SWEDISH ENVIRONMENTAL PROTECTION AGENCY

ENVIRONMENTAL QUALITY CRITERIA

Lakes and Watercourses

REPORT 5050

Environmental Quality Criteria – Lakes and Watercourses REPORT 5050

ENVIRONMENTAL

QUALITY CRITERIA

Lakes and Watercourses

SWEDISH ENVIRONMENTAL PROTECTION AGENCY

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Foreword

Based on favourable experience with "Environmental Criteria for Lakes and Watercourses", the Swedish Environmental Protection Agency decided in 1994 to develop a more comprehensive system for evaluating a variety of ecosystems, under the heading of "ENVIRONMENTAL QUALITY CRITERIA". This development work has resulted in six separate reports on: the Forest Landscape, the Agricultural landscape, Groundwater, Lakes and Watercourses, Coasts and Seas, and Contaminated Sites.

ENVIRONMENTAL QUALITY CRITERIA provide a means of interpreting and evaluating environmental data which is scientifically based, yet easy to understand. Indicators and criteria are also being developed by many other countries and international organizations. The Swedish Environmental Protection Agency has followed those developments, and has attempted to harmonise its criteria with corresponding international approaches.

The reports generated thus far are based on current accumulated knowledge of environmental effects and their causes. But that knowledge is constantly improving, and it will be necessary to revise the reports from time to time. Such revisions and other developments may be followed on the Environmental Protection Agency's Internet web site, www.environ.se. Concise versions of the reports are available there as well.

Development of the environmental quality criteria has been carried out in co-operation with colleges and universities. Various national and regional agencies have been represented in reference groups. The project leaders at the Environmental Protection Agency have been: *Rune Andersson*, Agricultural landscapes; *Ulf von Brömssen,* Groundwater; *Kjell Johansson*, Lakes and Watercourses; *Sif Johansson,* Coasts and Seas; *Marie Larsson* and *Thomas Nilsson,* Forest Landscapes; and *Fredrika Norman,* Contaminated Sites.

Project co-ordinators have been Marie Larsson (1995-97) and Thomas Nilsson (1998). Important decisions and the establishment of project guidelines have been the responsibility of a special steering committee consisting of *Erik Fellenius* (Chairman), *Gunnar Bergvall, Taina Bäckström, Kjell Carlsson, Rune Frisén, Kjell Grip, Lars-Åke Lindahl, Lars Lindau, Anita Linell, Jan Terstad, Eva Thörnelöf* and *Eva Ölundh.*

In April of 1998, public agencies, colleges and universities, relevant organizations and other interested parties were provided the opportunity to review and comment upon preliminary drafts of the reports. That process resulted in many valuable suggestions, which have been incorporated into the final versions to the fullest extent possible. The Swedish Environmental Protection Agency is solely responsible for the contents of the reports, and wishes to express its sincere gratitude to all who participated in their production.

Stockholm, Sweden, January 2000
Swedish Environmental Protection Agency

Summary

This report on lakes and watercourses is one of a six-part series of reports published by the Swedish Environmental Protection Agency under the title ENVIRONMENTAL QUALITY CRITERIA. The other titles in the series are the Forest Landscape, the Agricultural Landscape, Groundwater, Coasts and Seas and Contaminated Sites. The purpose of this report is to enable local and regional authorities and others to make accurate assessments of environmental quality on the basis of available data on the state of the environment and thus obtain a better basis for environmental planning and management by objectives. Each report contains model criteria for a selection of parameters corresponding to the objectives and threats existing in the area dealt with by the report. The assessment involves two aspects: (i) an appraisal of the state of the environment *per se* in terms of the quality of the ecosystem; (ii) an appraisal of the extent to which the recorded state deviates from a "comparative value". In most cases the comparative value represents an estimate of a "natural" state. The results of both appraisals are expressed on a scale of 1 – 5.

The report on lakes and watercourses provides a basis for assessing the status of aquatic areas in terms of physical and chemical factors such as nutrients/eutrophication, oxygen levels and oxygen-consuming substances, visibility, acidity/acidification and metals. The report also contains data on which to base an assessment of biological conditions in the form of species balance and quantities of planktonic algae, aquatic plants, diatoms, benthic macroinvertebrates and fish. In general, assessments are assumed to have been based on data gathered in accordance with the instructions in the Swedish EPA Environmental Monitoring Handbook. These environmental quality criteria for lakes and watercourses represent a substantial modification and expansion of the previous version (Swedish EPA General Guidelines 90:4), which they replace.

Environmental Quality Criteria

The vision of an ecologically sustainable society includes protection of human health, preservation of biodiversity, conservation of valuable natural and historical settings, an ecologically sustainable supply and efficient use of energy and other natural resources. In order to determine how well basic environmental quality objectives and more precise objectives are being met, it is necessary to continuously monitor and evaluate the state of the environment.

Environmental monitoring has been conducted for many years at both the national and regional levels. But, particularly at the regional level, assessments and evaluations of current conditions have been hindered by a lack of uniform and easily accessible data on baseline values, environmental effects, etc.

This report is one of six in a series which purpose is to fill that information gap, by enabling counties and municipalities to make comparatively reliable assessments of environmental quality. The reports can thus be used to provide a basis for environmental planning, and for the setting of local and regional environmental objectives.

The series bears the general heading of "ENVIRONMENTAL QUALITY CRITERIA", and includes the following titles: *The Forest Landscape, The Agricultural Landscape, Groundwater, Lakes and Watercourses, Coasts and Seas*, and *Contaminated Sites.* Taken together, the six reports cover most of the natural ecosystems and other types of environment found in Sweden. It should be noted, however, that coverage of wetlands, mountains and urban environments is incomplete.

Each of the reports includes assessment criteria for a selection of parameters relating to objectives and threats that are associated with the main subject of the report. The selected parameters are, for the most part, the same as those used in connection with national and regional environmental monitoring programmes; but there are also some "new" parameters that are regarded as important in the assessment of environmental quality.

Most of the parameters included in the series describe current conditions in natural environments, e.g. levels of pollution, while direct measures of human impacts, such as the magnitude of emissions, are generally not

included. In addition to a large number of chemical parameters, there are several that provide direct or indirect measures of biodiversity.

In all of the reports, assessments of environmental quality are handled in the same way for all of the parameters, and usually consist of two separate parts (see also page 11). One part focuses on the effects that observed conditions can be expected to have on environment and human health. Since knowledge of such effects is often limited, the solution in many cases has been to present a preliminary classification scale based on general knowledge about the high and low values that are known to occur in Sweden.

The second focuses on the extent to which measured values deviate from established reference values. In most cases, the reference value represents an approximation of a "natural" state, i.e. one that has been affected very little or not at all by human activities. Of course, "natural" is a concept that is not relevant to the preservation of cultural environments; in such contexts, reference values have a somewhat different meaning.

The results of both parts are expressed on a scale of 1-5, where Class 1 indicates slight deviations from reference values or no environmental effects, and Class 5 indicates very large deviations or very significant effects.

The report on Contaminated Sites with its discussion of pollutants in heavily affected areas complements the other five reports. In those cases where the parameters are dealt with in several of the reports, which is particularly the cases for metals, the report on Contaminated Sites corresponds (see further pages 11-12). However, the various parameters cannot be compared with each other in terms of risks. The following paragraphs review the extent of agreement with corresponding or similar systems used by other countries and international organizations.

INTERNATIONAL SYSTEMS FOR ENVIRONMENTAL QUALITY ASSESSMENT

Among other countries, the assessment system that most resembles Sweden's is that of Norway. The Norwegian system includes "Classification of Environmental Quality in Fjords and Coastal Waters" and "Environmental Quality Classification of Fresh Water". A five-level scale is used to classify current conditions and usability. Classifications are in some cases based on levels of pollution, in other cases on environmental effects.

The European Union's proposal for a framework directive on water quality includes an assessment system that in many ways is similar to the Swedish Environmental Quality Criteria.

If the parameters used in the latter are regarded as forms of environmental indicators, there are many such systems in use or under development. However, the concept of environmental indicators is much broader than the parameters of Environmental Quality Criteria.

Internationally, the most widely accepted framework for environmental indicators is based on PSR-chains (Pressure-State-Response). Indicators are chosen which reflect the relationship between environmental effects, and/or there causes and measures taken. There is also a more sophisticated version, called DPSIR (Driving forces-Pressure-State-Impact-Response). Variants of the PSR/DPSIR systems are used by, among others, the OECD, the Nordic Council of Ministers, the United Nations, the World Bank, the European Union's Environmental Agency.

ASSESSMENT PROCEDURE

Measurements/data

Assessment of current conditions — indicates environmental effects associated with current conditions

Assessments of deviation from reference values — indicates environmental impact of human activity

Assessment of current conditions

Wherever possible, the scale used in assessments of current conditions is correlated with effects on different parts of the ecosystems and their biodiversity, or on human health (”effect-related classification”). In some cases, the assessment is based only on a statistical distribution of national data (”statistical classification”).

The scale is usually divided into five classes. Where the assessment is based on effects, Class 1 indicates conditions at which there are no known negative effects on the environment and/or human health. The remaining classes indicate effects of increasing magnitude. Class 5 includes conditions leading to the most serious negative effects on the environment and/or human health. Due to wide natural variations, especially with regard to biological phenomena, the indicated effects are not always the result of human activities, in which case they can not be labelled as “negative”(see below).

Where the assessment is based only on a statistical distribution, there is no well-defined relationship between effects and class limits. It should be noted that parameters that are evaluated on the basis of different criteria cannot be compared with each other.

Reference values

Ideally, the reference value for a given parameter represents a natural state that has not been affected by any human activity. In practice, however, reference values are usually based on observations made in areas that have experienced some slight human impact. In some cases, historical data or model-based estimates are used. Given that there are wide natural variations of several of the parameters, reference values in many cases vary by region or type of ecoystem.

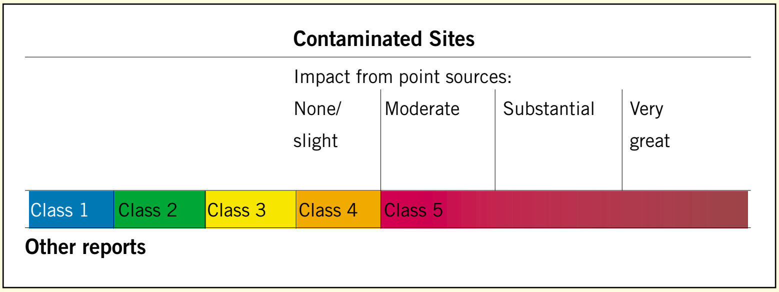
Deviations from reference values

The extent of human impact can be estimated by calculating deviations from reference values, which are usually stated as the quotient between a measured value and the corresponding reference value:

$$\text{Deviation} = \frac{\text{Measured value}}{\text{Reference value}}$$

The extent of deviation is usually classified on a five-level scale. Class 1 includes conditions with little or no deviation from the reference value, which means that effects of human activity are negligible. The remaining classes indicate increasing levels of deviation (increasing degree of impact). Class 5 usually indicates very significant impact from local sources.

