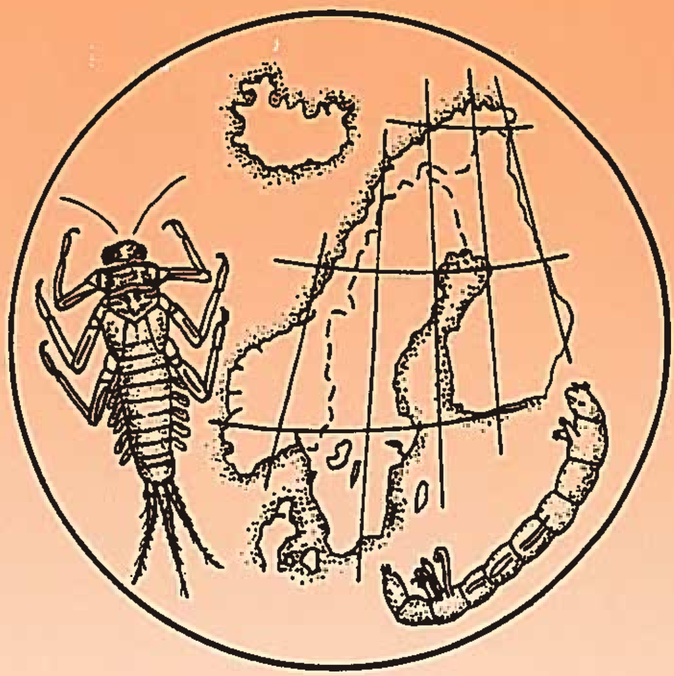
Environment

Biological Monitoring of Streams



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Methods used in the Nordic Countries based on macroinvertebrates

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Nordic Environmental Cooperation
Environmental cooperation is aimed at contributing to the improvement of the environment and forestall problems in the Nordic countries as well as on the international scene.The cooperation is conducted by the Nordic Committee of Senior Officials for Environmental Affairs. The cooperation endeavours to advance joint aims for Action Plans and joint projects, exchange of information and assistance, e.g. to Eastern Europe, through the Nordic Environmental Finance Corporation (NEFCO).

The Nordic Council of Ministers
was established in 1971. It submits proposals on co-operation between the governments of the five Nordic countries to the Nordic Council, implements the Council's recommendations and reports on results, while directing the work carried out in the targeted areas. The Prime Ministers of the five Nordic countries assume overall responsibility for the co-operation measures, which are co-ordinated by the ministers for co-operation and the Nordic Co-operation Committee. The composition of the Council of Ministers varies, depending on the nature of the issue to be treated.

The Nordic Council
was formed in 1952 to promote co-operation between the parliaments and governments of Denmark, Iceland, Norway and Sweden. Finland joined in 1955. At the sessions heldby the Council, representatives from the Faroe Islands and Greenland form part of the Danish delegation, while Åland is represented on the Finnish delegation. The Council consists of 87 elected members - all of whom are members of parliament. The Nordic Council takes initiatives, acts in a consultative capacity and monitors co-operation measures. The Council operates via its institutions: the Plenary Assembly, the Presidium and standing committees.

Contents

Summary (English)

This report gives a short description of the major impacts, legislation, and monitoring of stream quality using macroinvertebrates today, in each of the Nordic countries. All of the Nordic countries have legislation relating to the environmental quality of streams, and many similarities exist among countries regarding legislation governing streams. Hence, there is the legislative basis for biological monitoring within the Nordic countries. However, the extent of this monitoring varies today considerably between countries, despite a high degree of similarity with respect to sampling techniques. In conclusion, there is at present the basis for co-operation among the Nordic countries concerning biological monitoring of streams using macroinvertebrates. However, there is an apparent need for a higher degree of standardisation and refinement of the methods and approaches used among the countries. The working group recommends that sampling methodology, taxonomic resolution and data storage should be done in each of the Nordic countries in such a way that inter-country comparisons are possible. Sampling should be done in a way so that both temporal and spatial variability are reduced, and it is recommended that in future predictive modelling of stream macroinvertebrates communities of the Nordic countries are made. The last chapter of the report is a proposal of how this could be done.

Sammanfattning (Swedish)

Nordiska Ministerrådet finansierar projektet "Biologisk övervakning av rinnande vatten i de Nordiska länderna med hjälp af bottenfauna". Projektets målsättning är att standardisera provtagningsmetoder, taxonomisk upplösning och datalagring i de Nordiska länderna med avseende på bottenfauna, samt att göra en sammanställning af kvaliteten på vattendrag i de Nordiska länderna med hjälp af data från bottenfaunaprovtagningar. I arbetsgruppen deltar representanter för samtliga Nordiska länder.

Denna rapport, som sammanställts av arbetsgruppen, ger för vart och ett av de Nordiska länderna en kort översikt över huvudsakling påverkan på vattendragen, lagstiftning som berör vattendrag, samt en beskrivning av dagens övervakning av vattendragskvalitet med hjälp af bottenfauna. I samtliga Nordiska länder finns en lagstiftning som relaterar till vattendragskvalitet, och utformningen av denna lagstifning uppvisar många likheter mellan länderna. Det finns därför ett stöd i lagstiftningen för biologisk övervakning av vattendrag. De provtagningsmetoder som användes vid övervakning av bottenfauna i de olika länderna är likartade, men omfattningen af övervakningen varierar avsevärt mellan länderna.

Likheter mellan de Nordiska länderna ifråga om lagstiftning och provtagningsmetoder ger förutsättningar för ett internordiskt samarbete när det gäller biologisk övervakning av vattendrag med hjälp af bottenfauna. Det finns dock ett uppenbart behov av en högre grad av standardisering och förbättring av metoder och tillvägagånssätt vid övervakning. Arbetsgruppen rekommenderar att provtagningsmetoder, taxonomisk upplösning och datalagring i de Nordiska länderna anpassas så att jämförelser mellan länderna möjliggörs. Provtagning bör utföras så att både den rumsliga och den tidsmässiga variationen reduceras. En viktig målsättning för ett framtida internordiskt samarbete är att utveckla prediktiva modeller för förekomst av olika bottenfaunasamhällen. Det sista kapitlet i denna rapport visar hur ett sådant arbete skulle kunna utformas.

Yhteenveto (Finnish)

Tämä raportti on lyhyt kuvaus virtaaviin vesiin vaikuttavista tekijöistä, lainsäädännöstä sekä niissä elävien selkärangattomien käytöstä vesien seurannassa kussakin Pohjoismaassa. Kaikissa Pohjoismaissa virtavesiympäristö on otettu huomioon lainsäädännössä ja se on paljolti samankaltainen maiden välillä. Täten on olemassa lainsäädännöllinen perusta virtavesien biologiselle seurannalle Pohjoismaissa. Seurannan laajuus vaihtelee kuitenkin nykyisellään huomattavasti maiden välillä huolimatta näytteenottotapojen samankaltaisuudesta. Siitä johtuen on olemassa perusta Pohjoismaiselle yhteistyölle virtavesien selkärangattomien seurannassa. On kuitenkin nähtävissä selvä tarve standardoida ja hioa erimaiden käyttämiä menetelmiä ja lähestymistapoja. Työryhmä suosittelee, että näytteenotto, lajinmäärityksen tarkistus ja tietojen tallennus suoritetaan kussakin Pohjoismaassa siten, että vertailut maiden välillä ovat mahdollisia. Näytteenotto pitäisi suorittaa siten, että ajallinen ja paikallinen vaihtelu olisi mahdollisimman vähäinen. Tulevaisuudessa suositellaan työstettäväksi ennustemalleja, jotka perustuvat Pohjoismaiden virtaavien vesien selkärangattomien yhteisöihin. Raportin viimeinen kappale on ehdotus siitä kuinka tämä voitaisiin tehdä.

Chapter 1

Introduction

The flora and fauna present in a stream generally reflect the amount and quality of water in the stream, and the physical environment of the stream (velocity, substratum, channelization, maintenance etc.). It is habitat quality, however, that is the single most important factor determining the development of biological communities in most European streams. Although many of the methods used for assessing stream water quality are based on chemical measurements, biological methods are being used increasingly throughout the world. Indeed, as biodiversity has taken a central place in many monitoring studies, monitoring of biological indicators provide a more direct measure of anthropogenic effects on aquatic resources. Biological indicators have the advantage that they integrate water quality over a period of time, thereby giving a much more direct picture of the effects of a pollutant at the ecosystem level than chemical methods, which provide only a momentary picture of water quality (unless continuous and costly sampling is undertaken). Ideally, however, biological and chemical methods should be used together, to provide a more complete characterisation, that is often needed for proper water management.

Biological assessment of streams is usually based on changes in community structure e.g. changes in taxon richness, diversity, density, and/or the relative predominance of indicator taxa. As it would be far too time-consuming to assess the response of all groups of organisms in the stream ecosystem, a specific group of organisms has therefore often been selected. Although protozoa, ciliata, algae, macroinvertebrates and fish have all been used at one time or another in various methods, macroinvertebrates are the group at present being used in more than two thirds of all modern biological methods. The main reasons for this choice are:

a. Macroinvertebrate community structure reflects stream environmental quality since different macroinvertebrates have different levels of tolerance towards pollutants.

b. Macroinvertebrates are conspicuous, are often abundant, and are relatively sedentary.

c. Macroinvertebrates are easy to collect, and are relatively simple to identify (at least at family level) and enumerate.

d. Macroinvertebrates have a relatively long life-history (generally weeks to years).

Biological indicators appear to be the best methods currently available for biological assessment of stream water quality. They include the most desirable features of saprobic and diversity indices, thus combining the use of indicator organisms with the measurement of diversity. As the level of identification necessary when employing many biotic indices is usually only family and/or genus, the indices are easy to use, even for people without a substantial taxonomic knowledge. Furthermore, it has been shown that biotic indices are able to detect not only organic pollution, but also other kinds of pollution.

For countries within the European Union, De Pauw et al. (1992) has compiled which macroinvertebrate based method is currently used in the member countries (Table 1.1).

Table 1.1 Biological assessment methods currently used in EU countries. B: Biotic S: Saprobic

Country	Index method	B/S	Community	Standard
Belgium	Belgium Biotic Index	B	Macroinvertebrates	National
Denmark	Danish Fauna Index	B	Macroinvertebrates	National
France	Global Biotic Index	B	Macroinverte brates	-
Germany	BEOL/Saprobic	S	Macroinvertebrates	-
Ireland	Qualit Rating System	B	Macroinvertebrates	National
Italy	Extended Biotic Index	B	Macroinvertebrates	Regional
Luxemburg	Biotic Index	B	Macroinvertebrates	National
Netherlands	Quality Index K 135	B	Macroinvertebrates	Regional
Portugal	Belgium Biotic Index	B	Macroinvertebrates	-
Spain	BMWP Spanish Modf.	B	Macroinvertebrates	-
The UK	BMWP-Score	B	Macroinvertebrates	National

However, at present a similar status for the Nordic countries is not available. Because of the lack of knowledge of the methods used in the Nordic countries, the Monitoring and Data group under the Nordic Council of Ministers sponsored a project with the following objectives:

- To describe the macroinvertebrate based monitoring methods used in the Nordic countries including the strategy followed (aim, location of stations, sampling frequency etc.).

- To recommend the future use of macroinvertebrate based methods within the Nordic countries.

- To investigate the possibilities of making a report of biological water quality that covers all the Nordic countries.

The project has included three working group meetings in 1993 and 1994. The working group consisted of the following members:

Iceland
Gisli Mar Gislason, Institute of Biology, University of Iceland, Reykjavik.

Finland
Esa Koskenniemi, Vasa vatten- och miljödistikt, Vasa.

Sweden
Lars Eriksson, Sveriges Lantbruksuniversitet, Uppsala.
Richard K. Johnson, Sveriges Lantbruksuniversitet, Uppsala.

Norway
Torleif Bækken, Norsk Institutt for Vannforskning (NIVA), Oslo.
Karl Jan Aanes, Norsk Institutt for Vannforskning (NIVA), Oslo.

Denmark
Torben Moth Iversen, Danmarks Miljøundersøgelser, Silkeborg.
Nikolai Friberg, Danmarks Miljøundersøgelser, Silkeborg.

In addition, the following national experts have been participating in one or more project meeting:

Hans-Göran Lax, Vasa vatten- och miljödistrikt, P.O. Box 262, SF-65101 Vasa

Heikki Hamalainen, Joensuu Universitet, Biol. Inst., P.O. Box 111, SF-80101 Joensuu

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Hans Ole Hansen, Danmarks Miljøundersøgelser, Postbox 314, DK-8600 Silkeborg

The aim of this report is to give a short introduction to macroinvertebrate methods used in the Nordic countries today and to discuss future possibilities of co-operation between Nordic countries according to project objectives. The specific chapters on what methods are currently being used are written by:

Iceland: Gísli Már Gíslason

Finland: Esa Koskenniemi

Sweden: Richard K. Johnson

Norway : Torleif Bækken & Karl Jan Aanes

Denmark: Nikolai Friberg

1.1 References

De Pauw, N., Ghetti, P.F., Manzini P. and Spaggiari, R. 1992. Biological Assessment methods for running waters. Paper presented at the International Conference on River Water Quality, Brussels, 16-18 December 1991.

