# Trilateral Cooperation on Environmental Challenges in the Joint Border Area

## Activity 2: Comparison of National and International Classifications of Ecological State, Natural Habitat Types and Environmental Health

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# Contents

# 1. Introduction

## 1.1. Introduction

This study is the start of Activity two in project Climate Change and Airborne Pollutants in Pasvik River Basin. It compares inland surface water typologies and classification systems used in the northern parts of European Union, Kola Peninsula in Russia, Canada and Alaska in the United States. European countries of focus are Finland, Norway, Sweden together with Northern Ireland and Scotland in the United Kingdom. They were selected from Nordic intercalibration block, inside which the biological elements in classification have been harmonized.

The study observes national typologies in terms of their hierarchy and environmental factors in chapter 2. Chemical standard concentrations or class limit values are compared and national chemical indices introduced in chapter 3. Physiochemical parameters are similarly considered under chemical classification. The structure and scope of national biological classifications are introduced in chapter 4. Biological metrics with their limit values and threshold ecological quality ratios are compared.

## 1.2. Setting the target environmental impacts

Special focus in the study is set on factors reflecting the current changes in North European environment. Mining and smelting industries have had a prominent impact on North Europe environment. The run-off from mining processes and emissions from smelters contain heavy metals and acidifying substances. Thus detecting pollution and acidification is commonly targeted in chemical and biological surface water monitoring. Hydromorphological alterations from building hydropower have had another set of very long-lasting effects on rivers throughout the northern boreal and arctic areas. The physical change reflects to chemical status and most of all to biodiversity. Ecological community structure can be studied as a parameter in biological classification. Perhaps still the most prolonged impact on waters has been organic pollution and nutrition run-off from agriculture and forestry showing as eutrophication in lakes. The lake trophic status and biological community responses to nutrients are integrated in all water classification systems. Recently awareness of climate change has arisen and its effects have been under focus in terms of water quality. It is widely assumed warmer climate to enhance production and change biological community structures, especially in the northern cold climate. These changes may interact with other environmental issues.

# 2. Typologies

The purpose of typology is to group surface waters into types that are comparable in their natural characters. The Water Framework Directive (2000/60/EC) Annex II specifies that altitude, size and geology should be the minimum factors in typology. Nevertheless, there is variation even between the European systems.

The WFD, United States Environmental Protection Agency and Environment Canada apply typology based reference state approach on ecological assessment. Reference states are determined for each type from pristine water bodies or historical data. The observed water quality parameters are compared with their reference value in the same type. Therefore natural variation within a type should be low enough to detect possible human impact.

## 2.1. National typologies

### Finland

#### Rivers

Latest description of Finnish typology is published in Pilke (2012) [in Finnish]. Rivers in Finland are typed first by the size of catchment area into four as follows:

1. Small rivers: catchment area < 100 km$^2$
2. Medium sized rivers: catchment area 100-1000 km$^2$
3. Large rivers: catchment area 1000-10 000 km$^2$
4. Very large rivers: catchment area > 10 000 km$^2$

Secondly they are categorized by catchment area soil quality into peatland, mineral soil and clay soil (Table 1.1.). The minimum threshold proportion for peat type is 25 % peat land of the catchment area and the type is usually characterised by humid water with colour value >90 mg Pt. Clay soil type has big enough proportion of clay in the catchment area to be detected from the water quality. Otherwise mineral soil type is used.

Rivers above forest line differ significantly from their southern counterparts and they may be considered as northern subtypes according to above principles. In addition a third subdivision, where watersheds are grouped into southern and northern (north of Siikajoki and Lumijoki watersheds) may be used in classification to reach more accurate reference states.

Table 1.1. The basic Finnish river typology.

| | | |
|---|---|---|
| 1. Small rivers | | |
| 1.1. mineral soils | 1.2. peatland (>25 %) | 1.3. clay soil |
| 2. Medium-sized rivers | | |
| 2.1. mineral soils | 2.2. peatland (>25 %) | 2.3. clay soil |
| 3. Large rivers | | |
| 3.1. mineral soils | 3.2. peatland (>25 %) | 3.3. clay soil |
| 4. Very large rivers | | |
| 4.1. mineral soils | 4.2. peatland (>25 %) | |

### Lakes

Lakes are typed according to their surface area, water quality, depth, water retention and location. North Lapland lakes above forest line, lakes with water retention less than 10 days and naturally calcium- or nutrient-rich lakes are all separated into types of their own (Table 1.2.). From the remaining lakes, those with mean depth less than three meters are separated and grouped by humus content into three types. The remaining deeper lakes are grouped using the humus thresholds and secondarily by surface area. The lake typology factors and their categories' threshold values are as follows.

Lake depth (m)

- shallow < 3
- deep > 3

humus (water colour Pt/l)

- clear < 30
- humic: 30-90
- very humic > 90

surface area ($km^2$)

- small < 5
- medium: 5-40
- large > 40

Table 1.2. Finnish lake typology.

| | | |
|---|---|---|
| 1. North-Lapland Lakes | | |
| 2. Lakes with short water retention (<10 d) | | |
| 3. Nutrient-rich lakes | | |
| 4. Calcium rich lakes | | |
| 5. Shallow lakes | | |
| 5.1. clear | 5.2. humic | 5.3. very humic |
| 6. Clear water lakes | | |
| 6.1. medium-sized | 6.2. large | |
| 7. Humic lakes | | |
| 7.1. small | 7.2. medium-sized | 7.3. large |
| 8. Very humic lakes | | |

## Norway

Norwegian surface water typology has been constructed in line with the WFD together with multivariate analysis in various natural environmental gradients (Lyche Solheim et al. 2003). The typology is based primarily on three levels of altitude: lowland: < 200 m above sea level, forest: 200-800 m.a.s.l. or below tree line and fjell: > 800 m.a.s.l. or above the forest line (Table 1.3-4). Type 'lowland' is not used north of Saltfjellet, in the two northernmost ecoregions (Direktoratsgruppa 2009). Inside the altitudinal group types are divided first by size, secondly by calcium concentration, also expressed as alkalinity, and thirdly by humus content, as detailed below. The threshold values of the latter two are the same for both rivers and lakes.

River catchment ($km^2$)

- small: 10-1000
- moderate or large > 1000

Lake surface area ($km^2$)

- small < 5
- large > 5

Alkalinity (meq/l)

- very poor: < 0,05
- poor: 0,05-0,2
- moderate: 0,2-1

Water colour (mg Pt/l)

- clear: <30
- humic: 30-90

Table 1.3. Norwegian lake types by Lyche Solheim & Schartau (2004).

| Altitude | No. | Size | Ca | Colour |
|---|---|---|---|---|
| Lowland | | | | |
| < 200 m | 1 | small | poor | clear |
| | 2 | | | humic |
| | 3 | | moderate | clear |
| | 4 | | | humic |
| | 5 | large | very poor | clear |
| | 6 | | poor | clear |
| | 7 | | | humic |
| | 8 | | moderate | clear |
| | 9 | | | humic |
| Forest | | | | |
| 200–800 m | 10 | small | very poor | clear |
| | 11 | | | humic |
| | 12 | | poor | clear |
| | 13 | | | humic |
| | 14 | | moderate | clear |
| | 15 | | | humic |
| | 16 | large | very poor | clear |
| | 17 | | poor | clear |
| | 18 | | | humic |
| | 19 | | moderate | clear |
| | 20 | | | humic |
| Fjell | | | | |
| > 800 m | 21 | | very poor | clear |
| | 22 | | poor | |
| | 23 | | | |
| | 24 | | moderate | |

Table 1.4. Norwegian river types by Lyche Solheim & Schartau (2004).

| Altititude | No. | Size | Ca | Colour |
|---|---|---|---|---|
| Lowland | | | | |
| < 200 m | 1 | small | poor | clear |
| | 2 | | | humic |
| | 3 | | moderate | clear |
| | 4 | | | humic |
| | 5* | | | clear* |
| | 6 | moderate-large | poor | clear |
| | 7 | | moderate | clear |
| Forest | | | | |
| 200-800 m | 8 | small | very poor | clear |
| | 9 | | poor | clear |
| | 10 | | | humic |
| | 11 | | moderate | clear |
| | 12 | | | humic |
| | 13 | moderate-large | poor | clear |
| | 14 | | moderate | clear |
| Fjell | | | | |
| > 800 m | 15 | | very poor | clear |
| | 16 | | poor | |
| | 17 | | | |
| | 18 | | moderate | |

* clay-affected subtype

## Sweden

The Swedish surface water typology is based on seven ecoregions defined by altitude and latitude (NFS 2006:1, map 1.1.). The highest coastline refers to the post-glacial maximum water height, which in the northern coast falls roughly between 200-300 meters above current sea level.

The inland surface waters are typed inside their ecoregion as follows. Lakes are typed by maximum depth, surface area, humus content (water colour) and alkalinity. For river typing size of catchment area, humus content and alkalinity are used. Threshold values for the latter two are the same for rivers and lakes.

River catchment ($km^2$)

- small < 100
- moderate or large > 100

Lake surface area ($km^2$)

- small < 10
- moderate or large > 10

Lake maximum depth (m)

- shallow < 5
- deep > 5

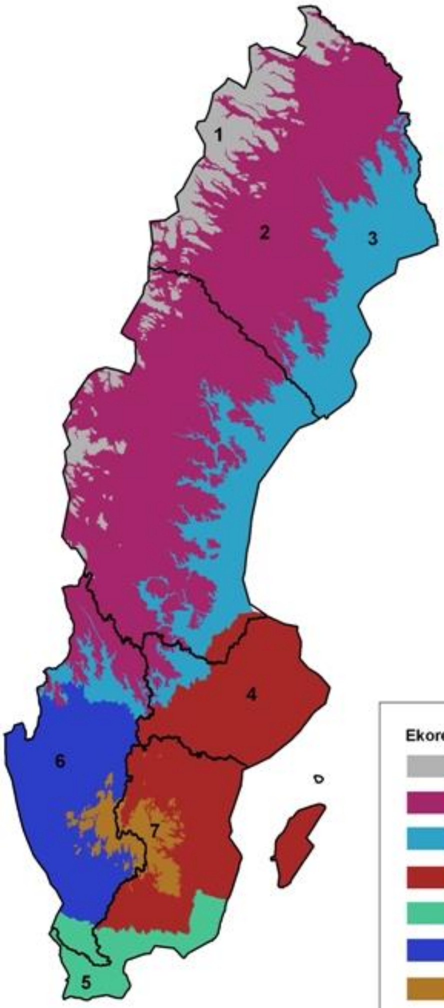
humus (water colour value)(mg Pt/l)

- clear < 50
- humic > 50

alkalinity (meq/l)

- low < 1
- high > 1

Map 1.1. The seven Swedish ecoregions according to NFS 2006:1. (c) Vattenmyndigheterna 2012.




Swedish ecoregions:

1. Fjells, above tree line
2. Norrland, between three line and the highest coastline
3. Norrland, below the highest coastline
4. South-East
5. South-Sweden
6. South-West
7. South-Swedish upland (200 m.a.s.l.)


The Swedish typology results in a number of surface water types. However, biological reference states are not determined for the most detailed types, but generally for the ecoregion level and using only humus if any of the lower level factors.  In case of some biological elements a division into three Illies ecoregions is used instead, in which case Swedish ecoregions 4-7 are merged into one and northern part cut into two following an altitudinal gradient other than in the Swedish typology.

## The UK

### Rivers

The UK typology follows the WFD minimum set of typology factors (UKTAG 2003a, b.). River typology separates waters first by catchment area mean altitude, secondly by catchment size and thirdly by dominant geology, categories as follows.

River catchment mean altitude (m)

- lowland < 200
- mid: 200-800
- highland >800

River catchment size ($km^2$)

- small: 10-100
- medium: 100-1000
- large: 1000-10 000

Catchment dominant geology

- siliceous
- calcareous
- organic

The UK river typology generates a number of types, of which altogether 18 are practical (UKTAG 2003a).

### Lakes

Lakes are typed first by catchment geology as in table 4.5, secondly by mean depth, thirdly by altitude and finally by surface area as follows.

Table 1.5. Criteria for lake typology according to catchment geology. Brackish type is separated from other by high conductivity (> 10000 uS/cm) (UKTAG 2003b.).

| | Catchment area | Alkalinity (meq/l) | Colour (MgPt/l) |
|---|---|---|---|
| Organic | > 75 % peat | | > 30 |
| Silicaceous | > 90% siliceous solid geology | < 0,2 | < 30 |
| Calcareous | >50% calcareous geology | > 1 | |
| Brackish | | | |

Lake mean depth (m)

- shallow < 3
- deep > 3

Lake altitude (m)

- lowland < 200
- mid.: 200-800
- high > 800

Lake surface area ($km^2$)

- very small: 0,01-0,09
- small: 0,1-0,49
- large: 0,55-100

The typology described above is not used as whole in practical classification. Instead biological parameters in lakes have reference states defined for few groups formed by using alkalinity, mean depth or humus content. River parameters most often have their reference states calculated using hydromorphological and physiochemical variables for each location individually.

### Canada and the United States

North-American nations use systems of ecoregions, also called ecozones in Canada, modified from Omernik (1987). They are delineated mainly by climatic gradients and geology to hierarchical levels. An ecoregion is assumed to have a certain degree of similarity in its natural characteristics. In this context ecoregion refers to the landscape level division.

In Canada there are 15 terrestrial and 5 marine ecoregions (ecozones) (Natural Resources Canada 2012). This is very similar to the North-American level II division (USEPA 2012a.). Inland fresh waters are generally grouped by the terrestrial ecoregion, when assessing the water quality (Chambers et al. 2001, Environment Canada 2004, CABIN 2009). Thus the system is an ecoregion-based surface water typology. In the modern reference state approach watershed delineations are more commonly used as units within which reference states are determined and analyses are conducted (Mercier p.c. 2012).

The USEPA uses a division into 9 ecoregions in lake and river assessment (USEPA 2006, 2009). This is slightly more robust delineation compared to Canada or to the general North-American level II ecoregions. The river nor lake assessment does not cover Alaska. Comparable Alaskan arctic ecoregions can be estimated using the American level II delineations. USEPA defines reference states inside ecoregions in a similar manner as types are used in Europe.

## 2.2. Comparison of typologies

### Altitude

Altitude is an obligatory typology factor in the WFD. Norwegian and the UK typologies have an altitudinal factor perfectly comparable between the two. Finland and Sweden do not follow the same altitudinal categories. Some Swedish ecoregions are delineated roughly using the 200 m above sea level threshold altitude. However all European countries have in common the type in high altitude (Table 2.1.). In Norway and Sweden this consists area above tree line, in Finland above pine forest line.

Table 2.1. Corresponding types of high altitude (>800 m.a.s.l.) or above forest line

| | River type | Lake type |
|---|---|---|
| Finland | subtypes above forest line | North Lapland |
| Norway | fjell (15-18) | fjell (21-24) |
| Sweden | fjells | fjells |
| The UK | highland | highland |

### Size

River size is measured in catchment area. The size categories are the same between Finland, the UK and Norway, where the two larger size types are just grouped into one. The other systems define small rivers as those having catchment area less than 100 km$^2$. This is a significant difference in size category definitions.

Lakes size is measured in surface area. The number of categories and threshold values for them reflect the variation in lake morphology between the countries. In Finland and Norway the threshold for small and larger lake is 5 km$^2$, and in Sweden it is 15 km$^2$. Lakes larger than this are further categorized into two more types in Finland. In the UK there are two categories for very small lakes from 0.01 to 0.5 km$^2$ and only the third category reaches the magnitude of several square kilometres. Practically all Nordic lakes noted in the ecological classification would fall into this largest UK category.

## Water quality parameters

Humus content (water colour value) is used as a factor in typology in all the considered countries. The maximum threshold for clear water is 30 mg Pt/l everywhere, apart from Sweden where a higher value of 50 mg Pt/l is used. In terms humus content the typologies are well comparable.

Alkalinity is used as a water quality factor in Norway and Sweden. Swedish threshold dividing low and high alkalinity waters, matches that of Norwegian moderate/high threshold. In Finland alkalinity is a key to identify the calcium rich lake type (Pilke 2012). In the UK alkalinity values have only indicative value as the main level of typology is soil catchment quality. Some alkalinity threshold values are presented in table 2.2.

Table 2.2. Alkalinity threshold values

| | type or category | alkalinity (meq/l) |
|---|---|---|
| Finland | calcium rich lakes | 0.4 |
| Sweden | high alkalinity | 1 |
| Norway | high alkalinity | 1 |
| The UK | calcareous geology | 1 |

## Catchment soil quality

Catchment area soil quality reflects in the water chemistry and it is directly used as a typology factor, in Finland to detect peatland influence and in the UK, where it is the main level creating the division into types. The interpretation of 'a peatland river' is very different: in the UK minimum threshold of peat cover is 75 % of the catchment area, in Finland it is only 25 %.

## Ecoregions

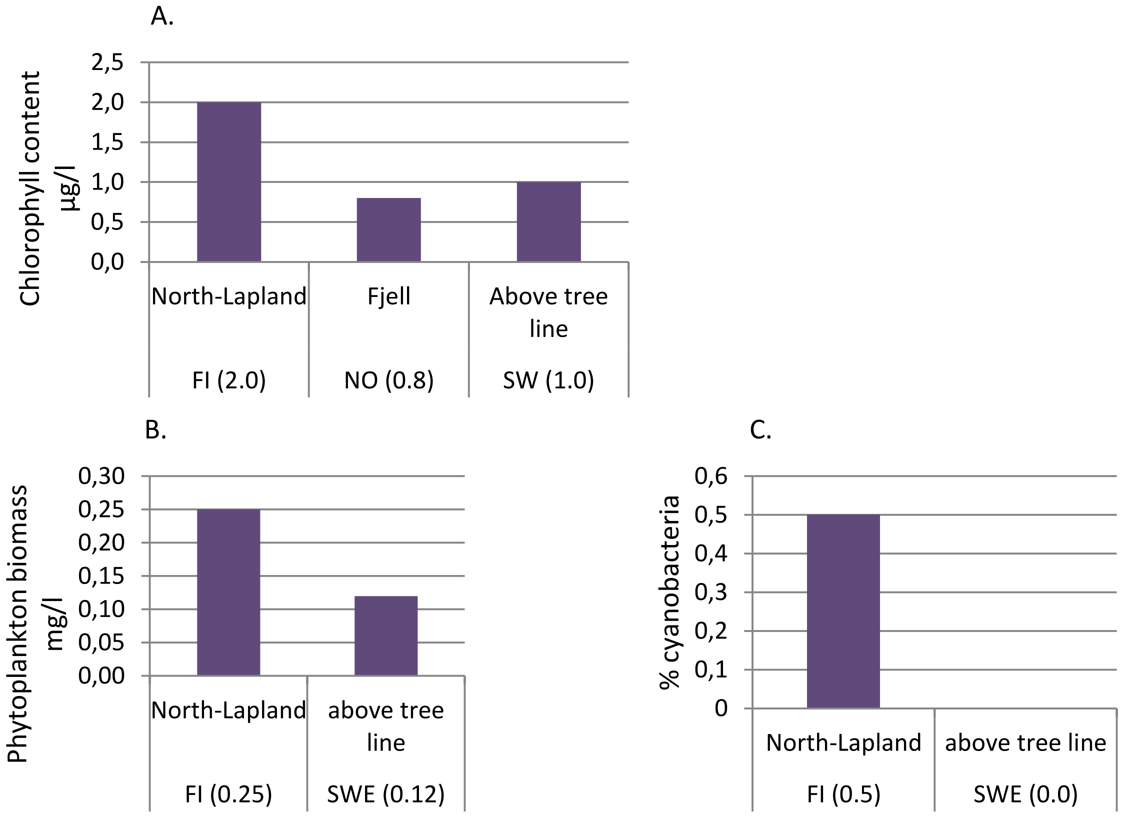
The borders of ecoregions are typically set mainly along climatic gradients created by latitude and altitude, but also geology through vegetation types may influence it. Sweden is the only European country among the considered to have ecoregions as basic typology structure. In practical classification process in Finland subtypes in three zones according to latitude and climate (North-Lapland, northern and southern watersheds) may be used to reduce variation inside the types. Each typology has a separate type for arctic or alpine areas above forest line. These may be considered as an ecoregion common to all systems.

