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Monitoring Alpine rivers: recent progress and future challenges

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Abstract

Alpine freshwaters are sensitive to climate change as hydroecological processes respond to changes in climate and alter ecosystem properties and function. In a long-term monitoring we have been studying environmental conditions, nutrients and benthic invertebrates in glacier-fed/spring-/groundwater-fed streams in four glaciated catchment in order to develop meaningful tools for the abiotic and biotic indication of climate change effects. After eight years of implementation, we report on significant results, recent progress and discuss future challenges.

Keywords

glacial, benthic invertebrates, aquatic insects, climate change, monitoring tools

Introduction

Alpine freshwaters are sensitive to climate change as hydroecological processes respond to variabilities in climate and consequently alter ecosystem properties and function (e.g. MILNER et al. 2001; FÜREDER 2007, 2012). The effects from climate change are particularly noticeable at high altitudes through glacier shrinking and permafrost melt influencing adjacent freshwaters in their catchments (MCGREGOR et al. 1995; MILNER et al. 2001; FÜREDER et al. 2001; BROWN et al. 2007). Aquatic organisms have been successfully used to indicate environmental change including the effects from climate alterations (e.g. MILNER et al. 2001; NIEDRIST & FÜREDER 2016). Under these circumstances a river monitoring was initiated in four glaciated catchments in the Hohe Tauern Nationalpark (Eastern Alps, Austria), with the goal to develop an effective long-term monitoring system (FÜREDER & SCHÖNER 2013). Together with the regular recording and measurement of abiotic parameters and hydrological characteristics, the indicator function of aquatic insects and other invertebrates was considered significant as adequate monitoring tools (FÜREDER & SCHÖNER 2013). Interim analyses of faunistic characteristics enabled the testing of several biological indices for their suitability and applicability in high mountain rivers (FÜREDER 2012). From relevant studies in the Alpine and other regions comprehensive knowledge was available (see MILNER et al. 2001; FÜREDER 2012), which could be employed for the analyses of spatial and temporal patterns in ecosystem structure and function. The pilot study produced essential theoretical and practical know-how, so that - together with the relevant scientific background and the hydrological, geomorphological and habitat characterizations – biological data could be used to provide information on the biodiversity of Alpine riverine systems, its spatio-temporal patterns of structure (community structure, taxa composition and dominance, diversity, abundance) and function (functional feeding types, species traits of resilience, resistance and environmental fitness) and potential effects from climate and environmental change. These hydromorphological, abiotic and biotic parameter and indices are essential data and tools for the monitoring, analyses and interpretations of alterations of freshwater systems in mountains.

Aim of this presentation is, based on several years of implementation of the monitoring program i) to predict community structure, taxa composition, abundances and diversity from so-far elaborated abiotic and biotic data and ii) to affirm these predictions through the comparison with new assessments and analyses. This is to test and evaluate appropriateness and applicability of tools and measurements, defined and applied as indicators of climate/environmental change effects in Alpine river ecosystems.

Methods

Fieldwork was carried out in four glaciated catchments in the Hohe Tauern Nationalpark during summer 2014 (Fig. 1). The methodology of hydro-ecological assessments and measurements of environmental characteristics followed FÜREDER et al. (2012). Benthic sampling was a stratified random sampling with a Surber sampler (100 µm mesh-size) of six replicate samples in each river stretch. Samples were preserved in the field and sorted into orders and/or families back in the laboratory. There, the animals were identified to the best taxonomic level possible. For this study, they were classified into the evaluation criteria taxa number, abundance, relative density, diversity and evenness. Indices were calculated with computer-assisted tools.

