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Vertical Distribution of *Cottus poecilopus* Heckel, 1837 in Streams of Tatra National Park in Poland

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Abstract. The aim of the study was to determine the prevalence of *Cottus poecilopus* in the main streams of the Tatra National Park in Poland. Fishing research was conducted within the summer and in the autumn of 2014 for fourteen streams. The catches were made with pulse fishing device (IUP-24) wading up stream. During fishing caught fishes have been characterized and habitat has been characterized by noting the speed of the current, the presence of obstacles and hiding places for fish, width, type and size of the bottom substrate, the presence of wood and shade. The beginning and end of each transect was described by the geographic coordinates using a Garmin GPS device. Based on the geographical coordinates the project was created in GIS (using ArcMap software 9.3.1) and determined the amount of occurrence of fish above sea level. In the course of fishing three species of fish were found: *Cottus poecilopus*, *Salmo trutta* m. *fario* and *Salvelinus fontinalis*. In the studied streams *Cottus gobio* was not found. The most numerous *Cottus poecilopus* were represented, a total of 485 individuals in 12 streams. Stream Chochołowski Potok (1077.3 m above sea level) was the highest position where the genre occured.

Keywords: *Cottus poecilopus,* distribution of habitats of fish, mountain strems.

Conference topic: Environmental protection.

Introduction

Streams of Tatra National Park (southern Poland) belong to the basin of the Dunajec, they flow in mostly Tatra valleys. Their river beds have a small width and length not exceeding 15 km; with slope of up to 40% and the turbulent flow of water. In the spring time, there often comes to the movement of rock rubble or even to change of their course. Fish fauna of streams is poor. According to archival materials (Kot 1994; Witkowski 1996; Radwańska-Paryska, Paryski 2004) and own research in the waters of Tatra National Park presently 6 species of fish occurs. These are: *Salmo trutta* m. *fario, Cottus poecilopus, Phoxinus phoxinus, Thymallus thymallus* (periodically dwelling) and *Salvelinus fontinalis* and *Oncorhynchus mykiss* (alien species). On the basis of oral information, in the park is probably also present *Cottus gobio*, what the cause may be progressive in recent years climate change. This species is on the list of species of interest to the European Community (which is mentioned in Annex II of the Habitats Directive), and therefore requires the designation of special areas of conservation and how to protect species.

The aim of the study was to determine the Vertical distribution of *Cottus poecilopus* Heckel, 1837 in streams of Tatra National Park in Poland.

Material and methods

Fishing research was conducted within the summer in June and July, and in the autumn, in September and October 2014 on thirteen streams: Rybi Potok, Potok Roztoka, Poroniec, Filipczański Potok, Sucha Woda, Małołącki Potok, Strążyski Potok, Goryczkowy Potok, Kościeliski Potok, Chochołowski Potok, Lejowy Potok, Olczyski Potok and Biały Potok. The fish catches were made with pulse fishing device (IUP-24), in 3 positions in each of the streams, wading up stream. Fish were collected intravitally. After determination of the species and counting, the fishes were released back into the water. On the basis of the length of the body, the fish were divided into three age groups, ie. "YOY" – juvenile fish in their first year of life (<50 mm), "YUV" – sexually immature fish (50–70 mm) and

"ADULT" – adult fish (> 70mm). It was also determined the density of fish on individual transects in individuals per m^2.

During electrofishing, habitat has been characterized by describing the 17 variables: the speed of the stream current; the presence of obstacles and hiding places for fishes; width, type and size of the substrate of bottom; the presence of wood and the degree of shading.

The beginning and the end of each transect was described by the geographic coordinates using a Garmin GPS device. Based on the geographical coordinates the project was created in GIS (using ArcMap software 9.3.1) and it was specified height above the sea level for fish occurrence.

For the evaluation of statistical significance in used tests the level of significance was assumed $p \leq 0.05$.

Compliance distribution of variables with normal distribution was described using the Kolmogorov-Smirnov test.