An example of differences reflected in biological characters: observing the reference states for phytoplankton metrics measured in Nordic countries, all the northernmost lakes have similar results indicating low productivity. However, Finnish 'North-Lapland lakes' are more southern to others and tend to have higher natural chlorophyll content, phytoplankton biomass and biomass percentage of harmful cyanobacteria (Figure 2.1.).

As numerical definitions for North American ecoregions are not openly presented, they are hard to compare with those in Europe. Canadian 'taiga shield' (5.1. in USEPA 2012b.) should be climatically comparable to North-Europe. Its main bulk of land lays between 200-700 m.a.s.l (Natural Resources Canada 2012), which corresponds to Nordic mid-elevations. Alaskan boreal interiors (3.1.) have more or less the same altitude range. Hudson plain (4.1.), which is all lowland below 300 m.a.s.l. , should be climatically rather comparable to Nordic lowlands. The South Arctic ecoregion (2.4.) marks the forest line and together with the two northernmost arctics it corresponds to the European ‘above tree line types’ by definition.

The landmass in each North American ecotype is several times larger than the ecoregions in Europe. Consequently the natural variation inside them is expected to be higher than in smaller entities.

Figure 2.1. Reference values measured from lakes in natural status in Nordic alpine-arctic ecotype for certain phytoplankton metrics: chlorophyll content (A.), total biomass (B.) and biomass percentage of harmful cyanobacteria (C.). Detailed descriptions of the metrics in chapter 4.2.



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# 3. Chemical classification

## 3.1. Chemical status

### The EU priority substances

Member states of the European Union and Norway follow chemical status assessment defined in the Water Framework Directive (2000/60/EC). The directive specifies a list of 33 priority substances and 8 other pollutants, which present a significant risk to aquatic environment. For each substance it gives an ecological quality standard (EQS) value for annual average and a maximum allowable concentration (MAC) for a single sample (Annex I: table 1.). All substances are measured in dissolved concentrations. For three substances EQS is also set for fish tissue in mg/kg of fresh perch.

If the observed arithmetic annual average concentration for a substance exceeds its EQS value or if any observation exceeds maximum allowable concentration, the chemical status is considered failing the ‘good’ criterion. Therefore the chemical status can either be ‘good’ or ‘not-good’.

According to the Water Framework Directive regional metal background concentrations may be taken into account when assessing the chemical status. This is done in practice by adding the background concentration to the EQS. Annex I: tables 6-7 presents the background concentration by countries that have defined them. Similarly water quality parameters affecting metals bioavailability, as pH and hardness, may be considered in assessment as it is done with Cadmium for example.

### Russia

Russian Federal Service for Hydrometeorology and Environmental Monitoring, Hydromet, is responsible for monitoring pollutants in aquatic environments. The following information was given by Hydromet representatives in personal communication in 2012. Hydromet uses maximum permissible concentrations (MAC) and three water quality indices to assess chemical quality. Pollutants are also divided into four ‘hazard classes’ based on their toxicity. The classes are used in defining high levels of pollution (table 1.1.). The monitored chemicals are specific for each water body. Values studied here are MACs for Pasvik River (Annex I: table 8.).

Environmental standards are defined also for oxygen and nutrients, which are addressed under physiochemical parameters for the WFD. Nitrogen as ammonia (NH3-N) and ammonium (NH4+-N) ion and phosphate phosphorus (PO4-P) have MAC values.

Table 1.1. Hydromet definitions for high levels of toxicity using MAC multiples.

| | **Multiplications of MAC value** | |
|---|---|---|
| | high level of pollution | extremely high level of pollution |
| 1—2 hazard class | 3 -5 | > 5 |
| 3—4 hazard class | 10-50 | > 50 |

Hydromet uses also a water quality index ‘K’, that is calculated as a percentual proportion of substances that exceed MAC. Thus the index values vary from 0 to 100 and they are divided into three classes of pollution (Table 1.2.).

Table 1.2. Water quality categories from K index.

| K | Category | Description |
|---|---|---|
| 0-10 | I | contamination from single substance or water quality indicator |
| 10-40 | II | contamination from several substances and water quality indicators |
| 40-100 | III | contamination on complex substances and water quality indicators |

There is also a third water quality index named SCPI (Specific Combinatorial Pollution Index) that is based on substances listed as “critical indicators of pollution”. The index values are derived from the number of observed critical indicators. It results in values from one upwards and indicates a class from one to five.

## Canada

Canadian Water Quality Guidelines for the Protection of Aquatic Life comprises a list of substances with their mainly long-term (chronic) quality standards (CCME 2012, Annex I: table 11). For few substances also short term (acute) standards are defined. The list includes metals and compounds from organic molecules to industrial chemicals. The standards for some metals are expressed as a function of water hardness ($CaCO_3$ mg/l).

The water quality guidelines also deal with nutrients, which are addressed under physiochemical parameters for the WFD. Total phosphorus is used as lake trophic status indicator (Table 1.3.)

Water quality standards are used in Water Quality Index (CCME 2001), which summarizes the data of concentrations in one multimetric index. The variables and sampling frequencies can be adjusted according to needs. The index takes into account the number of variables not meeting the standard, the frequency with which they are not meeting the standard and thirdly the amount by which the standards are not met. All this is combined in equations presented in CCME (2011). The final index is a value from 0 to 100, which falls into one of three classes: fair (65-79), marginal (45-64) or poor (0-44).

Table 1.3. Total phosphorus as trophic indicator in Canada.

| Trophic status | Canada total P (µg/l) |
|---|---|
| ultra-oligotrophic | < 4 |
| oligotrophic | 4 |
| mesotrophic | 10 |
| meso-eutrophic | 20 |
| eutrophic | 35 |
| hyper-eutrophic | 100 |

### The US

United States Environmental Protection Agency, USEPA, assesses surface water chemical quality by criteria for maximum short-term concentrations (acute) and continuous long-term (chronic) amounts of selected substances (USEPA 2012, Annex I: table 9). The same values apply the whole country, including Alaska. If observed concentration of any substance exceeds the acute standard or its long-term average exceeds the chronic standard the observed water body is classified as 'chemically impaired'. The list of substances covers extensively metals and industrial chemicals as well as dissolved oxygen and ammonia. For some metals criteria are as a function of water hardness.

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## 3.2. Specific pollutants in the WFD classification

In classification according to the Water Framework Directive (2000/60/EC) there are two parallel statuses: chemical (chapter 3.1.) and biological. Some chemical elements are integrated in the biological classification. They are considered here. The EU member states are obligated by the WFD to form environmental quality standards (EQS) for substances which are discharged in significant quantities into the waters in their region. Observed concentrations are set against the EQSs, and if any substance concentration exceeds its EQS, the ecological state may be at most moderate, regardless any better results in biological elements. National standards are expressed in annual average dissolved concentrations if not otherwise stated. In case of metals local background concentration may be taken into account. All standards are presented in Annex I, tables 2-5.

### Finland

Finland's list specific pollutants comprises of 16 compounds of industrial chemicals and pesticides. EQSs are formed for annual average concentrations. In addition other substances occurring in abnormally high concentrations, including zinc, may be used in classification through expert judgment without EQS (Aroviita et al. 2012).

### Norway

Norway is implementing the WFD as a non-EU member, but its specific pollutants are yet to be published (Morda-Hessen p.c. 2012).  The existing national classification system applies on coastal waters only, taking into account 42 specified pollutants (SFT 2007). Fjords and coasts are divided into four classes according to the long-term observed concentrations of pollutants. Class limit concentrations are set considering ecological point of view (SFT 2007). Due to the country's industrial impact focusing on the coasts, there are currently no environmental pollutant limit values set for fresh water (Mordal-Hessen p.c. 2012). Coastal areas differ from inland waters in their natural characters, which is why comparison between their chemical limit values is not feasible.

## Sweden

Specific pollutants are currently drafted and preliminary annual average EQSs are available for 29 substances including three metals (Naturvårdsverket 2008). Concentrations for Brome and Copper are total dissolvent amounts. For zinc the value is based on added risk, which is calculated by adding the known background concentration to the EQS.

## The United Kingdom

Specific substances for the WFD are proposed by UK Technical Advisory Group on the Water Framework Directive (UKTAG 2008a), for some of which preliminary EQSs are presented. The UK list consists of three metals, chromium oxides and synthetic chemicals.

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## 3.3. Supportive physiochemical elements in biological classifications

As part of biological classification so called ‘physiochemical support parameters’ are monitored as instructed by the WFD Annex V. All Nordic countries use pH and at least one total nutrient concentration as a physiochemical quality element. Sweden and Norway also apply oxygen concentrations. All physiochemical support parameters are published in national reports: Finland: Aroviita et al. 2012, Norway: Direktoratsgruppa 2009, Sweden: Naturvårdsverket 2007, the UK:UKTAG 2008b. Parameters are summarized in Table 3.1. Supportive parameters have the same five status classes from bad to high, as biological elements (chapter 4.) and they have a reference value representing natural status. The aim is to detect change from natural state by comparing observed value to the reference value. Their ratio is so called ecological quality ratio (EQR). The status class limit values are most often determined as expert judgment assessing biologically meaningful and critical values. Being only supportive, the physiochemical parameters do not automatically change the biological status class.

Similarly to the WFD classification USEPA (2006, 2009) stream and lake assessments include few physiochemical measures. As with biological elements three classes are applied:, good, fair and poor. The class limits dor good and fair are set as the 75$^{th}$ and 5$^{th}$ percentile points of the reference distribution, respectively.

## Total nutrients

In Finland both total nitrogen and total phosphorus are measured and they have type-specific reference values.

In Norway total nitrogen and total phosphorus are measured. All reference values are type-specific. In addition ammonium and ammonia nitrogen have one reference value and class limit for all types.

In Sweden only total phosphorus is measured and the reference state is calculated using altitude, absorbance and mean depth for a lake, and altitude, cation concentrations and absorbance for a river.

In the UK total phosphorus is measured in lakes and reference states are two according to the altitude and alkalinity.

USEPA measures in stream and lake assessment both total nutrients with type-specific threshold values.

## pH and acidity

pH is directly a supportive parameter in Finland, Norway and the UK. In Finland the parameter is used only for rivers and its reference values are type-specific. In Norway both pH and acid neutralizing capacity (ANC) are measured from lakes and rivers. Reference values are type-specific.

In Sweden acidification is studied through a geochemical model. The model uses information of water body location, pH, several ion concentrations, total organic carbon, run-off, the size of catchment area and lake. It estimates the reference state as pH before industrialization and classifies acidification impact as deviation from this state. Estimated pH change less than 0.4 results in good state.

In the UK pH is measured only from rivers and it has two reference states based on latitude. Limit values are set based on studies of diatom communities instead of reference approach. For lakes acid neutralizing capacity (ANC) is used with one reference state for all.

USEPA uses ANC in all assessment as measure of acidity. It has one indicative value to detect anthropogenically acidified waters.

## Dissolved oxygen concentration

Dissolved oxygen may be analysed from lakes and rivers. In lakes oxygen is generally measured from hypolimnion during thermal stratification. In Norway and in the UK dissolved oxygen concentrations are measured from lakes and rivers. Norway reference values apply all water types, in the UK reference state is depending on latitude and alkalinity.

In Sweden monitoring includes only dissolved oxygen in lakes. The reference values are determined separately for lakes with warm water fish and lakes with Salmonids. In case the lake does not reach good or high value, it is further analysed whether the result is due to an anthropogenic influence by estimating reference state again with an equation using more detailed oxygen measurements throughout the lake water circulation. The observed value is then compared with the new reference value.

USEPA measures dissolved oxygen in stream and lake assessments. There is one threshold value applied on all waters.

## Ammonia and ammonium

Ammonia ($NH_3$) is used as a chemical support parameter in the UK, where it is only applied on rivers. In Norway total ammonia is measured from all waters together with free ammonium ($NH_4^+$) concentrations. The reference state is only one for all waters in Norway and two based on altitude and alkalinity in the UK.

## Secchi depth

Secchi depth is a supportive lake parameter in Norway and Sweden. Norwegian reference values are type-specific, whereas in Sweden the reference state is calculated using absorbance and chlorophyll reference concentration. Therefore these are not comparable methods.

USEPA uses turbidity as an indicator of water clarity in lakes with type-specific reference values.

## Salinity

In the UK salinity measured as conductivity is used in lake assessment. The proposed reference value would be one for all types.

USEPA measures salinity in streams.

## Inorganic aluminium

In Norway inorganic aluminium is developed into a chemical parameter applied on both lakes and rivers. The reference values are type-specific, but the limit value for good state is fixed to 5 µg/l in practice (Direktoratsgruppa 2009). In addition in waters, where there is salmon, the aluminium concentration may be measured from salmon gills. Reference values are set for two age stages.

## Pollutants

USEPA lake assessment includes also actual pollutant indicators: sediment mercury and mercury with POPs measured in fish tissue.

Table 3.1. The physiochemical support parameters used in Finland (Aroviita et al. 2012), Norway (Direktoratsgruppa 2009), Sweden (Naturvårdsverket 2007), the UK (UKTAG 2008b.) and the US (USEPA 2006, 2009).

| | RIVERS | | | | | LAKES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FI | NO | SW | The UK | USEPA | FI | NO | SW | The UK | USEPA |
| Total P | X | X | X | X | X | X | X | X | X | X |
| Total N | X | X | | | X | X | X | | | X |
| pH | X | X | X | X | | | X | X | | |
| ANC | | X | | | X | | X | | X | X |
| Oxygen | | X | | X | | | X | X | X | X |
| Ammonia | | X | | | | | X | | | |
| Ammonium | | X | | | | | X | | | |
| Secchi depth | | | | | | | X | X | | |
| Turbidity | | | | | | | | | | X |
| Salinity | | | | | X | | | | X | |
| Inorgan aluminium | | X | | | | | X | | | |

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## 3.4. Comparison of chemical parameters

Most of the same substances are covered by Canadian Environmental Guidelines (CCME 2012), the USEPA (2012) and regulations in Europe. Many of these are listed in the EU priority substances for chemical status assessment, which serves an analogous function with the North-American water quality criteria for protection of aquatic life. Moreover the EU E-PRTR regulation (166/2006) for pollutant release and transfer includes many synthetic chemicals missing from the EU priority list. In addition countries may have specified substances that cannot be discharged at all. However, these are not part of water quality assessment.

Here are compared the long-term standard concentrations for substances found from Canada or USEPA national criteria, European specific pollutants and EU priority substances. Russian values are MACs by Hydromet. Physiochemical parameter values are compared if feasible and their good status class threshold EQRs, if published, are observed to assess the sensitivity of parameters.

### Nutrients

#### Phosphorus

Phosphorus in total is a trophic indicator in Canada and as phosphate ion in Russia. In the European countries total phosphorus is a physiochemical parameter only supporting the classification. Finnish lake types total phosphorus reference values span from 5 to 30 µg/l, depending on the type (Aroviita et al. 2012). By Canadian standards these lake reference states indicate a range of meso-eutrophic, mesotrophic or oligotropic statuses (table 1.3). North Lapland Lakes should be oligotrophic (reference tot.P 5 µg/l). Norwegian lake reference states for total phosphorus vary from 2 to 7 µg/l (Direktoratsgruppa 2009). Using Canadian standard (table 1.3.) they fall into oligotrophic category. The phosphorus good class threshold EQR values show high variation especially through the Finnish types (Figure 4.1A). For certain lake types reference status may be questionable and EQR is intentionally set low turning the parameter less sensitive. Overall the median good class EQRs across all national types are all relatively low, less than 0.5 (table 4.1.).

#### Nitrogen

Total nitrogen is monitored in Finland and Norway. For the good status class threshold EQRs the same applies as mentioned above for phosphorus. Nitrogen in other forms, ammonia and ammonium, are measured in Norway as part of physiochemical assessment and Russia by Hydromet. Also USEPA has a water quality standard for ammonia (USEPA 2012). Comparing the values, Norwegian system proves to be notably strict on both with the poor class threshold value being the lowest concentration of all standards (Table 4.2.).

Nitrate and nitrite are considered by Hydromet and Canadian standards (Table 4.1.).

Figure 4.1. Boxplot showing median, quartiles and the whole spread of values for total nutrient good status class EQRs across all national types for lakes (A.) and rivers (B.).