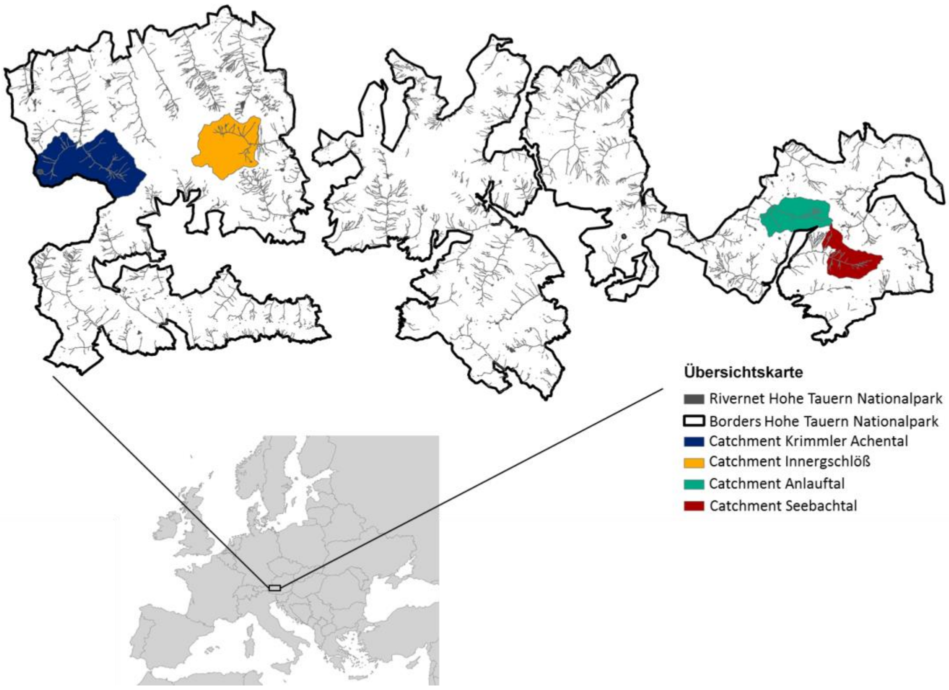

Figure 1: Catchments within the Hohe Tauern Nationalpark, Austria, selected for the river monitoring (source: HABITALP, NP HOHE TAUERN 2012; www.europakarte.org; partly produced by A. Mätzler).

Analyses

As the major aim of this study is the testing and evaluation of methods and analyses applied within the long-term monitoring, we divided the work flow into three steps: prediction, diagnosis and control (Fig. 2).

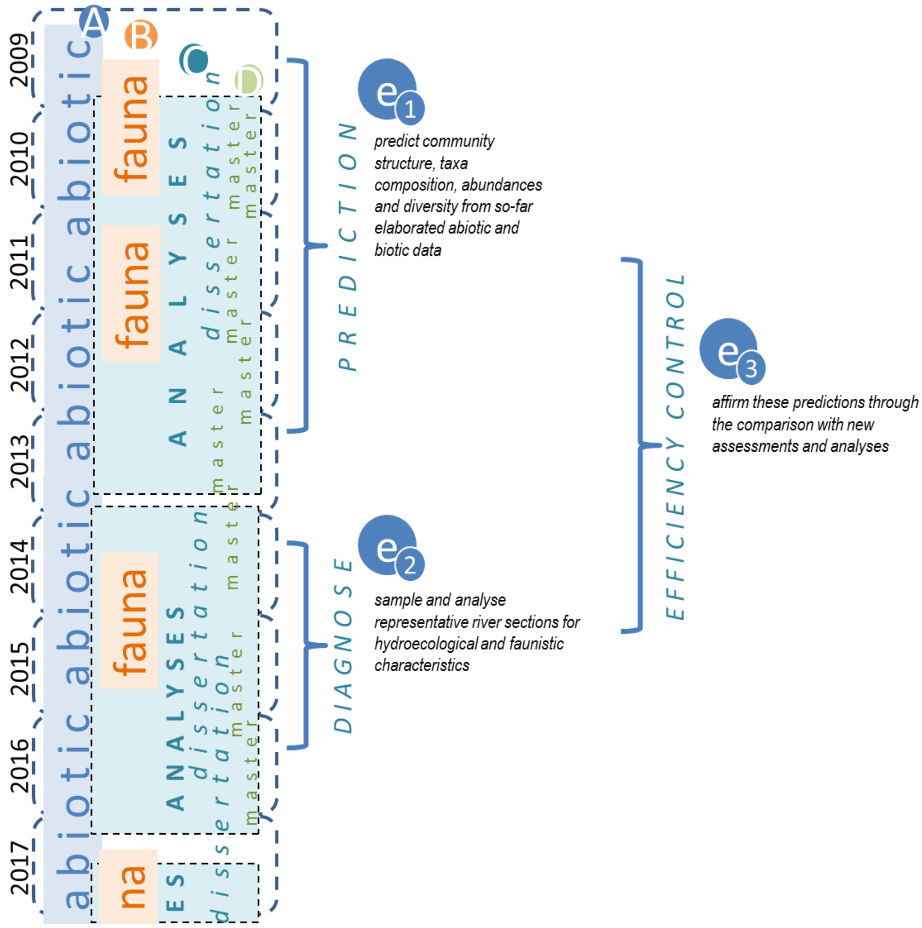

Figure 2: Scheme of efficiency control in order to test and evaluate appropriateness and applicability of tools and measurements, defined and applied as indicators of climate/environmental change effects in Alpine river ecosystems.

