# THE RESPONSE OF CHIRONOMID LARVAE TO HYDRAULIC CONDITIONS: *SYNORTHOCLADIUS SEMIVIRENS* (DIPTERA: CHIRONOMIDAE) IN TWO DIFFERENT RIVERS.

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With 1 figure and 1 table

ABSTRACT: We analyzed the response of *Synorthocladius semivirens* (Kieffer, 1909) abundance to hydraulic conditions in two rivers using regression analysis. Unimodal and linear regression models of the response were obtained for the Svratka and for the Bečva respectively. The possible causes of the different chironomid responses are discussed, however further measurements are needed to confirm or reject the hypotheses.

RESUMO: A relação entre a abundância do quironomídeo *Synorthocladius semivirens* (Kieffer, 1909) e as condições hidrológicas foi estudada em dois rios através de métodos de análise de regressão. Utilizaram-se análises da distribuição unimodal e modelos de regressão linear no tratamento de dados dos rios Svratka e Bečva, respectivamente. Discutem-se as possíveis causas da obtenção de respostas diferentes para os dois tipos de rios; no entanto, novas amostragens deverão ser realizadas, de modo a permitir a confirmação dos resultados obtidos.

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## INTRODUCTION

Water flow is a dominant feature of stream ecosystems. Although many factors influence the spatial distribution of benthic macroinvertebrates, hydraulic conditions are one of the most important. The movement of water has a direct effect on stream organisms, but also influences them indirectly, via levels of dissolved oxygen and the quality and quantity of organic particles (including algae), available as food items.

Water flow is very temporally and spatially complex. It is still difficult to measure and characterize the near-bed hydraulic conditions, which are a result of the interactions between substrate, velocity and depth. Mean velocity is an inadequate descriptor of the flow environment and several hydraulic parameters incorporating velocity, depth and/or substrate have been proposed (DAVIS & BARMUTA, 1989). These complex hydraulic parameters (e.g. dimensionless inferred boundary Reynolds number, inferred shear velocity and dimensionless Froude number) are considered to be the best predictors of invertebrate habitat preference by QUINN & HICKEY (1994). Complex dimensionless hydraulic parameters allow direct comparison of hydraulic conditions between streams and rivers of different size. The Froude number, which incorporates only velocity and depth, has been found to be strongly related to invertebrate abundance (e.g. ORTH & MAUGHAN, 1983; JOWETT *et al*., 1991; BENBOW *et al*., 1997) and an effective hydraulic parameter for identifying pool, run, and riffle habitats (JOWETT, 1993). We identified it as a variable best explaining the direction of the largest variability in our chironomid data (results of PCA, unpublished data).

The objective of this study was to test whether a single species shows the same preference for hydraulic conditions, expressed as the Froude number, in two different rivers. We chose *Synorthocladius semivirens* (Kieffer 1909) – a common and easily identifiable holarctic chironomid species (SÆTHER & SPIES, 2004), found in both flowing and standing waters and feeding mainly as a gatherer/collector and grazer (JANECEK *et al*., 2002).

## STUDY SITES

Two rivers with different characteristics were chosen (Table 1). The Svratka River is a relatively stable river with a simple channel, which drains the Czech-Moravian Highlands characterized by siliceous mineral bedrock. The Bečva River, which rises in the West Carpathian flysch zone, is a relatively dynamic gravel-bed river with gravel bars, side arms and pools. Discharge in the Bečva is generally higher and more variable than in the Svratka. Maximum summer water temperature is almost 10 °C higher in the Bečva and conductivity over 2.5 times higher (435 µS $cm^{-1}$) than in the Svratka (164 µS $cm^{-1}$).

TABLE 1. General characteristics of the sampling sites.

| Site attributes | Svratka | Bečva |
|---|---|---|
| Lattitude | 49º36' | 49º32' |
| Longitude | 16º14' | 17º47' |
| Elevation (m) | 480 | 253 |
| Catchment area (km$^2$) | 354 | 1222 |
| Mean channel width (m) | 12.5 | 30 |
| Mean annual temp. (C°) | 6.9 | 9.6 |
| Max. summer temp. (C°) | 20.2 | 30.1 |
| Annual discharge characteristics (m$^3$s$^{-1}$) | | |
| Median | 1.9 | 8.2 |
| 0.1 percentile | 1.1 | 4.1 |
| 0.9 percentile | 8.2 | 40.8 |

Stream-bed substrate in the Svratka was dominated by cobbles (mesolithal), but included sand (psammal) and boulders (macrolithal). In areas with low current the mineral substrate was often covered with fine particulate organic matter (FPOM) and/or leaves. In the streamline patches of water moss were observed. In the Bečva substrate was relatively uniform, dominated by small and large cobbles (microlithal and mesolithal) and often overgrown with filamentous algae which were overlaid with FPOM in low current areas.