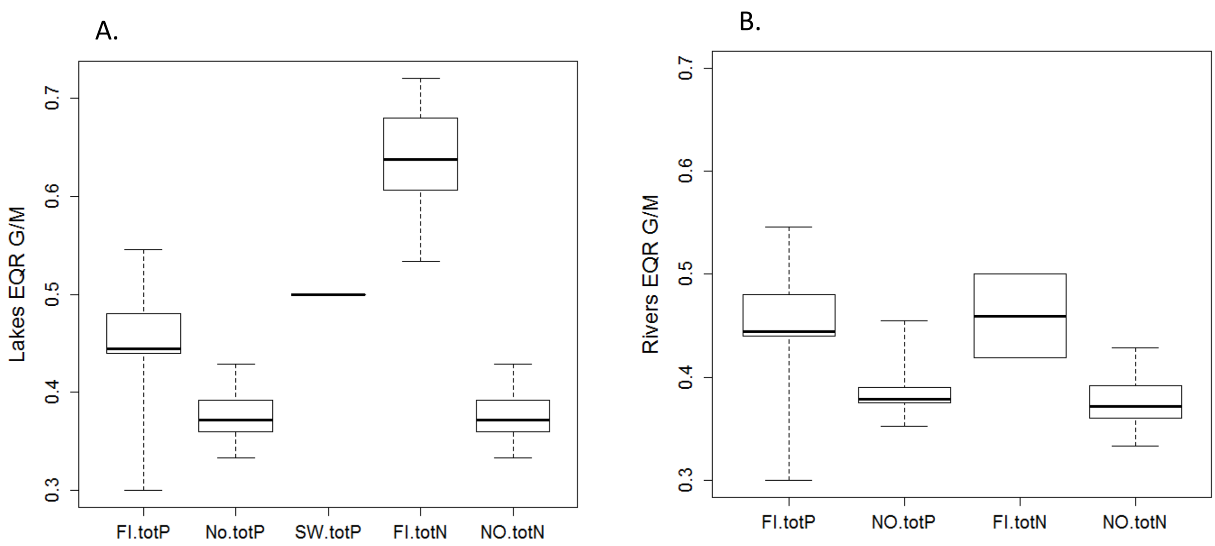



Table 4.1. Median threshold good status class EQRs for total nutrients in Finnish, Norwegian and Swedish rivers and lakes.

| | Rivers | | Lakes | |
|---|---|---|---|---|
| | totP | totN | totP | totN |
| Finland | 0.44 | 0.46 | 0.44 | 0.64 |
| Norway | 0.38 | 0.37 | 0.37 | 0.37 |
| Sweden | | | 0.50 | |

Table 4.2. Ammonia, ammonium, nitrate, nitrate: Russian Hydromet-used maximum allowable concentrations and for ammonia and ammonium and USEPA ammonia standard in comparison, Hydromet MAC and Canadian long-term standards for nitrate and nitrite.

| | ammonia (NH3-N) (µg/) | ammonium (NH4-N) (µg/) | nitrate (NO3-N) (mg/l) | nitrite (NO2-N) (mg/l) |
|---|---|---|---|---|
| Russian MAC | 50 | 400 | 9,1 | 0,02 |
| USEPA (mussels present) | 260 | | | |
| USEPA (mussels absent) | 1800 | | | |
| Canada | | | 13 | 0,06 |

## pH

Countries implementing the WFD have pH as a supportive parameter for rivers at least. All other countries have an annual minimum pH that applies river or all kind of water bodies. The most common standard value is 6.5 (Figure 4.2.). The WFD classification values are lower, possibly reflecting lower natural pH level. The Figure 4.2. values for these countries are medians across all national types meaning they hide variation between the types. There is no common ground in terms of typology to conduct comparison between types. The good status class threshold EQRs are comparable between Finland and Norway. They are generally higher than for most parameters, all above 0.8, and the variation across all national types relatively small (Figure 4.3.). All medians across types exceed 0.9 (Table 4.3.), which means the systems allow less than 10% change in pH before losing the good status class.

Figure 4.2. National annual minimum pH standards for rivers. For areas implementing the WFD* value refers to the minimum observed pH for high status class as median across all national types.

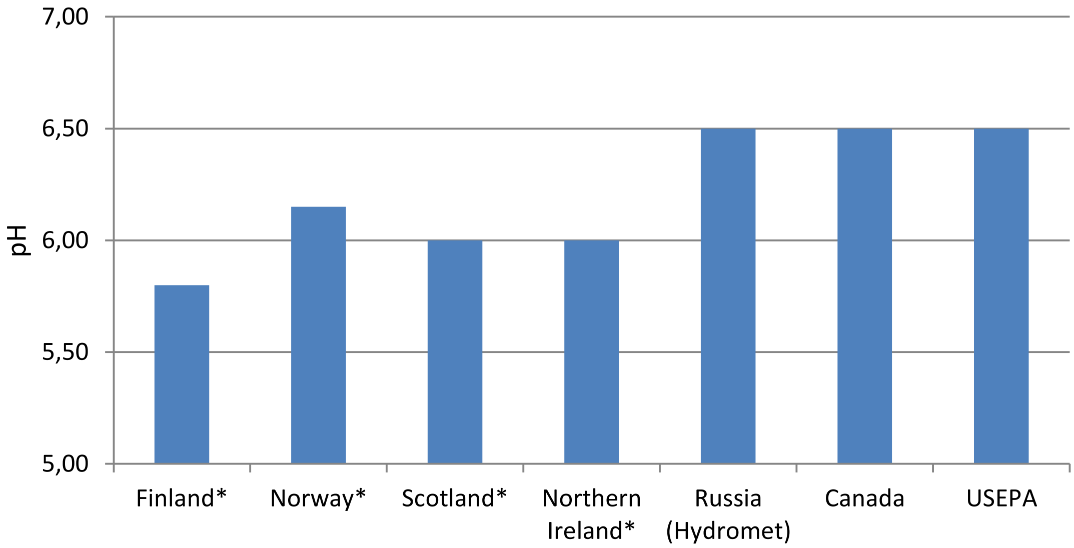



Figure 4.3. Boxplot showing median, quartiles and the whole spread of values for pH threshold EQRs for good status class across all national types in Finland and Norway.

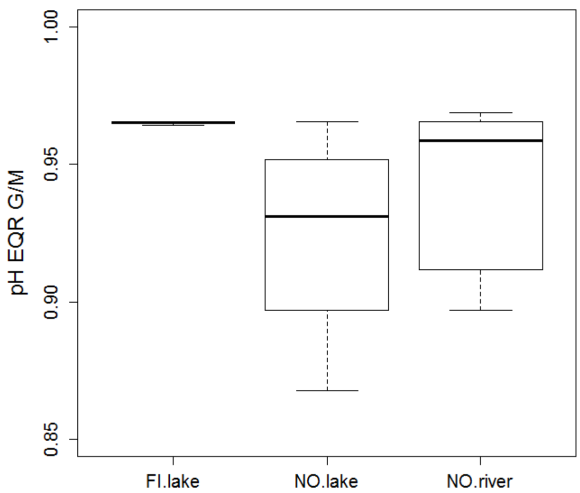



Table 4.3. Median pH threshold EQRs for good status class across all national types.

| FI.lakes | NO.lakes | NO.rivers |
|---|---|---|
| 0.965215 | 0.931034 | 0.958565 |

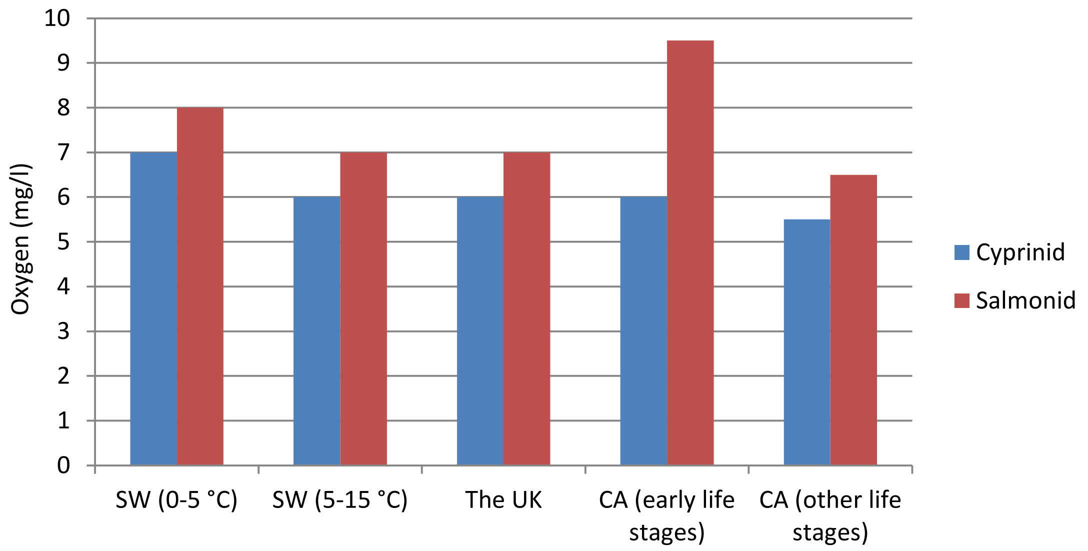
## Oxygen

Dissolved oxygen measured in rivers is comparable between countries. The systems often include division based on fish fauna into Salmonid rivers and those dominated by more tolerant warm water species (Cyprinid). Swedish system is further developed to recognize mean temperature and Canadian to take into account the early life stages, which have the highest oxygen requirements. The highest standard, 9.5 mg/l, is for Canadian rivers with early Salmonid life stages (Figure 4.4.). Other standards are roughly on the same level of 5.5-7 mg/l for Cyprinid/warm water spp. and 6.5-8 for Salmonid. USEPA and Russian Hydromet have one chemical standard value for dissolved oxygen, roughly on the same level with Cyprinid standards (Table 4.4.).

Table 4.4. USEPA and Russian minimum standard for dissolved oxygen.

| | |
|---|---|
| USEPA | 5 mg/l |
| Russia (Hydromet) | 6 mg/l |

Figure 4.4. Dissolved oxygen standards in rivers based on fish biota in Sweden, the UK and Canada. Swedish and the UK values are threshold concentrations for good quality status that are applied on all types.

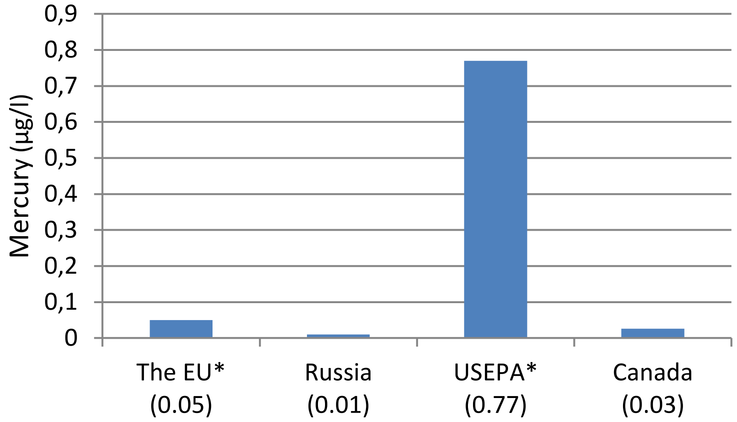



## Metals

### Mercury

Inorganic mercury concentrations are monitored primarily as other metals: dissolved in water. Long and short term mercury standards are included in the EU priority substances as well as Canadian and USEPA environmental standards. Russian Hydromet has one MAC value in use. Comparing the long-term national standards, USEPA value points out as several times higher than others (Figure 4.5.). The rest of national standards are roughly on the same level, Russian Hydromet applying the strictest one (Figure 4.5.). Natural background concentrations of mercury depend on bedrock quality and so vary regionally (USEPA 2012), which may explain differences in standards. Canadian aquatic life criteria include also organic methylmercury concentration, which is a magnitude lower to that of mercury (0.004 µg/l).

Figure 4.5. National long-term mercury standards in the EU priority substances, USEPA and Canada criteria for aquatic life and Russian (Hydromet) maximum allowable concentration.




*The EU and USEPA standards include mercury compounds.

Mercury standards for environment are also measured in fish tissue at least in the EU, Russia and the US (Table 4.5.). In the EU fish tissue standard is for determining chemical status, whereas in the US it is part of biological assessment. The current values between the regions are of different magnitude the EU and Russia (Hydromet) having the lowest standards. Standard values applied for environment are all significantly smaller compared to those for food products.

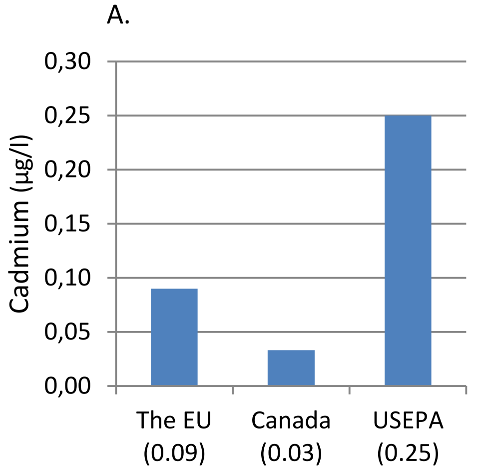
Table 4.5. Mercury standard values in fish tissue in EU priority substances, USEPA protection of aquatic environment criteria and Russian (Hydromet p.c. 2012) standard. In comparison certain standard concentrations for food products.

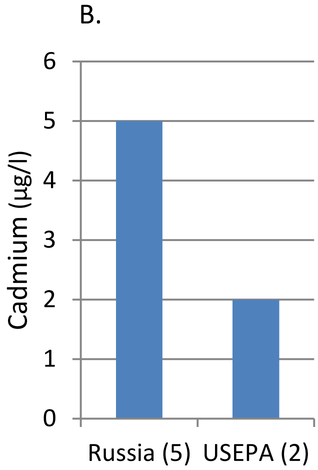
| | Country | mercury (mg/kg) | Reference |
|---|---|---|---|
| Environment | The EU | 0.02 | the WFD |
| | Russia | 0.01 | Hydromet |
| | US | 0.30 | USEPA |
| Food | Canada | 0.5-1.0 | Health Canada |
| | EU | 0.5-1.0 | EFSA |
| | US | 1.0 | USEPA |

## Other metals

Cadmium long-term standards are variable (Figure 4.6A). USEPA has relatively high standard value. There is also a multiple difference between the lower EU and Canadian values, the latter being the lowest. Russian Hydromet uses a cadmium maximum allowable concentration and as such it is higher than long-term standards (Figure 4.6B.).

Figure 4.6. Long-term cadmium standards in the EU priority substances, USEPA and Canada (chronic) criteria (A.), and Russian (Hydromet) MAC in comparison with the USEPA short-term (critical) standard (B.), when water hardness is 100 mg $CaCO_3$/l.

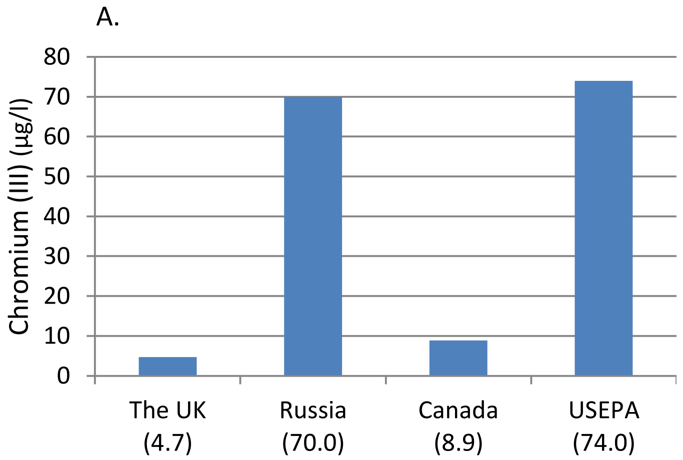



Standard long-term concentrations for trivalent chromium (Cr(III)) also show great differences between countries. Russian Hydromet and USEPA have the similar, relatively high standard around 70 µg/l, whereas the UK and Canadian standards don't exceed 10 µg/l (Figure 4.7A.). The more toxic hexavalent chromium (Cr(VI)) has lower standard values with less variation between systems (Figure 4.7B.).

For copper and lead all standards are roughly on the same magnitude, though all the national values are different (Figure 4.7C-D.). Inorganic aluminum is part of Norwegian physiochemical evaluation. Canadian and US standards apply total aluminum (Figure 4.7E.). Iron standards seem to fall in two categories: to that of the UK and US that applies the 1000 µg/l limit and those who have determined significantly lower values (Figure 4.7G.), possibly reflecting differences in the means of limit founding.

Figure 4.7. Chromium (III) (A.) and Chromium (VI) (B.), Copper (C.), Lead (D.), aluminium (E.), Nickel (F.) and Iron (G.) concentrations as national long-term standards or the EU priority standards in Europe, as criteria for protection of aquatic life in Canada and the US by USEPA. Russian standards are Hydromet maximum allowable concentrations. Applies water hardness 100 mg $CaCO_3$/l.



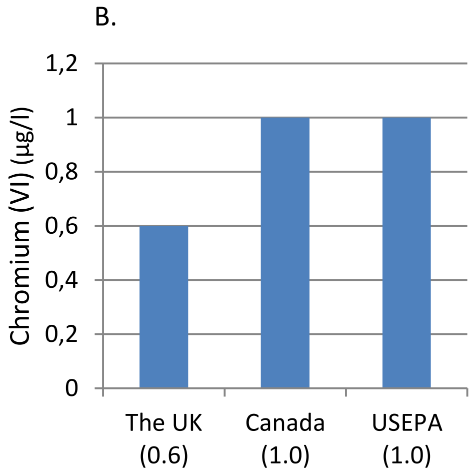
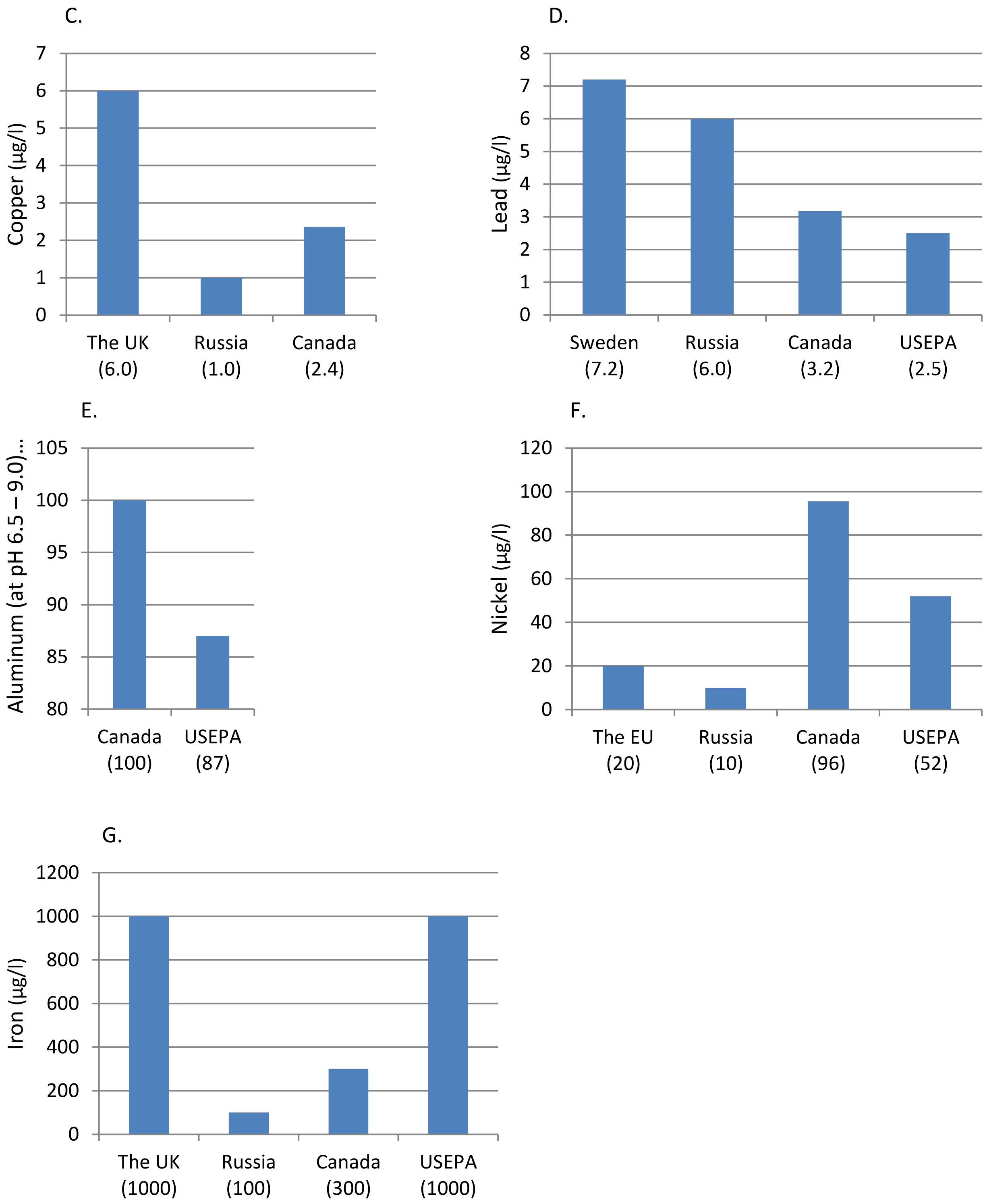



Figure 4.7. continue…



## Other substances

There is a wide variety of other chemical compounds that are monitored nationally (Annex I), depending on local circumstances. The following substances are the most common. As with metals, the means for determining the standards vary between the systems resulting in different values.