For each analyzed variable it was calculated: position measures, variability measures, asymmetry measures and concentration measures. These were: X-arithmetic mean, Min and Max. – Minimum and maximum values, SD – standard deviation, CV – coefficient of variation average.

Differences in the parameters habitat between segments of streams in which fishes occurred and segments of streams in which fishes were not harvested, were described by using Mann-Whitney U test.

For the description of the significance of differences in the numbers of fish between the groups (streams, sections of streams, etc.) an analysis of variance ANOVA (univariate), based on non-parametric Kruskal -Wallis test and post-hoc Dunn test, was used.

To determine the relationship between the abundance of fishes and studied characteristics of habitats the Spearman's rank correlation coefficient was used.

When assessing the homogeneity of variance two tests: Brown-Forsythe and Leven were used.

The strength of association was determined based on Stanisz (2007), assuming the following scale correlation: minuscule correlation: $0 < r < 0.1$; weak correlation: $0.1 \leq r < 0.3$; average correlation: $0.3 \leq r < 0.5$; high correlation: $0.5 \leq r < 0.7$; very high correlation: $0.7 \leq r < 0.9$; almost full correlation of $0.9 \leq r < 1.0$.

To determine whether and how the reduced assemblage of quantitative traits (variables on the numbers of fishes and hiding places) in a statistically significant groups studied streams, Principal Components Analysis (PCA) based on the covariance matrix was performed.

For statistical analysis of the data the software: Microsoft Excel 2007, XLSTAT-Pro 7.5 and StatSoft Statistica 10 were used.

Results

Of the 38 survey transects in 13 streams, the speed of the stream current classified as "weak" was described only at one position in streams Biały Potok and Filipczański Potok. On the other positions they were reported swift current and in some cases rapid current.

Numerous obstacles that could hinder the migration of fish was found on one of the transects of stream Gorczykowy Potok. In streams Rybi Potok, Poroniec, Małołącki Potok Strążyski Potok, Olczyski Potok and Biały Potok there were a few thresholds, which could affect the movement of the fish fauna.

The width of the studied streams was variable and ranged from 1.5 m in the upper sections of streams Małołącki Potok and Poroniec, for up to 20 m in the lower sections of streams Chochołowski Potok, Sucha Woda and Goryczkowy Potok.

The shading of the studied streams was variable. Twelve sections of studied streams was shaded more than in 80%. They belonged to the following streams: Goryczkowy Potok, Małołącki Potok, Poroniec, Lejowy Potok, Strążyski Potok, Chochołowski Potok, Goryczkowy Potok and Olczyński Potok. The streams with negligible shading (not exceeding 10%) of the bottom surface were: Sucha Woda, Potok Roztoka, Rybi Potok and Kościeliski Potok.

During the study, the occurrence of moss growing on the streams substrates of bottoms was also highlighted. In all streams it was found a total of 13 species of bryophytes: *Blindia acuta, Brachythecium rivulare, Cratoneuron filicinum, Hygrohypnum molle, Hygrohypnum ochraceum, Marchantia polymorpha, Marsupella emarginata, Palustriella communata, Platyhypnidium riparioides, Rhizomnium pseudopunctatum, Scapania uliginosa, Sciuro-hypnum plumosum, Warnstorfia exannulata* and one species of red algae of the genus *Audoinella* sp. The biggest cover of bottom was found for transects of stream Rybi Potok – 80% of the bottom surface. Over 10% of the bottom surface was covered in moss in streams Goryczkowy Potok, Olczyski Potok, Kościeliski Potok and Potok Roztoka.

On most surveyed sections of the streams there were no logs of wood that could slow down the stream and at the same time provide a hiding place for fishes. Only on one of the transects designated on streams Lejowy Potok, Goryczkowy Potok and Rybi Potok occasionally filled the branches and trunks.

The substrate of the bottom surface in the studied streams were mainly large stones. In the case Poroniec and one of the section of stream Strążyski Potok the rock outcrops were observed, and these rock formations accounted for over 75% of the bottom surface. Stones with over 40 cm in diameter were a dominant substrate of bottom (above 60%) on sections of streams Kościeliski Potok, Sucha Woda, Małołącki Potok and Rybi Potok.

