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Micro- and meiobiota patterns in glacier driven stream habitats

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Abstract

Glacier-fed rivers are among the most sensitive and endangered habitat types nowadays. Their upper reaches are located within areas of economic interest (e.g. skiing and glacier skiing, hydropower generation), but also within protected areas such as, for example, National Parks worldwide (e.g. Hohe Tauern, Pyrenees, Rocky Mountains). The majority of glacial river studies has focused on the macrozoobenthos. Thus, this study presents a comparison of the widely neglected stream micro- and meiobenthos (MMB) among different glacial-fed stream reaches driven by two different glacier catchments: the Möll River Catchment (MC) and the Kleinelendbach stream catchment (KC). The catchments differ in catchment and glacier area, and glacier retreat patterns. The stream reaches comprised different habitat types such as the glacier source and extreme harsh glacial stream main channels, but also benign, less glacier influenced side channels. Their ages (years since deglacierization) ranged from 0 to ~ 150 years. They were within the protected area of the Hohe Tauern National Park.

The regional diversity of the MMB (taxa numbers of fungi, algae, protists, nematodes, rotifers, invertebrates) was generally high in both catchments (MC: 270; KC: 291). The local (stream reach) diversity was also relatively high, but taxa numbers varied considerably between reaches and ranged from 64 – 195. Highest taxa numbers were recorded for benign stream habitats of the KC (195) and the MC (172). The latter was within the Sandur area downstream the margin of the Pasterze glacier. The benign sites represented not only local hot spots of diversity but also hot spots of ecological functionality with regard to the broad spectrum of abundant organisms, comprising primary producers (autotrophic flagellates, cyanobacteria, diatoms and other algae), decomposers (bacteria, fungi) and diverse consumers (heterotrophic flagellates, protists, nematodes, rotifers, copepods, tardigrades). ANOSIM resemblance analysis revealed similarity of fungi, protists and rotifers, and dissimilarity of bacteria, flagellates, diatoms and nematodes between the different stream reaches.

The perspectives of ongoing glacier retreat and expected alterations of glacial-fed rivers may have various consequences for the MMB: thermal and hydrological changes along main river channels will represent adaptive challenges to these organisms, whereas drying of side arms and surrounding wetlands will lead to regional extinctions. The latter would represent an enormous loss of diversity that may affect ecological processes and services of alpine areas. But actual habitat changes and their effects on biodiversity as well as on ecological processes and services of alpine glacier catchments clearly need further investigations.

Keywords

glacier retreat, glacial river, bacteria, fungi, algae, nematodes, rotifers, local diversity, regional diversity

Introduction

Several industries (i.e. ski and hiking tourisms, power generation) have regionally overexploited high alpine zones leading to their fragmentation, degradation and deterioration. But with increasing loss of intact alpine areas, awareness of their sensitivity and the need to preserve their ecological intactness has grown and protected alpine areas have been established world-wide. This protection is particularly of importance for glaciers and their forefields, because they represent unique, highly sensitive and intricately interwoven complex of icy, aquatic and terrestrial alpine habitats (McGregor et al. 1995). Several national parks worldwide comprise glacier catchments (e.g. Alps, Rocky Mountains; Pyrenees). Besides those negative affects above-mentioned, these peculiar habitats are affected by climate change. Climate change has been causing majorly (often rapid) retreat of glaciers (WGMS 2008), which are basically highly different in their characters (Cuffey & Paterson 2010). These differences, in turn, are responsible for differences and differently influenced changes of the hydrological and thermal regimes of glacier streams and rivers (Milner et al. 2009). All these changes are of influence on human water usage on the long run (IPCC 2007).

The final drastic consequence of complete glacier loss would be the loss of typically glacier-fed riverine habitats. These habitats are not only fed by surficial glacier meltwaters, but also by their subsurface storage (Malard 2003). Because macroinvertebrates have been the sole focus in glacier stream research, consequences of habitat alterations have majorly been discussed for them (Brown et al. 2010; Finn et al. 2010; Muhlfeld et. al. 2011). They generally represent less dense and diverse inhabitants of glacier-fed streams and rivers with species and individual numbers even distinctly decreasing river upstream towards glacier sources (MILNER et al. 2001; ILG & CASTELLA 2006; FUEREDER 2007).