Organic pollutants and metals in heavily polluted areas are dealt with in greater detail in a separate report, Contaminated Sites, which includes a further sub-division of Class 5, as follows:



Environmental Quality Criteria for Lakes and Watercourses

Choice of parameters

Environmental Quality Criteria for Lakes and Watercourses should be used to evaluate the results of environmental monitoring and other studies. The parameters and methods to be used for this purpose are largely determined using the Swedish EPA Environmental Monitoring Handbook. Similarly, studies commenced before publication of the handbook are governed by the Agency's General Guidelines for Coordinated Monitoring of Receiving Bodies.

The Swedish EPA method instructions contain a large number of parameters. It is hardly feasible or even desirable to produce model criteria for all of them. Instead, the parameters selected for this report are those considered to be the most important indicators of water quality in a wide sense. Hence, chemical parameters include those indicating threats to the environment such as eutrophication, acidification and the presence of metals. Among biological parameters are measures of the state of different parts of food chains and which in some cases are relevant to use of the water. The biological parameters do not usually reflect specific threats; rather they provide an integrated measure of the environmental situation as a whole and any impact to which an aquatic area may be exposed. The environmental relevance of each parameter is explained in detail in the individual chapters and in the reasons given for each type of investigation in the EPA Environmental Monitoring Handbook.

For various reasons it has not been possible to include some parameters, which do in fact represent important aspects of water quality. These include measures of hydrological and substrate conditions. Nor has it been possible to formulate instructions for assessing changes in water quality over time.

An outline of the parameters included is given in Table 1 on pages 14 and 15.

Classification and class delimitation

Environmental Quality Criteria use two types of scale: one for assessing current conditions and one for assessing deviation from reference values.

TABLE 1.

SUMMARY of parameters included in Environmental Quality Criteria for Lakes and Watercourses (a minus sign indicates the absence of model criteria).

Area/parameter	Lakes/ water-courses	Current conditions	Deviation from reference value
Nutrients/eutrophication			
Total phosphorus concentration	l	+	+
Total nitrogen concentration	l	+	-
Total nitrogen/total phosphorus ratio (by weight)	l	+	-
Area-specific total nitrogen loss	w	+	+
Area-specific total phosphorus loss	w	+	+
Oxygen status and oxygen-consuming substances			
Oxygen concentration	l/w	+	-
TOC (total organic carbon)	l/w	+	-
CODMn (chemical oxygen demand)	l/w	+	-
Light conditions			
Absorbency	l/w	+	-
Water colour	l/w	+	-
Turbidity	l/w	+	-
Secchi depth	l	+	-
Acidity/acidification			
Alkalinity	l/w	+	+
pH	l/w	+	-
Metals			
Metals in water, sediment, moss and fish	l/w*	+	-
Phytoplankton			
Total volume	l	+	+
Chlorophyll concentration	l	+	+
Diatoms	l	+	-
Water-blooming cyanobacteria	l	+	+
Potentially toxin-producing cyanobacteria	l	+	+
Biomass *Gonyostomum semen*	l	+	+

TABLE 1.

Continued

Area/parameter	Lakes/ water-courses	Current conditions	Deviation from reference value
Aquatic plants			
Submerged and floating-leaved plants,			
number of species and indicator ratio**	l	+	+
Periphyton – diatoms			
IPS index	w	+	-
IDG index	w	+	-
Benthic fauna			
Shannon's diversity index***	l/w	+	+
Danish fauna index***	l/w	+	+
ASPT index***	l/w	+	+
Acidity index	l/w	+	+
BQI index****	l	+	+
O/C index****	l	+	+
Fish			
Naturally occurring Swedish species	l/w	+	+
Species diversity of native species	l	+	+
Biomass of native species	l/w	+	+
Number of individuals of native species	l/w	+	+
Proportion of cyprinids	l	-	+
Proportion of Piscivorous fish	l	+	+
Proportion of salmonids	w	+	+
Salmonid reproduction	w	+	+
Species and stages sensitive to acidification	l/w	-	+
Species tolerant of low oxygen concentrations	l	-	+
Proportion of biomass comprising alien species	l/w	-	+
Composite value derived from (part of) the above	l/w	+	+

* lake sediment

** indicator value for assessing deviation from reference value

*** in lakes: the littoral zone

**** the profundal zone

The current conditions scale in this report is based on the levels occurring in Sweden for each parameter and, to some extent, on the biological and other conditions characterising different levels. Hence, as far as possible, the boundaries between the classes coincide with clear changes on the relevant gradient. Where it has not been possible to identify levels where such changes occur, boundaries have been decided statistically on the basis of the most representative data possible, or arbitrarily on the basis of an overall judgement of what can be considered reasonable.

The width of the classes varies, depending on the way each parameter changes along a gradient from low to high or vice versa. In some cases, changes in the lower range of the scale are particularly significant. Here scales have been graduated to give them sufficient resolution in this respect. In other cases, changes occur gradually along a gradient and the boundaries between classes are more evenly distributed along the scale. The way scales have been developed for individual parameters may be seen in each chapter.

It should be emphasised that the assessment scales cannot easily be interpreted as representing ”good” or ”bad” environmental quality. The parameters must be evaluated individually in the light of the quality aspects they are intended to reflect. This applies particularly to the scales for assessment of current conditions. A number of examples serve to illustrate this. Chemical parameters such as metals, organic pollutants and alkalinity are fairly closely related to water quality in the sense that increasing concentrations (decreasing for alkalinity) can generally be said to reflect a growing risk of negative effects on aquatic organisms or use of water resources. The scale for total phosphorus reflects conditions for increasing quantities of phytoplankton in water. From an aesthetic viewpoint, for bathing, water supply etc, an increase of this kind is generally considered undesirable, but in production terms, the scale should have been placed the other way round. This has not been done because the total phosphorus parameter is primarily intended to indicate conditions for the presence of phytoplankton and associated adverse effects. This rationale also underlies the form chosen for assessment scales for other parameters. Thus, classification of the state of fish assemblages is based on expected fish numbers and diversity of fish species. Class 1 (lakes) indicates a large number of fish, a large number of species with high diversity and a high proportion of piscivorous species, ie, a rich and diverse fish community. Class 1 watercourses feature a large number of salmonids with high breeding success. Class 3 indicates that the fish assemblages in the lake or watercourse are average for Swedish waters, whereas class 5 indicates assemblages poor in numbers of species and individuals. In the case of parameters where contradictory interpretations or evaluations are possible, the direction of the scales has been decided by the environmental quality aspects each parameter is primarily intended to indicate and factors that have been deemed essentially ”good” or ”bad” in this respect.

Assessing deviation from reference values is generally less of a problem than assessing current conditions. Increasingly pronounced deviation from the reference value, ie, from a natural state, is usually regarded as negative. Here too, therefore, class 1 represents the most favourable conditions and class 5 the least favourable. Once again, the assessment is made in the light of the quality aspects the respective parameters are primarily intended to reflect. Growing deviations may be favourable from other perspectives, which should be borne in mind when using the scales.

The boundaries between classes are such that the classes might be perceived to overlap. However, when entering recorded values account should be taken of the way the threshold for the highest or lowest class has been expressed. Hence, (2.0 for class 1 and 2.0 – 5.0 for class 2 (chlorophyll concentration in lakes) means that a readings of 2.0 should be entered in class 1 and a reading of 5.0 in class two, and so on.

Reference values

The reference values have been arrived at in different ways for different parameters, depending on the availability of data. In some cases it has been possible to use the reference stations in the Swedish National Environmental Monitoring Programme. In others, collated data from environmental monitoring or from specific studies has been used, usually having eliminated stations considered to be affected. As regards fish, calculations have been made using national or supra-regional data bases in their entirety. Thus, these reference values represent the mean situation in Swedish lakes and watercourses across the country or for different types of lakes and watercourses. It has not been considered possible to identify pristine waters. Finally, it has not been possible to set reference values for some parameters at all. Here, assessments can only be made using a state scale (current conditions).

In general, it has only been possible to a limited extent to give instructions on reference values specific to a given lake or watercourse, ie, on the way in which reference values for a particular lake or watercourse can be determined in the light of its position and other surrounding factors. Further work on development of calculation models is needed in this field. In the absence of such methods, reference values have been calculated statistically for regions (see next chapter) or groups of lakes/watercourses, eg, different types of lakes. The accuracy of these values varies and the assessment should be made with this in mind and in the light of the factors and conditions presented in the relevant background report (in Swedish with English summary). The method of identifying reference values is explained in each chapter. In general, it may be said that further systematic studies are needed for most parameters in order to obtain representative data.

It was proposed in the previous quality criteria for lakes and watercourses (Swedish EPA 1991) that county administrative boards and water management associations should compile maps on background conditions by catchment based on results from earlier surveys and studies of unaffected lakes and watercourses or using specified calculation algorithms. This is still to be recommended and would probably allow better adjustment to local or regional conditions than direct application of the reference values presented here, which are often regional and statistically based.

Division in type areas

Since available data varies greatly from one parameter to another and since various surrounding factors are significant to each parameter, it has not been possible to classify geographical regions and water types on the basis of principles common to all parameters. The various classifications are described in each chapter.

References

Swedish Environmental Protection Agency (1991): Bedömningsgrunder för sjöar och vattendrag (”Quality criteria for lakes and watercourses”). Swedish EPA General Guidelines 90:4.

Nutrients / eutrophication

Introduction

Elevated nutrient levels, known as eutrophication, result from an increased influx or increased availability of plant nutrients in lakes and watercourses. Eutrophication leads to increased production and plant and animal biomass, increased turbidity, greater oxygen demand resulting from the decomposition or organic matter and a change in species composition and diversity of plant and animal communities. In most cases the nutrients governing vegetative growth in fresh water are phosphorus (P) and, in a few cases, nitrogen (N).

Total phosphorus, total nitrogen and the phosphorus/nitrogen ratio are parameters used to assess *lakes*. Total phosphorus has been chosen even though this includes phosphorus fixed in minerals and humus, which is not directly available to plants. This is due to the need for an indicator that is analytically straightforward and generally used. The relative importance of phosphorus and nitrogen is proportional to the quantities in which they occur, here described as the weight ratio between the concentration of total nitrogen and that of total phosphorus. This indicates a deficit or surplus of the two elements and shows the potential for nitrogen fixation and for accumulation of nitrogen-fixing cyanobacteria ("blue-green algae"). The concentration of total phosphorus, like the N/P ratio, can be clearly linked to biological and biochemical effects. Unlike the N/P ratio, the scale for total nitrogen concentrations, which is also given, does not measure the effects of nitrogen on production; it is intended to differentiate between various typical concentrations in Swedish lakes.

The area-specific loss of nitrogen and phosphorus, respectively, is used when assessing *watercourses*. Although this indicator, in principle, mainly belongs to the criteria for the Agricultural Landscape and the Forest Landscape, it has been included here since monitoring and calculation of these losses are a normal and increasingly important part of the environmental water monitoring programme and since area-specific losses and discharge of plant nutrients are of importance to the pollution burden on lakes and marine areas.

Area-specific losses are also an indirect predictor of production conditions for watercourse flora and fauna. No specific scales are given for assessing concentrations of nitrogen or phosphorus in watercourses; it is expected that these will be evaluated having been converted in area-specific losses. Instructions for conversion are given with the scales in question.

High concentrations of nitrate in drinking water can constitute a health problem and the National Food Administration defines drinking water as ”fully fit for consumption” when nitrate concentrations are below 10 mg NO3-N/l. Assessment scales for nitrate are not given here, however.

