Alpine Streams: Diverse and Sensitive Ecosystems

Who does not know them – babbling mountain brooks and roaring glacier streams? They are still the quintessence of raw beauty and untouched nature; or are they? Because of the prevailing harsh conditions and their inaccessibility, remarkably little is known about alpine streams and their inhabitants. A comprehensive project conducted at EAWAG has been able to show that alpine streams comprise of a wide variety of habitats. Their resident flora and fauna have numerous ways of adapting to the often extreme conditions, though even the smallest disturbances by anthropogenic impacts or climate change may irrevocably destroy these sensitive ecosystems.

Alpine streams can be found almost anywhere in the world – from the poles to the tropics [1]. They are situated between the tree line and the permanent snow line. In the European Alps, this corresponds approximately to the zone between 2000 and 3500 m a.s.l. Within a very small geographical area, alpine streams can accommodate very different habitats that are usually home to specific species. There are, however, a number of characteristics that are common to all alpine streams [2]:

- They are subject to extreme weather and climate conditions. This generally implies to low water temperatures and high solar radiation.
- The growing season for organisms is extremely short due to long, hard winters and usually restricted to the summer months; for glacial streams, however, optimum conditions prevail during spring and fall, i.e., in the short periods between snow cover and summer snow melt.
- Because of sparse vegetation along their banks, alpine streams receive very little organic material that, in turn, limits the nutrient base for many aquatic animals.
- Alpine regions regularly experience natural disturbances such as floods and landslides.

Quiet Headwaters and Roaring Glacier Streams

We can distinguish between three main types of alpine streams, according to their primary water source: (1) **kryal** streams, otherwise known as glacial streams since they are fed primarily by glacial meltwater; (2) **krenal** streams are spring-fed and, therefore, depend on ground water, while (3) **rhithral** streams are primarily fed by rainfall and snow melt [3]. The origin of the water is an important factor in determining habitat conditions in each of these stream types (Tab. 1).

Glacial melt and snow melt occur during a relatively short period and cause strong seasonal fluctuations in many environmental conditions. The discharge volume of the glacial stream "Ova da Roseg" (Engadin, Switzerland), for example, increases from calm 0.2 m^3/s to roaring 30 m^3/s during the summer melt period. During this time, the otherwise stable streambed is completely reshaped. At the same time, the stream carries so-called glacier milk; the stream is extremely turbid and resembles milk due to high concentrations of suspended solids from the glacier [4]. Rhithral streams are far less affected by seasonal fluctuations and generally experience more moderate environmental conditions. Of the three types of alpine streams, groundwater streams have the most constant and stable conditions, since they receive a steady supply of ground water [5].

Alpine Streams: Diverse Ecosystems

One of our major findings from the current project is that no two alpine streams are alike; heterogeneity is much greater than has been traditionally assumed. The presence or absence of waterfalls, lakes, hydrological connectivity among streams, slope, exposure and many other factors determine the habitat conditions of such systems.

Lake outlets, for example, represent a transition zone between standing and running water ecosystems. The lake outlet habitat

Channel type	Water source	Seasonality	Channel stability	Temperature (°C)	Turbidity
Main channel (M)	kryal	high	low	0–4	high
Lake outlet (O)	kryal	medium-high	low-medium	0–9	high
Side channel (S)	kryal	high-medium	low-medium	0–4	high
Intermittently-connected channel (I)	kryal	high	medium-low	0–5	high-medium
Mixed channel (X)	kryal-krenal	high-medium	medium	0–5	medium
Tributary (T)	kryal-rhithral	low	high	0–8	clear-medium
Groundwater channel (G)	krenal	low	high	3–5	clear

Tab. 1: Channel types within the first 11 kilometers of the Roseg (Engadin, CH) and their main environmental characteristics [2]. See also Figure 1.