The highest sections of the streams were above 1,150 meters above the sea level. In stream Potok Roztoka the catches were completed at an altitude of 1,154.5 meters above sea level; in stream Sucha Woda at an altitude of 1,164.5 meters above sea level and in straem Rybi Potok at 1396.8 meters above sea level. The lowest located test stands were in streams Sucha Woda (832.1 meters above sea level), Filipczański Potok (832.5 m above sea level) and Poroniec (857.4 meters above sea level).

The maximum slope was observed in the lowest tested section of stream Sucha Woda (32.6% with an average slope of 10.1%); in the middle section of stream Strążyski Potok (28.1% with an average slope of 9.6%); and in the middle section of stream Olczyski Potok (27,6% with an average slope of 9.1%). The largest average of slope was observed in the middle section of stream Rybi Potok (14.7%), in the lowest section of stream Filipczański Potok 10.7%, in the highest section of stream Małołącki Potok (10.4%) and in the lowest section of stream Sucha Woda (10.1%). The smallest average of slope was recorded in the central sector of stream Potok Roztoka (1.2%) and in the lowest section of stream Poroniec (1.9%).

On the basis of electrofishing conducted in selected streams of Tatra National Park it was found that in these watercourses three species of fish, ie. *Cottus poecilopus*, *Salmo trutta* m. *fario* and *Salvelinus fontinalis* occurred. The latter is an alien species in fish fauna in the Tatras and in the whole Poland. In terms of abundance (Fig. 1) *Cottus poecilopus* predominated in the analyzed streams. This species represented 80.1% of the total fish caught (*Salmo trutta* m. *fario* – 19.5% and *Salvelinus fontinalis* only 0.4%, respectively).

During electrofishing, *Cottus poecilopus* was found at 22 test stands in 11 streams: Rybi Potok, Potok Roztoka, Poroniec, Filipczański Potok, Sucha Woda, Małołącki Potok, Strążyński Potok, Kościeliski Potok, Chochołowski Potok, Lejowy Potok i Biały Potok (Table 1). On most of the test stands the fishes were caught during the summer and autumn. In the Lejowy Potok fishes were caught only in the autumn. The absence of fishes in this stream in the summer resulted from a very high state of water, which in addition, after a very heavy rain was opaque, which greatly reduced the visibility. A total of 706 individuals of *Cottus poecilopus* were observed. 459 individuals were removed from water and performed measurements of their length and body weight.

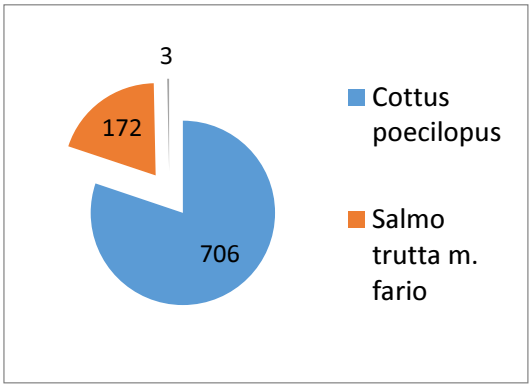

Fig.1. The abundance of fishes [ind.] in the electofishing in all test stands (source: own study)

Among *Cottus poecilopus* the most abundant was group ADULT – 338 individuals, YUV group consisted of 98 fishes, a group YOY – 23. Other *Cottus poecilopus* speciments, similarly like trout, escaped from the electric field, or, as occurred more frequently, quickly fell into electronarcosis and swam into numerous gaps between the stones and they could not be drawn using landing net. Table 2 summarizes the abundance and density of *Cottus poecilopus* at different test stands. The most of *Cottus poecilopus* speciments were found in stream Filipczański Potok – 148 individuals (60 individuals in the summer and 88 individuals in the autumn) and in stream Strążyński Potok – 89 individuals (38 individuals in the summer and 51 individuals in the autumn). During the summer, there was a little of *Cottus poecilopus* in streams Chochołowski Potok and Lejowy Potok. This fact was associated with high water and difficulties in catches. Whereas, in the autumn in those streams 74 and 91 individuals were caught, respectively. The lowest density per m^2 was observed in streams Potok Roztoka (0.001 ind. per m^2) and Chochołowski Potok (0.002 ind. per m^2). In contrast, the largest density was noted in streams Biały Potok (0.193 ind. per m^2) and Lejowy Potok (0.143 ind. per m^2).