## MATERIAL AND METHODS

Water temperature and discharge data were obtained from the nearest gauge station for the Svratka as well as the discharge data for the Bečva. At the Bečva the water temperature was measured continuously using data logger at 15 minute intervals. The rivers were sampled in early autumn (3-4 October 2002 and 5-6 October 2004, Svratka and Bečva respectively) during a period of low and stable flow conditions which support the creation of distinct habitat patches. Sampling was carried out in order to obtain material representative for the river stretches and also to collect samples from the majority of hydraulic conditions available. A total of 20 samples were taken at both sites following the AQEM methodology (HERING *et al*., 2004), except that the samples were kept separately, and additional samples (7 and 8 at Svratka and Bečva respectively) were taken from "rare" habitats (<5 % of the study area). All samples were taken using a hand-net (mesh size 250 µm) from an area of 0.0625 m$^2$ and preserved on site in 4 %

formaldehyde. In the laboratory, all macroinvertebrates were identified and counted, but only counts of *S. semivirens* are used in this study.

At each sampling point we estimated the proportion of substrate categories classified according to HERING *et al*. (2004) and measured the depth and the average current velocity ( 0.4 depth) from which the Froude number was calculated: $Fr = U/(gD)^{0.5}$, where U = current velocity, g = acceleration due to gravity, and D = depth (DAVIS & BARMUTA, 1989). Physicochemical parameters (water temperature, dissolved oxygen, pH and conductivity) were recorded prior to sampling at the Svratka, while at each sampling point in the Bečva because of the higher environmental variability.

Four samples from the Bečva, taken from side arms and a marginal muddy habitat, characterized by very low dissolved oxygen and very distinct chironomid communities with low numbers of *S. semivirens,* were removed from the analysis to reduce the unwanted variability in the data, resulting in a total of 27 and 24 samples from the Svratka and from the Bečva respectively.

All data were square root transformed to be normally distributed. Normality was tested using the Shapiro-Wilk's W test (Statistica for Windows version 7). Using R software, a backward stepwise regression analysis was used to determine the effect of hydraulic conditions, expressed as the Froude number, on the abundance of *S. semivirens* at both sites separately. Linear, quadratic and cubic terms of the Froude number were used as the possible explanatory variables.

## RESULTS

A total of 1575 and 560 larvae of *S. semivirens* were collected from the Svratka and the Bečva respectively. Normalized larval abundance was significantly higher in Svratka samples than the Bečva (t-test, d.f. = 49, p = 0.002). Normalized Froude numbers did not differ significantly between the sites (t-test, d.f. = 49, p = 0.19). The densities of all chironomid larvae were not significantly different between the sites (t-test, d.f. = 49, p = 0.46).

The following regression models of the relationship between Froude number and the abundance of *S. semivirens* were obtained:

Svratka: $y = 46.983x - 60.165x^2$,

Bečva: $y = 10.8215x$,

where y is the square root of the abundance of *S. semivirens* and x is the square root of the Froude number. Both models (Fig. 1) were highly significant and explained a large portion of the variability (p-values were $2.475 \cdot 10^{-12}$ and $4.026 \cdot 10^{-12}$, the adjusted R-squared 0.873 and 0.876 for the Svratka and the Bečva model respectively). The models show a unimodal response of *S. semivirens* abundance to Froude number with the peak at Froude number 0.152 (the square of 0.39) in the Svratka, but a linear response in the Bečva with abundance increasing along with Froude number.

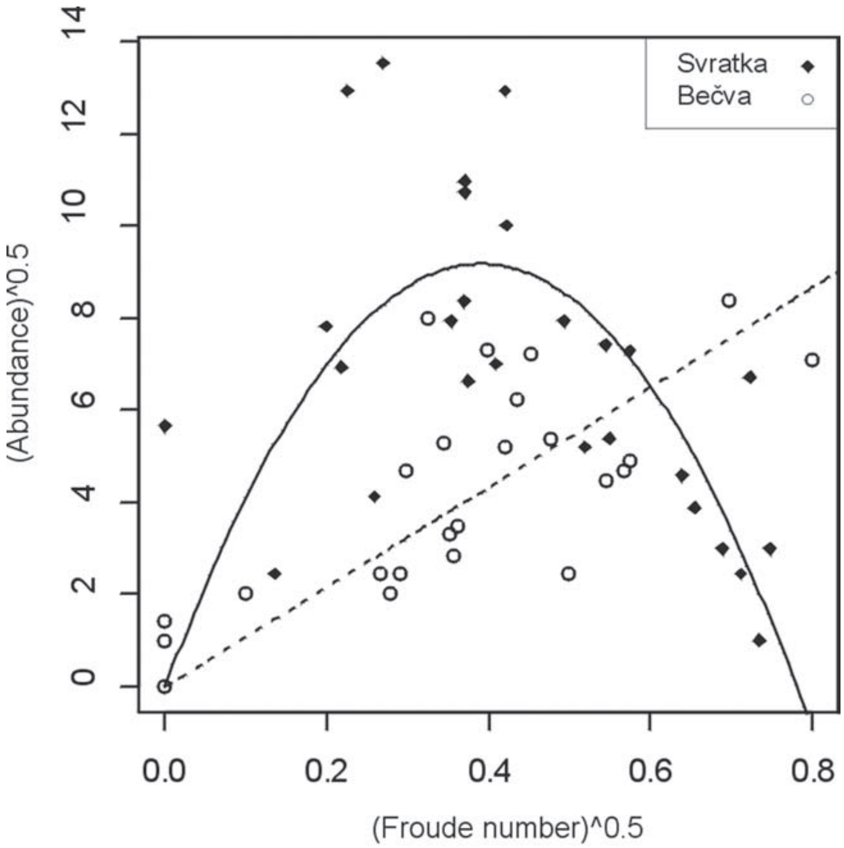


**Figure 1.** The relationship between the abundance of *S. semivirens* larvae and Froude number at the Svratka and the Bečva (both variables are square root transformed).

