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Animal Communities in Icelandic Rivers in Relation to Catchment Characteristics and Water Chemistry

Preliminary Results

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Catchment areas of Icelandic rivers are mostly barren or with little vegetation cover in the highlands, but with heathland and mire vegetation in the lowlands. Chemical composition and nutrient availability in Icelandic rivers are influenced by geology, topography and vegetation cover in the river basins. This seems to determine the density and diversity of benthic invertebrates, species composition of anadromous fish and catch of salmon in Icelandic rivers. Species composition of benthic communities is determined by particulate organic matter drifting downstream from river head-waters. Filter feeding blackfly larvae dominate lake outlets, while algal grazing chironomid larvae dominate rivers not influenced by lakes. In well vegetated catchment basins, lake-fed rivers have higher catches of salmon than non-lake fed rivers. Only a few of the rivers flowing from poorly vegetated areas sustain salmon. Glacial rivers have the lowest density and diversity of benthic invertebrates of all river groups and do not sustain fish populations.

Introduction

Hynes (1975) concluded in the paper, *The stream and its valley*, that "in every respect the valley rules the stream. Its rock determines the availability of ions, its soil, its clay, even its slope. The soil and climate determine the vegetation and the vegetation rules the supply of organic matter. The organic matter reacts with the soil to control the release of ions, and the ions, particularly nitrate and phosphate, control the decay of the litter, and hence lie right at the root of the food cycle". With this in mind, we have launched a project in Iceland on the nature of catchment areas, the animal communities and productivity of rivers and how they are influenced by surrounding areas.

Characteristics of River Ecosystems

In a recent publication, Petersen *et al.* (1995) attempted to classify the ecology of benthic communities in the Nordic countries according to the conceptual framework of the River Continuum Concept (RCC) (Vannote *et al.* 1980). The central theme of the RCC is that "... it relates changes in lotic communities to the downstream gradient of abiotic factors from the head-waters to the mouth" (Cole 1983). The downstream longitudinal change forms a biological predictive basis for streams and the geomorphic setting and associated hydrology are the main determinants for the physical basis of stream ecosystem structure and functioning (Petersen *et al.* 1995). The classification is based on the main vegetation zones of the Nordic countries, as described by Sjörs (1963, 1967). Sjörs recognized four major vegetation zones: nemoral, boreo-nemoral, boreal and alpine. The main climatic zones of the Nordic countries also fall into a similar set of zones (Emmanuelsson and Johansson 1987). Iceland falls within the boreal/alpine vegetation zone.

Objective

This paper presents studies on animal communities in Icelandic rivers, based on studies currently carried out by the authors as well as review on earlier studies. It is not meant to replace earlier classifications (Kjartansson 1945, 1965; Rist 1956, 1979; Gardarsson 1979) of Icelandic freshwater systems, but to provide a framework for understanding animal communities and production of Icelandic rivers. However, in the future we are hoping to develop a predictive tool, based on environmental variables, for sustainable management of Icelandic rivers, especially in view of environmental impact of human activity, such as changes in hydrology.

Geomorphology of Iceland

Iceland is situated at 63°25'N-66°32'N and has an area of 103,300 km^2. About 60% of the island is a highland plateau, over 400 m a.s.l. Coastal lowlands generally extend only a short distance inland, although some valleys reaching approximately 40-80 km inland. Birch (*Betula pubescens*) grows up to an altitude of 600 m a.s.l., and covered most of the area below 400 m a.s.l. before human settlement (870 AD), but covers now about 1% (Steindorsson 1964).

Ice caps cover 11,300 km^2 (11%), while lakes and rivers cover 2,300 km^2 (2.2%) (Landmælingar Islands 1993). Cultivated land is limited, 1,426 km^2, or 1.4% (Upplysingathjonusta landbunadarins 1994) and urban areas cover only 70 km^2 (0.07%).

Rivers in Iceland were classified as arctic and alpine rivers by Petersen *et al.* (1995). Although the area is influenced by the North Atlantic Drift, the high latitude and altitude results in low annual temperatures. Only one permanent weather station is located in the central highlands of Iceland at 600 m a.s.l. In addition weather stations have been operated in a few areas for short periods. Annual mean temperature is about -1°C with mean air temperatures in January between -6 and -10°C. In July, the warmest month of the year, the mean temperature for the highlands is 6-8°C. Average length of yearly frost free periods at 2 m above ground is about 40 days (Eythorsson and Sigtryggsson 1971; Einarsson 1979; Thorhallsdottir 1997). However, coastal areas have higher temperatures with annual mean temperatures of 3-5°C and January means between 0 and -3°C and 9-11°C in July and yearly frostfree period is 94 to 153 days (Eythorsson and Sigtryggsson 1971). Annual precipitation in the highlands vary from 340 to 800 mm/year (excluding glaciers) (Thorhallsdottir 1997). In the lowlands, precipitation is from 500 to 2,200 mm/year, with more precipitation in the south than in the north.

The chemical composition of the water is influenced by the bedrock in the catchment areas, the percolation time and water temperature. Chemical composition changes on its way to the sea. The time it takes for the water to flow to the sea is very important, as well as the amount of organic production in the watercourse and on land.

Geology

Geology and topography of the catchments determine important characteristics of running waters, *e.g.* types of river channels, discharge characteristics and chemical composition of the river water.