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Fig. 1: Different stream types in the Val Roseg: O = lake outlet, M = main channel, G = groundwater channel, S = side channel, I = intermittently-connected channel, X = mixed channel, T = tributary.

is, therefore, significantly influenced by both adjacent ecosystems. In fact, both typical "lake" and typical "stream" organisms are found [6]. Flood plains, on the other hand, contain a number of very different habitats which, depending on discharge conditions, are either connected or isolated. They are subject to constantly changing conditions due to snow- and glacial melt. Our research showed that within the first 11 kilometers of the Roseg stream, we are able to distinguish seven different channel types (Fig. 1 and Tab. 1) [4]. Depending on seasonal discharge conditions, the degree of connectivity between channels varies, and with it the total stream length and origin of the water. While the total channel length is only about 5 km in winter, it expands to more than 20 km during summer. In winter, the network of channels is predominantly fed by ground water and is relatively homogeneous; in summer, however, the main water source is glacial meltwater and the channels are very heterogeneous [4].

Life in Extreme Habitats

How do aquatic organisms in these very diverse stream types deal with small-scale differences in habitat characteristics and extreme environmental conditions? As early as the beginning of the 20th Century, Steinmann [7] noted: *"The mountain stream offers its inhabitants an environment of such distinct character that this has to be reflected in the way these organisms live."* In addition to the stream fauna, algae and higher plants have developed a wide range of adaptations to the distinct environmental conditions characteristic of alpine streams. The majority of organisms in alpine streams are benthic, i.e., closely associated with the substrate. This improves their chance for survival during frequent, high-flow velocities. Other adaptations to fast-moving water include the strong claws of some stonefly larvae (Plecoptera), the flattened body shape of many mayfly larvae (Ephemeroptera), the ventral suction cups of the blephariceridlarvae *(Liponeura)* (Fig. 2), life in self-made cases constructed from a range of materials, such as stones (caddisfly larvae, Trichoptera), or the formation of gelatinous crusts of many algae. Characteristic diatoms and insect families typically dominate algae and invertebrate communities found in alpine streams. Organisms in kryal streams experience particularly extreme habitat conditions and fluctuations resulting in communities that are very similar worldwide (cosmopolitan), but are restricted to a relatively short longitudinal zone of the stream (stenozonal). In contrast, inhabitants of rhithral streams are rather moderately cosmopolitan, but are distributed over longer sections of the stream (euryzonal) [3]. Due to their extreme environment, kryal streams typically harbor biotic communities that are rather species poor

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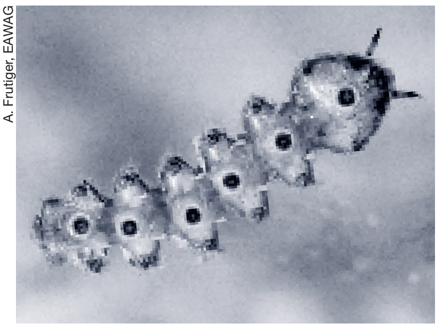

Fig. 2: The ventral suction cups of the blephariceridlarvae *Liponeura* allow survival in fast moving water.

compared to communities in rhithral and krenal streams (Fig. 3).

The effect of upstream lakes varies with the source of the water: more species were found in kryal lake outlets than in kryal streams, but fewer were found in rhithral lake outlets than in rhithral streams. The individual stream types differ not only in the number of species, but also in the community composition and in the dominance of different taxa. Kryal and rhithral streams are mostly colonized by insects, while we also find many non-insect species such as oligochaets and benthic crustaceans such as copepods and ostracods in the more stable and homogenous spring-fed streams and rhithral lake outlets (Fig. 3).

Alpine Streams: Sensitive Ecosystems

How do alpine streams respond to anthropogenic impacts and changes in climate? Some effects of anthropogenic disturbances are quite obvious: water diversions may result in the drying up of entire streams, dams change the discharge regime (see also article by A. Wüest on p. 18 and M.Fette on p. 21), and flood protection structures force mountain streams into solid, impermeable stream beds. The effects of climatic change, on the other hand, are more difficult to predict. Scientists predict a general increase in temperature as well as changes in precipitation patterns: it appears likely that there will be more precipitation during the winter months, while summer months could become drier (see article by B. Schädler on p. 24). All around the world, glaciers have continually retreated over the last 150 years (Fig. 4) and extreme prognosis predict that glaciers may completely disappear from the Engadin within the next 50 years [8].

