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Ecological Impact of Eurasian Beaver (*Castor fiber*) Activity on Fish Communities in Lithuanian Trout Streams

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1. Introduction

Although beavers were exterminated in Lithuania, reintroductions in the last century have reestablished the species. According to the official census, the number of beavers in Lithuania has dramatically increased over the last 10–15 years due to reduced trapping and continuous colonization of new territories by these rodents. The number of beavers recorded in 1995 approximated 19 000, while in 2000 it was already estimated at about 36 000. In accordance with the investigation data of recent years, the minimum number of beavers in Lithuania is estimated at 85 879 individuals, the maximum number amounting to 121 025 individuals. Habitat selectivity of beavers varies with different habitats. Approximately 36% of all beaver ponds in Lithuania are found in drainage ditches, which are their most preferable habitat. 18% of all beaver lodges were recorded in large rivers [14], 16.5% in lakes and 14.5% – in wetlands. For siting their dams, beavers prefer large and small rivers [14], forests canals and those on the forest outskirts. The relative beaver abundance in water bodies of different type was very much alike, fluctuating from 0.81 beaver pond/km in natural streams with discharge exceeding $0.5 m^3/s$ to 1.1 beaver ponds/km in canals [27, 28, 29].

There is a close interrelation between physical geographical conditions in the locality and the distribution and occurrence of ichthyofauna in

Lithuanian rivers. According to fish community distribution, all rivers can be classified into two major types: salmonid and cyprinid rivers [24]. As salmonid fishes are much more demanding with respect to environmental conditions, they are widely distributed only in cold-water and fairly clean rivers. In contrast to cyprinid rivers, salmonid rivers in Lithuania are not very numerous, their number reaching only about 180. Most of them host brown trout, anadromous sea trout being common in 76 streams. Meanwhile, salmon occurrence is recorded in 14–16 streams of this type [15]. Most of them contain restored populations, and only two contain natural salmon populations [16].

It is widely recognized that there are strong and continuous interactions between hydrology, geomorphology, water chemistry and temperature in rivers [21]. All of them are significant factors influencing aquatic organisms. However, all of them are subject to beaver-induced modifications. Beaver activities, i.e. tree felling and dam construction, are extremely important ecological factors affecting trout streams in forests [18]. As a result of beaver activity, the proportion of wetland and ponds in the area increases, new watercourses with slow-flowing water appear [9]. Such changes in living conditions significantly affect fish communities and the ecological state of streams. Beaver activity causes a number of modifications in the natural environment. Firstly, the watercourse of a stream is transformed into a series of small slow-flowing water ponds, and in some places into running-water swamps. In beaver-formed ponds water level and temperature rise, water flow slowing down [3, 23]. Beaver dams trap sediment carried from the upper reaches, which accumulates in dammed sections of a stream. Moreover, beaver activity alters the composition of bottom substrate: as beavers dig their burrows, gravel-sand substrate gets mixed with earth, the resultant sediment, a thick layer of shifting silt, settling and accumulating on the river bed. In such areas water is muddy – it is most often dark or brown, depending on the composition of bottom substrate. Sometimes beaver dams divert the water flow from the natural watercourse to a valley, forming miry and running-water swamps, overgrown with aquatic and land plants. That is characteristic of streams with low banks. In our study, waterlogged swamps were abundant at beaver ponds in the Saria and Derežna streams.

Beaver activities – tree felling and dam building, are important ecological factors in forest-zone countries. In small streams that are easily dammed, beavers can alter many of the habitat characteristics crucial to fish survival, growth and reproduction. These beaver-induced habitat modifications can be either beneficial or detrimental, depending on the beaver population density and the prevailing constraints on local fish species composition and abundance [3]. Beaver-induced habitat modifications have a great impact on the composition of fish communities in forest streams in Sweden, and may enhance fish species diversity. The two most common fish species were minnow (*Phoxinus phoxinus* L.) and brown trout (*Salmo trutta* L.). Other three species – sculpin (*Cottus gobio* L.), burbot (*Lota lota* L.) and pike (*Esox lucius* L.) occurred in lower numbers. In contrast to brown trout, which were more common in beaver-unaffected sections, the occurrence of minnow was higher in sections affected by beaver activity [6]. Ozolin and Rantin [22] recorded the following fish species in beaver ponds of Latvian streams: pike (*Esox lucius*), roach (*Rutilus rutilus* L.), belica (*Leucaspius delineatus* (HECK.)), chub (*Leuciscus cephalus* L.), gudgeon (*Gobio gobio* L.), bleak (*Alburnus alburnus* L.), carp (*Carassius spp.*; *Cyprinus carpio* L.), stone loach (*Barbatula barbatula* L.), weather loach (*Misgurnus fossilis* L.), ell (*Anguilla anguilla* L.), burbot (*Lota lota* L.), sticklebacks (*Gasterosteidae spp.*), perch (*Perca fluviatilis* L.), and sculpin (*Cottus gobio* L.).

2. Material and methods

2.1. Assessment of hydrological and ecological stream conditions in natural stream sections and beaver ponds

All five study streams in Lithuanaia – Dūkšta, Saria, Derežna, Agluona, Ežeruona were small trout type streams in different regions and river basins. Ežeruona (stream length – 31.1 km) and Agluona (stream length – 36.8 km) belongs to Jūra River basin in western Lithuania. Derežna (stream length – 13.4 km) belongs to Merkys basin in southern Lithuania. Saria (stream length – 27.9 km) belongs to Žeimena river basin in south eastern Lithuania and Dūkšta (stream length – 29.2 km) belongs to Neris River basin in south eastern Lithuania [5] (Fig. 1).