Iceland is entirely of volcanic origin and is mainly built of basalt lava flows (90%) and the rest is rhyolites and sediments. The island saddles the Mid-Atlantic Ridge System which marks the boundary between the North American and Eurasian crustal plates. The active volcanic zones (rift zones) in Iceland are the continuation of the oceanic rift system. A new crust is constantly formed at the crustal boundary and drift to the northwest and southeast out of the volcanic zone. The rift zones branch trough the island from southwest to northeast. In the southern part of the island there are two separate zones which join in the centre of the island and they have SW-NE trend. In the north is only one zone with N-S trend. Due to the crustal drift the bedrock gradually becomes older further away from the volcanic zones (Sæmundsson 1979; Einarsson 1994). The oldest rocks are Late Miocene in age, about 15 m.y. old. During the early part of the geological history of Iceland, from 15 m.y. up to about 3.3 m.y. the climate was more temperate than at present (Simonarson 1979). At that time there were no glaciers and the island was covered by deciduous and conifer forests. The volcanic activity was characterized by extensive lava flows which piled up and formed a regularly stratified lava plateau. At about 3.3 m.y. ago the first wide spread glacier covered the island. Since then the climate has been repeatedly changing from relatively moderate climate (named interglacial periods) to extreme cold climate (named glacial periods). During the glacial periods most of the island was covered by huge glacial caps. During the interglacial periods lava flows behaved as before, but during the glacial periods the volcanic eruptions melted caves into the glaciers and the magma exploded into ash fragments due to interaction between the hot magma and the cold melt water. The volcanic products piled up within the cave and formed hyaloclastite mountains when the glacier later melted. The hyaloclastites are most common within the active volcanic zones and in the adjacent areas. During the Holocene (last 10,000 years) the volcanic activity has produced extensive lava flows.

Due to repeated glaciation during the Ice Age, when meltwater carried most of the silt and sand to the lowland and the sea, the retention time of water was short. The soil is thin on mountains and mountain slopes. The permeability of lava layers lessens as their age increases with increasing geothermal alteration of the basalt formation. Therefore, there is little groundwater storage and seepage in the oldest basalt formation, but much more in recent geological formations (Egilsson *et al.* 1991; Sigurdsson 1993).

Discharge Characteristics

Discharge characteristics of running waters depend upon the origin of their catchment areas. Accordingly they have been divided into three categories (Kjartansson 1945, 1965).

a) Glacial rivers originate from glaciers due to ice melt. The large glaciers are in areas associated with the volcanic zone and adjacent areas (areas 1.1, 1.2, 1.3, 2, 2.3 and 5.3 in Fig. 1). Their greatest discharge is during the summer with extensive sediment transport (Palsson and Vigfusson 1991). During winter they have a low discharge with little sediment load. Glacial rivers have the greatest annual fluctuations in discharge of all river types. Light penetration is often less than 10 cm. The bottom substrate of the channels is unstable and coarse silt erodes the bottom. Algal growth and production are therefore limited.

b) Direct run-off rivers characterize catchment areas with little permeability which are on Tertiary and Plio-Pleistocene geological formations, *i.e.* in East, West and Central North Iceland (areas 2, 3.1, 3.2, 4.1, 4.2, 5.1, 5.2, 5.3 in Fig 1). Increased influence of groundwater is found in the lowlands, when the rivers reach alluvial plains with thicker soil and lakes. Discharge is greatest during the spring thaw, but is often low in dry summers and in winters during periods of frost. The bottom substrate is usually unstable.

c) Spring-fed rivers are most common close to the edges of the permeable bedrock on the palagonite and Pleistocene geological formation (areas 1.1, 1.2 and 1.3 in Fig. 1). Their origin is often connected with fissure systems (Sigurdsson and Einarsson 1988; Sigurdsson, 1990). Their discharge is characterized by an even flow and little seasonal fluctuation, although usually with a peak in discharge following spring thaw. The bottom substrate is stable compared with glacial rivers and direct run-off rivers.

