

Table 1. Mean total length, mass and condition factor of trout fry *(Salmo trutta trutta)* in the day of its stocking to Sitna stream before and after the beaver dam appearance
Tabela 1. Średnia długość całkowita, masa i wskaźnik kondycji narybku troci *(Salmo trutta trutta)* w dniu jego wsiedlenia do cieku Sitna w okresie przed i po spiętrzeniu wody przez bobry

	Before	Before	After	After
	2007	2008	2010	2011
Length TOT (cm)	36.52	38.71	35.24	36.82
Mass (g)	0.4852	0.5239	0.5123	0.4963
Condition factor	1.00	0.90	1.17	0.99

Table 2. Mean total length, mass and condition factor of trout fry *(Salmo trutta trutta)* in the day of its stocking to Pokrętna stream before and after the beaver dam appearance
Tabela 2. Średnia długość całkowita, masa i wskaźnik kondycji narybku troci *(Salmo trutta trutta)* w dniu jego wsiedlenia do cieku Pokrętna w okresie przed i po spiętrzeniu wody przez bobry

	Before	After	After	After
	2007	2008	2009	2010
Length TOT (cm)	36.52	38.71	37.25	35.24
Mass (g)	0.4852	0.5239	0.5644	0.5123
Condition factor	1.00	0.90	1.09	1.17

The fish were transported to the stocking place in plastic bags saturated with oxygen. In each year, 200 fish were released to the stream. Prior to the beaver dam appearance the fry was introduced at three sites along the section of about 200 m long. After the appearance of the dam, the fry was introduced at three sites over a section of 50–100 m above the

beaver dam. Fish were captured from streams in the second half of September 2009 with the use of electric fish gear. The fish were caught along the section of ca. 400 m long below the dam, at the dam and above the dam. To make sure that all the fish were caught, the procedure was performed three times on the same day. The fish were caught by three persons: two persons were collecting the fish, while the third person walked 50 meters behind them to check if the stunned fish left were not carried down the river.

The condition factor (K) was calculated by

$$K = 10^5 \, M \, L_F^{-3}$$

where: M – mass, L_F – fork length. The statistical significance of the differences in the value of length, mass and the condition factor of the captured fish between years before and after the beaver dam appearance were tested by the Mann-Whitney U test.

3. Results

The length of the section over which the fish were caught was of about 400 m in each stream. In the years prior to the dam appearance the trout fry was captured along the whole length of the section. After the dam appearance, although the trout fry was introduced below and above the beaver pool, the fish were caught only below the dam; no fish were caught above the beaver pool and in it.

In the years after the beaver dam appearance in the selected sections of Sitna and Pokrętna the number of fish captured was drastically smaller when compared to that caught in the years before the beavers arrival (Table 2, 3). In Sitna in the first and second year after the dam appearance the number of fish captured decreased by 87–95% relative to their number caught in the years before the dam appearance. The number of fish caught in the section of Pokrętna after the dam appearance decreased by 80–93% relative to that caught in 2007. It should be noted that the number of fish caught in Pokrętna was always higher than that caught in Sitna.

No significant differences were found in the total length, mass and condition of fish captures before and after the dam appearance ($P > 0.05$). The only significant difference observed before and after the dam appearance was in the survival of the fry; it was much smaller after the

beavers occurrence (Table 2). It seems that this difference was related to the beaver dam construction and its influence.

Table 3. Survival, mean ± SD total length, mass and condition factor of trout *(Salmo trutta trutta)* captured from the section of Sitna stream in years before and after the beaver dam appearance
Tabela 3. Przeżywalność, średnia ± SD długość całkowita, masa i wskaźnik kondycji troci *(Salmo trutta trutta)* odłowionych z odcinka cieku Sitna w okresie przed i po spiętrzeniu wody przez bobry

	Before	Before	After	After
	2007	2008	2010	2011
Survival (%)	17	15	1	2
Length $_{TOT}$ (cm)	10.4 ± 2.6	11.1 ± 1.3	12.5 ± 1.4	11.8 ± 1.4
Mass (g)	18.5 ± 9.9	17.0 ± 5.6	21.0 ± 5.4	20.8 ± 6.5
Condition factor	1.4 ± 0.2	1.2 ± 0.1	1.1 ± 0.1	1.3 ± 0.1