Chapter 2

The use of macroinvertebrate methods in the Nordic countries today: aim, strategy and methods

In the following chapters, a short description is given of the major impacts, legislation, and monitoring of stream quality today in each of the Nordic countries. Each section follows the same outline, with minor exceptions due to slight differences among the countries.

2.1 Iceland

2.1.1 Background: major impact on Icelandic streams

Introduction

Water is a prominent feature of the Icelandic landscape. Glaciers cover 11 300 km^2 (11 %) and freshwater covers 2 300 km^2 (2.2 %) of the islands 103 300 km^2 (Landmælingar Islands 1993). Lakes larger than 1 ha (0.01 km^2) cover 1,500 km^2, the largest lake being 86 km^2 (Thingvallavatn) (National Energy Authority, Reykjavík, unpublished information). Ten rivers have more than 100 m^3 s^{-1} average discharge, the largest river has an average discharge of 440 m^3 s^{-1} (Ölfusá, spring-fed, direct run-off and glacier river).

Cultivated land is 1 426 km^2, or 1.4 % (Upplysingathjónusta landbúnadarins 1994) and populated up areas cover 130 km^2 (0.1 %), thereof 70 km^2 urban areas and 60 km^2 summer house reserves.

Classification of rivers

The source of the water in river systems determines the chemical characteristics, and it is possible to divide them into four categories (Gardarsson 1979): (1) cold waters of the palagonite formation, (2) cold waters of the tertiary and early Pleistocene basalt, (3) geothermal water and (4) glacial waters.

The chemical composition of the water is determined by a number of factors. For example, the rock formation in the catchment areas, the time it takes for the water to percolate and water temperatures are factors which determine the chemical composition of the water. The chemical composition changes as the water flows on the surface 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.

The length of running waters, the slope of the landscape it flows through and the size and depth of lakes is very important in determining the organic production of the water systems. In addition to these factors, several other factors can affect the nature of the water systems, e.g. the effect of sea spray and direct mixing of salt when water flows in old sea sediments when the water approaches the sea. Also precipitation, wind born soil, vegetation in the water catchment areas are important.

These characteristics of the water catchments have made it possible to divide water systems into five main classes (Gardarsson 1979) as shown in Fig. 2.1.1. However, it should be kept in mind, that this classification may change with increasing knowledge of the nature and biology of the systems.

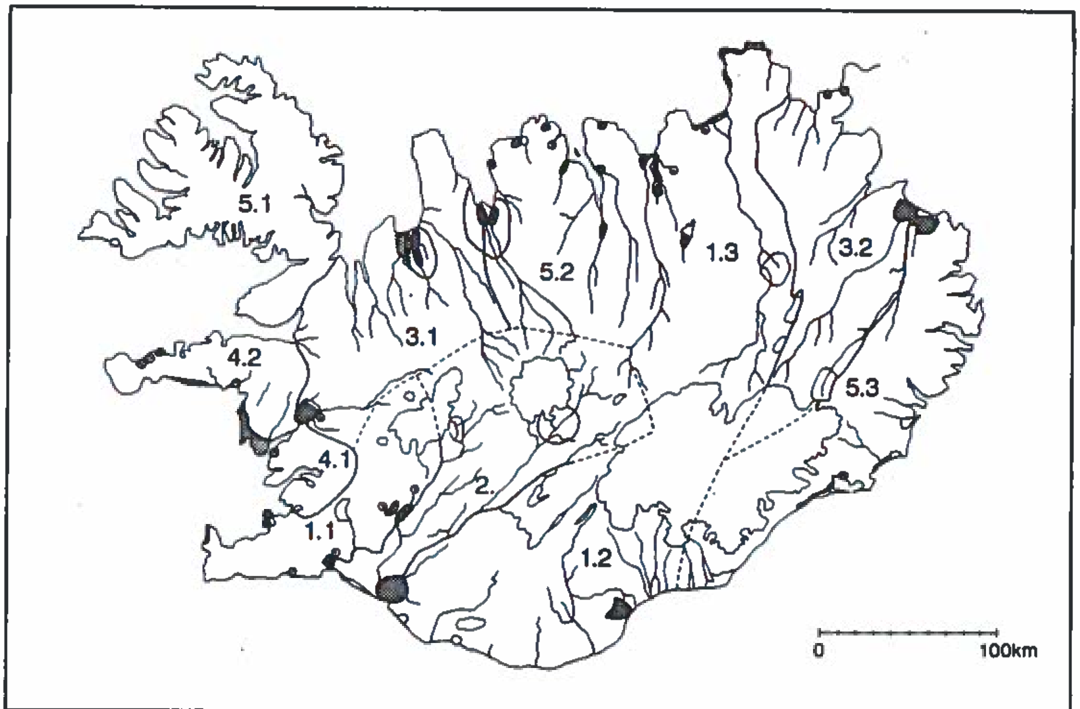

Fig. 2.1.1 Classification of Icelandic water systems. See text for a description of classification groups.

Palagonite formation

Waters of the younger palagonite formation are usually spring-fed, but those of the older are usually run-off water systems.

1. *Spring-fed systems of the younger palagonite formation.* These waters originate in springs. They are rich in chemicals and nutrients. These waters predominate in three areas of Iceland, 1.1 South-west, 1.2 South, and 1.3 North- east.

   The spring-fed streams are of two types: spring-fed streams with lakes near their origin and spring-fed streams without lake effects. The former are probably the most productive of all streams in Iceland. The organic production in the lakes provide drifting organic matter, whereas the latter are not as productive as the other spring--fed rivers, due to short retention time and little organic drift.

2. *Direct run-off systems of the older palagonite formation* (early Pleistocene basalt formation). These waters are in the south extending north of the large glaciers. Their catchment areas have various cover of vegetation and some are sparsely vegetated. Few lakes are in this area and many of the streams are mixed with glacial water. Many of the rivers have a considerable amount of spring-fed water in them, although they are classified as run-off waters.

Tertiary basalt formation
Waters of the tertiary basalt formation are usually run-off waters. They have low concentrations of dissolved ions and nutrients near their origins. These characteristics can change on their course towards the sea, with increasing amount of dissolved ions and nutrients further away from the origins. On the basis of this, these waters are divided into three different categories: run-off systems from the highland plateau, valley waters and direct run-off systems.

3. *Run-off systems with shallow lakes and wetland near the origins.* Water systems where shallow lakes and bogs increase the retention time of the water and makes the discharge more even. Their organic production is probably rather intensive and in many of them there is a great amount of drifting organic matter. These waters are in two main areas:

3.1 *Run-off waters in highland plateau north-west of Glaciers Langjökull and Hofsjökull.* Many of these rivers are the best salmon rivers in Iceland with over 40 % of all salmon caught in Iceland. The lakes in the highlands support large populations of arctic charr and rich bird life.

3.2 *Run-off waters in highland plateau in the East.* Good catches of salmon are in some of the rivers in these areas and the lakes support large populations of arctic charr.

4. *Valley waters.* Mainly run-off systems with relatively large deep lakes near origins. Water systems where water discharge is controlled by deep lakes. The origin of the water is precipitation in the mountains surrounding the lakes. These mountains often have some vegetation. Little is known about the chemical characteristics of these lakes, but they may be divided into two categories according to topography:

4.1 *Valley waters in the South-west.* Usually good salmon rivers which originate in large and productive lakes in the younger tertiary basalt formation.

4.2 *Valley waters at Snæfellsnes and Myrar (West).* Different origin, run-off and spring-fed. In the eastern part of the area, rivers originate from large lakes, often dammed by lava flows, but no lakes influence the rivers of the western part of the Snæfellsnes peninsula.

5. *Direct run-off systems on tertiary basalt, mainly originating on barren high ground.* The rivers and streams are usually short, running down steep hills, with little retention of the water and unfavourable conditions for life. They have little drift of organic matter, low and fluctuating temperatures, fluctuating discharge and are fast flowing. These rivers are unproductive.

5.1. *Direct run-off waters in North-west.* Short water systems in barren areas, without influence of other types of water systems. A few run-off systems with influence of shallow lakes and wetlands.

5.2 *Direct run-off waters in the Central North.* Often long water systems and sometimes mixed with glacial waters during the summer. They are usually without lakes near the origin of the river. Often there is little vegetation at the origin of the rivers. In the lowlands, lakes occur and their deltas usually are dominated by productive wetlands.

5.3 *Direct run-off waters in the East.* Usually run-off rivers without lakes near origin. Lowland lakes and vegetated deltas are usually not found.

Certain water systems and areas do not fit the above scheme. Outside this classification are:

6. *Glacial rivers, originating from glaciers.* They are found on all geological formations in Iceland. Their discharge is usually the greatest of all rivers in Iceland, their transparency is very low, hence primary production and density of benthic invertebrates is low. Many of them serve as pathways for migrating salmon, which spawns in the non-glacial tributaries.

7. *Other waters:* geothermal waters; coastal systems with a varying degree of influence from the sea, e.g. salt water, sea weed, calcium rich sand; flood plains, riparian marshes and deltas and upland spring-fed marshes.

In a publication by Rist (1990) on Iceland's drainage net, the length of most rivers are given, but streams are omitted. It is difficult to estimate the size category for inclusion to his list, but all these rivers are shown on maps of 1:100000 published by the Geodetic Institute of Iceland, but there are also running waters omitted, that are shown on these maps. According to his list, the total length of rivers in Iceland is 14 128 km. Of those glacial rivers are 1 489 km (Table 2.1.1). Direct run-off rivers in the mountainous highlands in the North-west, Central-north and East are 4 645 km, run-off rivers from the highlands are 3 520 km, spring-fed rivers 2 490 km and valley rivers 1 275 km.

Table 2.1.1 Length of Icelandic rivers, divided into water systems according to Gardarsson (1979).

	Length of clear rivers (km)	Length of glacial rivers (km)	Total length of rivers (km)
Spring-fed waters			
1.1	987	58	1045
1.2	955	607	1562
1.3	548	277	825
Total km	2409	942	3432
Direct run-off waters on the older palagonite	2709	166	875
Total km	709	166	875
Run-off waters in highland plateau			
3.1	1835	0	1835
3.2	1685	150	1835
Total km	3520	150	3670
Valley waters			
4.1	747	0	747
4.2	528	0	528
Total	1275	0	1275
Direct run-off waters			
5.1	1537	18	1555
5.2	2208	4	2212
5.3	901	209	1109
Total km	4645	231	4876
Grand total	12639	1489	14128

Characteristics of the invertebrate fauna
Iceland is an island, lying 63° 25' - 66° 32'N. About 60 % of the area is a highland plateau, above 400 m a.s.l. The lowlands of Iceland extend only a short distance inland. The lowland areas furthest from the coast are the valleys in the north, and east, and the southern lowlands reaching ca. 40 km inland. Birch grows on the island up to the altitude of 400 m a.s.l. and covered most of these areas before human settlement. Rivers on the island bear the characteristics of arctic and alpine rivers, their catchments lacking woodlands. Their fauna is mainly grazers (= scrapers) (Orthocladiinae and Diamesinae Chironomidae), feeding on the autochthonous production of benthic algae of the river (see Petersen et al. 1994). Exceptions are lake outlets, especially in the volcanic zone, where filter-feeders (mainly *Simulium vittatum*) feed on drifting particulate organic matter originating from the source lakes. Glacier rivers have much lower density of benthic invertebrates, mainly Diamesinae, and further downstream Orthocladiinae. The low transparency in glacial rivers obscures primary benthic production.

The isolation of Iceland in the Atlantic contributes to the low diversity of benthic fauna of rivers and elsewhere. Of the major invertebrate groups in freshwater, only a small portion of the benthic invertebrates found in Scandinavia occur in Iceland.

The best studied river in Iceland is the River Laxá, the effluent of Lake Myvatn. There the following numbers of invertebrate species have been recorded:

COELENTERATA: 1 species
BRYOZOA: 1 species
ANNELIDA: 7 species
MOLLUSCA:
Bivalvia 1 sp.
Gastropoda 1 sp.
ARTHROPODA
Crustacea several species drifting from the lake
Arachnida 1 sp
Insecta
<u>Plecoptera</u>: 1 species
<u>Trichoptera</u>: 4 species
<u>Coleoptera</u>: 1 species
<u>Diptera</u>: Tipulidae 2 spp; Simuliidae 1 sp; Chironomidae 29 spp; Empididae 1 sp; Muscidae 1 sp.