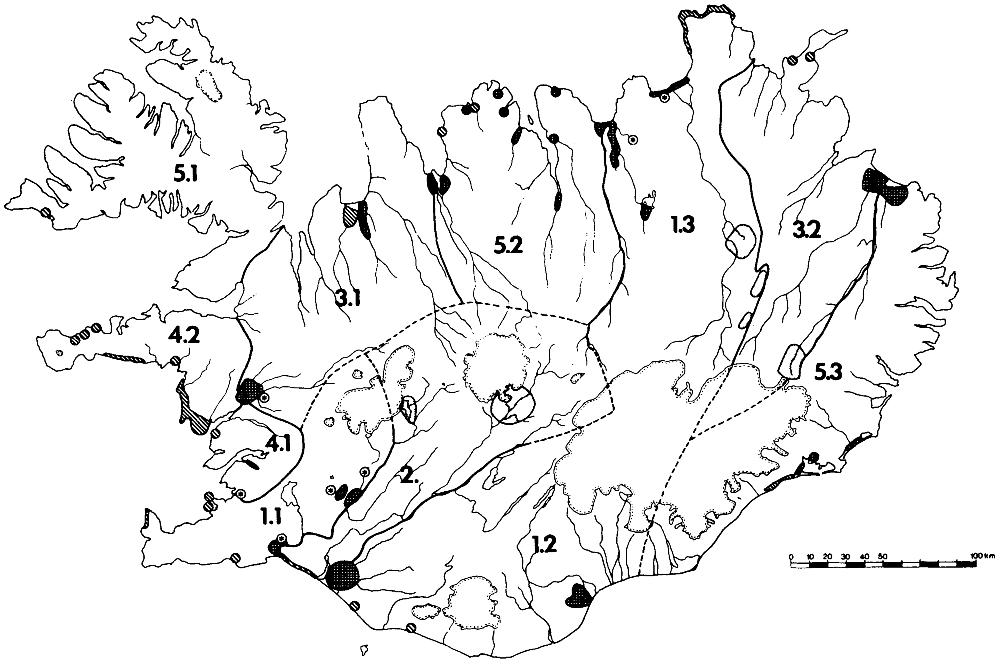

Fig. 1. Ecological classification of of Icelandic freshwaters. The classification is based on geology and topography of the catchment areas. 1) Spring-fed systems of the younger palagonite formation: 1.1 South-West, 1.2 South and 1.3 North-East; 2) direct run-off systems of the older palagonite formation; 3) run-off systems with shallow lakes and wetlands: 3.1 highland wetlands north-west of the glaciers, 3.2 highland wetlands in the North-East and East; 4) mainly run-off systems with relatively deep lakes near origins in the Faxafloi Bay area: 4.1 Hvalfjördur and Borgarfjördur valleys and 4.2 Myrar and Snaefellsnes valleys and 5) direct run-off systems on tertiary basalt: 5.1 Westfjords peninsula, 5.2 Central North and 5.3 Eastern fjords. Shaded areas other types of wetlands. From Gardarsson (1979).

Methods

All known publications and reports on rivers and catchment areas in Iceland were searched for information on physical, chemical and biotic factors of rivers. In addition, we have conducted studies on rivers and catchment basins since 1995. We have followed the protocol developed within the European Commission project "Arctic and Alpine Stream Ecosystem Research (AASER)".

Several rivers were selected to represent each catchment type as defined by Gardarsson (1979) see Fig. 1. The number of sampling stations depended on the length of each river. At least 4 stations representing each reach of the river were usually selected. The location of the sampling sites were usually as follows: close to the headwaters (upper 1/4); in the middle reaches (1/2 way); in the lower reaches (3/4 of the total length) and close to the river mouth.

Sampling of the benthic communities was conducted in September. We used satellite images (resolution 30 × 30 m) to estimate vegetation cover of the catchment areas. These analyses were made by the Icelandic Geodetic Survey. The pH and specific conductance were measured with an Orion pH meter model 230A and Cole Palmer conductivity meter 19820-00 respectively at each sampling site at least twice, in May/June and in September. Samples for analyses of major ions and nutrients were taken in September. The results of these analyses are not presented here. Two 1 litre samples were taken at each sampling site for analyses of fine particulate organic matter (FPOM), which was preserved in 2% formaldehyde, filtered through preweight GF/C 45 mm glass fibre filters, dried, weighed, ignited and weighed again, giving information on dry weight and ashfree dry weight.

At each sampling site, a 15 m stretch was selected. It was divided into a 33 × 33 cm grid with one axis along the bank and the other on the far bank or to 60 cm water depth. From these grids 10 sampling units were randomly selected. At each sampling unit, a stone was removed while holding a net (mesh size 250 μm) downstream to collect dislodged invertebrates. The stone was scrubbed and the content sieved through 250 μm sieve and preserved in 70% alcohol. Each stone was placed on a grid paper and its outlines drawn to estimate the area the stone covered. The area was used to estimate macroinvertebrate density.

In May window traps were placed at the sampling sites and operated through the summer. The traps are a modified version of the traps described by Jonsson *et al.* (1986). Formaldehyde (10%) was used as a preservative in the traps with a drop detergent to reduce its surface tension.

Benthic invertebrates and adult insects were identified under a stereo-microscope, with up to 250 times magnification.

Downstream of each sampling site, 50-100 m^2 of river bed along the bank, with water depth less than 50 cm, were electrofished.

Results and Discussion

Chemical Composition

We used pH and specific conductance (Table 1) as a preliminary measure of water chemistry, while we have not completed the water analyses. This is justifiable due to the fact that Gudjonsson (1990) found the relationship between specific conductance and concentration of total dissolved solids (TDS) in 53 streams in Iceland, with a large span of concentration of TDS (20-110 mg/l), highly significant:

$$\text{Specific conductance } (\mu\text{S/cm at } 25°\text{C}) = -1.69 + 1.51 \times \text{TDS (mg/l)}, \; r = 0.89$$

Table 1 – pH and specific conductance at 25°C in streams from different types of catchment areas. See Fig. 1 for area numbers. Measurements based on this study, Adalsteinsson 1982, Gíslason (1993), Gudjónsson (1990), Tiller (1991) and Gíslason *et al.* (1996)

	pH	µS/cm
Rain water	4.2-6.9	11.5
Spring-fed rivers of younger palagonite formation		
South-West (1.1)	7.1-8.9	54-105
South (1.2)	6.9-10.3	124-214
North-East (1.3)	7.7-9.7	111-192
Direct run-off rivers of the older palagonite formation (2)	7.3-8.2	51-92
Run-off rivers from the highland wetlands		
West & North-West (3.1)	7.4-8.1	38-108
Run-off rivers from relatively deep lakes, South-West (4.1)	7.1-7.2	65-73
Direct run-off rivers of the Tertiary basalt formation		
Westfjords (5.1)	5.8-7.5	27-69
Eastfjords (5.3)	6.1-7.2	11-53
Glacial rivers		
North	6.1-7.8	9-84
South-east	7.9-8.1	28-50
South	6.4-7.6	19-88