Arsenic is only noted in North-American aquatic life criteria. As natural deposits are a major source of arsenic run-off to water (USEPA 2012), the natural background levels very regionally and that may explain the relatively big differences in standards (Figure 4.8A.).

Selenium has standard concentration by Hydromet in Russia and in Canada and USEPA aquatic life criteria. Its emissions are associated with coal-fired power plants and petroleum refinery (USEPA 2012). The standards are on the same magnitude, though all different (Figure 4.8B.).

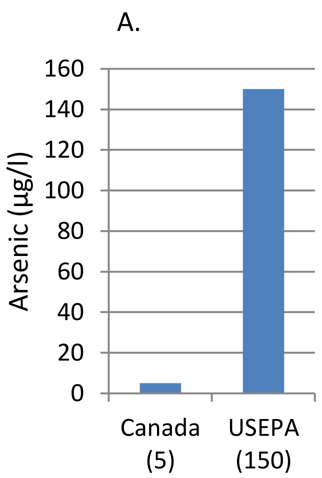
Benzene is a petrochemical noted in the EU priority substances and Canadian criteria for aquatic life. The two standard concentrations are very unequal, the EU EQS being clearly stricter (Figure 4.8C.).

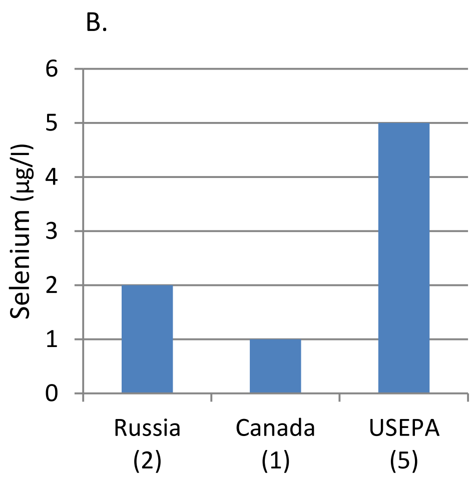
Cyanide emissions are associated with a number of industries. Cyanide is often monitored as hydrogen cyanide (HCN) and cyanide ion (CN-) concentration in water. In Europe it is only included among the UK specific substances with a relatively strict standard compared to those of Canada and USEPA (Figure 4.8D.).

There are three synthetic herbicides that are commonly monitored in Europe or North-America. MCPA (2-methyl-4-chlorophenoxyacetic acid) is monitored in Finland, Sweden and Canada. There is moderate variation between the standards the European ones being stricter, but all falling below 3 µg/l (Figure 4.8E.). Metamitron is included in Finnish and Swedish specific substances with rather different concentrations (Figure 4.8F.). Simazine is a herbicide currently banned in the countries under focus. It is monitored as an EU priority substance in Europe and also as part of aquatic life criteria in Canada. There is a notable difference between the standards, the EU EQS being stricter, 1 vs. 10 µg/l (Figure 4.8G.).

Chlorpyrifos (O,O-diethyl O-3,5,6-trichloropyridin-2-yl phosphorothioate) is a synthetic insecticide. It is noted in the EU priority substances as well as Canada and USEPA criteria for aquatic life. The standard concentration are very low, but do have large variation between the systems (Figure 4.8H.). Canada applies clearly the strictest EQS of 0.002 µg/l.

Figure 4.8. Selenium (A.), Cyanide (B.), MCPA (C.), Metamitron (D.), Simazine (E.), Chlorpyrifos (F.), Arsenic (G.) and Benzene (H.) concentrations as national long-term standards or the EU priority standards in Europe, as criteria for protection of aquatic life in Canada and the US by USEPA. Russian standards are Hydromet maximum allowable concentrations.



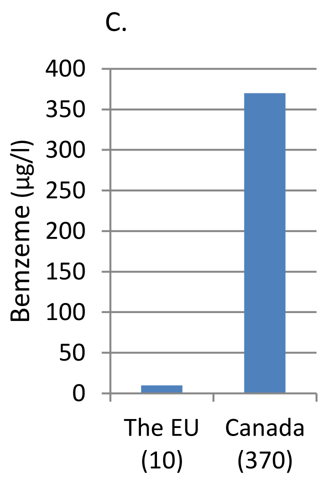
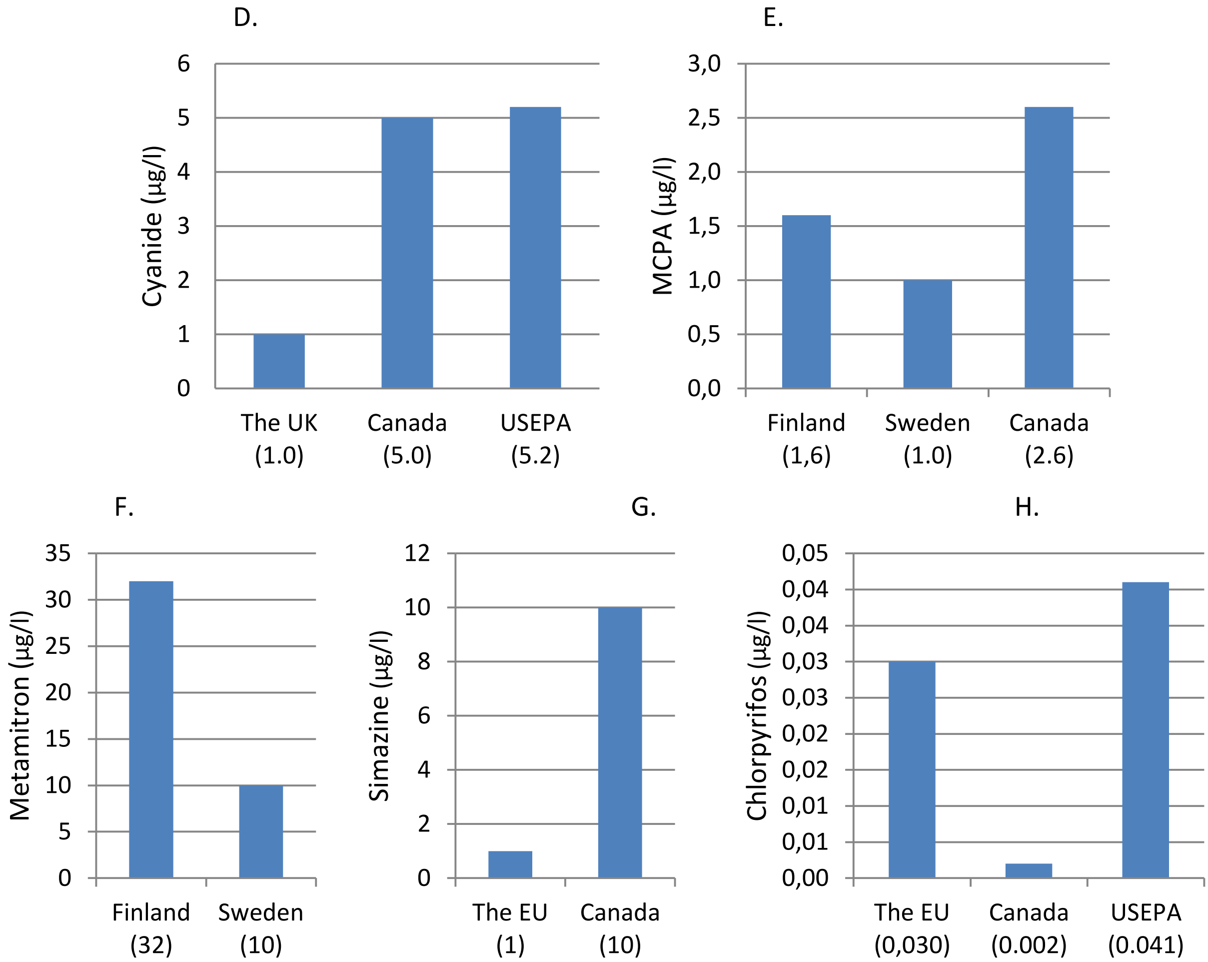



Figure 4.8. continue…



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# 4. Biological classification

## 4.1. National systems of biological classification

### The EU

The EU member states and Norway follow the Water Framework Directive's guidelines for biological elements in water classification.

The WFD (EU Water Framework Directive 2000/60/EC) states that for classification of a lake phytoplankton, aquatic flora, benthic invertebrate and fish should be monitored. For rivers the requirements are the same excluding phytoplankton. These elements are monitored through several indices and metrics indicating shift from natural biological and chemical state. To detect any deviation from natural state, metric values in natural state must be studied. The limit value for unaffected 'high' status class is usually fixed to the 25$^{th}$ percentile point of the reference distribution, formed by values measured from reference locations. Most often the median value of the reference distribution represents a reference value. The difference is verified by calculating the ratio of the reference and the observed value. This creates so called 'EQR' (Ecological Quality Ratio). The closer the parameter is natural state, the closer the ratio is to 1. Based on the EQR each parameter is given a status class. If the result does not reach high class limit, other threshold values are applied to classify it into one of the lower classes: 'good', 'moderate', 'poor' or 'bad'. The threshold for good status is usually set as ¾ * 25$^{th}$ reference percentile point value. It is an important limit, because the aim of the WFD management is to reach the minimum of good status for all surface waters by 2015. Due to its definition the good status threshold EQRs are not the same for all the different types and countries. Class threshold EQRs reflects the percentual change from reference state the metric allows for each status class and so differences in EQRs are differences in metric sensitivity. Therefore good status class threshold EQRs are compared.

Despite the targets of monitoring being the same, different parameters for each element are measured nationally. The Norwegian system has different parameters for locations more influenced by eutrophication or and those influenced by acidification (Direktoratsgruppa 2009). The main pressure is identified from chemical data. Using the parameter results, each quality element and further the whole water body gets its final status class. There are some differences in the way the parameters are combined into an element class and further into the final class from all elements.  In Finland the parameter results are mainly converted to normalized scale and then averaged to element class. Element classes are then averaged into the final class. Norway follows the same first step with Finland, Swedish practice varies between the elements. However, the final class in other Nordic countries is always formed by 'one out – all out' principle, where it equals to the worst of its components. The UK method is by far unexplained.

### Russia

Institute of the North Industrial Ecology Problems, INEP, conducts monitoring mostly in lakes and Murmansk Department for Hydrometeorology and Environmental Monitoring, Hydromet, in rivers. The biological monitoring procedures follow state standards, which give the set of parameters measured for each quality element. The biological data is used to assess the trophic status and pollution level, or the biological status may be described through the metric values, depending on the situation.

## The US

The United States Environmental Protection Agency, USEPA conducts nation-wide surveys on 'biological integrity' of lakes and rivers (USEPA 2006, 2009). These "National Aquatic Resource Surveys" sample a representative portion of lakes every fifth year and once every sixth year for rivers and streams. Currently for rivers results are available only for streams (USEPA 2006). The arctic ecotypes in Alaska are monitored by the same standard, though no published results are yet available.

The biological elements in the latest lake assessment (USEPA 2009) included sediment diatoms, phytoplankton and zooplankton. The previous stream assessment used zoobenthos as biological element. The measured or calculated parameters are classified as one of the three: 'good', 'fair' or 'poor' in relation to condition in ecotype-specific reference lakes. Lake status class is generally presented for each parameter independently, or overall biological quality is expressed only as percentage of taxa loss of phytoplankton and/or zoobenthos.

## Canada

CABIN (Canadian Aquatic Biomonitoring Network) is the organisation responsible for national ecological fresh water monitoring. The main focus is on wadeable streams, which are assessed through zoobenthos communities (Mercier p.c. 2012). Also the North American Great Lakes are under CABIN monitoring. Other biological elements, for example phytoplankton and phytobenthos, are used locally in water quality assessment, but they lack protocols on national level. Data analysis is conducted by using statistical modeling.

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USEPA. 2009. National Lakes Assessment. A Collaborative Survey of the Nation's Lakes. United States Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C. 103 p.

## 4.2. Biological quality elements

### Plankton

Plankton is usually monitored in lakes. In Russia also rivers are sampled. In the context of the WFD only phytoplankton is targeted. In Russia and the United States both phytoplankton and zooplankton are monitored.

#### Finland

Phytoplankton quality element comprises four parameters:

1. chlorophyll a content (µg/l),
2. total biomass (mg/l),
3. percentage of harmful cyanobacteria (%),
4. trophic plankton index (TPI) adjusted with local indicators from Willen (2007). Index is formed using taxon specific biomass and predescribed indicator values. It varies from -3 to +3 towards eutrophy.

For all parameter reference states are type-specific. The parameter results are scaled and the medium value is used as an element status class.

#### Sweden

Swedish phytoplankton indices target to assess eutrophication and acidification impact separately (Naturvårdsverket 2007). The main phytoplankton parameters are three:

1. total biomass (mg/l),
2. percentage of toxic cyanobacteria (%),
3. trophic plankton index (TPI).

Chlorophyll a content is only used, if the data is not sufficient enough for the previous. All these parameters are expected to indicate eutrophication pressure. Reference states are determined for types that are derived from ecoregions so that the northernmost 'above forest line' cover ecoregion 1, Norrland regions 2-3 and South-Sweden regions 4-6.

Total number of species may be used as a parameter, if acidification is suspected to be a significant pressure. Its reference values are calculated with respect to pH.

Element class is formed first by scaling and averaging the parameters indicating eutrophication and scaling the total number of species. The final status comes from the worst class indicated by the average value measuring eutrophication or the result from total number of species (acidification).

#### Norway

The first round of WFD implementation Norway had only one phytoplankton parameter: chlorophyll a content (Direktoratsgruppa 2009). Reference states are type-specific.

### The UK

According to the published information from 2008, the UK has two phytoplankton parameters in use:

1. Chlorophyll content, reference values of which are formed using an equation presented in UKTAG (2008) that is in relation to the four depth categories and mean annual alkalinity.
2. Percentage of harmful cyanobacteria (UKTAG 2008). Reference value for harmful cyanobacteria percentage is fixed in 2 % for all waters.

The procedure to combine the two variables is not explained.

### Russia

The Russian full state standard protocol for phytoplankton and zooplankton includes nine metrics listed below (Hydromet p.c., INEP p.c. 2012). The last two concern only phytoplankton.

1. total number of (cells/ml),
2. total number of species,
3. total biomass (mg/l),
4. number of main algae groups (cells/ml),
5. biomass of main algae groups (mg/l ),
6. number of species in a group,
7. saprophytic species (for Saprobic Index, see table 2.8.),
8. photosynthesis activity ($mgO_2$/l·day) (phytoplankton),
9. chlorophyll content (mg/l) (phytoplankton).

There is also a practice to use plankton metrics as trophic status indicators (Hydromet p.c. 2012). Hydromet has definitions for trophic statuses based on the ratio of eutrophic and oligotrophic taxa, zooplankton density, the ratio of zooplankton and phytoplankton biomass and mean chlorophyll content (table 2.1.).

Table 2.1. Plankton metrics as trophic status indicators in Russia according to Hydromet (2012).

| | oligotrophy | mesotrophy | eutrophy |
|---|---|---|---|
| eutrophic /oligotrophic zooplankton taxa | <0.5 | 0.5-1.5 | >1.5 |
| zooplankton density ($10^5$ /m²) | 1-3 | 3-8 | >8 |
| zooplankton biomas/phytoplankton biomass | 4:1 | 1:1 | 0,5:1 |
| total phytoplankton biomass (mg/l) | <1 | 1-3 | 3-10 |
| mean chlorophyll a content (mg/m$^3$) | <2.5 | 2,5-8 | 8-25 |

### The US

Two parameters of national lakes assessment (USEPA 2009) concern plankton measurements:

1. Observed/expected taxa (taxa loss), which is a taxa richness metric for phytoplankton and zooplankton. The limit for good status is set in 20$^{th}$ percentile.
2. Chlorophyll content as indirect phytoplankton metric is considered a recreational indicator of trophic status and it doesn't affect the biological assessment. Reference contents are not published.

In addition cyanobacteria cell counts and Microcystis spp. occurrence were studied as a metric of recreational suitability.

Table 2.2. The most common plankton metrics.

<table>
<tr><th>chlorophyll content</th><th>total biomass</th><th>% harmful cyanobacteria</th><th>TPI</th><th>number of species</th></tr>
<tr><td colspan="5">Sweden</td></tr>
<tr><td colspan="4">Finland</td><td></td></tr>
<tr><td colspan="3">the UK</td><td></td><td></td></tr>
<tr><td colspan="2">Russia</td><td></td><td></td><td>Russia</td></tr>
<tr><td>US</td><td></td><td></td><td></td><td>US</td></tr>
<tr><td>Norway</td><td></td><td></td><td></td><td></td></tr>
</table>

## Comparison

### *Class limit values*

In Finland and Sweden the limit between unaffected sites and those affected by human is set to 25th or 75th percentile of reference data distribution depending on whether metric values react to pressure by growing or decreasing (table 2.3.). For Norway the UK information is not available. In the US taxa loss index the limit between ‘good’ and ‘fair’ status is the 80th percentile point of the reference distribution.

The remaining class limits are set in various methods. Finnish total biomass, chlorophyll content and biomass % of cyanobacteria have their good-moderate threshold determined as the 95th reference percentile + median reference value/2. The medium class limit is two times the good limit and poor limit twice the medium limit. TPI also has good status class limit value is fixed in the reference distribution as 95th percentile, and the rest class limits are even proportions of it.  In Sweden limits are set within even distances as proportions of the metric limit value for high (H/G): G/M: ¾, M/P: ½, P/B: ¼. The US taxa loss index ‘fair’ and ‘poor’ status class limit is the 40th percentile point of reference distribution.

### *Indices*

Most plankton indices are indirect measures of nutrient status and eutrophication pressure. Increased productivity in the northern areas may be an impact of climate change and thus especially phytoplankton can be considered a feasible mean for observing it. The most common plankton metrics are presented in table 2.2.