## DISCUSSION

Although *S. semivirens* is referred to be a generalist occurring in running waters from springs to the potamal zone of rivers and also in the littoral zone of lakes (JANECEK *et al*., 2002) the regression analysis showed that *S. semivirens* larval abundance was highly related to hydraulic conditions expressed as the Froude number. Relationships differed between the study sites, even though the range of Froude numbers was similar. In the Svratka larvae preferred hydraulic conditions corresponding to Froude number 0.152 and their density decreased with higher and lower Froude numbers. In the Bečva larval density increased with increasing Froude number. Using Froude number for identification of pools and riffles (boundary value 0.23, JOWETT, 1993), *S. semivirens* preferred pools in the Svratka and riffles in the Bečva.

It is likely that the difference in the habitat preferences of *S. semivirens* larvae was caused by the large difference between the studied sites, although we can only hypothesize which were the causal factors. The higher water conductivity and filamentous algae covering the substrate in the Bečva suggests higher nutrient enrichment (e.g. HART & ROBINSON, 1990). Higher microbial activity can also be expected (e.g. ELWOOD *et al*., 1981) at these sites. These factors combine to decrease dissolved oxygen levels at night which will negatively influence the occurrence of *S. semivirens* larvae in areas of low current velocity. Further, filamentous algae growth might also alter hydraulic conditions directly above the substrate, reducing flow and promoting sedimentation of fine particles (SAND-JENSEN & MEBUS, 1996).

In conclusion, our results demonstrate strong and inconsistent effect of near-bed hydraulic conditions on the distribution of *S. semivirens* larvae in two different rivers. The difference between the regression models led us to hypothesize several possible causative factors but more exact flow measurements directly above the substrate and analysis of oxygen dynamics are needed to confirm or reject the discussed hypotheses.

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## BIBLIOGRAPHY

BENBOW, M. E., A. J. BURKY & C. M. WAY:
1997. Larval habitat preference of the endemic Hawaiian midge, *Telmatogeton torrenticola* Terry (Telmatogetoninae). *Hydrobiologia*, **346**: 129-136.

DAVIS, J. A. & L. A. BARMUTA:
1989. An ecologically useful classification of mean and near-bed flows in streams and rivers. *Freshwater Biology*, **21**: 271-282.

ELWOOD, J. W., J. D. NEWBOLD, A. F. TRIMBLE & R. W. STARK:
1981. The limiting role of phosphorus in a woodland stream ecosystem: effects of P enrichment on leaf decomposition and primary producers. *Ecology*, **62**: 146–158.

HART, D. D. & C. T. ROBINSON:
1990. Resource limitation in a stream community: Phosphorus enrichment effects on periphyton and grazers. *Ecology*, **71**: 1494-1502.

HERING, D., O. MOOG, L. SANDIN & P. F. M. VERDONSCHOT:
2004. Overview and application of the AQEM assessment system. *Hydrobiologia*, **516**: 1–20.

JANECEK, B., O. MOOG, C. MORITZ & R. SAXL:
2002. Diptera: Chironomidae: Orthocladiinae. In: *Fauna Aquatica Austriaca, Edition 2002.* (ed.: O. Moog), 33 pp., Wasserwirtschaftkataster, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien

JOWETT, I. G.:
1993. A method for objectively identifying pool, run, and riffle habitats from physical measurement. *New Zealand Journal of Marine and Freshwater Research*, **27**: 241-248.

JOWETT, I. G., J. RICHARDSON, B. J. F. BIGGS, C. W. HICKEY & J. M. QUINN:
1991. Microhabitat preferences of benthic invertebrates and the development of generalised *Deleatidium* spp. habitat suitability curves, applied to four New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research*, **25**: 187–199.

ORTH, D. J. & O. E. MAUGHAN:
1983. Microhabitat preferences of benthic fauna in a woodland stream. *Hydrobiologia*, **106**: 157-168.

QUINN, J. M. & C. W. HICKEY:
1994. Hydraulic parameters and benthic invertebrate distributions in two gravel-bed New Zealand rivers. *Freshwater Biology*, **32**: 489-500.

SAND-JENSEN, K. & J. R. MEBUS:
1996. Fine-scale patterns of water velocity within macrophyte patches in streams. *Oikos*, **76**: 169-180.

SÆTHER, O. A. & M. SPIES:
2004. Fauna Europaea: Chironomidae. In: *Fauna Europaea: Diptera, Nematocera* (ed.: H. de Jong). Fauna Europaea version 1.5, http://www.faunaeur.org.

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