The pH in rain water in Iceland was 4.2-6.9 (Gíslason 1993) and the specific conductance was 11.5 µS/cm at 25°C in rain water in central highlands (Table 1). In streams of the Tertiary formation in East Iceland, it was about 12 µS/cm near the headwaters and 20-30 µS/cm in the lowlands (Adalsteinsson 1982, 1995; Gíslason *et al.* 1996; Jonsson and Gudbergsson 1993, present study). High specific conductance of up to 69 µS/cm has been observed in streams at 300-450 m a.s.l. in the fjords of East- and West-Iceland, presumably due to oceanic influence. Spring water in the active volcanic zone had a specific conductance of 54-214 µS/cm. In glacial rivers the specific conductance was 10-20 µS/cm close to the glaciers and increased to 60-88 µS/cm with increasing discharge from groundwater. Specific conductance increased downstream in all river groups, presumably due to leakage from soil and bedrock in their catchment basins (Table 1) and increased influence of sea spray.

Nitrogen originates in the atmosphere, but phosphorus and silica in rocks (Wetzel 1983). In precipitation in Iceland the average concentration of nitrogen is 120 µg/l (NO_3, NO_2 and NH_4 as N) and the estimated average phosphorus concentration is

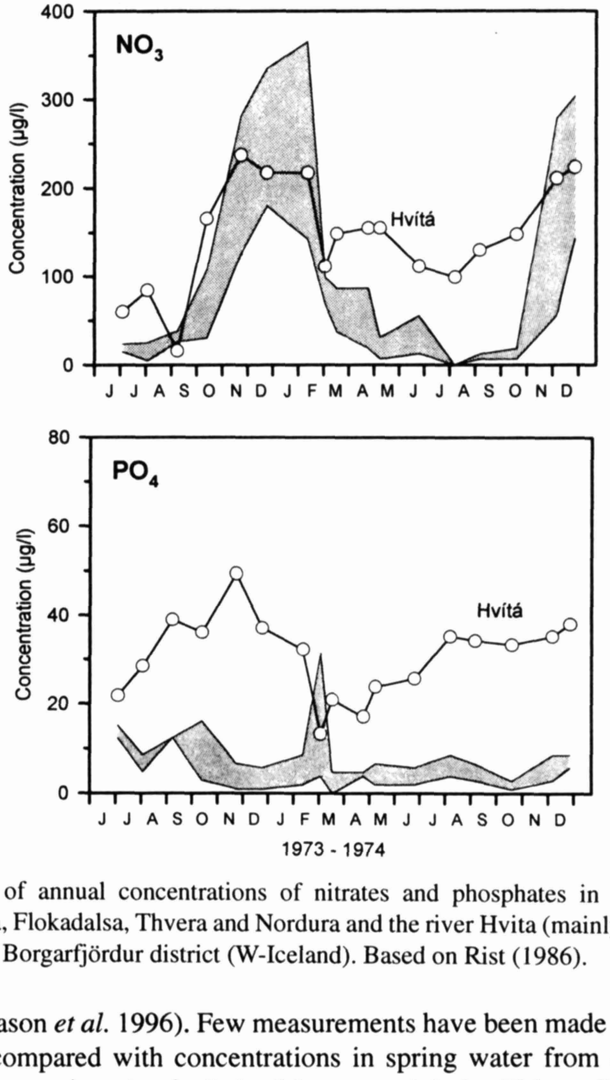

Fig. 2. Range of annual concentrations of nitrates and phosphates in the run-off rivers Grimsa, Flokadalsa, Thvera and Nordura and the river Hvita (mainly spring-fed at this site) in Borgarfjördur district (W-Iceland). Based on Rist (1986).

1.5 µg/l (Gíslason *et al.* 1996). Few measurements have been made in fresh water in Iceland, but compared with concentrations in spring water from catchment areas with sparse vegetation, *i.e.* in Lake Myvatn and Lake Thingvallavatn (Olafsson 1979, 1992) and in springs in River Tungnaa (Einarsson and Adalsteinsson 1991), it is likely that half of the nitrogen loading is returned to the rivers and half is bound in soil in the catchment areas.

Gíslason and Arnorsson (1988) and Gíslason *et al.* (1996) found that chemical erosion is greater in Iceland than in most other regions of the world due to great precipitation and bedrock characteristics. The average pH value of rain water was 5.6 and increased rapidly to 7 upon contact with basalt rock in the surface environment (Gíslason and Eugster 1987a,b).

Bedrock with high concentrations of glass, like palagonite, volcanic ash and tephra released ions more rapidly than crystallized bedrock of the same chemical com-

