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Studies on arctic and alpine streams in Europe with special emphasis on glacial rivers in Iceland

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Abstract

The characteristics of stream and river ecosystems in arctic and alpine areas are deteremined mainly by the relative contribution of glacial meltwater, snowmelt, rainfall and groundwater. Each source generates a particular seasonal hydrological signature, affecting physical and chemical properties, and hence biological communities. The relative contribution of each source is sensitive to climate change. An European project, Arctic and Alpine Stream Ecosystem Research (AASER), is investigating the primary physical and chemical varialble determining the distribution of macroinvertebrates in glacial catchments and along a latitudinal and climatic gradient encompassing sites in the Pyrenees, the Alps, Iceland, Norway and Spitzbergen. The Icelandic contribution to the project was concentrated at the glacial river W-Jökulsá and its tributaries in the northwestern highlands of Iceland. The water in the glacial river was pure glacial meltwater at the glacial snout, but glacial contribution was about 20% 40 km downstream. However, its tributaries were mainly springfed. The invertebrate fauna was confined to chironomid midges of the genus *Diamesa* close to the glacier, but other species and groups occupied the river further downstream, approaching the diversity found in the tribuataries.

Keywords: Glacial river, spring-fed rivers, suspended material, water chemistry, benthic communities, species diversity

Introduction

An international project financed by the European Union, "Arctic and Alpine Stream Ecosystem Research (AASER)", is now investigating the primary physical and chemical variables determining the distribution of macroinvertebrates in glacial catchments along a latitudinal and climatic gradient across Europe (BRITTAIN et al. 1998). This is the first time an attempt has been made to undertake a co-ordinated study of such a wide variety of glacial stream ecosystems. The AASER project started in 1996 and will run until 1999. It is a co-operative effort between several institutions: the University of Oslo, Norway, the University of Birmingham, U.K., the University of Geneva, Switzerland, the University of Iceland, Reykjavik, the Trento Museum of Natural Sciences in Italy and the National Energy Authority of Iceland. The project is co-ordinated by the University of Oslo.

The study sites have been selected to represent a gradient in both latitude from 43°N in the Pyrenees to 79°N on the arctic archipelago of Svalbard, and in degree of continentality from the oceanic climates of Iceland and Western Norway to the continental climates of the Alps and Eastern Norway. The study areas also represent the types of glacial situation present in Europe at present: retreating, advancing and "stable". The glacier at the Icelandic site retreated from the turn of this century to 1970, but has been stable since. These characteristics will strongly influence conditions in the rivers fed by these glaciers.

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Studies on arctic and alpine streams in Europe with special emphasis on glacial rivers in Iceland

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In this paper we will deal with the glacial river W-Jökulsá in N-Iceland and non-glacial rivers and streams in the same area, comparing the faunal composition of the two systems and the influence of glacial water on the stream fauna. Understanding the faunal composition of glacial rivers Iceland is important, since approximately 36% of all run-off water in Iceland is of glacial origin (ADALSTEINSSON et al. 1999).

The aim of the AASER project is to test the conceptual model by MILNER &PETTS (1994) on downstream zonation of macroinvertebrates in glacial rivers from sides across Europe that differ widely in their characteristics. That will improve the validity of the conceptual model over a wide range of arctic and alpine stream ecosystems. This paper is a contribution towards the understanding of such ecosystems by comparing communities of a glacial river with non-glacial reference rivers in the same area. By doing so, we will test the function of channel stability and water temperature and look into the effects of suspended solids on macroinvertebrate communities in the glacial river.