Impacts on streams
Impact on catchments, rivers and streams has occurred since human settlement in the 9th century. Erosion, mainly occurring in the highlands of Iceland, with the disappearance of woodlands. Moreover, erosion is probably the main impact on the water systems from the early settlement in the ninth century up till now.

Water systems have been changed, generally with negative environmental effects:

Hydroelectric power development often leads to negative impacts on water systems, with construction of dams.

Salmon ladders are often an ugly sight in the environment. Their ecological effect is unknown, but salmon reaching areas of rivers only occupied with brown trout, or without any fish populations, must have effect on other animal populations. Changes of river beds have also been made to make rivers more accessible to fish. Also, fish have been transported from one water system to another or from hatcheries to natural waters, without considering the consequences.

Gravel removal for road construction has been carried out in river beds of run-off rivers, even in good fishing rivers. It may look better in the landscape, but it has negative effects on the biota in the rivers.

Draining of wetlands and lowering of the ground water has been made to make grass fields and pastures, which has lead to disappearance of numerous bogs and lakes in the lowlands. Draining of wetlands makes the water systems simpler, with more fluctuations in discharge and chemical composition of the water. Use of fertilisers and as well as organic pollution from farming and aquaculture is probably increasing. Pollution from fish farming is increasing with increasing number of fish hatcheries and fish farms all over Iceland in the last decade.

Industry and urbanisation cause pollution of lowland waters (e.g. the warm rivers of the South-west and South), draining of land, filling and sometimes deepening of lakes. In urban areas, coastal lakes and river deltas have been filled up. Industry and urban areas also need ground water of good quality. Several hot and cold water springs have been used for this purpose. However, since most towns and villages are situated on the coast, these effects rarely affect rivers far from the sea.

2.1.2 Aim and legislation

The Water Act no. 15/1923, deals with the rights of landowners of rivers and lakes and their utilisation of water and other water resources on their properties. It states that it is not allowed to change river beds, course of running waters, and discharge, increasing or decreasing water level, make dams in rivers or flood water on someone else's land, without government's permit or special permission by other law. Changes in water level requires the constructor to set up a water level gauge to monitor water level.

The National Energy Authority surveys the country's sources of energy, their nature and conditions for utilisation thereof (The Energy Act no. 58/1967), which includes surveys of catchment areas, water courses and geothermal areas.

In 1932 legislation was passed in order to direct a greater proportion of fishing income to locations upstream, i.e. to the farmers inhabiting the valleys. The Act on Salmon and Trout Fishing was repeatedly altered (1934, 1957, 1970 and 1994) in order to improve salmon management. According to the Act on Salmon and Trout Fishing 76/1970, landowners along each salmon river are required to form a fishing association. These associations supervise fishing activities along their respective rivers. Associations either lease fishing rights to angling clubs or sell angling privileges directly to individuals. The associations are also obliged to practise fish management, i.e. "the protection of fish, improvement of its conditions for life, the importation of fish into fishing water, the easing of fish passage, fishing supervision and anything else which may be conductive to increase or maintenance of stock of fish". A comprehensive data collection system was established for angling catches on each river: an angling log is kept yearly and data on sex, length, weight, bait, site and date of capture of fish, and name of angler are recorded for each salmon caught. These records are returned to the Institute of Freshwater Fisheries each year.

The Nature Conservation Act no. 47/1971 is to ensure that the nature develops and evolves according to its own natural law. All construction, alteration of the nature and other human activities that may change the natural environment, needs evaluation of the Nature Conservation Council, and its approval in Nature Parks and Nature Reserves. If changes to the environment have occurred, which had not been accepted before by the Nature Conservation Council, the Council can order alterations to minimise the effect or order complete removal of the construction. In each county experts work on monitoring human impact on the environment.

The Conservation on Lake Myvatn and Laxá Act no. 36/1974 was set in order to conserve the Myvatn and Laxá, their catchment areas and their banks (200 m from the Laxá river on each side). According to the act, the Myvatn Research Station was established with the aim of being an advisory body regarding conservation in the area with regard to the Nature Conservation Council and the Ministry for the Environment. It has set up programmes to monitor changes in the biota of the lake and the river, to fulfil its obligations.

The Meteorological Office monitors the air pollution and pollution in precipitation (Act on the Meteorological Office of Iceland no. 30/1985).

The Hygiene and Public Health Act no. 81/1988 and Radiation Protection Act no. 117/1985 deals with pollution of air, land and water. The Minister for the Environment published Regulation on Pollution Control no. 48/1994 and later alterations no. 378/1994 and Regulation of Prevention of Oil Pollution from Land based Sources no. 35/1994, which state how these preventive measures should be carried out. The Regulation on Pollution Control covers pollution of water (ground water), air and land. In the regulation are included emission levels for pollutants and it implements EEC (EU) directives, which are in Annex XX of the EEA Agreement. The main rule is that pollution of rivers is not permitted without a prior permission from the local hygiene committee, the Environment and Food Agency of Iceland or the Ministry for the Environment. This is regularly implemented by the Environment and Food Agency of Iceland, local municipalities and Department of Pollution Control, Directorate of Shipping (Act on Directorate of Shipping no. 32/1986).

2.1.3 Monitoring

The Environment and Food Agency of Iceland (Hollustuvernd ríkisins) and Directorate of Shipping in Reykjavik and local municipalities are responsible for monitoring effluents from industry and urban areas. This is done on regional basis (each local municipality) and central control is with the Environment and Food Agency of Iceland, that provides expert advice in many cases. This monitoring is done by chemical analyses and monitoring of bacteria.

The catch of salmon in all rivers and brown trout and arctic charr in some rivers and lakes is monitored by the local fishing association and data collection and analyses are carried out by the Institute of Freshwater

Fisheries in Reykjavik. Yearly catch data are available for all rivers from 1971 and for some rivers back to 1933.

Invertebrate monitoring in rivers
To understand an ecosystem, it is necessary to collect information on different parameters over a long time. Most limnological studies are conducted over relatively short periods, often for only 2-3 years. Although such studies may show considerable variation between years, the study period is too short to assess population fluctuations. Long-term population studies in lakes and rivers all over the world are surprisingly few.

In studies on the Myvatn-Laxá ecosystems, the researches (mainly from the Institute of Biology, University of Iceland and the Myvatn Research Station) found it necessary to develop methods to monitor different invertebrate and vertebrate populations in the ecosystems. Monitoring studies in the River Laxá were carried out on water temperature, the quantity of seston, FPOM and number of Cyanobacteria and other bacteria in the water (fortnightly samples from May to September from 1987, less frequently earlier), the population sizes of midges (from 1977), number of ducks and duckling production (from 1975) and catch of brown trout (from 1973).

In 1977, when monitoring studies on invertebrate populations in the River Laxá and Lake Myvatn began, window traps were developed to catch flying insects and monitor populations of midges (Chironomidae) and blackflies (Simuliidae). By studying production of *Simulium vittatum* from 1977 to 1985 at the outlet and 4.5 km downstream, it was possible to test the relationship between the window trap catches and *S. vittatum* production. A highly significant positive correlation was found between the window trap catches and the production of *S. vittatum* at the two sites. The proportional numbers of different Chironomidae species found in traps coincided with their proportional numbers in benthic samples in Lake Myvatn in 1972 -74. The cost of analysing the trap catches is estimated to be less than 10 % of the cost of sorting benthic samples for production studies (See Gíslason 1994).

In 1989 a window trap was set up close to the outlet of Lake Svartárvatn, Northern Iceland to monitor insect populations in the lake and its effluent river. This year such traps have been set up along the glacial river Thjórsá and along a stream and a dike in Flói, in Southern Iceland.

2.1.4 Data handling and availability
Monitoring data regarding pollution, chemical analyses and bacteria counting are kept at the Environment and Food Agency of Iceland. Freshwater fish data at the Institute of Freshwater Fisheries, where they are annually published in their publications.

Data on invertebrate monitoring of River Laxá and on recently started monitoring at other sites are kept at the Institute of Biology, and published in international journals in relation to studies on other populations or as studies on these insect populations.

2.1.5 Stream quality today

In Iceland, stream quality is considered good and fresh water of sufficient purity for human consumption has been considered an easily available and inexpensive commodity. This is understandable in view of the low population density of 2.5 inhabitants per km^2, and that only about 2.5 % of the total population live in inland urban settlements, with most of the population living along the coast, high precipitation, averaging 2000 mm $year^{-1}$ (local variation 400 - 4000 mm $year^{-1}$), small farming land (1.4 % of total area) and small areas built up (0.1 % of total area).

It is estimated that 6 400 tonnes nitrogen (N) and 5 000 tonnes phosphorus (P) sustain the annual loading which enter the sea via rivers. In addition to that about 3 400 tonnes N and 130 tonnes P from agriculture enters rivers (Gunnar Steinn Jónsson pers. comm.). However, nitrogen and phosphorus from sewage, fish processing factories and fish farms (about 4 650 tonnes N and 770 tonnes P annually) enter mainly directly into the sea, without flowing first through freshwater systems. In addition to that, iron (Fe) probably enters the lowland rivers, due to draining of lowland bogs and wetlands.

Though not much work has been done on the effect of pollution on benthic invertebrates, one such study exists on two rivers in Southwest Iceland (Gíslason 1979).

Catchment areas of rivers has been altered severely by deforestation, erosion and draining of bogs and wetlands. It is estimated that only about 14 500 km^2 has a vegetation cover of over 75 % and 37 300 km^2 are without vegetation (glaciers and freshwaters excluded) (Landmælingar Islands 1993). In the southern lowlands, only 2.5 - 3 % of the original wetlands are still intact (Thórhallsdóttir 1994)

Several rivers have been altered by damming for hydroelectric production, especially major lake outlets, both spring-fed and valley lakes and glacial rivers. Numerous fish ways have been constructed in salmon rivers and river-beds have been altered by road and bridge construction.

In general, water quality is good, but natural conditions of running waters have been changed by changing their catchment areas, especially by changing the type of vegetation in their catchments or by soil erosion.

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2.2 Finland

2.2.1 Background: major impacts on Finnish rivers

In Finland, rivers are distinguished from brooks on the basis of The Watercourse Act (ratified on May 19, 1961 but subject to continuous change because of additional governmental ordinances), in which all channels that are more than 2 $m^3 s^{-1}$ (MQ) are regarded as rivers. In addition to these also smaller channels, where, with the exception of the driest period, rowing traffic is possible, are regarded as rivers. At present it is possible to calculate the number of brooks and rivers, and their regional division, by means of a base map system (scale 1:20 000). In future, however, it will be possible to calculate the land use qualities and the watercourse properties of all Finnish catchment areas by means of a digital map-reading system (LANDSAT-images). The system is being developed by the National Board of Waters and the Environment (NBWE, on the 1st of March 1995 onwards the Finnish Environmental Agency), and the first catchment area (Vantaanjoki, south coast, ca 1700 km^2) is used as a test area. Rivers (> 1 $m^3 s^{-1}$, total length 20 500 km) have been calculated to occur in Finland as follows:

Average discharge (MQ, $m^3 s^{-1}$)	Total length (km)
> 100	1500
10-100	4500
1-10	14500

As a consequence of efficient sewage treatment measures that have been implemented for municipalities and industries since the 1970's, the problems of surface water quality are increasingly concerned with the effects of agriculture and forestry on non-point loading. Long-term monitoring is required to solve this problem. For instance, for monitoring agricultural effects this will consist of a programme monitoring the development and use of more ecological cultivation methods. Regarding peatland areas which cover about one third of Finland's total area, more than half (over 70% of the peatlands in southern Finland) have already been drained. Loading from these areas is hard to control and requires laborious measures. The regulation of water systems and the cleaning of river channels have changed the original flow of the Finnish river systems to a great extent, and it has prevented the tending operation of valuable migratory fish species. Only a few are left of the rivers that flow into the Baltic Sea and that hold species of salmon, and it is necessary to sustain the species by intensive planting.

2.2.2 Aim and Legislation

The above-mentioned Watercourse Act, that originally mainly regulated the use of the watercourses (pollution of the watercourses, constructions), is now increasingly concentrating on water protection. In Finland there are three Water Rights Courts (Helsinki in Western Finland, Kuopio in Eastern Finland and Oulu in Northern Finland) and limnologically educated persons participate in their decision-making. All projects that impair or change watercourses of some size require permission from the water rights court. The permission usually includes a statutory monitoring programme for the watercourse, which is to be carried out in a way accepted by the water authorities (the Water and Environment Districts, the Fishing Districts). Biological indicators, often macroinvertebrates, have been included in these programmes. When granting permission, the Water Rights Court considers the value of the watercourse for different users (comparison of interests), and also to restrictions of other regulations (species under protection, for instance *Margaritifera*).

