Conference Volume	6th Symposium for Research in Protected Areas 2 to 3 November 2017, Salzburg	pages 357 - 360

Index to evaluate the vulnerability to climate change of Mayfly, Stonefly and Caddisfly species in alpine springs

Daniel Küry, Verena Lubini, Pascal Stucki

Abstract

In 2014 and 2015 the macrozoobenthos and the water temperature of 61 alpine springs of the Central Swiss Alps between 1720 and 2515 m a.s.l. were investigated and gave evidence of 99 EPT species (Ephemeroptera, Plecoptera, Trichoptera). A CCA showed, that 27 Plecoptera and Trichoptera species were associated with springs of high altitudes and especially cold water. Preference of high elevation, headwaters and spring habitats, endemism and short emergence period were the ecological traits used to develop a value indicating the vulnerability for each species. A new climate change vulnerability index (CCVI) revealed 53 of the 61 investigated spring habitats as being vulnerable to climate change.

Keywords

Ephemeroptera, Plecoptera, Trichoptera, global warming, sensibility

Introduction

Even though most spring habitats can show considerable annual and diel variations, the water temperature of alpine spring is rather stable and depends primarily on elevation, exposure and permafrost location in the catchment area (KÜRY et al. 2017). Temperature in springs shows a decrease with increasing elevation (CANTONATI et al. 2006; KÜRY et al. 2017; MARTIN et al. 2015; WIGGER et al. 2015). It is one of the key factors determining the species richness (VON FUMETTI & BLATTNER 2017; WIGGER et al. 2015) and can have a higher impact on the composition of faunal communities than habitat structure (SMITH et al., 2003).

In high altitude springs of the Central Swiss Alps a high proportion of the fauna of EPT (Ephemeroptera, Plecoptera and Trichoptera) is considered as endemic and is therefore endangered in Switzerland (KÜRY 2015; LUBINI et al. 2012). Like all other habitats, springs will be exposed to climate change during the next decades. Scenarios for Switzerland predict that air temperatures will increase and precipitation will decrease in summer (CH2014-Impacts, 2014). The water will be warmer mainly in springs, where water is moving fast through wide subterranean flow paths (KÜRY et al. 2017). In high altitude springs the consequence will be a loss of suitable habitats for cold adapted species. While at lower altitudes crenobiont animals can climb to higher elevations to find suitable cold habitats, the macrozoobenthos of high alpine springs is expected to be unable to do so, because of a lack of suitable habitats. In previous studies, EPT species were predicted vulnerable to climate change by the following ecological traits: cold stenothermic adaptation, high elevation distribution, occurrence in springs or headwaters, endemism and short emergence period (CONTI et al. 2014; HERSHKOVITZ et al. 2015). The aim of this investigation was:

1. to verify the results of these trait studies,
2. to identify the vulnerable crenobiont and crenophil species by a field study and
3. to develop an index to evaluate spring communities and habitats endangered by climate change.

Methods

A total of 61 rheocrenes situated in the Swiss Central Alps (GONSETH et al. 2001) were investigated. Their elevation was between 1720 and 2515 m a.s.l. (median: 2027 m a.s.l.) and the catchments were dominated by alpine vegetation types. To investigate the temperature, HOBO loggers (Water Temp Pro v2, by onset®) were placed as close as possible to the water outlet to record temperature every 10 minutes for approximately twelve months (KÜRY et al. 2017).

All spring habitats were visited at least two times to investigate the macrozoobenthos. The sampling was performed using a standard protocol for spring habitats in Switzerland and included also a catch of adult EPT specimens (LUBINI et al. 2014). Data analyses was performed using the software StatPlusPro:Mac by AnalystSoft Inc. © (linear regressions), multivariate statistics was performed with R (R DEVELOPMENT CORE TEAM 2015).

Results

The sampling of the macrozoobenthos resulted in 99 species: 11 Ephemeroptera, 40 Plecoptera and 48 Trichoptera. Crenobiont species had a proportion of 0%, 21% and 35% in Ephemeroptera, Plecoptera and Trichoptera respectively.

The number of all EPT species and Trichoptera species significantly decreased with declining mean annual temperature and decreasing distance to potential permafrost (Tab. 1). On the contrary, the correlation between the temperature or distance to potential permafrost and the number of Plecoptera and Ephemeroptera taxa was not significant.