Methods

The river W-Jökulsá was chosen as a reference glacial river in Iceland. It emerges from the north-western part of the glacier Hofsjökull in three main branches (Fig. 1). In the eastern branch 5 sampling stations were situated from the glacier snout at 860 m a.s.l. until it joins the other brances 22 km downstream from the glacier at 630 m a.s.l. The middle branch was sampled 3.5 km from the glacier and the western branch was sampled 3.5 km from the glacier and 22 km from the glacier, just above the confluence of the branches. In the river, after the branches had joined together, a sampling station was 22.5 km from the glacier (630 m a.s.l.), 42 km (190 m a.s.l.) (Fig. 2). At each station pH, conductivity and temperature were measured and samples taken for analyses of suspended sediment, FPOM, nutrients (PO_4^{-},NO_3^{-}, NO_2^{-}, NH_4^{+}, Total N) and major ions (HCO_3^{-}, Cl^{-}, SiO_2, SO_4^{-}, Mg^{++}, Ca^{++}, Fe^{+++}). Discharge was measured upon each visit. In additon, during each sampling period, measurements of pH, conductivity and discharge was repeated during lowest and highest discharge in the eastern branch 4.5 km downstream from the glacier (200 m a.s.l.) and 45 km downstreams from the glacier.

Estimates of the origin of water is based on mass balance calculations of discharge at different stations, i.e. increase in discharge in a lower sampling station compared with an upper station and changes occurring in specific conductance (increase downstream compared with glacial water).

We have followed the protocol developed within the European Commission project Arctic and Alpine Stream Ecosystem Research (AASER) (GÍSLASON et al. 1998) in all sampling.

Macroinvertebrates were sampled three times a year in the lowland stations (June, July and September/October), but twice (July and September/October) in the highlands. At each sampling site, a 15 m stretch was selected. It was divided into a 33x33 cm grid with one axis along the bank and the other across to the far bank or to 60 cm water depth. From these grids 10 sampling units were randomly selected. From each sampling unit, a stone was removed while holding a net of mesh size 250 µm below. The stones were brushed in water to remove the invertebrates and the water

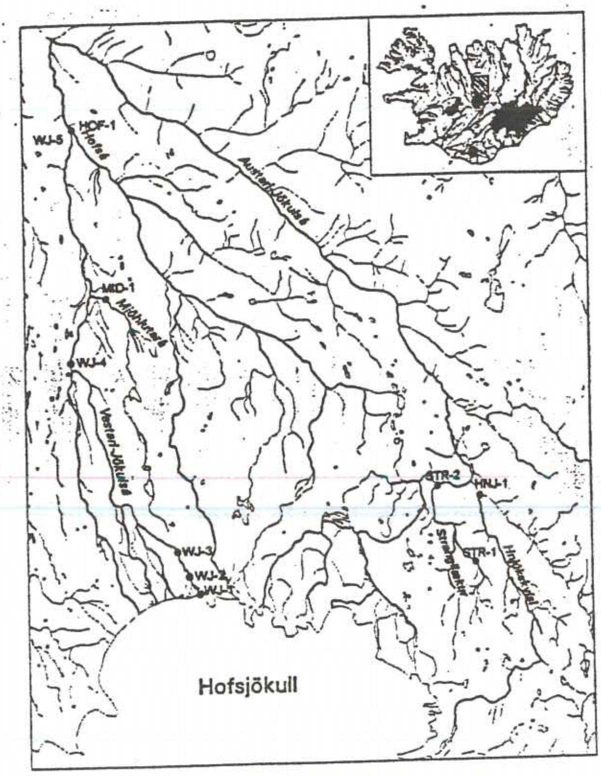

Fig. 1. W-Jökulsá and tributaries showing sampling sites and catchment areas above each sampling site.

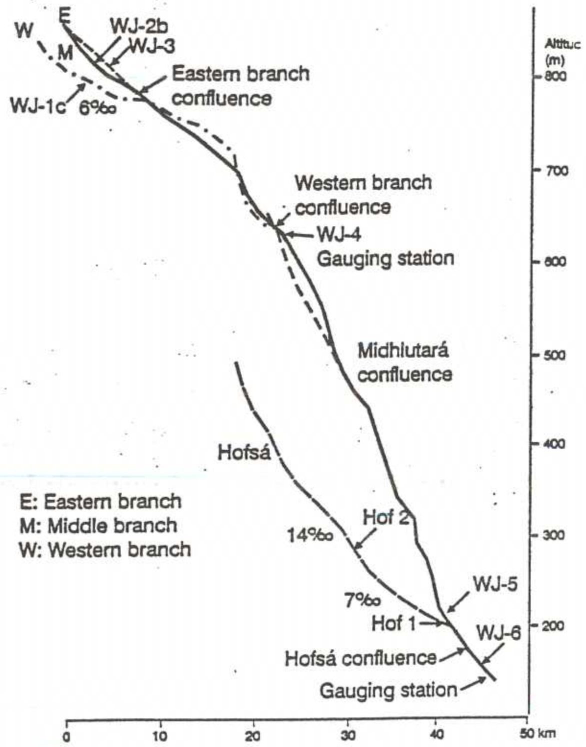

Fig. 2. Profile of the River W-Jökulsá and its tributaries.

