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Alpine Streams – Natural Ecosystems as Indicators of Environmental Change

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Abstract

Streams are common features of alpine landscapes, and the attention given alpine streams has increased recently in response to increased recognition of the important role that these headwater streams play in major river systems throughout the world, and the vulnerability of these streams to local and regional environmental change (e.g., associated with changes in adjacent land use, acid and nutrient deposition, global climate patterns). Current climate change scenarios indicate proportionally more detectable impacts at both high altitude and latitudes. In recent investigations we have been focusing on the large variety of natural freshwater ecosystems in the Hohe Tauern Nationalpark, as their importance is often recognised in their dominating appearance in the alpine landscape, their re-creating and formative, sometimes threatening natural dynamics, but also in their progressive decline within the Alpine countries. Since lakes and rivers are highly driven by climatic, catchment and thereof dependent internal processes they are considered to be sensitive ecological systems and may serve as models to examine the consequences of environmental changes. Our results from various investigations in high mountain landscapes help to understand how alpine running water systems and their biota can be regarded as catchment-scale integrative monitors for a set of hydrological, thermal and biotic variables. In that sense, Alpine running waters can be regarded as research foci in the context of environmental change. These investigations in larger protected areas provide essential contributions for a forward-looking environmental research.

Keywords

River typology, habitat assessments, glaciation, global climate change, aquatic invertebrates

Project aims and duration

Running waters are inherently important components of alpine landscapes because they are vital water and nutrient conduits that connect high elevation snowfields, glaciers, and alpine meadows to natural and human resources at lower elevations. Awareness of the environmental value of headwaters, as ultimate resource of unpolluted waters for the future, has grown among the scientific community, land/water managers, administrators and the public. Notwithstanding this interest, few studies have focused on the ecology of mountain running waters. However, recently, greater attention has been given alpine streams in response to increased recognition of the important role that these headwater streams play in major river systems throughout the world (e.g., BRITTAIN and MILNER 2001). In the last decade awareness of the environmental value of Alpine headwaters has grown, as testified by various international activities, like recent international congresses and scientific programs. Interest has also grown among the general public as a consequence of a more widespread knowledge of environmental problems caused by human activities, both at the local (hydropower, tourism, artificial snow, etc.) and global scales (climate change, acid rain effects, etc.). These changes are known to impact even the most remote areas, at high latitude and elevation, in ecosystems that are particularly vulnerable to organic pollution, tourism, acid rain and global warming.

In this presentation I want to summarize the results of several research projects carried out within the last decade in the Central Alps. The major aims of these investigations were to

- provide an inventory of Alpine running waters in selected mountain areas,
- identify the habitat conditions at reach as well as catchment scale in a representative selection of Alpine running waters within these areas,
- identify major abiotic and biotic factors important for the structure and function of running water ecosystems, and
- identify the indicator role and quality of alpine running water systems and their biota for climate and environmental change issues so that they can be regarded as catchment-scale integrative monitors for a set of hydrological, thermal and biotic variables expected to change.

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Area of study

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The investigations presented and summarised herein were carried out in the Nationalpark Hohe Tauern (Austria), the Naturpark Rieserferner-Ahrn (Italy) and in various running waters in the Inner Oetz Valley around Obergurgl (Austria).

Methods

Detailed descriptions of research methods were provided in several publications (Füreder et al. 2000, Füreder et al. 2001, Füreder et al. 2002, Füreder et al. 2003), and used for further analysis for answering the above mentioned questions.

Results

With the inventory of 344 streams and rivers (1159 km) and the habitat assessments of 354 reaches (from 33 streams and rivers comprising 187 km) in randomly selected running waters in protected areas in Austria (Hohe Tauern National Park) and Italy (Naturpark Rieserferner-Ahrn) (FÜREDER & AMPROSI 2001, FÜREDER & VACHA 2001, FÜREDER et al. 2001,), a comprehensive characterization of alpine streams and a database is available which resulted in a typology of Alpine running waters (FÜREDER et al. 2002). The defined stream types are based on the origin, hierarchy and channel/catchment morphology, together with the detailed characterization from habitat measures, and provide important information for the definition of reference conditions for impact measures and for the evaluation of the ecological status of alpine streams. The principal components of the abiotic milieu of river ecosystems – hydrology, temperature and channel morphology – reflected regional-scale climate and geology.