Indices of the investigated streams (water temperature (ºC), oxygen amount (O_2, mg/l), water saturation with oxygen (O_2, %), pH, water conductivity (µS/ cm), river width (m), mean depth (m), flow velocity (m/s), vegetation amount (%) and river bed substrate) were determined both in natural stream sections and in beaver ponds.

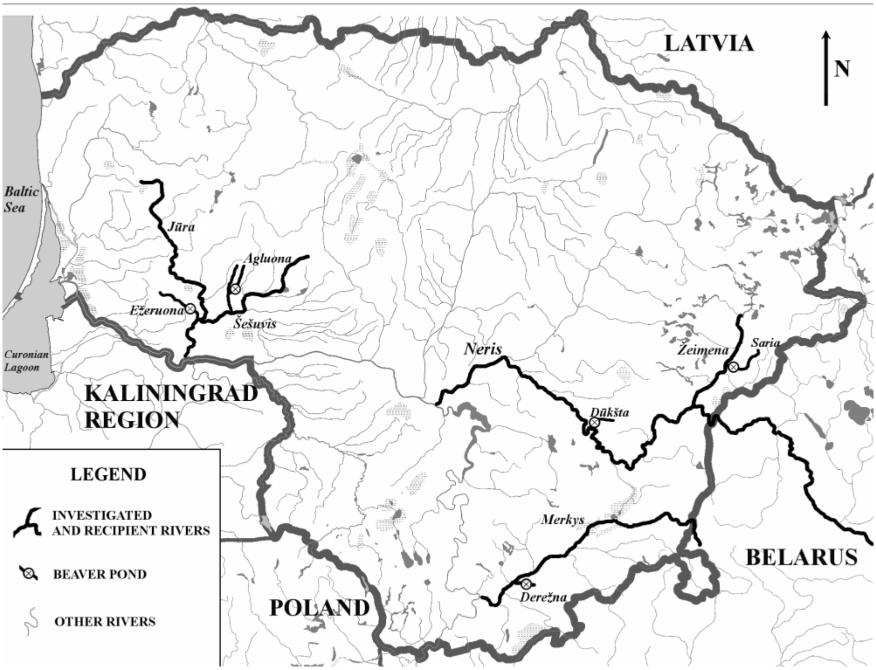

Fig. 1. Beaver pond investigation sites in salmonid streams of Lithuania
Rys. 1. Lokalizacja stawów bobrowych na strumieniach łososiowych na Litwie

2.2. Investigations of fish communities

Investigations of fish community composition and abundance were carried out in July in natural stream sections as well as in beaver ponds in small trout rivers. To determine the composition and abundance of fish communities, a total of 16 electro-fishing samplings were conducted in natural stream sections (8 samplings) and in beaver ponds (8 samplings). An electrofishing gear IG200/2 (producer HANS GRASSL GmbH) was used for fish sampling. Depending on fish abudance, fish sampling was performed 1–2 times at an interval of 15 minutes in a 100–150 m long beaver-unimpacted section and in a beaver pond.

Fish density N (ind.) and biomass B (kg) were calculated by Zippin's method of three removals, modified by Junge & Libosvarsky [10]. Fish density and biomass were extrapolated for 100 m^2 (ind /100 m^2 and kg/100 m^2):

$$N, B = y/S \cdot 100 \quad (1)$$

where:

S – area of the investigated site;

y – abundance or biomass at the investigated site.

The diversity of ichthyofauna was assessed in sections downstream and upstream of beaver dams separately. Investigations were performed on all beaver dams in each river. Occurrence frequency of fish species (V, %) $V = a/A \cdot 100\%$ [8]); A – number of samples, a – number of samples with individuals of each (i) species.

Fish species diversity in a community was estimated using the Shannon-Wiener' index H' [25]:

$$H' = -\sum P_i \log_2 P_i \quad (2)$$

where:

H' – index of species diversity;

S – number of species in a community;

P_i – number of individuals in each (i) species.

2.3. Investigation of salmonid fishes spawning migration and spawning grounds

Investigations of salmonids spawning grounds in the vicinity of beaver ponds were conducted on 10–14 November, after the spawning was finished. The count of spawning grounds and spawning nests was done by walking 500 m long distances along the stream bank downstream and upstream of a beaver pond. Location and area (m^2) of spawning grounds, their total number as well as the number of spawning grounds per 1km of the stream section were determined visually. The impact of beaver ponds on spawning grounds of salmonids was evaluated in all the investigated streams: the Derežna, Dūkšta, Saria, Ežeruona.

2.4. Assessment of the ecological state of trout streams

In this study we attempted to assess the ecological state of small trout streams containing beaver ponds applying the ecological state assessment method adapted to Lithuanian rivers (Lithuanian Fish Index – LFI) based on index values of specific fish communities and populations [30].

According to morphological parameters – catchment area (km^2) and the mean stream inclination – the investigated streams were grouped into 3 types, the Derežna stream representing stream type 1, the Saria and Agluona streams – type 2, and the Dūkšta and Ežeruona streams – type 3 (Table 1).