Results

Abiotic conditions and benthic invertebrates

In the cold (Fig. 3), highly-dynamic and nutrient-poor river systems, highly specialized invertebrate taxa occur. Most of them are restricted to a narrow range of environmental conditions, usually expanding their amplitudes when conditions get more benign. Taxa number, abundance and diversity follow this general trend: Less taxa occur in glacier-fed rivers, more in groundwater and spring-fed systems. A similar pattern is true for abundances and diversities. The dipteran family *Chironomidae* seems to correspond in particular to these predictions.

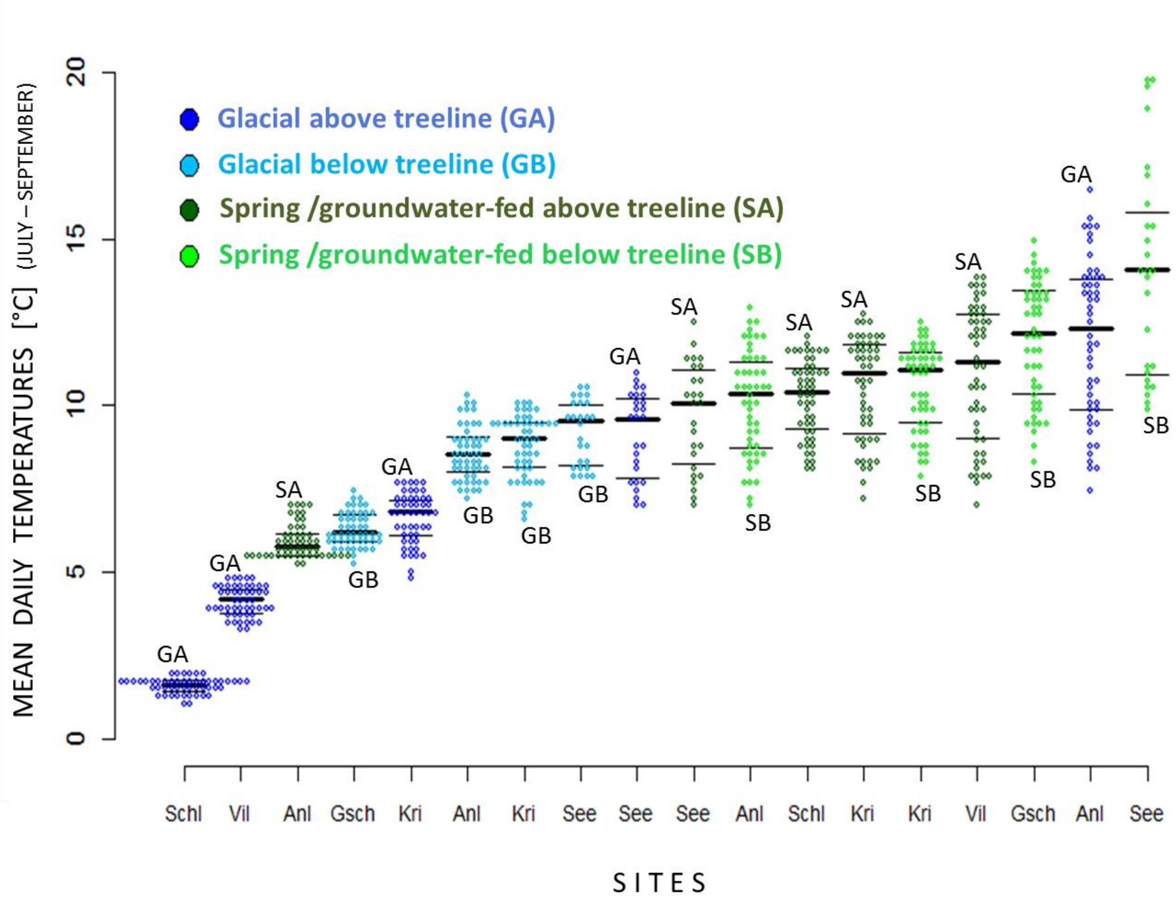

Figure 3: Box-Whisker Plot of mean daily temperatures of sites from July to September in 2015. Colours indicate stream type and position.

