

BRIEF COMMUNICATIONS**Abundance of *Cottus poecilopus* is influenced by O₂ saturation, food density and *Salmo trutta* in three tributaries of the Rožnovská Bečva River, Czech Republic**

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The distribution patterns of alpine bullhead *Cottus poecilopus* in three tributary streams of the Rožnovská Bečva River (Danube basin) were studied with respect to temperature, oxygen concentration and saturation, shading, current, conductivity, total organic carbon (TOC), nitrates and phosphates, biochemical oxygen demand (BOD₅), pH, redox potential, bottom grain structure, density of macroinvertebrates and the abundance of brown trout *Salmo trutta*. Sites with lower abundance per hectare of *C. poecilopus* differed significantly in dissolved oxygen saturation, density of macroinvertebrates during the autumn period (positive correlation with *C. poecilopus*) and in abundance per hectare of *S. trutta* (negative correlation). These results indicate that these factors significantly influence the distribution of this endangered species in the studied catchment and that stocking of *S. trutta* will impair its recovery.

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Key words: Alpine bullhead; brown trout; macroinvertebrates; organic carbon; shading; water temperature.

Alpine bullhead *Cottus poecilopus* Heckel 1837 inhabits European mountain streams. Its main areas are Scandinavia and the Baltic region, and the Carpathian Mountains (Kottelat & Freyhof, 2007). In the Czech Republic, *C. poecilopus* is limited to the Odra River (Baltic Sea basin) and Morava River (Black Sea basin) drainages. In this country, the ecologically similar, close relative bullhead *Cottus gobio* L. 1758 occurs in the Elbe River (North Sea basin) (Starmach, 1965; Čihař, 1969). *Cottus poecilopus* often coexists with brown trout *Salmo trutta* L. 1758 in well-oxygenated mountain streams

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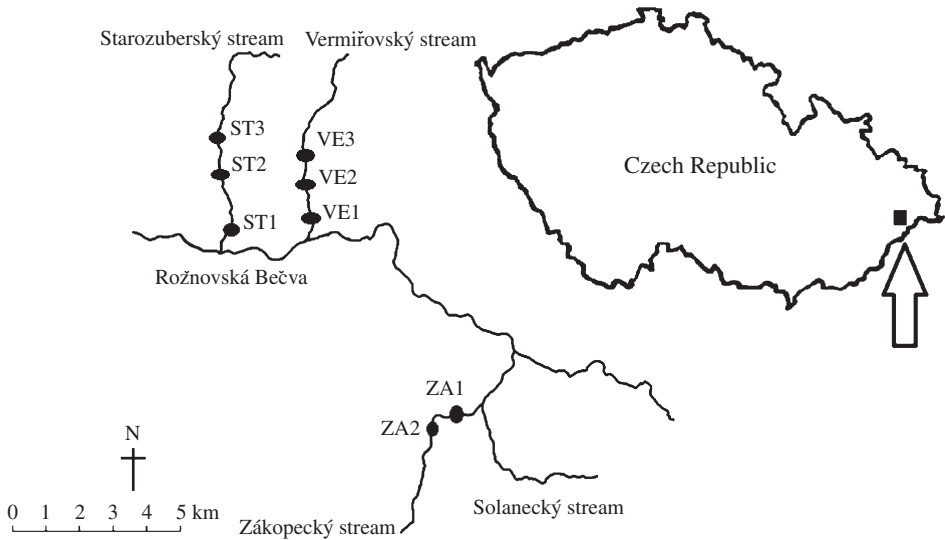


FIG. 1. Study area and location (■) in the Czech Republic (VE, Vermířovský stream; ST, Starozuberský stream; ZA, Zákopecký stream).

(Lusk *et al.*, 2008) and is categorized as being of least concern on the European red list (Freyhof & Brooks, 2011) while in the Czech Republic it is categorized as near threatened (Lusk *et al.*, 2011). *Cottus poecilopus* is adapted to a narrow range of conditions, and can therefore be considered a bio-indicator species (Hanel & Lusk, 2005). In the Czech Republic, the occurrence of *C. poecilopus* is limited to clear unpolluted streams as they are particularly sensitive to water temperature and dissolved oxygen concentrations. The aim of this study is to investigate the influence of physical and chemical factors on *C. poecilopus* and to identify the main determinants of its abundance.

