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The River Torne International Watershed

Common Finnish and Swedish typology, reference conditions and a suggested harmonised monitoring programme

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Results from the TRIWA project

The River Torne International Watershed

Common Finnish and Swedish typology, reference conditions and a suggested harmonised monitoring programme

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Preface

This report is the result of a project run by the Lapland Regional Environment Centre in Finland and the County Administrative Board of Norrbotten in Sweden in 2003-2006. The aim was to develop a common set of methods for a joint management of the River Torne International River Basin district. The main goals were to define chemical and biological reference conditions for the most common surface water types and to propose a harmonised monitoring programme. The sub-projects were partly financed by the EU Regional Development Fund, INTERREG IIIA Nord. A sub-project was partly financed by The North Calotte Council and the Swedish-Finnish Border River Commission.

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Luleå and Rovaniemi, August 2006

The authors

Summary

According to the EU Water Framework Directive (WFD), the River Torne in the border of northern Sweden and Finland is an international River Basin District. The directive is a legislative framework to protect and improve the quality of waters within the EU, with the objective to achieve good status for all waters by 2015. The WFD requires cross-border cooperation in areas where waters are common for many countries. In the Torne River Basin District, the County Administrative Board of Norrbotten in Sweden and the Lapland Regional Environment Centre in Finland are the responsible water authorities for fulfilling the demands of the directive. The work will be done in a cooperation network between regional and local authorities as well as other stakeholders in each river basin district.

The practices for the monitoring of environmental state and management of surface waters varies between Finland and Sweden. Some harmonisation of methods is needed in order to get comparable estimates concerning the ecological status of the waters. Management practices should also be consistent when common actions for achieving the goals of WFD are taking place. The two northern regional authorities in Sweden and Finland initiated the TRIWA project (The River Torne International Watershed) as a step towards a common river basin management. The project started in October 2003 and ended in August 2006. The results are presented in this report.

The TRIWA project developed a harmonised typology for the watershed surface waters and established reference conditions for biological and chemical quality elements used in the assessment of ecological status of the different water types. Further, potential reference lakes and rivers were identified and used as a basis for suggestion towards a common monitoring network for the River Torne watershed.

Intensive field work was required for fulfilling the goals of the project. A set of 20 pristine lakes and 15 rivers were selected for monitoring during 2004 and 2005. The sampling sites represented the most common surface water types according to the preliminary common typology, which was developed on a basis of existing water and land use data. The preliminary typology consisted of 13 lake types and 11 river types. The division of types was based on the ecoregion, size and geology of the surface waters and their catchment areas. The waters were sampled and analysed for phytoplankton, benthic invertebrates, fish fauna and water chemistry.

The water chemistry differed significantly between the preliminary water types. Most prominent between-type differences could be found from concentrations of carbon, nutrients (total P and N) and metals (Fe and Al). However, differences were not as clear in biological quality elements. Benthic invertebrate fauna showed significant differences only between northern mountain waters and southern lowland water types, which were separated by the coniferous tree limit. A similar, although weaker, trend was visible also with phytoplankton flora. The differences between northern and southern waters were most significant for the variables of species diversity due to the species-poor nature of the northern waters. The fish communities did not differ between the types. Because of the ecoregional similarity of fauna and flora below the coniferous tree limit, the preliminary typology was simplified by combining the southern ecoregions. Final suggestion for common typology resulted in 7 types for both rivers and lakes. Type-specific reference conditions and border values between high and good ecological status were estimated for the most important variables using the medians and quartiles of the gathered data.

Almost all of the studied lakes and rivers appeared to be suitable for use as reference sites in the future monitoring programs. Some southern lakes exhibited high algal biovolumes and nutrient concentrations, but in the end only one lake was judged unsuitable for reference purposes. The naturally nutrient-rich nature of the discarded lake pointed out the possible need for further adjustment of the common typology. Additional types for naturally eutrophic and calcium-rich lakes, along with the depth division of the lakes, may be needed in the future, when the accuracy and spatial coverage of the available data increases.

The current national and regional monitoring programs were evaluated in relation to WFD:s demands. The selection of monitored quality elements as well as the spatial coverage and type-specific representativeness of the present programs appeared to be inadequate. Analyses of biological and hydrological quality elements must be included in the list of frequently measured variables. The number of monitored sites per type should also be increased in order to achieve reliable estimates about the ecological status of the area. The project presented two alternative suggestions for the common monitoring network for River Torne international river basin district. The final decision for the future monitoring will be done in cooperation by Swedish and Finnish environmental authorities and local interest groups.

Sammanfattning

Torne älv utgör gränsen mellan norra Sverige och Finland och definieras av EU som ett internationellt vattendistrikt, enligt EG:s Ramdirektiv för vatten. Direktivet är en lagstadgad ram för skydd av vattenmiljöer och förbättring av vattenkvaliteten. Målet är att Europas vattenmiljöer ska nå upp till kraven för "god ekologisk status" senast år 2015. Direktivet ställer krav på gränsöverskridande samarbete i de fall där vattenmiljöer är gemensamma för flera länder. Länsstyrelsen i Norrbotten och finska Lapplands Miljöcentral är utsedda som ansvariga myndigheter för Torne älvs vattendistrikt och ska arbeta för att uppfylla direktivets mål. Arbetet ska ske i samarbete med regionala och lokala myndigheter samt andra aktörer och intressegrupper i vattendistriktet.

Den nuvarande övervakningen av miljötillståndet och förvaltningen av ytvatten skiljer sig åt mellan Sverige och Finland. Metoderna bör harmoniseras för att ge jämförbara bedömningar av miljötillståndet på båda sidor om älven. Förvaltningsmetoderna bör också vara likartade så att länderna kan arbeta gemensamt med åtgärder för att nå direktivets mål. Länsstyrelsen och mljöcentralen initierade TRIWA-projektet (The River Torne International Watershed) för att komma ett steg närmare en gemensam förvaltning av Torne älvs vattendistrikt. Projektet startade i oktober 2003 och avslutades i augusti 2006. Resultaten presenteras i denna rapport.

TRIWA-projektet har utvecklat en harmoniserad metod för att dela in avrinningsområdets sjöar och vattendrag i olika typer. Vi har också undersökt vad som är typiskt för Torne älvs vattenmiljöer genom att ta fram referensförhållanden för biologiska och kemiska kvalitetsfaktorer. Dessa kan användas för att bedöma den ekologiska statusen i olika vattentyper. Projektet har identifierat sjöar och vattendrag som kan ingå i ett framtida gemensamt nätverk av miljöövervakningsstationer i Torne älvs avrinningsområde och fungera som referensområden till påverkade områden.

En omfattande insamling av nya miljödata var nödvändig för att nå projektets mål. 20 sjöar och 15 vattendrag med naturligt eller nära opåverkat tillstånd valdes ut till fältundersökningar under 2004 och 2005. Lokalerna representerade de vanligaste vattentyperna enligt en preliminär typindelning, som grundades på befintliga data för vattenkemi och markanvändning. Den preliminära typindelningen omfattade 13 sjötyper och 11 vattendragstyper. Indelningen baserades på ytvattnens ekoregiontillhörighet, storleksklass och geologi (klara eller humösa vatten). Sjöarna och vattendragen undersöktes genom provtagningar av vattenkemi, växtplankton, bottenlevande djur och fisk.

Resultaten för vattenkemi visade att de preliminära vattentyperna skiljde sig signifikant från varandra. Halterna av totalt organiskt kol (TOC), näringsämnen (totalfosfor och totalkväve) och metaller (järn och aluminium) stod för de tydligaste skillnaderna mellan typerna. De biologiska kvalitetsfaktorerna gav inte lika klara indikationer som vattenkemin. Bottenfaunaanalyserna visade signifikant skillnad enbart mellan vattentyper ovanför (fjällvatten) och nedanför barrskogsgränsen. Analyser av växtplanktonfloran gav liknande resultat. Skillnaden mellan nordliga och sydliga vattentyper var tydligast för olika artdiversitetsindex, vilket speglar den artfattiga miljön i fjällområdet. Fisksamhället skiljde sig inte mellan de olika typerna. Flora och fauna verkar inte skilja ut typerna nedanför barrskogsgränsen och därför reviderades den preliminära typindelningen genom att slå samman de sydliga ekoregionerna. Det slutliga förslaget till typindelning resulterade i 7 sjötyper och 7 vattendragstyper. Typspecifika referensförhållanden beräknades som medianvärden och kvartiler för de viktigaste kvalitetsfaktorerna, vilket motsvarar gränsen mellan god och hög ekologisk status.

Nästan alla sjöar och vattendrag som ingick i undersökningen kan användas som referensområden i framtida övervakningsprogram. Några sjöar i den södra delen av avrinningsområdet hade höga näringshalter och stor biovolym växtplankton, men endast en sjö bedömdes vara olämplig som referenslokal. Typindelningen kan behöva kompletteras med en typ för naturligt näringsrika sjöar som förekommer i södra Tornedalen. Även typer för kalkhaltiga vatten och en indelning med avseende på sjödjup kan bli aktuella om dataunderlaget förbättras i framtiden.

De nuvarande nationella och regionala miljöövervakningsprogrammen utvärderades i förhållande till de krav som direktivet ställer. Den framtida övervakningen måste täcka in fler vattentyper och den rumsliga fördelningen av övervakningsstationer i avrinningsområdet bör anpassas så att både påverkade och opåverkade områden övervakas. Antalet stationer som representerar en viss vattentyp måste dessutom vara tillräckligt många för att ge tillförlitliga bedömningar av den ekologiska statusen i området. Fler biologiska och hydrologiska kvalitetsfaktorer måste tas med i analyserna om vi ska kunna utvärdera om miljömålen nås. Projektet har tagit fram två alternativa förslag till ett gemensamt nätverk av övervakningsstationer för Torne älvs internationella vattendistrikt. Förslagen ska tas upp till diskussion med svenska och finska miljömyndigheter samt avrinningsområdets aktörer och intresseorganisationer innan beslut om den framtida miljöövervakningen fattas.

Yhteenveto

Ruotsin ja Suomen pohjoinen rajajoki, Tornionjoki on Euroopan Unionin Vesipolitiikan puitedirektiivin (VPD) mukaan kansainvälinen vesienhoitoalue. Direktiivillä pyritään turvaamaan ja parantamaan EU:n alueen vesivarojen laatua, ja tavoitteena on saavuttaa kaikkien vesien hyvä tila vuoteen 2015 mennessä. VPD edellyttää kansainvälistä yhteistyötä rajavesialueilla. Tornionjoen vesienhoitoalueella direktiivin toteutuksesta vastaavat Ruotsissa Norrbottenin lääninhallitus ja Suomessa Lapin ympäristökeskus. Toteutus tapahtuu yhteistyössä aluehallinnon ja paikallisten vesienkäyttäjien kanssa.

Vesialueiden hallinnointia ja ympäristön tilan seurantaa koskevat kansalliset käytännöt eroavat toisistaan. Menetelmien harmonisointia tarvitaan vesien ekologisen tilan arviointien vertailtavuuden turvaamiseksi. Myös hallinnointikäytäntöjä tulisi yhdenmukaistaa kun vesienhoitoalueelle yhteisesti asetettuja tavoitteita aletaan toteuttaa. Ruotsin ja Suomen direktiivin toteutuksesta vastaavat tahot käynnistivät TRIWA-projektin (The River Torne International Watershed) yhteisen vesienhoitotyön pohjaksi. Projekti alkoi lokakuussa 2003 ja päättyi elokuussa 2006. Tässä raportissa esitellään projektin tulokset.

TRIWA-projekti kehitti yhteisen, harmonisoidun tyypittelyn vesialueen pintavesille ja määritteli biologiset ja kemialliset vertailuolosuhteet, joita käytetään eri tyyppisten vesien ekologisen tilan määrittelyssä. Projektissa kartoitettiin myös potentiaalisia referenssijärviä ja –jokia, joita käytettiin Tornionjoen yhteistä seurantaverkkoa koskevien suunnitelmien pohjana.

Projektin tavoitteiden saavuttaminen vaati intensiivisiä maastoseurantoja. Vuosina 2004 ja 2005 toteutettuun seurantaan sisällytettiin 20 luonnontilaista järveä ja 15 jokea. Näytteenottoon valittiin alueen yleisimpiä pintavesityyppejä, jotka oli määritelty vesi- ja maankäyttöaineistojen pohjalta kehitetyn alustavan tyypittelyn perusteella. Alustava tyypittely sisälsi 13 järvityyppiä ja 11 jokityyppiä. Typologia perustui pintavesien ja niiden valuma-alueiden biomaantieteelliseen sijaintiin, kokoon ja geologiaan. Maastoseurantaan valituilta vesialueilta otettiin kasviplanktonia, pohjaeläimistöä, kalastoa ja vedenlaatua kuvastavia näytteitä.

Alustavat pintavesityypit erosivat vedenlaadun perusteella tilastollisesti toisistaan. Selvimmät tyyppien väliset erot löytyivät hiilen, ravinteiden (kok. P ja N) sekä metallien (Fe, Al) pitoisuuksista. Biologisten laatutekijöiden suhteen erot eivät kuitenkaan olleet yhtä selviä. Pohjaeläimistössä merkitseviä eroja löytyi vain pohjoisten tunturivesien ja eteläisempien tyyppien väliltä. Samanlaisia, joskin vähemmän selviä eroja oli havaittavissa myös kasviplanktonissa. Voimakkaimmat erot pohjoisten ja eteläisten vesien eliöstössä havaittiin lajiston monimuotoisuutta kuvaavissa muuttujissa pohjoisten vesien lajiköyhyydestä johtuen. Kalayhteisöjen rakenteessa ei havaittu tyyppien välisiä eroja. Havaitusta lajiston samankaltaisuudesta johtuen alustavaa tyypittelyä yksinkertaistettiin yhdistämällä eteläiset biomaantieteelliset alueet. Lopullinen ehdotus yhteiseksi pintavesityypittelyksi sisälsi 7 tyyppiä sekä järville että joille. Tärkeimmille ympäristön tilaa kuvaaville muuttujille määriteltiin tyyppikohtaiset referenssiolot sekä erinomaisen ja hyvän tilan väliset raja-arvot kerätystä aineistosta laskettujen mediaanien ja ylä- ja alakvartaalien perusteella.

Lähes kaikki tutkitut järvet ja joet soveltuivat vertailualueiksi tuleviin seurantaohjelmiin. Muutamilla eteläisillä järvillä havaittiin ajoittain korkeahkoja levätiheyksiä ja ravinnepitoisuuksia, mutta vain yksi tutkituista järvistä arvioitiin sopimattomaksi vertailualueena käytettäväksi. Kyseinen järvi vaikuttaa luontaisesti rehevältä, ja onkin mahdollista, että yhteistä tyypittelyä täytyy jatkossa kehittää. Järvien syvyystyypittely, sekä lisätyypit reheville ja kalkkirikkaille järville saattavat olla tarpeen, kun olemassa olevan aineiston määrä, tarkkuus ja alueellinen kattavuus tulevaisuudessa lisääntyvät.

Nykyisiä kansallisia ja alueellisia seurantaohjelmia arvioitiin VPD:n velvoitteet huomioonottaen. Ohjelmien alueellinen kattavuus, tyyppikohtainen edustavuus ja analyysivalikoima osoittautuivat riittämättömiksi. Biologiset muuttujat täytyy liittää seurattaviin ympäristön laatutekijöihin. Seurantapisteiden tyyppikohtaista määrää tulisi myös lisätä ekologisen tilan arviointien luotettavuuden takaamiseksi. Projektin tuloksena esiteltiin kaksi vaihtoehtoista ehdotusta Tornionjoen kansainvälisen vesienhoitoalueen yhteiseksi seurantaverkoksi. Lopullisen päätöksen tulevasta seurannasta tekevät Suomen ja Ruotsin ympäristöviranomaiset yhdessä paikallisten intressiryhmien kanssa.

1 The River Torne international river basin

1.1 The Water Framework Directive

The main channels of River Torne and River Muonio constitute the border between northern Finland and Sweden. The watershed has been identified as an international River Basin District (Figure 1) according to the EU Water Framework Directive (WFD) 2000/60/EC. The directive is a legislative framework for water management and it was adopted by EU member states in October 2000. The directive aims to protect and improve the quality of all rivers, lakes, groundwater, transitional and coastal water resources within the EU. The objective is to achieve “good status” for all European waters by 2015. Water use must be sustainable throughout Europe.

The new management is divided into river basin districts according to the natural geographical and hydrological borders of the waters. This requires cross-border cooperation in areas where waters are common for many countries. River Torne is an example of such an international river basin district. The environmental goals demanded by the WFD will be achieved by building a cooperation network between regional and local authorities as well as other stakeholders in each river basin district. The Lapland Regional Environment Centre in Finland and The County Administrative Board of Norrbotten in Sweden are the responsible water authorities for the management of the international district.

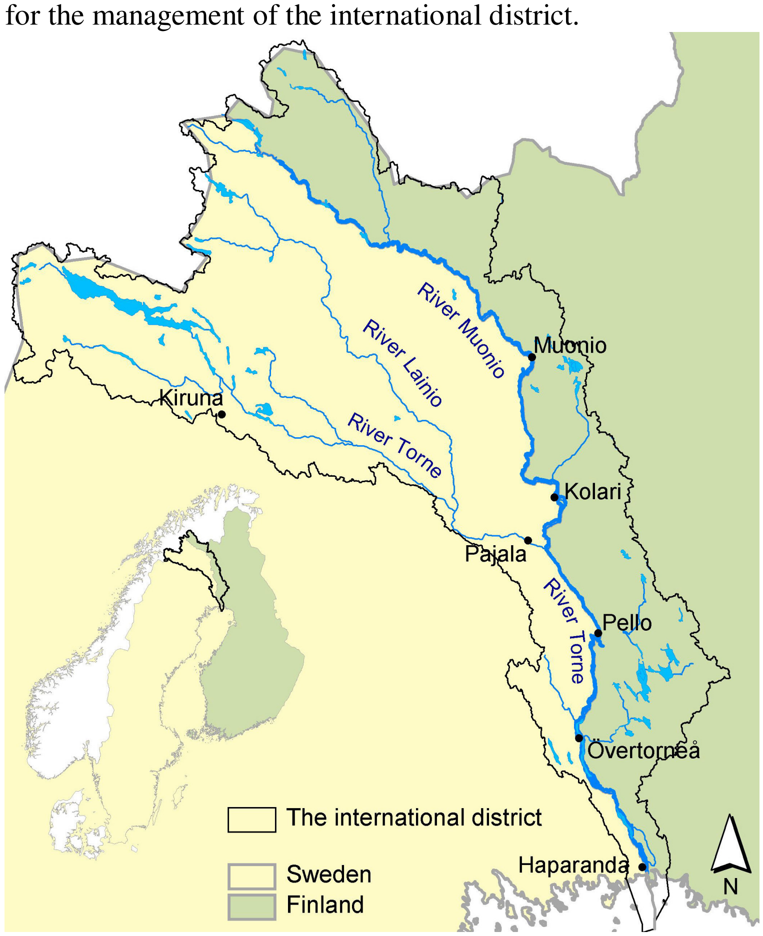


Figure 1. The international River Basin District of River Torne. © Lantmäteriet

A river basin management plan will be produced for each river basin district and it will be updated every sixth year. It shall include a description of the river basin characteristics, pressures, protected areas, water use and economical analysis, environmental objectives and a plan for measures. The directive has set several distinct goals and a time schedule for the work (Table 1).

Table 1. Time table for the implementation of the EU Water Framework Directive.

Year	Issue
2000	Directive entered into force
2003	Transposition in national legislation
	Identification of River Basin Districts and Authorities
2004	Characterisation of river basin: pressures, impacts and economic analysis
2006	Establishment of monitoring network
	Start public consultation (at the latest)
2008	Present draft for river basin management plan
2009	Finalise river basin management plan including programme of measures
2010	Introduce pricing policies
2012	Make operational programmes of measures
2015	First cycle ends, environmental objectives achieved
2021	Second management cycle ends
2027	Third management cycle ends, final deadline for meeting objectives

The implementation work will follow the "water planning cycle", which consists of five steps as shown below. The member states and the Commission have agreed on a Common Implementation Strategy for the practical work. Working groups with mandates from the member states have developed several guidance documents regarding the different parts of the implementation.

1. Characterisation	Identification of river basin districts and water bodies (e.g. lakes, rivers, stretch of coastal water) within it, analysis of waters bodies in the districts (state and pressure), typing of different water bodies and definition of reference conditions for the different water types
2. Environmental objectives	Set environmental objectives for the district and its water bodies, define good status for different water types
3. Programmes for measures	Plan for measures needed to reach the environmental objectives
4. Monitoring programme	Monitoring of ecological status (long-term changes, effects of measures, effects of activities and accidents)
5. Management plans	A water management plan for the district summarises current knowledge of status and pressure, and includes a plan for needed measures and effects

First water bodies have to be identified and delineated. Water bodies are the smallest water units that the Directive deals with, it can e.g. be a lake or a river segment. This is followed by a differentiation of water bodies with respect to type and establishment of type specific reference conditions needed for status classification. Further, the characterisation of water bodies includes identification of pressures and impacts in the river basin and a final classification of ecological status. Environmental objectives and a plan for the measures needed to achieve the goals must be set for the water bodies. Monitoring programs for assessing trends in natural conditions, anthropogenic activities and effects of measures will then be established. All this will be included in the river basin management plan.

Cooperation between municipalities, authorities, actors and other interest groups in a watershed is the key to a successful management.

There are many questions to resolve concerning the international river basins. Reporting to EU can be done separately by both countries, but in order to ensure a reasonable implementation of the directive at the regional level it is necessary to conduct a common trans-boundary development and harmonisation of methods where regional conditions are taken into account. E.g. there is a lack of harmonised methods and practices on defining ecological status of boreal watersheds typical for River Torne water basin. Especially the methods to determine the reference conditions and human impact on a river basin scale in boreal watersheds need to be demonstrated. River Torne is an international water basin with a good opportunity to build and demonstrate the "networking infrastructure" between local and national authorities. Further, the area offers a possibility for testing and applying national typologies and different methods to define reference conditions and assess human impact.

1.2 Characteristics of the River Torne watershed

River Torne runs along the border between northern Sweden and Finland. The catchment area is 40 157 km^2 of which approximately 60% is within Swedish borders and the rest is in Finland. A small area in the northernmost part of the watershed is within Norway. The watershed reaches from the alpine areas of northern Sweden and from the north-western parts of Finnish Lapland through taiga and wetlands down to the southern agricultural lowlands, where the river empties in the Bothnian Bay. The water system consists of two major rivers, River Torne which drain the western parts and River Muonio which is the border river in the northern part of the area. The rivers are joined just south of the town of Pajala (Figure 1).

River Torne with its tributaries is nationally and internationally unique and valuable water system. The main parts of the watershed are undisturbed and the human impact is generally low. The river is one of the last unregulated big rivers with naturally reproducing populations of Baltic Sea salmon and sea trout. In Western Europe the number of large freely flowing rivers has notably decreased during the last 50 years as a result of hydroelectric power constructions. Due to its un-harnessed nature, River Torne is very important for the preservation of many different species of plants and animals dependent on natural discharge fluctuation and floods.

River Torne has been included to the Natura 2000 nature protection network both in Finland and Sweden. In the Swedish side, the whole water system, including tributaries, is listed as Natura 2000 area. Likewise, Finnish part of the watershed belongs to Natura-network, with the exception of few southernmost tributaries. In total, about a quarter of the watershed is protected as national parks, reserves and other protected areas. Most of these are located in the mountainous region or in the mountain coniferous forest.

On account of their protection value, the most important aquatic environments are the freely flowing main channel and the flooding shore areas of the River Torne and its tributaries. The coast of Bothnian Bay, where uplift still continues, is also an internationally significant natural habitat with its continuously changing shallow bays and lagoons. Threatened plant species of flood areas include for instance almond-leaved willow (*Salix triandra*) and myrinia moss (*Myrinia pulvinata*). Endemic field mugwort (*Artemisia campestris ssp. bottnica*) can be found only from the shore areas of Bothnian Bay, including several sites in the coastal area of River Torne. Among the most precious animal species of the tributaries and small headwaters are reproducing populations of salmon (*Salmo salar*) and pearl mussel (*Margaritifera margaritifera*).

The conditions of the River Torne watershed has been described in the report "The River Tornio - state and loading of river system" (in Finnish and Swedish) by Lapland Regional Environment Centre and The County Administrative Board of Norrbotten (Puro-Tahvanainen et al. 2001). The following is a short summary of some parts of the report.

Hydrology

River Torne belongs to the big rivers of the North Calotte, both regarding the watershed size as well as discharge. In 1911-2001 the average discharge has been 380 m^3/s. The seasonal and annual variations are great. Water is at the highest level during springtime flood and is at the lowest level in the late winter before the spring floods. Occasionally, there are also flood events in the autumn following periods of high precipitation.

During the spring flood the discharge is multiple compared to the average flow, and it sometimes causes damage to the waterfront constructions and buildings, especially in areas near the estuary. Blocks of ice causes obstructions and can raise the water level several meters during the spring flood. The weather conditions and rapid snow melting have major influence on the forming of the ice blocks.

Lake Torneträsk is the largest lake in the watershed. Photo S. Elfvendahl

For the largest part of the watershed the altitude varies from 200-500 meters above sea level. In the Caledonian mountains there are several peaks reaching over 1000 m.a.s.l. The highest peak is Tidnotjåkka (1539 m.a.s.l), located west of Lake Torneträsk, which drains from the mountains in the western part of the watershed. The average slope and drop of River Torne is quite small, due to the low altitude of Lake Torneträsk (342 m.a.s.l.). The drop is larger in the tributaries River Lainio and River Rautas.

The River Torne water system represents a rare hydrological phenomenon – a bifurcation. River Torne is connected to the River Kalix water system through a natural bifurcation in Junosuando. Over half (56 %) of the water from the northern parts of River Torne run to the sea through River Kalix.

Most of the lakes in the River Torne water system area are small, less then 1 km^2. Only 18 lakes are larger than 10 km^2. The total lake area is approximately 4,6 % of the watershed area. In some sub-basins the lake percentage is much higher because of the large lakes like Miekojärvi, Iso-Vietonen, Raanujärvi, Kilpisjärvi and Torneträsk.

The lakes Raanujärvi, Vietonen and Portimojärvi in Finland are regulated for the purposes of hydroelectric power. Lake Puostijärvi in River Armas water system is the only lake regulated in the Swedish side.

Geology and soil

The major part of the bedrock of the River Torne basin belongs to Fennoscandian shield, which consist of 1,6-2,7 billion years old primary rock. The Caledonian mountains in the west and north demarcate the shield. The mountains emerged when tectonic plates of North America and Eurasia collided 400 million years ago. The northern Caledonian mountains consist of schistose sedimentary rocks and igneous rocks, characterised by quite a large proportion of easily weathered and calcareous rocks. Vegetation is rich in these areas due to the leaching of calcium and magnesium.

Distribution and stratification of loose soil types that cover the bedrock are governed by the events that took place during the glacial periods. Areas between River Lainio and River Muonio, as well as the area of Enontekiö, are characterised by long sections of eskers. Eskers are mainly located in the NW-SE direction, which was the flowing direction of the glacier melt waters. The most common soil types of the watershed are glacial till and peat, which stratifies from organic matter. There are large mires in the flat areas of the middle and lowest parts of the watershed.

Large areas in southern and western Lapland and in south-eastern Norrbotten were covered by water when the ice sheet melted. The highest historic coast line is located today at the altitude of c. 200 m.a.s.l. The areas below the historic coastline have aroused from the sea to form dry land. The uplift still continues with a speed of approximately 8-9 mm per year in the coast of the Bothnian Bay. Sulphide- and nutrient rich soils are therefore frequent in the coastal lowland areas.

Climate

The climate conditions differ strongly between the northern and southern parts of river basin as a consequence of the long north-south gradient of the River Torne. The annual average temperature varies from –2,6 ºC in the northern and western parts to 1 ºC in the southern parts. The thermal growing season is approximately 110 days in the northernmost parts, which is over a month shorter compared to the lower parts of the river.

The temperature conditions are also affected by distance from the sea. In the lower parts of the river, the influence of the Bothnian Bay is compensating the seasonal differences between temperatures. The Caledonian mountains in the coast of Norway restrain the spreading of warm air from the North Sea to the inner parts of the mainland.

The annual precipitation varies from 400 mm to 550 mm. The northern-most parts have the lowest rainfall. Caledonian mountains create a west to east precipitation gradient with higher precipitation in the western parts. Over 40 % of the annual precipitation falls as snow. The winter season lasts about 6 months in the middle part of the watershed.

Vegetation and landscape

Vegetation and landscape of the water basin are very diverse. According to the botanical biogeographical classification, the River Torne area belongs mostly to the middle and north boreal vegetation zones. Mountain birch forms the tree line along the Caledonian mountains, which belong to the alpine zone (Virtanen, 1997).

Low field layer vegetation dominates the areas above the tree line in the alpine zone. Locally, the alpine flora is very rich because of the calciferous rock types.

In the north boreal zone, the growth of tree stands is slow and forests are thin and low. Mountain birch dominates the woody vegetation in the northern-most areas of the north boreal zone. Landscape is characterised by large and moist Aapa mires. There are also areas with permafrost and palsa bogs. Besides separate mountains (fjelds), the large alpine areas are characterised by mountain ridges.

Low mountains and wide mires are typical for the northern part of the Torne watershed. Photo S. Elfvendahl.

The middle boreal zone is dominated by pine and mixed forests. Spruces thrive in fine-grained soils and wetlands. Mountains and hill ridges bring diversity to the landscape. Wide aapa mires are typical for northern parts of the middle boreal zone. The coastal lowland areas near Bothnian Bay are widely covered by flood meadows.

Settlements and other human activities have mainly been concentrated along the waterways, which have traditionally been important routes for people and trade in the northern parts of Finland and Sweden. Typical cultural environment for River Torne area has been formed as a result of long-term agriculture, reindeer husbandry and fishing. Agricultural areas characterise the Torne Valley from the coastal areas up to Pello and is recognised as an important and valuable cultural landscape. Cultural biotopes in the middle part of the watershed compose of scattered meadows, pastures and wetlands used for haymaking. Also, the mountain area is a living cultural landscape influenced by reindeer husbandry and grazing.