Chlorophyll a content is used directly as a parameter Finland, Norway, Sweden and Russia. In the UK chlorophyll content is measured, but in a method too deviant for comparison. Comparing the median good-moderate threshold EQRs, which result from good class limit definition,  Finnish median is the highest, but the spread across types is multiple to those of Sweden and Norway (figure 2.1A.). Among the corresponding alpine-arctic types, the highest threshold EQR is in North-Lapland with the difference of 0.1 (figure 2.2A.).  In Russia chlorophyll is part of lake trophic status assessment done by the OECD standards (OECD 1981).

Total phytoplankton biomass or biovolume is a metric in Finland and Sweden as well as in Russia. Good-moderate threshold EQRs across all Finnish types tend to be higher compared to Swedish types (figure 2.1B.). In the alpine-arctic types ratios are nearly identical between the countries (figure 2.2B.).

The biomass share of harmful cyanobacteria is measured in Finland, Sweden and the UK. Monitoring of toxic cyanobacteria is included in INEP’s additional measures in Russia. The taxa included in the parameter vary between the countries reflecting regional differences (Annex). Apart from three specified species in the UK, the taxa are on genus level. The good-moderate EQRs for the parameter are generally higher than usual (figure 2.1C.), the medium across all types staying above 0.8 (table 2.4.). The same applies to alpine-arctic ecotype good status threshold EQRs (figure 2.2C.): both Finland and Sweden require ratio above 0.8. This might result from overall very low occurrence of cyanobacteria blooming in the north.

TPI-index is in common with the new Finnish classification and the previous Swedish system. Finnish classification proves to be notably stricter applying mostly threshold EQRs above 0.5 for good status class, whereas the Swedish EQRs for all types stay below 0.4 (figure 2.1D.). The difference shows also in EQRs for northernmost lake types (figure 2.2D.). For the second WFD development round the index has been intercalibrated.

US O/E-taxa is the only pure community metric among plankton indices. Russian used Saprobic Index is targeting to detect more generally organic pollution giving status classes in terms of pollution degree (table 2.8.). Saprobic Index, however, is a poor tool detecting inorganic pollution (INEP 2012), that is a problem in parts of north.

Table 2.3. Plankton indices' high-good class limit values as percentile points of reference distribution.

| FI, SW | US |
|---|---|
| $25^{th}/75^{th}$ | $80^{th}$ |

Table 2.4. Phytoplankton index good threshold EQR median values across all national types.

| | FI | SWE | NO |
|---|---|---|---|
| Chlorophyll content | 0.41 | 0.33 | 0.33 |
| % cyanobacteria | 0.83 | 0.80 | |
| biomass | 0.38 | 0.30 | |
| TPI | 0.62 | 0.57 | |

Figure 2.1. Boxplot of threshold ecological quality ratios (EQR) for good status classes across all national types showing median, quartiles and the whole spread of values for chlorophyll content (A.), total biomass (B.), % biomass of harmful cyanobacteria (C.) and TPI (D.).

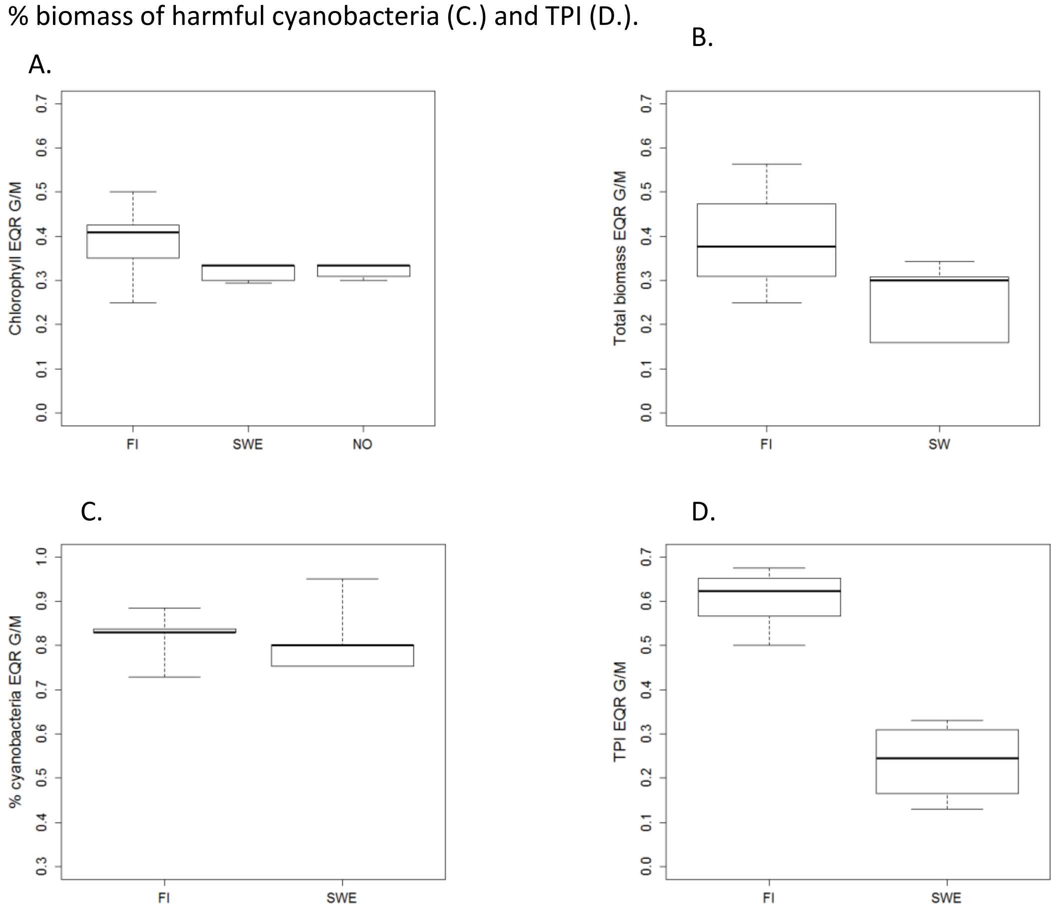
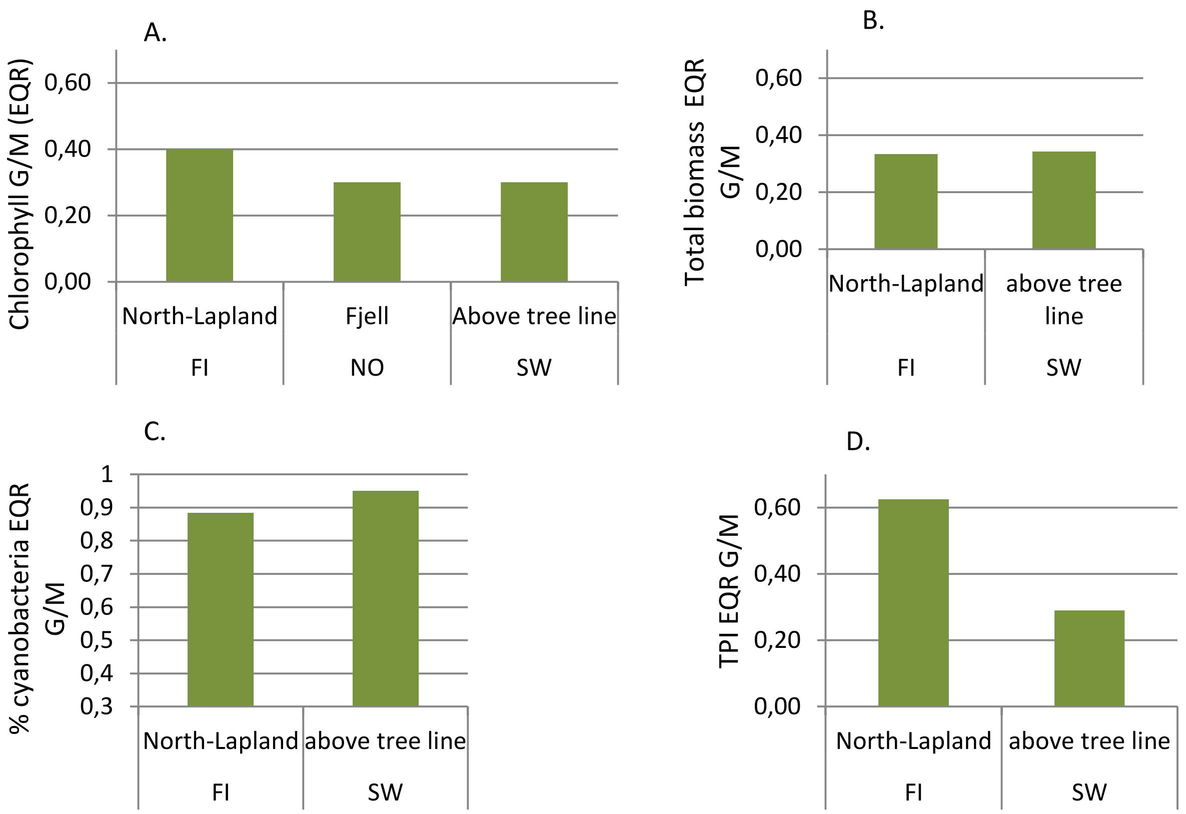


Figure 2.2. Comparison of available good-moderate EQRs between national alpine-arctic ecotypes for chlorophyll content (A.), total biomass (B.) and Trophic Plankton Index (C.).

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## Phytobenthos and macrophytes

According to the WFD phytobenthos and macrophytes form one element together. Thus in countries applying the WFD if both are measured their results are combined. The term 'phytobenthos' most often refers to mere diatom communities in countries under the WFD. In Russia it is understood wider consisting of all types of benthic algae.

### Finland

#### *Rivers*

Phytobenthos indices are two:

1. Number of type-specific taxa (Aroviita et al. 2008), e.k. a. such that is found from at least 40 % of the reference rivers.
2. Percent model affinity (PMA) (Novak & Bode 1992) compares the observed and expected relative abundances of certain taxa.

Reference states are type-specific with partly sub-divisions into north and south halves of the country. Indices are scaled and averaged into an element class.

#### *Lakes*

Phytobenthos indices are again number of type-specific taxa and PMA.

There are three indices for lake macrophytes:

1. Proportion of type-specific species of the total number of observed species. Type-specific species are such that are found from at least 50% of the reference lakes.
2. Percent model affinity (PMA).
3. Reference-index (Schaumburg et al. 2004), which groups the macrophytes into eutrophication sensitive, tolerant and indifferent species. The index is difference of sensitive and tolerant species with respect to the total number of species. Values range from 100 to -100 towards eutrophication.

Reference states for lake phytobenthos indices are determined for four groups of types based on size, humus content and mean depth. Reference states for macrophyte indices are for each type in north and south half of the country separately. Indices for phytobenthos and macrofytes are scaled and averaged into their own classes. Whichever shows poorer result becomes the element class. Reference states are type-specific.

### Norway

#### *Rivers*

Acidificataion Index Periphyton (AIP) (Schneider & Lindstrøm 2009) is the phytobenthos metric applied on rivers. The index works on acidification indicator values given for 115 benthic algae, including also macroalgae. Reference values are determined for each type.

#### *Lakes*

Macrophytes are monitored in lakes (Direktoratsgruppa 2009). 'Trophic Index' is by principle identical to Reference Index introduced earlier in Finnish indices with the exception of excluding helophytes. Reference states are determined for modified types so that forest and lowland types are dealt as one and the fjell type is excluded from analysis.

## Sweden

### *Rivers*

Diatom communities are studied as phytobenthos element in rivers. The main indices are two:

1. IPS (Indice de Polluo-sensibilité Spécifique) (Cemagref 1982) is a community metric responding to eutrophication and organic pollution. It is calculated using taxa indicator and pollution sensitivity scores with relative abundances (Naturvårdsveket 2007).
2. Acidity index for diatoms (ACID) (Andrén & Jarlman 2007) is calculated through a function using taxa division into groups according to their response to pH. ACID scale is rather a pH gradient from acid to alkanic and its class limit values are set using mean annual pH that corresponds to a certain ACID value.

In addition two supporting parameters are calculated: %PT (pollution tolerant valves) and TDI (Trophic diatom Index). Results of these do not affect the status class, but may suggest unreliability to it, if worse than the main index results, indicating organic pollution (%PT) or eutrophication (TDI).

For all phytobenthos indices there is only one reference state for the whole country.

### *Lakes*

Macrophytes are monitored and analysed with a metric called ‘Trophic Index’. It is different to previously mentioned macrophyte indices. Helophytes are excluded from the focus. Species in other life forms have an indicator value and a weighting factor. The index production and the EQR calculation described in Naturvårdsveket (2007). Reference states for the index are determined in three types so that the northern ecoregions 1 and 2 above highest coastline are combined into one, region 3 under highest coastline stands as one and all the southern regions 4-7 are combined. The Index scale is from 10 to 1 towards eutrophication.

## The UK

### *Rivers*

Diatom community is studied using Diatom Assessment of Lake Ecological Status (DALES), which is a metric for detecting eutrophication pressure (UKTAG 2008a). It counts sensitive taxa abundances with taxon-specific sensitivity scores. Reference states are separately for lakes with mean annual alkalinity less than 10 and for those more than 10 mg/l $CaCO_3$.

The UK is the only country, where macrophytes are monitored as a classification element in rivers. So called River Leafpacs is a multimetric index developed to detect eutrophication as well as community changes from hydromorphological alterations (UKTAG 2009a). River Leafpacs includes:

1. River Macrophyte Nutrient Index (RMNI),
2. River Macrophyte Hydraulic Index (RMHI),
3. number of macrophyte taxa,
4. number of functional groups,
5. percentage cover of green filamentous algae.

Helophytes are excluded from focus. Reference state for each sub-metric is calculated using equations with certain hydromorphological details and alkalinity. Index calculation procedure is described in UKTAG (2009a).

### *Lakes*

Phytopbenthos is sampled in lakes and assessed using an application of DALES, which counts taxa abundances and sensitivity scores as in rivers (UKTAG 200b).

Lake macrophytes are analysed with a multimetric index Lake Leafpacs, which integrates six sub-metrics.

1. Lake Macrophyte Nutrient Index is constructed from observed species nutrient scores presented in UKTAG (2009b.), which are then summed and divided by the total number of species. The reference state is calculated for each case individually with an equation.
2. Number of functional groups of macrophyte taxa is a sum of different observed functional groups defined in UKTAG (2009b.). The reference state is calculated for each case individually with an equation.
3. Number of macrophyte taxa. Reference state is calculated for each lake separately using information on its alkalinity and hydromorphological measures.
4. Mean percent cover of hydrophytes as the mean cover of studied area relative to total number of species. The expected reference cover is set to 8.5% for all types.
5. Relative percent cover of filamentous algae is filamentous algae cover relative to hydrophyte cover in the studied area. The expected reference cover is set to 0.05% for all types.

The method description UKTAG (2009b.) does not explain the procedure of combining the sub-metric's results.

Another macrophyte metric 'Free Index' is in use in Northern Ireland (UKTAG 2008c.). It consist six sub-metrics:

1. Maximum depth of macrophyte colonization
2. Mean depth of macrophyte presence
3. Percent relative frequency of Chara in the study area (only for lakes with alkalinity ≥ 100 mg/l $CaCO_3$)
4. Percent relative frequency of Elodeids in the study area
5. Plant trophic score, which is the sum of observed taxa nutrient scores presented in UKTAG (2008c.) divided by the total number of taxa.
6. Percent relative frequency of tolerant taxa in the study area.

Sub-metrics are combined through scaling, but the process is not fully explained. Index has one reference value of 0.8 for all types.

Further on is also not described how the final element status class is formed from Diatom DALES-index and Lake Leafpack or Free Index if used.

## Russia

### *Rivers and lakes*

Russian state standard advices to measure:

1. total number of taxa,
2. frequency of taxa,
3. Saprobic Index, which is a product of taxa abundances and their saprobic value. The index results value from 1 to 4 towards organic pollution. There are six levels of pollution with limit values for the index (Table 2.8).

INEP (p.c. 2012) also keeps records of other indicator taxa and may calculate additional indices.

## The US

### *Lakes*

Sediment diatom communities are included in the national lake assessment (USEPA 2009). The Lake Diatom Condition Index consist five metrics categories:

1. taxonomic richness as number of taxa,
2. taxonomic composition as relative abundances of taxa,
3. taxonomic diversity measured by diversity metrics,
4. morphology or the occurrence of different diatom life-forms (benthic, planktonic, motile, epiphytic, colonial, chain-forming),
5. pollution tolerance.

The actual parameters are unspecified. The metrics results are averaged and summed to Lake Diatom Condition Index (USEPA 2010).

## Comparison

### *Class limit values*

In Finland the default class limit of 25$^{th}$ percentile of reference distribution is used for high status class. Other class limits are set in even proportions of the 25$^{th}$ percentile value. The same applies to Swedish macrophyte 'Trophic Index'. IPS responds to pressure by decreasing, thus its high-good limit is the 75$^{th}$ reference percentile point. As for rest IPS class limits and ACID the class limit values are determined through expert judgment assessing ecologically meaningful index values (Kahlert et al. 2007). For the US Lake Diatom Condition Index the limit of the best class 'good' is similarly set to the 25$^{th}$ percentile of reference distribution. The limit between fair and poor statuses is set to the 5$^{th}$ percentile.

### *Indices*

Some phytobenthos metrics have predefined target of pressure they measure (Table 2.5.). Swedish ACID and support parameter %TP are developed as measures of acidity. The UK DALES is based on taxa sensitivity to eutrophication. Swedish IPS measures community reaction to organic pollution, as does Russian Saprobic

Index. Other metrics are more general measures of community structure, which may indicate all types of impacts. Finnish PMA compares observed and expected taxa abundances. Also by USEPA taxonomic composition is studied through certain taxa abundances. None of the metrics is common between several nations. Consequently phytobenthos metrics are a feasible tool to detect changes such as acidification, organic pollution and eutrophication.

Table 2.5. National phytobenthos and macrophyte indices for rivers (A) and lakes (B.) colour-coded either as community metrics or according to the intended target pressure.

A.

| | phytobenthos | | | | macrophytes | |
|---|---|---|---|---|---|---|
| Finland | type-specific taxa | | PMA | | | |
| Norway | AIP | | | | | |
| Sweden | IPS | ACID | %TP | TDI | | |
| The UK | DALES | | | | River Leafpacs | |
| Russia | No. of taxa | Frequency of taxa | Sabrophyte Index | | | |

B.

| | phytobenthos | | | macrophytes | | |
|---|---|---|---|---|---|---|
| Finland | type-specific taxa | PMA | | proportion type-specific sp. | PMA | RI |
| Norway | | | | NO TI | | |
| Sweden | | | | SW TI | | |
| The UK | DALES | | | Lake Leafpacs | Free Index | |
| Russia | No. of taxa | Frequency of taxa | Sabrophyte Index | | | |
| US | The Lake Diatom | Condition Index | | | | |

| | | | |
|---|---|---|---|
| community integrity | eutrophication | organic pollution | acidification |

Most macrophyte metrics target to detect eutrophication and as such they could serve as indicators of climate change through increased production. Finnish Reference Index and Norwegian Trophic Index result from the same equation, but TI does not include helophytes. There are no other shared indices between the countries. Swedish TI is a more complex adaptation of the previous indices. Finnish type-specific species and PMA measure more community structure than any pressure separately. Similarly to PMA abundances of certain taxa are integrated in the UK indices.