When the Watercourse Act was implemented the industries and municipalities founded water protection associations with laboratories throughout the country to be able to carry out monitoring. These programmes, as well as the statutory monitoring carried out by consultants, are subject to public supervision (NBWE), and the laboratories are inspected on a regular basis. In addition to NBWE's field of responsibility, a general obligation of environmental monitoring has recently been added which will in the next few years be expanded to a monitoring programme for the water systems.

In 1987, parliament enacted a Protection Act concerning riffles, through which 53 watercourses, or parts of watercourses, are protected against the construction of new hydroelectric power stations. The reasons for protection have for instance been cultural history or protection of the fish fauna. In addition, two other rivers (Ounasjoki [1984] and Kyrönjoki [1991]) have been protected by special regulations. The transboundary water commissions have, because of this agreement, been able to prevent the construction of power stations at the boundary rivers (Tornionjoki and Tenojoki).

2.2.3 Monitoring

Regional monitoring of stream quality

Traditionally, the NBWE:s regional monitoring has emphasized on physico-chemical analyses. The sampling network is extensive. In some areas macroinvertebrates have been included in the monitoring programmes, often because they are lacking in the statutory monitoring programmes. In the 1980's an extensive investigation was carried out on the suitability of macroinvertebrates as environmental indicators (Nyman et al. 1986). In this study, some 300 samples were taken from 10 rivers and 72 riffles, and identified to the species level. Indices and ordination methods were used when examining the results. This project is important when developing macroinvertebrate monitoring programmes in Finland.

In 1989, the Finnish-Norwegian Transboundary Water Commission launched an extensive research programme at Tenojoki. The programme, which includes monitoring of macroinvertebrates, investigates the general state of the river and its natural value (Lax et al. 1993). The intention is to repeat the monitoring every four or five years. The sampling sites are riffles, and apart from the kick-net method, colonization methods have also been used. When examining the results, ordination methods (DCA) and indices (e.g. BMWP) are used.

In southern and central Finland, water protection associations have used macroinvertebrates in connection with monitoring the state of several rivers. The monitoring will be repeated every 3 - 7 years, and concerns both sections of riffles and slowly flowing sections. The sampling methods used are core or Ekman samples on soft bottoms and the standardized "kick-net" method (SFS 5077) in riffles. When examining the results the ROCI-index (River Oligochaeta-Chironomidae Index, Paasivirta (1990)) has been applied to the slowly flowing sections.

National monitoring of stream quality
As the Water and Environment Administration is being reformed, the environmental expert knowledge of the NBWE's districts and of the county administrative boards will be pooled into regional environmental centres in 1995. Through the central administrative board, which directs the centres' work, national monitoring of environmental conditions will be carried out according to governmental decrees. The monitoring comprehends seven subprogrammes: integrated monitoring, terrestrial ecology, hydrology, water condition, airborne loading, bioaccumulating compounds, data registers. At present the costs are about 40 million Fmk. a year.

The macroinvertebrate monitoring programme of rivers is prepared for 1994 (NBWE's projects 5S526 and 5S169: Biological Monitoring of Inland Waters). The choice of sampling sites will be made on the basis of a national network of observation stations for water quality (60 sampling stations in all). Of these stations probably around 15-20 will be chosen for the first stage of the monitoring.

The purpose of the monitoring can be divided into four parts:

1. General state of the river. Strain on the Baltic Sea. (first stage)
2. Biotope diversity. Sampling sites and the habitat diversity of the nearby river channel (a section of about 2 km from the sampling station).
3. Biodiversity. Species diversity. Endangered species.
4. Acidification. River areas threatened by acidification and areas of reference.

The sampling method used is the kick-net method (SFS 5077) and the sampling will begin in autumn 1995. From each station the main habitat (stone, gravel, moss, shore) will be included in the investigation. In addition, the monitoring of bioaccumulating compounds is incorporated in the sampling of zoobenthic material.

2.2.4 Data handling and availability
The NBWE is using a diversified and extensive data register that is easy to use and available to all employees. The file consists of several registers

(hydrology, water quality, water system maps, hydrobiology). The hydrobiological register is already completed as regards phytoplankton (8 000 samples) and development is proceeding and will include periphyton and zoobenthic information in the register (monitoring of lakes and later of rivers). Through graphic and statistic programmes (SAS, EXCEL) employees can benefit from the information of the register.

2.2.5 Stream quality today

Traditionally, since the 1960's, an extensive monitoring system for water quality has been established in Finland (NBWE's local districts, 13 in all). In co-operation with the industries and the municipalities about 70 000 samples are collected each year from more than 10 000 sites, and 600 000 analyses are performed. Information gathered by NBWE has been summarized in the form of maps, where the water condition can be shown by means of different colours. Feasibility classifications of this kind have been made for the watercourses according to their use (general classification, classification for raw waters, recreational use and fishing grounds).

According to NBWE's general classification barely half of the river systems have a water quality that is 'good' or 'excellent'. Only about 3 % are considered 'poor' and the rest are classified as 'satisfactory' or 'passable'. However, the water quality of the rivers usually deteriorates not so much because of pollution but because of a high content of humus. Because of this the classification is not a measure of the natural state of the watercourse. As mentioned, the state of the Finnish rivers has even improved, especially since the 1970's, as a result of sewage water treatment measures.

2.2.6 References

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2.3 Sweden

2.3.1 Background: major impacts on Swedish inland surface waters

Sweden has a total of about 300 000 km of streams and rivers, and approximately 9 % of Sweden's surface is covered by lakes with a surface area greater than 10 ha (ca. 85 000 lakes). Despite the large number and diversity of lakes and watercourses in Sweden, over the last 100 years a number of systems have experienced some form of water regulation. For example, up until the mid-1900's the water level in a large number of lakes was regulated by ditching or drainage (lowering of the water-level) activities (Bernes and Grundsten 1991). Indeed, the water-level in some 17 000 lakes was lowered between 1881 and 1933 (op cit.). Similarly, the majority of Sweden's large rivers (ca. 70 %) have been greatly affected by the construction of hydroelectric power plants.

Other major environmental problems affecting Swedish inland surface waters include organic pollution, eutrophication, and acidification. In the early 1960's discharges of organic matter were estimated to be some 700 000 tonnes per year, measured as BOD_7 (SEPA 1993, p. 108). However, since then discharges of organic matter by forestry industries (the dominating source) have decreased to 130 000 tonnes per year. Further, in the last 30 years, industrial discharges of organic matter also have decreased considerably, and on a national level this form of anthropogenic stress is no longer considered as a major threat to aquatic biodiversity.

Likewise, in the last three decades large financial investments have been made towards reducing discharges of municipal sewage phosphorus to inland and coastal waters. For example, all densely populated areas have both chemical and biological sewage treatment facilities, often resulting in a 90 to 95 % reduction P, and organic and suspended materials. At present, P discharges from sparsely populated areas is estimated to be ca. 500 to 700 tonnes per year. Improved agricultural practices such as restrictions on the use and storage of fertilizers and autumn- and winter cultivation practices in southern Sweden should decrease P loading even more. Although on a national scale P discharges are not considered as a major environmental problem, at the regional level P discharges may adversely affect the biodiversity of streams and lakes, resulting in eutrophication and late-summer blooms of "nuisance" algae.

Although pollution by organic matter and discharges of phosphorus are not considered as major threats to inland surface water biodiversity on a national level, since the late 1960's acidification of terrestrial and aquatic ecosystems is considered as a major national and international environmental problem. For example, of the roughly 85 000 lakes in Sweden, some 38 500 (ca. 45 %) have a winter pH of less than 6, and over 6 000 have a pH of less than 5. It has been estimated that about 21 500 lakes have an alkalinity below 50 µeq/L, and as a result of this low buffering capacity many are expected to have depauperate fauna and flora (Bernes 1991). Similarly, macroinvertebrate surveys of watercourses suggest that about 40 %, or some 120 000 km of Swedish rivers and streams are adversely affected by acidification.

2.3.2 Aim and legislation

One of the overall objectives for the management of Sweden's freshwater resources is that "*Native species should occur in stable, well-balanced populations, and pollution should not limit the value of water as a fisheries, recreation, and raw water resource*" (SEPA 1990). Physico-chemical water quality criteria have been established (SEPA 1991a), and are frequently used in the assessment of surface water quality at national and regional levels.

A number of laws and regulations govern the quality of inland surface waters. Listed below, in chronological order, are a number of laws which are related to pollution problems of inland surface waters. English translations are given when available.

(1) Nature Conservation Act (1964:822), last revised (1993:1613).
(2) Environmental Protection Act (1969:387), last revised (1993:1543).
(3) Lag (1970;:244) om allmänna vatten- och avloppsanläggningar, last revised (1993:417).
(4) Lag (1971:1154) om förbud mot dumpning av avfall i vatten. Last revised (1993:578).
(5) The Waste and Disposal Act (1979:596), last revised (1993:416).
(6) Hälsoskyddslag (1982:1080), last revised (1992:1544).
(7) Vattenlag (1983:291), last revised (1993:1416).
(8) Act on Chemical Products (1985:426), last revised (1992:1204).
(9) Ordinance on Pesticides (1985:836).
(10) Förordning om vissa hälso och miljöfarliga produkter (1985:840), last revised (1993:1271).
(11) Plan- och bygglag (1987:10), last revised (1993:911).
(12) Act on the Management of natural resources etc. (1987:12), last revised (1993:189).
(13) Environmental Protection Ordinance (1989:364), last revised (1993:1265).
(14) Brottsbalk, last revised (1993:207).

Three laws which are frequently used in the management of freshwaters are: (i) Nature Conservation Act, (ii) Environment Protection Act, and (iii) Vattenlagen. The Nature Conservation Act governs the protection of national parks and reserves. The Environment Protection Act and Vattenlagen, on the other hand, restrict pollution and exploitation of natural resources. The Environment Protection Act governs discharges of anthropogenic wastes to lakes and watercourses. In short, the law prohibits the discharge of untreated waste water (e.g. sewage) to surface waters. The law is frequently used to impose restrictions on industrial discharges, as well as implement programmes for monitoring of surface water quality. Vattenlagen is used in questions regarding regulation of watercourses (construction of hydroelectric facilities), ditching, and even the use of groundwater reserves.

2.3.3 Monitoring

Regional monitoring programmes

Regional monitoring programmes have been ongoing in some areas since the early 1950's. However, prior to the 1980's these programmes were of varying quality, with little effort devoted to quality control. To improve regional monitoring programmes and enhance their uniformity and usefulness, in 1986 the Swedish Environmental Protection Agency (SEPA) issued general guidelines on local monitoring of freshwater systems. These guidelines recommended that monitoring be built around a basic programme. For example, in synoptic studies samples should be taken from reference areas as well as perturbed sites, and long-term studies should take into consideration seasonal variability. A minimum, base water quality programme should be performed, with specific pollution situations being supplemented with additional chemical and biological analyses. SEPA recommended standardized methodology for chemical and biological analyses. To date, much of Sweden is now covered by regional environmental monitoring. To allow for ease of access to data collected from this monitoring network, the use of a joint database (KRUT) was implemented in the late 1980's.

Table 2.3.1: The total number of sites monitored by the SRK (Regionally Integrated Water Quality Programme), and the number of sites analysed for water and sediment chemistry and biological variables (Löfgren 1993).

	Number of sites	
	Lakes	Watercourses
Total	672	1539
Water Chemistry	468	1134
Sediment chemistry	22	22
Biological variables:	504	602
Phytoplankton	233	0
Periphyton	51	155
Macrophytes	27	54
Zooplankton	102	0
Macroinvertebrates	379	412
Fish	63	15

Regional freshwater monitoring programmes are mainly co-ordinated under the auspices of the "Regionally Integrated Water Quality Programme" (SRK). Generally, the various SRK-programmes monitor water quality by physico-chemical and biological studies in lakes and watercourses within a single watershed. Most programmes are established in Sweden's most perturbed areas, namely in the southern and middle parts of the country. The drainage from approximately 75 % of Sweden's total land area is monitored by SRK, at a yearly cost of about 23 million

SEK. Approximately 670 lake and 1 500 watercourse sites are included in the Regionally Integrated Water Quality Programme (Table 2.3.1).

Biological studies such as macroinvertebrates and phytoplankton are commonly performed (Löfgren 1993). For example, 68 % of stream and 75 % of lake studies selected macroinvertebrates as biological metrics, followed by phytoplankton (46 % lakes), and periphyton (26 % streams and 10 % lakes). Sampling frequency was found to vary considerably among the various monitoring programmes and indicators selected. Sampling of lake macroinvertebrates averaged 0.6 yr^{-1} (min = 0.2, max = 4), with 13 of the 33 programmes using a frequency of once annually. Sampling frequency of stream macroinvertebrates was similar to that of lakes, average 0.7 yr^{-1} (min = 0.2, max = 12), however, annual sampling was more frequently employed (21 of the 35 programmes, or 60 %, had a sampling frequency of once yearly compared with 39 % of lake monitoring programmes).

