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Species Composition, Distribution and Ecological Features of Ichthyofauna in the Pymvashor Geothermal Valley (Bolshezemelskaya Tundra, Nenets Autonomous Okrug)

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Abstract—Ichthyofauna in the studied streams in the Pymvashor Geothermal Valley contains six species from six families; the basis of the fish assemblage is formed by three species such as European grayling *Thymallus thymallus*, common minnow *Phoxinus phoxinus* and stone loach *Barbatula barbatula*. Fish distribution patterns are expressed well in spatial and seasonal aspects. Fish inhabiting water bodies in the Pymvashor Geothermal Valley belong to two faunal complexes with prevalence of species of the boreal piedmont complex; three groups are distinguished in respect to the feeding habits, i.e. benthophagous, predatory, and euryphagous fishes. Species which lay eggs on rocky-pebbly substrates in late spring and early summer prevail. According to the economic status three fish species are non-commercial; common bullhead is listed in the regional Red Data Book of the Nenets Autonomous Okrug.

Keywords: Pymvashor Geothermal Valley, species diversity, spatial and seasonal distribution, faunal complexes, patterns of feeding and reproduction

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In conditions of long-term environmental degradation the problem of fish population inventory becomes especially urgent and the information on the ichthyofauna composition may be used in the development of national and regional programs for the study and conservation of biological diversity (Reshetnikov and Shatunovskii, 1997; Sokolov and Reshetnikov, 1997). In addition, the updated data from regional fish catalogues may be the basis for compiling a comprehensive list of fish in continental water bodies of Russia.

Numerous occurrences of fishes at rather high temperatures to 32–40°C are reported in the body of literature (Bolotov et al., 2016). Among freshwater fish along with species that prefer rather narrow temperature ranges, there are also species with broader ranges of the final selected temperature. The results of integrated studies on the effect of the thermogradient on behavior, feeding, and physiological adaptations of fish under natural and artificial conditions are presented in a number of publications (Brown and Feldmeth, 1971; Poddubnyi et al., 1978; Golovanov and Bazarov, 1981; Golovanov and Linnik, 1981; Goolish and Adelman, 1984; Ponomarev, 1991, 1995; Golovanov, 1996, 2003, 2012; Malinin et al., 1996, Svirskii, 1996; Golovanov et al., 2005, 2012; Kishi et al., 2005; Bohlen et al., 2008; Darveau et al., 2012; Akbarzadeh and Leder, 2016; Goebel et al., 2017). The analysis of the body of scientific literature showed that available information on the species diversity and the state of ichthyofauna in conditions of unloading hydrotherms near outlets of thermal waters is limited (Bolotov et al., 2016).

Hydrothermal systems are the most unusual and effective at high latitudes where the heat availability of landscapes is extremely low due to zonal climate reasons. Such watercourses are characterized by increasing mineralization (to 180 mg/dm^2) which is especially pronounced in the winter low-water flow that is due to participation of ground and underground waters in feeding of surface waters (Vlasova, 1962). The information on fish assemblages inhabiting such watercourses is not available in the literature except for brief reports on fish (Aksenova, 2013) and feeding of European grayling *Thymallus thymallus* (Bolotov et al., 2012) living in watercourses of the Pymvashor Geothermal Valley.

The Pymvashor Geothermal Valley is the only outlet of mineral and thermal springs located above the Arctic Circle in the territory of continental Europe (*Funktsionirovanie*..., 2011). Since 2000, the valley has the status of the regional nature monument which includes a complex of eight mineral thermal springs with an annual average water temperature of 16.0 to 28.5°C and this is despite the fact that the temperature of fresh karst waters in the region usually does not exceed 2–3°C. Throughout the winter the springs and the sites of their confluence with the stream remain free of ice and snow even in heavy frosts. In this regard, the data on the species composition, ecological diversity and biological features of fish inhabiting the hydrothermal system of the Pymvashor stream are of a certain scientific interest.

The aim of this work is to study the species composition and ecological features of fish assemblages in the Goryachiy Stream and in two sections of the Pymvashor Stream in the Pymvashor Geothermal Valley (downstream and upstream of the confluence of hot springs).

MATERIALS AND METHODS

The Pymvashor Valley is located in the southeastern part of Nenets Autonomous Okrug on the eastern edge of Bolshezemelskaya tundra along the Pymvashor Stream near its confluence with the Adzva River (a right tributary of the Usa River, the Pechora River basin) (67°09′ N 60°51′ E) (Fig. 1, a). The length of the Pymvashor Stream is 21 km, its width reaches 20–30 m at some sites; the current velocity is 0.3–0.5 m/s, the depth varies from 0.2 m at rapids to several meters in pools at bends of the stream, the average depth of the stream in the area of the tract is 0.5 m; the bottom is rocky, sometimes sandy, and pebbly at the rapids; the average annual water temperature is 5°C (*Resursy* ..., 1972). Three areas with the sites of the confluence of thermal waters with the Pymvashor Stream were marked within the valley (*Funktsionirovanie* ..., 2011) (Fig. 1 b). The Goryachiy Stream is the longest of all thermal watercourses inflowing the Pymvashor Stream. Its length is 45.5 m, the width is 0.3–1.7 m, the average current velocity is 0.3 m/s; the bottom is rocky-sandy.