was then sieved (mesh size 250 µm) and the invertebrates preserved in 70% alcohol. Each stone was placed on a grid paper and its outlines drawn to estimate the area the stone covered. This area was used to estimate marcroinvertebrate density. Benthic invertebrates were identified under stereo-microscopes, with up to 250 times magnification.

Results

The river W-Jökulsá originates from the northern part of the Hofsjökull ice cap (Fig. 1). The glacier watershed is 90 km^2 out of 820 km^2 at the lowest gauging station in the lowland valley, 50 km away from the glacier and 5 km above the confluence with the main river. The annual average discharge is 21.4 m^3/s for 1971-1997 (HYDROLOGICAL SURVEY). It runs steeply from the glacier to the lowlands, mostly with 5-10‰ in the upper and middle reaches and in the lowland valley (below 200 m a.s.l.), but in slope from the central highlands to the lowland, the slope is about 20‰ (fig. 2).

The glacial river originates from a 7.5 km long stretch of the northern margin of Hofsjökull glacier, in mainly three branches. A hyaloclastite mountain ridge separates the eastern branch from the others. A fissure zone, assumed to be connected with a central volcano, a caldera, below the glacier (SIGURDSSON 1990, BJÖRNSSON 1988), cuts through the area. According to SIGURDSSON (1990), carbon dioxide is conspicuously high in the groundwater connected with the fissure zone and in our