The medium good-moderate class threshold EQRs across all national types are roughly on the same level (table 2.6-7.). Finnish indices' variation of the critical ratio tends to be large between the national types (figure 2.3A). As for river diatoms, Swedish IPS applies only one ratio for all types, whereas Finnish indices show modest variation between the types. ACID-index is not included, because it yields a status in a different scale measuring degree of alkalinity.

Finnish type-specific macrophyte species and PMA EQRs for good class go notably low, less than 0.6 for some types (figure 2.3B). The corresponding macrophyte indices Finnish Reference Index and Norwegian Trophic Index have good threshold EQRs rather on the same level in terms of median and minimum ratio.

Swedish TI has the highest good threshold ratios and the highest median (table 2.7.) making it the strictest index.

Norway has not extended its methods to the alpine-arctic ecotype and Swedish system has included the type to a larger northern entity. Thus comparing type-specific EQRs is not feasible.

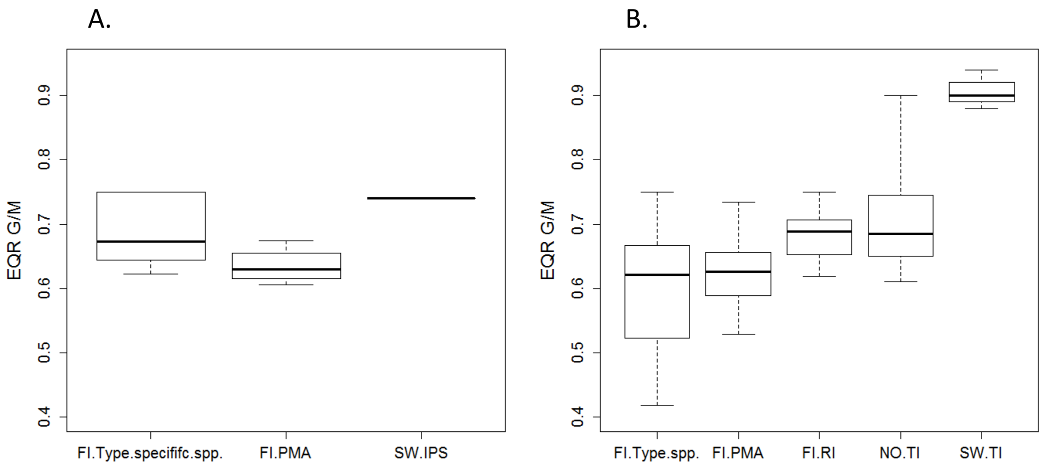
Table 2.6. River phytobenthos index good class EQR medians across all national types in Finland and Sweden.

| FI | | SW |
|---|---|---|
| Type-specific taxa | PMA | IPS |
| 0,67 | 0,63 | 0,74 |

Table 2.7. Lake macrophyte index good class EQR medians across all national types in Finland, Norway and Sweden.

| FI | | | NO | SW |
|---|---|---|---|---|
| Type-specific spp. | PMA | RI | TI | TI |
| 0,62 | 0,63 | 0,69 | 0,69 | 0,90 |

Figure 2.3. Boxplot of threshold ecological quality ratios (EQR) for good status classes across all national types, showing median, quartiles and the whole spread of values for available river phytobenthos metrics (A.) and lake macrophyte metrics (B.).

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## Zoobenthos

### Finland

#### *Rivers*

The indices calculated from river zoobenthos data are three:

1. number of type-specific taxa taxa (Aroviita et al. 2008), such that occurs in at least 40 % of reference rivers in the same type,
2. number of EPT families (the amount of Ephemeroptera, Plecoptera and Trichoptera families),
3. PMA (percent model affinity)

#### *Lakes*

Lake zoobenthos is sampled from littoral and profundal area.

The lake littoral indices:

1. abundance of type-specific taxa,
2. PMA (percent model affinity)

Littoral reference states are determined for groups of 2-3 types together. North-Lapland lakes are not dealt separately, but in the groups their hydromorphology indicates.

Lake profundal zoobenthos indices:

1. PMA (percent model affinity). Reference values are type-specific, but the index is not used for all types including North-Lapland.
2. PICM (profundal invertebrate community metric) (Jyväsjärvi & Hämäläinen 2011), which measures densities of 46 predefined taxons. The reference states are modelled for each type.

### Norway

#### *Rivers*

1. NIVA index is applied on rivers under acidification impact. It is adjusted from Raddum indices to more humic streams and rivers. The indices indicate a degree of acidification by measuring the occurrence of certain sensitive species. Range of NIVA index is from 1 to 4 towards acidification impact. Due to calculation technicalities actual reference states are not determined. Status class threshold values are currently the same for all river types.

In addition to NIVA index, occurrence of young fresh water pearl mussel (*Margaritifera margaritifera)* is used as an optional indicator for good status.

2. ASPT (Average Score per taxon) (Armitage et al 1983) is applied on rivers under eutrophication pressure. The index is based on invertebrate families' tolerance towards eutrophication among other impacts, which is expressed as a tolerance value from 1-10 towards intolerance. ASPT is the sum of sample tolerance values divided by the sample number of families. There are currently no reference values and status class threshold values are the same for all types.

#### *Lakes*

Lake littorals are sampled (Directoratsgruppa 2009). The first round general zoobenthos index was Raddum acidification index 1. In addition Gammarus spp. was used as a general qualitative indicator and Lepidurus ssp. as specific arctic lake indicator for good status. New Norwegian classification guide is expected to be out in 2013 and to update previous information.

## Sweden

### *Rivers*

There are three Swedish river zoobenthos indices:

1. ASPT (Average Score per taxon) for habitat disturbance and eutrophication,
2. DJ-index for detecting eutrophication is composed of five sub-metrics (Dahl & Johnson 2005):

- relative abundance of Crustaceae
- ASPT
- number of taxa in EPT-families
- relative abundance of EPT-families
- Saprobic-index (Zelinka & Marvan 1961)

DJ-sub-metrics are scaled so that each value gets score from 1-3. Scores are summed into the final index, which can have a value from 5 to 15.

3. MISA (Multimetric Index for Stream Acidification) (Johnson & Goedkoop 2005) is composed of six sub-metrics indicating acidification impact:

- number of families
- number of Ephemeroptera taxa
- number of Gastropoda taxa
- ratio of Ephemeroptera and Plecoptera relative abundances
- AWIC index (Davy-Bowker et al. 2005)
- relative abundance of shredders

MISA sub-metrics are scaled and summed. The multimetric index is formed by dividing the sum by the amount of sub-metrics used, to create an average score, and by multiplying it by 10.

All the indices' reference values determined for Illies ecoregions (see x.x.). One reference state is applied on all rivers within an ecoregion.

The worst class indicated by any of the three lake zoobenthos indices is chosen to represent the element level ecological status.

### *Lakes*

Both littoral and profundal zone are sampled. Lake littoral indices are two:

1. ASPT (Average Score per taxon) (Armitage et al 1983),
2. MILA (Multimetric Index for Lake Acidification) (Johnson & Goedkoop 2007). MILA comprises six sub-metrics reacting to acidification:

- relative abundance of Diptera
- relative abundance of Ephemeroptera
- number of Gastropoda taxa
- number of Ephemeroptera taxa
- AWIC index (Davy-Bowker et al. 2005)
- relative abundance of predators

MILA sub-metrics are combined and the final index formed the same manner as MISA for rivers.

3. BQI (Benthic Quality Index) (Wiederholm 1980) is applied on lake profundal samples. It measures bottom oxygen condition through sensitivity degree of observed Chironomidae species.

All the indices' reference values determined for Illies ecoregions. All lakes within a region have the same reference state.

The worst class indicated by any of the three river zoobenthos indices is chosen to represent the element level ecological status.

## The UK

### *Rivers*

There are two river zoobenthos indices for zoobenthos used in Scotland:

1. SAWIC (Scottish Acid Water Indicator Community) (UKTAG 2009), in which the taxa is grouped into four classes according to their sensitivity to acidification. Taxa are then scored using observed abundances and their sensitivity class. Index value is an average score through all taxa. SAWIC is a regional metric for Scotland and it has one reference value for all rivers.
2. RICT (River Invertebrate Classification Tool) (UKTAG 2008a), which indicates community changes mainly from eutrophication and pollution pressure. It comprises of two indices: number of taxa and ASPT (average score per taxon). The indices are bias-corrected after calculation. RICT reference values are calculated site-specifically using several hydromorphological variables (UKTAG 2008).

### *Lakes*

Two indices have been developed for lake zoobenthos in the UK according to the latest publications:

1. LAMM (Lake Acidification Macroinvertebrate Metric) (UKTAG 2008b.) is an alternative form of average score per taxon, where sensitivity scores are weighted by pre-described constants. Index indicates acidification impact and its equation presented in UKTAG (2008b.). Reference states are two according to water dissolved organic carbon concentration (mg/l).
2. CPET (Chironomid Pupal Exuviae Technique) (UKTAG 2008c) is exceptionally requiring a method collecting Chirnomid larvae from the lake surface. The index is a simple average score per taxon application on eutrophication impact. Reference values are calculated site-specifically using hydromorphological variables (UKTAG 2008c.).

It is unknown how the class limits are set for the UK zoobenthos indices. EQRs are calculated with specific equations instead of straight ratio of reference state as in most other countries. Also the status class threshold EQRs are mostly not introduced.

## Russia

### *Rivers*

Hydromet monitors rivers in Kola Peninsula. Exceptionally to other river sampling methods their standard applies a hand-held dredge to collect the sample (Hydromet p.c. 2012). The Russian state standard procedure for water quality control includes many community measures as number of taxa, taxa relative abundances, density of individuals and total biomass. Three indices are calculated:

1. Woodiwiss biotic index (Woodiwiss 1964), where taxa is grouped according to their sensitivity to organic pollution and observed taxa give a site a biotic index from 10 to 0 towards increasing pollution.

2. Goodnight-Whitley biotic index or so called 'oligohaetic index' (Goodnight & Whitley 1960) is applied on river reach areas. The index considers Oligochaetas and is simply their percentual proportion of all the observed taxons. The proportion of Oligochaeta is expected to increase with organic pollution.
3. Sabropic Index.

Each index is calculated. The results will indicate one of the six pollution classes (table 2.8.). The final quality evaluation is done based on all three results.

### *Lakes*

INEP accounts for monitoring of zoobenthos in Kola Peninsula lakes (INEP p.c. 2012). Both littoral and profundal zone are sampled, littoral by kick-net and profundal by Ekman dredge. Again the Russian state standard includes several community measures as dealing with rivers. Depending on situation different indices may be calculated. Those calculated as a standard procedure include:

1. Woodiwiss biotic index is used to analyse lake littoral.
2. Goodnight-Whitley biotic index is applied on lake profundal.

The same limit values as with rivers are applied on indices.

Table 2.8. Russian index limit values for pollution status classes from clean (I and II) to moderately and more polluted.

| Status class | Oligochaetic Index | Woodiwiss | Saprobic Index |
|---|---|---|---|
| I | <20 | 8-10 | <1,00 |
| II | 21-35 | 5-7 | 1,00-1,50 |
| III | 36-50 | 3-4 | 1,51-2,50 |
| IV | 51-65 | 1-2 | 2,51-3,50 |
| V | 66-85 | 0-2 | 3,51-4,00 |
| VI | 86-100 | 0 | > 4,00 |

## Canada

### *Rivers*

The focus is on wadeable streams, in which zoobenthos is the principle ecological monitoring element (Mercier p.c. 2012). The standard method for rivers and data management is described in Reynolds et al. (2001). All the monitoring data is stored in an electronic database, where a variety of indices can be calculated. According to Reynolds et al. (2001) the following metrics are recommended to be used:

1. number of families (taxonomic richness),
2. number of EPT families,
3. Shannon-Wiener diversity index, which uses taxa relative abundances,
4. equitability or evenness, which is an application of the previous index the measure how evenly the individuals are distributed,
5. dominance, which is the inverse of evenness, expressed graphically, so that taxa is ranked in decreasing order of their relative abundance and plotted against the relevant species rank.
6. Hilsenhoff family biotic index (Hilsenhoff 1988) is mainly an indicator of organic pollution. The index is formed from family-specific tolerance values using abundance data.

The indices’ reference states are not available in public. The typology delineations are based on ecoregions (Reynolds et al. 2001) and watersheds (Mercier p.c. 2012).

Taxonomic richness analysis is conducted using either RIVPACS (Wright et al. 2000) or BEAST (Reynoldson et al. 1995) models statistical models (Mercier p.c. 2012). Reference states are determined usually specifically for each watershed. The models create a predicted sate for each target relative to of how its natural characters correspond to those of reference water bodies. The observed result is compared with the predicted one. If the target dissimilarity exceeds the threshold, it is classified as ‘divergent’.

### *Lakes*

Lake monitoring on national level is focused on the North American Great Lakes, where the same practice applies as introduced for rivers.

## The US

### *Rivers*

The zoobenthos condition in USEPA wadeable stream assessment (USEPA 2006) was measured with so called Index of Biological Integrity, consisting six metric categories:

1. number of taxa (taxonomic richness),
2. taxonomic composition, which is possible to measure using different taxon relative abundances (Stribling et al. 1999) or as proportion of insects in the sample (USEPA 2010),
3. trophic feeding groups, which are measured in relative abundances of each observed feeding groups in the sample,
4. habitat diversity is measured through observed relative abundances of habitat groups: burrowing, clinging, climbing and sprawling taxa (USEPA 2010),
5. tolerance to pollution may calculated as regional modification of Hilsenhoff Biotic Index (NCDEM 2001).

The compositions of sub-metrics have varied between the ecoregions and they are not specified by USEPA (2006 nor 2010). The final index is the sum of its scored sub-metrics, a value from 0 to 100. Reference states are determined inside 9 ecoregions in national wadeable stream assessment (USEPA 2006). In other separate studies also North-American level III delineations have been used (USEPA 2010).

In addition to previous, observed/expected number of taxa is used independently in monitoring as an indicator of taxa loss (USEPA 2010).

### *Lakes*

At the time of previous national lake assessment lake zoobenthos metrics were still in under development (USEPA 2009).

## Comparison

### *Class limit values*

The limit between unaffected sites and those considered affected by human is determined rather systematically as the 25th percentile of the reference data distribution (table 2.11.). Canada makes an exception: if taxa richness is analyzed by RIVPAC the limit is the 80th percentile, or in other words the community is lacking more than 20% of the predicted taxa, but if the analysis is done BEAST even 1% difference yields a divergent status. Also if observed/expected taxa is used by USEPA, the limit for good status is the 80th percentile. The Swedish indices MILA and MISA result an acidity class, the class limits of which are set as expert judgment through significant pH thresholds they represent. Russian pollution classes are fixed on actual index values (table 2.8.).

Other class limits are usually set as even proportions of the high limit value in the WFD classification. In Canada RIVPAC only uses classification into two and BEAST further groups the data, 'divergent' and 'mildly divergent' by the 95th and 90th percentiles, respectively.

Table 2.11. Percentile point applied on reference data distribution to divide between unaffected and human impacted water bodies. The Canadian values are applied on taxa richness analysis only and represent the deviation or loss of taxa in relation to the expected by RIVPAC/BEAST analysis.

| | **percentile** |
|---|---|
| Finland | 25th |
| Sweden | 25th |
| Canada | 80th / 99th (20/1% difference) |
| US | 25th (biological integrity) / 80th (20% taxa loss in O/E taxa) |

### *Indices*

The Norwegian and Swedish classification systems are designed to investigate acidification and eutrophication impacts separately. A similar approach is evident in the UK zoobenthos metrics, though through different methods. The main standard indices in Russia deal with organic pollution, whereas the EU countries lack direct pollution indices. In addition to direct environmental impact metrics, the WFD instructs on monitoring the community structure, for which purpose more general richness and diversity metrics have been developed in the EU countries. The North-American systems include most of the latter aspects, excluding a direct acidification indicator. All in all there is a wide range of environmental pressures zoobenthos can be used to detect. Summary of national metrics is presented in tables 3.9. and 3.10.

Taxon composition is measured with various methods, often using relative abundances of taxa, as the Finnish PMA does systematically. In Canada an actual diversity-index is used. Swedish and USEPA multimetric indices include taxa relative abundances, but also a focus on feeding groups. Relative abundance of any feeding group is considered a potential metric also by USEPA (2010). Swedish river index MISA measures shredders and lake index MILA predator relative abundance. USEPA extends community metrics to habitat diversity through measuring habitat group abundances.

Table 2.9. National river zoobenthos metrics in countries applying the WFD (A.) and in Russia, Canada and The US (B) colour-marked by the target impact if other than community integrity.

A.

| | | | |
|---|---|---|---|
| Finland | No. Type-specific taxa | No. EPT families | PMA |
| Norway | NIVA-index | ASPT | |
| Sweden | ASPT | DJ-index | MISA |
| The UK Scotland | SAWIC | RICT | |

B.

| | | | | | | |
|---|---|---|---|---|---|---|
| Russia | Woodiwiss | Goodnight-Whitley BI | Sabropic Index | | | |
| Canada | number of families | number of EPT families | Shannon-Wiener diversity | Equitability | Dominance | Hilsenhoff family biotic I. |
| US | number of taxa | taxonomic composition | trophic feeding groups | habitat diversity | tolerance metric | |

| | | | |
|---|---|---|---|
| community integrity | eutrophication | acidification | organic pollution |

Table 2.10. National lake zoobenthos metrics in countries applying the WFD and Russia, colour-marked by the target impact if other than community integrity.

| | Lake littoral | | Lake profundal | |
|---|---|---|---|---|
| Finland | No. Type-specific taxa | PMA | PICM | PMA |
| Norway | Raddum 1. | | - | |
| Sweden | MILA | ASPT | BQI | |
| The UK Scotland | LAMM | CPET | - | |
| Russia | Woodiwiss | | Goodnight-Whitley | |

| | | | |
|---|---|---|---|
| community integrity | eutrophication | acidification | organic pollution |

Number of taxa is a common community metric, which is included nearly every system. In Finland only type-specific taxa is calculated. In Sweden and USEPA taxa richness in integrated in multimetric indices. In Canada only families are count. More specifically only APT-families may be count, as is done in rivers in Finland and Canada, and in a sub-metric of DJ-index. EPT families are considered the most sensitive to environmental changes. Community metrics potentially react to all kind of pressures from disturbance from water level regulation to water quality changes.

All the countries have independent solution for attempted direct measure of acidification impact. Sweden applies multimetric indices for the purpose, Norway has a national index and the UK modifies ASPT-method for the new purpose.

The standard ASPT (Armitage et al 1983), which reacts to nutrient enrichment, among other impacts, is used by Sweden on all waters and by Norway on rivers. The UK uses a modified ASPT-method for measuring eutrophication impact. The differences in ASPT applications do not enable comparison of limit values. Lake profundal indices in Finland and Sweden apply method of scoring taxa from the point of view of oxygen depletion.