Table 1. Characteristics and water parameters of the investigated streams
Tabela 1. Charakterystyka i parametry wody badanych strumieni

Stream	Ežeruona		Egluona		Derežna		Dūkšta		Saria	
Stream length, km	36.8		31.1		13.4		29.2		27.9	
Catchment area upstream of the beaver dam, ~km²	186.5		100		32.9		137.3		78.7	
Stream type	3		2		1		3		2	
Stream habitat	unaffect.	beaver pond	unaffect.	beaver pond	unaffect.	beaver pond	unaffect.	beaver pond	unaffect.	beaver pond
Water temperature, °C	18	18.2	15.9	14.3	11.9	12.1	18	18	14.7	15.2
Dissolved oxygen, mg/l	6.8	7	5.5	4.4	7.58	7.38	9.4	9.42	8.43	8.58
Oxygen saturation, %	71.3	71.6	57	43	71.2	70	100.5	107	83.9	86.7
pH	8.02	8.05	7.94	7.62	7.27	6.97	8.2	8.14	7.83	7.77
Conductivity, µS/m	559	570	564	630	256	259	581	583	406	406
Width at the study site, m	4.5	7	2.5	2.5	5	9	4.5	6	4	4
Average depth at the study site, cm	60	60	20	35	50	100	35	80	60	70
Flow velocity, m/s	0.1	0.02	0.2	0.02	0.7	0.02	0.4	0.02	0.1	0.1
Substrate	pebbles	gravel, silt	pebbles	gravel, silt	pebbles	silt	pebbles	sand-silt	gravel	gravel

2.5. Statistical methods

The General linear model ANOVA was used to assess differences in abundance and biomass of fish communities in the investigated streams. Calculations were done with Statistica for Windows, version 6.0 (StatSoft, 2001). Processing of other data was performed using the software Microsoft Excel 2000.

3. Hydrological and ecological characterization of the investigated streams

Hydrological and ecological characteristics of the investigated trout streams (both in natural stream sections and in beaver ponds) are presented in Table 1. The investigated trout streams were not large, their width ranging from 2.5 to 5 m (mean 4.3 m). At beaver dams, the width of streams varied from 2.5 to 9 m (average 5.1 m). Trout streams are characterized by lower water temperature. Water temperature in the investigated streams was measured in the warm season, i.e. in August, when temperature is the highest. As the structure of the surface relief, hydrological regime as well as other characteristics vary with different locations, water temperature in the investigated streams ranged widely between 12 and 18°C. However, the comparison of water temperature in natural stream sections with that in beaver ponds revealed slight differences. Water temperature in beaver ponds was found to be slightly higher in the Saria (1.2°C), Derežna (0.2°C), Agluona (1.6°C), Ežeruona (0.2°C) streams. The amount of oxygen O^2 (mg/l) and saturation with O_2 (%) in natural stream sections did not differ significantly from those in beaver ponds.

In contrast to the Agluona and Derežna streams, where the concentration of oxygen in natural stream sections was higher than in the section under the impact of beaver activity, in the Ežeruona, Dūkšta and Saria streams the oxygen concentration was found to be slightly higher in beaver ponds. The concentration of pH in natural stream sections and in beaver ponds of the Dūkšta, Saria and Ežeruona streams was the same, while in beaver ponds in the Dūkšta and Agluona streams pH was lower by 0.3–0.4. Water conductivity in the investigated streams varied a great deal, which was mainly related to the general stream mineralization, beaver ponds having only a negligible impact on this index. An insignificant difference in water conductivity was recorded between natural stream sections and beaver pond in the Agluona an Eežeruona streams. Depth varied significantly with different places, natural stream sections being shallower (mean 38.6 cm) than beaver ponds (mean 62.5 cm). In the Ežeruona stream, which is very shallow throughout, there were no depth differences recorded between natural stream sections and beaver-impacted sections. Flow velocity was higher in natural stream sections

(0.4 m/s on average), while in beaver ponds it was very low (0.08 m/s on average). The vegetation cover varied considerably among the investigated streams. It was found to be dependent on the composition of bottom area substrate and flow velocity. However, the summary of the data obtained showed that in natural stream sections vegetation covered 25.7% of the bottom area, while in beaver ponds this figure was slightly higher – 38.4%. The bottom substrate of small salmonid streams of Lithuania commonly consists of, sand, gravel and pebbles. In some sites even clay substrate can be found. The composition of bottom substrate in beaver ponds changes with the pond age. As a result of earth and natural bottom substrate intermixing, sediment – shifting silt, gradually accumulates in beaver ponds.

Beaver dams in the study streams were constantly maintained and enlarged with wooden debris, bush sticks, silt and clay. Height of dams varied from 0.7 to 1.2 meters. Beavers often build up to 4 dams in same location and the most downstream dam usually is the largest. Beavers strengthen dams in autumn before autumn floods and such obstacles became impassable for migrating sea-trout and brown trout.

4. Results

4.1. Diversity and abundance of fish communities in beaver ponds

Small trout streams are most often dominated by rheophilous fish, while beaver ponds by fish belonging to the rheo-limnophilic complex.