Though widely neglected in glacier river research, benthic meioinvertebrates, and in particular nematodes among them, contribute to biological complexity in glacier-fed river habitats, where they occurred in relatively high densities and numbers of species (EISENDLE 2008). In general, benthic invertebrates of any size are important to ecosystem processes and services (PRATHER et al. 2012) - similarly as bacteria, algae and fungi. But despite the particular importance of the small groups (fungi, algae, bacteria and meiofauna), partly due to high turnover rates (short generations times), they are still the least studied organisms in glacier rivers. As a consequence, their alterations in response to changes of hydrological and thermal regimes are difficult to estimate and, moreover, far reaching effects of potential alterations for other organisms but also for the water quality of glacial rivers can hardly be assessed to date.

Ongoing retreat of alpine glaciers and expected changing river habitat conditions together with the awareness for a relatively unknown small biota, represent the background for this study. Its intention was to reveal potential differences of bacteria, fungi, diatoms, other algae, protists and meiofauna communities between different riverine habitats, whose conditions were hypothesized to be differently shaped among and between two catchments due to the different basic characters of these catchments.

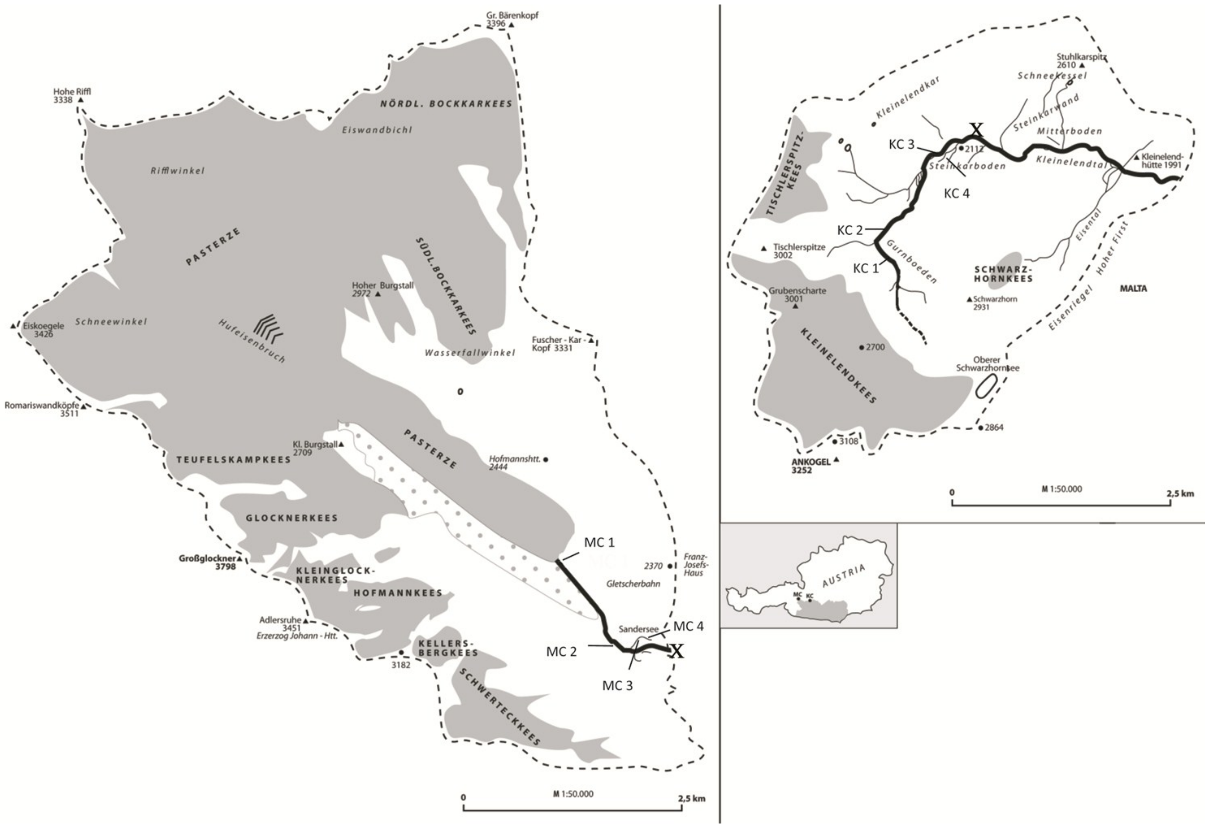

Figure 1: The two study sites situated within the Hohe Tauern National Park. MC = Möll River catchment and KC = Kleinelendbach stream catchment. MC1-4 and KC1-4 indicates the river reaches investigated therein.