Water quality and general biology

Water quality changes naturally along the River Torne water system from headwaters to the coastal areas. The mountain waters are characterised by low nutrient conditions and a very clear water. The watersheds are dominated by mountain heath and bouldery terrain. Due to calcareous bedrock formations, mountain lakes have a pH close to neutral and quite high conductivity and alkalinity. However, the local variation is large. Many mountain lakes located south of the River Torne area in Swedish Lapland have naturally low pH and a low alkalinity due to the geological characteristics of the area.

The production of the mountain lakes is limited by the low nutrient concentrations and extreme climate conditions, resulting in low biomasses of phytoplankton and zooplankton. The fish fauna of the alpine region is dominated by arctic char (*Salvelinus alpinus*). Brown trout (*Salmo trutta)*, grayling (*Thymallus thymallus)*, burbot (*Lota lota*) and whitefish (*Coregonus lavaretus*) also inhabit the mountain water systems. Many mountain lakes naturally lack fish but the past introductions of fish species have altered the natural ecosystem of several lakes.

In the northern and middle boreal regions the watersheds are dominated by pine forests and wetlands. Soil and vegetation characteristics result in a more humic and coloured water with higher content of nutrients and organic compounds than in the mountain waters. The boreal waters are still generally classed as nutrient poor. Due to humic substances, many forest lakes and rivers have a slightly acidic water and moderately weak buffering capacity. This makes the surface waters naturally sensitive to load of acidifying pollutants. The productivity of phytoplankton is generally moderately low. The typical fish community of the lakes consist of perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), pike (*Esox lucius*) and whitefish (*Coregonus lavaretus*). In rivers the fauna includes e.g. salmon (*Salmo salar*), brown trout (*Salmo trutta*), grayling (*Thymallus thymallus*), minnow (*Phoxinus phoxinus*) and European and Arctic bullhead (*Cottus gobio* and *C. poecilopus*).

The soils of the lowland coast are dominated by fertile old sea sediments, thus the waters below the highest glacial coast line are naturally quite rich in nutrients. Many lakes are shallow and relatively productive. They are also more coloured and humic than northern surface waters. The fish fauna resemble the fauna of the middle boreal region. Coastal rivers are important breeding grounds for many fish species living in the Bothnian Bay and the Baltic Sea. Salmon (*Salmo salar*), sea trout (*Salmo trutta*) and lamprey (*Lampetra fluviatilis*) are typical migratory species for River Torne watershed.

Human impact

The river and its watershed is regarded as a pristine area with relatively low loads of pollutants. The main channels are free from hydropower dams, although there are power plants in the southern tributaries River Tengeliönjoki in Finland and River Puostijoki in Sweden. A single power plant is located in River Torne in Kengisforsen but it does not bank up the riverbed.

The population in the watershed was approximately 45 600 in the Swedish Torne municipalities in 2005, of which approximately 41 000 lives within the River Torne watershed. In Finnish side of the watershed, the population sums up to approximately 36 000 people. The population is mainly concentrated to two areas: Haparanda-Tornio area in the mouth of the river (> 50% of the population), and Kiruna in the western part of the watershed (c. 30% of the population).

The main impacts from point sources originate from waste water of towns and scattered settlements and industry. A majority of the point sources in the area are public wastewater plants with various degree of treatment. The largest industries are the steel mill Outokumpu Stainless Oy in Tornio and the LKAB iron ore mines and pelletising plants in Kiruna and

Svappavaara. Other point sources include peat mining, fish farming and some small-scale industries (Figure 2).

Impact from land use is mainly attributable to forestry and agriculture. Agriculture is concentrated to the southern municipalities and is dominated by livestock husbandry and milk production. The arable land is for the most part used for hay or silage production. The number of agricultural farms has decreased rapidly during the last decades, while the remaining farms have become larger and more efficient. In the past, lakes were also lowered to increase arable lands and pastures.

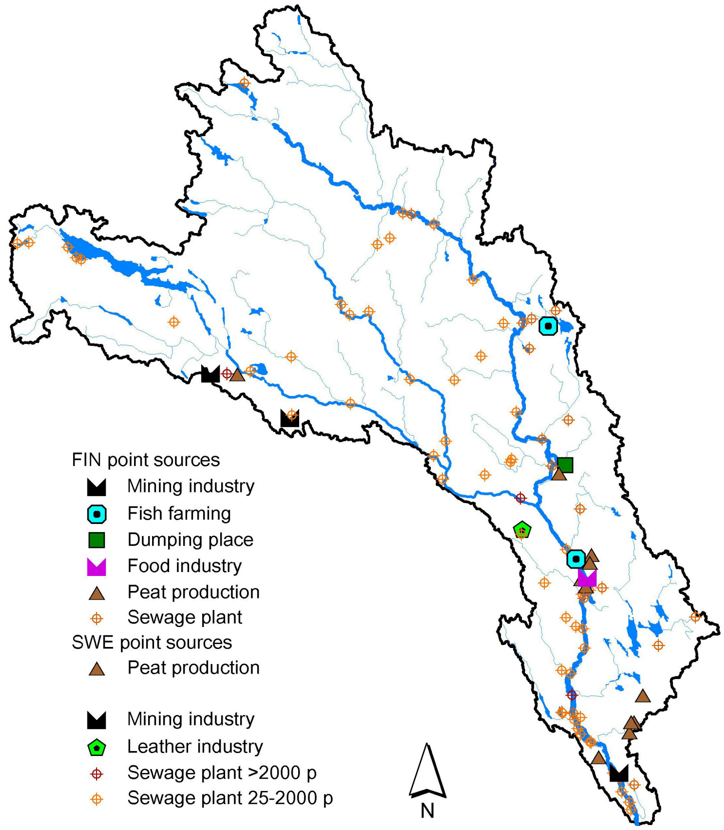


Figure 2. Major point sources in the River Torne watershed.
©Lantmäteriet

About 58 % of the River Torne watershed are forests and about 11 % are wetlands (Figure 3). Coniferous forests constitute to about 39 % of the total area. Forestry has probably caused the most extensive impact on the waters in the watershed. Ditching of forest land and clearing of rapids for log-driving have also caused physical alterations in many tributaries and in the main channels. Development of forestry practices has been similar in Sweden and Finland and practices have changed prominently over the last century. The modern mechanised forestry has changed from large clear-cuttings, ploughing, ditching and heavy ground preparations to more lenient methods. 30-50 % of the mires in the Finnish side have been ditched for use of agriculture, forestry and peat mining, mainly in the southern parts of the watershed. In Sweden ditching has been less common. The nutrient load on waters caused by cuttings and ground preparations varies substantially with soil types, topography and timing (season, weather conditions) of the forestry measures. Water protection measures, like riparian buffer zones, are important in minimizing the environmental impacts of forestry.

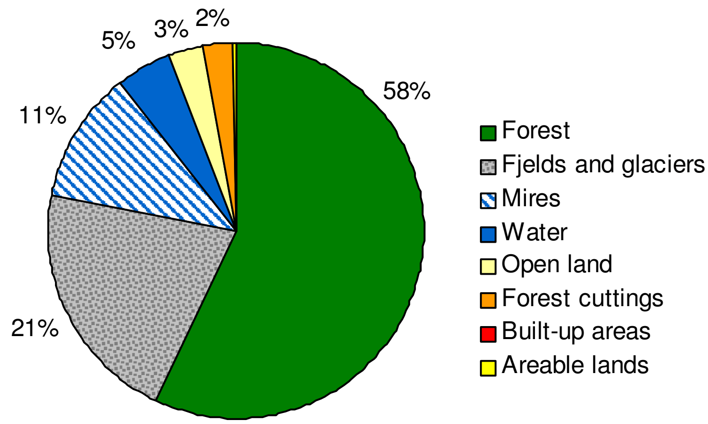


Figure 3. Land use in the River Torne watershed. Data from the TRK-project in Sweden (SLU and SMHI, 2006)

The impacts of the various forms of land use can be seen as increased loads of nutrients and organic substances and elevated turbidity of waters. Combined effects of agriculture, forestry and past hydrological alterations (lowering of water level) have caused problems in several small lakes in southern part of the watershed. Typical symptoms of eutrophication and severe organic loading include recurrent blooms of blue-green algae, harmful spreading of the aquatic vegetation, alterations in fish communities and prominently increased sedimentation in the littoral and profundal areas. In Finland, the attempts have been made to restore some of the problematic lakes by raising the water level, cutting down aquatic plants and by biomanipulation of the overpopulated fish stocks.

Approximately 950 km of the tributaries on the Finnish side and 900 km on the Swedish side have been cleared for log-floating during the 1950s and 1960s. This has caused a marked decrease in biodiversity and permanent changes in river channel morphology. When log-floating ceased in 1971 rapids were partly restored. An open floatway was left in the middle of the river to enable log-floating in the future. Many dams for controlling the water level of small tributaries were also left untouched. Ecological factors were neglected in many restoration measures, e.g. spawning grounds for migrating fish were restored in a very small scale and with varying success. Restoration of spawning areas and living habitats for small trout and salmon fry is still needed in some tributaries.

According to a mapping of the log-floating in Norrbotten, there were 60 log-floating dams in the Swedish tributaries of the Rivers Torne, Muonio and Lainio (Wikström, 1980). It is uncertain to what extent these dams still affect the water flow and constitute migrating barriers or if they have been demolished. In Finland, the dams were either demolished or opened during the restorations, and should not hinder the migration of fish and other organisms. Road culverts often constitute migrating barriers. An estimation for Norrbotten declares that approximately 1/3 of all culverts constitutes barriers to migrating fish. The effects of culverts have not been inventoried in the Finnish part of River Torne, but it is most probable that the situation is similar than in Sweden.

In the River Torne watershed, the diffuse load of acidifying substances via atmospheric deposition is very low in a Nordic perspective. The deposition of sulphur has decreased since mid-1980's, as a consequence of decreased sulphur emissions from industries and other point sources. There is no similar trend for nitrogen compounds, which originate mainly from traffic emissions and are more difficult to clean out. At present, there is no impending risk that waters in the area will become acidified, although some areas are more sensitive to acidifying load due to watershed characteristics.

2 The TRIWA project

The two northern regional authorities in Sweden and Finland have initiated the TRIWA project (The River Torne International Watershed) as a step towards a common river basin management. TRIWA is run by a working group from the Lapland Regional Environment Centre and the County Administrative Board of Norrbotten. The project has a steering group with representatives from national and regional authorities and the water protection association. The project is partly financed by the EU Regional Development Fund, INTERREG IIIA Nord. A sub-project was partly financed by The North Calotte Council.

TRIWA constitutes of two sub-projects:

- Developing a harmonised typology for lakes and rivers in the River Torne watershed (partly financed by The North Calotte Council).
- Reference Conditions in Lakes and Streams in River Torne International Watershed - a Step Towards a Harmonised Monitoring Programme (partly financed by the EU Regional Development Fund, INTERREG IIIA Nord)

Additionally, Swedish-Finnish Border River Commission financed fish inventories conducted in the small reference rivers in the River Torne area.

2.1 Aims

The aim of TRIWA is to establish reference conditions for chemical and biological parameters that can be used as criteria for the assessment of ecological status for the most common water types of the River Torne watershed. Another aim is to identify potential reference sites and to develop a harmonised Finnish-Swedish typology and a scheme for monitoring of ecological status of lakes and rivers of the River Torne watershed. In all, the scope of the project is to develop bases for the common management of the surface waters of River Torne International watershed.

2.2 Tasks

The project work was divided into four tasks:

Field surveys (Chapter 3)

The field studies are of importance for all the other tasks. Field surveys are used for defining reference conditions, testing and validating the typology, and as a base for the common monitoring programme.

Development of a harmonised typology (Chapter 4)

The aim was to develop a common typology for lakes and rivers in the River Torne water basin. Methods included 1) Comparison of the availability and structure of national data, 2) Identification and delineation of surface water bodies, 3) Classification of lakes and rivers in different water types and 4) Testing of different Swedish and Finnish typology approaches in the River Torne area in order to create a harmonised typology system appropriate for the watershed.

The observed differences in national typologies and GIS-data (Geographical Information

System) in Finland and Sweden underlined the need for development of a harmonised typology system for the River Torne International watershed. Lack of water chemistry data required for the typology (water colour) also induced the need for alternative methods. Further, the serious lack of preliminary biological data created need for intensive field inventories in order to collect comparable sets of different type water bodies for the testing of the developed typology.

Reference conditions and ecological status (Chapter 5)

The definition of type-specific reference conditions for the most common lake and river types in the River Torne watershed included: 1) Compiling and analysing of existing monitoring data from the watershed to locate potential reference lakes and rivers, 2) Conducting field surveys (described in chapter 3) in the most common lake and river types to provide new data for the characterisation and 3) Establishing of reference conditions and estimating class boundaries between high and good ecological status. The results were used to select possible reference lakes and rivers for the monitoring program. They will work as indicators of high ecological status for the water types they represent.

Common monitoring programme (Chapter 6)

The aim was to make a suggestion for a harmonised monitoring programme for surface water status within the River Torne watershed. Analysing the validity of the current monitoring programmes in comparison of WFD demands and developing alternate suggestions as a basis for a representative and cost-effective co-operative programme fulfilled the task. The final monitoring programme will be formulated in cooperation with the responsible authorities and actors (the water protection associations, municipalities and other stakeholders) in the area. The programme should give continuous information about the ecological state of the surface waters and follow the pressures from different activities.

3 Field surveys

Compilation of existing data on the surface waters of River Torne watershed revealed serious lack of biological data. In Finland, small lakes and rivers, which constitute the most abundant surface water types, are virtually unexplored. Some phytoplankton data from larger lakes exists. Fish data is scarce in both countries except for major tributaries and the main channels. In Sweden, there is some phytoplankton data from campaign surveys and from the lake monitoring stations. There is also Swedish data on benthic animals from about 40 small lakes and 30 small rivers in the watershed (from the national survey in 2000). However, many of these sites are too small to be included in the common typology and the implementation of WFD at this stage. Hence, the available data set was not large enough to be used in evaluations of the suggested typology or the definition of reference conditions of the different water types. The different methods used by the countries in previous sampling campaigns also causes difficulties when evaluating the old data. Therefore, field surveys were the crucial part of TRIWA-project and formed the basis for the fulfilment of the major tasks. Sampling was focused on the water chemistry, phytoplankton (lakes), benthic macroinvertebrates and fish fauna of the most common lake and river types in the watershed.

3.1 Selection of the survey sites

Because of the limited resources of the project, the decision was made to restrict the field studies to the most abundant surface water types. The most abundant types were selected according to the preliminary harmonised typology, which is described in more detail manner in chapter 4. In the first phase in 2004, 3 lake types and 2 river types from the coastal and inland regions were included in the survey. The lake types included small, clear water inland lakes (type 2), small, brown water inland lakes (type 3) and small, brown water coastal lakes (type 9). The studied river types were small, brown water inland rivers (type 4) and small, brown water coastal rivers (type 9). On the second field period in 2005 the investigations were extended to small lakes and rivers of northern mountain areas (lake type 1 and river type 1). The goal was set in finding five lakes and rivers to represent each investigated water type. A total of 20 lakes and 15 rivers representing reference conditions were selected to the field studies (Figure 4).

Preliminary field inventories could not be conducted due to the short project period. Therefore the selection of potential reference sites was mainly based on the map investigations and existing water quality data. The requirements for potential sites were limited anthropogenic impact in the catchment area, good water quality (clearly eutrophic and impacted areas were excluded) and moderately easy accessibility by car with boat trailer. However, use of boat was regarded impractical in mountain areas requiring aerial transport. Maps and databases of vegetation, land use, forestry (fellings, drainage), point sources and other human activities were used for analysing the watershed conditions. Lakes and rivers with lowest possible impact were chosen and the priority was given to sites with reliable existing water quality data to assure reference conditions. The first sampling campaign revealed that some potential sites had to be excluded since they were shown to be inappropriate. In these cases, sites on a reserve list were picked as alternatives.

Finding of pristine water bodies proved to be problematic especially in water types of coastal region due to moderately dense population and effective land use activities. Further difficulties were caused by the shortcomings of the depth- and water quality data, especially in Swedish areas. In Finland, the selection of sites was done using moderately old map data.

Finnish electric map material was updated in the beginning of 2006. Updated maps revealed previously unmarked forest ditch networks on the catchment areas of the many selected reference sites. However, the effects of these ditching do not seem to have considerable impacts on the water quality of the selected sites.

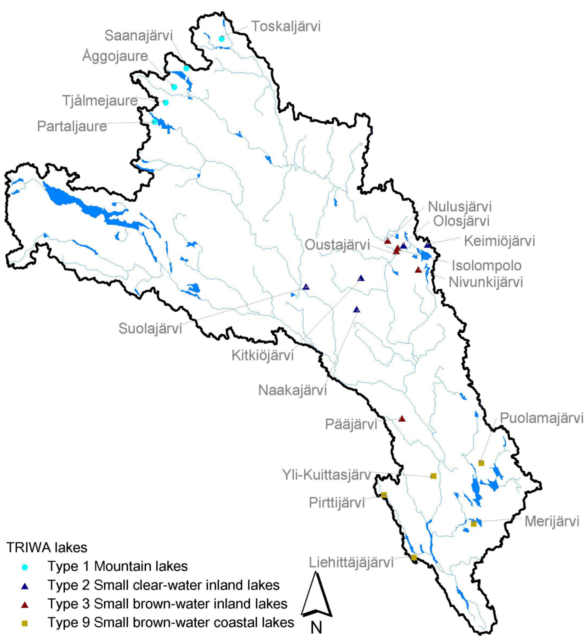
Main characteristics of the selected lakes and rivers are presented in Tables 2 and 3. Examination of new water analyses data and updated map data revealed further inaccuracies in the scarce preliminary data. Lake Yli-Kuittasjärvi appeared to be very nutrient-rich and was excluded from the analyses (see chapter 4.1 for more details). Some other lakes and rivers appeared to deviate also slightly from the class boundaries of the typology criteria. (for instance, lower water colour in Puolamajärvi and lower peat cover of the catchments of rivers Jylhäjoki and Orjasjoki. However, the overall representativeness of these sites was judged to be adequate.

Table 2. Characteristics of the surveyed lakes in River Torne international river basin district. Water quality parameters represent the seasonal means of surface water from 2004 (types 2, 3 and 9) and 2005 (type1). Preliminary surface water types are described in chapter 4.

Site	**Altitude (m.a.s.l)**	**Lake area (km^2)**	**Wetland (%)**	**Colour (Pt mg/l)**	**Depth (m)**	**pH**	**Total P (µg/l)**	**Total N (µg/l)**
Type 1								
Saanajärvi (Fi)	680	0.701	0	7.7	25	7.10	5	147
Toskaljärvi (Fi)	704	0.999	0	4.1	21	7.49	6	90
Partaljaure (Swe)	769	0.717	0	8.7	-	6.85	5	130
Åggojaure (Swe)	549	1.044	3.5	14.9	-	7.17	7	137
Tjålmejaure (Swe)	700	1.3	1.5	8.7	-	7.15	7	145
Type 2								
Isolompolo (Fi)	233	0.544	17.9	46.9	2	6.95	12	284
Keimiöjärvi (Fi)	333	0.608	5.3	38.3	7	6.97	14	232
Olosjärvi (Fi)	242	1.918	17.3	42.1	7	6.98	13	298
Naakajärvi (Swe)	331	1.097	2.1	11.3	4	6.91	21	387
Suolajärvi (Swe)	316	0.706	24.1	23.0	8	7.18	17	314
Type 3								
Nivunkijärvi (Fi)	298	1.442	19.8	58.9	3	6.92	14	323
Nulusjärvi (Fi)	233	0.816	26.2	72.5	3	6.95	16	350
Oustajärvi (Fi)	235	0.53	30.8	98.8	2	6.66	15	380
Kitkiöjärvi (Swe)	255	1.563	23.2	78.7	9	6.72	13	278
Pääjärvi (Swe)	189	0.92	27.8	62.7	4	6.89	33	638
Type 9								
Puolamajärvi (Fi)	91	1.642	23.1	43.9	8	7.11	11	282
Merijärvi (Fi)	85	1.138	40.2	108.6	6	6.91	21	472
Liehittäjäjärvi (Swe)	132	1.076	21.9	95.1	7	6.74	16	370
Pirttijärvi (Swe)	141	1.424	35.7	125.9	7	6.73	24	514
Yli-Kuittasjärvi (Swe)	77	1.701	10.9	97.3	2	6.90	57	1208

Table 3. Characteristics of the surveyed rivers in River Torne international river basin district. Water quality parameters represent the seasonal means of surface water from 2004 (types 4 and 8) and 2005 (type1). Preliminary surface water types are described in chapter 4.

Site	Altitude (m.a.s.l.)	Catchment area (km^2)	Peatland (%)	Colour (Pt mg/l)	pH	Total P (ug/l)	Total N (ug/l)
Type 1							
Poroeno (Fi)	590	158	0	7.7	7.21	5	59
Rommaeno (Fi)	530	381	1	30.0	6.91	8	177
Kåbmejåkkå (Swe)	667	102	2	8.3	7.15	5	117
Lafoljåkkå (Swe)	655	103	2	14.3	7.12	8	86
Skittsekallojåkkå (Swe)	725	60	6	11.0	6.90	6	99
Type 4							
Jerisjoki (Fi)	245	263	21	39.2	6.86	13	354
Keräsjoki (Fi)	285	112	29	101.0	6.70	13	274
Kuerjoki (Fi)	210	156	22	98.3	6.79	19	228
Käymäjoki (Swe)	184	194	47	62.7	7.22	10	372
Parkajoki (Swe)	228	632	17	77.0	6.85	12	186
Type 8							
Kuijasjoki (Fi)	85	127	56	172.3	6.95	17	568
Naalastonjoki (Fi)	145	82	32	107.3	6.97	14	308
Jylhäjoki (Swe)	184	145	16	119.7	6.57	17	382
Orjasjoki (Swe)	156	63	13	140.2	6.62	15	350
Tupojoki (Swe)	114	173	30	168.7	6.88	29	506



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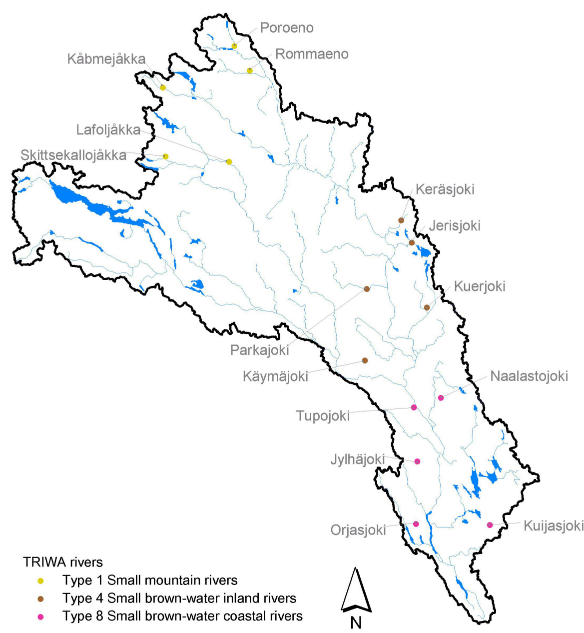


b)

Figure 4. a) Lakes and b) rivers included in the field survey of the TRIWA project. The sites are potential reference sites. © Lantmäteriet

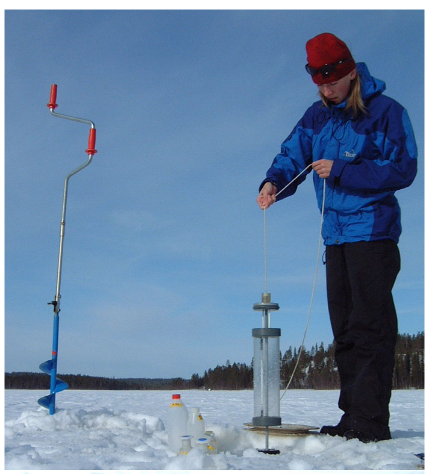
3.2 Sampling and analysis

In lakes, sampling included water chemistry, phytoplankton and littoral- and profundal benthic macroinvertebrates (with the exception of mountain lakes, where only littoral benthos and surface water chemistry were sampled). In rivers, the sampling was focused on the water chemistry, benthos and fish fauna of the swift-flowing rapids. Sampling and analyses were in accordance with standardised methods used in the Swedish and Finnish monitoring programs (Swedish EPA www.naturvardsverket.se).

Table 4. Sampling scheme for the rivers and lakes.

Inland and coastal sites			**2004**			**2005**	
	June	July	Aug	Sept	Oct	Mar/Apr	Aug
Chemistry	X	X	X	X	X	X	
Chlorophyll	X	X	X	X	X		
Phytoplankton (lakes)	X	X	X				
Macroinvertebrates				X			
Fish fauna (rivers)							X

Mountain sites			**2005**		
	June	July	Aug	Sept	Oct
Chemistry	X		X	X	
Chlorophyll	X		X	X	
Phytoplankton (lakes)	X		X		
Macroinvertebrates				X	



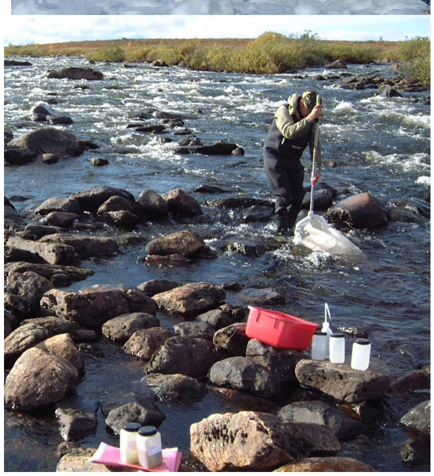


Figure 5 . Photos from the field work. The pictures show a Ruttner-sampler for water samples (top left) and an Ekman-grab for sampling of profundal macro-invertebrates (top right). Macro-invertebrates in rivers are sampled using a net (left). Photos S. Elfvendahl.

The sampling in the southern and central parts of the watershed was carried out from June to October in 2004. Additional winter samples were taken in late March or early April 2005. Electro-fishing of the inland and coastal rivers took place in August 2005. Mountain sites were sampled in 2005. The sampling was conducted according to the time-table in Table 4. Figure 5 shows some examples of the sampling equipment used.

Water chemistry

All samples were taken from a boat, except mountain lakes which were sampled from helicopter with floaters. Water samples were taken with a Ruttner-sampler at the deepest part of the lake. In inland and coastal lakes, a depth sounder was used to check the depth from boat. The mountain lakes were sampled for the surface water in the middle of the lake or where the depth seemed to be greatest. Surface water samples were taken on 1 meter depth and profundal samples were taken approximately 0,5-1 m above the bottom. Profundal sampling was excluded in lakes with maximum depth less than two meters. Chlorophyll was sampled in the 0-2 meter water column.

The analyses were done following the parameter list represented in Table 5. All analyses were conducted in the laboratory of Lapland regional environment centre. The results were registered in Finnish national water quality registers (LIMS and HERTTA).

Table 5. Variables included in the water chemistry analyses.

Lake littoral and river	Lake profundal
pH	pH
Conductivity (mS/m)	Conductivity (mS/m)
Alkalinity (mekv/l)	Alkalinity (mekv/l)
Ca (mg/l)	Total N (µg/l)
Mg (mg/l)	Total P (µg/l)
Na (mg/l)	O_2 (mg/l)
K (mg/l)	O_2-%
SO_4 (mg/l)	Colour (Pt mg/l)
Cl (mg/l)	
F (µg/l)	
NH_4-N (µg/l)	
NO_2+NO_3-N (µg/l)	
Total N (µg/l)	
PO_4-P (µg/l)	
Total P (µg/l)	
TOC (mg/l)	
Absorbance	
Si (mg/l)	
Fe (µg/l)	
Total Al (µg/l)	
Chlorophyll-α (µg/l)	
O_2 (mg/l)	
O_2-%	
Colour (Pt mg/l)	

Phytoplankton

Quantitative samples of phytoplankton were taken by using a 2 meter Ramberg-tube with 5 cm diameter. Five sub-samples were taken in the 0-2 meter water column and a pooled sample was collected in a jar and conserved using IIK (Iodine-Iodine-Potassium).

The identification of species and biovolume calculations were done at the Department of Environmental Assessment at The Swedish University of Agricultural Sciences (SLU). The identification was done according to species list used in Swedish national phytoplankton inventories. The results were registered in Swedish national phytoplankton register.

Due to considerable natural temporal variation in the volume and occurrence of phytoplankton, results from August sampling were used in the statistical comparisons of biovolumes in order to balance the data collected in different years and ecoregions. In August the water temperature, and consequently phytoplankton flora, is usually more stable than in the beginning and end of the sampling season, due to the lake stratification. Therefore, August is regarded as most comparable sampling occasion in Swedish monitoring programs. The data evaluation included calculations of total number of taxa, total biovolume, number of toxic species (Swedish EPA, 1999) and number of indicator species for eutrophy and oligotrophy (Tikkanen and Willén, 1992). Further, the proportions of the volume of main families from the total biovolume were calculated.

Benthic macroinvertebrates

Profundal macroinvertebrates were sampled using an Ekman-grab. Five samples were taken from the deepest zone of the lakes. The sediment was sieved in the field (sieve diameter 0,5 mm) and samples were conserved with 70 % ethanol. Profundal sampling could not be conducted in Finnish lake Isolompolo due to thick moss vegetation in the substrate of the profundal area. Similar problems, although not as severe, were experienced also on other shallow and clear water lakes. As mentioned before, the profundal sampling was not conducted in mountain lakes due to logistic constraints. Due to unfortunate navigation error, the littoral samples of Swedish mountain lake Tjålmejaure were actually taken from a near-by lake Sniertekluobbalah, located on a bit lower altitude closely downstream of Tjålmejaure. The characteristics of Sniertekluobbalah coincide Tjålmejaure and the samples were regarded to be representative for type 1 lakes.