The materials for the study of fish assemblages in watercourses of the Pymvashor Geothermal Valley were collected during six years in different seasons: in July (2009, 2013 and 2014), August–September (2010 and 2012), November 2009 and December 2011. Fish were caught with hook-and-line fishing tackles, fixed nets with a mesh size of 24–40 mm and a net at three sites (Figure, b). During the survey period the water temperature in the thermal Goryachiy Stream (site 1) varied from 15.6–19.5 in winter to 20.0–25.8°C in summer. In the Pymvashor Stream, 500–1000 m downstream from the site of inflow of all thermal springs (site 2) the average water temperature was several degrees higher than the zonal temperature due to the effect of thermal waters and the water did not freeze up in winter; there were typical zonal conditions at the site 3 located 100–500 m upstream from the confluence of hot springs, the average water temperature was ~5°C, and the freeze-up period was durable. During the survey period the water temperature in the Pymbashor Stream in the site downstream from the inflow of thermal streams was on average 5.5°C in winter and 22.0°C in summer, at the site upstream from the thermal zones the water temperature was 1.0° and 18.2°C, respectively. Altogether 202 specimens of different fish species were collected during the survey period.

The taxonomic status of fish and types of feeding and reproduction (spawning substrate and terms of egg laying) are given according to the Atlas of Freshwater Fish (2002) and a reference book *Fishes of Russia in the Global Fauna* (Romanov, 2010); the belonging of fish to faunistic complexes was determined according to Nikolskii (1980).

RESULTS AND DISCUSSION

As a result of the study it has been found that the fish assemblage in the Pymvashor stream is represented by six species of fish from six families (Table 1). All of them are resident rheophilic species which do not perform long-distance migrations and are associated with particular river sections.

Three species, European grayling, common minnow *Phoxinus phoxinus*, stone loach *Barbatula barbatula* form the basis of the ichthyofauna (95% of the total number of caught fish); the other fish species (Eurasian ruffe *Gymnocephalus cernua*, European bullhead *Cottus gobio*, and pike *Esox lucius*) were solitary in control samples (Table 2). Only three fish species were sampled in the Goryachiy Stream; among them minnow was dominant (74.0%), the proportion of stone loach was 23.3% and that of grayling was only 2.7%. All six fish species were recorded in the Pymvashor Stream downstream of the site of the thermal spring inflow; among them grayling prevailed in terms of abundance (82.4%); in the site located upstream of the thermal spring inflow the proportion of grayling in the sample increased to 92.2%, and minnow, ruffe, and stone loach were represented by one specimen.

The spatial distribution of all fish species is different (Table 2). Grayling mainly occurred in the Pymvashor Stream and twice as frequent in the site located downstream of the Goryachiy Stream inflow than in the site upstream from the thermal zones (66.9 vs. 31.3%); only two specimens were collected in the Goryachiy Stream (1.8%). The opposite pattern was observed for minnow: 54 of 62 specimens (87.0%) were sampled in the site in the Goryachiy Stream, much fewer in the site of the Pymvashor Stream downstream of the site of its inflow (11.3%) and only

Table 1. Composition of ichthyofauna in water courses of the Pymvashor Geothermal Valley

Taxon	Stream, number of the site		
	Goryachiy	Pymvashor	
	1	2	3
Thymallidae			
Thymallus thymallus (Linnaeus, 1758)—European grayling	+	+	+
Cyprinidae			
Phoxinus phoxinus (Linnaeus, 1758)—common minnow	+	+	+
Balitoridae			
Barbatula barbatula (Linnaeus, 1758)—stone loach	+	+	–
Percidae			
Gymnocephalus cernua (Linnaeus, 1758)—Eurasian ruffe	–	+	+
Cottidae			
Cottus gobio Linnaeus, 1758—European bullhead	–	+	+
Esocidae			
Esox lucius (Linnaeus, 1758)—pike	–	+	–

Table 2. Spatial distribution of fish in watercourses of the Pymvashor Geothermal Valley