During experimental fishing in the investigated streams, western brook lamprey and fish representing 14 species belonging to 8 families were caught: Petromyzontidae (*Lampetra planeri* (BLOCH)), Salmonidae (*Salmo trutta trutta* L., *Salmo trutta fario* L.) Esocidae (*Esox lucius* L.), Cyprinidae (*Rutilus rutilus* (L.), *Leuciscus cephalus* (L.), *Leuciscus leuciscus* (L.) *Phoxinus phoxinus* (L), *Leucaspius delineatus* (HECK.), *Gobio gobio* L.) Nemacheilidae (*Barbatula barbatula* (L.)), Percidae (*Perca fluviatilis* L.), Cottidae (*Cottus gobio* L.), Gasterostidae (*Gasterosteus aculeatus* L., *Pungitius pungitius* (L.)) (Table 2).

In this study, unaffected stream sections were found to harbour up to 9 fish species, mostly dominated by typical rheophilous fishes characteristic of this type of streams, i.e. by – brown trout (V – 100%) and minnow (90%). Sea trout, stone loach, sculpin and gudgeon (60–50%) proved to be common in fish communities, while euribiontic fish species represented by pike, roach and perch occurred much more rarely. In beaver ponds fish diversity was much greater (15 species caught), with brown trout (73%) being also common there. The list of fishes that are common in beaver ponds included dace, chub, stone loach and perch (46.7–40%) and rheo-euribiontic fishes, such as pike, roach, sun bleak, nine-spined stickleback (13.3–26.7%) (Table 2). Characterization of fish communities in the investigated sections using the Shannon-Wiener index (H') showed that this index differed among the streams. A considerably greater fish diversity in beaver ponds was established in the Saria (H' – 2.73) and Dūkšta (H' – 2.56) streams. The index of biodiversity both in the natural stream section and in the beaver pond (H' – 2.0) of the Ežeruona stream was practically the same. Meanwhile, in the Agluona (H' – 2.21) and Derežna (H' – 1.0) streams the index of biodiversity was found to be higher in the natural stream section (Table 3).

Table 2. Fish species diversity (V, %) in salmonid streams (n – unaffected stream sections, b – beaver ponds)
Tabela 2. Różnorodność gatunków ryb (V, %) w strumieniach łososiowych (n – sekcje strumienia bez zapór bobrowych, b – stawy bobrowe)

No.	Fish species	Dūkšta		Saria		Derežna		Agluona		Ežeruona		Occurrence frequency, V (%)	
		n	b	n	b	n	b	n	b	n	b	n	b
1	*Lampetra planeri* (BLOCH)				33.3								6.7
2	*Salmo trutta trutta* L.	100						100	100	100		60	20
3	*Salmo trutta fario* L.	100	100	100	66.6	100	100	100	100	100		100	73.3
4	*Esox lucius* L.				66.6					100		20	13.3
5	*Rutilus rutilus* (L.)				33.3					100	100	20	26.7
6	*Leuciscus cephalus* (L.)		100		33.3						100		46.7
7	*Leuciscus leuciscus* (L.)		50		33.3						100		46.7
8	*Phoxinus phoxinus* (L.)	50	50	100	66.6	100		100		100		90	23.3
9	*Leucaspius delineatus* (HECK.)								100				20
10	*Gobio gobio* L.	50	50					100		100		50	10
11	*Perca fluviatilis* L.				100					100	100	20	40
12	*Barbatula barbatula* (L.)	100	50	100	66.6			100	100			60	43.3
13	*Cottus gobio* L.	50	50	100	33.3	100		100			100	50	36.7
14	*Gasterosteus aculeatus* L.						100						20
15	*Pungitius pungitius* (L.)								100				20
	Total:	**6**	**7**	**4**	**10**	**3**	**2**	**6**	**5**	**7**	**5**	**9**	**14**

Table 3. Number of species and Shannon-Wiener biodiversity index (H) in investigated streams (n – unaffected stream sections, b – beaver ponds)
Tabela 3. Liczba gatunków i wskaźnik bioróżnorodności Shannona-Wienera (H) w badanych strumieniach (n – sekcje strumienia bez zapór bobrowych, b – stawy bobrowe)

Stream	Stream Habitat	Number of species	Shannon-Wiener biodiversity index (H)
Ežeruona	n	8	2.03
	b	5	2.09
Agluona	n	6	2.21
	b	6	1.13
Derežna	n	3	1.00
	b	2	0.52
Dūkšta	n	6	1.96
	b	7	2.56
Saria	n	5	1.72
	b	9	2.73

Fish abundance in the investigated streams ranged from 3 ind./100/m² (the Dūkšta stream-beaver pond) to 158 ind./m (the Agluona stream-beaver pond). An extremely great abundance of fish was recorded in a beaver pond in the Agluona stream, wherein the fish community was dominated by minnow – 70% and stone loach – 26.6%. In other beaver ponds fish abundance was 1.5- to 13-fold lower than in natural stream sections. The relative abundance (%) of common fish species in unaffected stream sections (n) and in beaver ponds (b) of the investigated streams is given in Figure 2. According to the summarized data, in natural stream sections of the investigated salmonid streams dominant in abundance were brown trout (30%), stone loach (18%), minnow (16%), sea trout (13%), sculpin (13%). In contrast, beaver ponds were clearly dominated by minnow (58.5%) and stone loach (23.6%) (Fig. 2).