What does this mean for alpine stream organisms? Retreat and disappearance of glaciers entail the loss of a unique habitat – the discharge regime shifts from a pattern dominated by glacial melt and snow melt to one that is shaped by rainfall and snow melt, extreme habitats disappear and habitat conditions become more homogeneous. This gives exotic species and organisms that occupy habitats further downstream the opportunity to colonize these previously unattractive locations and to displace the original species. Specific indicator organisms and glacial species will disappear since there are no higher and colder areas to which they may retreat.

Ecological Stream Management – a Contradiction in Terms?

It is obvious that the sustainable management of alpine streams is only possible if we understand the interactions between environmental conditions and biota. We, therefore, need to press on with basic research in order to better characterize these ecosystems. At the same time, we need to investigate more applied aspects. EAWAG is analyzing questions like these: how much in-stream flow is needed below dams in order to preserve near-natural conditions [9]? Is it feasible to preserve natural communities in such stream sections by artificially inducing flood events [10]? What form does the revitalization of a corrected section of a stream have to take in order to allow a natural biotic community to become re-established (see article by M. Fette on p. 21)? These and similar projects give us some hope that our alpine streams will be as enthralling in the future as they are now.

Mäggi Hieber, biologist, has recently completed her thesis on alpine streams, with an emphasis on the ecology of alpine lake outlets, in the Limnology department at EAWAG. Since then she is project leader at the Center for Applied Ecology Schattweid.

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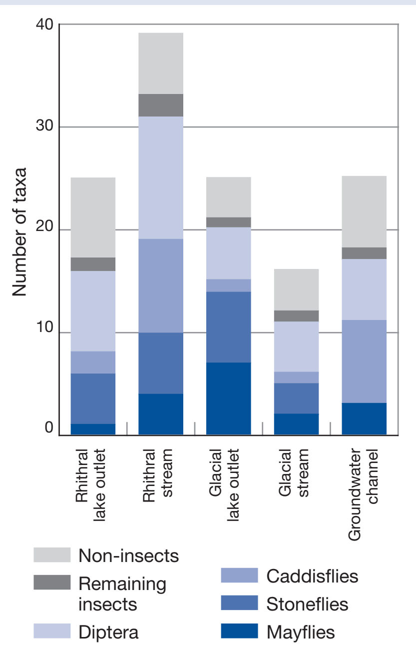

Fig. 3: The composition of invertebrate communities in different alpine stream types.

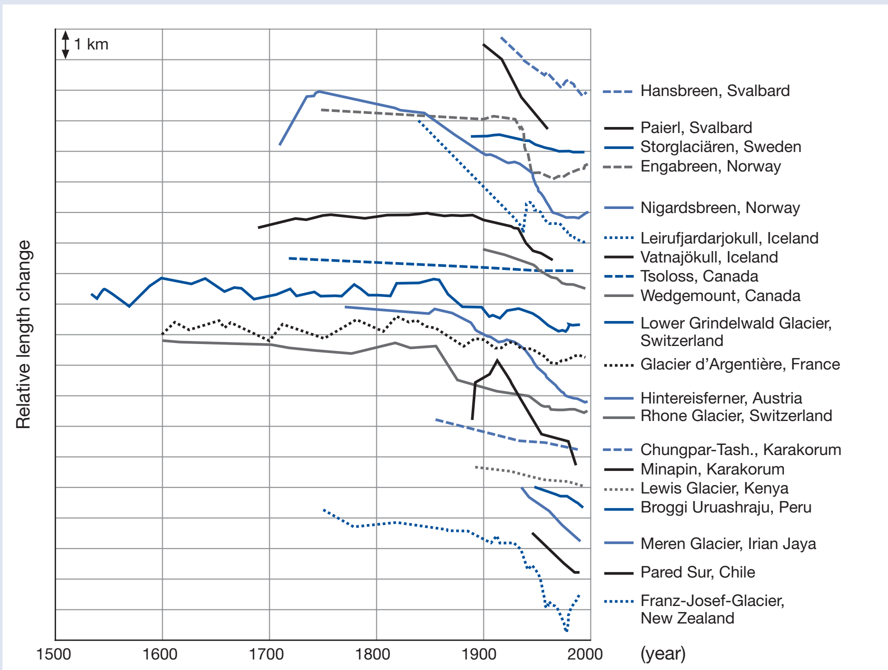

Fig. 4: Retreat of glaciers over the last 500 years. Adapted from [8]. 1 unit = 1 km.