Ammonium is converted into molecular ammoniac in an equilibrium reaction at high pH levels. The risk of fish and other aquatic organisms being poisoned rises rapidly at high ammonium concentrations at pH level exceeding about 8. Calculation methods and criteria for toxicity to fish and other aquatic organisms have been published (see references). Assessment scales for ammoniac are not given here.

Assessment of current conditions

TABLE 2.

CURRENT CONDITIONS: concentration of total phosphorus in lakes (μg/l)

Class	Description	Concentration May – October	Concentration August
1	Low concentrations	≤ 12.5	≤ 12.5
2	Moderately high concentrations	12.5 – 25	12.5 – 23
3	High concentrations	25 – 50	23 – 45
4	Very high concentrations	50 – 100	45 – 96
5	Extremely high concentrations	> 100	Not defined

Concentrations are given as seasonal mean (May – October) over one year based on monthly readings taken in the epilimnion or, if only one sample is taken, surface water (0.5 m). The concentration of total phosphorus displays little seasonal variation at lower concentration ranges and an assessment can also be made of concentrations recorded in August as shown above, although it should then be assessed as a mean figure over three years. Late summer concentrations vary enormously at extremely high concentrations and seasonal mean figures should be used to make an assessment. The classes relate to various production levels long used by limnologists, principally determined by the phosphorus concentrations. Using accepted terminology, the classes correspond to oligotrophy (1), mesotrophy (2), eutrophy (3 and 4) and hypertrophy (5). There is good reason to define a further characteristic sub-group with concentrations below 6 µg/l within the oligotrophic range. This group represents ultra-oligotrophy.

Total nitrogen is more variable during the season than total phosphorus and is therefore unsuitable for assessments based on concentrations in August. Inorganic nitrogen (nitrate + ammonium) peaks markedly in late winter and organic nitrogen reaches a peak in the summer. It is therefore difficult to describe a general pattern of variation for total nitrogen.

TABLE 3.

CURRENT CONDITIONS: concentration of total nitrogen in lakes (µg/l)

Class	Description	Concentration May – October
1	Low concentrations	≤ 300
2	Moderately high concentrations	300 – 625
3	High concentrations	625 – 1.250
4	Very high concentrations	1.250 – 5.000
5	Extremely high concentrations	> 5.000

TABLE 4.

CURRENT CONDITIONS: ratio of total nitrogen/ total phosphorus in lakes

Class	Description	Ratio June – September
1	Nitrogen surplus	≥ 30
2	Nitrogen – phosphorus balance	15 – 30
3	Moderate nitrogen deficit	10 – 15
4	Large nitrogen deficit	5 – 10
5	Extreme nitrogen deficit	< 5

The assessment scale is intended to group concentrations that are typical of Swedish lakes and is not related to biological/microbial effects.

The scale refers to the mean value during June – September over one year based on monthly readings taken in the epilimnion or, if only one sample is taken, surface water (0.5 m). The ratios are weight-based and show the availability of nitrogen in relation to phosphorus in lakes.

In class 1 the availability of phosphorus alone governs production; in class 2 there is a tendency for accumulation of cyanobacteria ("blue-green algae") in general; in class 3 the occurrence of nitrogen fixation and specific nitrogen-fixing cyanobacteria is likely; in class 4 nitrogen fixation is highly likely but cannot fully compensate for the nitrogen deficit, and in class 5 the nitrogen deficit is extreme and fixation is unable to compensate.

TABLE 5.

CURRENT CONDITIONS: area-specific loss of total nitrogen, watercourses (kg N/ha, year)

Class	Description	Area-specific loss
1	Very low losses	≤ 1.0
2	Low losses	1.0 – 2.0
3	Moderately high losses	2.0 – 4.0
4	High losses	4.0 – 16.0
5	Very high losses	> 16

Area-specific losses refer to the monitoring of concentrations 12 times a year over three years and recorded or modelled water flow per 24-hour period. It may be necessary to monitor concentrations more frequently in small watercourses. 24-hour water flow figures are multiplied by the corresponding concentrations obtained using linear interpolation between readings. The 24-hour transport figures thus obtained are accumulated to give annual figures and show area-specific losses after division by the area of the catchment.

Nitrogen loss includes input from all sources upstream of the monitoring point, which classifies the total area-specific input from the catchment to lakes and seas, for example. The scale is also intended to be used to assess losses from all types of soil in comparison with normal losses from different types of land use. Known input from point sources can be deducted to gain a better picture of diffuse nitrogen losses.

Class 1 represents normal leaching from mountain heaths and the poorest forest soils. Class 2 shows normal leaching from non-nitrogen-saturated forest soils in northern and central Sweden. Class 3 contains losses from unaffected bog/peat land and affected forest soils (eg, leaching from certain clear-cut areas), as well as leaching from arable soils (unfertilised seeded grassland). Class 4 shows common leaching from fields in lowland areas and class 5 represents leaching from cultivated sandy soils, often combined with manure use.

Since nitrogen losses over fairly large agricultural areas exceed 16 kg N/ha, there is reason to make particular note of areas where nitrogen losses are extreme (over 32 kg N/ha, year). This is particularly called for when setting priorities for remedial measures.

The different classes are matched by various flow-weighted annual mean concentrations, depending on the flow per unit surface area. Figure 1 shows the correlations between area-specific loss and concentration at four different levels of flow per unit surface area.

TABLE 6.

CURRENT CONDITIONS: area-specific loss of total phosphorus, watercourses (kg P/ha, year)

Class	Description	Area-specific loss
1	Very low losses	≤ 0.04
2	Low losses	0.04 – 0.08
3	Moderately high losses	0.08 – 0.16
4	High losses	0.16 – 0.32
5	Very high losses	> 0.32

Area-specific losses refer to the monitoring of concentrations 12 times a year over three years and recorded or modelled water flow per 24-hour period. It may be necessary to monitor concentrations more frequently in small watercourses. 24-hour water flow figures are multiplied by the corresponding concentrations obtained using linear interpolation between readings. The 24-hour transport figures thus obtained are accumulated to give annual figures and show area-specific losses after division by the area of the catchment.

Phosphorus loss includes input from all sources upstream of the monitoring point, which classifies the total area-specific input from the catchment to lakes and seas, for example. The scale is also intended to be used to assess losses from all types of soil in comparison with normal losses from different types of land use. Known input from point sources can be deducted to gain a better picture of diffuse phosphorus losses.

Class 1 represents the lowest leaching on record from unaffected forest soils. Class 2 shows normal leaching from normal forest soils in Sweden. Class 3 contains losses from clear-cut areas, bog/peat land,

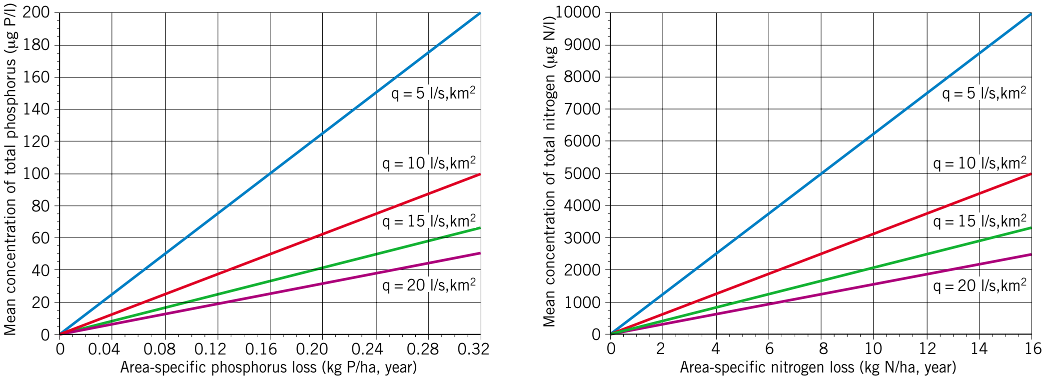


Figure 1. Annual mean concentration of phosphorus and nitrogen as a function of annual area-specific loss.

arable soils less susceptible to erosion, often with seeded grass cultivation. Class 4 represents losses from fields under open cultivation and class 5 shows leaching from arable soils susceptible to erosion.

Since phosphorus losses over fairly large agricultural areas exceed 0.32 kg P/ha, year, there is reason to make particular note the subgroup of areas within class 5 where phosphorus losses are extreme (over 0.64 kg N/ha, year). This is particularly called for when setting priorities for remedial measures.

The different classes are matched by various flow-weighted annual mean concentrations, depending on the flow per unit surface area. Figure 1 shows the correlations between area-specific loss and concentration at four different levels of flow per unit surface area.

Assessment of deviation from reference values

TABLE 7.

DEVIATION from reference value, concentration of total phosphorus in lakes

Class	Description	Recorded concentration/ reference value
1	No or insignificant deviation	≤ 1.5
2	Significant deviation	1.5 – 2.0
3	Large deviation	2.0 – 3.0
4	Very large deviation	3.0 – 6.0
5	Extreme deviation	> 6.0

This classification is based on an overall assessment taking account of the concentrations occurring in Swedish lakes at various degrees of human impact.

Recorded concentration represents the mean value over three years for the period May – October. By using 3-year mean values for August alone, account must be taken of the element of uncertainty introduced.

Reference values can be calculated or estimated in a number of ways. They can be estimated on the basis of historical studies of the area in question or studies of similar but unaffected lakes in the vicinity. However, phosphorus concentrations in some acidified lakes may be lower than the original level. In the absence of other data, reference values can be calculated using the correlation between total phosphorus and coloured organic matter:

$$TP_{ref}\,(\mu g\ P/l) = 5 + 48 \cdot \text{abs } f_{420/5}$$

This function gives minimum observed values at a given absorbency and, generally speaking, a higher degree of deviation. In some cases, the extent of deviation may be estimated to be up to one class higher than in reality. Clear mountain waters are a case in point. The function has been derived from environmental monitoring programme data where series of at least five years have been available. Taking account of the element of uncertainty introduced, absorbency (abs $f_{420/5}$) can be calculated by multiplying water colour (mg Pt/l) by 0.002.

In some limed or acidified lakes the ratio of recorded concentration to reference value may be less than 1, which may indicate oligotrophication, ie, a shift towards a more nutrient-poor state. Conditions of this kind should be particularly noted so as to allow further study of possible acidification-related effects.

TABLE 8.

DEVIATION from reference value, area-specific loss of total phosphorus in watercourses

Class	Description	Recorded area-specific loss/reference value
1	No or insignificant deviation	≤ 1.5
2	Significant deviation	1.5 – 3
3	Large deviation	3 – 6
4	Very large deviation	6 – 12
5	Extreme deviation	> 12

TABLE 9.

DEVIATION from reference value, area-specific loss of total nitrogen in watercourses

Class	Description	Recorded area-specific loss/reference value
1	No or insignificant deviation	≤ 2.5
2	Significant deviation	2.5 – 5
3	Large deviation	5 – 20
4	Very large deviation	20 – 60
5	Extreme deviation	> 60

This classification is based on an overall assessment taking into account the area-specific losses occurring in Swedish watercourses affected by man to varying degrees. In some catchments, the ratio between recorded concentration and reference value may be less than 1, which may indicate a phosphorus deficit. Conditions of this kind should be particularly noted so as to allow further study of possible acidification-related effects. In some catchments, the ratio of recorded concentration to reference value for nitrogen may be less than 1, which may indicate a nitrogen deficit.