Lake littorals and river riffle habitats were sampled using a kick-net (net diameter 0,5 mm), following the methods used in Swedish national benthic inventories in year 2000 (Wilander et al., 2003). After selecting a suitable site with stony substrate (and high current velocity in rivers), five replicate samples were taken and all material in the net was sieved and conserved in jars with ethanol. The sampling methods used are further described in the Swedish monitoring handbook (www.naturvardsverket.se).

The sampling sites were inventoried in connection with benthic sampling. Inventories included rough estimates concerning the substrate type, vegetation and water velocity of the sampling site and characteristics of the vegetation and land use of the nearby catchment area. The classification of different habitat characteristics was later judged to be too general to be used in the multivariable analyses as environmental variables. However, inventories could have been used as background information in cases, where the results differ suspiciously from the other sites of the same water type.

The biological variables calculated from the lake littoral and river species data were total number of taxa, number of individuals, biomass (for lakes), Shannon's diversity index, number of sensitive species (Ephemeroptera, Plecoptera and Trichoptera, "EPT-species"), British environmental quality indexes (BMWP and ASPT), Danish Fauna Index, Medin's acidity-index and Saprobia-index (Henrikson & Medin 1986) Further, several variables were calculated from profundal samples (like BQI and Oligochaeta/Chironomidae-ratio), but further comparison of profundal data was regarded futile due to strong variation in the maximum depth between the lakes. True profundal area was lacking from the majority of the shallow lakes, making the use of biological variables unreliable.

Species identification, index calculation and registering of data was done at the Department of Environmental Assessment at The Swedish University of Agricultural Sciences. The identification level followed the Swedish standards used in the national survey (Wilander et al., 2003). In Swedish inventories, a list of selected “operational species” is used in index calculation in order to enhance the comparability of results between different ecoregions in Sweden and diminish the effect of random species on diversity. However, in TRIWA-project the index calculation and further statistical analyses were carried out using whole species list (“normal species list”) in order to enable the comparison with existing Finnish material. Further, the diversities and species numbers calculated with “operational species list” were observed to be misleadingly low in some species-poor mountain lakes.

Fish fauna

The electro-fishing of the small, brown water rivers of inland and coastal region was conducted in August 2005. In Finland, the fishing was carried out by the Finnish Game and Fisheries Research Institute and in Sweden by the Swedish Board of Fisheries. In addition to the sites used for water chemistry and benthic sampling, 2-3 near-by rapids were electro-fished in every river to get a representative view of the fish fauna. Electric fishing was done using the established practices and equipments, which are quite well comparable between the two countries (Handbook for monitoring). The fishes caught were measured for length and weight. Scale samples were taken from salmonids for age determination.

Finnish and Swedish institutions reported their results separately using the variables and indices commonly used in national surveys (Swedish EPA 1999, & Böhling & Rahikainen 1999). This led to problems regarding the comparability of some variables indices, when the data for whole River Torne watershed was compiled. Especially the lists of species regarded as sensitive to anthropogenic activities differed between the countries. To overcome the problem with comparability, a harmonised list of sensitive species was created, consisting of the species regarded as sensitive in both countries (Salmon (*Salmo salar*), Brown trout (*Salmo trutta*), Grayling (*Thymallus thymallus*), Minnow (*Phoxinus* phoxinus) and Burbot (*Lota lota*)). The biological variables used in subsequent analyses were total number of species, number of individuals, total biomass, number of salmonid species, number of reproducing salmonid species and number of sensitive species.

3.3 Statistical methods

The differences in biological variables and water chemistry between the types were tested with one-way Analysis of Variance (ANOVA). In the case of statistically significant difference ($p< 0,05$) the pair-wise differences were revealed using Tukey’s test. With the fish data with only two types to compare, the comparison was made using T-test. In cases, where the analysed variables did not meet with the requirements of the tests (normal distribution and homogeneity of variances), the distributions were modified with square-root or logarithmic transformations.

The possible environmental trends in the distribution of the benthic fauna and phytoplankton flora were tested using multivariable analyses (Ter Braak 1996). Detrended Correspondence Analysis (DCA) was first used to reveal the length of the environmental gradient. Since the observed gradients were moderately long, Canonical Correspondence Analysis was used to find out the relationships between species distribution and environmental variables. The importance of different environmental variables in explaining the species distribution was estimated using Forward Selection- procedure. All multivariable analyses were carried out using the computer program Canoco for Windows 4.1 (Ter Braak & Šmilauer 1998).

4 Development of a harmonised typology

4.1 Typology guidelines

The WFD requires that member states differentiate the relevant surface water bodies with respect to their natural type, and that member states establish type specific reference conditions for these types. Deviation from the reference conditions is then used as a base for the classification of the ecological state of the surface water bodies. The classifications will be subsequently included in the river basin management plans which will be reported to the EU Commission for the first time in 2009 (Directive, 2000).

The types shall be classified using either system A or system B (Annex II in the 2000/60/EG Directive). The two systems are similar in the way that the same obligatory factors are to be used in both: geographic position, altitude, size, geology and, for lakes, depth. The difference is that system A prescribes with preset categories how water bodies shall be aggregated spatially (ecoregions) and with respect to specific altitude, size and depth intervals. The system B, besides lacking strict prescription, permits the use of additional factors. It is up to member states to decide what system to use. Hence, the member states can develop their own specific guidelines for the typology according to system B. Most member states, including the Nordic countries, have indicated to prefer the system B.

Comparison of Swedish and Finnish typologies

The national typologies have been made according to available knowledge of different biological lake- and river types, distributions of regional quality factors in water bodies and the correlations between biological quality elements and environmental factors. During the time of the TRIWA project there has been several suggestions for national typology guidelines in Finland and Sweden. Harmonised typology for River Torne basin was created on the basis of preliminary Swedish and Finnish typology suggestion from the years 2003 and 2003, respectively (Fölster et al. 2003; Ministry of Environment 2002). More detailed information of preliminary national typologies is given in TRIWA projects typology-report (Alanne et al. 2005).

By the beginning of 2006, new typology suggestions have been published in both countries. In Finland, the new typologies were formalised by Ministry of the Environment in February 2006 (Ministry of Environment, 2006). The Swedish typology was finalised in spring 2006 (Swedish EPA, 2006). The new typologies came quite late during the TRIWA work and have not been regarded in harmonisation of typology.

In the present Swedish typology, seven ecoregion classes have been selected as an adaptation to the variation in biological quality elements. This regards a region-specific typology for each quality element, which seems to enhance the applicability compared to the earlier typology suggestions. The reference conditions for each quality element will hence be region-specific rather than type-specific.

The new Swedish typology criteria are:

Criteria for ecoregion and altitude

1. The alpine region, over the tree limit
2. The northern inland, below the tree limit, above the highest coastline
3. The northern coast, below the highest coastline
4. The southeast, south of Limes Norrlandicus, the basin of the Baltic proper, below 200 m.a.s.l.

5. The south region, Scania, the coast of Blekinge and southern Öland
6. The southwest, south of Limes Norrlandicus, the basin of the Kattegatt and Skagerrak west coast, below 200 m.a.s.l.
7. The southern highlands, south of Limes Norrlandicus, above 200 m.a.s.l.

Criteria for hydromorphology

	Watershed size	Depth (max)	Size	Humus (colour)	Calcareous
Lakes		>5 m	>10 km2	>50 mg Pt/l	>1,0 mekv alk
		</=5 m	</= 10 km2	</= 50 mg Pt/l	</= 1,0 mekv alk
Rivers	>10 km2			>50 mg Pt/l	>1,0 mekv alk
	</= 10 km2			</= 50 mg Pt/l	</= 1,0 mekv alk

This results in 48 possible lake types and 24 river types for the River Torne area, of which several types are most likely very scarce, e.g. humic lakes and rivers in the alpine region.

The official national typology in Finland contains 12 lake types and 11 river types. The main difference towards Swedish typology is the lack of ecoregions (with the exception for the lakes in Northern Lapland). However, some regional adjustments can be made in implementation of the typology in different River Basin Districts.

<u>The following lake types are included in the Finnish typology:</u>

1. Small and medium-sized humic-poor lakes
2. Small humic lakes
3. Medium-sized humic lakes
4. Large humic-poor lakes
5. Large humic lakes
6. Humic-rich lakes
7. Shallow humic-poor lakes
8. Shallow humic lakes
9. Shallow humic-rich lakes
10. Lakes with very short retention time
12. Lakes of Northern Lapland
13. Eutrophic and lime-rich lakes

Typology contains three size-classes (small: < 5 km^2, medium: 5-40 km^2 and large: > 40 km^2) and three colour-classes (humic-poor: < 30 mg Pt/l, humic: 30-90 mg Pt/l and humic-rich: > 90 mg Pt/l). Lakes with mean depth below three meters are classified as shallow. Lake is considered having short retention time, when it detents water only for few days. Lakes are classified as eutrophic and lime-rich, when the water quality is naturally nutrient- and chalk-rich due to soil- and bedrock characteristics of the catchment area. Lakes of Northern Lapland refers to lakes located on mountainous areas above the conifer tree limit.

Types for Finnish rivers are as follows:

1. Small peat land rivers
2. Small mineral land rivers
3. Small clay land rivers
4. Medium-sized peat land rivers
5. Medium-sized mineral land rivers
6. Medium-sized clay land rivers
7. Large peat land rivers
8. Large mineral land rivers
9. Large clay land rivers
10. Very large peat land rivers
11. Very large mineral land rivers

The typology has four size-classes for catchment area (small: < 100 km^2, medium: 100-1000 km^2, large: 1000-10 000 km^2 and very large: > 10 000 km^2). The river is classified as peat land river, when the peat land cover of the catchment area is more than 25%, or the above lake has a water colour higher than 90 mg Pt/l. Rivers with lower peat coverage in their catchments are mainly classified as mineral land rivers. Clay land rivers are usually located in coastal catchment areas with clayey soil that naturally affects the water quality of the river. Conifer tree limit can be also used as a border value to separate mountainous rivers, although that specific type is not included in the official river typology.

In the River Torne basin, the national typologies in many cases proved to be complicated and impractical to use. Both latest typologies have their advantages and disadvantages. For instance, Swedish typology has ecologically sound boundaries for ecoregions, but the total number of types is still overwhelming. The Finnish system has a practicable number of types, but the types are too trivial and omit some ecologically and biogeographically sound types. Especially the lack of formal type for northern high-altitude rivers seems ecologically unjustified. According to the numerous studies, several biological quality elements show a distinct ecoregional division, especially in the waters of Northern Scandinavia (Heino 2002, Pedersen 1990, Sandin & Johnson 2000). Further, the Finnish guidelines for regional adjustment and specification of the typologies are at present poorly characterised, and are likely to cause confusion in the implementation of the typology on the regional level.

4.2 Harmonisation of national typologies

The main goal was to create a practical, logical and simple common typology, where the number of lake and river types should be moderately low. However, the number of types had to be sufficient to characterise the whole range of ecologically different surface waters in the River Torne watershed. The number of types should also be adjusted to a level, on which the type-specific reference conditions would have adequately low variability (Alanne et al. 2005).

Identification and outlining of boundaries of surface water bodies was the initial task. This was done using maps of scale 1:250 000. Due to the large number of small water bodies in the River Torne watershed, only lakes larger than 0,5 km^2 and river catchments larger than 200 km^2 were outlined and taken into account in development of a harmonised typology. However, the outlining of river catchments was done following the natural barriers of the drainage areas (sub-basins and tributaries). Therefore the size of the smallest outlined catchment units varied from 50 km^2 to 300 km^2.

The next step was to classify lakes and rivers into the different water types depending on e.g. geographic location/ecoregion, size and geology. The different approaches of Swedish and Finnish typologies were compared and applied in the River Torne area in order to develop a harmonised typology system appropriate for this watershed particularly.

Main factors of the TRIWA typology

The ecoregion factor was defined into three classes: mountain, inland and coastal regions. Mountain waters were defined to be above the conifer tree limit, which represents a climate limit. Therefore the mountain waters are generally clear and less humic compared to forest waters. The conifer tree line (Figure 6) is comparable to the biogeographical limit between the borealic upland and the fenno-scandian shield (Fölster, 2003). The classification by a constant altitude (> 250 m m.a.s.l), which was the Finnish definition for mountain lakes in the earlier national typology suggestion, resulted in classification of many forest land lakes into the mountain lake-category, which increased the within-type natural variation excessively. The highest coastline (HC) since last glacial period (Lake Ancylus), which is located approximately 200 meters above the present sea level in the River Torne area, was used to differentiate the inland and coastal waters. It is an ecologically relevant limit for e.g. fish and zooplankton, which is related to migration history. It also represents differences in catchment geology and water chemistry of waters above or below HC. The chosen ecoregion criteria correspond very well to the Swedish typology guideline, except that the conifer tree limit sets the border to mountain waters instead of the alpine tree limit.

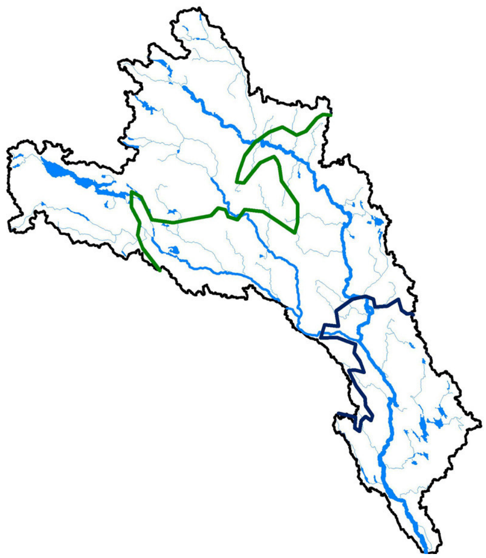


Figure 6. The pine tree limit (green) and the highest coastline (dark blue) since the last glacial period. © Lantmäteriet

Division of different size classes for the lakes and river catchments were done following the early suggestions of national typologies. Size classes for lakes were 1) small: 0,5–2,0 km^2, medium: 2-10 km^2 and large: > 10 km^2. Size division for river catchments was 1) small: < 1000 km^2, large: 1000-10 000 km^2 and very large: > 10 000 km^2.

The geological factor was used to characterise the humic content of the water, which is greatly influenced by the share of peat land (wetland) in the catchment area (Kortelainen & Saukkonen 1998, Kotanen 2005). The factor was determined using the measured or estimated water colour for lakes, and peat land cover of the catchment area for rivers. The limit values for the two classes (clear/brown) were determined using the results of a regression analysis (described below). Calcareous waters are scarce in the River Torne watershed and thus excluded in the suggested typology for the time being.

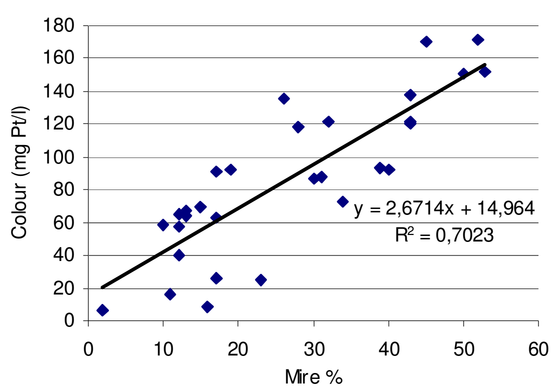
Although obligatory in EU's A and B systems, lake depth-factor was discarded due to lack of depth measurement data on the watersheds lakes, especially in the Swedish area. Further, the use of constant depth limit (mean depth 3m and maximum depth 3m in the Swedish and Finnish national typologies, respectively) seemed rather artificial in biological point of view. The chosen depth factors are supposed to correspond to lakes where thermal stratification is likely to occur in summer. However, estimation of lake's thermal stratification by depth data alone seems unreliable and does not ensure the presence of true profundal area. Depth limit should perhaps be related to some more biologically valid variable, for instance the thickness of lake's productive layer (estimated from Secchi depth) or the presence of real profundal benthic invertebrate community. The depth factor can be included to the harmonised typology in a later stage, when larger and spatially extensive depth data is available.

Modelling of the geology factor

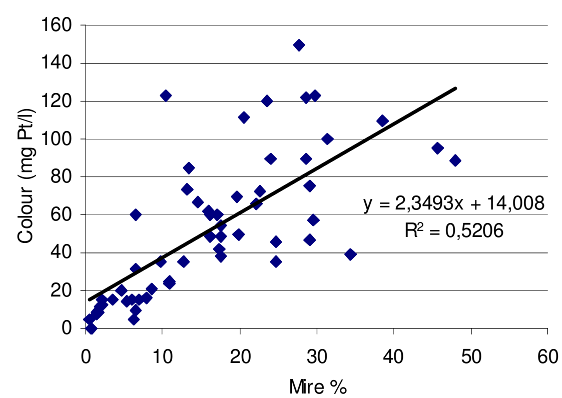
Water chemistry data from Sweden and Finland was available for 141 of 469 lakes larger than 0,5 km2. The problem of missing water colour observations for the remaining 328 lakes was solved using several methods. Using existing data, a regression was calculated between the water colour of water bodies and peat land (wetland) cover of their catchment areas. Further, missing water colours of lakes were estimated from the available water colour values of neighbouring water areas. This was done using an IDW –method (Inverse Distance Weight) with GIS-program ArcView 3.2a. The method is based on spatial interpolation. Finally, expert judgement was used with problematic cases (water bodies with strong human impact etc.). Lake turnover time and the proportion of surface waters in the lake catchment are also important factors affecting the water colour (Fölster 2003). A long turnover time and a large proportion of surface waters in the catchment results in clearer water due to sedimentation. However, data on retention times is scarce in both Finland and Sweden and could not be included in the calculations.

In Sweden, the calculations of peat land cover and other land use characteristics for lake and river catchments were performed using Lantmäteriet's vegetation maps. In Finland, Finnish Environment Institute's national land use database for small-scale river catchments gave sufficiently accurate estimates for peat land cover of the lake and river catchments.

Regression between lake water colour and catchment's peat land cover was calculated using data of 30 frequently monitored, nearly pristine lakes located on the Finnish side of River Torne watershed. Further, similar regression was calculated for Swedish river data consisting of 56 rivers. The results indicated that almost all lakes and rivers with peat land cover more than 20 % of their catchment area had a water colour around or over 60 mg Pt/l. The regression gives a small overestimation of colour for water bodies with low peat area coverage (Figure 7).



a) Lakes



b) Rivers

Figure 7. Regression analysis between water colour and the peat land (wetland) cover of catchment area. a) No. of lakes with >10 observations=30. b) No. of rivers =56.

The geology factor was tested using different number of classes and limits for water colour and peat land cover. Separation of water bodies into more than two colour classes raised the number of types impractically high. Further, use of three or more colour classes often led to erroneous typing of lakes and rivers with scarce data or strong human impact. Therefore, the decision was made to use two classes for humic content of the water, with limits of </>60 Pt mg/l water colour for lakes and </>20% peat land cover for river catchments.

4.3 Preliminary typology

The preliminary harmonised typology for lakes of River Torne watershed has a total of 13 types (Figure 8). It includes three classes for ecoregion, three size classes and two classes for geology-factor. Geological class is derived from observed or modelled water colour.

The most common lake types are mountain lakes (type 1), small clear-water and brown-water inland lakes (type 2 and 3) and small brown-water costal lakes (type 9) (Table 6). A total number of 469 lakes larger than 0,5 km2 were identified in the watershed.

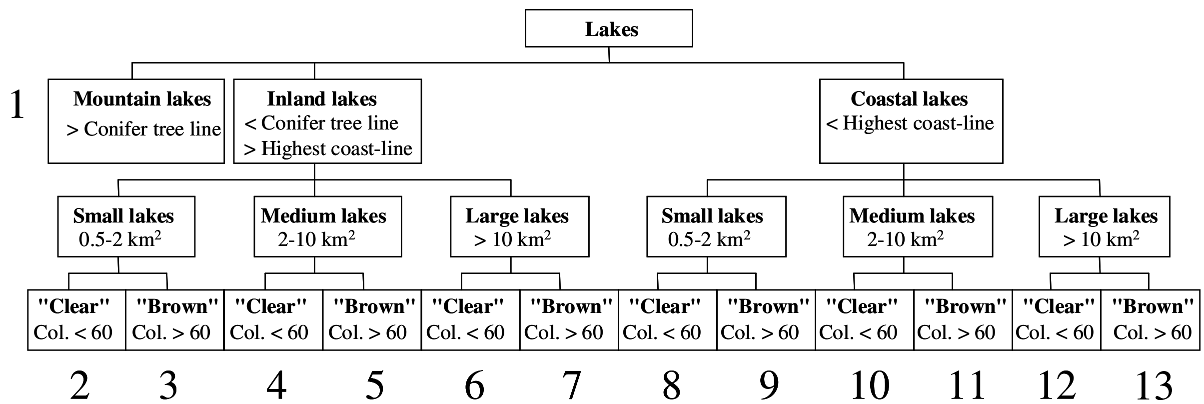


Figure 8. Preliminary harmonised typology for the lakes of River Torne watershed.

Table 6. The preliminary lake types and number of lakes in the River Torne watershed:

Type	Description	Sweden	Finland	Total
1	Mountain lakes	155	58	213
2	Small clear-water inland lakes	63	18	81
3	Small brown-water inland lakes	24	9	33
4	Medium clear-water inland lakes	12	3	15
5	Medium brown-water inland lakes	2	5	7
6	Large clear-water inland lakes	3	2	5
7	Large brown-water inland lakes	-	-	-
8	Small clear-water coastal lakes	6	10	16
9	Small brown-water coastal lakes	14	52	66
10	Medium clear-water costal lakes	-	8	8
11	Medium brown-water costal lakes	4	16	20
12	Large clear-water coastal lakes	-	1	1
13	Large brown-water coastal lakes	1	3	4

The preliminary harmonised typology for rivers has three ecoregions, three size classes and two classes for geological characteristics defining the natural humic content of the water. The suggested hierarchy adds up to a total of 11 types (Figure 9). Humic content is estimated using the peat land cover of the river's catchment area.

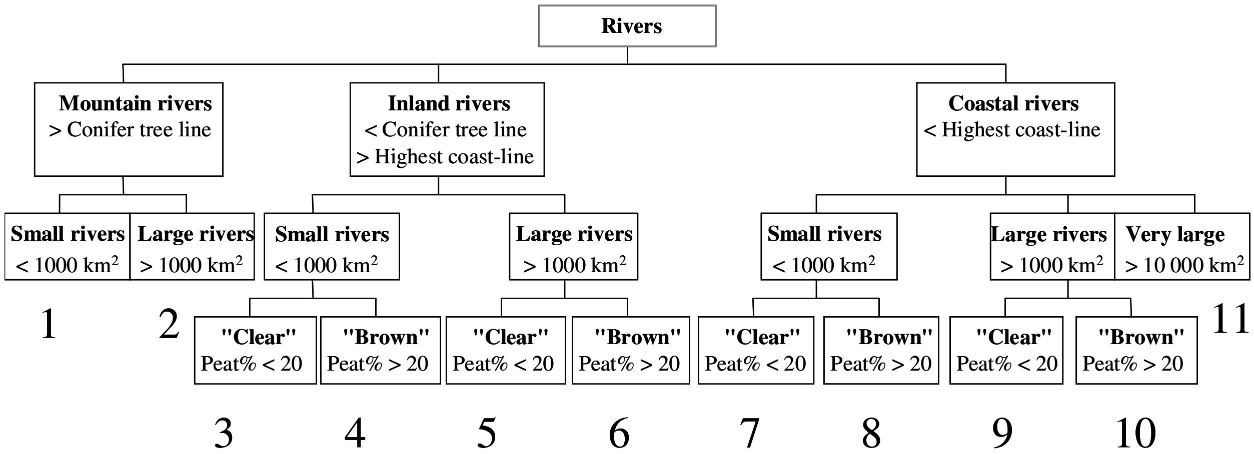


Figure 9. Preliminary harmonised typology for rivers of River Torne watershed.

For rivers, 141 water bodies were delineated. The most common types are small mountain rivers (type 1), small brown inland rivers (type 4) and small brown costal rivers (type 8) (Table 7).

Table 7. Number of river water bodies (delineated as watersheds) and their preliminary types in the River Torne watershed.

Type	Description	Sweden	Finland	Shared	Total
1	Small mountain rivers	41	10	-	51
2	Large mountain rivers	4	1	1	6
3	Small clear-water inland rivers	9	2	-	11
4	Small brown-water inland rivers	35	7	-	42
5	Large clear-water inland rivers	-	-	-	-
6	Large brown-water inland rivers		-	1	1
7	Small clear-water coastal rivers	3	1	-	4
8	Small brown-water coastal rivers	7	16	-	23
9	Large clear-water coastal rivers	-	-	-	-
10	Large brown-water coastal rivers	-	2	-	2
11	Very large coastal rivers	-	-	1	1

The validity of preliminary typologies was tested using the biological data collected in field surveys in years 2004 and 2005. Biological variables, along with water chemistry characteristics, were measured from the most common lake and river types mentioned above. The results and conclusions of typology testing are presented in chapters 4.4 and 4.5.

4.4 Testing of preliminary typology

Water chemistry

The comparison of types with Analysis of Variance (ANOVA) was done using seasonal means of the surface water samples taken between June to October in 2004, with the exception of winter O_2-minimum, which was measured from the samples taken in March-April 2005. Five sites were included for each type, except for type 9 lakes where data from Yli-Kuittasjärvi was excluded. Because water colour measurements were lacking from some sampling occasions, colour is presented as estimated colour derived from the regression between absorbance and colour measurements. The estimations proved to be very accurate.

The results for lakes suggest that the water quality variables separate the types quite accurately (Figure 10). As expected, significant between-type differences were observed for colour and absorbance, which were used as a basis for the division between clear and brown water types. Further, temperature and concentrations of total organic carbon (TOC), chemical oxygen demand (COD), total nutrients (total nitrogen and total phosphorus), silica (Si), sodium (Na) and metals (iron (Fe) and aluminium (Al)) showed clear differences between the types. All mentioned variables are closely connected to geological properties of the catchment area, and present clear increasing gradient from northern mountains to southern coastal area. Same trend can be seen with potassium (K) and fluoride (F), although the differences are not as clear statistically. Oxygen concentration, pH and calcium show a gradient in the opposite direction, the highest concentrations are found in mountain lakes. Observed gradients reflect the trends in climate and geological history. Southern coastal region is former seabed, which is geologically quite young. Therefore nutrient-rich organic soil types (peat land) dominate the surface soil of the area. The deeper clayey layers of coastal soil also contain elements originating from the marine sediments (Si, Na). On the contrary, old bedrock rich in calcium characterise northern mountain areas. Alkaline bedrock elevates pH of the surface waters, as was observed in the studied mountain lakes.

The results from the river type comparisons are virtually similar to lakes. Absorbance, colour TOC, COD, total nutrient and metal concentrations differ significantly between types (Figure 11). The results suggest clear differences between brown-water rivers above and below the highest coastline. Also the temperature and the concentrations of silica, sodium, magnesium, fluoride and chloride behave in a similar fashion. Their concentrations show increasing gradient from the mountains to the coastal area. However, the concentration of calcium was lower in northern mountain rivers, which contradicts to the lake results. There are several possible reasons for the difference in the behaviour of calcium in lentic and lotic environments. One reason may be the differences in the balance between CO_2 and calcium bicarbonate due to higher primary production (photosynthesis) in river habitats. Decreasing CO_2-concentration causes calcium to precipitate into insoluble calcium carbonate (Wetzel 2001). Further, the studied headwater lakes have small catchment areas and are in closer contact to the surrounding bedrock than the rivers, which usually flow through narrow strips of organic soil. Higher load of calcium together with longer residence time and poor primary production may result in high concentrations of soluble calcium in mountain lakes.

Figure 10. The medians and quartiles (25% and 75%) of the most important water quality parameter of the surveyed lake types. Statistically significant differences between the types are marked with lines and asterisks (ANOVA, *: </= 0.05, **: <0.01 and ***: < 0.001).