Table 4. Survival, mean ± SD total length, mass and condition factor of trout *(Salmo trutta trutta)* captured from the section of Pokrętna stream in years before and after the beaver dam appearance
Tabela 4. Przeżywalność, średnia ± SD długość całkowita, masa i wskaźnik kondycji troci *(Salmo trutta trutta)* odłowionych z odcinka cieku Pokrętna w okresie przed i po spiętrzeniu wody przez bobry

	Before	After	After	After
	2007	2008	2009	2010
Survival (%)	30	3	6	2
Length $_{TOT}$ (cm)	11.1 ± 1.4	12.1 ± 0.6	11.4 ± 1.9	12.2 ± 1.5
Mass (g)	16.1 ± 5.5	20.6 ± 2.2	18.8 ± 10.1	20.9 ± 8.3
Condition factor	1.4 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	1.1 ± 0.1

4. Discussion

On the basis of the results obtained it can supposed that the appearance of beaver dam has deteriorated the biological and morphological conditions needed for salmonids survival and had negative influence on the effects of stocking. This negative influence was most pronounced in the number of fish caught in selected sections of the streams studied. According to many authors the activity of beavers and in particular the dams they make cause changes in the environmental conditions in the ecosystems of flowing waters. The changes concern first of all the hydrological, geomorphological, physicochemical conditions and temperature [1, 16, 19]. The results of our study point to deterioration of the conditions required by salmonids in the two streams studied, but in general the opinions of many authors as to the influence of beaver dams are different. According to some authors the beaver dams have positive influence on the qualitative and quantitative status of ichthyofauna as they lead to increased number of fish, increase the number of ecological niches and hiding places and indirectly increase the amount of nutrients. Grasse [6] claims that beavers should be introduced into the watercourses with salmonids as their activity has positive effect on the fish growth and production. However, it is not obvious. It seems that the influence of beaver dams on salmonids is different in cold watercourses in highlands and mountains and different in those localised in zones of lowlands. In cold watercourses with strong currents beaver ponds are important habitats for salmonids because they cause an increase in nutrients production, provide a greater number of refuge and the fact that temperature remains relatively cold -preferred by salmonids - even after the slowing down of the current [11, 12, 13]. In such currents the survival of young salmonids can be greater than in the watercourses devoid of beaver activity [20]. In warmer watercourses localised in lowlands, the beaver dams cause an additional increase in water temperature, not preferred by salmonids, so they move to the cooler parts of the watercourse, which could be a direct reason for a decreased number of salmonids caught in Sitna and Pokrętna. In Sitna above the beaver pond there is a concrete dam which cannot be overcome by fish so they could only migrate down the stream to the lake. In Pokrętna the fish could migrate up the river but they did not do it because no fish were caught in the upper parts of the stream. Moreover,

although below the beaver pond the number of hiding place for the salmonids fry was sufficient, they were caught in much smaller number than in the years with no dam. Another difference is that the beaver ponds in the watercourses in highlands and mountain watercourses of high slope are shorter than in lowland ones.

Negative opinions as to the influence of beaver ponds on the status of salmonids focus mainly on the limited sites of spawning, negative changes in physicochemical parameters and rapid slowdown of water current [10]. Fewer negative opinions concern the difficulties in migration caused by beaver dams, as salmonids can rather easily manage to overcome them thanks to their small size and loose structure [11, 14, 22]. Some authors claim that salmonids overcome beaver dams only at high water levels and recommend that the problem of beaver dam influence on salmonids migration should be better investigated [5].

Although the salmonids fry was introduced to Sitna above the beaver dam, in the 200 metre section above the breaver pond no trout was captured. Probably the appearance of the dam caused changes in the conditions preferred by salmonids not only above but also below the dam, e.g. silting up of the river bed, increased temperature and changes in oxygen saturation [4]. As follows from literature, adult salmonids do not choose the river sections above the beaver dam for spawning. Taylor et al. [21] over the 100-300 m section above the beaver dam have found none spawning nest of salmonids, although the watercourse was cold and seemed suitable for salmonids. Some Scandinavian authors claim that recolonisation of beaver near small watercourses leads to disappearance of natural spawning sites of salmonids [8]. Similar opinion have Pollock et al. [16] who claim that beaver ponds can cause a reduction in salmonids production by even 60% because of the disappearance of typical sites preferred by salmonids.