Appropriate indicator groups

The individual river stretches show differences in taxa numbers, abundances and diversity. Therefore it was necessary to test which taxa group was more appropriate to demonstrate the effect along the gradient of abiotic conditions. Four insect orders, i.e. *Ephemeroptera, Plecoptera, Trichoptera* and *Diptera*, are the dominant benthic invertebrates. The latter is primarily presented by the family *Chironomidae*, which reaches highest numbers in taxa, abundances and diversities the harsher the relevant environmental parameters are, i.e. glacier-fed vs. groundwater/spring-fed streams, above vs. below treeline (Fig. 4).

Prediciton & affirmation of community structure

From available abiotic and biotic data we predicted the range of benthic macroinvertebrates abundance, taxa number and diversity and compared the model with new data from 2014 (Fig. 5, left). The elaborated model allowed us in a second step to compare the causal relationship of predicted and newly assessed results (abundance, taxa number and diversity) with abiotic factors (Fig.5, right).

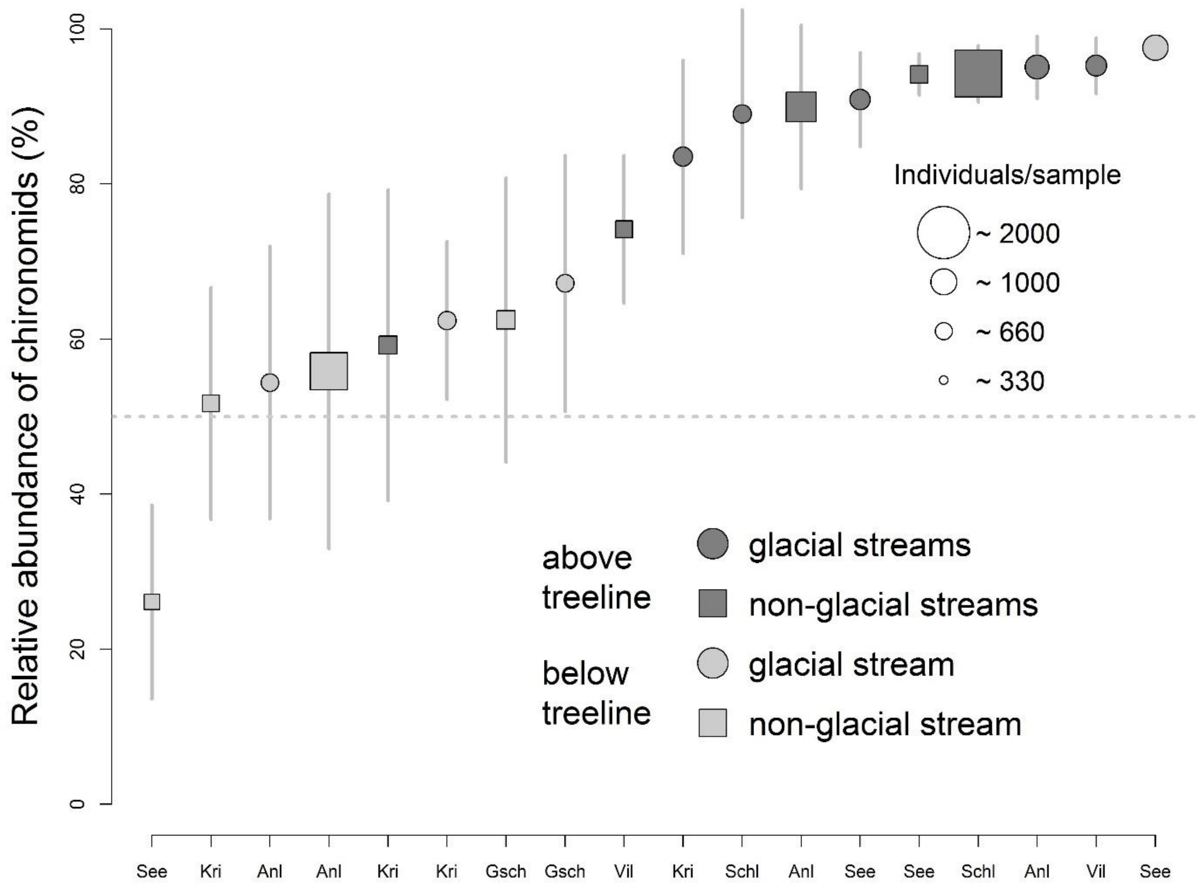

Figure 4: The relative abundance of *Chironomidae* in the Alpine rivers. With these patterns, the *Chironomidae* follow a reverse trend compared to the other three orders. While chironomid taxa number, abundance and diversity increase in harsh conditions, *Ephemeroptera, Plecoptera* and *Trichoptera* show lower values the harsher the conditions get.