National monitoring programmes

Initiated in the early 1960's, freshwater environmental monitoring in Sweden uses a combination of both physico-chemical and biological indicators (Table 2.3.2).

Table 2.3.2: The number of subprogrammes constituting the present national freshwater environmental monitoring programme.

	Number of sites		Parameter(s)[a]
	Lakes	Watercourses	
PMK1, Material transport to marine areas		49	P/C
PMK2, Material transport to Sweden's 4 great lakes		35	P/C
PM K3, Water quality of Sweden's 4 great lakes	4		P/C, B
PMK4, Weathering within selected catchment areas		39	P/C
PMK5, Integrated monitoring of PMK reference areas[b]		5	P/C, B
PMK6, Chemical monitoring of 190 reference lakes	190		P/C
PMK7, Integrated monitoring of lime-reference lakes	26		P/C, B
PMK8, Integrated monitoring of limed lakes and streams	14	7	P/C, B
PMK9 , National Lake Survey[c]	4000		P/C

a) P/C = physico-chemical and B = biological monitoring

b) PMK5 is an integrated terrestrial and aquatic monitoring programme of 18 small catchment areas.

c) 1990's NLS included some 4000 randomly selected lakes

Over the years, several subprogrammes have been implemented to monitor and survey inland surface water quality (SEPA 1991b). Chemical monitoring subprogrammes consist of: (i) discharges to Sweden's coastal waters (49 river mouths) and upstream weathering sites (n = 39), (ii) inflows and outflows of Sweden's four large lakes (n = 35 stations), and (iii) monitoring of 190 ecoregion, reference lakes (start 1983 - 84). Moreover, using a combination of physico-chemical and biological indicators, the water quality of inland lakes/streams are monitored in several subprogrammes including: (i) Sweden's four great lakes (start mid to late 1960's and early 1970's), (ii) 26 ecoregion-representative, temporal reference lakes (start 1988), (iii) temporal monitoring of 5 streams (start 1985 to 1987) as part of the subprogramme "Integrated monitoring of 18 small catchment areas", and (iv) effect follow-up of 14 limed lakes and 7 streams (start 1989). In addition, a national lake survey of surface water quality is performed every fifth year, and in the last survey (1990) some 4 000 randomly selected lakes were sampled for winter water chemistry and 1 000 of these included analysis of nutrient levels.

Although many of the early monitoring programmes consisted for the most part of the use of chemical indicators (the exception being biological monitoring of Sweden's 4 great lakes), more recent endeavours, such as the 26 reference lake and liming-effects follow-up subprogrammes mentioned above, have emphasised the use of biological indicators in the assessment of water quality. Furthermore, greater emphasis has been placed on the use of biological indicators in the recently revised national freshwater monitoring programme (sensu Wiederholm et al. 1992).

A brief review of the recently revised freshwater monitoring programme in Sweden (FEMS) - Wiederholm et al. (1992) have proposed a nested design for the national freshwater monitoring programme with three levels (Fig. 2.3.1).

Tier 1 National lake (NLS) and stream (NSS) surveys to be conducted in the autumn once every fifth year (NLS = 1000 and NSS = 300 sites). Indicators of the national surveys will consist of both physico-chemical and biological indicators: water column chemistry and littoral macroinvertebrates of lakes and water chemistry and riffle macroinvertebrates of streams.

Tier 2 Annual monitoring of physico-chemical and biological (profundal and littoral macroinvertebrates and August phytoplankton of lakes and riffle fauna of streams) indicators of 100 temporal reference lakes (TRLs) and 50 temporal reference streams (TRSs).

Tier 3 Integrated, annual monitoring of physico-chemical and biological indicators of 15 integrated, trophic-level, temporal reference lakes (ITRLs) and streams (ITRSs).

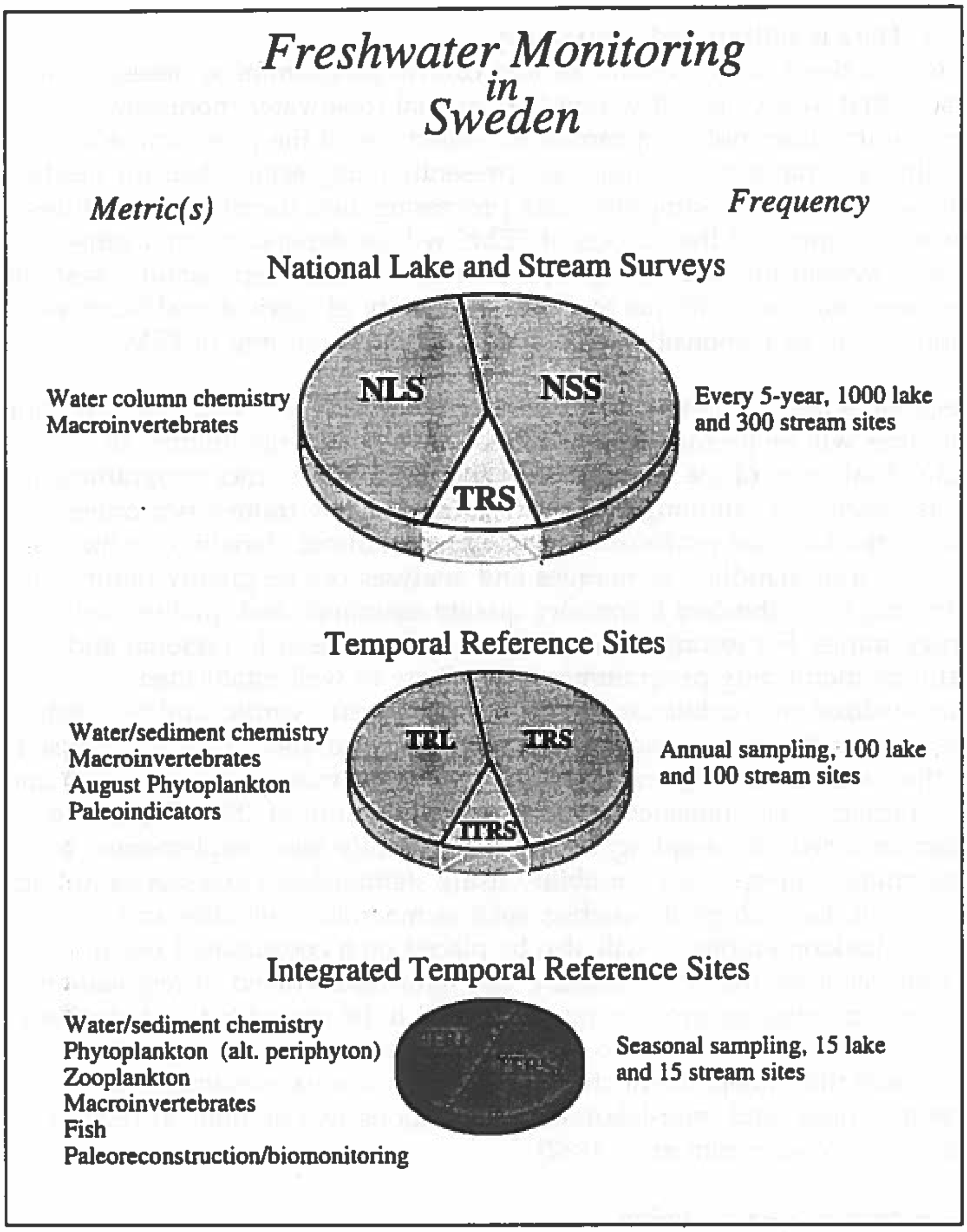

Figure 2.3.1: The revised freshwater monitoring programme in Sweden.

As mentioned, emphasis in the revised national monitoring programme is placed on the use of biological indicators in monitoring anthropogenic effects of freshwater quality. However, in contrast to the well developed and widely established use of chemical criteria for the classification of surface water quality (SEPA 1991b), the use of biological indicators and predictive algorithms is poorly developed in Sweden. A project has recently been implemented towards the development of biological criteria for classifying lake/stream quality. Predictive models and classification schemes are being established for: (i) lake and stream macroinvertebrate, fish and macrophyte species assemblages and (ii) lake phytoplankton communities.

2.3.4 Data handling and availability

A well-defined quality assurance and control programme is necessary to insure that data collected within the national freshwater monitoring programme does not compromise the objectives of the programme(s). Quality assurance programmes are presently being established for FEMS, and will encompass sampling, data processing, and handling procedures. Moreover, much of the success of FEMS will be dependent on a satisfactory system for data storage and access. A media-responsibility systems has been adopted, with the Swedish University of Agricultural Sciences proposed to be responsible for data storage and handling of FEMS.

Regional-scale sampling will be necessary for much of FEMS. As sampling activities will be performed for the most part by a large number of individuals, one of the main goals of the quality assurance programme is to ascertain that sampling efforts are carried out by trained personnel using standardized protocols. Measurement induced variability which is derived from handling techniques and analyses can be greatly reduced by adhering to established laboratory quality assurance and quality control programmes. For example, sampling procedures used in regional and national monitoring programmes will adhere to well-established, standardized methodologies such as international, Nordic, and Swedish standard methods. A handbook describing the sampling procedures used in the national and regional monitoring programmes is in preparation and is expected to be published by SEPA in the autumn of 1994. Regarding macroinvertebrate sampling, a study has recently been implemented to determine inter-operator variability using standardized kick-net sampling. Moreover, for biological variables such as macroinvertebrates and phytoplankton emphasis will also be placed on a coordinated use of taxonomic keys and nomenclature. Laboratories involved in regional and national monitoring programmes will need to be accredited and certified by SWEDAC (Swedish Board for Technical Accreditation). It has been proposed that independent checks on species counts, weights, and identifications, and inter-laboratory calibrations will be done at regular intervals (Wiederholm et al. 1992).

2.3.5 Stream quality today

To date, benthic macroinvertebrates are collected from only 5 streams as part of the national freshwater monitoring programme. However, as mentioned above, the revised programme (FEMS) consists of a nested design, with national surveys of 300 watercourses to be conducted every fifth year, and annual monitoring of 50 temporal reference streams (including 15 integrated, temporal reference streams). In the latter subprogramme, 15 ITRSs, the effects of trophic-level interactions on indicator metrics will be studied.

Although the present national monitoring programme has not emphasised the use of biological indicators (e.g. macroinvertebrates) in monitoring the biodiversity of inland waters, a number of stream surveys have been conducted by SEPA through research grants. For example, a consultant frequently employed by SEPA has surveyed some 4000 streams for macroinvertebrates, and classified sites according to the presence/absence of indicator taxa (Lingdell and Engblom 1990). Relying for the most part on mayfly and crustacean indicator taxa, the authors showed that taxa which are known to be sensitive to acidification were found at ca. 60 % of the sites sampled, whereas at about 25 % of the sites only acid-tolerant taxa were collected. Moreover, the authors argued that approximately 20 % of Sweden's 85000 lakes are affected by acidification. A large percentage (74 %) of the sites surveyed had taxa which are known to be sensitive to organic pollution, lending support to the argument that acidification is a more serious threat to aquatic biodiversity in Sweden.

Malmqvist and Mäki (1994) recently showed that variability of macroinvertebrate communities from 60 riffle sites in streams in northern Sweden was correlated with drainage area, elevation, the presence of macrophytes, and water quality parameters such as alkalinity, water colour, and phosphate. Classification (TWINSPAN) resulted in eight community types, with stream size, chemical conditions and algae appearing as strong determinants of community structure. Multiple regression showed that taxon richness was best predicted ($R^2 = 0.46$) by drainage area, amount of organic matter, and discharge.

Moreover, a large survey of stream habitat quality was recently conducted in northern Sweden (Degerman et al. in prep.). Some 1129 stream sites were surveyed using macroinvertebrate indicators to assess stream quality. Some 1 226 samples were collected between 1989 to 1992, according to Lingdell and Engblom (1991). In brief, 30 kick-net samples were collected along a 50 m stream reach with a handnet (diameter 16 cm, mesh size 1 mm). Each sample consisted of about 0.2 m^2 of stream bottom and samples were taken after disturbing the substratum for 5 seconds. All 30 samples per site were pooled, and preserved in 70 % ethanol. The data are presently being evaluated, and the final report is expected to be published by the end of the year.