When we looked into the structure and function of Alpine running water ecosystems, four main factors were found to be responsible for species numbers, abundances and diversity (Fig. 1): time since glaciation, temperature, channel stability and nutrient / food availability. Results from several investigations indicated that these factors had a pronounced effect on ecological conditions in these systems.

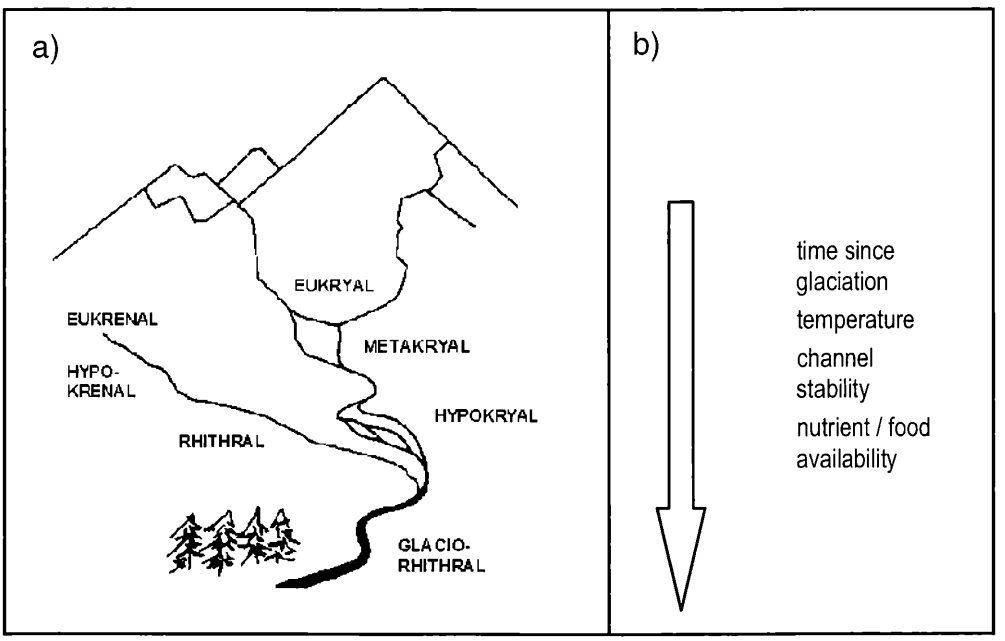

Fig. 1: a) Alpine stream types and b) factors responsible for the structure and function of running water ecosystems.

Alpine streams were found to be extreme environments and to be located on the declining limb of a harshness-diversity curve (Fig. 2). Decreasing environmental harshness (e.g., due increasing groundwater influence, decreasing glaciation) favours overall biodiversity, which also is expected to occur as a potential effect of climate change. After considerable alterations of flow patterns as well as temperature and channel dynamics, the relative contribution of channel types providing numerous refugia for the aquatic fauna will increase with the continued glacial retreat. The occurring flora and fauna will indicate a less harsh environment.

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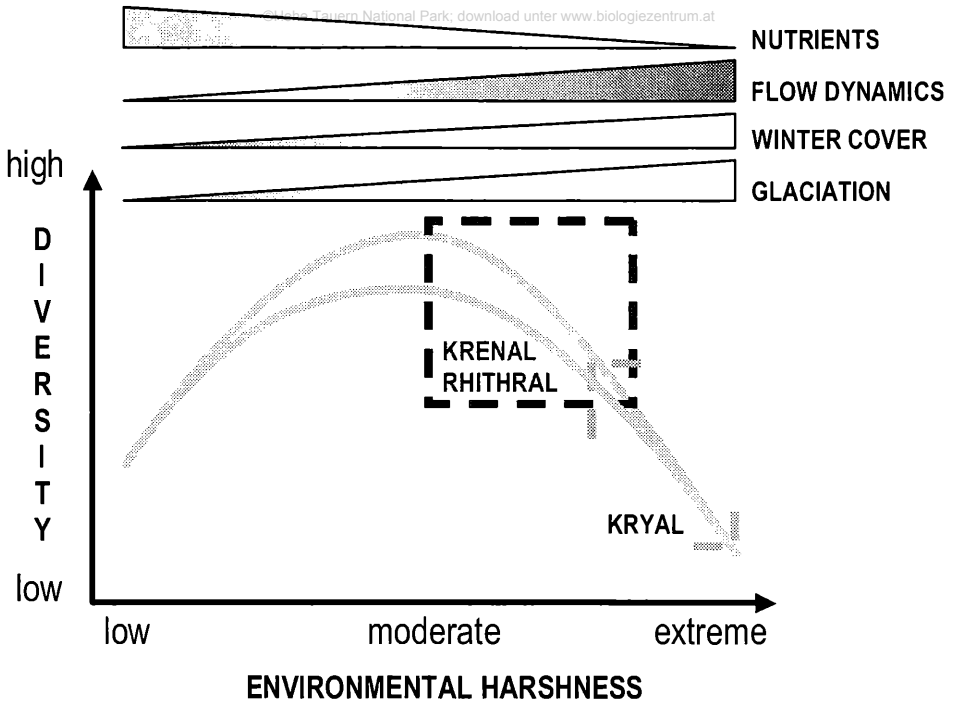