Both Canada and USEPA apply some form of Hilsenhoff Biotic Index as an organic pollution indicator. However, regionally adjusted methods are not comparable.  Saprobic Index measures saprophytic taxa abundances as indicators of organic pollution, and it is common between Russia and Swedish DJ-index.

For those Finnish and Swedish river indices a comparison of good status threshold EQRs is possible, the ratios are on the same level (figure 2.4A.). Swedish river indices only have one EQR for all types. Lake littoral threshold EQR medians are similarly close (table 2.12.), though Swedish ASPT has very large variation across national types from ratios more than 0.8 to ones less 0.5 (figure 2.4B.). Profundal indices have greater difference, Swedish BQI being stricter (figure 2.4C, table 2.12.).

Figure 2.4. Boxplots of threshold ecological quality for good status class ratios across all national types showing median, quartiles and the whole spread of values for available river (A.), lake littoral (B.) and lake profundal (C.) zoobenthos indices.

A.

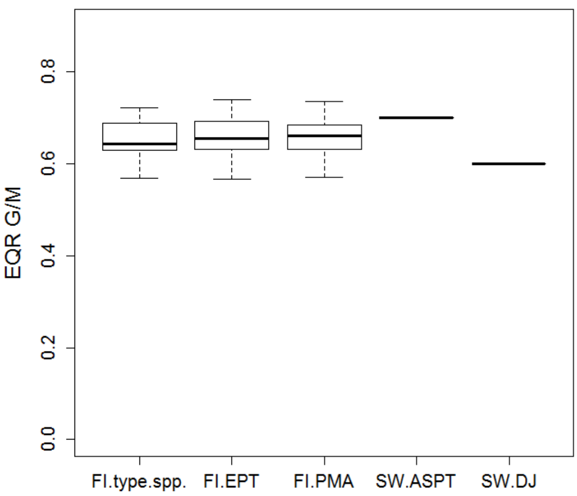
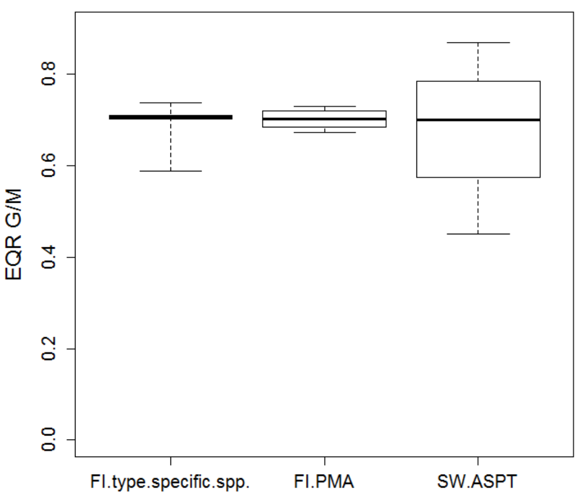


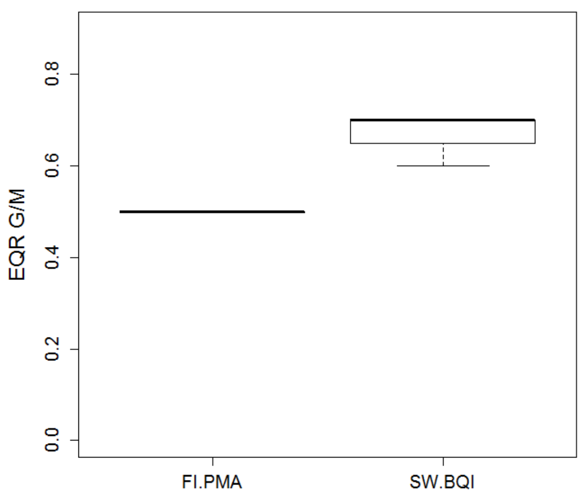

Table 2.12. Zoobenthos index good threshold EQR median values across all national types.

| | | |
|---|---|---|
| River | FI type. spp. | 0.64 |
| | FI EPT | 0.65 |
| | FI PMA | 0.66 |
| | SW ASPT | 0.70 |
| | SW DJ | 0.60 |
| Profundal | FI PMA | 0.50 |
| | SW BQI | 0.70 |
| | FI type.spp. | 0.71 |
| Littoral | FI PMA | 0.70 |
| | SW ASPT | 0.70 |

B.




C.



Although it is not the main focus of this paper to go into the field methods, some obvious differences affecting data correspondence were revealed. The most apparent issues arisen from national classification guides and personal consultation are presented in table 2.13.

Table 2.13. Some national field method procedures for lake littoral and river kick-net sampling. Meissner et al. 2012, Direktoratsgruppe 2009, Naturvårdsverket 2007, UKTAG 2008a, INEP p.c. 2012, CABIN 2009, USEPA 2012).

| | Finland | Norway [1] | Sweden | The UK [2] | Russia | Canada [1] | USEPA [3] |
|---|---|---|---|---|---|---|---|
| kick-net timing rivers/lakes | 30/20 sec | 3/- min | 60/20 sec | 3/- min | | 3/- min | not set |
| sieve mesh size (mm) | 0.5 | 0.25 | 0.5 | 1 | 0.27-0.35 | <0.4 | 0.5 |
| Replicates | 2-3 | 4 | 5 | 2 | 2-3 | | |
| Sampling season | autumn | spring and autumn | autumn | spring | autumn | autumn | spring and/or autumn |

[1] Lake littorals are not sampled. In Canada lake littorals are sampled with a dredge.

[2] Excluding CPET.

[3] There are three standard sizes of kick-net (USEPA 2012)

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## Fish

### Finland

#### *Rivers*

Finish Fish Index for rivers (Vehanen et al. 2010) comprises five sub-metrics:

1. 0+-salmonids density,
2. Cyprinidae density (per 100 m²),
3. total number of species,
4. proportion of sensitive species,
5. proportion of tolerant species.

Index is formed by comparing observed sub-metrics to the cumulative frequency distributions of type-specific reference datasets. Data processing takes place in Finnish Game and Fishery Research Institute.

#### *Lakes*

Finnish Fish Index for lakes (Tammi et al. 2006) is result of four sub-metrics.

1. Total biomass kg/net/night. The values may either rise or decline in response to pressure.
2. Total number of individuals. The values may again either rise or decline in response to pressure and the direction of response should be recognized.
3. Proportion of Cyprinidae of the total biomass,
4. occurance of species listed as indicators

The Index has type-specific reference values, however, North-Lapland lakes are not separated. Final index is formed by scaling the sub-metrics and averaging them into the final value.

### Norway

#### *Rivers*

Two fish indices may be applied on a river according to Direktoratsgruppa (2009).

1. To assess general ecological condition so called “Fish Index” is used. It deals with occurrences of species that each belongs to one of three groups: dominant, sub-dominant or rare.  The less common species is, the more it weighs on the final index, which compares the observed community to that of expected. Reference states are calculated for each location individually.
2. Juvenile salmon density (per 100 m²) is used metric for rivers under acidification pressure. For juvenile salmon densities and support parameter same reference values go with all types.

Two chemical support parameters may be used: aluminium concentration in juvenile salmon gills and water pH in terms of salmon parr and smolt tolerance.

The final fish element class is a scaled and averaged result of the main parameters.

### *Lakes*

1. Fish Index described for rivers is also applied on lakes.
2. Trout catch per unit effort (CPUE) (per 100 m² net area/day) is a metric for lakes under acidification pressure. The resulting status class is relative to growth estimated to the lake. Reference states are type-specific.

pH can again be used as a supportive parameter using class limits that trout is expected to respond to. If more than one metric is measured the final element class is attained by scaling and averaging.

## Sweden

### *Rivers*

So called river index "VIX" is the main metric consisting six sub-metrics (Naturvårdsverket 2007):

1. density of salmon and trout,
2. number of tolerant individuals,
3. number of lithophiles,
4. proportion of tolerant species,
5. proportion of intolerant species,
6. number of salmonid species reproducing in the river.

Certain compositions of the VIX sub-metrics are dealt as decision supportive metrics that may indicate a more clearly defined pressure. Sub-metrics 1,3,5 and 6 are considered to be sensitive for acidification and these four analysed together form supportive "VIXsm" index. Sub-metrics 1,2,4 and Simpsons diversity index form supportive "VIXh" index for hydromorphological impact. The supportive indices do not affect status class.

The sub-metrics are transformed into probability values that represent the odds the location is unchanged from natural state. The final index calculation is adjusted using morphological measures and the end result is the mean value of its sub-metrics.

### *Lakes*

The lake index "EQR8" has 8 sub-metrics (Naturvårdsverket 2007):

1. number of native species,
2. Simpson's diversity index based on number of individuals,
3. Simpson's diversity index based on biomass,
4. biomass proportion of the native species,
5. proportion of native species,
6. mean weight of the total catch,
7. biomass proportion of perch (Percidae),
8. Percidae/Cyprinidae in biomass.

Reference state is calculated for each lake individually from morphological measures and temperature. The sub-metric results are transformed as described in Naturvårdsverket (2007). The final index value is a mean.

## The UK

Currently there is no description available for assessing inland fish fauna in Scotland or Northern Ireland.

## Russia

There is no actual state standard for fish monitoring as an element of ecological quality. Fish monitoring is conducted by INEP as research and analysis method is chosen in terms of the research question. Research may concern any level from cellular to community.

## Comparison

### *Class limit values*

Total biomass and number of individuals in Finnish lake index respond into two directions. If the response is considered to be growing, the limiting value for good is the minimum of reference distribution. All the other class limit values are set in relation to the good limiting value as proportions of it in even distances. If the response is considered to be decreasing 25$^{th}$ percentile of the reference distribution is used as limit for high status class, the other class limit values are defined as proportions of it in even distances.

## Indices

The fish metrics have different compositions between the countries. There are similarities between the Finnish and Swedish metrics: Cyprinidae and sensitive taxa abundance are important community indicators. Salmonid species are considered most sensitive to changes and their density is measured in all the Nordic river metrics.

The national analysis methods are hard to compare. Reference states and good class threshold values are available for Finnish lake index and Norwegian fish Index. Plotting good class threshold EQRs across all national types of these together reveals high variation with low ratios among the Finnish indices and relatively high EQR for Norwegian Fish Index (figure 1, table 2.).

Figure 2.5. Boxplot of threshold ecological quality for good status class ratios across all national types showing median, quartiles and the whole spread of values for available lake fish indices.

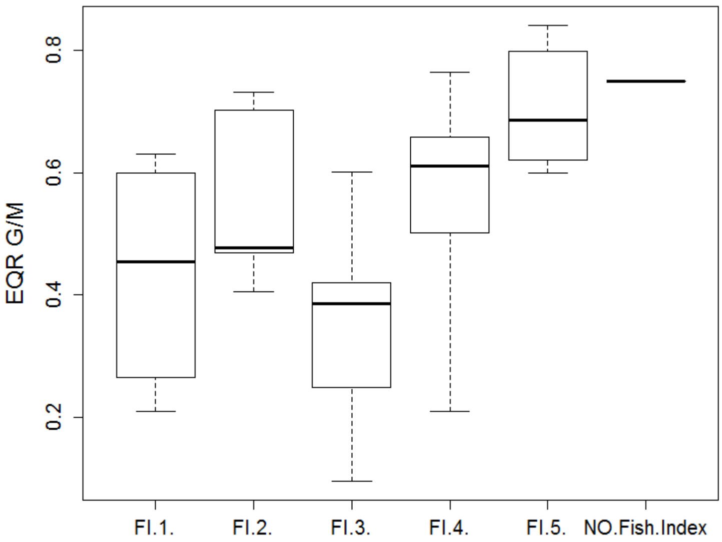


Table 2.14. Finnish indices.

| | |
|---|---|
| FI 1. | biomass (rising) |
| FI 2. | biomass (declining) |
| FI 3. | no. individuals (rising) |
| FI 4. | no. individuals (declining) |
| FI 5. | biomass % Cyprinidae |

Table 2.15. Index median threshold good class EQRs across all national types.

| Index | Median |
|---|---:|
| FI 1. | 0,45 |
| FI 2. | 0,48 |
| FI 3. | 0,39 |
| FI 4. | 0,61 |
| FI 5. | 0,69 |
| NO Fish Index | 0,75 |

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# 5. Conclusions for further actions in activity two

Further steps in activity 2 aim for evaluating the validity of different classifications by testing them with data from the project area in the northernmost Finland and Norway and western parts of Kola Peninsula, Russia.

Chemical classifications are independent of typologies and so chemical standards can be applied on study area as far as the values are known (chapter 3.). Swedish pH parameter is achieved by modelling and Canadian water quality index is handled by a private database, therefore they are ruled out of the scope. Hydromet's pollution indices require more instruction for practical usage.

For biological classification to be feasible, national typologies should be extended to the study area. This should be possible with Finnish, Norwegian and Swedish typologies, assuming the essential hydromorphological and physiochemical measures are known (chapter 2.1.). It should be noted that there are differences in type-forming factors and categories, which affect the result's comparability (chapter 2.2.).

Biological variables were described and compared in chapter 4. Most of Finnish, Norwegian and Swedish biological classification can be conducted manually and thus they are possible to independently test with project data. Some Swedish indices require an extensive amount of accessory information for determining the reference state and data from study area might not meet their needs. Moreover, calculation of Finnish and Swedish fish indices takes an extensive effort due to their complexity. The known Russian biological metrics are straightforward and should pose no difficulties.

Consequently, Finnish, Norwegian, Russian and most of Swedish biological classifications can be tested with project data, on the condition the data is adequate quality.

Parameters in the WFD implementation have class limit values and ecological quality threshold ratios, which affect their sensitivity to environmental changes. The study brought up differences in parameter sensitivities and these should be taken into account, when evaluating each system's validity in practise.

# Annex I. Chemical standards

Table 1. The EU priority substances and other pollutants with their environmental quality standard and maximum allowable concentration for inland surface waters as presented in Procedure file 2006/0129. Cadmium concentrations are in relation to the water hardness class.

| | Name | EQS (µg/l) | MAC (µg/l) | EQS in fish (mg/kg) |
|---|---|---|---|---|
| 1 | Alachlor | 0.3 | 0.7 | - |
| 2 | Anthracene | 0.1 | 0.4 | - |
| 3 | Atrazine | 0.6 | 2 | - |
| 4 | Benzene | 10 | 50 | - |
| 5 | Pentabromodiphenylether | 0.0005 | - | - |
| 6 | Cadmium[1] | ≤ 0.08 (Class 1) | ≤ 0.45 (Class 1) | - |
| | | 0.08 (Class 2) | 0.45 (Class 2) | - |
| | | 0.09 (Class 3) | 0.6 (Class 3) | - |
| | | 0.15 (Class 4) | 0.9 (Class 4) | - |
| | | 0.25 (Class 5) | 1.5 (Class 5) | - |
| 7 | C10-13 Chloroalkanes | 0.4 | 1.4 | - |
| 8 | Chlorfenvinphos | 0.1 | 0.3 | - |
| 9 | Chlorpyrifos | 0.03 | 0.1 | - |
| 10 | 1.2-Dichloroethane | 10 | - | - |
| 11 | Dichloromethane | 20 | - | - |
| 12 | Di(2-ethylhexyl)phthalate | 1.3 | - | - |
| 13 | Diuron | 0.2 | 1.8 | - |
| 14 | Endosulfan | 0.005 | 0.01 | - |
| 15 | Fluoranthene | 0.1 | 1 | - |
| 16 | Hexachlorobenzene | 0.01 | 0.05 | 0.010 |
| 17 | Hexachlorobutadiene | 0.1 | 0.6 | 0.055 |
| 18 | Hexachlorocyclohexane | 0.02 | 0.04 | - |
| 19 | Isoproturon | 0.3 | 1 | - |
| 20 | Lead and its compounds | 7.2 | - | - |
| 21 | Mercury and its compounds | 0.05 | 0.07 | 0.020 |
| 22 | Naphthalene | 2.4 | - | - |
| 23 | Nickel and its compounds | 20 | - | - |
| 24 | Nonylphenol | 0.3 | 2 | - |
| 25 | Octylphenol | 0.1 | - | - |
| 26 | Pentachlorobenzene | 0.007 | - | - |
| 27 | Pentachlorophenol | 0.4 | 1 | - |
| 28 | Polyaromatic hydrocarbons | | - | - |
| | Benzo(a)pyrene | 0.05 | 0.1 | - |
| | Benzo(b)fluoranthene | Σ0.03 | - | - |
| | Benzo(k)fluoranthene | | | - |
| | Benzo(g.h.i)perylene | Σ0.002 | - | - |
| | Indeno(1.2.3-cd)pyrene | | | - |
| 29 | Simazine | 1 | 4 | - |

| | | | | |
|---|---|---|---|---|
| 30 | Tributyltin compound | 0.0002 | 0.0015 | - |
| 31 | Trichlorobenzenes | 0.4 | - | - |
| 32 | Trichloromethane | 2.5 | - | - |
| 33 | Trifluralin | 0.03 | - | - |
| 1 | DDT total | 0.025 | - | - |
| | para-para-DDT | 0.01 | - | - |
| 2 | Aldrin | Σ0.010 | - | - |
| 3 | Dieldrin | | | - |
| 4 | Endrin | | | - |
| 5 | Isodrin | | | - |
| 6 | Carbontetrachloride | 12 | - | - |
| 7 | Tetrachloroethylene | 10 | - | - |
| 8 | Trichloroethylene | 10 | - | - |

[1] Cadmium EQS values are set in relation to water hardness that is divided into five classes according to calcium carbonate ($CaCO_3$) concentrations : Class 1: <40 mg/l, Class 2: 40 to <50 mg/l, Class 3: 50 to <100 mg/l, Class 4: 100 to <200 mg/l and Class 5: ≥200 mg/l).