Material and Methods

The two glacier catchments were situated in the Hohe Tauern National Park: the Möll river catchment (47°04'N12°45'E) and the Kleinelendbach stream catchment (47°04'N 13°15'E; Fig. 1). The former (MC) belongs to the Großglockner region and originates at the Pasterze glacier; the Kleinelendbachstream catchment (KC) belongs to the Ankogel region and originates at the Kleinelendkees. They differ in catchment and glacier area, and in their deglacierzation activity given the retreat patterns during the last decades and during the study period (Tab. 1). We sampled main stream reaches and side channels by corer sampling before during and after the glacier melt period in 2010. From these corer samples we analysed abundance patterns of bacteria, nano-flagellates, fungi (CFU counts), algae, protists, and small invertebrates (nematodes, rotifers, copepods, tardigrades and insects) as well as morphotypes of bacteria and nanoflagellates, genera of algae and protists, and species of fungi, nematodes and rotifers. In addition, five to ten stones were taken (except at MC3 and MC4, where we took small amounts of glacier silt) at each sampling occasion in order to obtain the number of diatom species.

We tested for significant differences of resemblance patterns between the reaches for each group (microbiota, algae, protists, fungi CFU, diatoms, nematodes, rotifers) by means of ANOSIM analysis (square root transformed or presence/absence data, Bray-Curtis similarity matrix).

Table 1: Characteristics of the two catchments situated in the Hohe Tauern National Park (MC = Möll River catchment, KC = Kleinelendbach stream catchment). * Summary of OEAV Gletscherberichte 1998-2010.

	MC	KC
Geographic coordinates (N/E)	47°04'/12°44'	47°04'/13°16'
Catchment area (km²)	36	12
Number of glaciers	9	2
Glacier area (km²)	22	3
Percentage glacierization	61	25
Main glacier	Pasterze glacier	Kleinelendkees glacier
Retreat 2010 (m)	40	2,7
Retreat since 1998 (m)*	403 (debris free tongue)	26

Results

The regional number of taxa was high: 271 and 290 in the MC and the KC, respectively. The local (river reach) taxa numbers ranged from 64 (MC2) – 195 (KC 4). Beside KC4 high taxa numbers were observed at MC3 (172) and MC 4 (166). Nematodes and rotifers dominated the invertebrates with percentage maxima ranging from 66% to 94%. High rotifer portions appeared at the Möll River glacier source (MC1: 94%) and the MC proglacial (MC2: 88%) and the oldest KC main channel reach (KC3: 80%), which is accompanied by glacier cliff remnants. Nematodes dominated particularly the benign reaches of the Sandur area (MC3: 51%, and MC4: 66%). Each nematode feeding type, according to Yeates et al. (1993), occurred at each reach. Copepods were present with higher portions only at KC4 (18%) and tardigrades only at MC3 (22%) and MC4 (33%). Chironomids and other insects such as stoneflies, mayflies and caddiesflies were rarely observed (≤ 1%).

Table 2: Ranges of bacteria and nanoflagellates (n=4; ind/cm²/ml), fungal CFU counts (n=5; ind/cm²), algae and protists (n=2-3; Ind/cm²) nematodes and rotifers (n=5; Ind/cm²/ml) at each reach summed for the study period. WT indicates the range of water temperatures measured at these sites during the study.