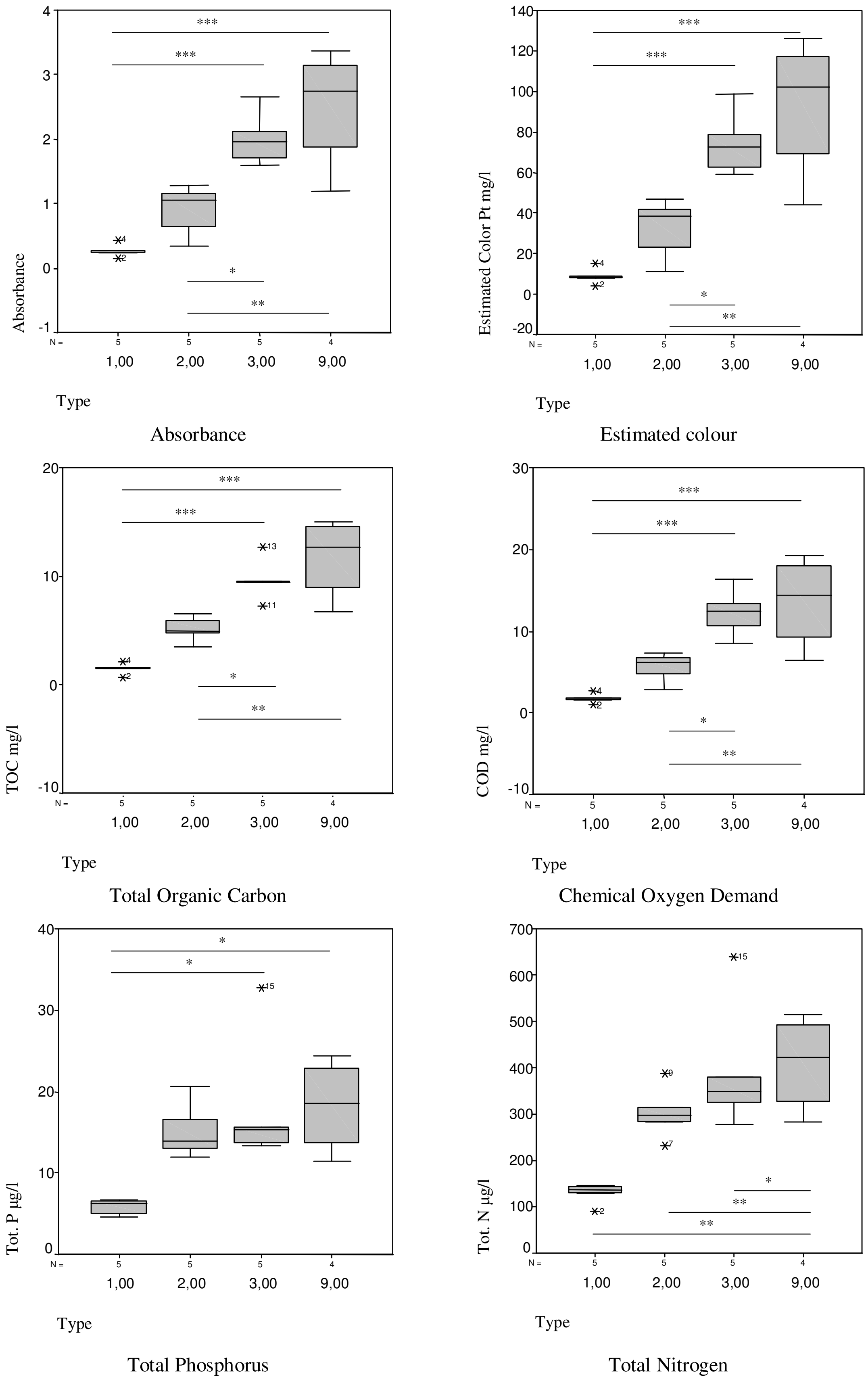
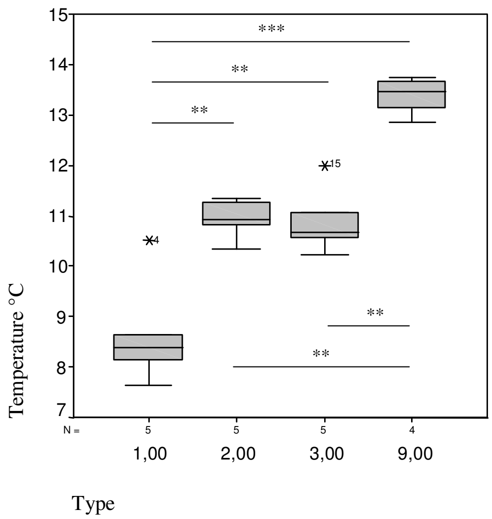
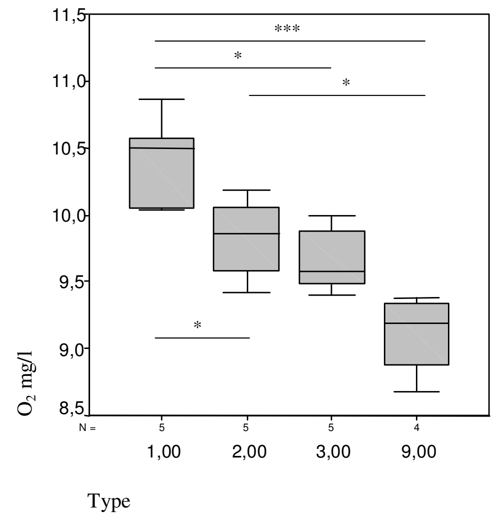


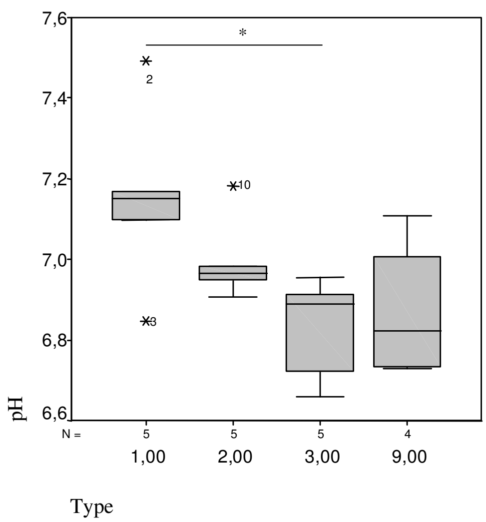
Figure10 continued



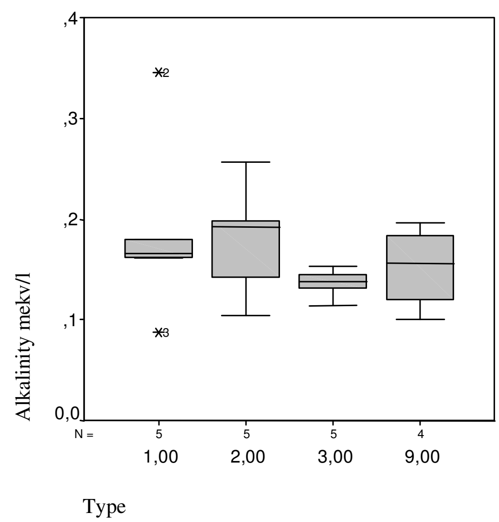
Temperature



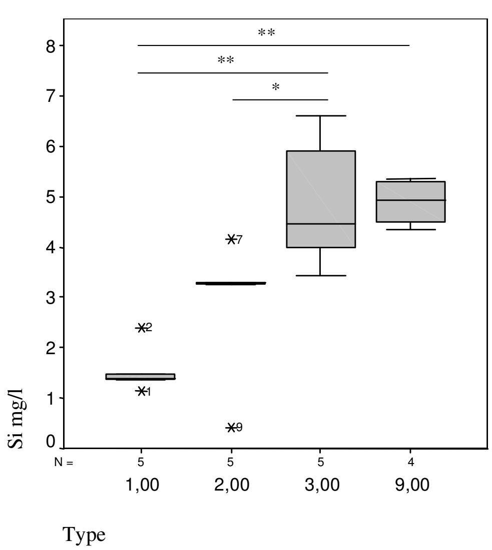
Oxygen



pH

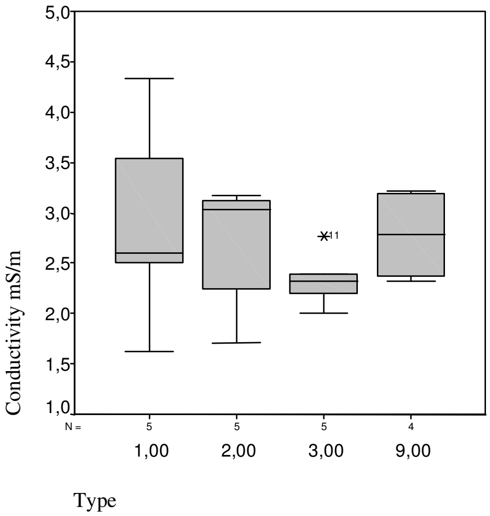


Alkalinity

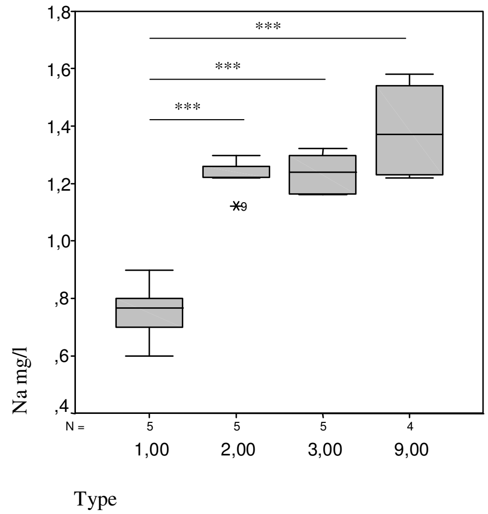


Silica

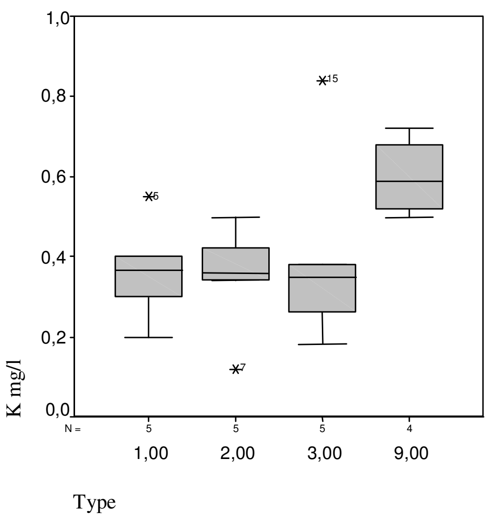
Figure10 continued



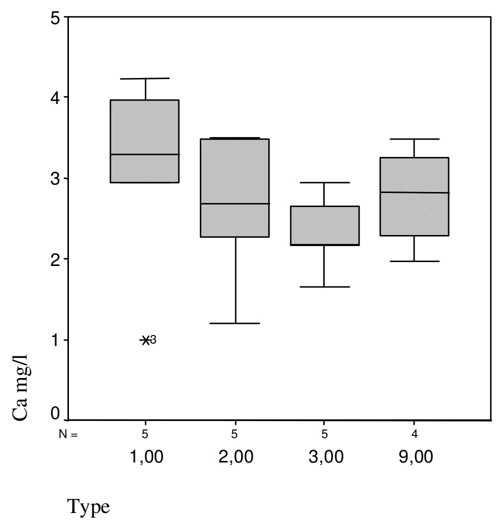
Conductivity



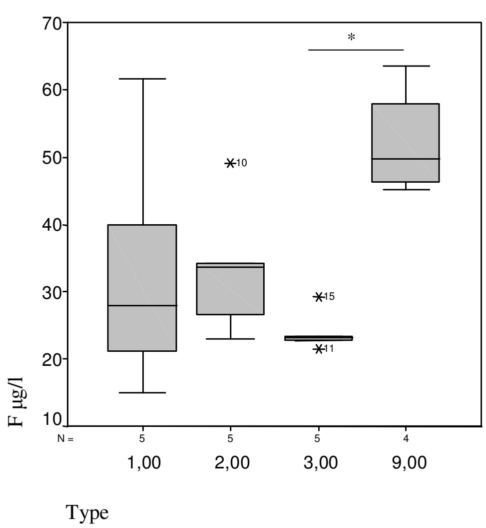
Sodium



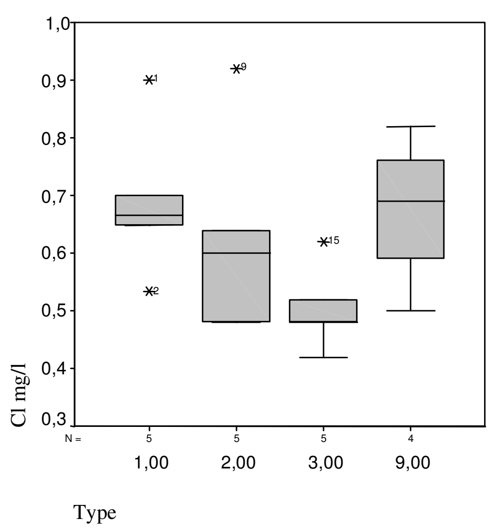
Potassium



Calcium

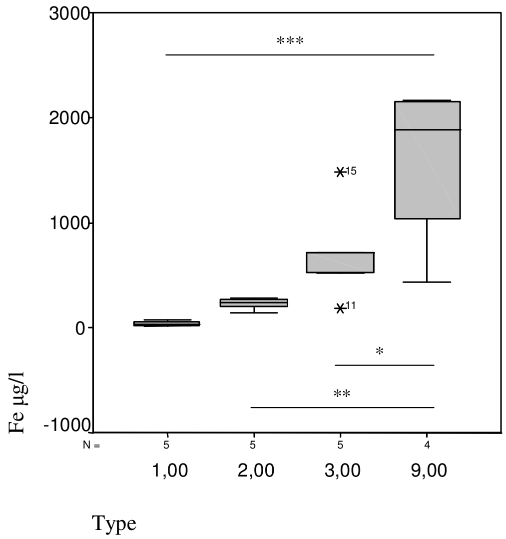


Fluoride

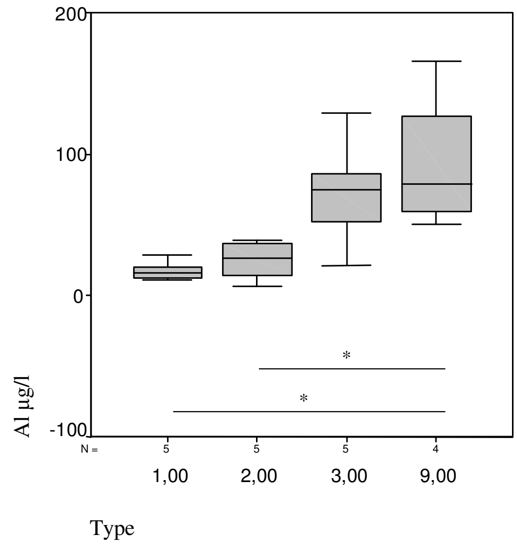


Chloride

Figure10 continued

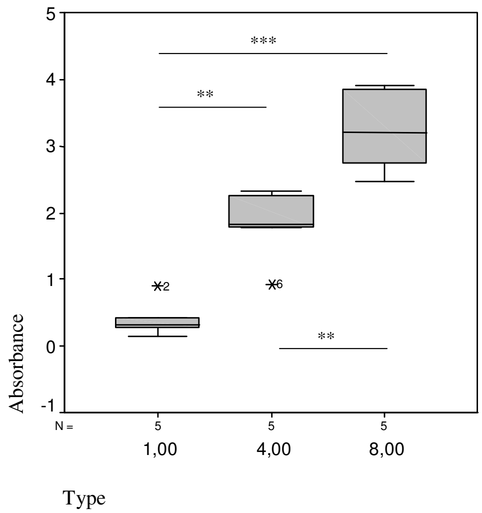


Iron

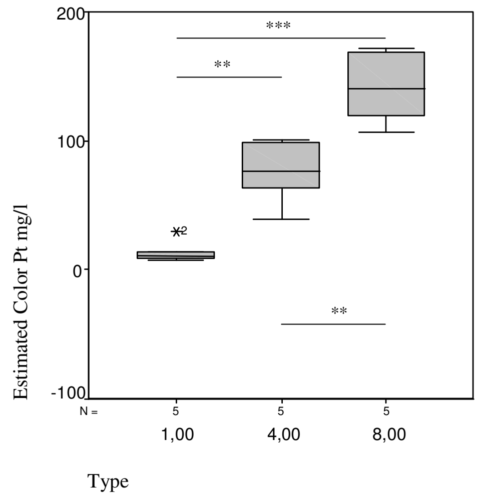


Aluminium

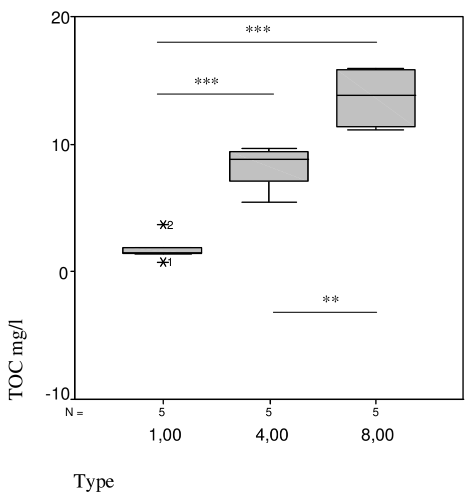
Figure 11. The medians and quartiles (25% and 75%) of the most important water quality parameter of the surveyed river types. Statistically significant differences between the types are marked with lines and asterisks (ANOVA, *: </= 0.05, **: <0.01 and ***: < 0.001).



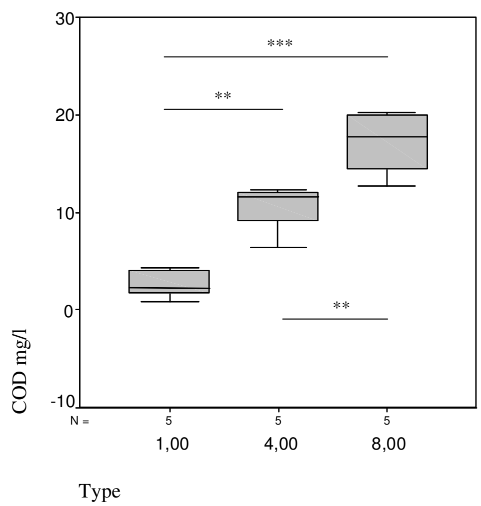
Absorbance



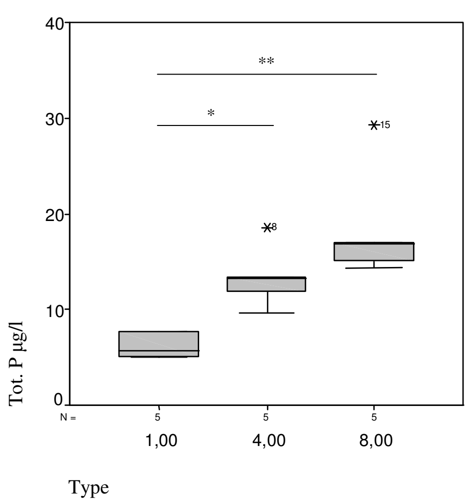
Estimated Colour



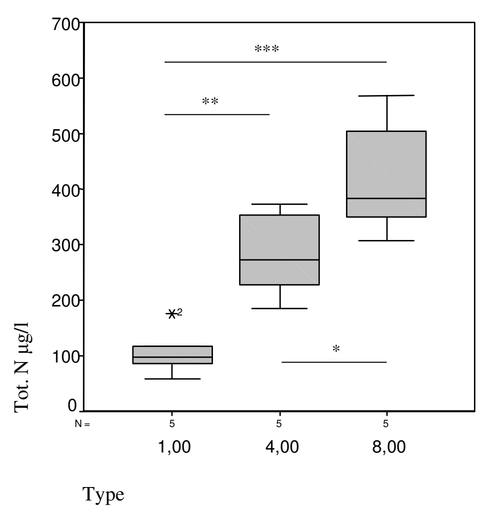
Total Organic Carbon



Chemical Oxygen Demand

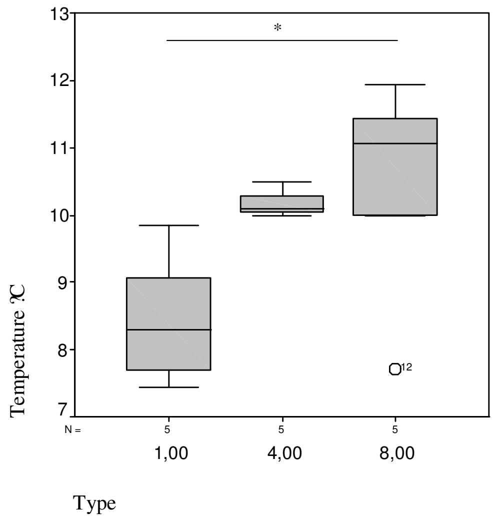


Total Phosphorus

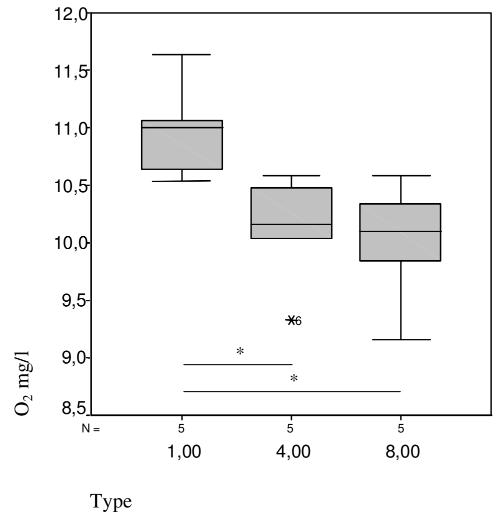


Total Nitrogen

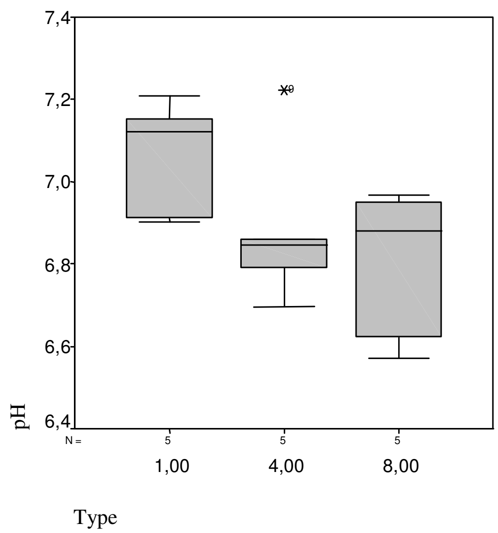
Figure 11 continued



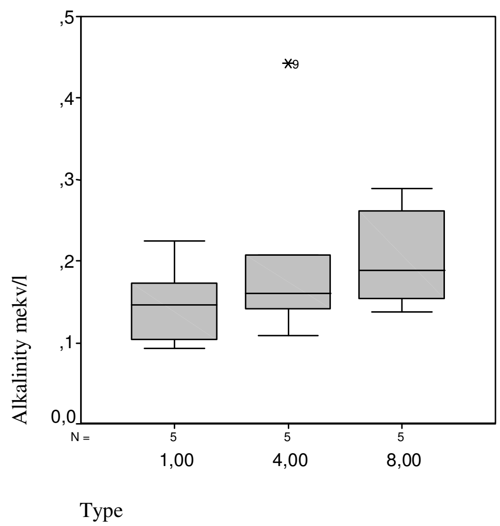
Temperature



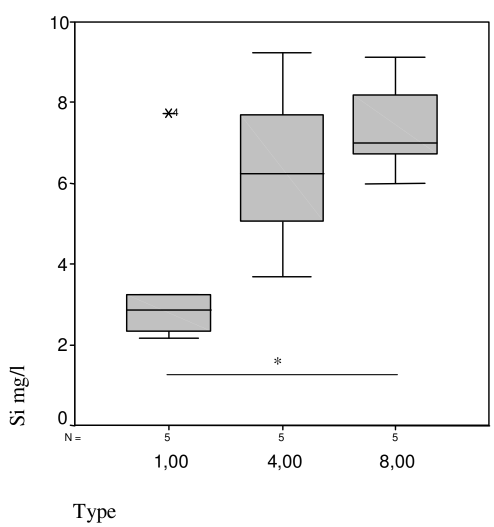
Oxygen



pH

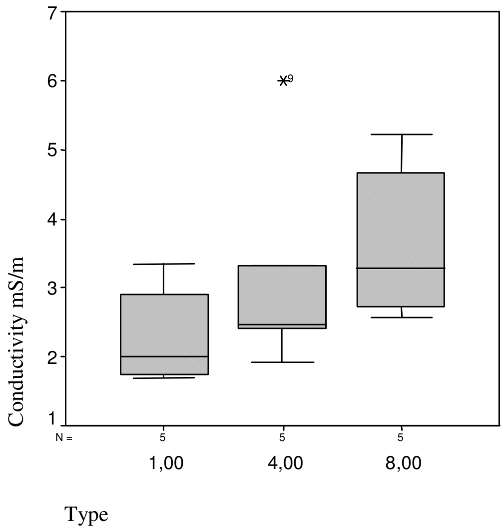


Alkalinity

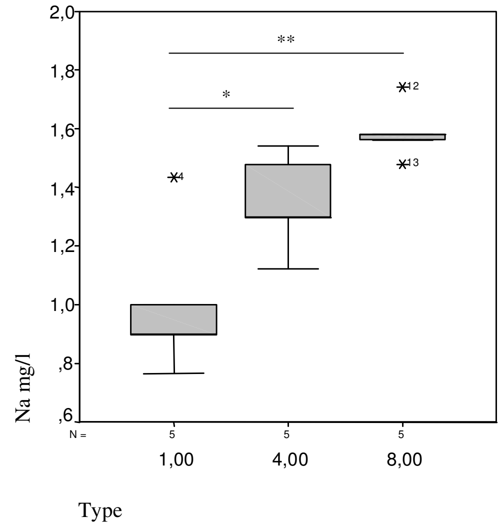


Silica

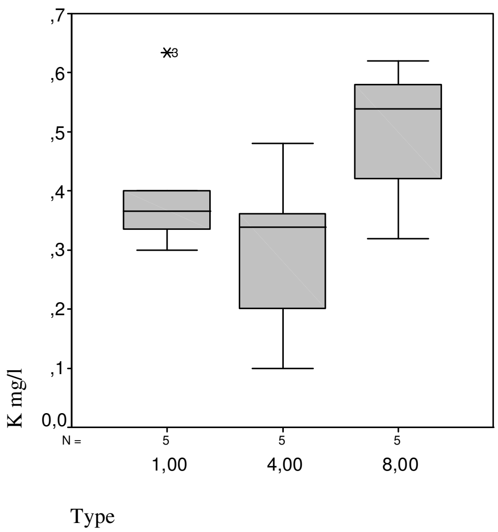
Figure 11 continued



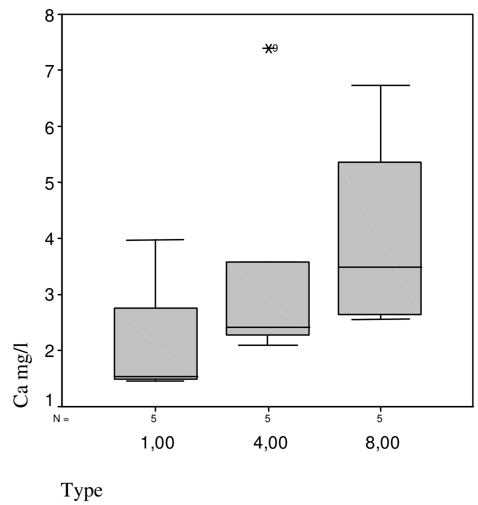
Conductivity



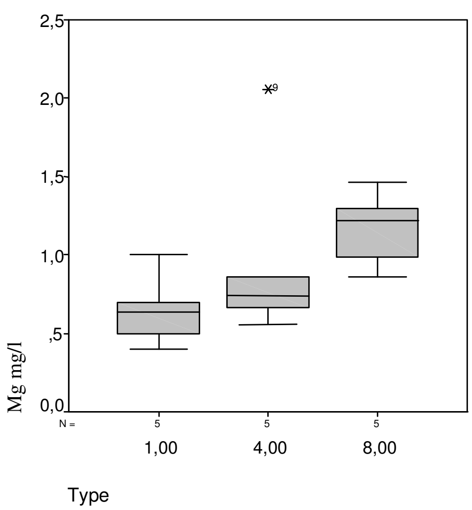
Sodium



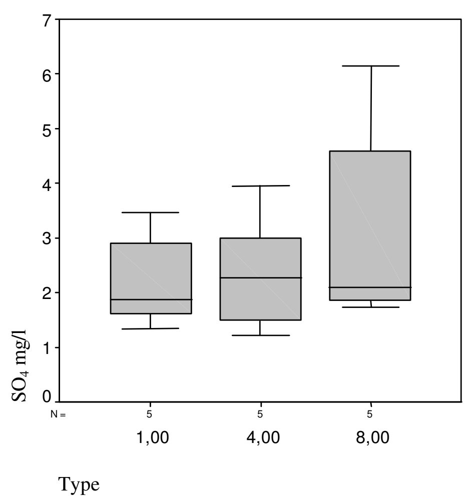
Potassium



Calcium

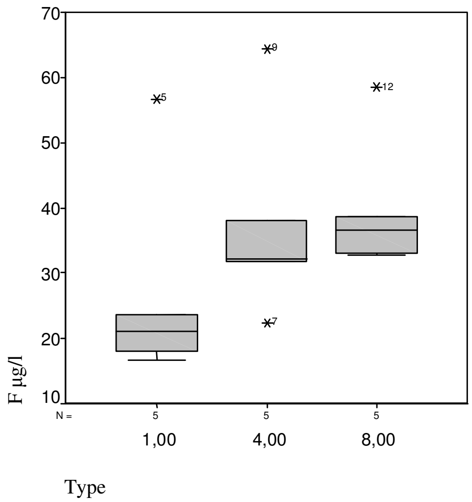


Magnesium

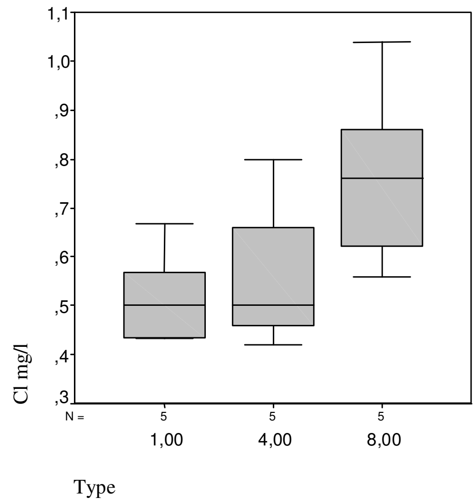


Sulphate

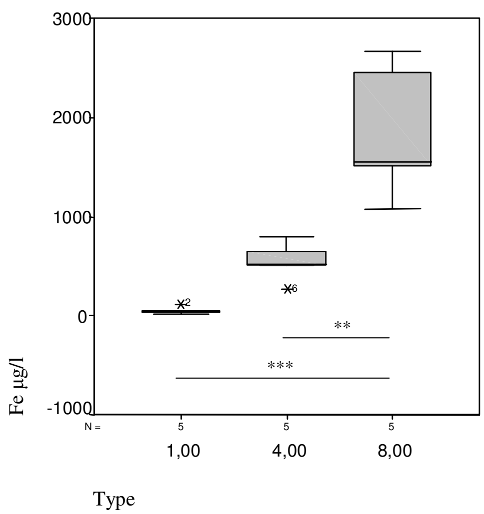
Figure 11 continued



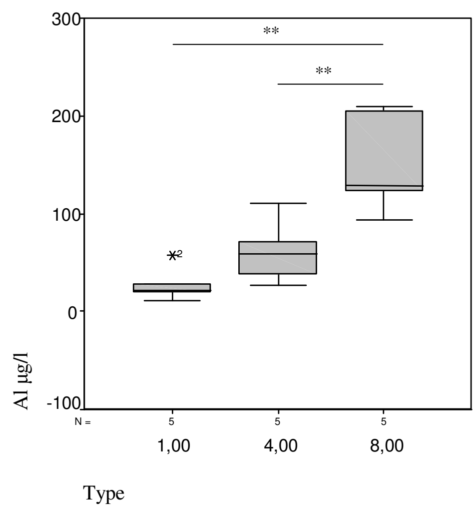
Fluoride



Chloride



Iron



Aluminium

Benthic macroinvertebrates

With lakes, only the littoral macroinvertebrates were included in the statistic analyses. The profundal data proved to be unreliable for lake type comparison due to large variation in the depth of the lakes. Many of the surveyed lakes had the maximum depth less than five meters and the fauna of the deeper areas was composed of littoral species, especially in clear lakes with high transparency. Further, profundal macroinvertebrates were not sampled in the mountain lakes due to logistic confines. Therefore the results of profundal sampling are presented only as a species list in Appendix 1.