Recorded area-specific loss refers to a mean figure for a 3-year period, calculated as shown above for classification of current conditions for area-specific losses.

Reference values can be calculated or estimated in several ways. They may be estimated on the basis of historical studies of the area in question or studies of similar but unaffected watercourses in the vicinity. In the absence of other data, reference values can also be calculated using the characteristics of the catchment and other features of the watercourse. The equations specified in the previous Quality criteria for lakes and watercourses (Swedish EPA 1991) can be used for this purpose, together with the additional equation shown below. All these relationships are expected to yield low estimates and the highest figure obtained using equations (1) – (5) and (6) – (10) should be used as the reference value. One exception is where the lake percentage is less than or equal to 2, where equations (2) and (7) should not be used.

TP_{ref} (kg P/ha, year) =

$$0.002 \cdot x_1 + 0.015 \quad (1)$$

$$(0.10 \cdot x_2 + 1.2) / (5 \cdot x_2 + 12) \quad (2)$$

$$0.91 \cdot x_3 \cdot 10^{-3} + 0.02 \quad (3)$$

$$2.45 \cdot x_4 \cdot 10^{-3} + 0.024 \quad (4)$$

$$3.15 \cdot x_1 \cdot 10^{-4} \cdot (5 + 60 \cdot x_5) \quad (5)$$

TN_{ref} (kg N/ha, year) =

$$0.018 \cdot x_1 + 0.85 \quad (6)$$

$$-0.023 \cdot x_2 + 1.25 \quad (7)$$

$$0.008 \cdot x_3 + 0.85 \quad (8)$$

$$0.03 \cdot x_4 + 0.90 \quad (9)$$

$$3.15 \cdot x_1 \cdot 10^{-4} \cdot (125 + 500 \cdot x_5) \quad (10)$$

where x_1 = specific flow (l/km^2, sec)

x_2 = lake percentage in catchment

x_3 = area-specific loss COD_{Mn} (kg/ha, year)

x_4 = area-specific loss silicon (kg/ha, year)

x_5 = flow-weighted mean absorbency 420 nm (abs $f_{420/5}$)

The new function (5, 10) uses the absorbency of the water measured using filtered water (0.45 μm membrane filter) in a 5 cm cuvette at a wavelength of 420 nm. Taking account of the element of uncertainty introduced, absorbency (abs $f_{420/5}$) can be calculated by multiplying water colour (mg Pt/l) by 0.002.

COD_{Mn} is derived by dividing the permanganate number by 3.95.

One of these equations may be unsuitable for use in some situations. Hence, organic matter may raise the concentration of oxygen-consuming substances, which will render use of COD inappropriate. If the pollutant is largely uncoloured matter, the absorbency function (5, 10) will be a better guide. This should in turn be avoided where it is suspected that water colour is anthropogenically elevated, eg, as a result of discharges from pulp and paper mills, leachate from rubbish tips or because of increased humus losses caused by forestry practices. Silica (4, 9) may also be anthropogenically affected, eg, in the form of lower concentrations due to eutrophication, which will particularly impact on water systems containing many lakes.

Comments

Classifications must be based on samples taken and analyses made in accordance with the Swedish EPA Environmental Monitoring Handbook. The scales should be used bearing in mind the wide natural variation between individual lakes and watercourses and from year to year. The number of sampling occasions or the time scale on which the various assessments are based represents minimum figures. If and when assessments are made on the basis of more limited data, this should be stated.

The scale for N/P ratios in lakes is intended to be used provisionally and with a degree of feedback as to results obtained. The ratios have been obtained using older analytical methods for total nitrogen (Kjeldahl-N + ammonium-N) and are affected in calculation terms by the reduction in the concentrations of total nitrogen obtained using new analytical methods (total-N using Swedish Standard SSO28131). No correction has been made to take account of this, however. The effects the class boundaries are intended to identify may therefore occur at somewhat lower ratios than those given in the criteria.

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Oxygen status and oxygen-consuming substances

Introduction

Dissolved oxygen is vital for respiration and many microbial and chemical processes in the ecosystem. The concentration may thus regulate the biological structure. Oxygen conditions vary, mainly due to changing production conditions and the organic load, including natural humic substances leaching from the catchment area. In the bottom water of stratified lakes (the hypolimnion), the oxygen situation is at its worst at the end of the stagnation period in summer, at which time conditions may become critical for many organisms. The end of the period when lakes and rivers are ice-covered is another crucial time. Oxygen conditions in watercourses may be poorest at times of low flow, particularly in polluted rivers. Significant variations in oxygen levels and oxygen saturation can occur from one day to the next in the surface waters of unstratified lakes and in rivers and streams.

Oxygen concentration is prefered to saturation as a means of characterising oxygen status because the thresholds of tolerance of various organisms are usually expressed as concentrations. However, merely stating the oxygen concentration may give an incomplete picture of oxygen conditions, particularly in rivers and streams. This is due to variations in oxygen input and organic load. The presence of oxygen-consuming substances should therefore also be taken into account. The concentration of organic matter provides essential information about the risk of low oxygen levels occurring between the occasions on which oxygen concentrations are monitored.

A high oxygen concentration or oxygen saturation is not always a sign of a ”healthy” environment. Assimilation by plants may result in saturation figures of over 100 per cent in eutrophic waters.

Scales have only been given for assessing current conditions because of the difficulties of determining reference values.

Assessment of current conditions

Oxygen status is assessed in the bottom waters of stratified lakes and also in the circulating water column in unstratified lakes. Annual minimum values based on concentrations monitored during critical periods (late winter/spring, i.e. ice-covered period, late summer/autumn) over three years are assessed for all lakes.

Annual minimum values for watercourses are also assessed, although here assessment should be based on samples taken 12 times a year over three years. It may be necessary to monitor concentrations more frequently in small watercourses, particularly during the summer.

TABLE 10.

CURRENT CONDITIONS: oxygen concentration (mg O_2/l)

Class	Description	Annual minimum concentration
1	Oxygen-rich	≥ 7
2	Moderately oxygen-rich	5 – 7
3	Moderately oxygen-deficient	3 – 5
4	Oxygen-deficient	1 – 3
5	No or almost no oxygen	≤ 1

Note: The presence of hydrogen sulphide (H_2S) is indicated by ††

Samples from the deepest point in a stratified lake sometimes give a misleading picture of oxygen state if only a very small proportion of the total volume of the lake is deep water. To avoid this, a rule of thumb should be that readings taken from localities or sampling depths representing at least 10 per cent of the bottom area of the lake should be used to reflect the oxygen status of stratified lakes.

TABLE 11.

CURRENT CONDITIONS: organic matter (oxygen-consuming substances)

Class	Description	Concentration as TOC or COD_{Mn} (mg/l)
1	Very low concentration	≤ 4
2	Low concentration	4 – 8
3	Moderately high concentration	8 – 12
4	High concentration	12 – 16
5	Very high concentration	> 16

In lakes, seasonal mean values for TOC or COD_{Mn} (May – October) over one year are used, based on monthly readings taken in the epilimnion or, if only one sample is taken, in surface water (0.5 m).

Annual mean values are also assessed in watercourses, although here the assessment should be based on samples taken 12 times a year over one year.

COD_{Mn} is derived by dividing the permanganate value by 3.95. For practical reasons, the same scale is given here for TOC and for COD_{Mn}. It should also be noted that the correlation between these variables may vary, both naturally and as a result of admixture of sewage or waste water, depending on the composition of the organic matter.

Comments

Classifications must be based on samples taken and analysed in accordance with the Swedish EPA Environmental Monitoring Handbook. The scales should be used bearing in mind the wide natural variation between individual lakes and watercourses and from year to year. The number of sampling occasions or the time scale on which the various assessments are based represents minimum figures. If and when assessments are made on the basis of more limited data, this should be stated.

References

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Light conditions

Introduction

Light conditions are crucial for the survival of many organisms. Water quality in this respect is assessed on the basis of absorbency readings taken from filtered water at a wavelength of 420 nm in a photometer or equivalent readings taken using a colour comparator, using brownish-yellow platinum chloride as a reference. A high water table, eg, in bogs and marshes, results in run-off with a high humus content and hence a higher colour figure. Various chemical, photochemical and biological processes cause a certain amount of discoloration. This means that lakes with a long retention time are less discoloured than those with rapid turnover. From some points of view, a high concentration of humic matter is advantageous, since it provides scope for complexing, which reduces the toxicity of metals.

The turbidity of the water is assessed by analysing light dispersion measured according to the FNU scale. These readings quantify the particulate content of the water in the form of clayey matter as well as organic matter such as humus floccules, plankton etc.

Turbidity is determined electronically using a turbidimeter in accordance with the Swedish standard. Particles in the water scatter light and, after calibration, the intensity of this light is used as a measure of turbidity. One complication is that readings are affected by the concentration as well as the nature of the particles. The turbidity of natural running water is mainly caused by inorganic particles. The main source of material like this, which causes turbidity, is probably erosion. Inorganic matter has a high density and therefore sediments fairly quickly. Lakes thus serve as clarification basins, where the predominant cause of turbidity is usually organic matter.

Measuring the Secchi depth of lakes gives an indication of the optical characteristics of the water. Secchi depth readings are taken using a Secchi dish *in situ*, which indicates the overall effects of water colour and turbidity on light penetration. The Secchi depth thus gives a direct, simple measure of the optical characteristics of the water. It is generally considered that the Secchi depth represents the depth reached by approximately 10 per cent of natural light. A Secchi depth figure can be used to estimate the distribution of benthic vegetation, for example, since double the Secchi depth is regarded as a rough measure of compensation depth, ie, the depth at which photosynthesis does not occur.

Only current conditions scales are given for the above parameters. Assessment of deviation from reference values is hindered by the absence of background data more than is the case with other quality parameters.

Assessment of current conditions

TABLE 12.

CURRENT CONDITIONS: water colour

Class	Description	Abs $f_{400/5}$	Colour figure (mgPt/l)
1	Clear, or hardly discoloured water	≤ 0.02	≤ 10
2	Slightly discoloured water	0.02 – 0.05	10 – 25
3	Moderately discoloured water	0.05 – 0.12	25 – 60
4	Substantially discoloured water	0.12 – 0.2	60 – 100
5	Heavily discoloured water	> 0.2	> 100

In lakes, classification of water colour is based on seasonal mean values (May – October) over one year, based on monthly readings taken in surface water (0.5 m) or in samples taken from several depths. Assessment of watercourses should be based on samples taken 12 times over one year. The assessment scale is intended to group water colour levels typical of Swedish lakes and watercourses and is not related to biological or microbial effects.

Photometer readings of the absorbency of filtered water (0.45 μm membrane filter) in a 5 cm cuvette at a wavelength of 420 nm give greater accuracy than readings of water colour using a colour comparator, particular at low colour levels. Photometer readings are therefore preferable. The table shows a multiplication factor of 500, used to convert absorbency units (abs $f_{420/5}$) to a colour value. This factor involves an element of uncertainty.

TABLE 13.

CURRENT CONDITIONS: turbidity

Class	Description	FNU units
1	No or insignificant turbidity	≤ 0.5
2	Slightly turbid	0.5 – 1.0
3	Moderately turbid	1.0 – 2.5
4	Substantially turbid	2.5 – 7.0
5	Highly turbid	> 7.0

In lakes, turbidity is classified using seasonal mean values (May – October) over one year, based on monthly readings taken in surface water (0.5 m) or in samples taken at several depths. Assessment of watercourses should be based on samples taken 12 times over one year. The assessment scale classifies group concentration levels typical of Swedish lakes and watercourses and is not related to biological or microbial effects.