Based on ANOVA results it was established that the total fish abundance in natural stream sections differed significantly from that in beaver ponds ($F = 165.67$, $p = 0.00001$), with the exception of the Saria stream. The study revealed that fish abundance in natural stream sections was higher than in beaver ponds, except the Agluona stream (Fig. 3).

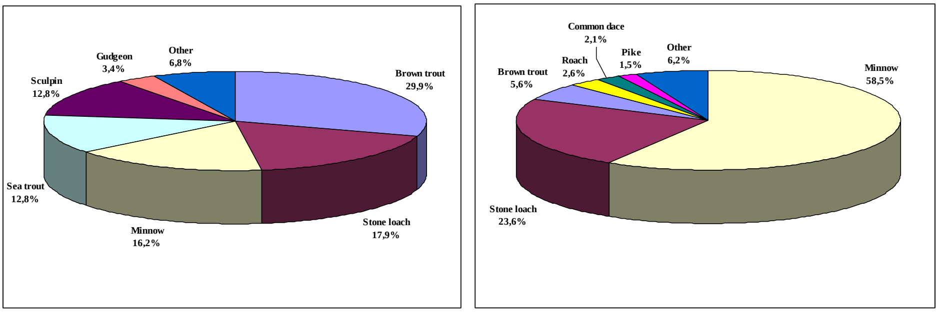

Fig. 2. Relative density (%) of various fish species in unaffected stream sections and beaver ponds
Rys. 2. Względne zagęszczenie (%) różnych gatunków ryb w nienaruszonych sekcjach strumieni i stawach bobrowych

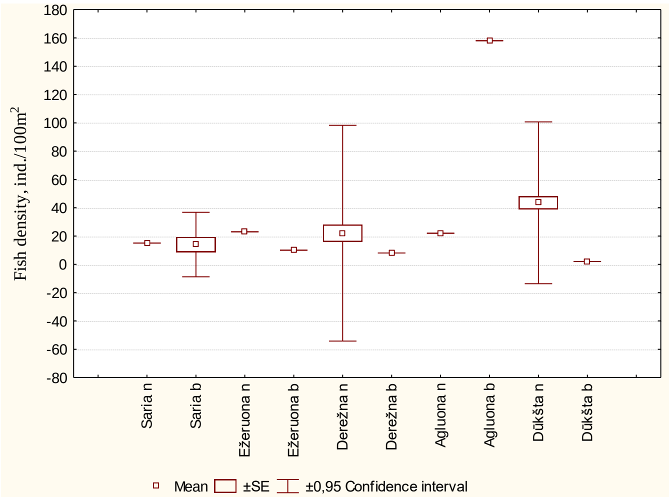

Fig. 3. Total abundance of ichthyofauna in investigated streams (n – unaffected stream sections, b – beaver ponds, F= 165.68, p < 0.001)
Rys. 3. Całkowita liczebność ichtiofauny w badanych strumieniach (n – sekcje strumienia bez zapór bobrowych, b – stawy bobrowe, F = 165,68, p <0,001)

In the investigated streams fish biomass varied from 0.066 kg/100/m² (the Saria stream) to 1.542 kg/m² (the Dūkšta stream). The mean biomass of fish in natural stream sections upstream of beaver dams was comparatively high – 0.704 kg/m². As it has been mentioned already, the most pronounced differences in biomass indices were recorded between the Dūkšta and Saria streams, while biomass values in the Ežeruona, Agluona and Derežna streams were practically the same – about 0.600–0.678 kg/m. Meanwhile, the mean biomass of fish in beaver ponds (approximately 0.524 kg/m²) was lower than that in natural stream sections. Biomass indices of different fish species varied depending on ecological conditions in stream habitats. Two trends were discerned in biomass variation: 1. sea trout, pike and especially brown trout displayed significantly higher total biomass in natural stream sections; 2. dace, roach, minnow demonstrated significantly higher total biomass in beaver ponds (Fig. 4).

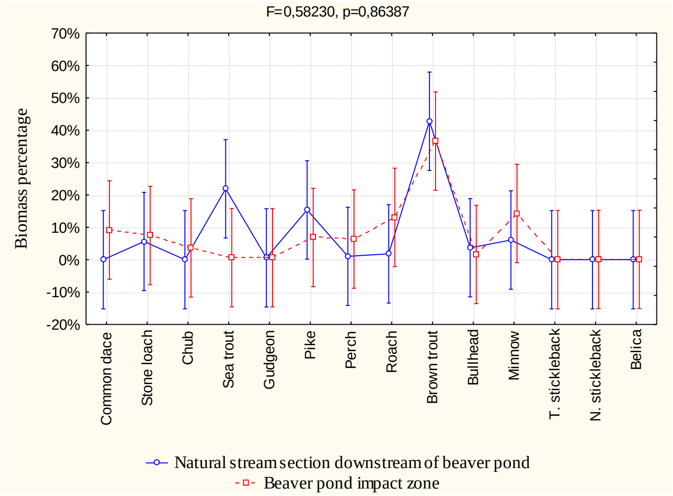

Fig. 4. Fish community structure according to biomass (kg/100 m ²) in salmonid streams; unaffected stream sections and beaver ponds (Mean ± 0.95 confidence interval)
Rys. 4. Struktura populacji ryb według biomasy (kg/100 m^2) w strumieniach łososiowych; sekcje strumienia bez zapór bobrowych i stawy bobrowe (średnia ±0,95 przedział ufności)

It was also found that the relative biomass of salmonids (sea trout + brown trout) in natural stream sections differed significantly from that recorded in beaver ponds (F = 21.417, p = 0.00004). The biomass of salmonids was higher in natural stream sections of the Dūkšta, Saria, and significantly in natural stream sections of the Ežeruona and Agluona streams. Meanwhile, in the Derežna stream higher biomass of salmonids was recorded in beaver ponds (insignificantly), because only large trout individuals were found therein (Fig. 5). Results of these and previous investigations [17] show that large brown trout prefer and inhabit deeper beaver ponds.