Cottus poecilopus were sampled in three tributaries of the Rožnovská Bečva River (the Vermířovský, Starozuberský and Zákopecký streams) in October 2010 (Fig. 1). Electrofishing was performed in eight 100 m long sections, three sections located in each of the Vermířovský and Starozuberský streams and two in the Zákopecký stream (Table I). Mean width varied between 3.6 and 4.3 m. The water depth was measured with a calibrated bar at 10 sites in each section and the average depth was calculated. Before sampling, the study sections were screened off with a 5 mm bar mesh net. This prevented the fish from escaping. Each section was sampled twice, 1 h apart, in the upstream direction with a battery electrofishing device SEN 8 A, 192–423 V (manufactured by Bednář; www.vojtechbednar.cz) and two catches were conducted in each section. As the smallest individuals are very difficult to catch, only *C. poecilopus* 1 year and older and total length >40 mm were sampled. Fish abundance (number of fish ha^{-1}) was calculated for each sampling event and the overall abundance estimate was determined using the two-catch method of Seber & LeCren (1967).

The middle part of each section was marked and physical and chemical variables of water (temperature, dissolved oxygen, oxygen saturation, pH, conductivity, redox potential and current) were measured on the day of sampling, and every month from October 2010 to September 2011. Water temperature was measured in the shade at a depth of *c.* 10 cm away from the main stream flow. Temperature,

TABLE I. Basic characteristics of each sampled river section, mean \pm s.d. of oxygen saturation, abundance of macroinvertebrates in autumn (Ma) and in spring (Ms), mean \pm s.d. of *Cottus poecilopus* (Cp) and *Salmo trutta* (St) total length (L_T), captured numbers and calculated fish per hectare

Locality	Length (km)	Slope (%)	Oxygen saturation (%)	Ma ($n\ m^{-2}$)	Ms ($n\ m^{-2}$)	L_T (mm)	Cp ($n\ 100\ m^{-1}$)	St ($n\ 100\ m^{-1}$)	Cp ($n\ ha^{-1}$)	St ($n\ ha^{-1}$)
VE1	0.8	2.5	96.67 \pm 13.61	834	2168	0 \pm 0	0	122	0	3050
VE2	2.1	4.0	100.00 \pm 12.50	1445	2525	80 \pm 18	9	131	215	3119
VE3	3.1	6.5	100.25 \pm 11.13	2094	2223	70 \pm 10	90	38	2093	884
ST1	0.7	2.5	97.42 \pm 10.92	584	2102	0 \pm 0	0	88	0	2200
ST2	2.6	3.0	100.50 \pm 13.83	1602	1119	77 \pm 9	11	114	262	2715
ST3	3.8	5.0	100.33 \pm 12.56	897	1614	82 \pm 14	27	14	750	389
ZA1	0.9	2.5	100.83 \pm 10.94	1792	3940	80 \pm 20	83	40	1977	953
ZA2	1.8	5.0	101.83 \pm 10.75	1312	3143	90 \pm 11	50	53	1163	1233

n, number; VE, Vermřřovský stream; ST, Starozuberský stream; ZA, Zákopecký stream.

pH and redox potential were measured using a Greisinger GHM 3530 portable multimeter (<http://gsg-messtechnik.de/>). Dissolved oxygen content and oxygen saturation were measured by a Hanna Oxy-check dissolved oxygen meter, and temperature-compensated conductivity was determined by a Hanna DIST3 conductivity meter (www.hannainst.com). A Flo-mate 2200 flowmeter (www.flow-tronic.com) was used to measure current velocity at three points in the main stream flow of each section. Total organic carbon (TOC) was measured by Pt-catalysed high-temperature combustion on a Formacs analyser (Skalar Analytical; www.skalar.com). Determination of nitrates and phosphates was done on mixed water samples taken from each section. To prevent further microbial decomposition, 1.5 ml of chloroform CHCl_3 was added to the sample. A Dr 2000 spectrophotometer (Hach Company; www.hach.com) was used to analyse nitrate and phosphate levels. Determination of biochemical oxygen demand (BOD_5) was made during August 2011 using an OxiTop Control 6 BOD respirometer system (Wissenschaftlich-Technische Werkstätten; www.wtw.de).