The littoral fauna of mountain lakes differed from the other types for the indicators of species richness: Total number of taxa, number of sensitive taxa (EPT, species of orders Ephemeroptera, Plecoptera and Trichoptera) and Shannon's diversity were significantly lower in the northern mountain lakes (Figure 12). Further, mountain lakes presented notably lower values for indices based on indicator species, like saprobic-index (indicator of organic loading), Swedish acidity index (Medin's index) and British ecological quality index BMWP (Armitage et. al 1983, Henrikson & Medin 1986,Zelinka & Marvan 1961). However, BMWP's enhanced and more comparable version ASPT (Average Score Per Taxon) did not differ between lake types. The total number of individuals and the biomass were low and less varying in the mountain lakes compared to the other types, but the difference was not statistically significant.

Figure 12. The medians and quartiles (25% and 75%) of the most important littoral benthic community variables of the surveyed lake types. Statistically significant differences between the types are marked with lines and asterisks (ANOVA, *: </= 0.05, **: <0.01 and ***: < 0.001).

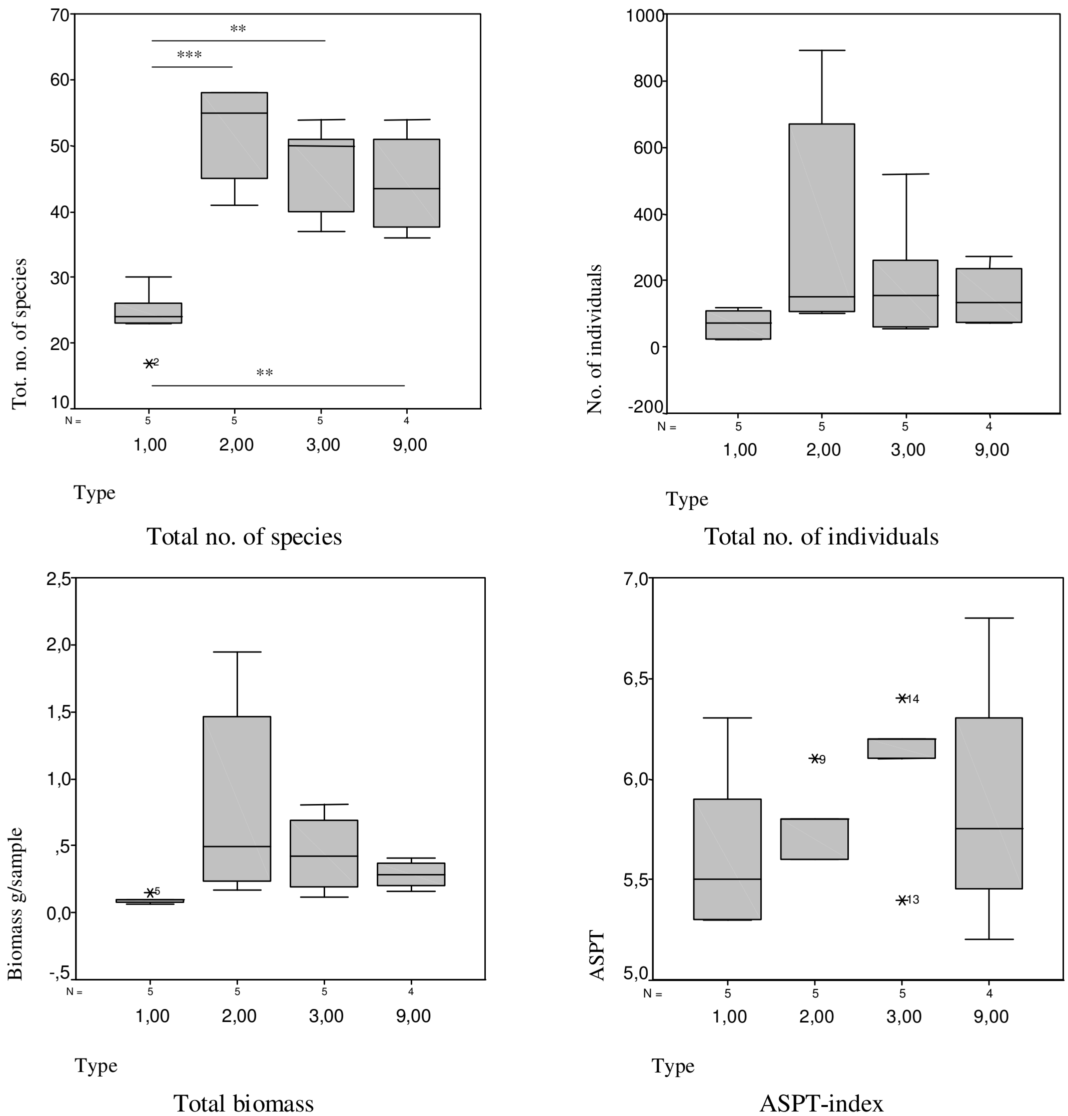
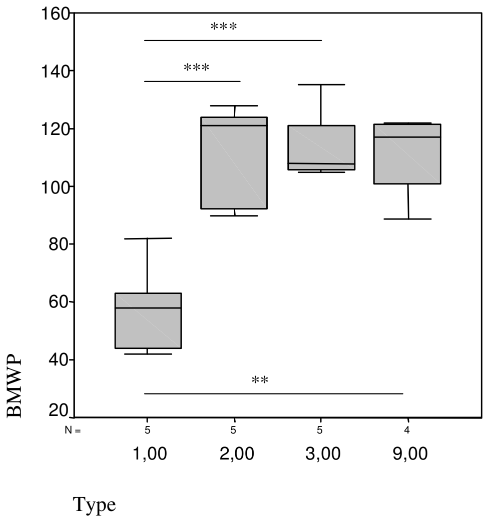
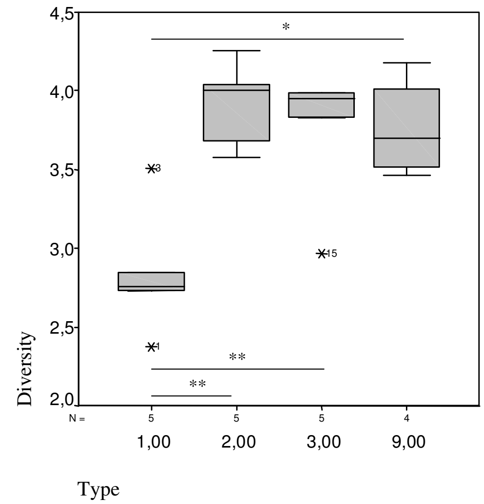


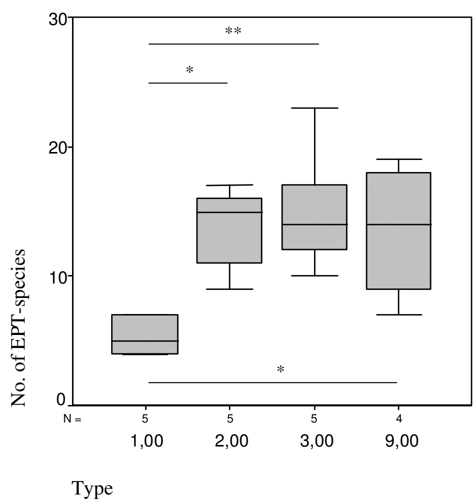
Figure 12 continued



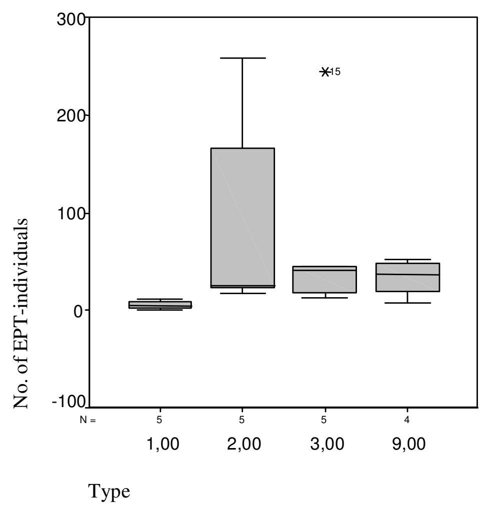
BMWP-index



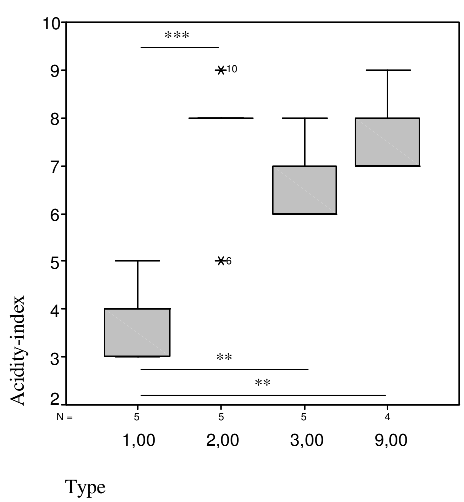
Shannon's diversity



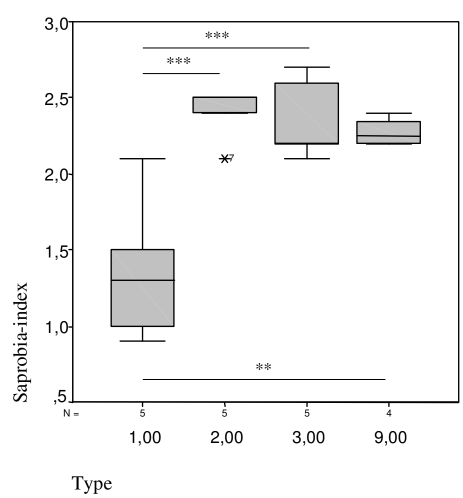
No. of EPT-species



No- of EPT-individuals

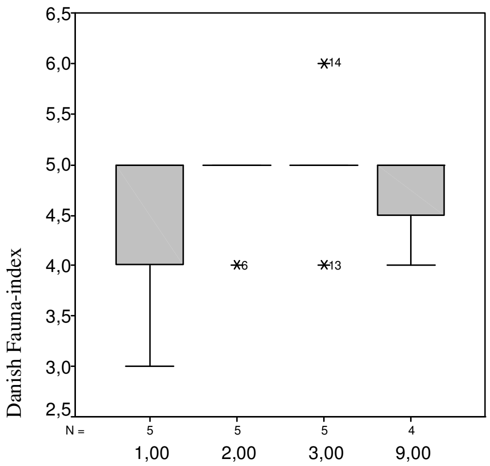


Medin's Acidity index



Saprobic index

Figure 12 continued



Type

Danish Fauna Index

Multivariate analyses of the littoral species distribution confirmed the results of ANOVA-tests. Detrended Correspondence Analyses (DCA) revealed moderately strong environmental gradient in species data (Standard deviation value, SD= 3.106), which allowed unimodal Canonical Correspondence Analyses (CCA) to be used in examining the relations between species distribution and their environment. Two main axes of CCA explained 61.6% of the relationship between species and the measured environmental variables. Species distribution clearly separated mountain lakes from the other lake types. The fauna of the brown- and clear lakes of inland and coastal regions did not differ significantly. The most important environmental variables explaining the occurrence of the macroinvertebrate species were altitude and latitude. Also temperature, along with the concentrations of major nutrients and sodium (Na) controlled the species distribution (Figure 13). Species list for littoral benthic fauna is presented in Appendix 2.

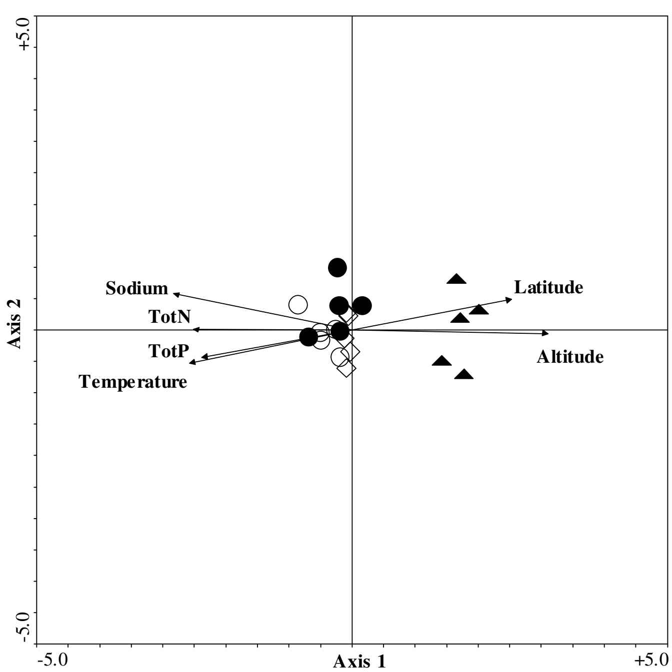
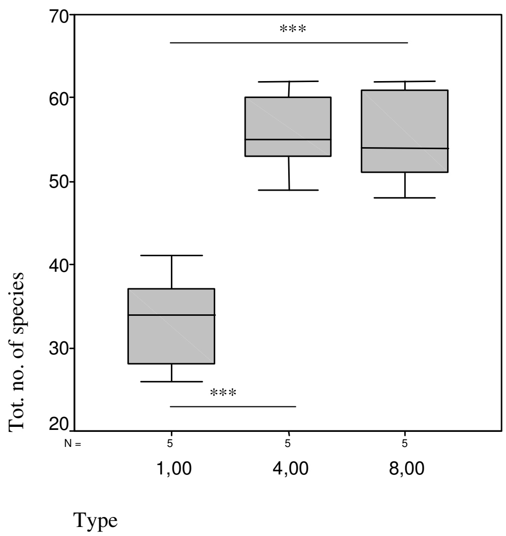


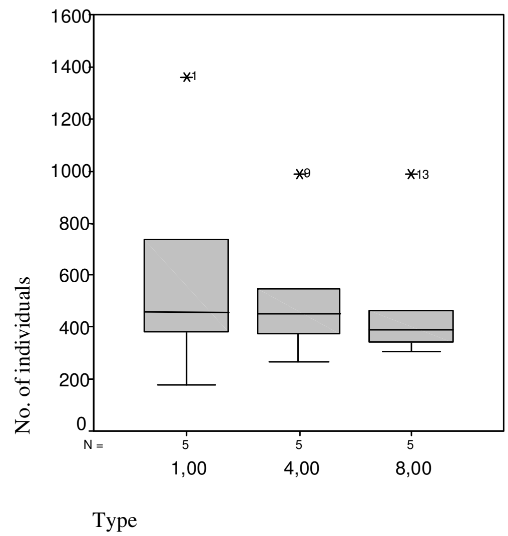
Figure 13. The results of CCA-analysis with littoral benthic fauna of the surveyed lakes.
Triangle= lake type 1, square= type 2, filled circle= type 3 and open circle= type 9.

For rivers, the results of variance analysis were comparable to the lakes for many of the tested variables. Total number of species, number of sensitive taxa, diversity, Acidity index and BMWP were significantly lower in mountain rivers than in the river types of southern ecoregions (Figure 14). However, some results were contradictory to the lake results: the number of individuals, biomass and saprobic-index were highest in mountain streams, although the types did not differ statistically.

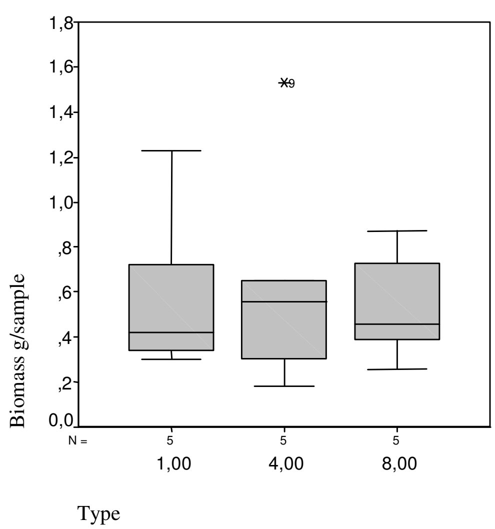
Figure 14. The medians and quartiles (25% and 75%) of the most important benthic community variables of the surveyed river types. Statistically significant differences between the types are marked with lines and asterisks (ANOVA, *: </= 0.05, **: <0.01 and ***: < 0.001).



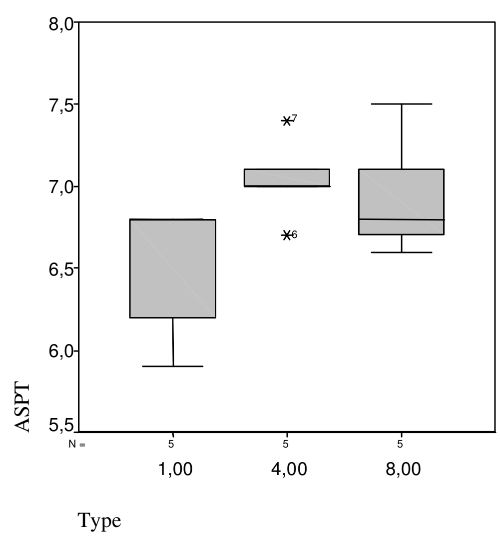
Total no. of species



Total no. of individuals

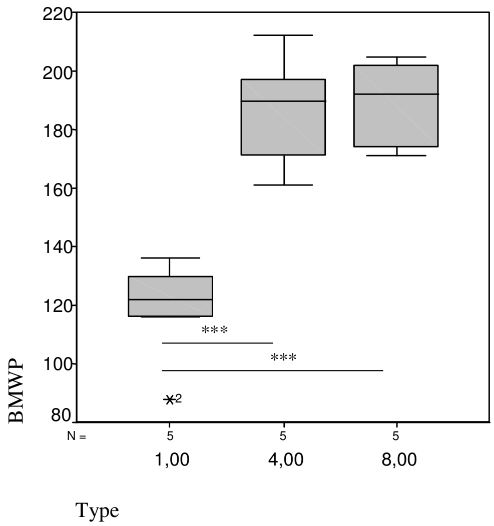


Total biomass

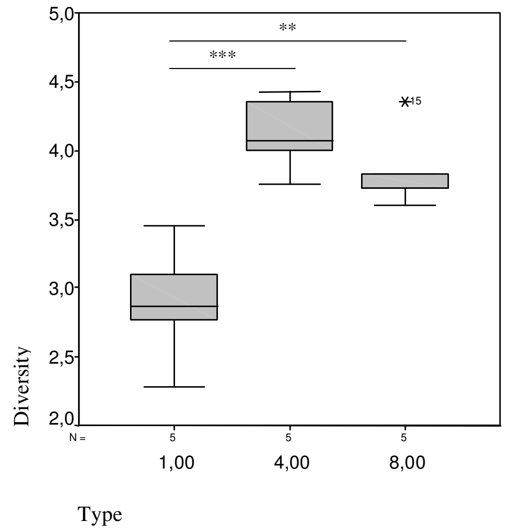


ASPT-index

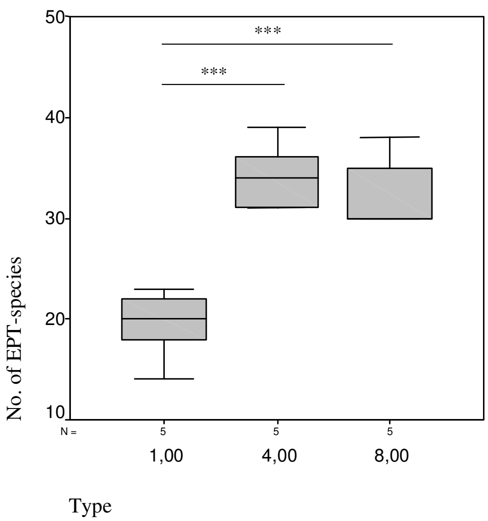
Figure 14 continued



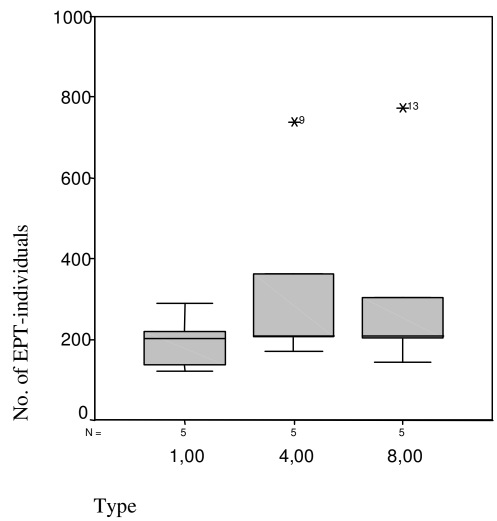
BMWP-index



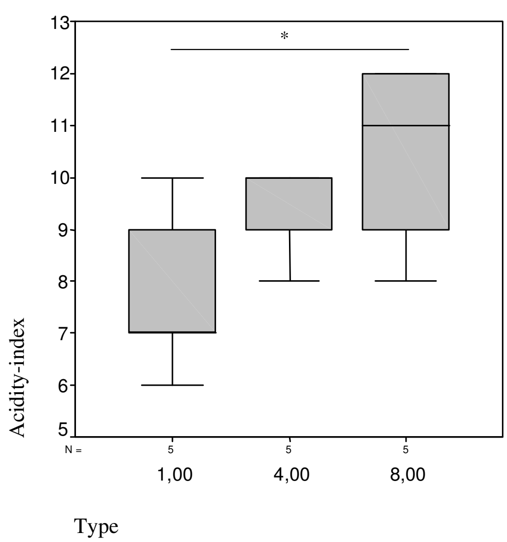
Shannon's diversity



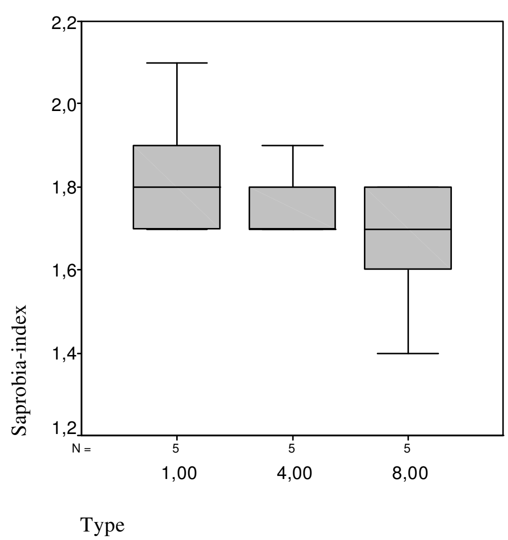
No. of EPT-species



No. of EPT-individuals



Medin's Acidity Index



Saprobia Index

As with lake littoral fauna, multivariate analyses conducted with river macroinvertebrates divided mountain streams from the southern river types. The distribution of species also showed differences between brown-watered small rivers of inland and coastal regions, but the division of types was not very distinct. The observed environmental gradient in species occurrence was shorter than in littoral fauna (SD= 1.967). CCA-test explained 58.8% of the species-environment relationship, and revealed the important role of altitude, latitude and oxygen concentration in the species occurrence (Figure 15). Further, temperature, chemical oxygen demand and concentration of total nitrogen dictated the distribution of lotic macroinvertebrate fauna. Species list for river fauna is presented in Appendix 3.

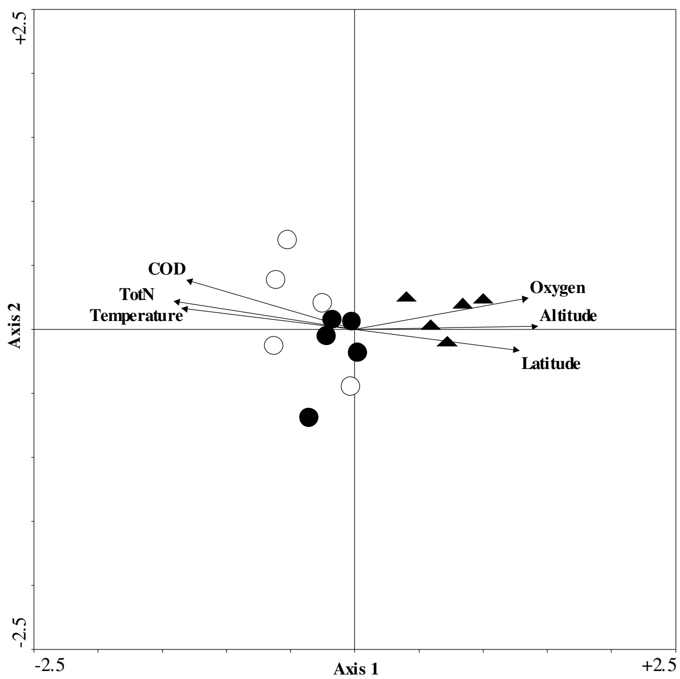


Figure 15. The results of CCA-analysis with benthic fauna of the surveyed rivers. Triangle= rive type 1, Filled circle= type 4 and open circle= type 8.

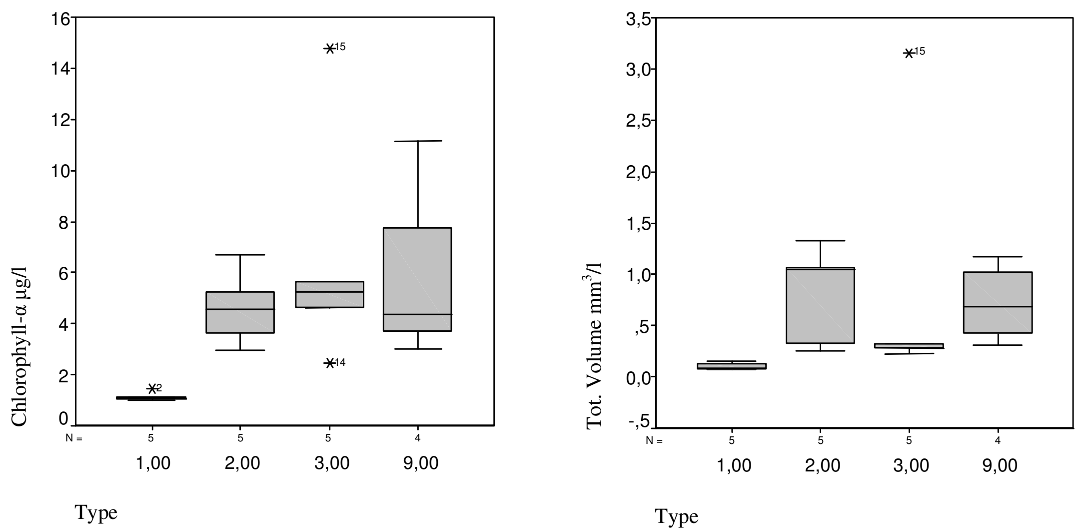
The observed species-poor nature of northern mountain waters is in accordance with other studies dealing with the biogeographic characteristics of benthic macroinvertebrate communities (Heino 2002). The different indices of ecological state and organic loading gave contradictory results. British BMWP underestimated the status of indicator-species poor mountain waters. However, the modified index ASPT gave more comparable results concerning the state of different waters. ASPT is derived from BMWP by dividing the original index with the total number of indicator groups of the sampling site (Armitage et al. 1983). With proper regional adjustment, ASPT seems quite valid for the WFD's assessment of the natural status, and is already widely used in Scandinavia (Wilander et al., 2003). The same cannot be said about Medin's acidification index. Despite the alkaline water quality of the mountain waters, the index values were suspiciously low and indicated acidified conditions. The usability of the acidification index in northern waters is therefore questionable. The index will require considerable bioregional weighting in order to give comparable estimates about different waters. The difference in Saprobic index between mountain lakes and other lake types accurately reflected the naturally low organic load of the clear-water mountain lakes with small, mineral catchment areas. However, the index is not widely used in Scandinavian studies at present.

The variance analyses pointed out the difference in the productivity between lakes and rivers in mountain region. While the number of individuals and biomass of the lake littorals was very poor, rivers surpassed even the southern types in productivity. The explanation for high productivity of mountain rivers in comparison to mountain lakes is possibly found in higher detritus loading from the larger catchment areas. Although the water quality do not directly reflect the differences in the amount of loading of coarse organic material, some evidence may be found in high saprobic index of the highland rivers. When compared to other river types, reasons for high number of individuals and biomass in northern rivers may be found from the differences in predation pressure, inter-species competition and the species adaptation to extreme conditions.