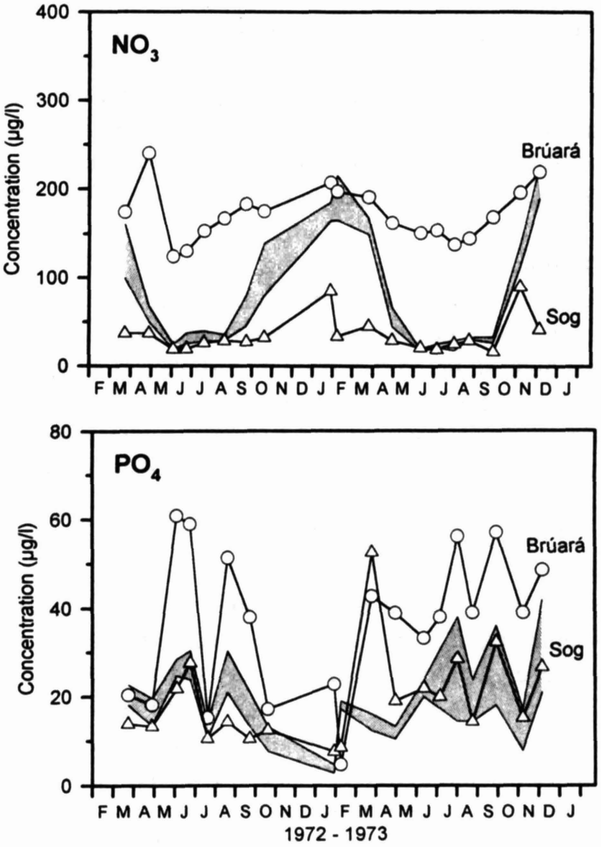

Fig. 3. Range of annual concentrations of nitrates and phosphates in the run-off rivers Fossa, and Stora-Laxa and the spring-fed rivers Bruara and Sog in S-Iceland. Based on Armannsson *et al.* (1973) and Rist (1974).

position (Gíslason and Eugster 1987a; Gíslason 1993). This may explain the higher concentrations of ions in spring water in the neo-volcanic zone surface water than in the Tertiary rock formation.

Most phosphorus measurements have been made in headwaters of spring-fed streams. Phosphorus concentrations change rapidly because of uptake by algae and sediment. This makes it difficult to assess individual measurements of phosphorus in streams. Specific conductance is a general indicator of dissolved ions (Mackereth *et al.* 1978), and there is a general positive relationship between organic and inorganic chemical concentrations and the vegetation cover of catchment areas.

Phosphorus and nitrogen concentrations frequently vary seasonally (Figs. 2 and 3). The seasonal differences are a result of the concentrations of the nutrients in water entering the rivers and their uptake and loss by algae (Armannsson 1970, 1971; Armannsson *et al.* 1973; Rist 1974, 1986).

The concentration of nitrogen was high during winter when little or no production occurred in the rivers and their catchments. Similar seasonal fluctuations occurred in spring-fed and run-off rivers (Figs. 2 and 3), but not for phosphorus in the River Hvita, which is mainly spring-fed with glacial influence. Higher phosphorus concentrations in the South than in Borgarfjördur were possibly due to the extent of neovolcanic bed rock formations in the southern rivers (Gíslason *et al.* 1996).

Productivity and Communities

There can be a considerable difference between the nutrient budget of lakes and streams. Nutrients may be depleted in epilimnion or in certain areas of lakes, where the density of algae is highest, but in streams with turbulent flow and mixing, a rapid renewal of water occurs, and the concentration of ions depends upon the input.

As a preliminary measure we have formed 3 groups of clear water rivers plus glacial rivers, which have much higher turbidity than any other freshwater systems in Iceland. Group A rivers originate in lakes in well vegetated areas (in catchment areas 1.1, 1.3, 3.1, 3.2, 4.1 and 4.2 in Fig. 1). Group B rivers are drained from well vegetated catchments without lake influence (in areas 3.1, 3.2, 4.1, 4.2 and rivers in long lowland valleys in areas 5.1, 5.2 and 5.3). Group C rivers originate from poorly vegetated catchments (1.2, 5.1, 5.2 and 5.3). Rivers originating in lakes and in catchments with rich vegetation have large quantities of fine particulate organic matter (FPOM) at their origin. Rivers originating from barren land had only the benthic algae as a food source for invertebrates. The filter-feeding blackfly larva *Simulium vittatum* Zett. dominates the lake-fed river Laxa, N-Iceland. Its productivity and life cycle reflected the quantity of FPOM (Gíslason and Gardarsson 1988; Gíslason and Johannsson 1991). Densities of chironomid larvae, which mainly scrape algae from the substrate, were not influenced by FPOM (Gíslason 1994; Gíslason *et al.* 1994), though some species declined in numbers downstream, possibly due to higher primary production close to the outlet, than elsewhere in the river (Fig. 4). Run-off rivers without the influence of lakes were dominated by chironomid larvae that feed on benthic algae (scraping/grazing). Their density increased downstream in the R. Svarta , N-Iceland (Fig. 5). Only a few chironomid species were found in the headwaters of glacial rivers, mainly the genus *Diamesa*, with increasing number of species downstream from the glaciers (Fig. 6, Table 2). The density of benthic invertebrates in the River Laxa (outlet of the spring-fed lake Myvatn at 278 m a.s.l.) was 10-50 times higher than in R. Svarta in E-Hunavatnssysla (spring and run-off river originating at 560 m a.s.l.). The density of benthic invertebrates in the glacial river W-Jökulsa in Skagafjördur (Fig. 6), which originates at 860 m a.s.l. in the glacier Hofsjökull, was about one third of the density in the River Svarta (Fig. 5). The number of species was greatest in the lake-fed river Laxa (Table 2), and lowest in the glacial river W-Jökulsa. Vertebrate diversity was also much higher in the lake-fed river Laxa than in any of the other streams, and the glacial river did not sustain waterfowl or spawning fish.