Species	Stream, number of the site						Total	
	Goryachiy		Pymvashor					
	1		2		3			
	ind.	%	ind.	%	ind.	%	ind.	%
European grayling	2	2.7	75	82.4	35	92.2	112	55.4
Common minnow	54	74.0	7	7.7	1	2.6	62	30.7
Stone loach	17	23.3	2	2.2	–	–	19	9.4
Eurasian ruffe	–	–	5	5.5	1	2.6	6	3.0
European bullhead	–	–	1	1.1	1	2.6	2	1.0
Pike	–	–	1	1.1	–	–	1	0.5
Number of fish	73		91		38		202	

one specimen (1.7%) was sampled upstream of its inflow. The same tendency is typical for stone loach, 89.5 and 10.5% (it was not recorded in the site upstream of the thermal zones). Ruffe was more often recorded downstream of the thermal springs inflow than upstream of the sites of the confluence (83.3 vs. 16.7%). One specimen of bullhead each was caught in the Pymvashor Stream upstream and downstream of its confluence with a thermal spring. The only specimen of pike was found in the sample in the site downstream from the inflow of the Goryachiy Stream.

Patterns of fish distribution reflect their habitat conditions and determine success of their survival, feeding, and reproduction. The same site of the surveyed watercourse may represent quite different habitats in different seasons (Pavlov and Mochek, 2009). The fish distribution in watercourses of the Pymvashor Geothermal Valley significantly differed in the seasonal aspect (the vegetation period during the open water and winter ice periods). If in the open water period fish were found in all three surveyed areas and all six species were recorded in the samples, then in the winter period fish were not found in the Goryachiy Stream and only grayling and ruffe were recorded in the Pymvashor Stream (Table 3). Ruffe was recorded only in catches in the site downstream from the thermal spring inflow (3 ind. or 7%). In summer and autumn, grayling (43.5% of all fish sampled) and minnow (40.2%) were equally predominant in samples in watercourses of the Pymvashor Geothermal Valley area while stone loach (12.3%) occupied the third place. The spatial distribution of fish and the ratio of specimens of different species in the surveyed area were almost identical to those described above (Table 2) except for a slight decrease in the degree of dominance

Table 3. Seasonal distribution of fish in watercourses of the Pymvashor Geothermal Valley

Species	Stream, number of the site						Total	
	Goryachiy		Pymvashor					
	1		2		3			
	ind.	%	ind.	%	ind.	%	ind.	%
	Summer-autumn period (July–September)							
European grayling	2	2.7	35	72.8	30	91.0	67	43.5
Common minnow	54	74.0	7	14.6	1	3.0	62	40.2
Stone loach	17	23.3	2	4.2	–	–	19	12.3
Eurasian ruffe	–	–	2	4.2	1	3.0	3	2.0
European bullhead	–	–	1	2.1	1	3.0	2	1.3
Pike	–	–	1	2.1	–	–	1	0.7
Number of fish	73		48		33		154	
Temperature, °C	20.0–25.8		13.3–22.0		8.2–18.2			
	Winter period (November–December)							
European grayling	–	–	40	93.0	5	100	45	93.8
Eurasian ruffe	–	–	3	7.0	–	–	3	6.2
Number of fish	–		43		5		48	
Temperature, °C	15.6–19.5		5.5–5.9		1.0–1.1			

of grayling and the increase in the proportion of minnow and stone loach (Table 3).

According to the classification of Nikol'skii (1980) all fish inhabiting waters in the Pymvashor Geothermal Valley belong to two faunal complexes, boreal plain and boreal piedmont complexes. Grayling, minnow, stone loach, and bullhead (4 species or 67%) belong to a boreal piedmont complex and pike and ruffe (33%) belong to a boreal plain complex.

Fish species inhabiting water bodies in the Pymvashor Geothermal Valley are divided into three groups according to the predominant type of feeding: highly specialized feeding on zoobenthos (ruffe), predatory feeding (pike) and euryphagous feeding strategy (grayling, minnow, stone loach, and bullhead). Euryphages are characterized, as a rule, by a broad feeding spectrum with a predominant consumption of a particular food. The subdivision of ichthyofauna into the above groups is rather conditional and characterizes only general food preferences. In fact, the food spectra of almost all fish species go beyond the dominant groups of forage objects. In addition, small forms of zooplankton are consumed practically by all fish species at early stages of ontogenesis.

Grayling and pike spawn in spring; minnow, ruffe, stone loach, and bullhead spawn in late spring to early summer. According to the type of spawning substrate all considered fish species use a certain substrate (litho-, psammo-, and phytophilous). Grayling, minnow, ruffe, and bullhead (4 species or 67%) lay eggs on rocky and rocky-sandy bottoms; pike and stone loach (33%) prefer to lay eggs on vegetation substrate (submerged aquatic vegetation, roots or dead plants).

According to the economic value only pike and ruffe (33%) are commercial fish species; grayling (17%) is a popular object for sports and amateur fishing; minnow, stone loach, and bullhead (50%) are of no commercial interest.