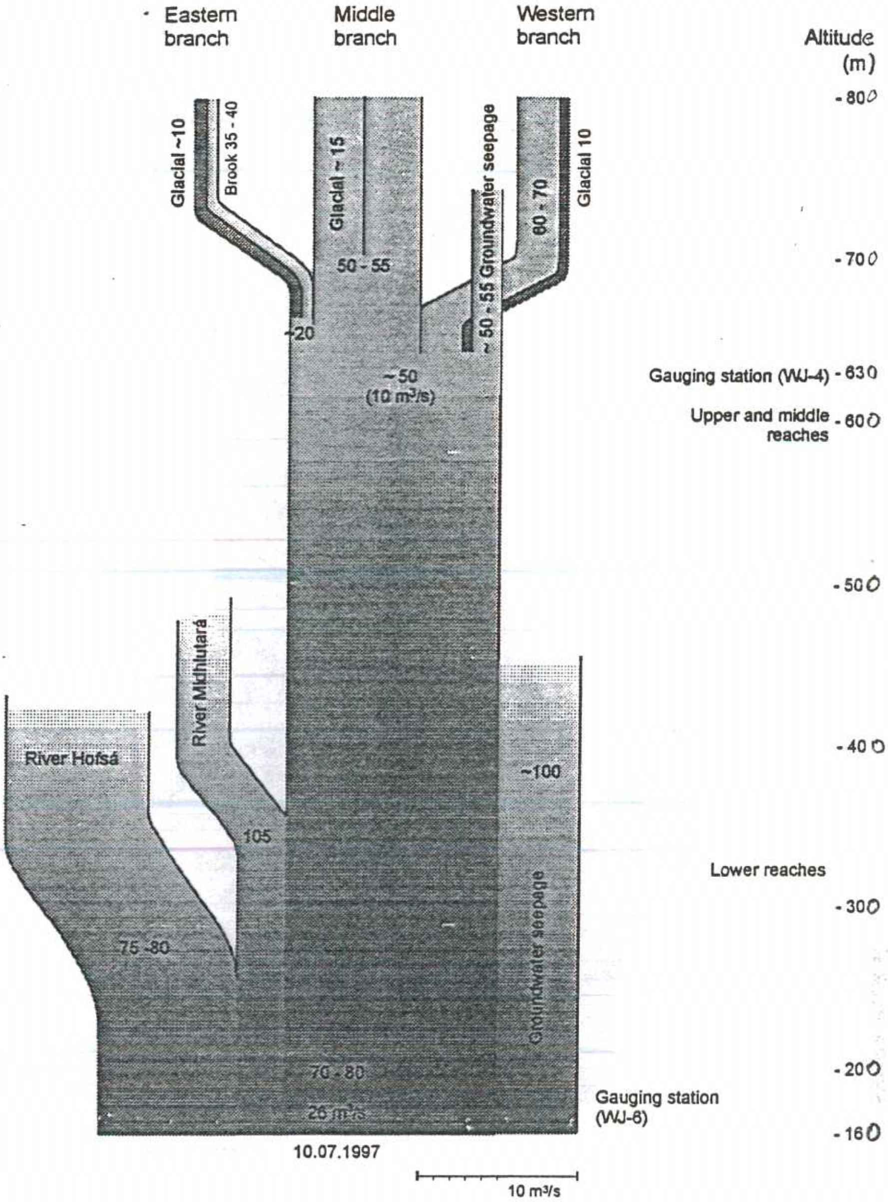

Fig. 3. Estimates of the origin of water in W- Jökulsá in the upper, middle and lower reaches of the river in July 1997. The width of the channels reflect the discharge. The numbers refer to the specific conductance (μS/cm at 25°C).

study this was seen in an increasing mineral concentration from the eastern branch to the middle and western branches. The mineral content, as deduced by the conductivity of water, indicated that the middle branch (WJ-2b) is fed by meltwater originating directly or interfering with the assumed volcanic area, as its mineral content was already high (> 50 μS/cm) in July, while the other branches (WJ-3 and WJ-1c) had as low conductivity as 10 μS/cm (figs. 3-4). In July WJ-1c was dominated by clear meltwater, but later in the season (September 1997) all branches were glacial. Then the eastern branch kept its low mineral content while the others had high mineral content (> 40 μS/cm), indicating that the glacial meltwater had interfered with the volcanic area. Because of the assumed interference with the upwelling carbon dioxide, the glacial meltwater in the middle and western branches do not fit to the supposed model of mineral content and it is difficult to trace the glacial and snowmelt influence of the runoff, unless in the eastern branch. Thus the estimated glacial influence are to a great extent based on direct discharge measurements and mass