Phytoplankton

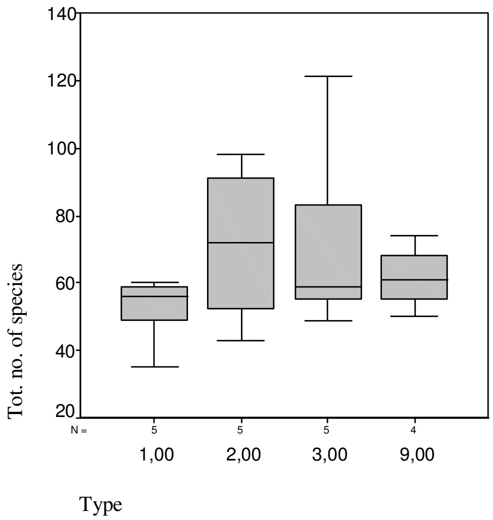
In order to enhance the comparability of the data, the ANOVA-tests with the phytoplankton biovolumes were done using results from August samples. Contrary to benthic communities, the phytoplankton flora did not express clear between-type differences (Figure 16). Chlorophyll-α concentrations and biovolumes were lowest in the mountain lakes. The total number of taxa was also generally lower in the mountain lakes, but with greater variation than for chlorophyll and biovolumes. However, the mentioned differences were not statistically significant. Toxic blue-green algae species were almost absent from mountain lakes. The number of indicators of eutrophy and oligotrophy did not differ between the types. A clear difference in the flora was observed in the share of diatoms (Family Bacillariophyceae) from the total biovolume. Diatoms were most abundant in brown coastal lakes (although the within-type variance was high), which differed statistically from the other lake types. The reason for higher diatom biovolumes in brown coastal lakes may be found in availability of silica. However, diatom biovolumes were low in brown-water inland lakes despite the fact that silica concentrations equated brown lakes of coastal region. Further reasons to observed difference could be the regional differences in the temperature and wind conditions etc. during the August sampling seasons.

Figure 16. The medians and quartiles (25% and 75%) of the most important phytoplankton community variables of the surveyed lake types. Statistically significant differences between the types are marked with lines and asterisks (ANOVA, *: </= 0.05, **: <0.01 and ***: < 0.001).

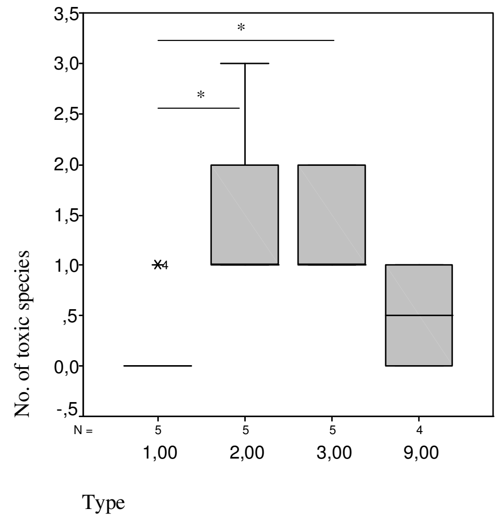


Chlorophyll-α   Total biovolume

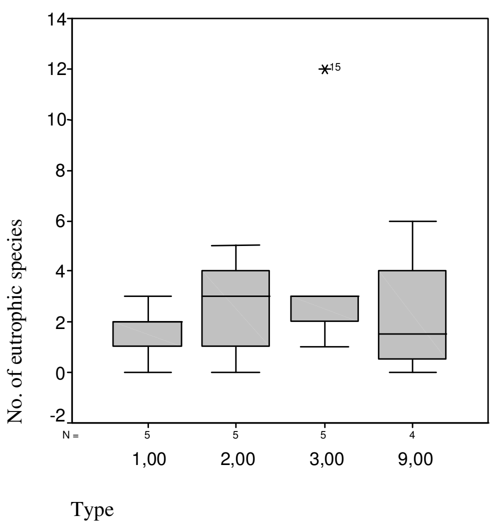
Figure 16 continued



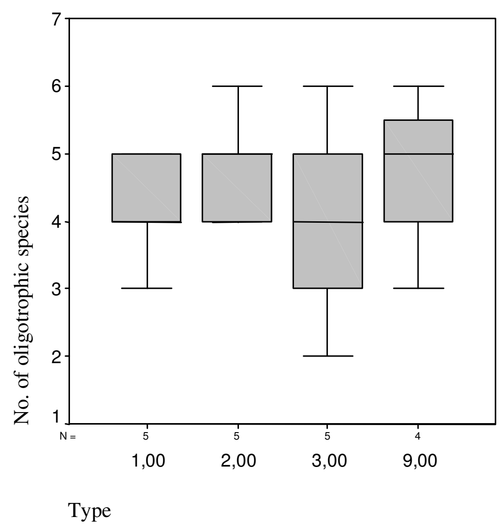
Total no. of species



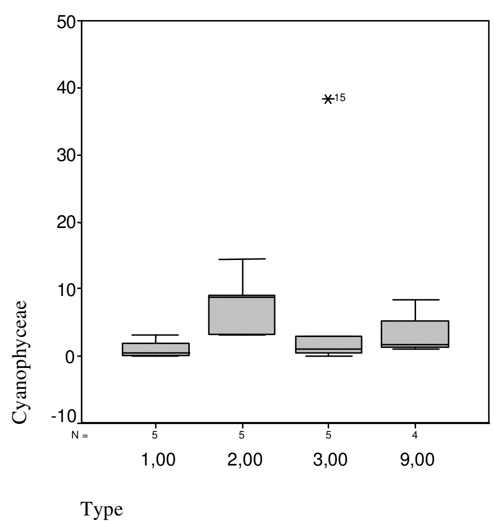
No. of toxic species



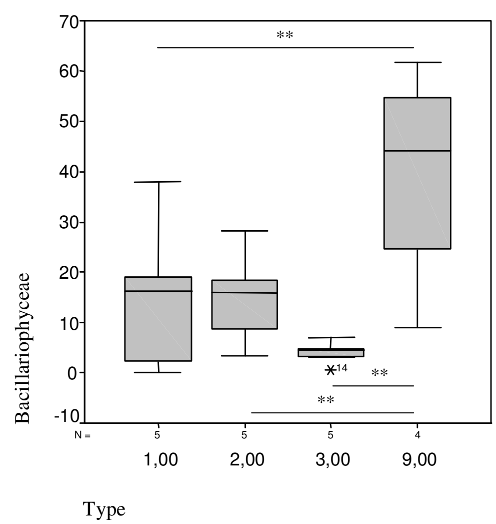
No. of indicators of eutrophy



No. of indicators of oligotrophy

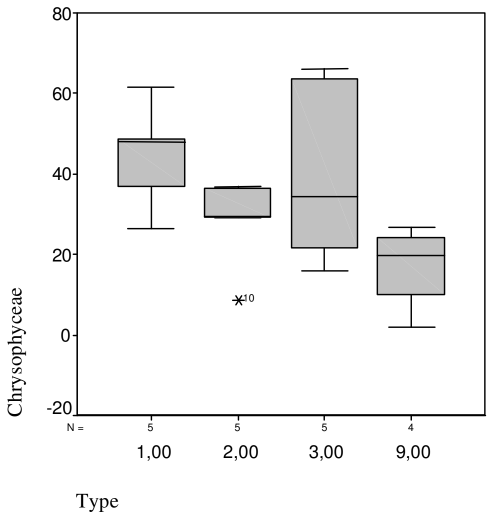


Cyanophyceae-%

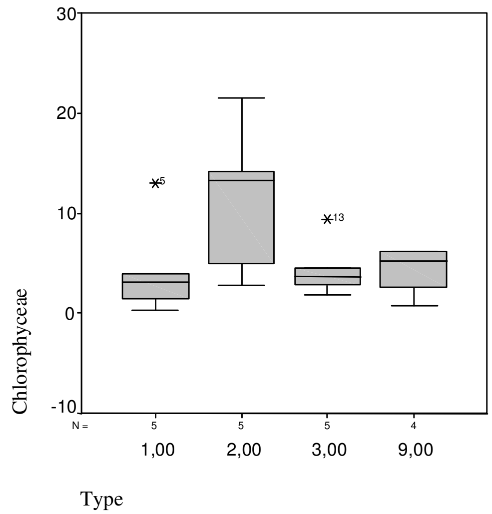


Bacillariophyceae-%

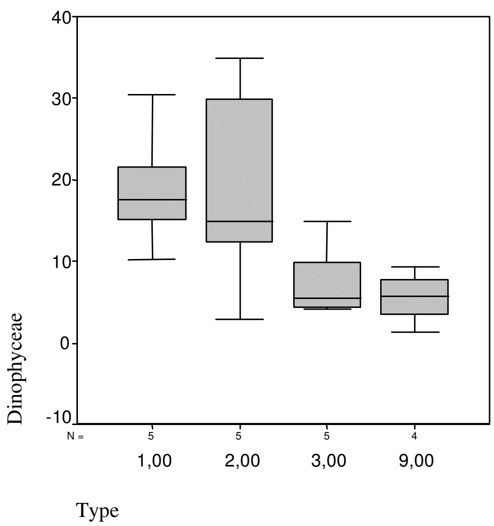
Figure 16 continued



Chrysophyceae-%



Chlorophyceae-%



Dinophyceae-%

Multivariable analyses of phytoplankton flora revealed moderately clear environmental gradient (SD= 2.076), but compared to benthic fauna, the community structure was controlled more directly by water quality than the variables used in typology (Figure 17). First and second axis of CCA-test explained 63,6% of the relationship between environment and flora. The most important variables affecting the species occurrence were concentrations of total phosphorus, phosphate, chemical oxygen demand, iron and potassium. Although the analyses showed some division between the mountain lakes and other lake types, the trend was considerably weaker than with benthic macroinvertebrates. The results strongly suggest that phytoplankton species are widely spread in different lake types and their occurrence is dictated more by the nutrient level of individual lake than the wider scale environmental variables commonly used in typologies. Similar conclusions have been made also in other studies dealing with biogeography of phytoplankton flora (Willén & Larson, 2004; Willén, 2005). In these studies, mountain lakes were clearly separated from other lakes. Contrary to our results, altitude and organic material (humic content) were shown to be important variables for phytoplankton species composition and biovolumes. It is possible that a larger dataset would reveal prominent regional and between-type differences also in River Torne watershed. The list of phytoplankton flora is presented in Appendix 4.

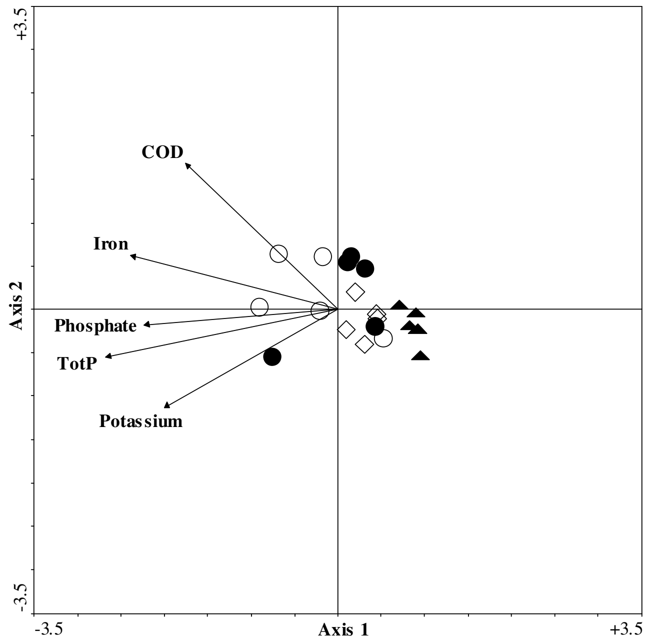


Figure 17. The results of CCA-analysis with phytoplankton flora of the lake types. Triangle= type 1, Filled circle= type 4 and open circle= type 8

Fish fauna

The fish fauna of brown-water rivers of inland and coastal region (types 4 and 8) was studied by electro-fishing in August 2005. As mentioned in chapter 3, the work was done separately in Sweden and Finland by the Swedish Board of Fisheries and the Finnish Game and Fisheries Institute. Both institutes presented also their results separately (Vehanen 2006; Nilsson, 2006).

Both reports concluded that overall environmental status of the studied rivers was good and many sites could be classified having a high status. However, the fish community of studied rapids (2-3/river) varied considerably within the same river. The classification of nearby rapids varied in some cases from high to moderate status. This may indicate human impact in the single rapids, but a more likely cause for variation can be found from the selection of indicator species used in the fish indexes. Due to low total species number, the random occurrence of single indicator species can have a strong effect on the index-value. Especially the mass occurrence of minnow (*Phoxinus phoxinus*), a species regarded sensitive to acidification and eutrophication, affected the indices excessively. Further, moderately small natural differences in habitat characteristics like current velocity, substrate composition, vegetation etc. seem to affect the species composition and sampling efficiency (Vehanen 2006). Accurate estimates would require longer time series, since the yearly variations in catches are great due to fluctuating discharge conditions. More detailed national results can be found from the original reports from the project's internet address (www.triwa.org).

Comparison of the types was done with compiled data using variables common in both countries (see chapter 3). T-tests did not reveal statistically significant differences between the two river types (Table 8). Fish densities and biomass varied strongly in type 4 rivers. Main reason for high variation was the dense minnow shoal caught in the sampling of River Jerisjoki. The densities of brown trout (*Salmo trutta*) also varied between the rivers

(Appendix 5). Fish stockings and other fishery activities often affect brown trout densities. The same applies to all salmonids, so the effect of human activities to fish community composition can not be ruled out. The occurrence of large-sized cyprinids (Common dice (*Leuciscus leuciscus*) and Roach (*Rutilus rutilus*) seems to be limited to coastal rivers. However, the occurrence of the mentioned species was too sporadic to allow any conclusions about the validity of the biogeographical division between inland and coastal areas. Further, earlier inventories have demonstrated that the distribution of roach and common dace covers most of the River Torne water system, except the northernmost parts.

Table 8. Results of the fish fauna inventories in River Torne watershed.

Site	**Tot. No. of species**	**Density/100 m^2**	**Biomass/100 m^2**	**No. of salmonid species**	**No. of re-producing salmonid species**	**No. of sensitive species**
TYPE 4						
Jerisjoki	7	140.0	422.2	0	0	2
Keräsjoki	5	12.5	86.0	1	1	3
Kuerjoki	5	14.6	99.4	1	1	3
Käymäjoki	6	17.7	89.1	1	1	3
Parkajoki	5	4.4	39.5	3	2	3
Mean	**5.60**	**37.86**	**147.25**	**1.20**	**1.00**	**2.80**
s.d.	**0.89**	**57.31**	**155.44**	**1.10**	**0.71**	**0.45**
TYPE 8						
Kuijasjoki	7	34.1	78.2	1	1	3
Naalastonjoki	5	20.3	203.9	2	1	4
Jylhäjoki	7	11.8	60.4	1	1	3
Orjasjoki	2	10.0	158.7	1	1	1
Tupojoki	9	14.0	198.5	3	3	4
Mean	**6.00**	**18.04**	**139.96**	**1.60**	**1.40**	**3.00**
s.d.	**2.65**	**9.79**	**67.10**	**0.89**	**0.89**	**1.22**
T-test:						
t-value	**-0.320**	**0.762**	**0.096**	**-0.632**	**-0.784**	**-0.343**
Sig.	**0.757**	**0.468**	**0.926**	**0.545**	**0.455**	**0.740**

Conclusions

The preliminary common typology seems to be valid for the water chemistry; variables like TOC and COD among others expressed clear differences between the types. Water quality showed significant differences between the typology's geology and ecoregion classes. However, the between-type differences were not as obvious with biological quality elements. Surface waters of the northern mountain region were clearly separated from the other types by macroinvertebrate communities, and similar division could be seen to some extent in lake phytoplankton. Conversely, the differences between the water types of inland and coastal region were less evident, if they existed at all. Therefore the reduction of types in both lake and river typology seems logical.

Biological elements showed only minor differences between the southern ecoregions of the River Torne watershed. Thus it would seem wise to make the typology more simple and practical by combining the waters of inland and coastal regions. Reducing the ecoregion typology factor from three to two classes would limit the amount of types to 7 for both lakes and rivers. Discarding or omitting the other typology elements seems less well grounded. Many water quality elements showed strong separation in the overall chemistry between clear and brown-water surface waters. Further, periphyton flora, which will be one of the monitored biological elements in the implementation of WFD, reflects the changes in the humic content of the water (Miettinen 2006, Vuori et al. 2006). Therefore discarding the geological element from the typology is hardly justified. Further, there are no grounds to cut-down size-classification, since the resources of the project did not allow the testing of different size-classes. The modified suggestion for the typology of River Torne watersheds surface waters is presented in chapter 4.5.

When drawing conclusions from the results one must bare in mind the limited data set used to test the types. The suggested typology will most likely be enhanced along with the accumulation of biological and other environmental data. If benthic macroinvertebrates of lake profundal zones are to be used in the implementation of WFD, depth classification must be included in the typology. At present, the available data is not sufficient for the estimation of mean or maximum depth in small lakes. Further, the thickness of the productive layer varies with the water colour and turbidity, resulting in occurrence of littoral fauna in the deeper areas of clear-water lakes. This affects the comparability of profundal data, and makes the idea of setting a constant depth limit value quite suspicious. Estimation of the productive layer thickness via secchi disc measurements may give a more reliable typology element for the separation of lakes with and without real profundal areas.

4.5 Revised harmonised typology

Field survey results were used to test the relevance of the suggested typology for water chemistry, phytoplankton flora (lakes), benthic macroinvertebrates (lake littoral and rivers) and fish (rivers). The main emphasis in evaluation was put to biological variables, since they are of most importance in estimation of the ecological state, whereas physico-chemical characteristics are regarded as auxiliary variables by the WFD.

The results of the field surveys demonstrated that biological quality elements did not accurately support the ecoregion classification of the preliminary harmonised typology. Therefore it seems justified to combine inland and coastal ecoregion classes to one class of southern lowland surface waters. This leads to the division of 7 lake- and river types, which makes the typology more practical to use. Revised harmonised typologies for lakes and rivers are presented in Figures 18 and 19. In the river typology, type 5 (large clear-water lowland rivers) does not occur in River Torne watershed. The frequencies of the River Torne watershed's lakes and rivers in different types are presented in Tables 9 and 10. The maps showing the distribution of different surface water types are presented in Figure 20.

Table 9. The revised lake types and number of lakes in the River Torne watershed.

Type	Description	Sweden	Finland	Total
1	Northern highland lakes	155	58	213
2	Small clear-water lowland lakes	69	28	97
3	Small brown-water lowland lakes	38	61	99
4	Medium clear-water lowland lakes	12	11	23
5	Medium brown-water lowland lakes	6	21	27
6	Large clear-water lowland lakes	3	3	6
7	Large brown-water lowland lakes	1	3	4

Table 10. The revised river types and number of rivers in the River Torne watershed.

Type	Description	Sweden	Finland	Shared	Total
1	Small highland/mountain rivers	41	10	-	51
2	Large highland/mountain rivers	4	1	1	6
3	Small clear-water lowland rivers	12	3	-	15
4	Small brown-water lowland rivers	42	23	-	65
5	Large clear-water lowland rivers	-	-	-	-
6	Large brown-water lowland rivers	-	2	1	3
7	Very large lowland rivers	-	-	1	1

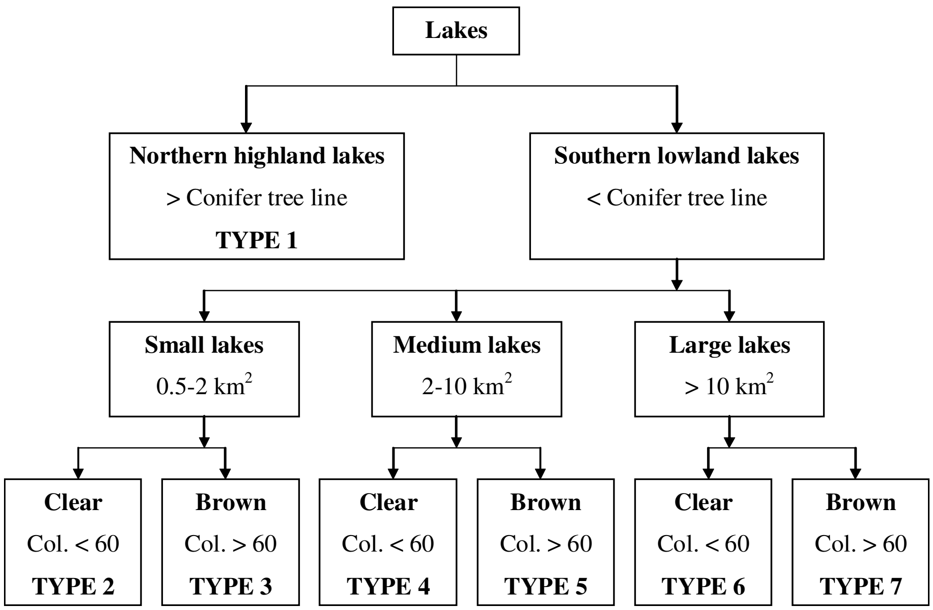


Figure 18. Revised harmonised typology for lakes in River Torne watershed.

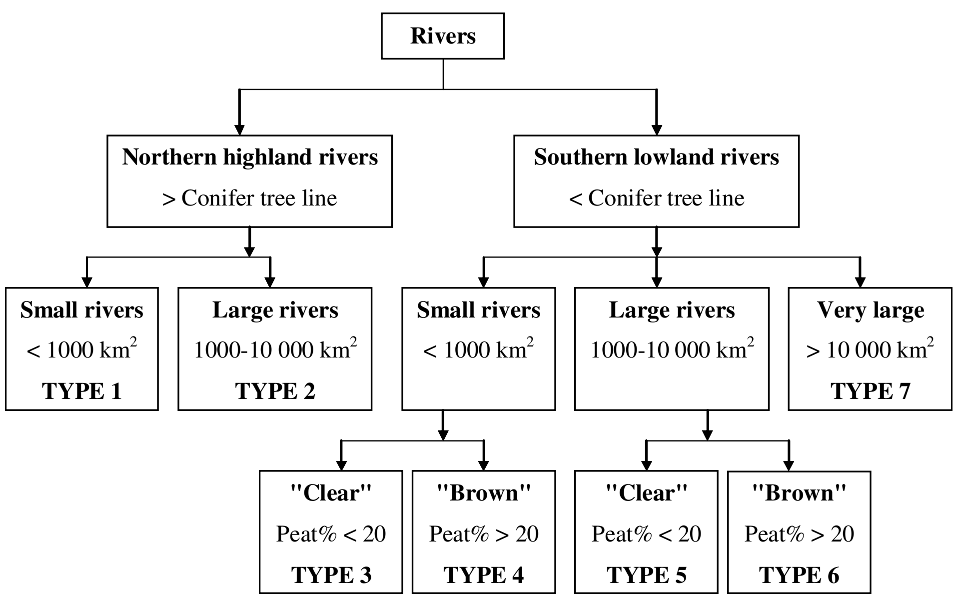
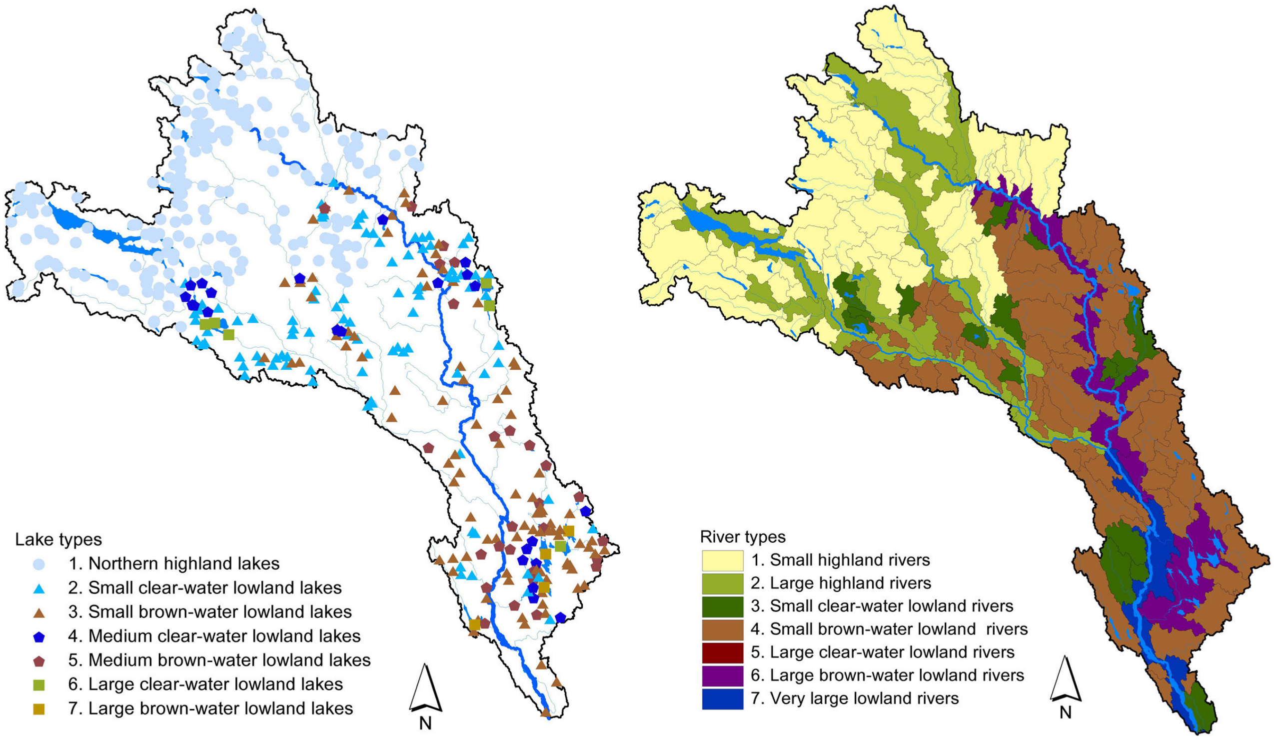


Figure 19. Revised harmonised typology for rivers in River Torne watershed.



a) b)

Figure 20. a) Lake types and b) river types according to the revised typology. © Lantmäteriet

The revised suggestions for a common, harmonised typologies for the surface waters of River Torne watershed are open to changes and improvements, when new data accumulates in the future. The addition of lake depth classification is one of the most probable future improvements for the typology. The validity of the size-classification will be judged, when sufficient biological data from surface waters of different size is available. The naturally eutrophic condition observed in Lake Yli-Kuittasjärvi suggests the possible need for an additional type for shallow, nutrient rich lakes. However, intensive inventories concerning biological quality elements, lake characteristics and water quality are needed in River Torne watershed in order to fill the deficiencies of the present data.

5 Assessment of reference conditions and ecological status

5.1 Guidelines for determination of reference conditions

In order to analyse the characteristic and assess the risk for failing the environmental objectives for individual water bodies in accordance with Annex II in the WFD, there are guidelines on methods for establishment of reference conditions and setting class boundaries of ecological status (European Communities, 2003). The ecological status is determined using biological quality elements, supported by hydromorphological and physico-chemical quality elements. The reference condition represents undisturbed conditions with no or only very minor human impact. The reference condition thus corresponds to high ecological status.

Reference conditions can be determined using different approaches outlined in the guidance document:

- Spatially based reference conditions
  Using of monitoring or survey data from a network of reference sites, gives spatially based reference conditions. This requires an adequate number of undisturbed sites with data for statistically reliable estimations of percentiles and confidence limits for different quality elements.

- Predictive modelling
  Modelling can be used when an adequate number of reference sites are not available in a region or type and when data is scarce. Existing data from similar regions or types is used to model the expected reference conditions.

- Historical reference conditions
  Extrapolation of historical data or paleoreconstruction of the past conditions can be used when human impact is widespread and there is a lack of sites with reference conditions. However, historical data may too be limited in availability and the quality may be questioned if poorly documented.

The guidelines also points out that expert judgement can be used, but that subjectivity and bias may limit the usefulness of such reference conditions.

In the TRIWA project, the spatial approach with a network of reference sites was used. The human impact in the area is generally low and there are sufficient sites with possible reference conditions. Sites representing supposed reference conditions were selected for the field surveys as described in chapter 3. A total of 20 lakes and 15 river representing the four most common lake types and the three most common river types (five sites per type) were studied in 2004 and 2005. The results from the analyses of water chemistry, phytoplankton (lakes), benthic invertebrates and fish (rivers) were used to estimate type-specific reference conditions. For some types, additional sites from Swedish monitoring programs were included in the analysis.

The ecological quality classes should be divided into five classes or ecological quality ratios (EQR's) on a scale from 1-0, where 1 represents reference conditions and high ecological status. The guideline gives practical examples on how to set class boundaries between the ecological classes. If sufficient data representing reference sites is available, the reference value can be obtained by simple summary statistics of the median value or arithmetic mean for each quality element and type. The EQR's are normalised values created by dividing the real observed values with the reference value (i.e. the mean or median). The borderline between high and good status can be calculated as the 10th percentile (or another suitable percentile) for the quality element. The normalised values must be inverted if an increased nominal value indicates increased impact.

To calculate the borderline between good and moderate conditions a data set of sites representing good status is needed and the procedure is repeated. The values representing good status are divided by the reference value and if necessary inverted. The 10th percentile can be used to determine the border value to moderate status.

EQR (example)	**Status class**
≥1,0-0,8	**High**
0,8-0,6	**Good**
0,6-0,3	**Moderate**
0,3-0,1	**Poor**
<0,1	**Bad**

WFD Environmental objective

5.2 Ecological status in the studied lakes and rivers

Results from the field survey were compared to the Swedish environmental quality guidelines for lakes and watercourses (Swedish EPA 1999) to determine the status and to verify if the studied sites represent reference conditions according to the present guidelines. The guideline reference values are based on seasonal means, i.e. from May to October or June to September for most chemical quality elements. Guideline's reference values are available only for the most important chemical and biological variables.

The chemical and biological statuses of the sites are shown in Tables 11 and 12 for lakes and rivers, respectively. Status values for water quality are expressed as seasonal means (June to October samples). Results from winter sampling are left out. The colour code in the tables is in accordance to the Swedish guideline where class 1 (blue) is the highest status class and class 5 (red) is the lowest class. The results suggest that the studied sites are representing reference conditions, with some exceptions described below.

For chemistry, most lakes and river sites were classed in the highest classes. The brown-water types were classed in lower status classes for TOC, colour and secchi depth. However, the status class does not necessarily judge the site as impacted, because the regional and individual variation among the surface waters is considerable and the division into classes is based on percentiles of the background data used to develop the guidelines. Many of the type 9 lakes are classed as strongly coloured, class 5 (red), which does not imply if this is due to natural conditions or if the site is impacted. Comparative reference values are used to test if acidification and eutrophication impact the site. The extent of deviation from the reference values is a measure of the impact No sites showed signs of acidification when calculating alkalinity in pre-industrial time.