Turbidity readings using different methods yield somewhat different results. The previous Swedish standard expressed turbidity as FTU (formazine turbidity units). The present Swedish and ISO standard states readings in the form of FNU (formazine nephelometric units). Other methods involve readings expressed as NTU (nephelometric turbidity units) or JTU (Jackson turbidity units). For practical purposes, 1 FTU = 1 FNU = 1 NTU ≈ JTU.

TABLE 14.

CURRENT CONDITIONS: Secchi depth in lakes

Class	Description	Depth (m)
1	Very great Secchi depth	≥ 8
2	Great Secchi depth	5 – 8
3	Moderate Secchi depth	2.5 – 5
4	Little Secchi depth	1 – 2.5
5	Very little Secchi depth	< 1

In lakes, Secchi depth is classified using seasonal mean values (May – October) over one year, based on monthly readings using a Secchi disk in the offshore area of the lake. Underwater binoculars should be used to ensure that accurate readings can be taken in different weather conditions. The assessment scale is intended to group concentration levels typical of Swedish lakes and watercourses and is not related to biological or microbial effects.

Comments

Classifications must be based on samples taken and analyses made in accordance with the Swedish EPA Environmental Monitoring Handbook. If assessments are made on the basis of more limited data, this should be stated.

The variables to be used for classification should be decided from case to case. As a rule, it is not necessary to use all the given variables.

The scales should be used bearing in mind the wide natural variation between individual lakes and from year to year. All the given variables vary from season to season, in running water often depending on the flow rate. Periods of high flow are frequently associated with high colour and turbidity. Sampling should therefore ensure that periods with highest flow are also represented. Algal production has a very powerful influence on both turbidity and Secchi depth in lakes, particularly eutrophic ones.

References

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Acidity / acidification

Introduction

The acidity of water is significant to aquatic organisms because it affects a number of important biotic and abiotic processes. Indirectly, acidity is also important to aquatic organisms because it governs the chemical form in which metals occur. Dissolved aluminium is particularly important, since this may occur in toxic form at high concentrations under acid conditions.

Most waters have a buffering capacity, ie, they are able to neutralise the input of acidic substances. Buffering capacity is principally determined by hydrocarbonate; only when this is nearly exhausted can water become severely acidified. Alkalinity is used here as a measure of buffering capacity. The lower the alkalinity, the greater the effect of acidic input on the acidity.

An alternative measure of buffering capacity is ANC (acid neutralising capacity), which, in addition to hydrocarbonate, also includes organic anions. The difference between ANC and alkalinity is fairly small in clear waters, but in brown (humic) waters, ANC may be substantially higher than alkalinity. ANC has become more widely used internationally for acidification assessments in recent years, although alkalinity has a simpler and clearer correlation to the acidity of water. When alkalinity approaches zero pH falls most rapidly, regardless of the ANC level at that point.

The water's natural content of organic anions may have an appreciable effect on its acidity and sensitivity to acidification. However, the fact that alkalinity rather than ANC has been chosen as the measure of buffering capacity does not mean that this natural effect is assumed to be non-existent, nor that it is confused with anthropogenic impact. The calculation below showing how present buffering capacity differs from that during the pre-industrial era, solely refers to the change caused by the sulphur deposition of recent years, regardless of the original acidity of the water. In practice, this change in buffering capacity will be equally great, whether it is measured as the difference in alkalinity or the difference in ANC. However, the estimated correlation between present and pre-industrial alkalinity is easier to use than the equivalent ANC correlation as the basis for an assessment of whether the pH of the water has been affected by acid deposition.

Assessment of current conditions

Acidity can be assessed from alkalinity and pH value or either. Whereas alkalinity is primarily a measure of sensitivity to acidification, pH value reflects actual acidity as such. However, pH usually varies much more over the year than alkalinity. If the assessment is based on a single sample, alkalinity is thus preferable to pH as a basis for classification of current conditions.

TABLE 15.

CURRENT CONDITIONS: alkalinity (meq/l)

Class	Description	Alkalinity
1	Very good buffering capacity	> 0.20
2	Good buffering capacity	0.10 – 0.20
3	Poor buffering capacity	0.05 – 0.10
4	Very poor buffering capacity	0.02 – 0.05
5	No or insignificant buffering capacity	≤ 0.02

The boundaries between the classes are related to impact and response. An alkalinity figure of 0.05 meq/l is the upper limit for swedish government-subsidised liming.

TABLE 16.

CURRENT CONDITIONS: pH

Class	Description	pH
1	Almost neutral	> 6.8
2	Weakly acidic	6.5 – 6.8
3	Moderately acidic	6.2 – 6.5
4	Acidic	5.6 – 6.2
5	Highly acidic	≤ 5.6

Assessment of deviation from reference values

Estimated alkalinity during the pre-industrial era is used as a reference value. Deviation from this value is expressed as the ratio between present alkalinity and the reference value. This ratio can be fairly accurately converted into a pH difference (the difference between present and pre-industrial pH). The change in acidity since the pre-industrial era – *acidification* – should essentially reflect human impact.

TABLE 17.

DEVIATION from reference value, alkalinity

Class	Description	Present alkalinity/reference value (alk/alk_o for alk ≥ 0.01 meq/l)*	Corresponding difference in pH
1	Insignificant deviation	> 0.75	≤ 0.1
2	Moderate deviation	0.50 – 0.75	0.1 – 0.3
3	Large deviation	0.25 – 0.50	0.3 – 0.6
4	Very large deviation	0.10 – 0.25	0.6 – 1.0
5	Extremely large deviation	≤ 0.10	> 1.0

* Classification for alk < 0.01 meq/l, see *modified alkalinity ratio* below

The reference value (alk_o) is calculated as follows (a simplified and modified version of the method described by Bernes, 1991):

$$alk_o = alk + (1 - F)(SO_4^* - SO_4^*{}_o)$$

$$SO_4^* = SO_4 - 0.103\ Cl$$

$$SO_4^*{}_o = 0.005 + 0.05\ BC^*$$

$$BC^* = Ca + Mg + Na + K - 1.111\ Cl$$

$$F = 0.8 \arctan(4.3(alk + 0.2))$$

where alk_o = reference value
alk = present alkalinity
SO_4^* = present concentration of sulphate ions of non-marine origin
$SO_4^*{}_o$ = pre-industrial concentration of sulphate ions of non-marine origin
BC^* = present concentration of base cations of non-marine origin
F = a measure of the proportion of anthropogenic sulphur deposition neutralised by ionic exchange reactions in the soil

All concentrations are expressed in meq/l, whereas F is expressed in radians. If the water has no detectable alkalinity, acidity should be measured instead. Acidity is expressed throughout as negative alkalinity.

The concentration of base cations in limed lakes must be determined on the basis of reliable readings taken prior to liming or by calculating the calcium concentration from the magnesium content of the water and the Ca/Mg ratio in nearby, similar but unlimed waters. The latter alternative presupposes that limestone containing no magnesium (ie, limestone containing little dolomite) has been used for liming.

If present alkalinity is less than 0.01 meq/l, the alkalinity ratio derived above cannot be used as a basis for classifying deviation. Instead, a *modified alkalinity ratio* can be estimated as shown below.

	$alk < -0.01$	$-0.01 < alk < 0.01$	$alk \geq 0.01$
$alk_o > 0.01$	$0.25\,(-0.01/alk)\,(0.01/alk_o)$	$(0.01/alk_o)\,2^{-100\,(0.01 - alk)}$	alk/alk_o
$-0{,}01 < alk_o < 0.01$	$(-0.01/alk)\,2^{-100\,(alk_o + 0.01)}$	$2^{-100\,(alk_o - alk)}$	
$alk_o < -0.01$	alk_o/alk		

The modified alkalinity ratio can be used instead of the normal alkalinity ratio to determine the deviation class in the deviation table.

Example: Present alkalinity is measured (by acidity analysis) at -0.02 meq/l. Pre-industrial alkalinity is estimated at 0.02 meq/l. The modified alkalinity ratio (using the expression at top left above) will then be 0.25 (-0.01/-0.02)(0.01/0.02) = $0.25 \cdot 0.5 \cdot 0.5 = 0.06$. It may be seen from the deviation table that this represents deviation class 5.

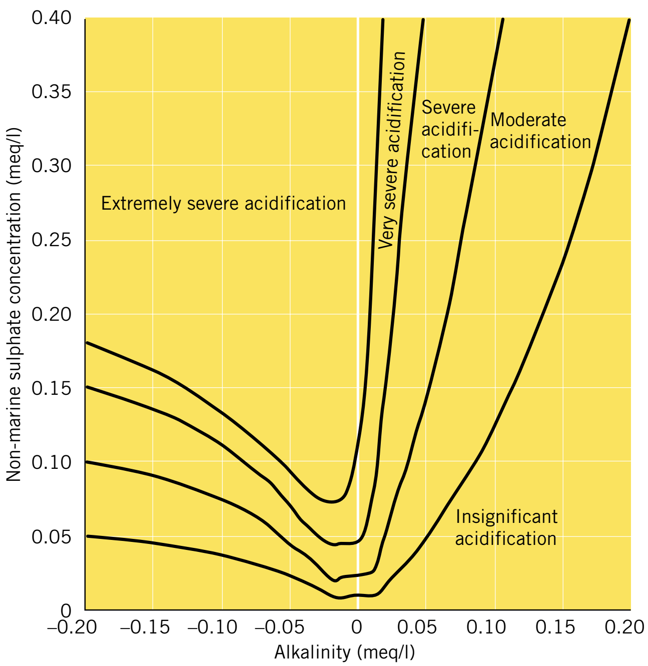

Figure 2. Diagram showing deviation class (acidification) based on recorded alkalinity and concentration of non-marine sulphate.

The pre-industrial concentration of sulphate ($SO_4{}^*{}_0$) in the majority of acidified waters or waters sensitive to acidification can safely be set at zero, in which case the alkalinity ratio and deviation classification will depend solely on present alkalinity and sulphate concentration. This means that the deviation class (acidification class) can be identified directly from Figure 2.

Comments

Classifications must be based on samples taken and analyses made in accordance with the Swedish EPA Environmental Monitoring Handbook.

The assessments should be based on data from at least 12 samples taken either monthly over one year, every other month over two years or quarterly over three years (see Environmental Monitoring Handbook – water chemistry of lakes and water chemistry of watercourses). The calculations and classifications described above are intended to refer to the *median values* of the relevant parameters during the sampling period.

If assessments are made on the basis of single samples, such as synoptic studies, this should be stated. If so, samples must have been taken at a time of year when the acidity of the water is reasonably stable.

The class boundaries given for assessing current conditions take account of the fact that lakes and running waters can be appreciably more acidic for a short time during the spring flood than during the rest of the year. However, ”acidic surges” during the spring flood may cause pronounced biological effects in waters (principally streams), even though buffering capacity is fairly or even very good at other times of year. In such cases, relevant assessments of the acidity of such watercourses require study of both biological parameters and water chemistry.