In most streams all of age groups of *Cottus poecilopus* were found (Table 2). In streams Poroniec, Strążyński Potok and Chochołowski Potok fishes from the group YOY (the youngest stages) have not been catched, and in stream Kościeliski Potok only fishes from a group ADULT have been caught. Absence of these age groups in catches was not associated with their lack of in the above-mentioned streams, but with the difficulty in fishing them. As previously mentioned, *Cottus* sp. has poor anode reaction, which results in an earlier electronarcosis and falling the fish on the bottom of streams. For a large number of stones on the bottom, it is very difficult to catch those fishes.

The highest density of fish found at altitudes from 911 to 979 m above sea level in streams: Biały Potok, Lejowy Potok, Rybi Potok and Filipczański Potok. The greatest height above sea level, where *Cottus poecilopus* was found

was 1,077.2 m above sea level in stream Chochołowski Potok. While the lowermost position with the presence of *Cottus* was stream Poroniec – 832.5 m above sea level. Analysis of correlation of the abundance of fishes with 17 habitat variables and the correlation between abundance different species of fish revealed a number of statistically significant correlation ($p \leq 0.05$) between them. The abundance of *Cottus* was strongly negatively correlated with the presence of plants on the bottom of streams ($r = –0.763$) and the altitude of catching position (m above sea level) ($r = –0.456$). Statistically significant differences between sections of streams with and without fishes in the case of four variables of habitat was found (Table 3). The sections of the streams in which *Cottus* sp. occurred there was less plant compared to sections of streams in which there were no fish. Sections with fishes were located at a lower altitude above sea level than sections of streams without fishes.

Table 1. The abundance and density of *Cottus poecilopus* in different test stands (source: own study)

Steram	Test stand	Abundance [ind.] summer	Abundance [ind.] autum	Density [ind./m^2] summer	Density [ind./m^2] autum
Rybi Potok	1	18	19	0.014	0.038
Potok Roztoka	1	5	4	0.004	0.003
	2	5	5	0.001	0.006
Poroniec	1	5	–	0.007	
	2	–	8	–	0.023
Filipczański Potok	1	19	22	0.022	0.026
	2	25	40	0.023	0.036
	3	16	26	0.025	0.040
Sucha Woda	1	13	23	0.014	0.026
	2	16	34	0.011	0.023
Małołącki Potok	1	8	4	0.025	0.012
Strążyński Potok	1	10	16	0.029	0.046
	2	15	17	0.030	0.034
	3	13	18	0.024	0.033
Kościeliski Potok	1	–	14	–	0.014
Chochołowski Potok	1	5	24	0.007	0.032
	2	–	12	–	0.010
	3	3	30	0.002	0.021
Lejowy Potok	1	–	6	–	0.017
	2	–	42	–	0.120
	3	–	43	–	0.143
Biały Potok	1	35	58	0.014	0.193

Table 2. The abundance [ind.] of different age groups in selected streams (source: own study)

AGE GROUP / STREAM	YOY	YUV	ADULT
Rybi Potok	7	17	22
Potok Roztoka	1	2	4
Poroniec	–	1	8
Filipczański Potok	3	20	58
Sucha Woda	2	7	51
Małołącki Potok	1	1	7
Strążyński Potok	–	1	48
Kościeliski Potok	–	–	11
Chochołowski Potok	–	4	44
Lejowy Potok	6	15	50
Biały Potok	3	30	35
TOTAL	23	98	338