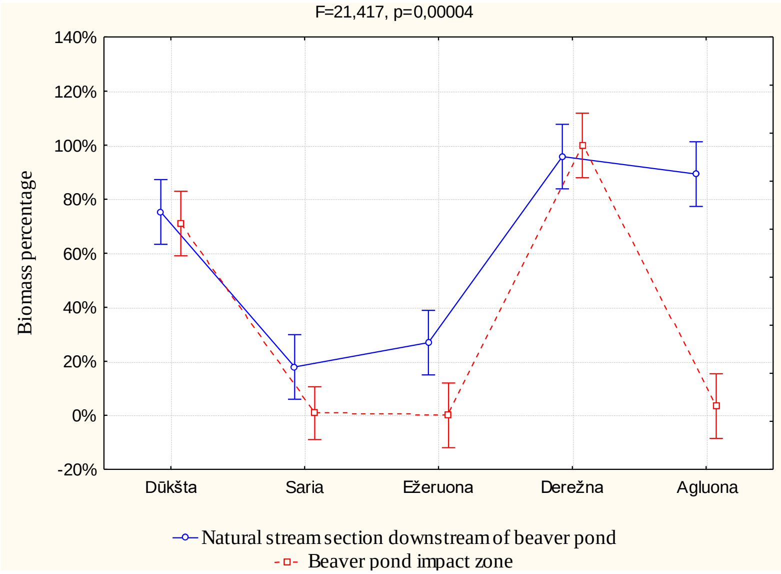

Fig. 5. Relative biomass of salmonid fishes in investigated unaffected stream sections and beaver ponds

Rys. 5. Względna biomasa ryb łososiowatych w badanych sekcjach strumienia bez zapór bobrowych i stawach bobrowych

Studies of salmonids spawning grounds were done in mid November, when average daily temperature are about 0 °C, and water temperature decreases to 3–4°C. At this time most of salmonids (80–90%) were after spawning. Assessment of spawning grounds was undertaken visually using polarised glasses when walking on the stream banks. All redds were counted and measured in 500 meters length stream stretches upstream and downstream from dam. In Saria, Derežna and Ežeruona streams all redds were found only downstream of dam demonstrating that consecutive dam were impassable for migrating salmonids. In Saria and Ežeruona streams most redds were 2–3 m², suggesting that majority of spawners were sea trout. Sea trout juveniles were most abundant salmonids, when those streams were electrofished in autumn during annual salmonids juvenile monitoring [17, 19]. In Derežna river there are only sedentary brown trout, therefore their redds were significantly smaller (0.3–1.2 m²). In Dūkšta river beaver dams were significantly smaller and partly damaged thus allowing to pass for migrating salmonids. Total area of redds were almost the same upstream and downstream from dam – 48.5 and 51.5% respectively.

Table. 4. Evaluation of ecological state according to Lithuanian River Fish Index in salmonid streams (unaffected stream sections and beaver ponds)
Tabela. 4. Ocena stanu ekologicznego strumieni łososiowych według Litewskiego Indeksu Rzek Rybnych (sekcje strumieni bez zapór bobrowych i stawy bobrowe)

Stream	Stream Habitat	LFI	Ecological state class
Derežna	n	0.944	high
	b	0.772	good
Saria	n	0.787	good
	b	0.672	moderate
Dūkšta	n	1.0	high
	b	0.794	good
Agluona	n	0.979	high
	b	0.749	moderate
Ežeruona	n	0.802	good
	b	0.394	poor

4.2. Assessment of the ecological state of small trout streams

The ecological state of the investigated streams was assessed by the Lithuanian Fish index (LFI) both in natural stream sections and in beaver ponds. It is possible to conclude that the ecological state of the studied streams different, values of LFI ranging from 1.0 to 0.394. The ecological state in natural stream sections of the Derežna, Dūkšta and Agluona streams was found to be very high, the LFI value ranging from 1 to 0.944, and that of the Saria and Ežeruona streams was found to be good (0.787–0.802). In all the streams studied, the ecological state in beaver ponds proved to be inferior to that in natural stream sections. The ecological state in beaver ponds in the Derežna and Dūkšta streams was favourable (0.772–0.792), that in the Saria and Agluona streams moderate (0.672–0.749), and in the Ežeruona unfavourable (0.394) (Table 4).

5. Discussion

In general, Lithuanian trout rivers are characterized by low diversity of ichthyofauna, which is predetermined by ecological conditions. The diversity of ichthyofauna in cold-water streams is estimated at 1–5 fish species and in small rivers at 10–15 fish species. In abundance and sometimes also in biomass, fish communities are most often dominated by brown trout, sculpin, roach, three-spined stickleback, minnow [13].