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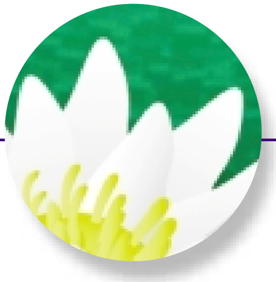

Metals

Introduction

Metals occur naturally in fresh water in low concentrations. Concentrations in sediment and organisms are higher owing to a natural process of accumulation. Concentrations vary depending on the geology and soil types in the catchment area of the lake or watercourse. The water's acidity and content of organic matter etc also affect metal concentrations so that a significant variation occurs even under natural conditions. In small quantities, many metals perform vital biological functions.

Man has increased the quantities of metals in the environment. Emissions to air and dispersal over large areas have caused concentrations of some metals to rise generally in Swedish lakes and watercourses. Moreover, emissions directly to water and other types of impact have, in many instances, multiplied metal concentrations in the vicinity of emission sources. Elevated metal concentrations are serious, since many metals cause biological damage even at relatively low concentrations. A deficiency of some metals may also cause adverse effects. Many metals are essential to plants and animals. However, there is unlikely to be a deficiency of metals in Swedish waters.

Damage caused by metals present in moderately elevated concentrations occurs primarily in organisms towards the bottom of the food chain, eg, phytoplankton and zooplankton. Fish reproduction is also susceptible to effects caused by metals, as are fish fry in the early stages of development. The lowest effect concentrations occur in connection with long-term exposure (weeks or months). More acute effects occur at concentrations some 3 – 10 times higher than those causing chronic effects.

Here, an assessment is made using the concentration of metals in water, sediment, aquatic moss and/or fish.

Concentration of *metals in water* provide the best opportunity to assess whether there is a risk of biological damage. Analyses of water also allow calculation of transport of metals in watercourses and thus provide data on which to assess the contributions made by different sources to the pollution load on an aquatic area. Methods of taking samples and analysing metals in water have been substantially improved over the last decade. Concentrations of metals in water can now be determined with a very high degree of reliability and at a much lower cost than previously.

Analyses of *metals in aquatic moss* (*Fontinalis antipyretica* and *F. dalecarlia*) can be used as an indirect measure of concentrations in water. Moss growing locally as well as planted specimens can be used. Concentrations in aquatic moss reflect metal concentrations in water over a lengthy period (weeks) and are an effective means of surveying sources and the size of contaminated areas and can also be used to gain an idea of the level of pollution in the aquatic area. However, absorption of metals by aquatic moss is not dependent merely on the concentration in water; acidity, for example is another factor. This limits the utility of the method, particularly in acidified waters.

Concentrations of *metals in sediment* provide a good picture of the influx of metals into an aquatic area. Sampling procedures and analyses are fairly simple and reliable and analyses of sediment are therefore highly suitable for surveying the impact of metals, for example. By analysing deeper sediment strata it is possible to extrapolate the time trend for load backwards in time and to determine original metal concentrations in the aquatic area.

Concentrations of *mercury in fish* mainly serve to provide a basis for assessing the risks to humans of eating fish. Metal concentrations in fish are also a useful means of evaluating the risk of damage to mammals and birds whose diet mainly consists of fish.

Assessment of current conditions

TABLE 18.

CURRENT CONDITIONS: metals in water (µg/l)

Class	Description	Cu [1)]	Zn	Cd	Pb	Cr	Ni	As
1	Very low conc.	≤ 0.5	≤ 5	≤ 0.01	≤ 0.2	≤ 0.3	≤ 0.7	≤ 0.4
2	Low conc.	0.5 – 3	5 – 20	0.01 – 0.1	0.2 – 1	0.3 – 5	0.7 – 15	0.4 – 5
3	Mod. high conc.	3 – 9	20 – 60	0.1 – 0.3	1 – 3	5 – 15	15 – 45	5 – 15
4	High conc.	9 – 45	60 – 300	0.3 – 1.5	3 – 15	15 – 75	45 – 225	15 – 75
5	Very high conc.	> 45	> 300	> 1.5	> 15	> 75	> 225	> 75

1) These values apply particularly to lakes and streams. Background concentrations are often higher in larger watercourses; concentrations of up to 3 µg/l are not uncommon. The boundary between class 1 and 2 has been set on the basis of the 75th percentile for northern Swedish streams and lakes.

The following may be said of the risk of biological effects caused by metals in concentrations corresponding to the various classes:

Class 1. No or only very slight risk of biological effects. The concentrations represent an estimate of concentrations in pristine waters, displaying no signs of anthropogenic impact.

Class 2. Slight risk of biological effects. The majority of waters in this class have elevated metal concentrations due to emissions from point sources and/or long-distance dispersal. However, the class may include concentrations that are natural in some areas with different geology, for example. The rise in concentration is such that it is not generally possible to detect any effects.

Class 3. Effects may occur. The risk is greatest in bodies of soft, oligotrophic water, low in humus and in waters with low pH. The term ”effects” here means impact on the reproduction or survival of the young of species or groups of species, which is often manifested as a reduction in the number of individuals. This may have repercussions on the communities of organisms in the water and on the structure of the entire ecosystem.

Class 4 and 5. A growing risk of biological effects. Metal concentrations in class 5 affect the survival of aquatic organisms even where exposure is short-term.

Since the extent of biological effects is largely dependent on water quality and the form in which metals occur, it is recommended that a follow-up biological examination be made if recorded concentrations reach class 3 or above.

There is reason to exercise particular care when assessing the state in relation to copper. Copper concentrations are generally higher in rivers than in streams and lakes. Since these concentrations are natural and are not the result of point-source emissions or long-distance dispersal, it is likely that the ecosystem is adapted to cope with them. The risk of biological effects in rivers caused by copper concentrations within class 3 is therefore not as great as it is in lakes and streams.

A more detailed assessment of the risk of biological effects will require that account also be taken of deviation from the reference value. This applies to copper in particular. The risk of effects is not very great if the metal concentration in a lake or river comes within class 3 but does not appreciably deviate from the reference value. The risk is substantially greater, on the other hand, if both current conditions and deviation from reference value are in class 3. A general rule of thumb is that the greater the deviation from reference value is, the greater the risk of effects.

The classification for metals in sediment (Table 19) is based on the variation of concentrations in superficial sediment in Swedish lakes. The classification is designed so that class 1–3 cover approximately 95 per cent of the levels recorded in the background data. Classes 4 and 5 represent concentrations generally found in areas where there is an exceptional local load. Only the highest levels recorded in Sweden fall within class 5.

The classification for metals in aquatic moss is based on the breakdown

TABLE 19.

CURRENT CONDITIONS: metals in sediment (mg/kg ds)

Class	Description	Cu	Zn	Cd	Pb	Hg
1	Very low concentrations	≤ 15	≤ 150	≤ 0.8	≤ 50	≤ 0.15
2	Low concentrations	15 – 25	150 – 300	0.8 – 2	50 – 150	0.15 – 0.3
3	Moderate high conc.	25 – 100	300 – 1000	2 – 7	150 – 400	0.3 – 1.0
4	High concentrations	100 – 500	1000 – 5000	7 – 35	400 – 2000	1.0 – 5
5	Very high conc.	> 500	> 5000	> 35	> 2000	> 5

Class	Description	Cr	Ni	As
1	Very low concentrations	≤ 10	≤ 5	≤ 5
2	Low concentrations	10 – 20	5 – 15	5 – 10
3	Moderate high conc.	20 – 100	15 – 50	10 – 30
4	High concentrations	100 – 500	50 – 250	30 – 150
5	Very high conc.	> 500	> 250	> 150

TABLE 20.

CURRENT CONDITIONS: metals in aquatic moss (mg/kg ds)

Class	Description	Cu	Zn	Cd	Pb	Hg
1	Very low concentrations	≤ 7	≤ 60	≤ 0.3	≤ 3	≤ 0.04
2	Low concentrations	7 – 15	60 – 160	0.3 – 1.0	3 – 10	0.04 – 0.1
3	Moderate high conc.	15 – 50	160 – 500	1.0 – 2.5	10 – 30	0.1 – 0.3
4	High concentrations	50 – 250	500 – 2500	2.5 – 15	30 – 150	0.3 – 1.5
5	Very high conc.	> 250	> 2500	> 15	> 150	> 1.5

Class	Description	Cr	Ni	Co	As
1	Very low concentrations	≤ 1.5	≤ 4	≤ 2	≤ 0.5
2	Low concentrations	1.5 – 3.5	4 – 10	2 – 10	0.5 – 3
3	Moderate high conc.	3.5 – 10	10 – 30	10 – 30	3 – 8
4	High concentrations	10 – 50	30 – 150	30 – 150	8 – 40
5	Very high conc.	> 50	> 150	> 150	> 40

of present concentrations in Sweden. The principles governing class delineation for metals in sediment have also been used here.

TABLE 21.

CURRENT CONDITIONS: mercury in fish (1-kilo pike, *Esox lucius*, muscle) (mg/kg ws)

Class	Description	Hg
1	Very low concentrations, naturally occurring	≤ 0.20
2	Low concentrations, usually elevated in comparison with background[1)]	0.20 – 0.50
3	Moderately high concentrations, elevated in comparison with background	0.50 – 0.75
4	High concentrations	0.75 – 1.0
5	Very high concentrations	> 1.0

1) Concentrations in this range may be natural in some oligotrophic forest lakes

Concentrations of mercury in fish are generally greatly elevated these days. Mean concentrations in one-kilo pike from lakes in various regions of southern Sweden vary between 0.5 and 1.0 mg Hg/kg. Consequently, the Swedish National Food Administration recommends that pregnant women and those planning to become pregnant should not eat certain species of fish, eg, perch (*perca fluviatilis*), pike (*Esox lucius*), burbot (*Lota lota*), zander (pike-perch) (*Stizostedion lucioperca*) and eel (*Anguilla anguilla*). Other people are recommended not to eat lake fish more than once a week on average. Consumption should be further reduced if fish contain more than 1 mg Hg/kg (National Food Administration 1992). Variations in mercury levels between lakes in different regions and health considerations have formed the basis for the above class boundaries.

Assessment of deviation from reference values

A somewhat modified classification system has been chosen here as compared with that proposed in the background report on metals (in Swedish). This is because the system used here is more consistent with corresponding model criteria for groundwater, coastal water and contaminated sites.

Classification is based on deviation from original, natural concentrations. Class delineation is not related to biological effects. The following applies to the respective classes:

TABLE 22.

DEVIATION from reference value, water

Class	Description	Recorded concentration/reference value				
		Cu	Zn	Cd	Pb	Cr
1	No deviation	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
2	Slight deviation	1.0 – 2.0	1.0 – 3.0	1.0 – 8.0	1.0 – 8.0	1.0 – 2.0
3	Significant deviation	2.0 – 4.0	3.0 – 8.0	8.0 – 15	8.0 – 15	2.0 – 6.0
4	Large deviation	4.0 – 7.0	8.0 – 13	15 – 30	15 – 30	6.0 – 11
5	Very large deviation	> 7.0	> 13	> 30	> 30	> 11

Class	Description	Recorded concentration/reference value			
		Ni	Co	V	As
1	No deviation	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
2	Slight deviation	1.0 – 2.0	1.0 – 8.0	1.0 – 3.0	1.0 – 2.0
3	Significant deviation	2.0 – 4.0	8 – 15	3.0 – 8.0	2.0 – 5.0
4	Large deviation	4.0 – 8.0	15 – 30	8.0 – 13	5.0 – 9.0
5	Very large deviation	> 8.0	> 30	> 13	> 9.0

TABLE 23.