Another reason for a decrease in the number of trouts captured in the Sitna stream could be an increase in the number and abundance of species typical of limnetic basins. Such fish include pike and perch, the predators which were surely feeding on the salmonids fry introduced. Adults and fry of the predatory species could flow down the watercourse from the higher lying lakes and then finding suitable conditions in the beaver ponds, they could have stayed there feeding on trout fry. In comparison to the situation prior the beaver dam appearance, in examined

sections of Sitna and Pokrętna fish representing other species have been noted only sporadically and they were mainly burbot and gudgeon. Hägglund and Sjöberg [7] report that the conditions after the beaver dam construction are particularly appropriate for Cyprynidae which find the slower current more suitable for living, while salmonids are there noted only in small amounts. The same observation was made in the watercourses studied in this work. In the years after the dam appearance, in the sections studied often met were ubiquistic roach and perch, and even pike, which were most abundant in the beaver pond.

Perhaps beaver dams are not significant in large rivers of large flow, but in small rivers their effect is considerable. The negative influence of beaver ponds on the salmonids increases with decreasing width, depth and water flow in a watercourse [10]. Results of our observations seem to confirm this standpoint. The beaver dams in narrow, shallow and small water flow watercourses Sitna and Pokrętna, have probably led to such environmental changes that were difficult for the trout fry.

5. Conclusions

Our results as well as those reported by some other authors indicate that the beaver dams have negative influence on the effect of stocking with salmonids fry. The main reasons for the decrease in the number of trout captured in the Sitna and Pokrętna streams sections could be the following changes caused by the beaver dam appearance: i) in hydrological conditions, ii) in physicochemical parameters, in particular an increase in water temperature, iii) an increase in the number of fish species typical of limnetic basins, including pike and perch – predators feeding on trout fry and iv) silting of the stream bottom.

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Czy zapory bobrowe w małych ciekach mają wpływ na efekty zarybiania trocią (*Salmo trutta trutta*)?

Streszczenie

Wpływ zapór bobrowych na stan ichtiofauny cieków jest rozważany od wielu lat. Jedni autorzy twierdzą że zapory bobrowe odgrywają pozytywną rolę w funkcjonowaniu ekosystemów wodnych, ponieważ zwiększają bioróżnorodność ichtiofauny, podczas gdy inni twierdzą, że wpływ tych zapór jest negatywny. Celem pracy było określenie bezpośredniego i pośredniego wpływu piętrzeń bobrowych na liczebność ryb łososiowatych i skuteczność zarybiania nimi małych cieków Sitna i Pokrętna. W latach przed powstaniem zapory bobrowej narybek troci odławiany był na całej długości odcinka. Natomiast później, pomimo, że narybek wsiedlany był również powyżej spiętrzenia spowodowanego zaporą bobrową, to ryby w niewielkiej liczbie odławiane były tylko na odcinku poniżej spiętrzenia. Na podstawie wyników pracy można przypuszczać, że zapory bobrowe przyczyniły się do pogorszenia warunków biologicznych i morfologicznych, właściwych dla przeżycia ryb łososiowatych, jak również negatywnie wpłynęły na efekty zarybień. To negatywne oddziaływanie w największym stopniu widoczne było w przypadku liczby odłowionych ryb. Głównymi powodami spadku liczby odławianych ryb łososiowatych mogły być wywołane powstaniem zapory bobrowej: i) zmiany warunków hydrologicznych; ii) zmiany warunków fizyko-chemicznych, szczególnie podwyższenie temperatury wody; iii) zwiększenie liczby ryb typowych dla zbiorników limnetycznych, w tym szczupaka i okonia, drapieżników zjadających narybek troci; iv) zamulenie dna cieku.