Two more anadromous species Atlantic salmon and sea trout is found in this type of streams, however, their distribution and occurrence frequency is different. Salmon in Lithuania usually occur in larger (salmonid type) rivers [12]; in smaller, i. e. trout type rivers, occur only in lower reaches of some streams, and in many streams are not occurred at all. In our investigated streams salmon juveniles are caught almost every year in Dūkšta and Saria lower reaches, however, their average abundance, as shown by the recent 10 years of monitoring data, is inconsiderable and varies from only 0.41 to 1.35 ind./100 m² [7, 11]. During electrofishing below beaver dams, salmon juveniles were also not caught. Therefore, research results suggest that this type of rivers is not important to Atlantic salmon. Meanwhile, these rivers are very important to reproduction of sea trout populations, because in many of this type of rivers are their main habitats. As shown by studies, juvenile sea trout and local brown trout occupy all suitable ecological niches in this type of streams. In those sections of streams where barriers cannot be passed for sea trout, resides local brown trout (e. g. Derežna River). In general, brown trout occurrence frequency in this type of rivers is the highest (V – 100%), as sea trout occurrence frequency were considerably lower (V – 50–60%). Distribution of anadromous salmonid species in rivers is highly dependent on hydroelectric and mill dams, including beaver dams, which are important for the spatial distribution of these species [12, 2, 4]. Despite the fact that the beavers maintain their dams, however some of them could be destroyed due to floods during the autumn. Sometimes foresters or hunters dismantle beaver dams. There are also cases because the lack of food, beavers leave dams and move to new areas. All these factors mentioned, have a positive impact on sea trout population, because it allows sea trout breeders to cross ruined dams and reach upper reaches of the river, also this determines trout recruitment in the stream. Similarly, say Mitchell and Cunjak [20] that two factors – autumn stream flow and locations of beaver dams are of critical importance in the spatial distribution of salmon and the subsequent fish community structure. According to results from research carried out during the summer, cascade of dams in the Agluona River was destroyed and sea trout juveniles were detected in both natural river section and above beaver dams. In the autumn migration of salmonids in the Derežna River, beaver dams was destroyed by humans and brown trout spawning sites were found above beaver dams. This study showed that part of the sea trout and/or brown trout breeders is able to pass beaver dams. In our investigation case sea trout and/or brown trout managed to pass beaver dams in 1 stream from 5 studied.

Another important aspect is that in beaver dam ponds, due to changes of ecological conditions, species diversity increases almost twice due to appearance of euribiotic fish species (roach, chub, dace, perch, pike, belica), which are unusually to fish communities in this type of streams. Fish communities upstream and downstream of the beaver dam complex differ significantly in terms of species diversity, composition, total production and species-specific production [20, 3]. Increase of various cyprinid species and appearance of predators (pike, perch) in beaver ponds indicates many authors: in Wisconsin [18], in New Brunswick [1], in Sweden [6], in Latvia [22]. Due to change of communities and appearance of new species, strengthens the competition for nutrition, and with presence of predatory fish (pike, perch) salmonid fish juveniles have very little chance to survive in beaver ponds.

The impact of beaver dams on fish migration and spawning conditions is mainly predetermined by the stream channel inclination, bottom substrate composition and state of dams [18, 26]. Investigations of salmonid spawning grounds carried out in November show that newly built beaver dams hinder migration of salmonid fishes and prevent them from reaching spawning destinations. For instance, all spawning grounds of anadromous salmon and sea trout were located downstream of beaver dams. This fact demonstrates that fish are unable to pass several fairly high beaver dams located in succession. Only local brown trout were found spawning in unaffected stream sections upstream of beaver dams. Only full or partial destruction of beaver dams can open up a possibility for fish to migrate. To provide passage for sea trout, all beaver dams were partially destroyed during the salmonid spawning period in the Dūkšta stream. Sea trout spawning was greatly affected by this undertaking – almost half of all spawning grounds (48.5%) were found in reaches upstream of beaver ponds. As we have noticed, in trout streams rheophilous and native species: western brook lamprey, brown trout, sculpin and anadromous sea trout are subject to the greatest beaver impact. Beaver dams restrict migration of these fishes within a stream, reduce the number of spawning grounds and their area, alter biotope structure, thus deteriorating fish living conditions (Fig. 6).

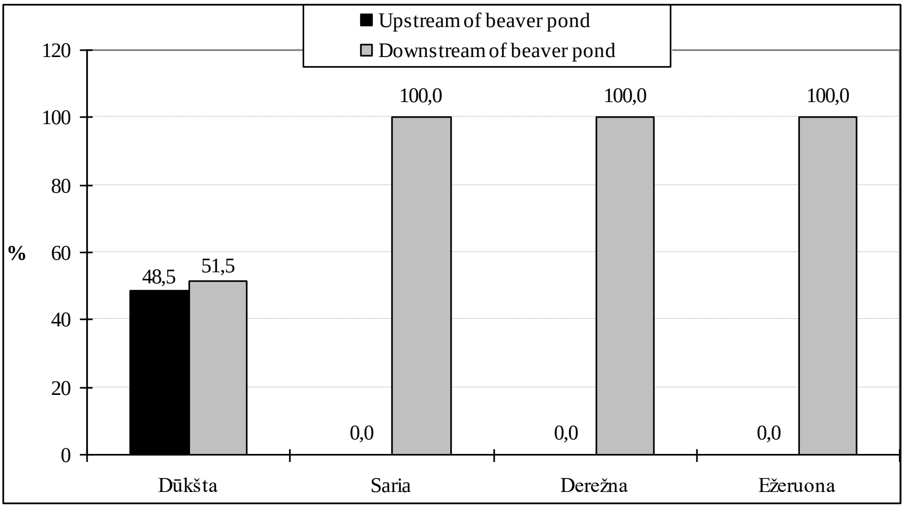

Fig. 6. Relative abundance (%) of salmonid fishes in spawning grounds in 100 m long stream sections upstream and downstream of beaver ponds
Rys. 6. Względna liczebność (%) ryb łososiowatych w tarliskach, w 100 m sekcjach strumieni przed i za stawami bobrowymi