Macroinvertebrate sampling was performed during the autumn (October 2010) and spring (April 2011). A metal frame benthic net with a mesh size of 500 μm and an area of 1089 cm^2 was used for quantitative sampling of macroinvertebrates at three points of each stream section. The macroinvertebrates were preserved in a 4% formaldehyde solution. Macroinvertebrates were identified to family level and density was expressed as number m^{-2} . Three samples of the bottom substratum were taken in each section in July 2011 with a metal shovel. After drying, sediment samples were sieved through mesh sizes 20, 10, 7, 3, 0.7, 0.4, 0.09 and 0.083 mm. All grain size fractions were weighed and the per cent mass of each size was calculated.

The abundance ha^{-1} of *C. poecilopus* was $\log_{10}(x + 1)$ transformed prior to the analysis to ensure the normality of data. Forward stepwise regression was used to choose appropriate explanatory variables. Because of the low number of data points, the Akaike information criterion (AIC) (R Core Team; www.r-project.org) did not reach its minimum value before a total fit was achieved (a total fit corresponds to using all of the seven available variables). Therefore, the chosen criterion was that the increase in r^2 with each added variable needed to be at least 3%. These revised stepwise analyses were conducted in Statistica 10 (Statsoft Inc.; <http://www.statsoft.com/>).

The abundance of *C. poecilopus* (Y , numbers ha^{-1}) increased with the O_2 saturation (X_{O} , %; $r^2 = 0.89$), increased with density of macroinvertebrates with autumn (X_{M} , numbers m^{-2} ; $r^2 = 0.94$) as a second predictor variable and decreased with density of *S. trutta* as a third predictor variable (X_{S} , numbers ha^{-1} ; $r^2 = 0.98$) (Table I). The correlations between *C. poecilopus* abundance and each of these factors are shown in Fig. 2 and the full model is $Y = -41.4400 + 0.4579X_{\text{O}} + 0.0010X_{\text{M}} - 1.0622X_{\text{S}}$ ($F_{3,4} = 103.03$, $P < 0.001$). The other factors were not significantly correlated with *C. poecilopus* abundance and not included in the model.

The lowest limit of oxygen saturation tolerated by *C. gobio* is 74% (Legalle *et al.*, 2008). Čihař (1969) reported a higher oxygen requirement for *C. poecilopus* and this may be the reason why this species occupies higher altitude sites than *C. gobio* in the Carpathian Mountains. There were no, or very limited, local sources of pollution in the area studied, and the values of BOD_5 and TOC indicated good water quality. The observed variations in oxygen saturation observed along the 1–3 km long stream sections were sufficient, however, to influence the distribution of *C. poecilopus* during its seasonal cycles, particularly in summer.