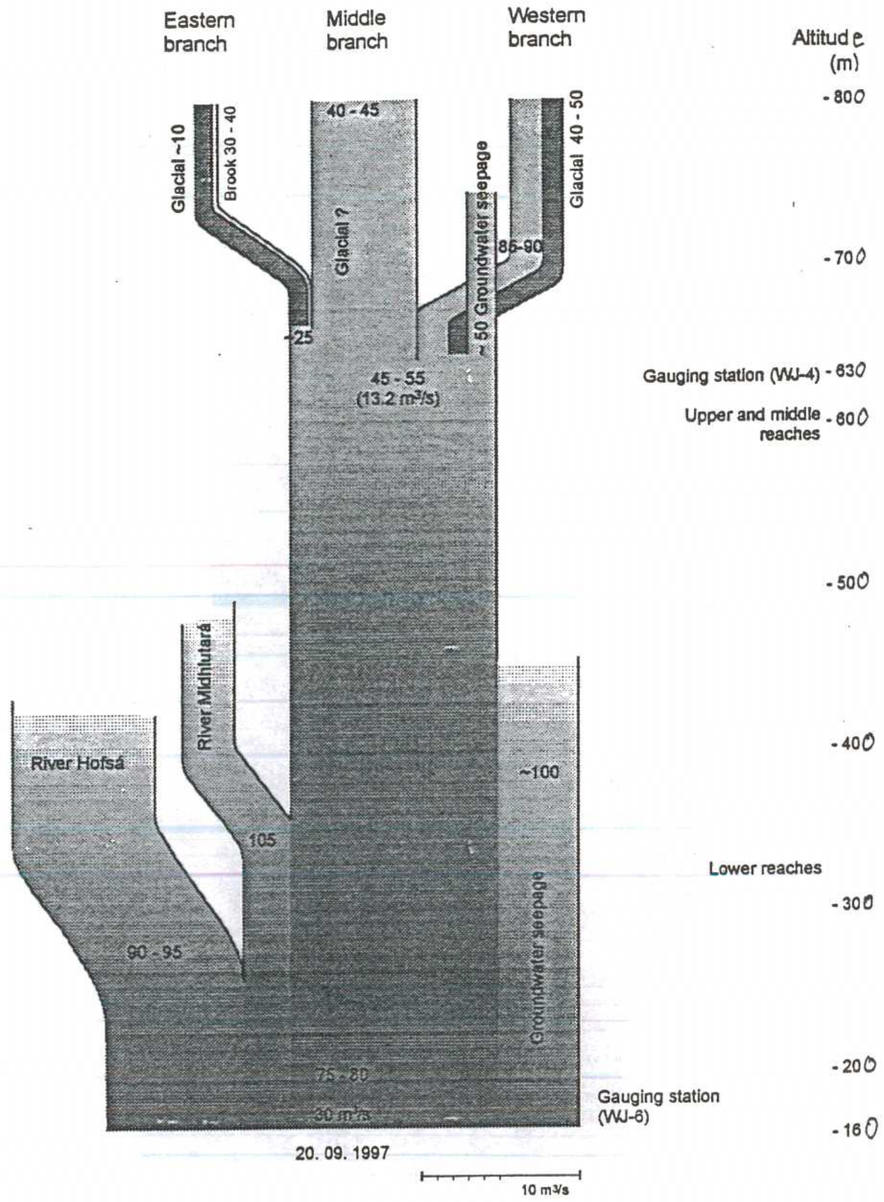

Fig. 4. Estimates of the origin of water in W- Jökulsa in the upper, middle and lower reaches of the river in September 1997. The width of the channels reflect the discharge. The numbers refer to the specific conductance (µS/cm at 25°C).

balance calculations. In the middle reaches all glacial tributaries are gathered at the gauging station WJ-4. Mass balance calculations indicate that the groundwater inflow is rather high in mineral content. In September it was estimated at ca. 100 µS/cm, but considerably lower in July, presumable due to meltwater influence. In the lower reaches where glacial influence was rather low, especially in the late season, the conductivity was 90-100 µS/cm.

In mid winter the W-Jökulsá is mainly spring-fed. At the upper gauging station (WJ-4) the discharge decreases to less than 1 m^3/s while the discharge at the lower gauging station is usually around 10 m^3/s. At that discharge total dissolved solids (TDS) commonly varies between 65 and 80 mg/l which corresponds 90-120 µS/cm (ADALSTEINSSON et al. 1999), or similar to that estimated as the groundwater component late in the summer season.

Physical and chemical parameters changed downstream in the glacial river (fig. 5). Maximum temperature increased downstream, from the permanent 0°C at the glacier snout to approximately 18°C 4.5 km downstream. Ion concentration increased, as shown with the specific conductance, pH increased, from approximately 6.7 to 7.9, suspended solids increased to above 1200 mg/l at 22,5 km downsream from the glacier, where all the branches have joined, chlorophyll increased downstream, from almost 0 to 1.85 µg/9 cm^2. This is in association with decreasing proportion of glacial melt water, that was approximately 50% at the glacier snout and only 20% 42 km downstream, when tributaries and ground water had entered the river (ADALSTEINSSON et al. 1999).

In the reference streams no such regular changes were observed. Specific conductance and pH were higher in all the rivers (pH 7.5-8.7, specific conductance 56-116µS/cm at 25°C). Chlorophyll was low as in the glacial rivers 0.08-1.15 µg/9 cm^2. Maximum tempreatures were similar to the maximum temperatures in glacial rivers, but continuous recording showed that the average temperatures were higher in the reference streams (ÓLAFSSON et al. 1999) and little suspended material was found.