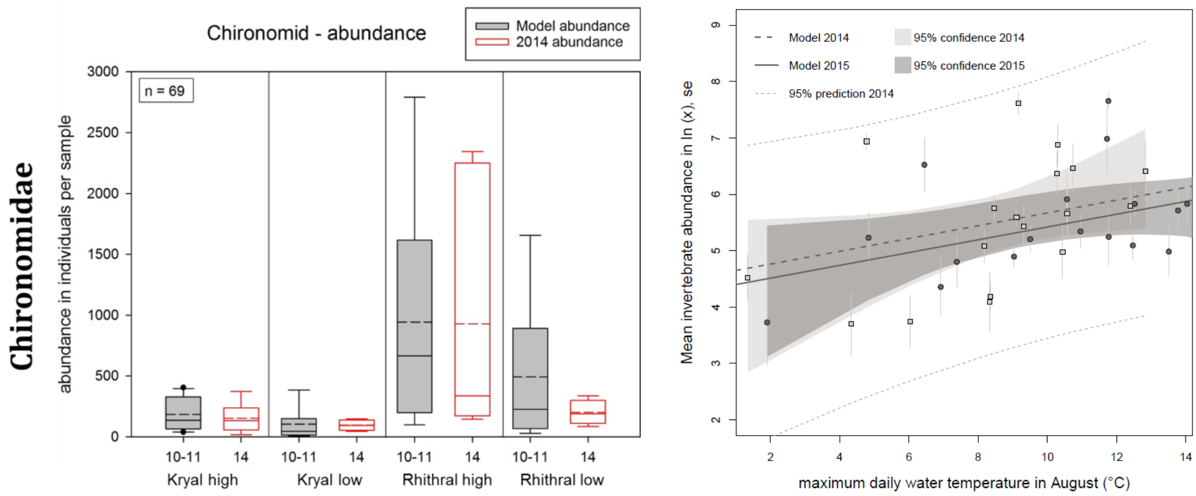

Figure 5: here chironomid abundance (grey boxes, 2010-11) and elaborated new data (empty boxes, 2014) for comparison are shown on left graph. Right graph compares causal relationship of predicted and newly assessed results with abiotic factors (here abundance and temperature shown).

Discussion and conclusion

Due to climate change in mountain areas the degree of glaciation and therefore mountain hydrology will change (McGregor et al. 1995; Brown et al. 2007). These alterations of environmental conditions will certainly change ecosystem structure and function of rivers (Füreder 2007, 2012). In the long-term river monitoring project in four glaciated catchments of the Hohe Tauern Nationalpark we measure and identify the causal relationship between environmental conditions and biology with the aim to develop and define indicator tools to detect and predict potential effects from climate/environmental change.

This approach seems to be meaningful and successful, as demonstrated by our results:

1. The chosen methodologies, to combine the information value and explanatory power of abiotic and biotic parameters and indices provide a comprehensive picture and understanding of ecosystem structure and function.
2. At the same these investigations deliver important information on the biodiversity of a widely distributed ecosystem in mountain life zones, previously barely known.
3. With the elaboration and demonstration of causal relationships between key environmental conditions and biotic features the modelling of potential climate change effects is feasible.
4. Our results indicate that only through the regular observations and measurements within the long-term monitoring, robust information on the spatial and temporal patterns of ecosystem properties is available, which is the essential requirement for reliable indication and prediction.
5. Fundamental requirements for such powerful indication are the elaboration of a comprehensive physico-chemical and biological data set, based on a robust taxonomy.
6. This kind of long-term monitoring on Alpine river ecosystems is unique, as to our knowledge no other program approaches these questions in this detail, spatial resolution and frequency.
7. Climate change research, biodiversity assessments in remote and understudied areas, investigations in extreme habitats and species adaptations are scientific topics that achieve high international significance and visibility and up value the management efforts in protected areas for ecosystem services provision.
8. The biggest challenge for this freshwater monitoring is the perpetuation of this kind of activities. Given the many pros of this program and promising results, joint effort is highly needed to guarantee its continuation. Funding, administration and scientific bodies have been supporting and collaborating with enthusiasm all the activities. Nevertheless, achievements for long-term observations are still in their initial phase.

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