Liming remediation measures - The allocation of funding for "acidification counter measures" has gradually increased since the mid-1970's, and at present between 150 and 200 million SEK are annually spent on liming activities. In 1990 alone, some 200 000 tonnes of limestone was applied to aquatic and terrestrial ecosystems to counteract the effects of acidification (Bernes 1991). For 1994, a liming budget of about 200 million SEK is expected, with about 20 million kronor of this funding allocated for municipal administrative costs and chemical and biological effect follow-up programmes. To date, some 6 700 lakes and over 6 000 stream km have been limed (Svenson 1994).

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2.4 Norway

2.4.1 Background: major impact on Norwegian streams

Norway has numerous small and large streams draining the different ecoregions within the country. Clear-water, nutrient-poor streams predominate, however, in the forested areas of south-eastern Norway streams are often affected by humic substances.

In Norway, knowledge of many freshwater macroinvertebrate groups and the geographical distribution of individual taxon is still in an inventory stage (Nøst et al 1986). However, for some invertebrate groups (such as snails, stoneflies and mayflies) species distribution patterns are fairly well known (Økland 1990, Lillehammer 1988).

The most severe pollution in Norwegian watersheds is acidification from long range transported pollution. Streams particularly in the south and west of Norway are severely affected by acid rain. In large areas of southern Norway fish are absent and invertebrate communities (both fauna and flora) are seriously altered. About 70 % of the fish populations in these areas are absent or threatened by extinction.

In some parts of the country extensive mining has occurred in the recent past or in some instances is still ongoing. Old metal mines may leak considerable amounts of heavy metals to streams draining from mining areas, often deleteriously effecting stream communities.

Agricultural areas cover some 3.3 % of the country. Streams in rural areas have been polluted by sewage and runoff from agricultural activities. In some intensively farmed and urban areas this is still a problem, albeit mostly local. Today most sewage is treated by sewage treatment plants, resulting in less loading of organic matter and nutrients from point sources to streams.

Pollution control authorities and users of the surface water are in need of information on the pollution situation and the water quality of the water resources. As a result of this need for the dissemination of information, The Norwegian Institute for Water Resource (NIVA) and the Norwegian State Pollution Control Authority (SFT) developed a system for water quality classification. The system distinguishes between 6 different kinds of observed pollution effects: (1) eutrophication, (2) organic matter (sewage, pulp industry), (3) acidification (acid rain), (4) toxic effects (metals, micro organic pollutants), (5) particles, and (6) faecal (sewage) bacteria (Holtan & Rosland 1992).

The state of pollution has most often been described using chemical parameters. However, in most cases the information on biological effects of the pollution are equally or more important. Biological methods are essential for detecting impairments on aquatic life and assessing their severity. Further, biological methods integrate the water quality over a longer period and reflect the general ecological condition of the streams.

Macroinvertebrates are the most frequently used biological parameter in monitoring Norwegian streams. They have been successfully used in monitoring acidification, heavy metal pollution, eutrophication/organic pollution, particle pollution and combinations of different types of pollution.Acidification is monitored using the Raddum index (Raddum et al. 1988) and a modification of this index (NIVA/SFT, Bækken and Aanes 1990). A general description of the use of macroinvertebrates in water quality classification according to the different kinds of pollution was given by Aanes and Bækken (1989)

In designing monitoring programmes, the most prevalent cause of pollution has dominated the designing of monitoring programmes. Thus, in Norway, the main monitoring activity has been connected to effects of acidification, heavy metal pollution from mines, effects of eutrophication and organic matter and, in a few cases, inorganic particles. In addition, some streams regulated for generating electric power have been monitored for number of years. As the importance of local pollution from industry, sewage, agriculture is decreasing, the effects of the long range, transboundary pollutants are becoming a more serious factor to be considered in monitoring programmes.

The majority of stream monitoring programmes have been carried out by the applied research institutions NIVA, NINA, and the LFI- institutions (Laboratory for Freshwater Ecology and Inland Fisheries) at the Universities in Bergen, Oslo and Trondheim. However, often some form of monitoring is also being done by a number of other institutions. Because of the complex institutional structure it is difficult to know the exact extent of monitoring or the resources put into it.

2.4.2 Aim and legislation

The legislation for protection of water from pollution of June 26, 1974 regulates the uses of water resources in Norway and gives guidelines for confronting pollution. § 1 states the aim as "protect ground water, watersheds and sea areas against pollution, and to reduce the present pollution, in particular with respect to health and well-being of human beings and animals, and to accomplish an effective protection of nature and landscape". The first proposal on a national programme for monitoring water quality was presented by NIVA in 1976 (Samdal 1976). The quoted law was later included in the Pollution Act from 1981.

Monitoring activity as such is not regulated by law. However, it is stated in "Stortingsmelding nr.107 1974-75" from the Norwegian Ministry of Environment that monitoring is needed to control the effects of pollution changes. Both central and local authorities are presently operating monitoring programmes. The State Pollution Control Authority (SFT) administrates and controls the main monitoring programmes connected to pollution control. Table 2.4.1 lists current laws dealing with streams and freshwater fauna.

Table 2.4.1: Current laws dealing with streams and water uses.

	stream flow	water quality	freshwater fauna
Lov om vassdragene 1940 Act relating to Water Resources	x		x
Lov om vassdragsreguleringer 1917 Act relating to Regulation of Watercourses	x		x
Lov om laksefisk og innlandsfisk 1992 Act relating to Salmonids and Freshwater fish	(x)	(x)	x
Plan og bygningsloven 1985 The Planning og Building Act	x		x
Forurensningsloven 1981 The Act of Pollution		x	x
Lov om naturvern 1970 The Act of Nature Conservation		(x)	x

2.4.3 Monitoring

Regional monitoring

Sampling and handling procedures used in local and regional monitoring of macroinvertebrates in streams are to some degree standardised. The wide range of different kinds of investigations, and different institutions, in which the macroinvertebrate fauna have been applied have, unfortunately, resulted in slightly different ways of sampling and handling the samples. Table 2.4.2 shows some of the main equipment and procedures used by the main institutions. In most cases the main principles of sampling, sorting, counting and assessment of data are similar. It is noted that even when standards do exist, they are not always used.

Selection of sampling sites

When selecting sampling sites in a monitoring programme, some criteria should be fulfilled. The sampling site should be representative of a given stream reach. However, preferably moderately flowing reaches with stone/gravel bottom, should be selected. Tributaries, point sources, mixing etc., should be taken into consideration.

Sampling, sorting procedures

Sampling is undertaken using a standard handnet according to Norwegian Standard 4719 or some handnet quite similar to the standard. The mesh sizes used are 250 or 500 µm. Sorting, counting and identification procedures may differ between laboratories. The standard handnet has an opening 25 cm wide, the two vertical parallel sides 25 cm. The kick-sampling method is applicable in water depths less than 1 m, in moderately flowing streams, and in fast flowing streams at lower depths.

Table 2.4.2: Main procedures used by some Norwegian institutions when monitoring streams using qualitative (semi-quantitative) macroinvertebrate methods.

Inst.	Sampling	Handling of sample	Assessment of data
NIVA	Qualitative: Kick sample, Handnet; Norwegian Standard (NS4719) 25 x 25 cm, 250/500 µm mesh size. 3 X 1 minute of sampling according to NS. Autumn/spring (summer)	Preserved in 70% ethanol, big samples are sub sampled before counting under microscope (12X). Regularly mayflies, stoneflies, caddisflies are identified to species. Other individuals to different taxa-levels. Data stored in a local database. Available to the institution	Presented as tables and figures. Colour codes. Assessment based on species list, the presence of other taxa and relative abundance.
NINA	Qualitative: Kick sample, Handnet; Norwegian Standard (NS4719) 25 x 25 cm, 250 µm mesh size. 5 minutes or less depending on animal density. Autumn/(spring)	Preserved in 70% ethanol, big samples are sub sampled before counting under a microscope (12X). Regularly mayflies, stoneflies, caddisflies are identified to species. Other individuals to different taxa-levels. Data stored in local database. Available to the institution.	Presented as tables and figures. Assessment based on species list, other taxa and relative abundance.
LFI Bergen	Qualitative: Kick sample, Handnet; Norwegian Standard (NS4719) 25 x 25 cm, 250 µm mesh size. Sampling according to individual judgement (at least 200 ind) Autumn/(spring)	Preserved in 70% ethanol, big individuals sorted out at the laboratory, followed by subjectively picking out a representative part from the remaining sample. Regularly mayflies, stoneflies, caddisflies and other groups important in the acidification index are identified to species. Other individuals to different taxa-levels. Data stored in local database. Available to the institution.	Presented as tables and figures. Assessment based on species list, other taxa and relative abundance. Raddum index
LFI Oslo	Qualitative: Kick sample, Handnet; 30x 30 cm, 250/450 µm mesh size. 3 X 1 minutes or less depending on animal density. Autumn/(spring)	Preserved in 70% ethanol, big samples are sub sampled before counting under a microscope at the laboratory(12X). Regularly mayflies, stoneflies, caddisflies and snails are identified to species. Other individuals to different taxa-levels. Data stored in local database Available to the institution	Presented as tables and figures. Assessment based on species list, other taxa and relative abundance.
LFI Trondheim	Qualitative: Kick sample, Handnet; Norwegian Standard (NS4719) 25 x 25 cm, 500 µm mesh size. 5 minutes or less depending on animal density. Autumn/(spring)	Preserved in 70% ethanol. Animals picked out and counted in the field, big samples are sub sampled before counting. Regularly mayflies, stoneflies, caddisflies are identified to species. Other individuals to different taxa-levels. Stored in local databases. Available to the institution.	Presented as tables and figures. Assessment based on species list, other taxa and relative abundance.

Most data are stored in local databases and available to scientists at each institution. The data are presented as tables and figures. The assessment is generally based on species lists and the presence and relative abundance of indicator taxa. In acid streams the results are calculated according to The Raddum acidification index (Raddum et al 1988) or the NIVA/SFT index (Bækken and Aanes 1990).

Streams in urban areas are often contaminated by different kinds of pollutants, from sewage, industry, urban runoff. The macroinvertebrate community in such streams therefore responds to a situation of "mixed" pollution, e.g., some streams monitored in the Bergen and Oslo region are of this type (NIVA LFI, Oslo). In many cases, however, there is often a major dominating pollutant such as acid water, heavy metals or easily degradable organic matter. With these types of stressors, the response of the macroinvertebrate community is generally pollutant specific.

Acidification - A number of watersheds in the eastern, southern and western parts of Norway are monitored for acidification and long range transported pollution. Included in some of these programmes are a few streams being monitored for the effects of liming. The number of streams including the use of macroinvertebrate communities are limited to less than 10 streams in southern and western Norway (Farsund, Ogna, Vikedalsvassdraget, Rødneelv, Naustavassdraget, Gaularvassdraget, Yndesdal, Audna)(LFI, Bergen). From 1994 the river Vosso is included.

Heavy metals - Monitoring programmes have been and many are still implemented in streams draining old mining areas, such as the streams Orkla, Gaula, Folla and the uppermost reaches of the stream Glomma (NIVA, LFI Trondheim).

Eutrophication/organic matter - Local and regional authorities in different parts of the country are monitoring small local/regional watersheds. Mostly this is connected to pollution from sewage or agricultural activity. The monitoring of the rivers Glomma and Otra, and some tributaries to lake Mjøsa (NIVA).

Hydroelectric power construction - From a total of about 4000 watercourses in southern Norway, about 1100 are regulated for hydroelectric production. Nearly all large watersheds are affected. Changes in water fluctuations, water flow and temperature regimes may have a severe influence on the macroinvertebrate fauna. Some long-term investigations have ongoing monitoring studies (NIVA, NINA, LFI Oslo, LFI Bergen, LFI Trondheim) .

Reference water sheds - The water shed of Atna is monitored as a reference. From 1994 the river Vikadalselva will be part of the reference monitoring (NINA, LFI Bergen).

National monitoring

National monitoring programmes on streams were common in the late 1970's and during the 1980's. However, at present there exists no national-scale, stream monitoring programmes.

2.4.4 Data handling/availability

There is no standardised procedure for the handling of collected data. Most data are stored in local databases and available to scientists at each institution.

2.4.5 Stream quality today

The main pollution problem of Norwegian streams is the impact of acid rain. Most streams, at least in their upstream parts, in southern Norway are acidified to such an extent that they do not support a normal invertebrate community. This also applies to many streams on the western coast of Norway, as well as for some watersheds in eastern and northern Norway, some situated on the border between Norway and Russia. Streams, particularly in the southern and western parts of Norway, are severely affected by acid rain. Macroinvertebrates have proved to be an effective way monitoring these streams.

Old metal mines often leak considerable amounts of acid water and heavy metals to surface waters. Large financial investments have been made to investigate and reduce trace metal leakage, and in some cases improvements have been observed. Streams in urban areas have been polluted by sewage and from runoff from agriculture activities. In some intensively farmed areas and urban areas this may still be a "local" problem. Today most sewage is treated by sewage treatment plants, resulting in less loading of organic matter and nutrients from point sources into streams.