Table 11. Ecological status of surveyed lakes according to the Swedish quality criteria (Swedish EPA, 1999)

LAKE CHEMISTRY Status	**Type**	**pH**	**Alkalinity mekv/l**	**TOC mg/l**	**Tot. P µg/l**	**Tot. N µg/l**	**TotN/TotP**	**Secchi m**	**Colour mg Pt/l**
PARTALJAURE	1	6,85	0,087	1,5	5	130	26		
SAANAJÄRVI	1	7,10	0,179	1,5	5	147	31		
TJÅLMEJAURE	1	7,21	0,180	1,5	6	140	23		
TOSKALJÄRVI	1	7,49	0,345	0,7	6	90	14		
ÅGGOJAURE	1	7,17	0,161	2,1	7	137	21		
LATNJAJAURE	1	6,41	0,027	0,7	3	207	62	12,5	3
ABISKOJAURE	1	7,12	0,220	1,5	6	201	36	9,3	6
ISOLOMPOLO	2	6,95	0,193	6,5	12	284	24	1,7	50
KEIMIÖJÄRVI	2	6,97	0,143	4,7	14	232	17	2,7	38
NAAKAJÄRVI	2	6,88	0,105	3,5	19	400	21	3,0	11
OLOSJÄRVI	2	6,98	0,198	5,9	13	298	23	2,6	
SUOLAJÄRVI	2	7,18	0,256	5,0	17	314	19	3,1	20
VALKEAJÄRVI	2	7,22	0,169	2,8	6	255	45	4,6	13
PAHAJÄRVI	2	7,03	0,151	4,3	10	245	25	2,6	20
KITKIÖJÄRVI	3	6,72	0,138	9,5	13	278	21	2,2	67
NIVUNKIJÄRVI	3	6,90	0,131	7,2	14	338	24	1,9	63
NULUSJÄRVI	3	6,95	0,153	9,5	16	350	22	2,0	77
OUSTAJÄRVI	3	6,66	0,114	12,6	15	380	25	1,8	105
PÄÄJÄRVI	3	6,89	0,144	9,4	33	638	19	1,2	67
LIEHITTÄJÄJÄRVI	9	6,74	0,101	11,2	16	370	23	1,8	101
MERIJÄRVI	9	6,91	0,173	14,2	21	472	22	1,6	115
PIRTTIJÄRVI	9	6,73	0,139	15,0	24	514	21	1,3	133
PUOLAMAJÄRVI	9	7,11	0,196	6,7	11	282	25	2,6	
YLI-KUITTASJÄRVI	9	6,90	0,153	11,8	57	1208	21	0,7	103
Seasonal means for all lakes (from June to October), winter samples are left out *In italic: Lakes in Swedish monitoring programme*	Class1	Almost neutral	Very good	Very low	Low	Low	Surplus-N	Very large	None or insign
	Class 2	Mildly acid	Good	Low	Mod. high	Mod. high	N-P Balance	Large	Slight
	Class 3	Mod. acid	Weak	Mod. high	High	High	Mod. N-deficit	Moderate	Moderate
	Class 4	Acid	Very weak	High	Very high	Very high	Large N deficit	Small	Very intense
	Class 5	Very acid	None / insignificant	Very high	Extremely high	Extremely high	Very large N deficit	Very small	Extremely intense

Reference values for alkalinity in pre-industrial time. The extent of acidification is insignificant for all sites.

Reference values for nutrients exists, but they are based on seasonal means for 3 years of measurements.

Table 11. cont

LAKE PHYTOPLANKTON Status	**Type**	**Number of species total**	**Chlorophyll µg/l**	**Totalvol season mean mm3/l**	**Extent of deviation**	**Totvol aug mm3/l**	**Extent of deviation**	**Cyanobact volume aug mm3/l**	**Extent of deviation**	**Number of toxin prod sp aug**	**Extent of deviation**
PARTALJAURE	1	56	1,0	0,0794	None	0,0547	None	0	No ref value	0	None
SAANAJÄRVI	1	59	1,0	0,0743	None	0,0822	None	0,0003	No ref value	0	None
TJÄLMEJAURE	1	49	1,0	0,1496	None	0,0491	None	0,0009	No ref value	0	None
TOSKALJÄRVI	1	35	1,4	0,0654	None	0,0382	None	0	No ref value	0	None
ÅGGOJAURE	1	60	1,1	0,1259	None	0,0643	None	0,002	No ref value	0	None
LATNJAJAURE	1	15	0,4	0,0551	None	0,0551	None	0	No ref value	0	None
ABISKOJAURE	1	30	0,5	0,0552	None	0,0315	None	0	No ref value	0	None
ISOLOMPOLO	2	91	3,0	0,2494	None	0,0693	None	0,0022	None	0	None
KEIMIÖJÄRVI	2	52	3,6	1,3253	Significant	0,7217	Slight	0,0234	None	0	None
NAAKAJÄRVI	2	43	5,2	1,0519	Significant	0,4867	None	0,0436	None	2	None
OLOSJÄRVI	2	98	4,6	0,3232	None	0,2854	None	0,025	None	0	None
SUOLAJÄRVI	2	72	6,7	1,0543	Significant	0,6861	Slight	0,0987	Slight	2	None
VALKEAJÄRVI	2	52	2,1	0,1658	None	0,1658	None	0,0114	None	1	None
PAHAJÄRVI	2	67	5,5	1,0923	Significant	1,0923	Significant	0,2947	Very large	1	None
KITKIÖJÄRVI	3	83	2,4	0,2829	None	0,4197	None	0,0015	None	0	None
NIVUNKIJÄRVI	3	49	4,6	0,2818	None	0,4345	None	0,0128	None	1	None
NULUSJÄRVI	3	59	5,2	0,3195	None	0,4723	None	0,0048	None	0	None
OUSTAJÄRVI	3	55	5,6	0,2254	None	0,3752	None	0,0005	None	0	None
PÄÄJÄRVI	3	121	14,8	3,1524	Very large	4,9264	Very large	1,8915	Very large	1	None
LIEHITTÄJÄJÄRVI	9	50	4,3	0,5210	Slight	0,4676	None	0,0092	None	1	None
MERIJÄRVI	9	60	4,4	0,8554	Slight	1,0381	Significant	0,0867	Slight	0	None
PIRTTIJÄRVI	9	62	11,1	1,1785	Significant	2,238	Large	0,0227	None	0	None
PUOLAMAJÄRVI	9	74	3,0	0,3076	None	0,392	None	0,0064	None	0	None
YLI-KUITTASJÄRVI	9	91	45,3	12,1155	Very large	18,0882	Very large	16,0749	Very large	5	Large
In italic: Lakes in Swedish monitoring programme	Class 1		Low	Very small	None or insign.	Very small	None or insign.	Very small	None or insign.	Few or none	None or insign.
	Class 2		Mod. high	Small	Slight	Small	Slight	Small	Slight		
	Class 3		High	Moderate	Significant	Moderate	Significant	Moderate	Significant	Moderate	Significant
	Class 4		Very high	Large	Large	Large	Large	Large	Large		
	Class 5		Extremely high	Very large	Very large	Very large	Very large	Very large	Very large	Large-very large	Large

Table 11. cont

LAKE LITTORAL MACROINVERTEBRATES

Status	Type	ASPT	Extent of deviation	Danish fauna index	Extent of deviation	Shannon index	Extent of deviation	Swedish acidity index	Extent of deviation
PARTALJAURE	1	5,9	None	5	None	3,503	None	5	Slight
SAANAJÄRVI	1	5,3	None	3	None	2,374	None	3	Large
TJÄLMEJAURE	1	5,3	None	5	None	2,76	None	3	Large
TOSKALJÄRVI	1	5,5	None	4	None	2,841	None	4	Significant
ÅGGOJAURE	1	6,3	None	5	None	2,735	None	4	Significant
ISOLOMPOLO	2	5,6	None	4	None	3,681	None	5	Slight
KEIMIÖJÄRVI	2	5,8	None	5	None	4,042	None	8	None
NAAKAJÄRVI	2	6,1	None	5	None	3,575	None	8	None
OLOSJÄRVI	2	5,8	None	5	None	4,259	None	8	None
SUOLAJÄRVI	2	5,6	None	5	None	4,004	None	9	None
KITKIÖJÄRVI	3	6,4	None	6	None	3,832	None	8	None
NIVUNKIJÄRVI	3	6,2	None	5	None	3,99	None	6	None
NULUSJÄRVI	3	6,1	None	5	None	3,988	None	6	None
OUSTAJÄRVI	3	5,4	None	4	None	3,953	None	6	None
PÄÄJÄRVI	3	6,2	None	5	None	2,966	None	7	None
LIEHITTÄJÄJÄRVI	9	6,8	None	5	None	3,558	None	7	None
MERIJÄRVI	9	5,8	None	5	None	3,843	None	7	None
PIRTTIJÄRVI	9	5,7	None	5	None	4,18	None	9	None
PUOLAMAJÄRVI	9	5,2	None	4	None	3,465	None	7	None
YLI-KUITTASJÄRVI	9	5,6	None	5	None	2,992	None	7	None
SLU "normal" species list	Class 1	Very high	None or insign.	Very high	None or insign.	Very high	None or insign.	Very high	None or insign.
	Class 2	High	Slight	High	Slight	High	Slight	High	Slight
	Class 3	Moderately high	Significant	Moderately high	Significant	Moderately high	Significant	Moderately high	Significant
	Class 4	Low	Large	Low	Large	Low	Large	Low	Large
	Class 5	Very low	Very large	Very low	Very large	Very low	Very large	Very low	Very large

Table 12. Ecological status of lakes according to the Swedish quality criteria (Swedish EPA, 1999)

RIVER CHEMISTRY

Status	Type	pH	Alkalinity mekv/l	TOC mg/l	Tot. P µg/l	Tot. N µg/l	Colour mgPt/l
KÅBMEJÅKKÅ	1	7,15	0,224	1,4	5	117	8
POROENO	1	7,21	0,173	0,7	5	59	8
ROMMAENO	1	6,91	0,102	3,7	8	177	30
LAFOLJÅKKÅ	1	7,12	0,146	1,9	8	86	14
SKITTSEKALLOJÅKKÅ	1	6,90	0,092	1,5	6	99	11
PESSISJÅKKA	1	7,42	0,315	2,0	5	258	17
JERISJOKI	4	6,86	0,207	5,5	13	354	37
KERÄSJOKI	4	6,70	0,108	9,4	13	274	91
KUERJOKI	4	6,79	0,161	8,8	19	228	89
KÄYMÄJOKI	4	7,22	0,442	9,7	10	372	58
PARKAJOKI	4	6,85	0,141	7,0	12	186	70
YLINEN KIHLANKIJOKI	4	6,50	0,103	6,4	15	266	77
JYLHÄJOKI	8	6,57	0,154	11,3	17	382	108
KUIJASJOKI	8	6,95	0,261	16,0	17	568	155
NAALASTONJOKI	8	6,97	0,289	11,1	14	308	97
ORJASJOKI	8	6,62	0,137	13,8	15	350	126
TUPOJOKI	8	6,88	0,188	15,8	29	506	151
In italic: Lakes in the current Swedish monitoring programme	Class 1	Almost neutral	Very good	Very low	Low	Low	None / insign.
	Class 2	Mildly acid	Good	Low	Moderately high	Moderately high	Slight
	Class 3	Moderately acid	Weak	Moderately high	High	High	Moderate
	Class 4	Acid	Very weak	High	Very high	Very high	Very intense
	Class 5	Very acid	None / insign.	Very high	Extremely high	Extremely high	Extremely intense

Reference values for alkalinity in pre-industrial time. The extent of acidification is insignificant for all sites.

Reference values for nutrients exists, but they are based on seasonal means for 3 years of measurements.

Table 12. continued

RIVER MACROINVERTEBRATES

Status	Type	ASPT	Extent of deviation	Danish fauna index	Extent of deviation	Shannon index	Extent of deviation	Swedish acidity index (Medin)	Extent of deviation
SKITTSEKALLOJÅKKÅ	1	6,2	None	7	None	3,102	None	10	None
KÅBMEJÅKKÅ	1	6,8	None	7	None	2,761	None	6	None
LAFOLJÅKKÅ	1	6,8	None	7	None	3,450	None	9	None
POROENO Valtijoki	1	6,8	None	7	None	2,282	None	7	None
ROMMAENO	1	5,9	None	5	None	2,868	None	7	None
PARKAJOKI	4	7,1	None	7	None	4,429	None	10	None
KÄYMÄJOKI	4	7	None	7	None	3,992	None	10	None
KERÄSJOKI Rovakoski	4	7,4	None	7	None	3,760	None	9	None
KUERJOKI Hautakosket	4	7	None	7	None	4,355	None	8	None
JERISJOKI	4	6,7	None	7	None	4,066	None	10	None
TUPOJOKI	8	6,6	None	7	None	4,349	None	11	None
ORJASJOKI	8	7,5	None	7	None	3,599	None	12	None
JYLHÄJOKI	8	7,1	None	7	None	3,832	None	9	None
NAALASTOJOKI Pitkäkoski	8	6,7	None	7	None	3,720	None	8	None
KUIJASJOKI Peurakoski	8	6,8	None	7	None	3,726	None	12	None
SLU "normal" species list	Class 1	Very high	None or insign.	Very high	None or insign.	Very high	None or insign.	Very high	None or insign.
	Class 2	High	Slight	High	Slight	High	Slight	High	Slight
	Class 3	Mod. high	Significant	Mod. high	Significant	Mod. high	Significant	Mod. high	Significant
	Class 4	Low	Large	Low	Large	Low	Large	Low	Large
	Class 5	Very low	Very large	Very low	Very large	Very low	Very large	Very low	Very large

The phytoplankton analysis showed that some of the type 2 and type 9 lakes deviated from the expected for total volumes (both for seasonal mean and for August values) and for cyanobacteria volumes.

Exploration of the biological data and the water chemistry revealed that the small brown water coastal lake Yli-Kuittasjärvi was a real outlier when compared to other lakes of type 9. The lake is quite shallow and showed high nutrient concentrations and extreme chlorophyll levels and phytoplankton biovolumes, in comparison to the other sites. The water quality is most likely reflecting natural conditions, since the anthropogenic land use is quite minimal on the lake's catchment area. Eutrophic conditions of the lake may be caused by catchment's soil and bedrock characteristics. Further, bottom sediment may influence water quality in this shallow and wind-exposed small lake. Yli-Kuittasjärvi was excluded from the subsequent analyses.

Lake Pääjärvi (type 3) is also an extreme case for nutrient conditions in its type. The lake showed large biovolumes of phytoplankton and a moderate level of cyanobacteria, which is regarded as a very large deviation from the comparative values. As for Lake Yli-Kuittasjärvi, there is no obvious human impact in the area and the conditions are likely due to naturally high nutrient conditions. However, the deviation from other lakes of the same type was not as severe as with Lake Yli-Kuittasjärvi and therefore Lake Pääjärvi was kept in the data set.

In Pääjärvi, Nulusjärvi (type 3 lakes) and Pirttijärvi (type 9) the phytoplankton community in august was characterised by the invasive nuisance Raphidophyceae specie *Gonyostomum semen*. It is a large flagellated algae that is quite common in humic lakes. Mass blooms of the alga can be problematic as it produces a slime that can cause skin irritation. In Pääjärvi and Pirttijärvi the *Gonyostomum semen* biovolume corresponded to moderate level (1-2,5 mm/l^3, class 3), which is not likely to cause skin irritation. It also occurred in small volumes in some other lakes in the study. The percentage distribution of phytoplankton groups in each lake is shown in Appendix 6.

Profundal oxygen concentrations measured in March-April 2005 indicated that type 9 lake Pirttijärvi suffered from springtime anoxia. Spring oxygen concentrations were also low in Lake Suolajärvi (type 2), although not completely depleted. The observed oxygen depletion may be natural in small, deep and moderately nutrient-rich lakes like Pirttijärvi and Suolajärvi.

For benthic macroinvertebrates, the ASPT and Shannon diversity indices indicate that all lake sites are within the reference conditions (i.e. high diversity and ecological quality) according to the Swedish environmental quality guidelines for lakes and rivers (Swedish EPA 1999).

The acidity index also reflects reference conditions in the studied lakes, except for lakes in the mountain area. The Swedish acidity index is low to moderate in the mountain lakes suggesting there is a large deviation from the expected, which implicates anthropogenic acidification. This is most probably caused by erroneous index reference value for the alpine region as the airborne deposition of acidifying pollutants is well below the critical load in this area.

The studied rivers also seem to reflect the natural conditions. The only exception in the data set is River Tupojoki (type 8), which has higher total phosphorous concentrations than the other type 8 rivers. The macroinvertebrate indices also imply that the studied river sites represent reference conditions. Shannon's index, ASPT and the acidity index were high for all river sites and there were no deviation from the reference values.

5.3 Reference conditions of the common water types

The data set obtained in the TRIWA project is rather limited (five sites per type) for statistical evaluation as recommended by the guidelines described above (European Communities, 2003). Sampling errors, analytical errors and especially the natural temporal variations may greatly influence the evaluation. Further, the data set does not represent status classes other than high status. Therefore, EQR's have not been calculated as normalised ratios, but given as a range of the observed values from the field survey together with the median value (reference value) of the reference data set. In addition, also the 75th percentile (and 25th percentile) was calculated as this is often used to determine the borderline between different classes in other environmental criteria (Swedish EPA, 1999) and Finnish guidelines (Vuori et al. 2006).

The reference conditions for the most abundant surface water types are presented in Table 12 and 13 for lakes and rivers, respectively. Lake Yli-Kuittasjärvi was excluded from the calculations.

REFERENCE CONDITIONS FOR LAKES

Table 13. Reference conditions for lakes in the River Torne watershed.
Yli-Kuittasjärvi is excluded from the data set.

Chemistry		pH	Alkalinity mekv/l	Colour mgPt/l		TOC mg/l	COD mg/l	Total-P µg/l	Total-N µg/l	Secchi m	Conductivity mS/m	Aluminium µg/l	Iron µg/l	Silica mg/l
Lake type 1	25 percentile	6,97	0,124	7	75 percentile	1,5	1,8	6	174	12	3,61	24	58	1,6
	median	7,12	0,179	7	median	1,5	1,7	6	140	11	2,93	19	33	1,4
	max	7,49	0,345	15	max	2,1	2,7	7	207	13	4,33	29	64	2,4
	min	6,41	0,027	3	min	0,7	1,0	3	90	9	1,63	11	11	0,5
Lake type 2	25 percentile	6,96	0,147	16	75 percentile	5,5	6,7	15	306	3	3,08	32	249	3,3
	median	6,98	0,169	20	median	4,7	6,2	13	284	3	2,69	14	192	3,3
	max	7,22	0,256	50	max	6,5	7,3	19	400	5	3,18	39	286	4,2
	min	6,88	0,105	11	min	2,8	2,8	6	232	2	1,72	6	60	0,4
Lake type 3	25 percentile	6,72	0,131	67	75 percentile	9,5	13,4	16	380	2	2,40	86	720	5,9
	median	6,89	0,138	67	median	9,5	12,5	15	350	2	2,32	75	708	4,5
	max	6,95	0,153	105	max	12,6	16,4	33	638	2	2,74	129	1480	6,6
	min	6,66	0,114	63	min	7,2	9,0	13	278	1	2,00	21	190	3,4
Lake type 9	25 percentile	6,74	0,129	88	75 percentile	14,4	17,4	22	483	2	3,18	108	2145	5,3
	median	6,82	0,156	108	median	12,7	14,4	19	421	2	2,79	79	1880	4,9
	max	7,11	0,196	133	max	15,0	19,2	24	514	3	3,22	165	2160	5,3
	min	6,73	0,101	47	min	6,7	6,5	11	282	1	2,32	50	436	4,3

75 percentile, when increasing values indicates pressure
25 percentile, when decreasing values indicates pressure

Table 13. continued

Phytoplankton		Number of taxa, season total	Chryso phyceae %		Chlorophyll µg/l	Totalvol season mean mm3/l	Totvol aug mm3/l	Cyanobact volume aug mm3/l	Cyano-phyceae %
Lake type 1	25 percentile	33	42	75percentile	1,1	0,103	0,060	0,001	1,1
	median	49	49	median	1,0	0,074	0,055	0,000	0,0
	max	60	92	max	1,4	0,150	0,082	0,002	3,1
	min	15	26	min	0,4	0,055	0,032	0,000	0,0
Lake type 2	25 percentile	52	19	75percentile	5,4	1,073	0,704	0,071	11,7
	median	67	29	median	4,6	1,052	0,487	0,025	8,8
	max	98	37	max	6,7	1,325	1,092	0,295	27,0
	min	43	8	min	2,1	0,166	0,069	0,002	3,2
Lake type 3	25 percentile	55	21	75percentile	5,6	0,320	0,472	0,013	2,9
	median	59	34	median	5,2	0,283	0,435	0,005	1,0
	max	121	66	max	14,8	3,152	4,926	1,892	38,4
	min	49	16	min	2,4	0,225	0,375	0,001	0,1
Lake type 9	25 percentile	60	2	75percentile	6,1	0,936	1,338	0,039	8,4
	median	62	18	median	4,4	0,688	0,753	0,016	2,0
	max	91	27	max	11,1	1,179	2,238	0,087	88,9
	min	50	0	min	3,0	0,308	0,392	0,006	1,0

25 percentile, when decreasing values indicates pressure (acidity gradient response)
75 percentile, when increasing values indicates pressure

Table 13. continued

Macro-invertebrates		Number of taxa	Number of ind. / sample		ASPT	Danish fauna index	Shannon index	Acidity index (Medin)	EPT Number of taxa	EPT Number of ind.	Saprobic index	BMWP
Lake type 1	75percentile	26	109	25 percentile	5,3	4	2,74	3	4	2	1,0	44
	median	24	73	median	5,5	5	2,76	4	5	4	1,3	58
	max	30	119	max	6,3	5	3,50	5	7	12	2,1	82
	min	17	21	min	5,3	3	2,37	3	4	1	0,9	42
Lake type 2	75percentile	58	671	25 percentile	5,6	5	3,68	8	11	23	2,4	92
	median	55	153	median	5,8	5	4,00	8	15	26	2,5	121
	max	58	891	max	6,1	5	4,26	9	17	259	2,5	128
	min	41	101	min	5,6	4	3,58	5	9	17	2,1	90
Lake type 3	75percentile	51	258	25 percentile	6,1	5	3,83	6	12	17	2,2	106
	median	50	154	median	6,2	5	3,95	6	14	40	2,2	108
	max	54	520	max	6,4	6	3,99	8	23	244	2,7	135
	min	37	53	min	5,4	4	2,97	6	10	13	2,1	105
Lake type 9	75percentile	50	214	25 percentile	5,6	5	3,53	7	10	24	2,2	96
	median	44	134	median	5,8	5	3,70	7	14	37	2,3	113
	max	54	272	max	6,8	5	4,18	9	19	52	2,6	122
	min	36	70	min	5,2	4	3,47	7	7	8	2,2	89

Normal sp list

REFERENCE CONDITIONS FOR RIVERS

Table 14. Reference conditions for rivers in the River Torne watershed.

Chemistry		pH	Alkalinity mekv/l	Colour mgPt/l		TOC mg/l	COD mg/l	Total-P µg/l	Total-N µg/l	Conductivity mS/m	Aluminium µg/l	Iron µg/l	Silica mg/l
River type 1	25percentille	6,97	0,113	9	75percentille	2,0	4,1	7	162	3,2	28	51	3,1
	median	7,14	0,160	13	median	1,7	2,3	5	108	2,5	21	39	2,6
	max	7,42	0,315	30	max	3,7	4,4	8	258	4,8	58	116	7,7
	min	6,90	0,092	8	min	0,7	0,9	5	59	1,7	11	24	1,4
River type 4	25percentille	6,72	0,116	61	75percentille	9,2	12,0	14	334	3,1	69	609	7,3
	median	6,82	0,151	74	median	7,9	11,6	13	270	2,4	60	512	5,6
	max	7,22	0,442	91	max	9,7	12,3	19	372	6,0	111	798	9,2
	min	6,50	0,103	37	min	5,5	6,5	10	186	1,8	27	268	2,7
River type 8	25percentille	6,62	0,154	108	75percentille	15,8	20,0	17	506	4,7	206	2460	8,2
	median	6,88	0,188	126	median	13,8	17,8	17	382	3,3	128	1548	7,0
	max	6,97	0,289	155	max	16,0	20,2	29	568	5,2	210	2660	9,1
	min	6,57	0,137	97	min	11,1	12,7	14	308	2,6	94	1082	6,0

Table 14. continued

Macro-invertebrates		Number of taxa	Number of ind. / sample	Saprobic index		ASPT	Danish fauna index	Shannon index	Acidity index (Medin)	EPT Number of taxa	EPT Number of ind.
River type 1	75percentille	37	737	1,9	25percentille	6,2	7	2,761	7	18	136,4
	median	34	456	1,8	median	6,8	7	2,868	7	20	201,6
	max	41	1361	2,1	max	6,8	7	3,45	10	23	288,6
	min	26	178	1,7	min	5,9	5	2,282	6	14	122,6
River type 4	75percentille	60	548	1,8	25percentille	7	7	3,992	9	31	205,2
	median	55	450	1,7	median	7	7	4,066	10	34	207,8
	max	62	988	1,9	max	7,4	7	4,429	10	39	739,8
	min	49	268	1,7	min	6,7	7	3,76	8	31	169,2
River type 8	75percentille	61	460	1,8	25percentille	6,7	7	3,72	9	30	202,2
	median	54	391	1,7	median	6,8	7	3,726	11	30	209,6
	max	62	986	1,8	max	7,5	7	4,349	12	38	774,6
	min	48	307	1,4	min	6,6	7	3,599	8	30	141,4

75^{th} percentile: index value increase when org impact increase
25^{th} percentile: index values decrease when impact is increased

Fish		Number of taxa	Density ind./m2	Biomass g/m2	Number of salmonid taxa	Number of reproducing Salmonid taxa	Number of sensitive taxa
River type 4	75percentille	5	18	99	2	1	3
	median	5	15	89	1	1	3
	max	6	20	204	3	2	4
	min	5	4	40	1	1	3
River type 8	75percentille	7	34	199	1	1	3
	median	7	14	159	1	1	3
	max	9	140	422	3	3	4
	min	2	10	60	0	0	1

75^{th} percentile: index value increase when org impact increase

6 Common monitoring programme

6.1 Monitoring guidelines

According to the WFD article 8, EU member states have to establish monitoring programs to follow the status of surface waters, groundwater and protected areas in each river basin district. Protected areas include water bodies used for abstraction of drinking water and habitat and species protection areas as identified under the Birds Directive (79/409/EEC 1979) or the Habitat Directive (92/43/EEC 1992). The specific requirements are listed in Annex V and the programs have to be operational by 22 December 2006. Three types of monitoring are required for surface waters - surveillance, operational and investigative monitoring (Table 15). The sampling frequencies have to ensure an acceptable confidence and precision of the assessment of status.

Table 15. Description of different monitoring programmes included in the WFD.

	Objective	Frequency minimum
Surveillance monitoring	Assessment of long-term changes in natural conditions Assessment of long-term changes due to anthropogenic activities Validating and supplementing of impact and risk assessment Development of efficient future monitoring programs	For a period of one year every 6^{th} year In water bodies with good status and low impact the frequency is once in 18 years.
Operational monitoring	Establish the status of water bodies at risk of failing to meet the environmental objectives Assessment of changes in status in water bodies included in measure programs	Depending on the parameters and statistical requirements
Investigative monitoring	Where reasons for surpasses of environmental objectives are unknown To follow the magnitude and impact of accidental pollution	Depending on the parameters and statistical requirements

The Directive Annex V 1.1 and 1.2 lists three groups of quality elements (biological, physico-chemical and hydro-morphological) that must be included in the monitoring programs for surface waters (Table 16). The physico-chemical and biological quality elements are similar for rivers and lakes, while the morphological elements are different. The variables included in the monitoring should be the ones giving the best indication of environmental state and the pressure that is expected in a water body. The monitoring programs can be developed so that certain relevant variables are analysed more frequently while others can be reduced to a minimum. Monitoring of biological quality elements must be at an appropriate taxonomic level to achieve good confidence and precision in the status classification.

Rivers with catchment areas >10 km^2 and lakes >0,5km^2 fall under the requirements of the Directive. The surveillance monitoring must be undertaken for at least a period of one year every 6^{th} year, i.e. once during the time frame of a River Basin Management Plan. A sufficient number of water bodies must be monitored to enable a reliable assessment of overall surface water status in the different catchments of the river basin district. Representative water bodies of a certain type or region can be selected for the monitoring when the water bodies have similar environmental state and pressure.

Table 16. Quality elements for monitoring of lakes and rivers in accordance with the EU WFD.