Depending on the stream inclination, beaver dams have impact on greater or lesser degree accumulate deposit (sand, silt, leaves) and impede water flow. As a result, spawning grounds get covered with sediment and their aeration properties deteriorate. It should be noted that dam construction and enlargement is a non-stop process: for that purpose beavers use parts of trees and bushes, which are plastered over with vegetation remains, clay and mud. Such constructions are built very fast, especially in autumn, when larger beaver families are getting ready for winter, and firmly so that autumn flood could not destroy them. Due to their height and abundance of protruding tree debris, newly built dams prove to be insurmountable for salmonids. Constructions themselves hinder fish migration, while impounded areas alter the natural river bed and spawning grounds. As beavers construct several (up to 4 units) dams at an interval of several tens of meters or more, their impact on streams is apparent. This pattern also depends on year, seasonal changes and geographical area [28, 29].

6. Conclusions

Beaver ponds affect the river bed morphology, sedimentation, retention of organic matter, cycle of substances, water quality and transport of nutritives, communities of fish and invertebrates as well as riparian habitats. Salmonid and trout streams of Lithuania are most often dominated by rheophilous fish, while beaver ponds by fish belonging to the rheo-limnophilic complex. Fish representing 15 species and lamprey were caught in the investigated streams. Diversity of ichthyofauna in natural stream sections was 9 species, while in beaver ponds – 15 fish species. Unaffected stream sections were dominated by rheophilous fishes: brown trout, sea trout, stone loach, sculpin and gudgeon, whereas beaver ponds were dominated by brown trout, dace, chub, stone loach, perch. A significant difference was recorded between fish abundance in natural stream sections and in beaver ponds, fish abundance in the former being greater than in beaver ponds. Significant differences were established between the relative biomass of salmonids (sea trout + brown trout) in natural stream sections and in those impacted by beaver activity. Based on Lithuanian Fish Index (LFI), it was established that the ecological state in natural stream sections of all the investigated streams is better than that in beaver ponds.

As it has been mentioned above, the number of trout streams in Lithuania is limited, while beaver abundance is constantly growing. It is only natural that this situation causes reasoned concern about the preservation of ecological integrity of these streams and maintenance of good overall ecological state. The summarized data of the conducted investigation show that beaver dams alter the composition of fish communities, deteriorate migration conditions for salmonid fishes, reduce their productivity area and degrade the overall ecological state of streams. The ever-increasing beaver abundance and their activity are a negative factor for trout streams. We recommend removing beaver dams in trout streams yearly to maintain the typical trout stream infrastructure and good ecological state, as well as to protect the nearby land, forest, riparian zones and the natural river bed from flooding. In order to maintain high and good ecological state of trout streams, it is essential to yearly remove all beaver dams in the lower and middle reaches of streams, i.e. in a section, constituting 2/3 of the stream length, upstream of the lower reaches. In the upper reaches (1/3 of the stream length) beaver dams should be removed periodically during the salmonid migration season (September–October). In natural circumstances section of the sea trout and/or brown trout breeders is able to pass partially damaged beaver dams, as shown in our study. Therefore level or timing of dismantling beaver dams in small trout streams due to habitat and stream ecological condition enhancement require further investigations.

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Ekologiczny wpływ aktywności bobra europejskiego (*Castor fiber*) na populacje ryb w litewskich strumieniach pstrągowych

Streszczenie

W artykule zanalizowano wpływ tam bobrów na różnorodność, liczebność, migrację i warunki tarliskowe ryb w potokach pstrągowych, które są licznie zamieszkiwane przez bobry. W zależności od rodzaju zapory i ich lokalizacji, strumienie zamieszkane przez bobry podlegają zmianom hydrologicznym, temperaturowym i chemicznym. Populacje ryb badano stosując elektro połów. Parametry populacji ryb (różnorodność gatunków, liczebność, biomasa) porównano w nienaruszonych przez bobry sekcjach strumieni i w sekcjach pod wpływem działalności bobrów. Ogólny stan ekologiczny strumieni oceniano stosując określone wskaźniki dotyczące ryb i wskaźniki zgodne z Ramową Dyrektywą Wodną. Przeprowadzone badania wykazały, że tamy bobrowe zmieniają skład populacji ryb, zmniejszają ich obszary produkcyjne i pogarszają warunki ów dla migracji rozrodczej pstrąga ora ogólny stan ekologiczny strumieni. Badania przeprowadzono w 2008 roku w 5 strumieniach pstrągowych - Dūkšta, Saria, Derežna, Agluona i Ežeruona zlokalizowanych w różnych częściach Litwy.