A large number of streams in Norway are affected by the use of water for hydroelectric power. This may change the water quality because of reduced water flow and consequently reduced self purification capacity. In some instances temperature regimes are changed resulting in relatively high winter temperatures and low summer temperatures. Some 399 watercourses or waterbodies are protected by law against hydropower regulation or installations.

Physical alterations of the watercourse from road construction and exploitation of riverbeds and banks for sand and gravel are becoming increasingly more common, thus requiring attention. Some of these activities increase the particle transport and negatively affect the biota.

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2.5 Denmark

2.5.1 Background: major impacts on Danish streams

There are approximately 65 000 km of streams in Denmark, corresponding to about 1.5 km per km^2 land area. Slightly more than 50 % of the streams (in terms of length) are considered natural in origin, while others result from ditches or drainage canals.

Land use in Denmark has traditionally been dominated by agriculture, and today 62 % of the total land area is intensively farmed, arable land. Hence, few, if any, Danish rivers and riparian areas have evaded the physical impact of the drainage practices characteristic of intensive farming such as drainage pipes, culverts, straightening, deepening, widening, etc. Less than 15 % of streams and rivers considered natural in origin have retained their natural channel dimensions and course of meandering. In some areas of Denmark (especially western Jutland) drainage has also led to acidification and high contractions of ferrous ion or ochre due to the oxidation of pyrite.

Furthermore the high population density in Denmark (approx. 120 per km^2) implies that the environment as a whole, and hence also streams, is heavily influenced by anthropogenic activities.

Streams have traditionally been polluted by easily degradable organic compounds from sewage, fish farms and illegal discharges from agriculture. Today most sewage is, however, treated biologically by sewage treatment plants, and the discharge of organic compounds from fish farms has, due to regulations, been reduced. As a result, the loading of organic compounds to Danish streams has decreased significantly during the last two decades, and the water quality of many larger streams has improved. Today the major problem with respect to organic pollution seems to arise from small sewage works and scattered rural households. Even small concentrations may have adverse effects because of the small size of most Danish streams and their poor physical quality. Moreover, in several parts of Denmark, insecticides seem to be an increasing problem, especially in small streams, and this is probably due to three factors: (i) pesticide pollution has become more 'visible' because of the reduction in organic pollution, (ii) the dilution is small, (iii) the introduction of more potent insecticides.

2.5.2 Aim and legislation

The legal provisions governing the use and protection of Danish streams are contained in seven acts (Table 2.5.1), three of which (The Environmental Protection Act 1973, 1991; The Water Supply Act 1978, and The Watercourse Act 1982) are of major importance as together they contain the regulations governing water quality, water quantity and physical properties of the streams. The overall objective of the Danish legislation is to ensure that streams have a diverse flora and fauna, that they are a natural part of the landscape, and that they are aesthetically and recreationally attractive.

Table 2.5.1: Current Danish Acts dealing with streams

	Main objective		
	Stream flow	Water quality	Physical quality
The Watercourse Act 1982			+
The Freshwater Fisheries Act 1992			(+)
The Environmental Protection Act 1978		+	
The Water Supply Act 1978	+		
The Nature Protection Act 1992			+
The Ochre Act 1985		+	
The Nature Management Act 1989			+

The 14 Danish counties are responsible for determining the quality objectives in their own regions (Table 2.5.2). As objectives for fish are useful in that they are easily understood by the public, the majority (78 %) of the quality objectives for Danish streams are related to fish and about half of them to salmonids specifically (Fig. 2.5.1). The counties are also responsible for monitoring whether the quality objectives are fulfilled or not.

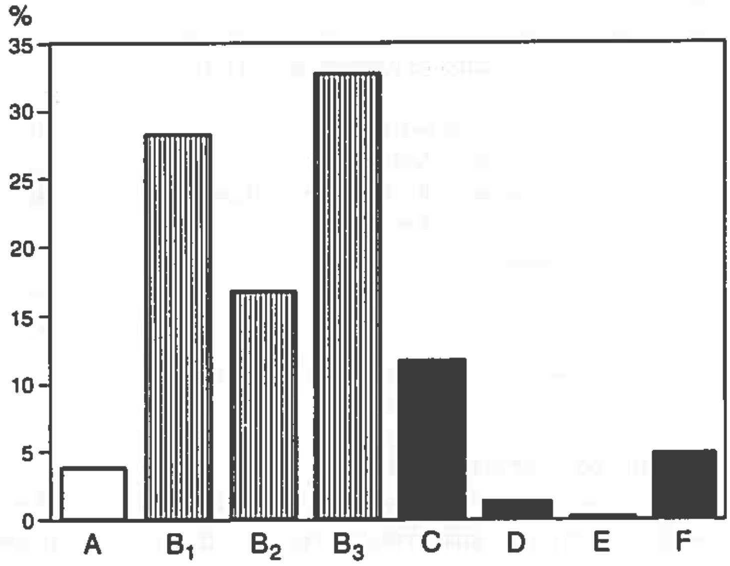

Figure 2.5.1: The relative distribution of stream objectives decided by the Danish counties. For explanation, see Table 2.5.2.

2.5.3 Monitoring

Regional monitoring of stream quality

Each year approximately 10 000 Danish stream sites are monitored on a regional scale by the 14 counties. All geographical regions of Denmark are covered, but sampling frequency and the number of stream sites monitored may vary from county to county.

The streams are monitored by the use of macroinvertebrate based methods. In 1970 a method based on the Saprobic system was described by the Ministry of Agriculture. Today, however, nearly all counties use more modern biotic indices to determine the degree of stream pollution, and the methods used may therefore differ greatly from county to county, both with regard to the collection of samples (at the majority of sites in all counties invertebrates are identified in the field) and calculation of index values. A new, more up-to-date and standardized, method to be used by all 14 counties is presently being developed. However, irrespective of the method used, stream pollution is expressed according to an index ranging from I (unpolluted) to IV (heavily polluted). The index contains a total of seven pollution categories (I; I-II; II; II-III; III; III-IV; IV) that are used to check whether the objectives are achieved (Table 2.5.2), and all counties prepare maps illustrating the pollution status of their streams and the number of streams that fulfil the objectives.

Table 2.5.2: Quality objectives for Danish streams. The Roman numerals refer to a system for describing the effect of organic pollution with I the least and IV the most polluted water.

		Quality objective	Maximum stream pollution index
Rigorous objectives			
General objectives	A	Area of special scientific interest	II
	B_1	Salmonid spawning and fry production area	II
	B_2	Salmonid water	II
	B_3	Cyprinid Water	II
Eased objectives	C	Streams with only run-off interests	II-III
		Streams affected by:	
	D	waste water	II-III
	E	groundwater abstraction	II-III
	F	ochre	II-III

National monitoring of stream quality

In 1987 the Danish Government passed the Action Plan on the Aquatic Environment, with the main objective to reduce the nitrogen and phosphorous discharge to the aquatic environment by 50 % and 80 %, respectively, before 1994. At the same time a nationwide monitoring programme was established to monitor the reduction in nutrient load from different sectors and the ecological effects on the aquatic environment. The monitoring programme was fully operational in 1989 and includes macroinvertebrate sampling at approximately 200 stream sites twice annually (in spring and autumn). Sampling is undertaken by the counties, and in the years 1989 - 1992 the counties employed the same methods as were used at regional stream sites (see above). From 1993 and onwards, however, all counties are expected to use a standardized sampling technique and index ('The Danish Fauna Index'), the basic outline of which is explained in Kirkegaard et al. (1992).

2.5.4 Data handling and availability

There is no standardised procedure for the handling of the regional data collected by the counties. As a result of this, data is stored on a variety of database programmes or only on paper, and they are therefore not easily accessible for persons/institutes outside the counties. However, all counties make status maps and reports on regular basis that describe stream quality within the county.

In June of each year data from the national programme is transferred from the counties to the National Environmental Research Institute (NERI), department of Freshwater Ecology, where it is placed in a database. All employees at NERI have access to the database, and on request persons or institutes outside the Ministry of the Environment can get hold of data. In addition, NERI publish each year, in November, a report on the results from national monitoring programme.

2.5.5 Stream quality today

Despite a marked reduction in the organic pollution from sewage treatment facilities, nearly 50 % of Danish streams do not fulfil the objective of the Danish Action Plan. The reason for this is partly, as mentioned above, the poor physical quality of many, especially small, streams combined with organic pollution from, for instance, scattered dwellings and/or pesticides.

Another explanation is the lack of standardised, objective methods in regional monitoring. Today, the value of the rather subjective methods used by many counties is highly dependent on the skills of the person undertaking sampling and field identification. Furthermore, as pollution categories tend to change over time, stream quality is without a doubt assessed more severely now than 10 - 15 years ago, and this has probably overshadowed some stream quality improvements.

2.5.6 References

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2.6 Summary of strategy and methods used in the Nordic countries

Tables showing the methods used for monitoring based on macroinvertebrates in the Nordic countries today.

Table 2.6.1

Country	National programme	Regional programme
Iceland	-	+ (Laxa#)
Sweden	(+) from 1995	+ (In each län/borough)
Finland	(+) from 1995?*	+ (In each län/borough)
Norway	(+) Some stations are monitored with regard to acidification	+ (county/borough)(Atna#)
Denmark	+ (230 stations year^{-1})	+ (approx. 10000 st. year^{-1})

* It has not been decided yet when the Finnish monitoring programme will commence.
\# The streams Laxa in Iceland and Atna in Norway are monitored primarily for scientific purposes and samples are taken frequently at a level far exceeding those of e.g. the Danish monitoring programme.

Table 2.6.2. Sampling methods presently being used by the Nordic countries.

Country	Mesh size	Kick technique	Rest habitat	Replica	Time of sampling
Iceland	-	-	-	-	-
Sweden	0.5 mm++++	6 kicks, 1 min. duration	stony bottom without vegetation	6	after the spring flood
Finland	0.5 mm+	kick for 30 - 60 sec.	all types of substrate	none	spring and/or autumn
Norway	0.5 mm+ 0.25 mm	3x1 min. per substrate type+++	all types of substrate	none	spring
Denmark	0.5 mm++	standardized 12 kicks in three transects	all, including the bank zone	none	spring and autumn

++++ Method to be used in the coming national programme. Regionally 1 mm mesh size was previously used.
+++ Several different methods are used depending on the institute taking samples.
++ Method used in the Danish monitoring programme - regionally other methods may be used.
\+ Mesh size and landing net in accordance with Nordic standard (Sweden (SS028191), Norway (NS4819) and Finland (SFS5077)).

Chapter 3

Conclusion and recommendations for future collaborative work among the Nordic countries

It can be concluded that all of the Nordic countries have legislation relating to the environmental quality of streams, and many similarities exist among countries regarding legislation governing streams. Hence, there is the legislative basis for biological monitoring within the Nordic countries.

In all of the Nordic countries macroinvertebrates have been used in monitoring or surveillance programmes. However, the extent of this monitoring varies considerably. The reasons for this relate mainly to demographic differences among the countries. The majority of stream monitoring programmes using macroinvertebrates occur on a regional scale, and are often directly related to known point-source pollution. At present, Denmark has the most intensive monitoring programme based on macroinvertebrates, but both Sweden and Finland are in the process of starting national monitoring programmes using stream macroinvertebrate communities as indicators of environmental quality.

Despite the finding that strategies behind the monitoring programmes differs among the Nordic countries, there is a high degree of similarity with respect to sampling techniques. With the exception of Iceland, kick-sampling is the most common method used for sampling macroinvertebrates. In Norway, Finland and Sweden the same standards are used in most cases and this can be attributed to work done in the 1980's by the Nordic standardisation group (INSTA C12: working group AG 14). The Danish kick-net and method is slightly different from these standards, although the basic principle and mesh size are the same.

In conclusion, there is at present the basis for co-operation among the Nordic countries concerning biological monitoring of streams using macroinvertebrates. However, there is an apparent need for a higher degree of standardisation and refinement of the methods and approaches used among the countries. This is of central importance if the ultimate aim of this work is to document, by inter-country comparison studies, stream habitat quality.

The working group recommends that the work should proceed in the following way:

(i) **Sampling methodology** - Kick-sampling should be the method used for sampling of stream macroinvertebrates. Work should be directed towards using the same kick-sampling procedure, and that the same kind of habitat should be sampled in each country. However, standardisation should be carried out within reasonable limits: the very different physical, and hence substrate, conditions found in streams and rivers within the Nordic countries makes it impossible to use the same sampling procedure everywhere. Therefore, work should also be conducted at solving how to sample 'difficult' areas, i.e. Icelandic and some Norwegian streams, and at the same time securing that the results of this sampling are comparable with the rest of the Nordic countries.