Table 2. Finland's national substances and their EQS values for annual average concentrations in inland surface waters (Aroviita et al. 2012).

| No. | Name | EQS µg/l |
|---|---|---|
| 1 | chlorobenzene | 9.3 |
| 2 | 1.2-dichlorobenzene | 7.4 |
| 3 | 1.4-dichlorobenzene | 20 |
| 4 | Benzylbutylphthalate (BBP) | 10 |
| 5 | dibutylphthalate (DBP) | 10 |
| 6 | Resorcinol | - |
| 7 | 2-(Thiocyanatomethylthio)benzothiazole) (TCMTB) | - |
| 8 | benzothiazole-2-thiol | - |
| 9 | bronopol | 4 |
| 10 | dimethoate | 0.7 |
| 11 | 4-chloro-2-methylphenoxy-acetic acid (MCPA) | 1.6 |
| 12 | metamitron | 32 |
| 13 | prochloraz | 1 |
| 14 | ethylene thiourea (mancozeb breakdown product) | 200 |
| 15 | tribenuron methyl (ISO) | 0.1 |

Table 3. Substances used in Norwegian coastal water chemical status classification and their limit concentrations for the highest class (SFT 2007).

| No. | Name | Good chemical class limit (µg/l) |
|---|---|---|
| 1 | Arsenic | 4.8 |
| 2 | Lead | 2.2 |
| 3 | Kadmium | 0.24 |
| 4 | Copper | 0.64 |
| 5 | Cromium | 3.4 |
| 6 | Mercury | 0.048 |
| 7 | Nickel | 2.2 |
| 8 | Sink | 2.9 |
| 9 | Acenaftylen | 1.3 |
| 10 | Acenaphthene | 3.8 |
| 11 | Anthracene | 0.11 |
| 12 | Benzo (a) pyrene | 0.05 |
| 13 | Benzo [a] anthracene | 0.012 |
| 14 | Benzo [b] fluoranthene | 0.03 |
| 15 | Benzo [ghi] perylene | 0.002 |
| 16 | Benzo [k] fluoranthene | 0.027 |
| 17 | Bisphenol A | 1.6 |
| 18 | Chrysene | 0.07 |
| 19 | Dibenzo [ah] anthracene | 0.03 |
| 20 | Diuron | 0.2 |
| 21 | Fluoranthene | 0.12 |
| 22 | Fluorine | 2.5 |
| 23 | HBCDD | 0.31 |
| 24 | HCB | 0.013 |
| 25 | Hexachlorbutadien | 0.44 |
| 26 | Indeno [123cd] pyrene | 0.002 |
| 27 | Irgarol | 0.008 |
| 28 | Lindane | 0.02 |
| 29 | MCCP | 0.1 |
| 30 | Naphthalene | 2.4 |
| 31 | nonylphenol | 0.33 |
| 32 | octylphenol | 0.12 |
| 33 | PBDE | 0.53 |
| 34 | Pentachlorobenzene | 1 |
| 35 | Pentachlorophenol | 0.35 |
| 36 | PFOS | 25 |
| 37 | Phenanthrene | 1.3 |
| 38 | Pyrene | 0.023 |
| 39 | SCCP | 0.5 |
| 40 | TBBPA | 0.052 |
| 41 | total DDT | 0.001 |
| 42 | Trichlorobenzene | 4 |

Table 4. Swedish draft for specific pollutants and their EQS values for annual average concentrations in inland surface waters (Naturvårdsverket 2008).

| No. | Name | EQS (µg/l) |
|---|---|---|
| 1 | Chrome | 2 |
| 2 | Zinc[1] | 8 (when hardness > 24 mg CaCO3/l)<br>3 (when hardness < 24 mg CaCO3/l) |
| 3 | Copper | 4 |
| 4 | Bronopol | 0.7 |
| 5 | Irgarol | - |
| 6 | Triclosan | 0.05 |
| 7 | MCCP | 1 |
| 8 | PFOS | 30 |
| 9 | HBCD | 0.3 |
| 10 | Bisfenol A | 1.5 |
| 11 | Nonylphenol ethoxilates[2] | 0.3 NP-TEQ |
| 12 | Aklonifen | 0.2 |
| 13 | Bentazone | 30 |
| 14 | Cyanazine | 1 |
| 15 | Diflufenikan | 0.005 |
| 16 | Diklorprop | 10 |
| 17 | Dimethoate | 0.7 |
| 18 | Fenpropimorph | 0.2 |
| 19 | Glyfosate | 100 |
| 20 | Chloridazon | 10 |
| 21 | MCPA | 1 |
| 22 | Mekoprop & Mekoprop p | 20 |
| 23 | Metamitron | 10 |
| 24 | Metribuzin | 0.08 |
| 25 | Metsulfuron-methyl | 0.02 |
| 26 | Pirimikarb | 0.09 |
| 27 | Sulfusulfuron | 0.05 |
| 28 | Tifensulfuron-methyl | 0.05 |
| 29 | Tribenuron-methyl | 0.1 |

[1] The limit for zinc is based on added risk

[2] The limit for NPE is based on the sum of nonylphenol equivalents (NPTEQ)

Table 5. Substances and their EQS for long and short-term exposure in the UK proposal for specific pollutants (UKTAG 2008).

| | | long-term | short-term |
|---|---|---|---|
| 1 | 2.4-Dichlorophenoxyacetic acid | 0.3 | 1.3 |
| 2 | 2.4-Dichlorophenol | 20 | |
| 3 | Chlorine [1] | 2 | 5 |
| 4 | Chromium VI | 3.4 | |
| 5 | Chromium III | 4.7 | 32 |
| 6 | Copper[2] | 6 | |
| 7 | Cyanide | 1 | 5 |
| 8 | Cypermethrin | 0.1 | 0.41 |
| 9 | Diazinon | 0.01 | 0.02 |
| 10 | Dimethoate | 0.48 | 4 |
| 11 | Iron | 1000 | |
| 12 | Linuron | 0.5 | 0.9 |
| 13 | Mecoprop | 18 | 187 |
| 14 | Permethrin | 0.01 | |
| 15 | Phenol | 7.7 | 46 |
| 16 | Toluene | 74 | 380 |
| 17 | Zinc [2] | 50 | |

[1] Expressed as total available chlorine
[2] Standard expressed as a function of hardness (mg $CaCO_3$/l) in the water column. The value given here corresponds to a hardness of 100 mg/l.

Table 6. Finnish metal background concentrations for lakes and rivers (Aroviita et al. 2012).

| | Cadmium[1] µg/l | Nickel µg/l | Led µg/l | Mercury (mg/kg fish) |
|---|---|---|---|---|
| Lakes | | | | |
| Clear (colour <30 Pt mg/l) | 0.02 (Classes 1 and 2) | 1 | 0.1 | 0.18 |
| moderately humic (colour 30—90 Pt mg/l) | 0.02 (Classes 1 and 2) | 1 | 0.2 | 0.2 |
| intensively humic (colour >90 Pt mg/l) | 0.02 (Classes 1 and 2) | 1 | 0.7 | 0.23 |
| Rivers | | | | |
| mineral and clay soils (catchment <25 % peatland) | 0.02 (Classes 1 and 2) | 1 | 0.3 | 0.18 |
| peatland (catchment > 25 % peatland) | 0.02 (Classes 1 and 2) | 1 | 0.5 | 0.23 |

[1] Cadmium EQS values are set in relation to water hardness that is divided into five classes according to calcium carbonate ($CaCO_3$) concentrations : Class 1: <40 mg/l, Class 2: 40 to <50 mg/l, Class 3: 50 to <100 mg/l, Class 4: 100 to <200 mg/l and Class 5: ≥200 mg/l).

Table 7. General background concentrations for metals in Sweden (Naturvårdsverket 2008).

| | Cu | Zn | Cd | Pb | Cr | Ni | Co | As | V | Hg |
|---|---|---|---|---|---|---|---|---|---|---|
| Large catchment areas | 1 | 3 | 0.003 | 0.05 | 0.2 | 0.5 | 0.05 | 0.2 | 0.1 | 0.001 |
| Small catchment areas | 0.3 | 1 | 0.002 | 0.02 | 0.1 | 0.3 | 0.03 | 0.06 | 0.06 | 0.001 |
| Lakes | 0.3 | 1 | 0.005 | 0.05 | 0.05 | 0.2 | 0.03 | 0.2 | 0.1 | 0.001 |
| Sediment | 15 | 100 | 0.3 | 5 | 5 | 10 | 15 | 8 | 20 | 0.08 |

Table 8. Murmansk Department for Hydrometeorology and Environmental Monitoring (Hydromet p.c. 2014) MAC values for certain substances monitored in Pasvik River (updated 24.1.2014).

| | Danger class | MAC mg/l |
|---|---|---|
| $NH_3$ | 4 | 0.05 |
| $NH_4^+$ (N) | 4 | 0.4 |
| $BOD_5$ | 4 | 2.0 |
| Fe | 4 | 0.1 |
| Cd | 2 | 0.005 |
| Mn | 4 | 0.01 |
| Cu | 3 | 0.001 |
| Mo | 2 | 0.001 |
| As | 3 | 0.05 |
| Ni | 3 | 0.01 |
| NO3 (N) | 3 | 9.1 |
| NO2 (N) | 4 | 0.02 |
| pH | 4 | 6.5 - 8.5 |
| $O_2$ | 4 | sum < 6.0<br>win < 4.0 |
| Hg | 1 | 0.00001* |
| Pb | 2 | 0.006 |
| Se | 2 | 0.002 |
| PO4 (P) mesotrof.<br>eutrofisille | 4 | 0.15<br>0.2 |
| COD | 4 | 15.0 |
| $Cr^{3+}$<br>$Cr^{6+}$ | 3<br>3 | 0.07<br>0.02 |
| Zn | 3 | 0.01 |
| Al | 4 | 0.04 |
| $SO^{2-}_4$ | 4 | 100 |
| | Cl | 300 |
| Na | 4 | 120 |
| Mg | 4 | 40 |
| K<br>mineralization up to 100 mg/l | 4 | 50<br>10 |
| Co | 3 | 0.01 |

Table 9. USEPA water quality criteria for aquatic life: substances and their acute and chronic limit values (USEPA 2012). The standards are mostly in use in the state of Alaska (State of Alaska 2008).

| No. | | Acute µg/l | Chronic µg/ |
|---|---|---|---|
| 1 | Acrolein | 3 | 3 |
| 2 | Aldrin | 3 | - |
| 3 | Alpha-Endosulfan | 0.22 | 0.056 |
| 4 | Aluminum pH 6.5 – 9.0 | 750 | 87 |
| 5 | Arsenic | 340 | 150 |
| 6 | beta-Endosulfan | 0.22 | 0.056 |
| 7 | Carbaryl[1] | 2.1 | 2.1 |
| 8 | Cadmium[2] | 2 | 0.25 |
| 9 | Chlordane | 2.4 | 0.0043 |
| 10 | Chloride | 860000 | 230000 |
| 11 | Chlorine | 19 | 11 |
| 12 | Chloropyrifos | 0.083 | 0.041 |
| 13 | Chromium (III) [2] | 570 | 74 |
| 14 | Chromium (VI) | 16 | 1 |
| 15 | Copper[3] | 4.67 | |
| 16 | Cyanide | 22 | 5.2 |
| 17 | DDT. 4.4' | 1.1 | 0.001 |
| 18 | Demeton | - | 0.1 |
| 19 | Diazinon | 0.17 | 0.17 |
| 20 | Dieldrin | 0.24 | 0.056 |
| 21 | Endrin | 0.086 | 0.036 |
| 22 | gamma-BHC (Lindane) | 0.95 | - |
| 23 | Guthion | - | 0.01 |
| 24 | Heptachlor | 0.52 | 0.0038 |
| 25 | Heptachlor Epoxide | 0.52 | 0.0038 |
| 26 | Iron | - | 1000 |
| 27 | Lead[2] | 65 | 2.5 |
| 28 | Malathion | - | 0.1 |
| 29 | Mercury/Methylmercury | 1.4 | 0.77 |
| 30 | Methoxychlor | - | 0.03 |
| 31 | Mirex | - | 0.001 |
| 32 | Nickel[2] | 470 | 52 |
| 33 | Nonylphenol | 82 | 6.6 |
| 34 | Parathion | 0.065 | 0.013 |
| 35 | Pentachlorophenol | 19 | 15 |
| 36 | Polychlorinated Biphenyls (PCBs) | - | 0.014 |
| 37 | Selenium | - | 5 |
| 38 | Silver[12] | 3.2 | - |
| 39 | Sulfide-Hydrogen Sulfide | - | 2 |
| 40 | Toxaphene | 0.73 | 0.0002 |
| 41 | Tributyltin (TBT) | 0.46 | 0.072 |

| | | | |
|---|---|---|---|
| 42 | Zinc[2] | 120 | 120 |

[1] Value by USEPA general national criteria

[2] Standard expressed as a function of hardness (mg $CaCO_3$/l) in the water column. The value given here corresponds to a hardness of 100 mg/l.

[3] Chronic criteria concentrations calculated by the Biotic Ligand Model.

Table 10. The USEPA Ammonia Criteria (2009) chronic values.

| | Total ammonia (µg/l) |
|---|---|
| mussel present | 260 |
| mussel absent | 1800 |
| fish early stages present | 1200 |

Table 11. Canadian water quality criteria for the protection of aquatic life: substances, their short and long term limit values (CCME 2011).

| No | | short-term (µg/l) | long-term (µg/l) |
|---|---|---|---|
| 1 | 1.2.4-Trichlorobenzene | | 24 |
| 2 | 1.2-Dichlorobenzene | | 0.7 |
| 3 | 1.2-Dichloroethane | | 100 |
| 4 | 1.3-Dichlorobenzene | | 150 |
| 5 | 1.4-Dichlorobenzene | | 26 |
| 6 | 3-Iodo-2-propynyl butyl carbamate | | 1.9 |
| 7 | Acenaphthene | | 5.8 |
| 8 | Acridine | | 4.4 |
| 9 | Aldicarb | | 1 |
| 10 | Aldrin | | 0.004 |
| 11 | Aluminium | | 5 µg/l if pH < 6.5 |
| 12 | | | 100 µg/l if pH ≥ 6.5 |
| 13 | Ammonia (un-ionized) | | 19 |
| 14 | Aniline | | 2.2 |
| 15 | Anthracene | | 0.012 |
| 16 | Arsenic | | 5 |
| 17 | Atrazine | | 1.8 |
| 18 | Benzene | | 370 |
| 19 | Benzo(a)anthracene | | 0.018 |
| 20 | Benzo(a)pyrene | | 0.015 |
| 21 | Boron | 29000 | 1500 |
| 22 | Bromacil | | 5 |
| 23 | Bromoxynil | | 5 |
| 24 | Cadmium[1] | 1 | 0.09 |
| 25 | Captan | | 1.3 |
| 26 | Carbaryl | 3.3 | 0.2 |
| 27 | Carbofuran | | 1.8 |
| 28 | Chlordane | | 0.006 |

| | | | |
|---|---|---|---|
| 29 | Chloride | 640000 | 120000 |
| 30 | Chlorothalonil | | 0.18 |
| 31 | Chlorpyrifos | 0.02 | 0.002 |
| 32 | Chromium. hexavalent (Cr(VI)) | | 1 |
| 33 | Chromium. trivalent (Cr(III)) | | 8.9 |
| 34 | Copper[1] | | 2.36 |
| 35 | Cyanazine | | 2 |
| 36 | Cyanide[2] | | 5 |
| 37 | Deltamethrin | | 0.0004 |
| 38 | Di(2-ethylhexyl) phthalate | | 16 |
| 39 | Di-n-butyl phthalate | | 19 |
| 40 | Dicamba | | 10 |
| 41 | Total DDT | | 0.001 |
| 42 | Dichloromethane | | 98.1 |
| 43 | Dichlorophenols | | 0.2 |
| 44 | Diclofop-methyl | | 6.1 |
| 45 | Didecyl dimethyl ammonium chloride | | 1.5 |
| 46 | Diisopropanolamine | | 1600 |
| 47 | Dimethoate | | 6.2 |
| 48 | Dinoseb | | 0.05 |
| 49 | Endosulfan | | 0.003 |
| 50 | Endrin | | 0.0023 |
| 51 | Ethylbenzene | | 90 |
| 52 | Ethylene glycol | | 192000 |
| 53 | Fluoranthene | | 0.04 |
| 54 | Fluorene | | 3 |
| 55 | Fluoride | | 120 |
| 56 | Glyphosate | | 800 |
| 57 | Heptachlor | | 0.01 |
| 58 | Hexachlorobutadiene | | 1.3 |
| 59 | Hexachlorocyclohexane | | 0.01 |
| 60 | Imidacloprid | | 0.23 |
| 61 | Iron | | 300 |
| 62 | Lead[1] | | 3.18 |
| 63 | Linuron | | 7 |
| 64 | Mercury | | 0.026 |
| 65 | Methoprene | | 0.09 |
| 66 | Methyl tertiary-butyl ether | | 10000 |
| 67 | Methylchlorophenoxyacetic acid MCPA | | 2.6 |
| 68 | Methylmercury | | 0.004 |
| 69 | Metolachlor | | 7.8 |
| 70 | Metribuzin | | 1 |
| 71 | Molybdenum | | 73 |
| 72 | Monochlorobenzene | | 1.3 |

| | | | |
|---|---|---|---|
| 73 | Monochlorophenols | | 7 |
| 74 | Naphthalene | | 1.1 |
| 75 | Nickel[1] | | 95.58 |
| 76 | Nitrate | 550000 | 13000 |
| 77 | Nitrite | | 60 |
| 78 | Nonylphenol and its ethoxylates | | 1 |
| 79 | Pentachlorobenzene | | 6 |
| 80 | Pentachlorophenol | | 0.5 |
| 81 | Permethrin | | 0.004 |
| 82 | Phenanthrene | | 0.4 |
| 83 | Phenols (mono- & dihydric) | | 4 |
| 84 | Phenoxy herbicides | | 4 |
| 85 | Picloram | | 29 |
| 86 | Polychlorinated biphenyls | | 0.001 |
| 87 | Propylene glycol | | 500000 |
| 88 | Pyrene | | 0.025 |
| 89 | Quinoline | | 3.4 |
| 90 | Reactive Chlorine Species* | | 0.5 |
| 91 | Selenium | | 1 |
| 92 | Silver | | 0.1 |
| 93 | Simazine | | 10 |
| 94 | Styrene | | 72 |
| 95 | Sulfolane | | 50000 |
| 96 | Tebuthiuron | | 1.6 |
| 97 | Tetrachloromethane | | 13.3 |
| 98 | Tetrachlorophenols | | 1 |
| 99 | Thallium | | 0.8 |
| 100 | Toluene | | 3 |
| 101 | Toluene | | 0.008 |
| 102 | Triallate | | 0.24 |
| 103 | Tributyltin | | 0.008 |
| 104 | Trichloromethane | | 1.8 |
| 105 | Tricyclohexyltin | | 18 |
| 106 | Trifluralin | | 0.2 |
| 107 | Triphenyltin | | 0.022 |
| 108 | Uranium | | 15 |
| 109 | Zinc | | 30 |
| | Sulphate[3] | 100000 | 50000 |

[1] Standard expressed as a function of hardness (mg $CaCO_3$/l) in the water column. The value given here corresponds to a hardness of 100 mg/l.

[2] As free concentration.

[3] Sulphate by aquatic life ambient water quality guidelines for British Columbia (2000)

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# Annex II. Local cyanobacteria taxa considered toxic by Finland, Sweden and the UK.

| FI | SWE | the UK |
|---|---|---|
| Anabaena spp. | Anabaena spp. | Anabaena spp. |
| Aphanizomenon spp. | Aphanizomenon spp. | Aphanizomenon spp. |
| | | Coelosphaerium naegelianum |
| Microcystis spp. | Gloeotrichia spp. | |
| Planktothrix spp. | Limnothrix ssp | Lyngbya spp. |
| Woronichinia spp. | Microcystis spp. | Microcystis spp. |
| | Planktothrix spp. | Oscillatoria spp. |
| | Pseudanabaena spp. | Pseudanabaena spp. |
| | Woronichinia spp. | Spirulina spp. |
| | | Woronichinia naegeliana |