DEVIATION from reference value, sediment

Class	Description	Recorded concentration/reference valuee				
		Cu	Zn	Cd	Pb	Cr
1	No deviation	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
2	Slight deviation	1.0 – 2.0	1.0 – 2.0	1.0 – 5.0	1.0 – 15	1.0 – 2.0
3	Significant deviation	2.0 – 4.0	2.0 – 5.0	5.0 – 13	15 – 45	2.0 – 6.0
4	Large deviation	4.0 – 7.0	5.0 – 10	13 – 23	45 – 80	6.0 – 11
5	Very large deviation	> 7.0	> 10	> 23	> 80	> 11

Class	Description	Recorded concentration/reference value		
		Ni	As	Hg
1	No deviation	≤ 1.0	≤ 1.0	≤ 1.0
2	Slight deviation	1.0 – 2.0	1.0 – 2.0	1.0 – 3.0
3	Significant deviation	2.0 – 4.0	2.0 – 3.0	3.0 – 8.0
4	Large deviation	4.0 – 8.0	3.0 – 4.0	8.0 – 13
5	Very large deviation	> 8.0	> 4.0	> 13

Class 1. No or insignificant impact caused by anthropogenic sources.

Class 2 – 4. These include waters that are increasingly becoming contaminated by local or non-point sources.

Class 5. A clear impact from local sources. The boundary between classes 4 and 5 is based on the 95th percentile for lakes and watercourses not affected by local sources.

Reference values comprise estimates of original, natural concentrations. Values specific to a given locality should be used as far as possible. If no such values are available, the standard values given in Table 24 may be used. If additional, higher class limits are required, those used in Environmental Quality Criteria for Contaminated Sites can be used. If so, the factor in class 5 is multiplied by 5 and 25, respectively. These classes are to be shaded purple and black, respectively, on maps, for example.

It should be noted that the dividing lines between the classes for deviation from the reference value differ between, on the one hand, sediment in lakes and watercourses and, on the other, coasts and seas. The factors are generally higher in freshwater sediment than in marine environments. One of the main reasons for this is that freshwater sediment generally

TABLE 24.

Reference values for natural, pristine concentrations in various types of Swedish lakes and watercourses, unaffected by local emissions and acidification (pH >6.0). The concentrations in water have been estimated on the basis of present levels in Northern Sweden. The table also shows present regional background levels, ie, present ”normal” concentrations in lakes and watercourses not affected by local sources. ”Northern Sweden” means areas north of the Dalälven river. Minor watercourses are defined as running waters having a catchment area of up to a few square kilometres.

	Cu	Zn	Cd	Pb	Cr	Ni	Co	As	V	Hg
Watercourses, major (µg/l)										
natural, pristine concentr.	1.0	3.0	0.003	0.05	0.2	0.5	0.05	0.2	0.1	0.001
background, N Sweden	0.9	2.9	0.005	0.12	0.2	0.5	0.05	0.2	0.1	0.002
background, S Sweden	1.3	4.3	0.014	0.32	0.4	1.0	0.13	0.4	0.4	0.004
backg., lowland streams	1.9	5.7	0.016	0.38	0.8	2.7	0.35	0.6	0.8	0.004
Watercourses, minor (µg/l)										
natural, pristine concentr.	0.3	1.0	0.002	0.02	0.1	0.3	0.03	0.06	0.06	0.001
background, N Sweden	0.3	0.9	0.003	0.04	0.1	0.3	0.03	0.06	0.06	0.002
background, S Sweden*	0.5	2.0	0.016	0.24	0.2	0.4	0.06	0.3	0.2	0.004

TABLE 24.

(continued)

	Cu	Zn	Cd	Pb	Cr	Ni	Co	As	V	Hg
Lakes (µg/l)										
natural, pristine concentr.	0.3	1	0.005	0.05	0.05	0.2	0.03	0.2	0.1	0.001
background, N Sweden	0.3	0.9	0.009	0.11	0.05	0.2	0.03	0.2	0.1	0.002
background, S Sweden	0.5	2.0	0.016	0.24	0.2	0.4	0.06	0.3	0.2	0.004
Sediment (mg/kg ds)										
natural, pristine concentr.	15	100	0.3	5	15	10	15	8	20	0.08
background, N Sweden	15	150	0.8	50	15	10		10	20	0.13
background, S Sweden	20	240	1.4	80	15	10		10	20	0.16
Aquatic moss (mg/kg ds)										
background, all Sweden	10	100	0.5	5	2	5	5	2		0.07

* There is no data on watercourses unaffected by acidification and the figures for southern Swedish lakes are therefore used.

contains far more organic matter and that most metals are found in that fraction of the sediment.

Comments

Classification must be based on samples taken and analyses made in accordance with the Swedish EPA Environmental Monitoring Handbook and analyses made in accordance with the Swedish standard. Data for water and aquatic moss should have been obtained over at least three years, whereas that for sediment and fish can derive from single years. Concentrations in running water should have been monitored once a month, those in lakes four times a year. It may be necessary to take samples more frequently in minor watercourses and lakes with shorter retention times. If assessments are made on the basis of more limited data, this should be stated.

Classification should be based on the arithmetical mean. However, account should be taken of the fact that biological effects may occur when the concentrations given under Assessment of current conditions are exceeded for about a month or more. If individual analyses indicate that this may have occurred, the water sample programme should be expanded and/or a biological sampling programme initiated to determine whether damage is occurring.

Assessment of mercury in fish should be based on analysis of pike weighing 0.4 – 1.6 kg. In lakes with a surface area of up to 10 km^2, at least five fish should be used; in larger lakes, at least ten fish.

Concentrations in sediment (present concentrations) refer to the level 0 – 1 cm on accumulation bottoms (loss of ignition >10%, ds < 25%).

Metals in aquatic moss refer to concentrations in annual growth. Moss growing locally as well as planted specimens can be used. Exposure should have lasted for at least three weeks in the latter case.

Where possible, it is recommended that local background concentrations recorded upstream or in a nearby aquatic area be used to determine present regional background concentrations. This applies particularly to aquatic moss, about which little is known in relation to regional background concentrations.

Natural concentrations in sediment should primarily be determined using local values obtained from deeper strata of sediment, which reflect pristine concentrations in the area. In the case of most metals, these concentrations are found in sediments some 15 – 30 cm deep. But in eutrophied waters (where sedimentation occurs rapidly), the 150-year-old sediment will be found much deeper down. Much older sedimentary strata must be analysed for lead, since the environmental load of this metal has been accumulating for much longer.

When analysing sediment, it is very important that the quantity of organic matter measured as loss on ignition is approximately as great in the sediment to be compared. This is particularly important with Pb and Hg, since the concentration of these metals in particular is correlated to the concentration of organic matter in the sediment.

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Phytoplankton in lakes

Introduction

Planktonic algae (phytoplankton) are an essential part of lake food chains as a producer of organic matter and oxygen, as food for grazing animals (zooplankton, ciliates, benthic fauna, fish) and because they excrete dissolved organic matter, which also serves as a source of energy and nutrition for other microbes.

Algae respond rapidly to changes in water quality because of their rapid reproduction rate. Changes in the physical and chemical status of the water can be identified after only a week or so in the form of changes in the balance of species and species abundance. Lasting water quality changes can be discerned in the plankton community from one vegetative period to another.

Some of the parameters used here to assess phytoplankton represent fundamental characteristics of plankton assemblages and reflect impact resulting from eutrophication. These include total volume of algae and spring-developing diatoms. As well as being an indicator of early effects of eutrophication, these latter organisms are also an important source of food for the benthic fauna. Other parameters are associated with harmful algae, which affect water use in various ways. These include water-blooming and potentially toxin-producing cyanobacteria, as well as *Gonyostomum semen*, a slime-producing flagellate.

Assessment parameters relate to different times of the year, depending on the occurrence of algae and their impact on water use:

Parameter	Period
Total phytoplankton volume	Seasonal mean during May – October, and August
Chlorophyll-a	Seasonal mean during May – October, and August
Diatoms	May or April
Water-blooming cyanobacteria	August
Potentially toxin-producing cyanobacteria	August
Gonyostomum semen	August

Assessment of current conditions

TABLE 25.

CURRENT CONDITIONS: total phytoplankton volume (mm^3/l)

Class	Description	Biomass May – October	Biomass August
1	Very small biomass	≤ 0.5	≤ 0.5
2	Small biomass	0.5 – 1.5	0.5 – 2.0
3	Moderate biomass	1.5 – 2.5	2.0 – 4.0
4	Large biomass	2.5 – 5.0	4.0 – 8.0
5	Very large biomass	> 5.0	> 8.0

The seasonal mean of the phytoplankton biomass has been correlated to a nutrient gradient where particular account has been taken of changes in proportions between different groups of algae when deciding the boundaries between the classes. Class boundaries for August values have been set on the basis of an average correlation to the seasonal mean. Class 1 represents oligotrophy, class 2 mesotrophy, class 3 and 4 eutrophy and class 5 hypertrophy. The algal biomass in ultra-oligotrophic lakes (eg, large clearwater lakes and some mountain lakes) is usually ≤ 0.1 mm^3/l, both as a seasonal mean and as a figure for August. Even a slight input of nutrients to waters in this class causes marked structural changes in the plankton community (including a manifold increase in cyanobacteria).

TABLE 26.

CURRENT CONDITIONS: chlorophyll (µg/l)

Class	Description	Concentr. May – October	Concentr. August
1	Low concentrations	≤ 2	≤ 2.5
2	Moderate concentrations	2 – 5	2.5 – 10
3	High concentrations	5 – 12	10 – 20
4	Very high concentrations	12 – 25	20 – 40
5	Extremely high concentr.	> 25	> 40

Chlorophyll-a concentrations refer to seasonal means (May – October) over three years, based on monthly readings taken in the epilimnion or, if only one sample is taken, surface water (0.5 m). Alternatively, August readings taken over three years can be used, although account must then be taken of the relatively high variation from one year to another, particularly in eutrophic environments (class 4 and 5). The chlorophyll concentrations represent the intervals on the phytoplankton scale and the corresponding interval on the total phosphorus scale. The chlorophyll concentration has been assumed to constitute 0.5 per cent of plankton volume. Discrepancies in relation to the concentration of total phosphorus depend on lake depth, among other things.

TABLE 27.

CURRENT CONDITIONS: spring-developing diatoms (mm^3/l)

Class	Description	Biomass
1	Very small biomass	≤ 0.05
2	Small biomass	0.05 – 0.5
3	Moderate biomass	0.5 – 2.0
4	Large biomass	2.0 – 4.0
5	Very large biomass	> 4.0

TABLE 28.

CURRENT CONDITIONS: water-blooming cyanobacteria (mm^3/l)

Class	Description	Biomass
1	Very small biomass	≤ 0.5
2	Small biomass	0.5 – 1.0
3	Moderate biomass	1.0 – 2.5
4	Large biomass	2.5 – 5.0
5	Very large biomass	> 5.0

The class boundaries have been set on the basis of the greatest biomass of diatoms occurring in corresponding classes for total volume of algae.

TABLE 29.