Especially noteworthy is common bullhead listed in the Red Data Books of the Komi Republic (2009) and Yamalo-Nenets autonomous okrug (2010) with the status "category 2" (Endangered). According to the regulatory and methodological framework all species of plants and animals listed in the Red Data Book of the Russian Federation should be also included into the Red Data Book of the federal entity in which territory they occur. According to this formal feature common bullhead was included into the Red Data Book of the Nenets Autonomous Okrug (2006) with an addition category 7 as species which is not threatened in the territory of the okrug (Novoselov, 2015). In addition, in salmon-spawning rivers of the northern region the abundance of bullhead is high as a rule and it is a trophic competitor of juveniles of the Atlantic salmon *Salmo salar* during its river life period (Studenov and Novoselov, 2000). Taking into consideration its high abundance and high tolerance to environmental pollution the inclusion of European bullhead into the list of rare and specially protected species seems unreasonable (Korolev, 2003).

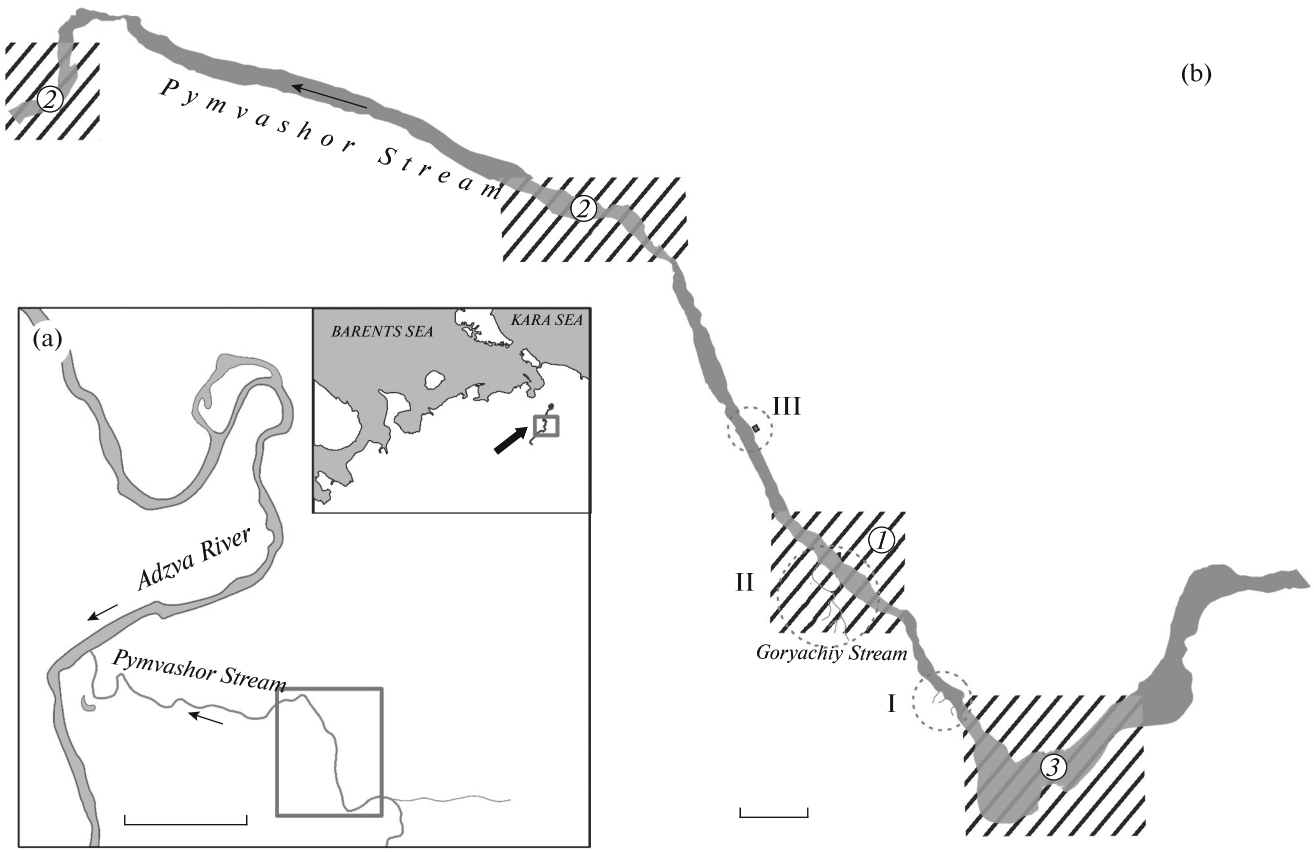

Fig. 1. Location of the survey region (a) and scheme of the Pymvashor Geothermal Valley (b) with the sampling sites (▨) in Goryachiy Stream (*1*) and Pymvashor Stream downstream of the inflow of thermal springs (*2*) and upstream of the thermal zones (*3*); I–III, thermal zones, (←), flow direction. Scale: a, 1 km, b, 100 m.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed

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