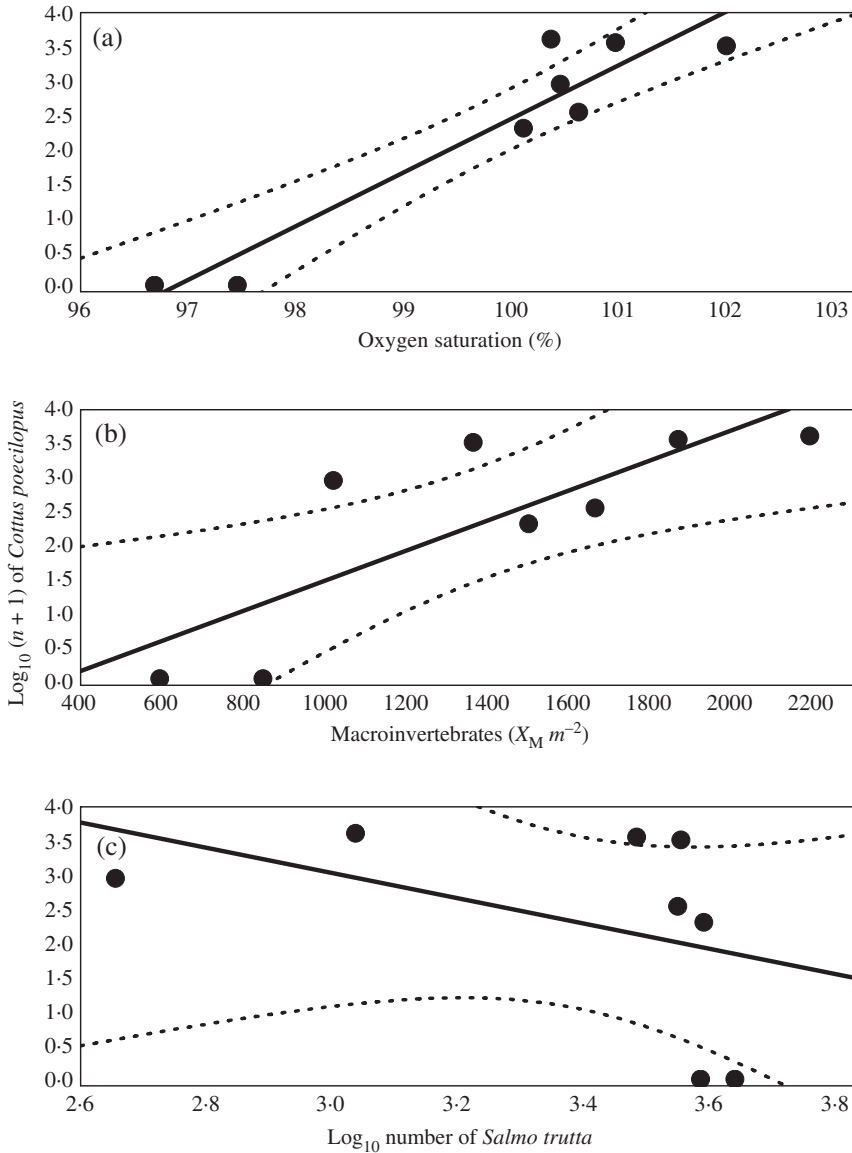


FIG. 2. $\text{Log}_{10}(n+1)$ of *Cottus poecilopus* ha^{-1} (Y) on (a) oxygen saturation (X_O) ($Y = -78.531 + 0.811X_O$; $r^2 = 0.899$, $t = 8.03$, d.f. = 6, $P < 0.001$), (b) density of macroinvertebrates in autumn ($X_M \text{ m}^{-2}$) ($Y = -0.835 + 0.0024X_M$; $r^2 = 0.6394$, $t = 3.83$, d.f. = 6, $P < 0.01$) and (c) number of *Salmo trutta* ha^{-1} ($\text{log}_{10} X_S$) ($Y = 8.7255 - 1.9057X_S$; $r^2 = 0.1884$, $t = -3.04$, d.f. = 6, $P < 0.05$). 95% C.I. are given (.....).

The dominant families of macroinvertebrates found in all the sampled sections were Gammaridae, Heptageniidae, Baetidae, Elmidae, Chironomidae and Leuctridae. The abundance of autumn macroinvertebrates in all sections was within an order of magnitude of that reported in the spring (Table I). Higher temperatures may speed up the emergence of adult insects and result in the lower abundance found in warmer sections.

This was reported by Vannote & Sweeney (1980) and Marten & Zwick (1989). The preferred diet of *C. poecilopus* is usually Chironomidae, Ephemeroptera and Trichoptera larvae (Holmen *et al.*, 2003; Hesthagen *et al.*, 2011).

The abundance ha^{-1} of *C. poecilopus* showed an inverse relationship with the abundance ha^{-1} of *S. trutta*. While Lusk *et al.* (2009) assumed that fishery management does not have a significant effect on *C. poecilopus*, the present data suggest a negative influence from the *S. trutta* stocking that occurs in this river. A dense *S. trutta* population in the investigated streams has been supported by the angling association, which periodically stocks and harvests *S. trutta* in 2 year cycles. Over 75% of *S. trutta* were age 2+ years. Both *C. poecilopus* and *S. trutta* appeared to prefer the most productive parts of the mountain streams where they may compete for food when their population density is high (Hesthagen & Heggenes, 2003). In Norway, an 80% diet overlap was found between *C. poecilopus* and *S. trutta* (Hesthagen *et al.*, 2004) and the newest observations of Louhi *et al.* (2014) suggest a negative effect of young *S. trutta* on *C. poecilopus*.

Thus, *C. poecilopus* occurs in streams with high oxygen saturation and high abundance of macroinvertebrates, but appears to avoid areas with a high density of *S. trutta*. The other factors studied appeared have minor influence on the distribution of *C. poecilopus* in the study streams. *Salmo trutta* stocking can hence have a negative effect on the occurrence and distribution of this rare fish species.

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