Chironomid larvae of the genus *Diamesa* (fig. 6) dominated the benthic invertebrate communities in the glacial river W-Jökulsá and in the non-glacial reference rivers. No invertebrates were found at the glacial snout, but at 1.4 km downstream from the glacier, densities of *Diamesa* and total invertebrates reached densities that were similar to the densities of these groups at all sampling stations downstream. Number of species and groups increased downstream, with *Orthocladius frigidus* appearing 4.5 km from the glacier snout and Simuliidae appearing 22.5 km downstream from the glacier (fig. 7).

The chironomids *Thienemanniella* sp., *Micropsectra atrofasciata* and the Hydracarina of the family Hydrachnellidae were found 42 km from the glacier. Invertebrate densities were approximately one order of magnitude higher in the non-glacial reference rivers than in the glacial river, except for *Diamesa* spp. and for all species or groups at the lowland stations 42-43 km below the glacier (approximately 200 m a.s.l.).

Discussion

In the conceptual model of MILNER & PETTS (1994) maximum temperature and channel stability are the determing parameters of species occurrence and their density. Though maximum summer temperatures in the glacial and reference rivers did not alter, OLAFSSON et al. (1999) found considerable difference in degree-days for the glacial river and the reference streams. We found that *Diamesa* species are widely distributed in temperatures above 2°C, up to 18°C and so are other groups, like Orthocladiinae and Simuliidae contrary to the conceptual model (MILNER & PETTS 1994). The algae feeding Trichoptera, *Apatania zonella*, and *Thienemanniella* sp. were only found furthest away from the glacier, but were found in all of the sampling stations of the reference rivers. That indicates that maximum temperature is not the determining factor, but average temperatures or degree-days could play an important role (OLAFSSON et al. 1999).

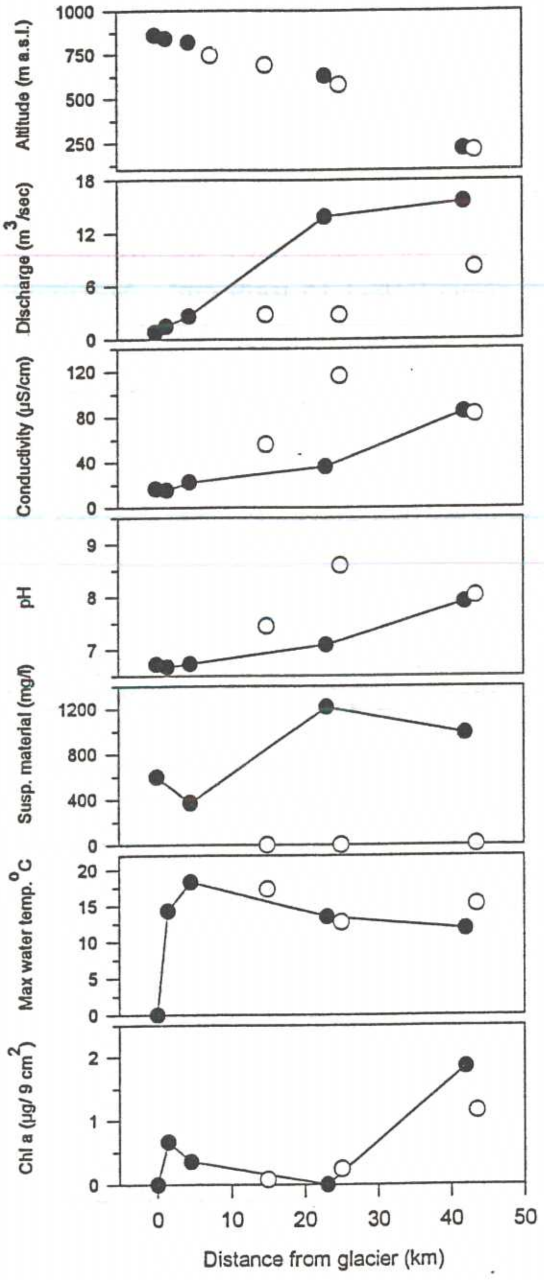

Fig. 5. Physical and chemical data from stations in the glacial river W-Jökulsá and the reference rivers. Filled circles: W-Jökulsá; open circles: reference rivers.