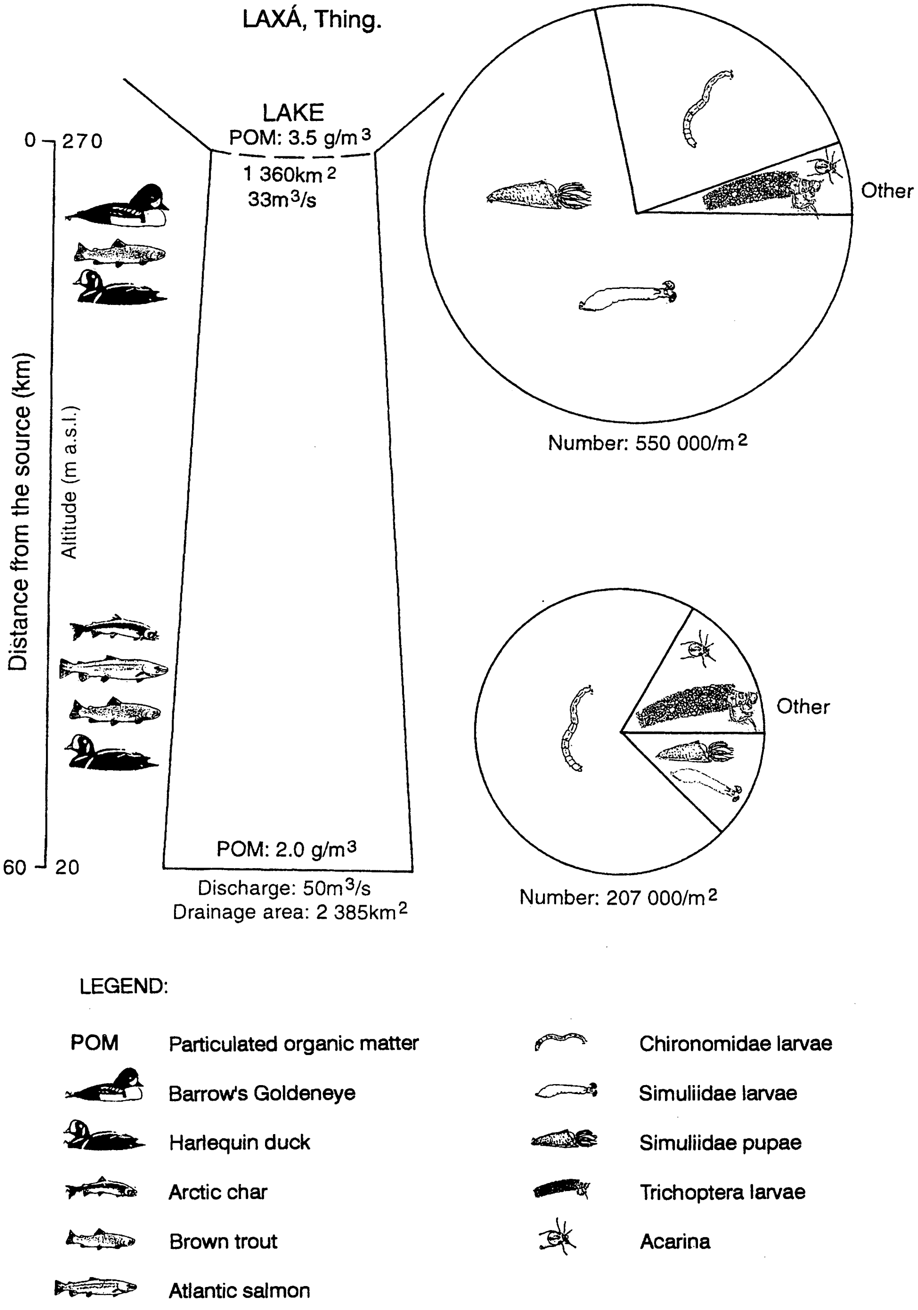

Fig. 4. A schematic representation of ecosystem characteristics in the lake-fed river Laxa in S-Thingeyjarsysla (N-Iceland) (Group A river in catchment area 1.3).