(ii) **Taxonomic resolution** - So as not to compromise inter-country comparisons of stream habitat quality, macroinvertebrate samples should be identified in the laboratory to the same minimum level of taxonomic resolution. In addition to a species list, it would be advantageous if one or more indices were developed for use in comparison studies of Nordic stream habitat quality.

(iii) **Data storage** - Data storage by the Nordic countries should be such that data are easily interchangeable among countries.

(iv) **Inter-country comparison's** - To make inter-country comparison's of stream habitat quality it may be necessary to stratify sampling effort to reduce indicator variability. This may be done by stratifying sampling by: (i) season to reduce temporal variability and (ii) stream size, habitat, and ecoregion to reduce spatial variability. For example, it is recommended that in the future predictive modelling of stream macroinvertebrate communities of the Nordic countries are made (see Chapter 4).

Overall, the above given recommendations will make it possible, in due course, to address stream quality of the Nordic countries in an inter-comparison study. This could be performed as a survey conducted once every third year. This would also fulfil the obligations to the European Union for Sweden and Finland as members.

The group also recommends that the Baltic countries are stepwise integrated into the work. However, at present they should have a status as observers, until more work has been done by the countries presently represented in the group.

Chapter 4

Future aims for macroinvertebrate monitoring in the Nordic countries: predictive modelling using stream benthos - a Nordic approach

4.1 Introduction

A predictive approach using benthic macroinvertebrates is a relatively new and promising direction in biomonitoring studies. Indeed, the ability to predict the probability of occurrence of a site-specific community allows for comparisons between expected and observed community and the identification of potential environmental stress. Furthermore, knowledge of predicted community structure (species or species assemblages) allows for the inference of water/habitat quality using predictive algorithms. A number of classification and ordination procedures are presently being used to predict community structure (e.g. Johnson et al. 1993). Two approaches which are commonly used to predict the probability of taxa occurrence are: (i) **indirect** gradient analysis, in which community samples are displayed along axes of variation in composition that "subsequently" can be interpreted in terms of environmental gradients and (ii) **direct** gradient analysis, in which taxa abundance and probability of occurrence are described as a direct function of measured environmental gradients.

Freshwater ecologists in Great Britain have used indirect gradient analysis to study the distribution patterns of lotic invertebrates (e.g. Wright et al. 1984; Wright et al. 1989). Expanding on this approach, predictive models were established using a combination of TWINSPAN-classification, DECORANA-ordination, and model construction using discriminant function analysis (DFA) (Moss et al. 1987). DFA is a multivariate approach to pattern recognition and interpretations that is frequently used in ecology to construct predictive models using environmental variables and [macroinvertebrate] groups. A similar approach, albeit using direct gradient ordination (CCA), has been used to predict profundal communities of Swedish temperate lakes (e.g. Johnson and Wiederholm 1989; Johnson in press). Although approaches using community classification have merit and have proven fruitful, a disadvantage is that the probability of taxa occurrence is based on group membership of previous site classifications. Simply put, a community classification approach assumes that discrete community types exist among habitat types. This assumption may not be valid for example if species replacements occur along a continuum of environmental gradient(s). One means of circumventing this assumption is using direct gradient analysis, and the prediction of taxa occurrences along defined environmental gradients.

4.2 Study proposal

As mentioned above, a predictive modelling approach using benthic macroinvertebrates to classify inland surface water and habitat quality is a relatively new and promising direction in biomonitoring studies. In Sweden, predictive models have been constructed for lake benthic communities (e.g. Johnson and Wiederholm 1989; Johnson et al. 1993; Johnson in press), and using a similar approach models are presently being constructed for the prediction of stream macroinvertebrate communities (Söderbäck et al. in prep).

A joint, Nordic project for the development and validation (calibration) of predictive algorithms for stream benthic communities would greatly enhance our ability to detect and assess changes among community types. A common ground for inter-country comparisons is stratification by ecoregion types (see below).

Model construction

Two approaches should be used in the development of predictive algorithms for stream benthic communities.

1. Indirect, discrete modelling consisting of three steps:

- *classification* - (e.g. using TWINSPAN analysis) is used to establish (distinguish) community types and potentially important indicator taxa,

- *ordination* - stepwise partial, constrained canonical correspondence analysis (ter Braak 1989) ordination will be used to select a number of explanatory variables to be used in predictive models,

- *predictive modelling* - discriminant function analysis (DFA) will be used to test for how robust indicators/ communities are at discriminating among lake types, and DFA-models will be used for predicting site-specific occurrence of indicator taxa or species assemblages.

2. Direct gradient, inverse regression, modelling consisting of two steps:

- *ordination* - (e.g. using canonical correspondence analysis) of indicators with explanatory variables in n-dimensional space is used to develop predictive relationships, and to establish in situ tolerance of indicator taxa along important environmental gradients,

- *logistic regression* - will be used to predict the probability of taxon occurrence.

Indicator variability and stratification techniques

A number of factors may confound community predictions. Indicator variability, for example, may strongly affect study design power and the ability to detect community /population change (e.g. Johnson in press). Population (lakes/streams) status and trend estimates will rely heavily on how representative sites are of the population, and how representative indicator variables are of the area (problem) to be detected. Indicator variability can be decomposed into: (i) measurement error or sampling precision, (ii) within-site spatial and temporal indicator variability, and (iii) true among-site differences. It is of course desirable to minimise within-site indicator variability, while maximising among-site variability. Techniques which are frequently used to reduce within-site indicator variability are spatial and temporal stratification of sampling effort. Moreover, stratifying among-site comparisons by large-scale regional variability is a means of further reducing indicator variability and increasing power. This may be done by simply stratifying sites by areas of relative homogeneity such as by ecoregions to reduce variability due to differences in vegetation- and soil types and climate (e.g. temperature and precipitation).

Stratification by ecoregion - Classification of lakes and watercourses by land-type, for example by ecoregion using vegetation and soil maps, is useful for identifying areas of relative homogeneity, and assumes that regional water quality varies according to the combined influence of natural conditions (e.g. climate and land type) and human activities (land usage and pollution impact). One of the advantages of ecoregion classification is that this form of stratification integrates spatially the effects of climate, topography, and soil type on lake chemical and biological processes. In this approach, predictive modelling of Nordic stream communities will be done after sites are stratified by ecoregion. Ecoregion stratification will be made using delineation's of the vegetation classification scheme of the Nordic Council of Ministers (Nordiska Ministerrådet, 1984).

Eight major ecoregions were recognized for the Nordic countries by the Nordic Council of Ministers (Nordiska Ministerrådet, 1984), and it is proposed that inter-country comparisons be made using these major ecoregion delineation's (Fig. 4.1). For example, as all of Denmark is classified as nemoral zone, benthic communities in Denmark should be compared with predictive models for communities of southern Sweden (also classified as nemoral zone). Similarly, as much of northern Sweden is classified as northern and middle boreal zones, benthic communities of these zones in Sweden should be compared with the similar zones in Finland.

Geographical stratification by ecoregion may not always be a viable approach due to the confounding effects of pollution on ecoregions. For example, in the south of Sweden where problems of acidification and eutrophication are most pronounced it may be desirable to complement ecoregion stratification with strata representing "impacted" areas to reduce within region variance. Furthermore, to obtain reference measures from unaffected sites may require stratifying lakes and watercourses by ecoregion to achieve a subpopulation not affected by point-source discharges (i.e. only airborne pollutants) followed by post-stratification of sites, after the degree of impact has been determined.

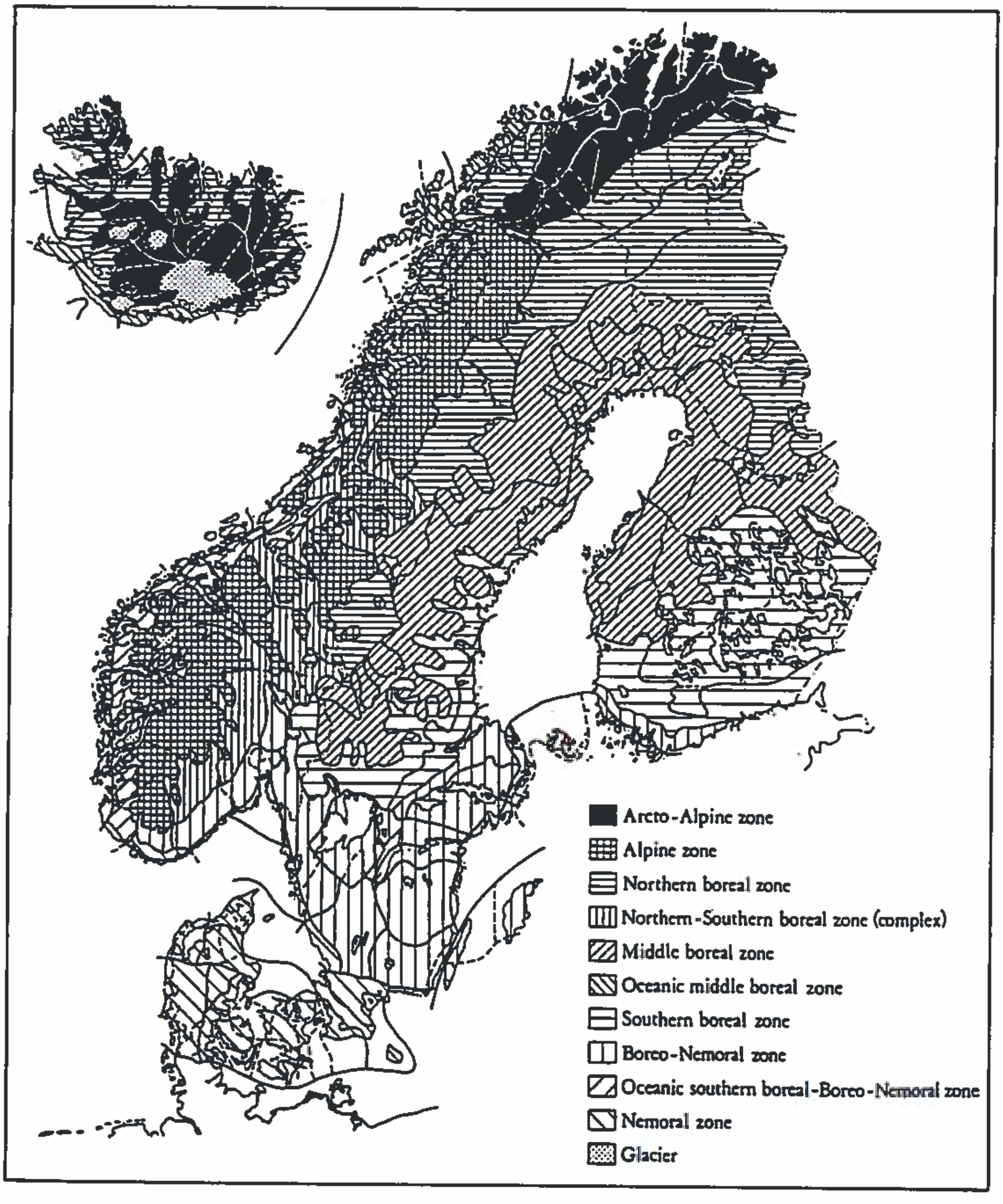

Fig. 4.1 The eight major ecoregions for the Nordic countries.

Stratification by size - Besides ecoregion effects on lake/stream typologies, lake/stream water characteristics are often dependent on soil properties in the catchment area and discharge (streams) or retention time (lakes). For example, shallow soil horizons in the catchment area of a small lake/stream provide inputs of organic matter, resulting in a higher concentration of humic acids. Moreover, the relatively higher proportion of humic acids, combined with the usually poorer neutralisation taking place in the catchment area, due to relatively rapid passage through the soil layers, consequently results in small lakes/streams often having lower pH than large lakes/streams. Hence stratifying sampling by lake/stream size is one means of reducing among-site variability, and thus increasing study design power.

Stratification of stream size in Sweden - In contrast to the relatively well documented statistics on surface waters, stratifying watercourses by size is hindered by the general lack of stream information readily available. Ideally, the closest measure of stream size is probably a measure of discharge. Unfortunately, however, these data are lacking for the majority of watercourses. Stream discharge may however be calculated from watershed size and using various modelling techniques. Other measures of stream size may include size of the watershed area, stream length, or stream order. For example, using topographic maps stream size may be classified by watershed area or stream order. These measures of stream size may also be regarded as a surrogate measure of stream flow, as annual discharge often varies with watershed size and stream order.

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Biological Monitoring of Streams

This report gives a short description of the major impacts, legislation, and monitoring of stream quality using macroinvertebrates today, in each of the Nordic countries. Differences and similarities are discussed, and future aims for the Nordic work are proposed.

Biological Monitoring of Streams

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