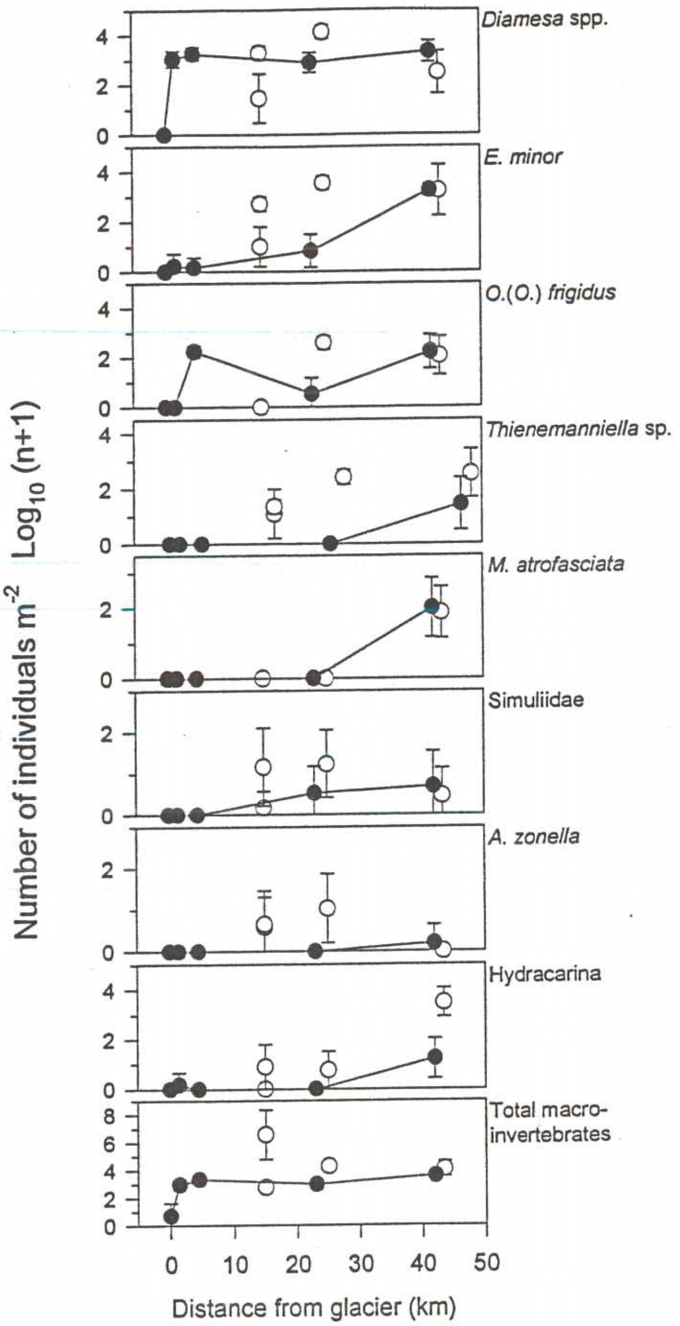

Fig. 6. Densities of macroinvertebrates in the glacial river W-Jökulsá and the reference rivers. Filled circles: W-Jökulsá; open circles: reference rivers.

All the reference rivers are dominated by spring water. Therefore, their discharge is very stable and their channel is also very stable. However, the glacial river has a

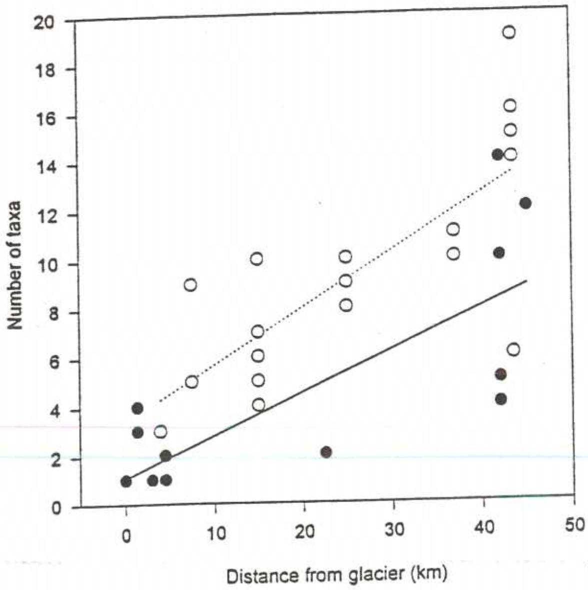

Fig. 7. Number of invertebrate taxa in W.-Jökulsá and the reference rivers. Filled circles: W-Jökulsá; open circles: reference rivers.