	Quality elements	**Mandatory variables** (+recommended variables)
Biological elements	Invertebrate fauna	Abundance
		Composition
		Diversity
		Presence of sensitive taxa
	Fish	Abundance
		Composition
		Life cycle/age structure
		Presence of sensitive taxa
	Phytobenthos	Abundance
		Composition
		(Presence of sensitive taxa)
	Macrophytes	Abundance
		Composition
		(Presence of sensitive taxa)
	Phytoplankton (for lakes)	Abundance
		Composition
		(Biomass)
		Bloom frequency/intensity
Physico-chemical elements	Thermal conditions	Temperature
	Oxygenation conditions	(Dissolved oxygen)
	Salinity	(Electrical conductivity)
	Acidification status	pH (mandatory for rivers, recommended for lakes)
		Alkalinity/ANC (mandatory for rivers, recommended for lakes)
		(TOC for lakes)
	Nutrient conditions	(Total phosphorous)
		(Soluble reactive phosphorous)
		(Total nitrogen)
		(Nitrate+nitite)
		(Ammonium)
	Transparency for lakes	(Secchi depth)
		(Turbidity)
		(Colour)
	(Other for rivers)	(Suspended solids)
		(Turbidity)
	Specific synthetic pollutants	(All WFD priority list substances)
		(Other relevant substances depending on catchment pressures)
	Specific non-synthetic pollutants	(All WFD priority list substances)
		(Other relevant substances depending on catchment pressures)
Hydromorphological elements	Hydrological regime	Quality and dynamics of water flow
		Connections to groundwater
		Residence time (for lakes)
	River continuity	(No. and type of barrier)
		(Provision of passage of aquatic organisms)
	Morphological conditions Rivers	River depth and width variation
		Structure and substrate of river bed
		Structure of the riparian zone
		Current velocity
		Channel patterns
	Morphological conditions Lakes	Lake depth variation
		Structure and substrate of lake bed
		Structure of the lake shore

6.2 Current monitoring in Finland and Sweden

Monitoring has a long history in both Finland and Sweden. Water quality monitoring in the River Torne watershed has been conducted through various programs since the 1960s. The first monitoring programs covered only the main river and the outlet to the Bothnian Bay. In the 1970's and 1980's some lakes and major tributaries were included in monitoring programs in both sides of the river. Information of the fish populations in the main channels and major tributaries has been collected since the beginning of the 1970's.

Long-term surveillance monitoring programs

National monitoring programs of Finland were renewed in the beginning of 2006, with the intention of adjusting the surveillance to meet the requirements of WFD. In the Finnish side, four river monitoring sites are located in the main channel of River Torne (Rivers Torne, Muonio and Könkämäeno) and two in the tributaries (Rivers Kangosjoki and Kuerjoki). Five lakes from River Torne catchment are included in the national surveillance: Lakes Kilpisjärvi, Miekojärvi, Koutusjärvi, Keräsjärvi and Keimiöjärvi (Figure 21). All sites are regarded as national reference sites for their type, with the exception of moderately human-impacted Miekojärvi. The selected lakes are have previously been frequently sampled for phytoplankton, and rivers have been electro-fished by Finnish Game and Fisheries Institute. Further, pollutant concentrations in fish tissues have been followed on the sites near the outlet of River Torne. In addition to this, occasional studies concerning benthic fauna and phytoplankton flora have been conducted in some of the sites, but a coordinated surveillance of these biological elements has been missing so far. In the near future, biological sampling will be included in the national monitoring programs. Additionally, six small lakes of the catchment area have been included in other national research programs (acidification and blue-green algae monitoring). Besides national programs, several lake and river sites have been frequently monitored in regional programs (regionally important lakes, restored lakes and rivers etc.).

The Swedish national monitoring program continuously follows the water quality in several reference lakes and rivers (Figure 21). The aim is to follow long-term changes and diffuse loading. The lakes Abiskojaure and Latnjajaure together with a regional monitoring lake Valkeajärvi are located within the River Torne watershed. The lake program comprises chemistry, chlorophyll, phytoplankton and macroinvertebrates. Fish monitoring is included for Lake Abiskojaure and will be included for Valkeajärvi in 2006. At present, there are four sampling stations in rivers. Rivers Abiskojåkka and Pessisjåkka are tributaries to Lake Torneträsk. The station in River Torne is located close to the outlet. The regional monitoring programme includes Ylinen Kihlankijoki, a tributary to River Mounio. Water chemistry and macroinvertebrates are included in the river programs, except for the river outlet where only chemistry is analysed. Fish will be included among biological quality elements also for Ylinen Kihlankijoki.

The largest lake in the watershed, Lake Torneträsk has been monitored during 2004 and 2005, when chemistry, chlorophyll, phytoplankton and macroinvertebrates were studied frequently. The plan is to follow the conditions in the large lake with repeated intensive program with a few years interval, as environmental changes are likely to appear very slowly in such a large and deep lake.

Swedish and Finnish monitoring is quite comparable. Sampling frequencies and times are similar, most of the sites are monitored on a yearly bases, with several sampling occasions per year. There are some small differences in the water chemistry variables analysed, but the results are mostly comparable. At present, Swedish programs includes more biological parameters compared to the Finnish programs. In Finland, most of the biological analyses have been done infrequently as a part of short-term scientific studies.

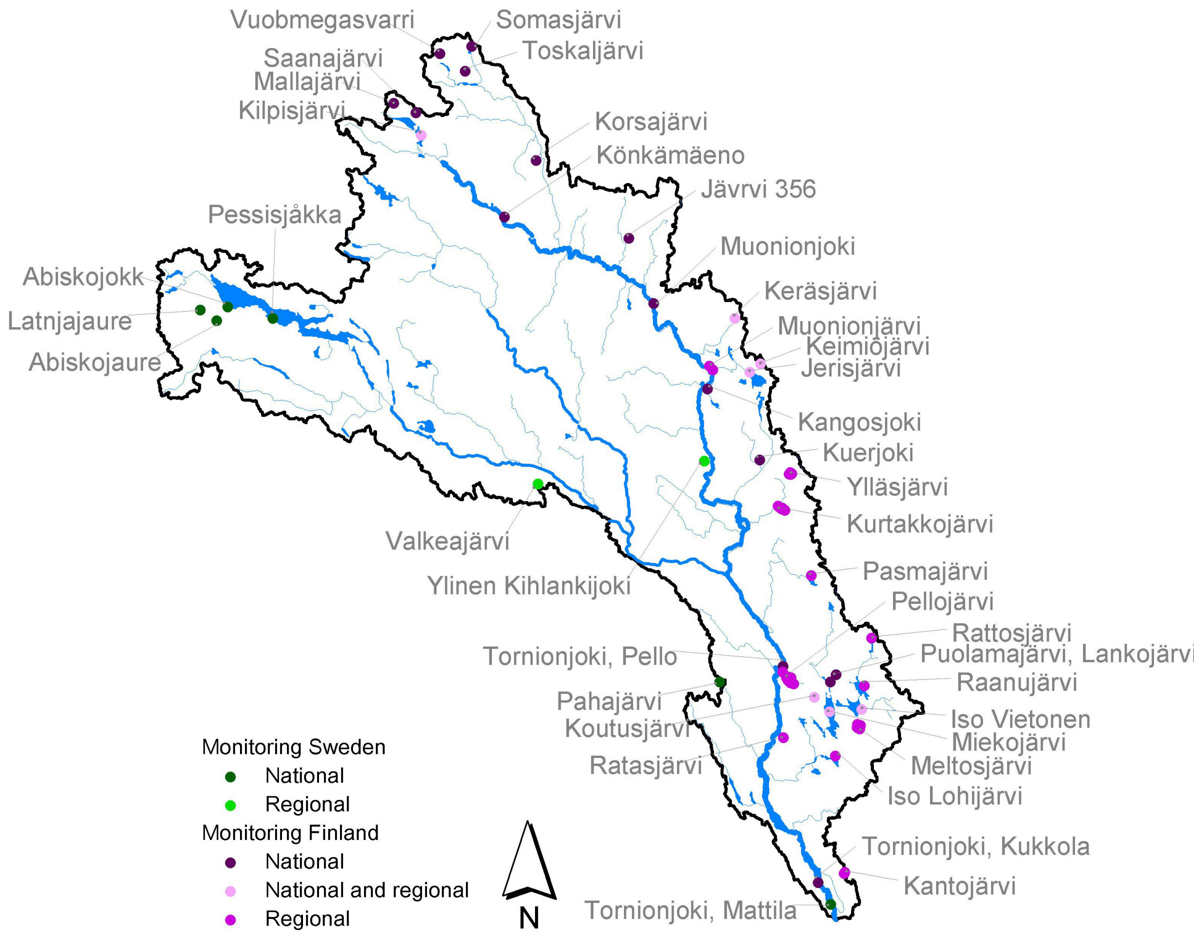


Figure 21. Current monitoring stations in the River Torne watershed. © Lantmäteriet

Other surveillance monitoring

Besides the long-term monitoring, there are additional surveys of water quality in both Finland and Sweden. Every fifth year since 1972, a Swedish national survey for monitoring of acidification and eutrophication have been conducted on the basis of physico-chemical analyses. In 1995 and 2000, also macroinvertebrates were included in the survey. In 2005, only water chemistry was sampled and the number of sites was decreased. Approximately 180 lakes in River Torne watershed has been sampled in the national survey, of which most are small lakes (<0,5 km^2).

In Finland, the first national survey was conducted in 1987 to map the acidification status. About 160 lakes were selected for further monitoring of acidification. The survey has continued as a monitoring of climate change with a reduced number of lakes. At present, four small monitored lakes are located in the River Torne watershed. There has also been a frequent sampling of some tributaries, e.g. Jietajoki, Jerisjoki and Kangosjoki, to monitor changes in water quality during flood episodes.

In 1995, a common Nordic lake survey was run in Norway, Finland and Sweden. Selection of sites, sampling methods and analysis were harmonised to get comparable results.

Operators' control

Environmental impact has to be monitored by those who pursue environmentally hazardous activities in accordance with the environmental codes in Finland and Sweden. The supervising authorities in Finland are either the regional environmental centres or the municipalities depending on the character of the activity. The conditions are similar in Sweden, where the major activities are supervised by the county administrative boards and the minor functions by the municipalities. River Torne is an exceptional case as there is an agreement between Finland and Sweden, the Border River Commission, which acts as supervising authority for activities and measures affecting the water of the border river.

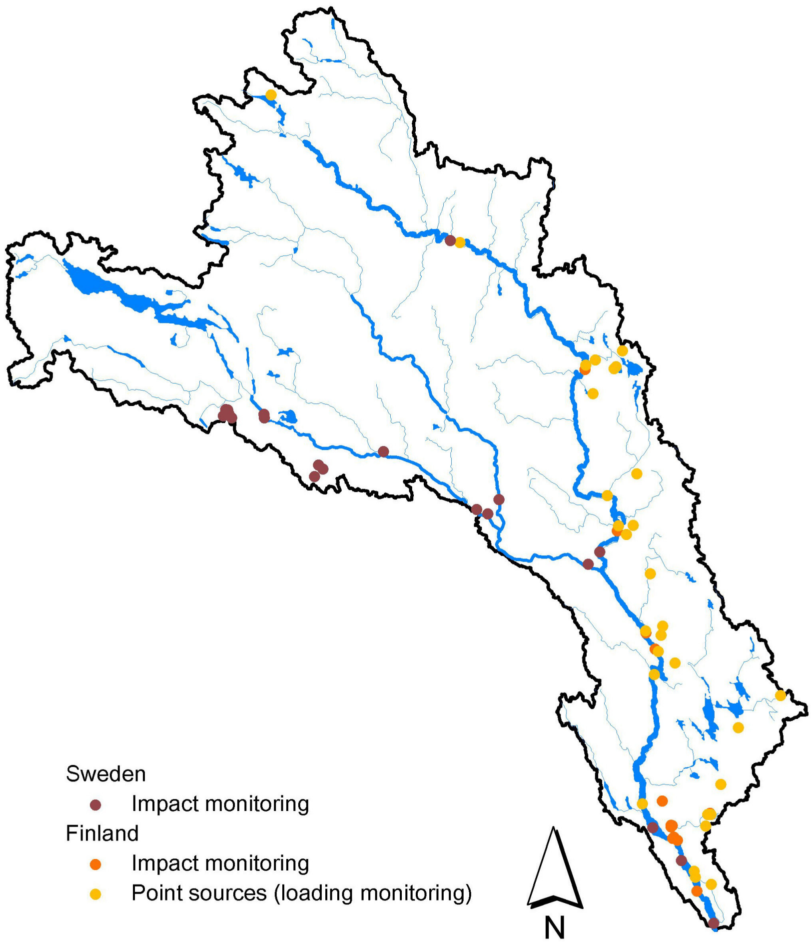


Figure 22. Current operator's control in the River Torne watershed.
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However, the supervision of the activities' fulfilment of environmental permits and operators' control proceeds according to the environmental code of each country. In some cases the supervising authorities in both sides of the river can approve the programs for operators' control.

In the Finnish side of the River Torne-Muonio, operators' control has been conducted as a common coordinated control program since 1981. The program concerns the main channel and the tributaries with load from point sources. Traditional water chemical variables are included in the program and samples are taken three times per year. The coordinated control program will be renewed by the end of the year 2006. The new program should include also some biological quality elements (probably benthic macroinvertebrates, fish). Besides the coordinated program, there are some local control programs for environmentally hazardous activities (Figure 22).

In Norrbotten County in Sweden, a program for coordinated control of the river was applied during the years 1974-1990. There were 37 sampling stations in the River Torne water system that were sampled twice per year. Only the basic chemical variables were analysed. A major revision of the program was suggested in the early 1990s and a new program, co-ordinated by the municipalities (7 Swedish and 1 Finnish), industries and other actors, has run since 2001. The Water Protection Association for Rivers Torne and Kalix was founded in year 2000. The program contains 12 stations in the Rivers Torne, Muonio and Lainio which are sampled 5-6 times per year. Metals are included in the program at some sites. The program also includes sites in the River Kalix

6.3 Deficiency analysis

The current national and regional surveillance monitoring programmes cover several stations in the main channels. There are a total number of 45 lakes (plus nine lakes that are <0,5 km^2) and 10 river stations (plus two rivers that are <50 km^2) in different surveillance programs. The monitoring sites are spread quite unevenly in the watershed (Figure 21). The majority of the stations is located in Finland. The Finnish sites have a better spatial distribution from north to south than the stations in the Swedish programme, which are concentrated to the southern mountain areas with only few sites in the southern and middle part of the watershed.

The current operator's control programmes include seven lakes (plus one lake <0,5 km^2, all located in Finland,) and 47 river stations (plus nine rivers that are <50 km^2). A great majority of the stations are located in the Finnish side.

Table 17. Number of current surveillance monitoring sites of each lake type according to the revised typology.

	Lake types	SWE >0,5km^2	SWE <0,5km^2	FIN >0,5km^2	FIN <0,5km^2	Total	Small
1	**Northern highland lakes**	2		4	1	**6**	1
2	**Small clear-water lowland lakes**	2		6	4	**8**	4
3	**Small brown-water lowland lakes**			9		**9**	
4	Medium clear-water lowland lakes			2		**2**	
5	Medium brown-water lowland lakes			8	4	**8**	4
6	Large clear-water lowland lakes			2		**2**	
7	Large brown-water lowland lakes			3		**3**	
		4		34	9	**38**	9

In bold: The most common types in the watershed.

Table 18. Number of current surveillance monitoring sites of each river type according to the revised typology.

	River types	SWE >50km^2	SWE <50km^2	FIN >50km^2	FIN <50km^2	Total	Small
1	**Small highland rivers**	2			1	**2**	1
2	Large highland rivers			1		**1**	
3	**Small clear-water lowland rivers**				1		1
4	**Small brown-water lowland rivers**	1		2		**3**	
5	*Large clear-water lowland rivers*						
6	Large brown-water lowland rivers			1		**1**	
7	Very large lowland rivers	1		2		**3**	
		4	0	6	2	**10**	2

In bold: The most common types in the watershed
In italic: A type that is not present in the watershed.

A simple deficiency analysis of the surface water types and ecoregions represented in the current surveillance programs in relation to the most common types of the area was made (Tables 17 and 18). All existing lake and river types are represented in the current programme, although the number of sites per type is low, especially in rivers.

The surveillance programmes aim to follow long-term changes and diffuse loading like atmospheric deposition in reference sites, while the operational programs follow impacts from point sources on its recipients. There are some impacts that are not surveyed in the present programs. Recipients of point sources are rather well surveyed in the operational programs, but there is a great lack of sites following the impact from sewage plants, at least in the Swedish side. Other types of pressures that need to be followed by surveillance monitoring are diffuse loading from forestry and agriculture and hydromorphological alterations. Further, WFD obliges the member states to monitor the status of protected water areas (drinking water sources, pristine, protected waters).

The WFD demands on sampling frequencies and quality elements are generally fulfilled for the current physico-chemical monitoring. The data series are dating back to the 1970's and many of the waters are sampled at a frequency that allows detection of environmental changes at sufficient statistical level for each studied site. The current surveillance programs are in some cases even more ambitious in sampling frequency than the minimum requirement of the WFD. The sampling frequency is of course related to the purpose of the program, what kind of phenomenon is studied and how many samples have to be taken to show significant trends. To detect a status change in a lake that is sampled only during one year every 6^{th} year will require a quite long time in order to gather reliable time series for analyses.

In the current program, it is necessary to include more sites for several water types in order to detect changes in water bodies of a certain type or region. The poor spatial distribution of sites and lack of sites in impacted areas, especially in the Swedish side need to be revised in future monitoring programs. To fulfil the demands of the WFD, it is also necessary to include more biological and hydromorphological monitoring as well as quality elements that indicate stress from synthetic and non-synthetic pollutants (Priority substances) listed in the WFD. However, the number of potential priority substances that require monitoring in River Torne watershed is quite limited.

EU's demand for the monitoring of protected water areas is fulfilled sufficiently with present monitoring, at least in the Finnish side. In Finland, virtually all households get their drinking water from groundwater sources, so there are no larger surface water areas used for abstraction of drinking water. Further, a majority of the waters in the watershed can be regarded as protected in the Natura2000 network, and the current monitoring programme thus fulfil the requirements of monitoring in protected areas. Additionally, large areas in the northern parts of the area are protected as national and nature reserve parks, and several of currently monitored pristine waters are located on these areas. In Sweden, the surface water monitoring in protected areas is currently being mapped on national level. This will most likely result in a deficiency analysis and a suggested improved programme.

6.4 Recommendations for a common monitoring programme

The project has developed two alternative suggestions to a harmonised programme for surveillance monitoring of surface waters. The demands set by the WFD has been taken into account as well as the costs for different alternatives. Operational monitoring has not been regarded at this point.

For several reasons we can only present suggestions to a common program at this point. Current revision of national surface water programmes in Finland and Sweden has to be considered before finalising a harmonised monitoring programme. The national revisions will be ready during 2006. Also, it is still uncertain how much resources will be available for regional monitoring in Sweden and Finland and how much can be spent in the River Torne area. It is also important to discuss the suggested programmes with actors and interest groups in the watershed, which will be done during 2006 and 2007.

A surveillance monitoring programme that fulfils the minimum demands of the WFD is shown in Figure 23. It includes monitoring of all water types, which results in 33 lakes (4-5 lakes per type) and 24 rivers (5 per type) and 3 stations in the main channel. Five sites per type is rather small for statistical evaluation, but sites with comparable characteristics are also present in neighbouring watersheds to River Torne. Sites of the same type from other watersheds can be included in surveillance and they can be evaluated as one unit. The monitoring network of River Torne must therefore be seen in a wider context. The suggested sites have primary been chosen from the existing reference sites in the present monitoring and field survey sites of TRIWA-project. Additional sites with presumed reference conditions have been added to cover all the types in the watershed.

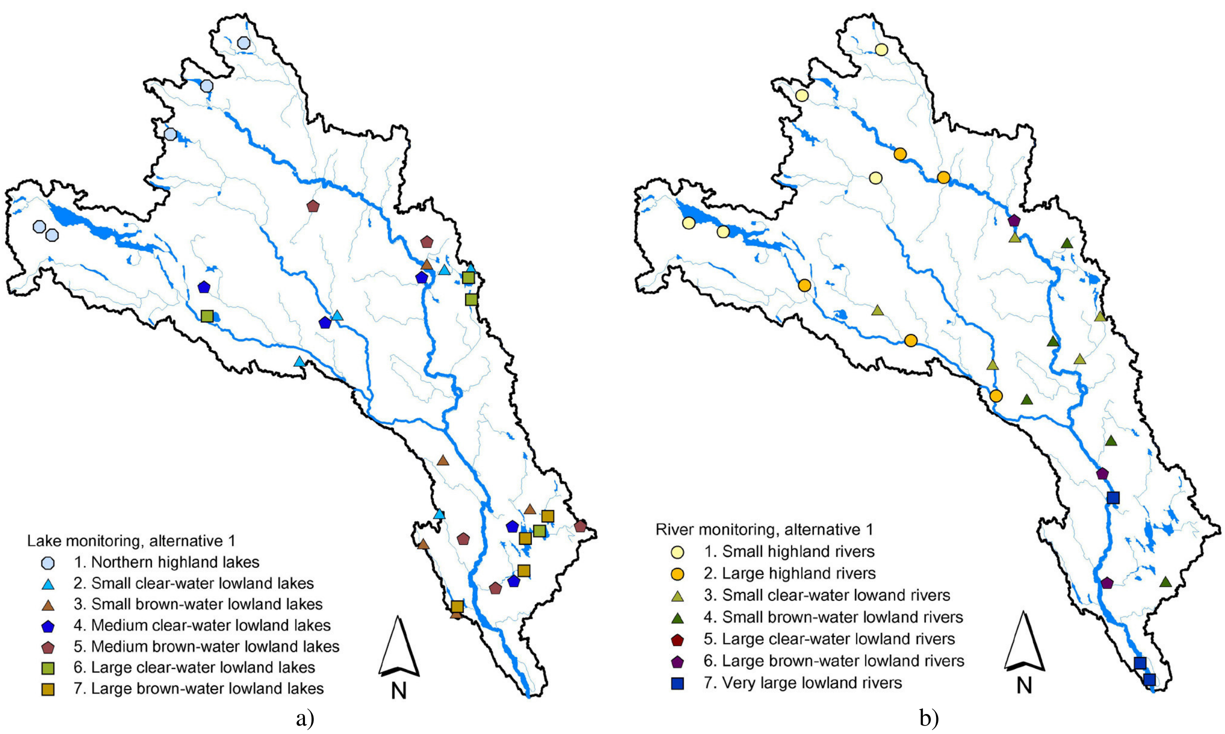


Figure 23. A monitoring programme that would fulfil the basic WFD demands on surveillance monitoring of a) lakes and b) rivers. © Lantmäteriet

The number of lake sites is actually lower in our suggestion when compared to the present surveillance programme (33 lakes instead of 38). On the other hand, number of river sites is increased from 10 to 24 rivers sites. In the final programme, the distribution of the sites can be re-evaluated in order to enhance spatial coverage. However, suitable reference sites with sufficient data are scarce, and are already included in this monitoring scheme.

The minimum sampling frequency is during a one-year period every 6th year for surveillance monitoring of sites with low impact. The estimated cost for the programme is about 415 000 € for a 6-year period or 70 000 € if divided per year. The cost includes sampling (travel costs) and analysis costs for biological and physico-chemical elements according to Table 19. Hydromorphological elements as well as specific synthetic and non-synthetic pollutants required by the WFD are not included. The cost is based on the minimum sampling frequency and it is about 8200 € for each lake and 5300 € for each river site. Sampling frequency may have to be increased in the lower parts of the watershed since the human impact is greater in this area.

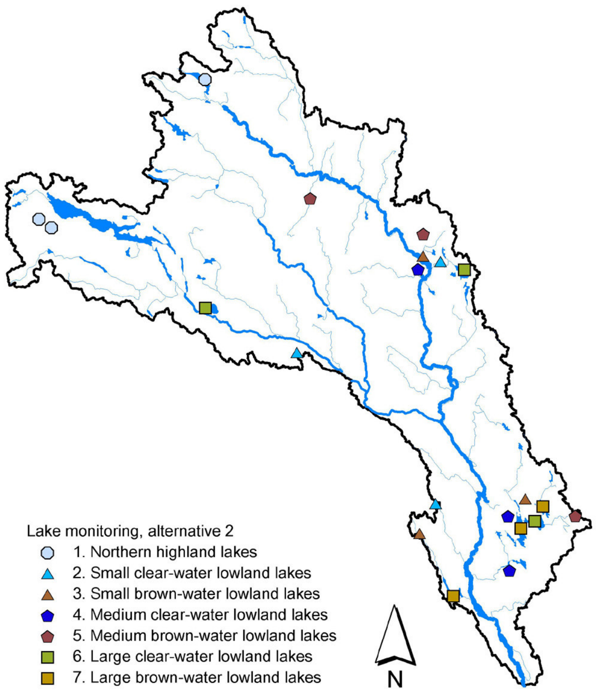
The ideal case would be to monitor every year to minimise the effect of natural variation. The cost would then be 331 800 € per year or about 2 000 000 € per 6-year period.

Table 19 Sampling frequencies and costs per year (for sampling and analyses) for different monitoring scenarios.

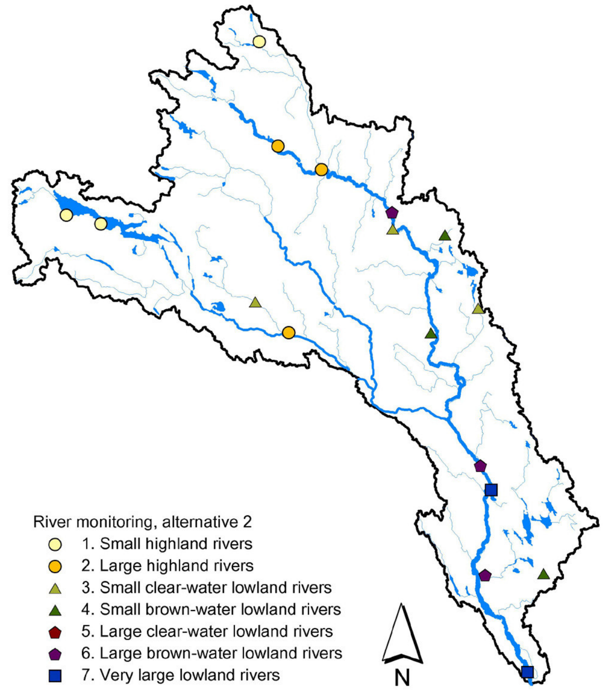
	During one year each 6-year period (minimum)		**Every year (ideal case)**	
Lake	Sampling frequency	Cost per year	Sampling frequency	Cost per year
Water chemistry*	5		5	
Phytoplankton	3		3	
Profundal benthos	1		1	
Littoral benthos	1		1	
Periphyton	1		1	
Macrophytes	1		1	
Fish	1	**1370 €/ lake**	1	**8200 €/ lake**
River				
Chemistry	5		5	
Benthos	1		1	
Periphyton	1		1	
Macrophytes	1		1	
Fish	1	**890 €/river**	1	**5300 €/river**

* Surface and bottom water

A reduced programme with only three sites per lake and river type is presented in Figure 24. It contains 21 lakes and 15 river sites plus two sites in the main channel. The cost for this programme would be about 263 000€ for a period of 6 years. This programme is developed as a cheaper alternative to the previous suggestion. The sampling frequencies would be the same as above (once in every 6th year). The programme might be enough if it is set in a wider context, taking monitoring in neighbouring watersheds into account.



a)



b)

Figure 24. A reduced surveillance monitoring programme of a) lakes and b) rivers.
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One must bear in mind that number of monitored sites in the watershed will still increase with the implementation of operational monitoring for point and non-point source loading. The costs for the suggested monitoring schemes will overrun the expenses of current monitoring (although the overall costs at present are hard to estimate due to variety of different national and regional monitoring programs). Coordinated, joint cross-border sampling can potentially lower costs. However, the final costs will still be higher than present costs due to increased biological monitoring. But as mentioned above, the final decision for the coverage and frequency of the future monitoring depends on available resources and overall representativeness of national monitoring networks.

7 Conclusions and future perspectives

The new water management in the River Torne water basin district is in full progress. To manage a river basin, we have to know and understand the ecological conditions in the aquatic environment and its surroundings. There are numerous methods and indicators that can be used for the assessment of status. Because of the unique characteristics of northern boreal watersheds, we have to ensure that the used indicators give us the appropriate information. Ecological information is needed both for setting the quality criteria for the surface waters and for assessing the effects of the impacts and measures in the environment.

The TRIWA project has identified similarities and differences in how Finland and Sweden work to evaluate the environmental status and in monitoring methods and strategies. A common set of quality criteria for surface waters is important for a mutual view of the environmental state and for definition of harmonised environmental goals for River Torne international water basin district. This will enhance the effectiveness of the management. Results from the TRIWA project provide a base for a common understanding of the conditions and what measures are needed in the area. The new data gathered in the project is also valuable for the in-depth characterisation of the surface waters and as basis for the monitoring program and risk assessment.

In May 2006, the results from the TRIWA-project were presented in a seminar held in Pajala. The seminar attracted about 45 participants from both sides of the river, representing municipalities, industries, the Border River Commission, local fishing interest groups and landowners among others. The participants discussed about the status of the surface waters and the human impact in the watershed. There is apparently a wide positive interest for water issues in the area and people are eager to participate and influence on the water protection work. The participants were asked to identify the major threats to the water environments. The top threat was sewage water and eutrophication followed by metals and other environmental pollutants, hydro-morphological alterations and climate change.

There are still common issues to solve to facilitate the cooperation in the district. The WFD expects cooperation between the states governing the same river basin district. The Directive does not define the level of cooperation, and it is up to the member states to develop the cooperation in relation to the prevailing conditions in each district. A structure for the cooperation network has to be formulated together with the actors in the district. There are also other related directives to consider (for example the nitrate directive) and their implementation can differ from state to state. In addition, other national legislation and procedures cause differences in management practices. As an example, the differences in regional and national practices in storing and controlling of environmental data must be solved.

Sweden and Finland thus have to agree on the level of cooperation and establish procedures for exchange of information. As responsible water authorities of the international district, the Lapland Regional Environment Centre and The County Administrative Board of Norrbotten have initiated a new project that aims to identify the best practices for the management. The project, “Best practices for the management of an international river basin district”, runs from 2006-2007 and it is partly financed by EU from the Regional Development Fund (INTERREG). The Finnish Game and Fishery Research Institute, the Swedish Board of Fisheries and the Finnish Environment Institute are partners in the project. The project will also focus on the collaboration between municipalities, actors and other interest groups in the watershed, which will be the key to a successful management.

The new project includes some biological studies as a continuation of the TRIWA project. Periphyton (in rivers) and fish (in lakes) will be studied to complement the reference conditions presented in this report. The acquired data can be used to further evaluation of the proposed common typology.

More about the TRIWA project and the new project can be found in the webpages www.triwa.org.

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