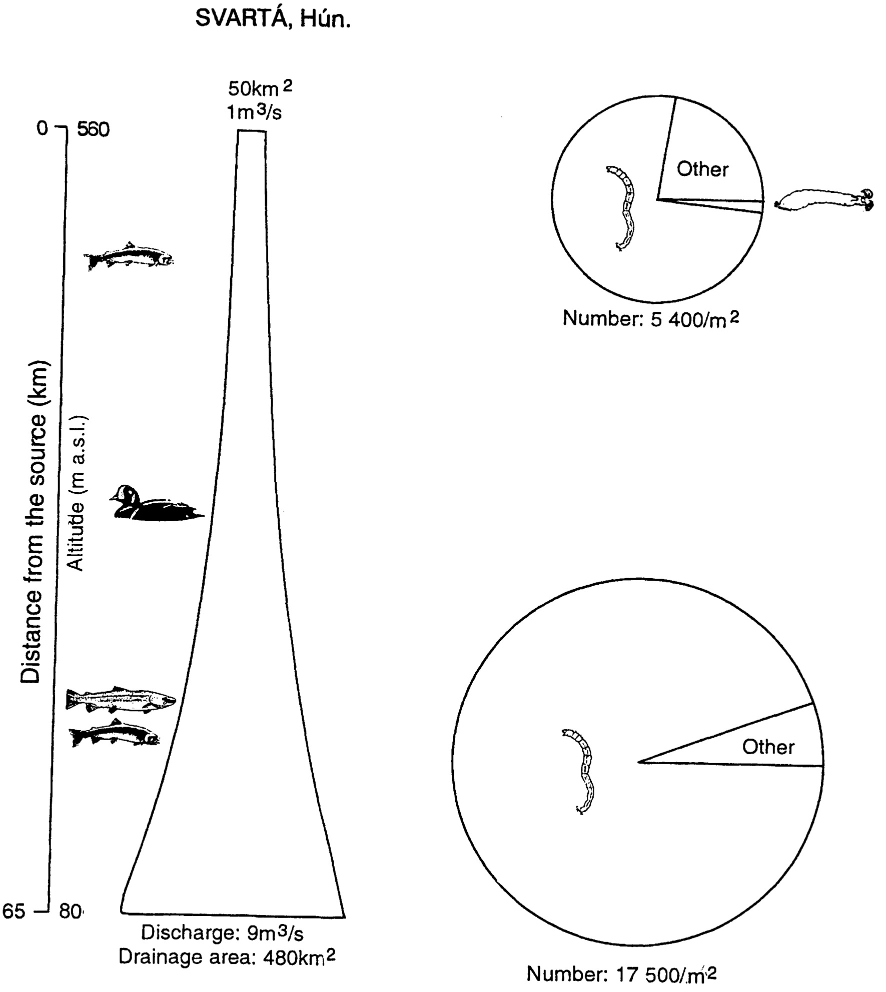

Fig. 5. A schematic representation of ecosystem characteristics in the run-off river Svara, E-Hunavatnssysla (N-Iceland) (Group B rivers in catchment area 3.1).

Gudjonsson (1990) found that anadromous Arctic charr (*Salvelinus alpinus* (L.)) dominated short rivers without lake influence (*e.g.* catchment areas 5.1, 5.2 and 5.3 in Fig. 1), Atlantic salmon (*Salmo salar* L.) spring-fed or lake-fed rivers of the palagonite formation (areas 1.2 and 1.3) (Fig. 4), rivers from the highland wetlands (areas 3.1. and 3.2) (Fig. 5) and run-off rivers originating in lakes with a relatively long retention time (areas 4.1 and 4.2). Anadromous brown trout (*Salmo trutta* L.) dominated spring-fed rivers of intermediate length (areas 1.1, 1.2 and 1.3) (Fig. 4) and direct run-off rivers of the older palagonite formation (area 2). Many rivers dominated by Atlantic salmon may harbour anadromous Arctic charr and brown

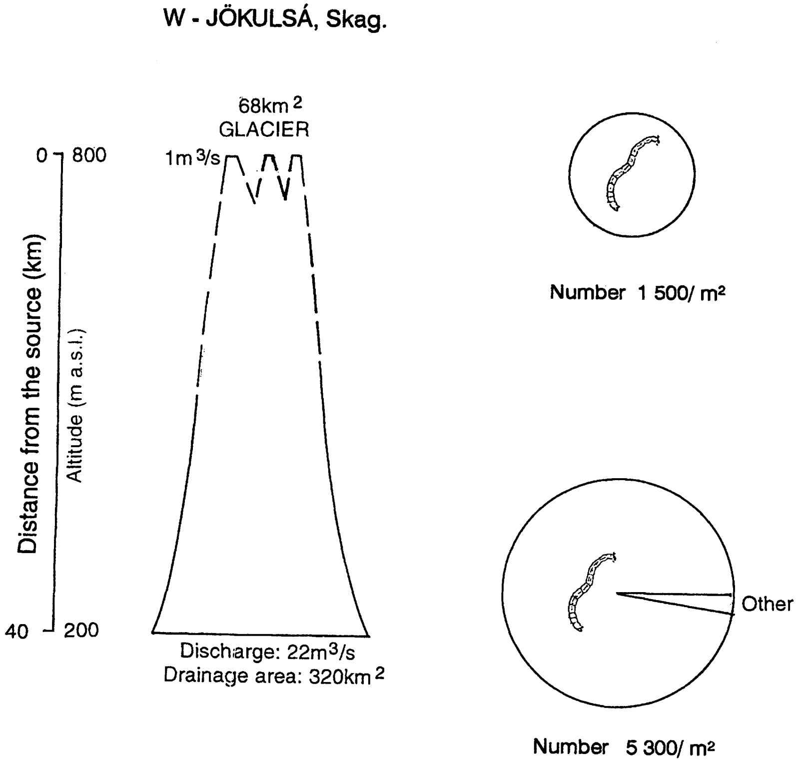

Fig. 6. A schematic representation of ecosystem characteristics in the glacial river W-Jökulsa, Skagafjördur (N-Iceland) (Catchment area 5.2).

trout, but rivers dominated by charr were rarely occupied by salmon. Resident stocks of brown trout often dominate reaches of the lake-fed rivers which are not accessible for anadromous fish and arctic charr often occupies the upper reaches of spring-fed and lake-fed rivers.

Using average catches of the Atlantic salmon for 21 years will eliminate biological fluctuations in the rivers as well as in the ocean and be representative for the average productivity of the rivers. Salmon can therefore be an estimator for productivity. A relationship was found between average salmon catches per area of catchment for different groups of rivers (Fig. 7). While productivity estimates are not available for rivers in different types of catchments, which are based on geology and topography, we have combined salmon catch data from rivers in different catchment types. Group A rivers showed a positive relationship between salmon catches and catchment sizes, but no relationship was found for Group C rivers (Fig. 7, Table 3). Salmon catches per length of rivers accessible for salmon were about 6 times greater for lake-fed rivers (Group A) than catches from rivers originating in poorly vegetated uplands (Group C).