	Number of species		Regression analysis (p-values)		
	all	crenobionts	Altitude	Average annual temperature	Distance Permafrost
EPT	99	24	0.00919**	0.00121**	0.00673**
Ephemeroptera	11	0	0,74173	0,50357	0,4963
Plecoptera	40	7	0,09077	0,37787	0,22167
Trichoptera	48	17	0.01263*	0.0003**	0.00758**

Table 1: Total number of taxa, number of crenobiont taxa and P-values of regression analysis of altitude, average temperatures, distance to permafrost and number of EPT taxa. Level of significance: **: p<0.01, *: p<0.05

Plecoptera	**Trichoptera**
Dictyogenus fontium **	*Acrophylax zerberus*
Isoperla lugens **	*Allogamus mendax/uncatus*
Leuctra ameliae **	*Apatania fimbriata* **
Leuctra dolasilla	*Consorophylax consors* **
Leuctra ravizzai	*Cryptothrix nebulicola* *
Leuctra rosinae	*Drusus alpinus* **
Leuctra rauscheri *	*Drusus melanchaetes* **
Leuctra schmidi	*Drusus monticola* *
Leuctra teriolensis	*Drusus muelleri* **
Nemoura undulata	*Drusus nigrescens* **
Nemoura sinuata **	*Ernodes vicinus* **
Protonemura brevistyla	*Rhyacophila bonaparti* **
Protonemura nimborella	*Rhyacophila glareosa*
	Rhyacophila intermedia

Table 2: Plecoptera and Trichoptera species associated with low temperatures according to the canonical correspondence analysis (CCA). *: crenophil species, **: crenobiont species. Gray letters: species occurring in < 3 springs.

In the canonical correspondence analysis (CCA) 27 species, 13 Plecoptera and 14 Trichoptera (Tab. 2), turned out to be associated with low temperatures and high altitudes. A weighted climate change vulnerability value (CCVV) for all EPT species (Tab. 3) was formulated by using their individual ecological traits. The highest weight of 4 was given to the trait cold stenothermic, while the altitude was weighted by a factor of 3. Both endemism and preference for spring habitats were weighted by a factor 2, and the life cycle trait had no extra weight.

A climate change vulnerability index (CCVI) was created to assess a possible impact of climate change on the spring habitats and their communities distinguishing five categories of different vulnerability. The CCVI takes into account the CCVV of all occurring species and their abundance (Fischer 1996; Lubini et al. 2014). By applying to the 61 springs investigated in the Swiss Central Alps 48 spring habitats (79%) proved to be moderately to highly vulnerable to climate change (Tab. 4).

	Score	Weight
T thermic factor (www.freshwaterecology.info)		
Cold stenotherm (<10°C)	1	4
Warm stenotherm / eurytherm	0	
A altitude factor (www.freshwaterecology.info)		
Median altitudinal distribution > 1500 m (sal/alp)	2	
Median altitudinal distribution 800 – < 1500 m (mon)	1	3
Median altitudinal distribution < 800 m (col)	0	
E endemism (www.freshwaterecology.info)		
Endemic Alps / Jura	1	2
Non endemic	0	
S preference springs (adapted for Switzerland)		
Crenobiont ÖWZ 16	2	
Crenophil ÖWZ 8	1	2
Rhithro- / potamphil ÖWZ ≤4	0	
Em emergence period (www.freshwaterecology.info)		
Short emergence period	1	1
Long emergence period	0	

Calculation of the specific CCV value (CCVV):

[(4 • T) + (3 • A) + (2 • E) +(2 • S) + (1 • Em)] / 5

Table 3: Scores and weight of the factors for the calculation of the specific climate change vulnerability value (CCVV). The factors are determined according to the traits in freshwaterecology.info except the preference for springs, where the traits were adapted according to the own experience.

Category CCV index	CCV index	Description	Number of springs
CCVI-5	> 2.70	Highly vulnerable	5
CCVI-4	2.11–2.70	Vulnerable	20
CCVI-3	1.51–2.10	Moderately vulnerable	23
CCVI-2	1.00–1.50	Slightly vulnerable	13
CCVI-1	< 1.00	Not vulnerable	0

Table 4 : Categories of CCV index (CCSI-5 to CCSI-1) in 61 springs habitats of the Swiss Central Alps.

Discussion and Conclusions

The 27 Plecoptera and Trichoptera species associated with the coldest springs in this field study highly correspond to the species vulnerable to climate change as proposed by CONTI et al. (2014) and HERSHKOVITZ et al. (2015). This allowed to develop a weighted vulnerability value for EPT species. Giving an individual weight to each trait permits to differentiate the traits by their importance. This is the prerequisite to calculate a gradual vulnerability for both single species and whole spring communities. In consequence, the CCVI will provide an additional approach for conservation purposes to evaluate the impact of disturbances by human activities and will therefore complete indices assessing «crenophily» (FISCHER 1996; LUBINI et al. 2014) or the threat of species (red list categories). This new index shows that there is a new impairment even for habitats presumed as pristine like alpine springs. It is an additional tool applicable to spring habitats to indicate climate change sensibility of biocenosis in streams and rivers (e.g. HALLE et al. 2016).

Acknowledgements

This study was supported by a grant from the Federal Office for the Environment (FOEN), the Department for Water Protection Canton Berne, the Office for Environmental Protection Canton Uri and the Office for Nature and Environment Canton Grisons. We are grateful to our collaborators during the field work.

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Contact

Daniel Küry
daniel.kuery@lifescience.ch
Life Science AG
Greifengasse 7
4058 Basel
Switzerland

Verena Lubini
lubini@sunrise.ch
Eichhalde 14
8053 Zürich
Switzerland

Pascal Stucki
contact@aquabug.ch
Aquabug, C.P. 1643
2001 Neuchâtel
Switzerland