discharge variation of 6 to 100 m^3/s 40 km away the glacier and at the glacier snout its discharge is reduced by 80% in the winter. Except for the area immediately downstream from the glacier, the channel bed consists of boulders embedded in silt and sand. That, with the suspended material in the water could be the main influencing factor of density, but not of species composition. At the lowest station in the reference river Hofsá the bottom consists of boulders and sand, possibly due to influence of glacial water during the spring spade, could explain the similarity of the benthic density in the lowest sampling stations.

In a study on the benthic communities in rivers in Iceland, GÍSLASON et al. (1998) concluded that catchment characteristics, mainly geology, vegetation cover, topography and lakes in the river basins were the main determining factors of species richness and invertebrate density. These factors influenced the retention of water and the quantity of organic matter drifting in the water, and hence, the invertebrate communities feeding on organic matter or benthic algae. Suspended material in glacial rivers, which in this case were above 1000 mg/l (transparency less than 10cm) prevents algae growth on the bottom and makes filtering inefficient for invertebrates.

We conclude that maximum temperature, and possibly stability do not determine distribution of invertebrates in glacial rivers and we have to look for other parameters, such as temperature expressed in degree days and suspended material.

Faunal diversity is also very different across the European gradient (BRITTAIN et al. 1999). Diversity is highest in the Alps and the Pyrenees, decreasing northwards. In Iceland and on Svalbard, situated far north and at a long distance from the mainland of Europe, many taxa are not found, and the freshwater fauna is dominated by Chironomidae, both in glacial and non-glacial systems.

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References

ADALSTEINSSON, H. GÍSLASON,G.M., GÍSLASON, S.R.& SNORRASON, A. 1999 Physical and chemical characteristics of glacial rivers in Iceland, with particular reference to the River W-Jökulsá, North Iceland. *Verh. int. Verein. Limnol.* **27**. (in press).

BJÖRNSSON, H. 1988. Hydrology of ice caps in volcanic regions. *Societas Scientarium Islandica* ,**45**. University of Iceland, Reykjavík 139 p text and maps.

BRITTAIN, J.E., LENCIONI, V. & MAIOLINI, B. 1998: Arctic and alpine stream ecosystem research (AASER). In: CASACCHIA, R. et al. (eds), The Arctic and Global Change, Ny Ålesund Science Managers Committee, 4 pp.

BRITTAIN,J.E., ADALSTEINSSON, H., CASTELLA, E., GISLASON,G.M., LENCIONI, V., LODS-CROZET, B., MAIOLINI,B., MILNER, A.M., PETTS, G.E. and SALTVEIT, S.J., 1999. Twards a conceptual understanding of arctic and alpine streams. *Verh. int. Verein. Limnol.* **27**. (in press).

GÍSLASON, G.M., ADALSTEINSSON, H. & ÓLAFSSON, J.S. (1998). Animal communities in Icelandic rivers in relation to catchment characteristics and water chemistry. Preliminary results. *Nordic Hydrology. An International Journal* **29** 129-148.

MILNER, A. M. & PETTS, G.E. 1994. Glacial rivers: physical habitat and ecology. *Freshwater Biology* **32**: 295-307.

ÓLAFSSON, J.S., GÍSLASON, G.M. & ADALSTEINSSON, H. Chironomids in glacial and non glacial rivers in Iceland, a comparative study. *Verh. int. Verein. Limnol.* **27**. (in press).

SIGURDSSON, F. 1990. Groundwater from glacial areas in Iceland. *Jökull* **40**:119-146.