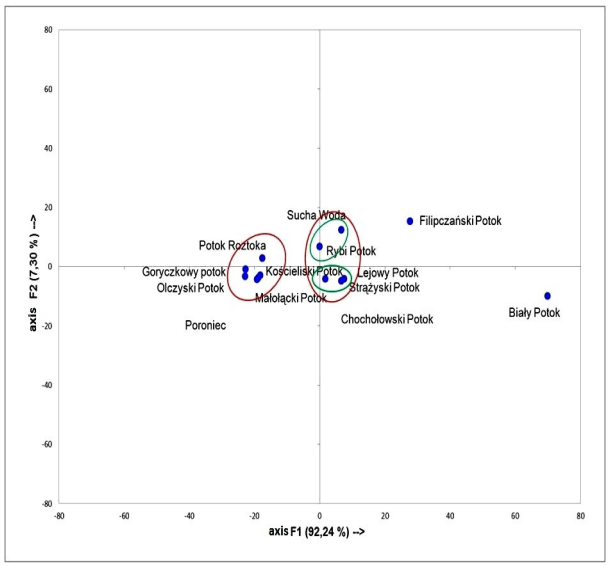

Fig. 2. Analysis PCA streams based on the abundance of fishes and hiding places (source: own study)

There were no statistically significant differences in the abundance of fishes between the streams in which there were barriers to migration and streams where these barriers were not there. Performed univariate ANOVA based on the Kruskall-Wallis test showed no statistically significant difference between the abundance of fishes in the sections of streams with different speed of the stream current. The analysis of the main components has divided the mountain streams into 2 distinct groups (Fig. 2). To the first group belonged streams: Goryczkowy Potok, Kościeliski Potok, Małołęcki Potok, Poroniec and Potok Roztoka. To the second belonged streams: Sucha Woda, Rybi Potok, Chochołowski Potok, Lejowy Potok, Strążyski Potok. Within the second group resemblance of streams Sucha Woda and Rybi Potok has been clearly marked. PCA analysis also revealed a clear distinction in terms of existing fish in streams Filipczański Potok and Biały Potok from the rest of watercourses.

Table 3. The differences between sections of streams with and without fishes on the basis of U Mann-Whitney test (source: own study)

	The sum of ranks (Group 1)	The sum of ranks (Group 2)	U	Z	p	Z (corr.)	p	N (Gr. 1)	N (Gr.2)
Stream current	322,5000	418,5000	165,5000	0.29566	0.767493	0.37300	0.709151	16	22
The thresholds	355,0000	386,0000	133,0000	1.25654	0.208922	1.46885	0.141875	16	22
Avg_Width [m]	322,0000	419,0000	166,0000	0.28087	0.778808	0.28147	0.778347	16	22
Shading %	317,0000	424,0000	171,0000	0.13305	0.894158	0.13346	0.893828	16	22
Plants %	465,0000	276,0000	23,0000	4.50876	0.000007	4.88420	0.000001	16	22
Wood	344,0000	397,0000	144,0000	0.93132	0.351690	0.96118	0.336464	16	22
Sand	315,5000	425,5000	172,5000	0.08870	0.929323	0.22917	0.818738	16	22
Gravel	307,0000	434,0000	171,0000	–0.13305	0.894158	–0.14268	0.886540	16	22
ϕ10–20	281,0000	460,0000	145,0000	–0.90175	0.367190	–0.91352	0.360969	16	22
ϕ20–40	253,0000	488,0000	117,0000	–1.72959	0.083705	–1.74154	0.081590	16	22
ϕ40–80	397,0000	344,0000	91,0000	2.49829	0.012480	2.53862	0.011130	16	22
Rocks	289,0000	452,0000	153,0000	–0.66523	0.505906	–0.85883	0.390432	16	22
Hideouts of *Cottus*	352,5000	388,5000	135,5000	1.18262	0.236959	1.19232	0.233137	16	22
Avg_Length	276,0000	465,0000	140,0000	–1.04958	0.293912	–1.04958	0.293912	16	22
Avg_Slope	341,0000	400,0000	147,0000	0.84262	0.399442	0.84262	0.399442	16	22
Z_Mean	397,0000	344,0000	91,0000	2.49829	0.012480	2.49829	0.012480	16	22