Table 2 – Species richness in three rivers in Iceland, the glacial river Vestari-Jökulsá, run-off river Svartá and the lake-fed river Laxá. Number of taxa (phylum, orders, families or species) at the headwaters and a downstream stations are shown

Animal taxa	V-Jökulsá		Svartá		Laxá	
	Headw	Down	Headw	Down	Headw	Down
COELENTERATA species					1	1
BRYOZOA species					1	
NEMATODA phylum			1	1	1	1
ANNELIDA						
Hirudinea species					2	
Oligochaeta orders			1	1	1	1
MOLLUSCA						
Gastropoda species					1	1
Bivalvia species					1	
ARTHROPODA						
ARACHNIDA						
Acarina species			1	1	1	1
INSECTA						
Trichoptera species		1	1	1	2	1
Plecoptera species			1			
Diptera:						
Chironomidae species	6	14	8	9	20	24
Simuliidae species		1	1	1	1	1
Limoniidae species					1	
Empididae species					1	1
Muscidae species					1	1
CRUSTACEA						
Copepoda orders			1		1	
PISCES species		1	2	3	1	3
AVES						
Duck species			1	2	13	14
Total number of taxa	**6**	**17**	**18**	**19**	**50**	**50**

Table 3 – Comparison by single factor ANOVA of average salmon catches (1974-1994) per km of river accessible to salmon in three groups of rivers. Group A: rivers originating in lakes in well vegetated areas, Group B: run-off rivers originating in well vegetated areas and Group C: rivers originating in poorly vegetated areas. Arithmitic arverages: Group A: 49.0, Group B: 18.1 and Group C: 8.2. Data log-transformed

Rivers	n	Sum of squares	Average	Variance
Group A	24	37.6285	1.5679	0.0957
Group B	31	35.5343	1.1463	0.1092
Group C	14	11.1918	0.7994	0.1574

Table 3 – continued

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Groups	5.5486	2	2.7743	24.3394	<0.001
Within groups	7.5229	66	0.1140		
Total	13.0715	68			

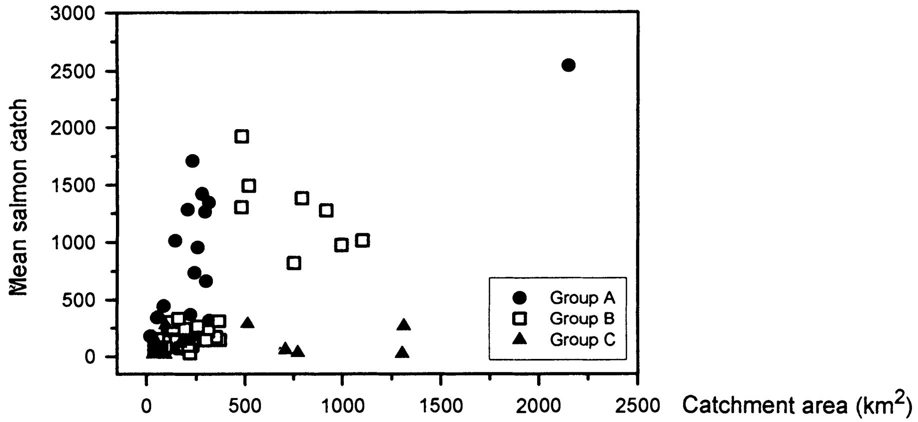

Fig. 7. Relationship beween average salmon catches 1974-1994 and size of catchment areas. Group A: filled circles: rivers originating from lakes in well vegetated areas, r^2 = 0.510, df = 22, $P < 0.001$. Group B: open squares: run-off rivers originating in well vegetated areas, r^2 = 0.553, df = 29, $P < 0.001$ and Group C: filled triangles: rivers originating in poorly vegetated areas at high altitude, r^2 = 0.012, df = 12, $P > 0.05$.

General Discussion

The preliminary results from our study strongly indicate that the type of catchment basin, vegetation cover and lakes influenced the animal communities and productivity of rivers. The bedrock determined the availability of ions and nutrients, while the supply of organic matter was brought in from the catchment area, its vegetation and soil. Rivers from drainage areas rich in soil and vegetation had higher productivity and diversity than rivers draining barren areas. Lakes in the catchments increase the retention time of the water, which allows time for algae to use the solar energy and dissolved nutrients, and supplied filter feeding benthic invertebrates with food.

The productivity reflected by salmon catches from Icelandic rivers. Rivers draining barren land (Group C) had very low catches and the catches were not related to the size of the catchments. A highly significant relationship was found between the size of the catchment area and the catch of salmon in rivers draining well vegetated wetland areas (Group B) ($r^2 = 0.553$, $n = 31$, $P<0.001$) and rivers originating in lakes, which were often in well vegetated catchment basins, had the largest catch of salmon (Group A) ($r^2 = 0.510$, $n = 24$, $P<0.001$).

When data from rivers in all catchment types have been collected and analysed we hope to have a much better knowledge of the relationship between catchment types, their geology, vegetation cover, water chemistry and allochtonous input, and animal communities in the draining rivers, their diversity, density and productivity. This will test the ecological classification presented by Gardarsson (1979).

The preliminary results we are presenting indicate strongly that ecological studies of rivers and river management should include catchment basins. Activities in the catchment areas will affect the biota of rivers. This includes the present land use as pasture land, which has changed the vegetation and especially where land has been subjected to overgrazing by sheep. The overgrazing has lead to soil erosion, which has greatly decreased the productivity of rivers. Similarily draining of wetlands has also affected the catchments. It has lead to changes in water balance of the rivers, altered the buffering of discharge and increased leaking of iron and organic matter from the wetlands. River managers must take the nature of the rivers and their catchments into account when decisions are made to stock rivers with salmon.

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