	Bacteria	Nanoflagellates	Algae	CFU - Fungi	Protists	Nematodes	Rotifers	WT
KC1	4.9E+05 - 1.1E+08	0.0E+00 - 7.1E+04	0 - 9.2E+04	0 - 347	0 - 102	0 - 1144	24 - 1060	7 - 9
KC2	3.4E+06 - 1.5E+08	1.4E+04 - 2.0E+05	3.8E+01 - 2.5E+04	0 - 80	0 - 1966	3 - 725	42 - 741	4 - 9
KC3	2.2E+06 - 1.1E+08	1.0E+04 - 8.5E+04	2.0E+01 - 1.2E+06	2 - 433	0 - 244	0 - 76	9 - 405	5 - 8
KC4	3.9E+07 - 8.6E+08	1.3E+05 - 1.0E+06	7.3E+03 - 4.3E+05	2 - 347	50 - 5184	46 - 3730	522 - 8712	8 - 12
MC1	3.9E+06 - 7.2E+07	1.9E+04 - 2.4E+05	6.1E+03 - 1.6E+05	9 - 249	0 - 390	1 - 11	9 - 202	0.3 - 0.5
MC2	9.4E+06 - 1.0E+08	3.2E+03 - 4.6E+05	0.0E+00 - 1.2E+03	1 - 218	0 - 113	3 - 27	15 - 264	0.6 – 1.4
MC3	5.0E+07 - 4.2E+08	3.4E+04 - 1.3E+06	4.7E+03 - 6.9E+06	4 - 110	0 - 25	53 - 4944	14 - 1858	9 - 15
MC4	1.8E+08 - 7.2E+08	1.9E+05 - 9.6E+05	0.0E+00 - 9.0E+05	4 - 839	0 - 41	397 - 4768	13 - 878	6 - 15

The abundance ranges of bacteria, nano-flagellates, algae, protists, fungi and invertebrates are shown in Table 2. The bacteria highest maxima were observed at the benign reaches (KC4 and MC4), the lowest at the uppermost reach of the Kleinelendbachstream (KC1). Highest nano-flagellate maxima appeared at MC3 and KC4, low values were observed not only at MC2, the instable proglacial of the Möll river site. The R-values of the ANOSIM analysis reveals that the resemblance patterns of most groups were significantly different between the reaches; only fungi, protists and rotifers were not significantly different between the reaches (Table 3).

Table 3: Results of the one-way ANOSIM analysis of respective groups based on Bray-Curtis resemblance matrices from square root transformed data (except diatoms - for which presence/absence data were used).

	Microbiota	Algae	Diatoms	Protists	Fungi	Nematodes	Rotifers	Invertebrates
R	0,49	0,54	0,47	0,25	0,05	0,66	0,17	0,65
p %	0,1	0,1	0,1	0,1	0,5	0,1	0,1	0,1
N ≥ 0	0	0	0	0	4	0	0	0

Discussion

The basic results of this study do not only show that the micro- and meiobenthos (MMB) have been wrongly neglected in glacier river research so far (see Milner et al. 2009), but also that protected areas are invaluable, undisturbed and suitable habitats for basic and highly timely research questions. This study reveals that the MMB contribute enormously to community complexity in glacier-fed river systems due to their high abundances and numbers of species. According to this, the micro-and meiobenthos can be assumed of major importance for glacier-fed rivers and their functioning. They consequently play a role in ecosystem services in glacier catchments. By comparisons of similarly aged habitat complexes (KC1 with MC2, or KC3 with KC4), we conclude that not stream age (year since the glacier retreat set free new habitats) but habitat conditions are the major determinants for the complexity of the benthic community.

Only certain groups (bacteria, fungi, the smaller nanoflagellates, diatoms, nematodes, tardigrades and bdelloid rotifers) contribute to the early coloniser communities, which might have specific, but so far unknown functions in glacier-fed streams. In general, the differences in the ANOSIM results indicate that habitat effects vary across the MMB groups. The similarity of the fungal patterns between the reaches, for example, might indicate the dominance of terrestrial effects over within-stream effects.

Hot spots of diversity (high species numbers) were found at the benign sites of the Möll and the Kleinelend catchments. Combined with high bacteria, flagellate, nematode and, partly high, CFU abundances, we consider these sites extremely active with regard to high nutrient assimilation and recycling, and thus, as highly functional sites involved in important ecosystem processes and services of alpine water reservoirs. The copepods and macroinvertebrates seem to be of little importance at such hot spots due to their minor abundances.

Retention, buffer and detoxification capacity of a complex small benthic biota with regard to pollutants derived from both short and long distance transports and short and long term storage (Bizzotto et al. 2009) could be considered, but should definitely be the focus of future studies. National parks provide invaluable habitats at least undisturbed from direct anthropogenic modifications, which might allow sensitive alpine riverine biota to adapt to and mitigate changing climate conditions. Furthermore, the undisturbed and morphological non-degraded river networks in protected alpine areas provide optimal conditions to study the consequences of climates changes and the risk involved for alpine water reservoirs and should therefore be used more often in this context as riverine "outdoor laboratories".

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