Fig. 2: Scenario of climate change effects on the abiotic factors and consequently on structure and function of aquatic biocenosis (here as diversity) in alpine streams. Alpine streams are situated along the right slope of the curve, where environmental harshness is moderate to extreme, depending on the glacial influence. In glacial streams (KRYAL) the environmental factors, like flow dynamics, temperature, nutrients, are most extreme and therefore only few but highly adapted species can be found. In spring-fed streams (KRENAL) and in snowmelt and rainfall induced systems (RHITHRAL) because of moderate environmental conditions the existence of many species is possible. Only when the environmental harshness is low, freshwaters can get very productive, single species are promoted resulting in lower species numbers but usually with high abundances. Climate change effects would alter the situation: glacial retreat would reduce the glaciation of the catchment, diurnal and annual dynamics of flow would decline. The duration of snow cover is expected to be reduced. As a consequence, the production both in the stream and in the catchment, respectively would increase and consequently favour nutrient and food availability for the aquatic fauna.

Results of our investigations demonstrate how alpine running water systems and their biota can be regarded as catchment-scale integrative monitors for a set of hydrological, thermal and biotic variables variables that might be modified by climate change. Since current climate change scenarios indicate proportionally more detectable impacts at both high altitude and latitudes, alpine running waters can be regarded as research foci in the context of climate change and their communities considered to be as much under change as other biological communities.

Discussion

The herein presented research covers a wide spectrum of themes in stream ecology, ranging from general ecological questions as structural and functional aspects in running water systems (habitat-biota-relationships, food availability and food web structure) to more specific topics, like river typology and the definition of reference conditions. These results provided a substantial basis to approach accurate subjects in ecology, like structure and function of ecosystems, biodiversity, climate change effects and environmental impacts.

Alpine stream ecosystems have been proposed as sensitive indicators of climate change and anthropogenic impacts (McGregor et al. 1995). Albeit scattered information existed from European limnologists early in the last century, only few holistic ecological studies have been carried out on alpine streams. Recently, greater attention has been given alpine streams in response to increased recognition of the important role that these headwater streams play in major river systems throughout the world, and the vulnerability of these streams to local and regional environmental

change (e.g., associated with changes in adjacent land use, acid and nutrient deposition, global climate patterns).

Our accomplished research in alpine streams provides essential knowledge for the assessment of biodiversity in alpine catchments. Besides well known and easily applicable parameters of the aquatic fauna (like taxa number, diversity, abundance) functional relationships (e.g., species traits vs. autochthonous production and/or habitat templates) in alpine stream communities are still poorly understood. Further investigations including field and laboratory experiments should approach these topics. Investigations of the distribution and ecology of Alpine aquatic invertebrates are of major concern when long-term monitoring is planned to elucidate climate change effects and human impacts. Without a profound knowledge in the taxonomy of aquatic invertebrates together with their biological and ecological traits, clear and satisfying results would not be achieved. Continued monitoring efforts would help on building reference collections for comprehensive biological and ecological data of species, the essentials for the quality of indicators of environmental change.

With the existing knowledge gained from our studies in streams and rivers in high altitudes in protected areas in Austria (Hohe Tauern National Park) and Northern Italy (Naturpark Rieserferner-Ahrn) it will be possible to model potential climate change effects and to differentiate anthropogenic effects from climate effects. As introduced herein, future research should encompass both short-term intensive studies and long-term monitoring studies developed within comprehensive experimental arrays of streams and lakes specifically designed to address the issue of anthropogenic versus climatic effects. Especially, in larger protected areas, like the Hohe Tauern Nationalpark, the conditions for these applications can be found, and when research is carried out in correspondence of current national and international research, these topics will meet high scientific value.

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