Disccusion

Cottus poecilopus in Europe occurs in two areas of the Carpathian - Sudeten, where it occurs in mountain and high mountain streams of Dniester basin, Danube basin, Vistula basin and Oder basin as well as in the area of Scandinavia and Romania (eg. Năstase, Oţel 2016; Sandlund *et al.* 2016; Starmach 1983, 1985). In Poland this species is under full legal protection of species (The ordinance of Ministry of Environment of 6 October 2010 on the protection of animal species). It is assumed that *Cottus poecilopus* occupies stands located above the range of distribution of *Cottus gobio*. The highest stands of *Cottus gobio* in Poland was found in the Sudeten Mountains at an altitude of 692 m above sea level in the Dzika Orlica (Witkowski *et al.* 2006) and in the Bieszczady Mountains at an altitude of 622 m above the sea level (Kukuła, Bylak 2010; Bylak, Kukuła 2013). The research presented in this work began at the height of more than 150 m higher than the maximum established for the occurrence of *Cottus gobio.* Oral information (Żurek 2014) about the occurrence of this species in the waters of the Tatra National Park was not confirmed. The coexistence of these species of fish is possible, however, onto lower altitudes. In waters of the tributaries of the Dunajec both species of *Cottus* sp. onto altitude of 480 and 550 m above sea level (Augustyn *et al.* 2005) were found. Tatras are the highest located place in Polish territory. So far, watercourses in Tatra Mountains have not been examined for the presence of the ichthyofauna comprehensively. It can therefore be stated, that in the course of this study for the first time the highest known stands of *Cottus poecilopus* was described in Chochołowskim Potok (1077.3 m above the sea level). In the basin of the Dunajec the highest height of *Cottus poecilopus* occurrence was found at an altitude of 750m above the sea level in Szczawniczek (Bylak, Kukuła 2013).

In the analyzed streams it was found all age groups of *Cottus* from the overwhelming dominance of the group ADULT. The density of fishes was at the level of 0,001–0,193 ind. per m^2. The density of *Cottus poecilopus* at a level above 0.01 ind. per m^2 allows, according to the guidelines of Chief Inspectorate Of Environmental Protection for *Cottus gobio* (Kotusz 2012), recognize the state of its population as a proper. In studies conducted on streams in the basin of the Poprad the higher level of density (2.03 ind. per m^2) was found, which was probably related to the higher trophy of these streams and lower height (Augustyn *et al.* 2005). Solewski (1965) found the density of *Cottus* sp. in Bialka Tatrzanska at 0,013–0,150 level.

Cottus gobio is considered the resident species, which means that over the life it not performs migrations (Witkowski, Terlecki 2000). The nature of the substrate of the bottom and the flow rate of water, affected in a small extent onto the distribution and abundance of *Cottus* sp. in the analyzed streams. These relationships are confirmed by studies by Wyżga *et al.* (2008) conducted on the Black Dunajec on sections strongly transformed by the aggregates extraction and on natural sections. The abundance of *Cottus poecilopus* was not statistically significant different for these two types of habitats.

Conclusions

On the basis of fish catches conducted in selected streams of Tatra National Park it was found that in these watercourses three species of fish, ie. *Cottus poecilopus*, *Salmo trutta* m. *fario* and *Salvelinus fontinalis* occurred. The most numerous *Cottus poecilopus* were represented, a total of 485 individuals in 12 streams. The Stream Chochołowski Potok (1077.3 m above sea level) was the highest position where the genre occured.

The abundance of *Cottus* was strongly negatively correlated with the presence of plants on the bottom of streams and the altitude of catching position (m above sea level).

Disclosure statement

Authors declare that they have not any competing financial, professional, or personal interests from other parties.

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