CURRENT CONDITIONS: potentially toxin-producing cyanobacteria

Class	Description	Number of genera, August
1	None or few	≤ 2
3	A moderate number	3 – 4
5	A large to very large number	> 4

The boundary between class 1 and 2 represents a level below which nuisance caused by water-blooming cyanobacteria does not usually occur (biomass 0.5 mm^3/l). Other class boundaries represent approximately the 25th, 50th and 75th percentiles in that part of the background material comprising lakes having a biomass exceeding 0.5 mm^3/l.

The number of genera of potentially toxin-producing cyanobacteria indicates whether there is a short or a long-term problem in a lake used for bathing, a reservoir or a lake where fish or shellfish are farmed. The more genera found on a single sampling occasion, the greater the risk of persistent problems, since conditions for development vary from one species to another.

Toxin-producing cyanobacteria are not unique to highly eutrophic lakes. They may also be found in true oligotrophic waters. As a rule, only one toxic genus is found in mountain lakes: *Anabaena*, which develops during a limited period of the summer season, but in other nutrient-poor lakes another genus may appear, eg, *Aphanizomenon.* The boundary for class 1 has therefore been set at 2 genera.

The following genera and species of planktonic cyanobacteria may produce toxins in Sweden (Willén & Mattsson, 1997).

Anabaena: *A. circinalis, A. farciminiformis, A. flos-aquae, A. lemmermannii, A. solitaria*
Aphanizomenon: *A. flos-aquae, A. gracile, A. klebahnii, A. yezoense*
Microcystis: M. aeruginosa, M. botrys, M. flos-aquae, M. viridis, M. wesenbergii
Planktothrix: *P. agardhii (alt. Oscillatoria agardhii)*
Woronichinia: *W. naegeliana (alt. Gomphosphaeria naegeliana)*
Gloeotrichia: *G. echinulata*

Toxic forms of Woronichinia and Gloeotrichia have not yet been discovered in Sweden, which is probably due to a lack of analysis, since their ability to produce toxins has been verified in many other countries. These two genera are more frequently found mass-developing in moderately eutrophic lakes. To classify current conditions, it is proposed that a taxonomic division be made at genus level, since species analysis requires considerable experience owing to the lack of modern identification keys and uniform flora.

TABLE 30.

CURRENT CONDITIONS: *Gonyostomum semen* (mm³/l)

Class	Description	Biomass
1	Very small biomass	≤ 0.1
2	Small biomass	0.1 – 1.0
3	Moderate biomass	1.0 – 2.5
4	Large biomass	2.5 – 5.0
5	Very large biomass	> 5.0

The class boundaries for *Gonyostomum semen* have been set to take account of problems in bathing waters. The biomass in the highest classes indicates that sensitive individuals may suffer skin reactions. The boundaries of the various classes coincide roughly with the 25th, 50th, 75th and 90th percentiles in the background material.

Assessment of deviation from reference values

TABLE 31.

DEVIATION from reference value, total phytoplankton volume, spring-developing diatoms, water-blooming cyanobacteria

Class	Description	Recorded volume/reference value
1	No or insignificant deviation	≤ 1.0
2	Slight deviation	1.0 – 2.0
3	Significant deviation	2.0 – 3.0
4	Large deviation	3.0 – 5.0
5	Very large deviation	> 5.0

Reference values for various types of lakes are shown in Table 34. The figures have been calculated for lowland lakes on the basis of an assumed pristine mesotrophic state with a typical total phosphorus concentration

TABLE 32.

DEVIATION from reference value, potentially toxin-producing cyanobacteria

Class	Description	No. of potentially toxic genera/ reference value
1	No or insignificant deviation	< 1
3	Significant deviation	1 – 1.5
5	Large to very large deviation	≥ 1.5

TABLE 33.

DEVIATION from reference value, *Gonyostomum semen*

Class	Description	Recorded volume/reference value
1	No or insignificant deviation	≤ 1.0
2	Slight deviation	1.0 – 10
3	Significant deviation	10 – 25
4	Large deviation	25 – 50
5	Very large deviation	> 50

of 15 µg/l. The reference values have then been based on correlations with the total biomass of planktonic algae. The biomass in August has been determined by calculating the relationship with the seasonal mean from the Environmental Monitoring Programme database. The volume of diatoms in April/May is based on the maximum figure in the database for mesotrophic lakes having a nutrient status of 15 µg/l (tot-P). Two reference lakes form the basis for assessment of forest lakes. Maximum figures from a number of published studies have been used for mountain lakes, since the Environmental Monitoring Programme database was inadequate.

Reference values for potentially toxic genera have been set using the Environmental Monitoring Programme database. Essentially, the reference value for *Gonyostomum semen* is considered to be an absence of viable communities. The reference value has been set using lakes where there is an influx of humic water capable of carrying limited quantities of *Gonyostomum*, which will temporarily survive in a given habitat.

TABLE 34.

Reference values for planktonic algae in various lake types

Indicator	Lowland lake, shallow*	Lowland lake, deep*	Forest lake*	Mountain lake*
Total volume, seasonal average, mm^3/l	1	0.5	0.5	0.5
Total volume, August, mm^3/l	1.5	0.75	0.5	0.5
Diatom biomass in April/May, mm^3/l	1	1	0.5	**
Water-blooming cyanobacteria in August, mm^3/l	0.5	0.5	0.05	**
No. of potentially toxin-producing cyanobacteria (genera) in August	4	4	3	2
Gonyostomum semen, biomass in August, mm^3/l	0.1	0.1	0.1	**

* Mountain lake: situated above the tree line

Forest lake: usually, but not always, situated above the reference elevation, referred to in Sweden as "the highest coastline", where surrounding land comprises > 60% forest

Lowland lake: situated on mud sediments, usually below the highest coastline, where surrounding land comprises > 60% cultivated land (arable land, meadow, fallow, other grazing land).

** No reference values available or the parameter is not relevant to the lake type.

Comments

Classification must be based on samples taken and analysed in accordance with the Swedish EPA Environmental Monitoring Handbook. Assessment need not necessarily be made using all parameters for a given lake. The choice of parameters is governed by the aspects of the presence of planktonic algae to be highlighted and the availability of background data. Hence, in some cases assessment will be confined to harmful algae. In others, assessment may focus on biomass quantities in parallel with the presence of toxic algae.

In oligotrophic lakes, where there is often little difference from one year to another, results from a single year may be used for assessment. In moderately eutrophic and eutrophic lakes, on the other hand, data should comprise figures from three years of study, so as to obtain mean values. Variations between years due to weather have a particularly marked impact on species balance and quantities of various algal groups in such lakes, which in turn affects total biomass. If an assessment is made using more limited data, this should be stated.

The scales for the respective parameters, as with the choice of parameters and reference values, are intended to be used during a trial period.

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Aquatic plants in lakes

Introduction

Aquatic plants play an important role in lake metabolism and form an essential part of the habitat of many organisms. The diversity and abundance of plants is affected by eutrophication, acidification and other changes in the environment. Both individual species and entire types of plant community can therefore serve as indicators of the state of the ecosystem.

This assessment system uses mainly floating-leaved and submerged plants. These groups have been chosen because they are well defined and contain many species giving a good indication of environmental quality. The assessment of current conditions is based on the number of species present. When assessing deviation from reference values, use is also made of indicator ratios, which reflect the normal occurrence of species in relation to the nutrient status of the water.

The assessment of aquatic plants is confined to lakes. There is no background data on which to base model criteria for watercourses.

Assessment of current conditions

TABLE 35.

CURRENT CONDITIONS: number of species of submerged and floating-leaved plants

Class	Description	Total number of species
1	Very high number of species	> 18
2	High number of species	14 – 18
3	Moderate number of species	9 – 14
4	Relatively few species	4 – 9
5	Very few species	≤ 4

The classification can be supplemented by specifying the predominant type of vegetation: A Isoetid type, B Elodeid type, C Floating-leaved type (see Appendix 1). If submerged and floating-leaved plants are lacking and emergent species are overwhelmingly dominant, this may be expressed as D Emergent type. The boundaries for classes 1 – 5 comprise the 75th, 50th, 25th and 10th percentiles, respectively, in the background data.

Class boundaries are based on a statistical analysis of data on Swedish lakes, which is as representative as possible.

Assessment of deviation from reference values

TABLE 36.

DEVIATION from reference values, number of species and indicator ratio for submerged and floating-leaved plants

Class	Description	Number of species and indicator ratio
1	No or insignificant deviation	The number of species and indicator ratio are equal to the reference value*
2	Slight deviation	The number of species *or* indicator ratio deviate from the reference value**
3	Significant deviation	The number of species *and* indicator ratio deviate from the reference value**
4	Large deviation	The number of species *and* indicator ratio deviate from the reference value; one of the measures deviates greatly***
5	Very large deviation	Mass presence**** of 1 - 3 species of elodeids/free-floating or emergent plants

* Reference values as shown in Table 37

** In order to count, the number of species deviation should equal a current conditions class and the indicator ratio deviation should be 0.5 - 1.0 units.

*** The number of species deviation should equal at least two current conditions classes and the indicator ratio deviation should be more than one unit.

**** The term ”mass presence” means that the surface area available for vegetation is largely (>75%) covered by individual species foreign to the lake type or that the surface shows signs of becoming completely overgrown.

The indicator ratio is calculated as the average of the trophic ranking scores for species present in the lake as shown in Appendix 1.

Reference values for different regions and lake types are given in Table 37.

TABLE 37.

Reference values for number of species and indicator ratios for submerged and floating-leaved plants in lakes of various sizes and location

	Northern Sweden*		Southern Sweden	
Lake area km²	No. of species	Indicator ratio	No. of species	Indicator ratio
< 60 m above sea level				
< 0.1	3 – 5	5.5	4 – 12	7.4
0.1 – 1	9 – 14	6.5	11 – 16	8.1
1 – 10	10 – 18	6.3	15 – 23	8.0
≥ 10	17 – 21	6.5	17 – 25	8.0
60 – 199 m above sea level				
< 0.1	**	**	5 – 11	6.9
0.1 – 1	5 – 13	6.3	10 – 17	7.0
1 – 10	10 – 16	5.8	17 – 25	6.5
≥ 10	13 – 20	6.3	> 17	6.6
> 200 m above sea level				
< 0.1	**	**	**	**
0,1 – 1	4 – 11	6.3	8 – 16	7.2
1 – 10	8 – 15	6.2	15 – 25	6.2
≥ 10	13 – 17	5.9	**	**

* North of the Dalälven River ** Reference values are not provided due to lack of data.

Comments

A survey to determine the number of species and indicator ratio in an entire lake requires the use of methods providing information on the vegetation of the whole lake. Studies should be made in high summer or late summer. The forthcoming description of methods in the Swedish EPA Environmental Monitoring Handbook should be used. For the time being, instructions issued in the form of ”Standards for Biological Surveys” (in Swedish only, Swedish EPA 1987) can be used.

Available data on the occurrence of aquatic plants in watercourses is inadequate as a basis for assessment. Systematic surveys are needed before work can progress.

Studies of contemporary vegetation that cover large or representative areas of the country are also lacking. Here, too, therefore, the data has great limitations, although it can be supplemented using regional surveys to determine reference values. These surveys can also provide data for a future revision of the Environmental Quality Criteria.

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Periphyton – diatoms in watercourses

Introduction

Periphyton algae play an important part as a primary producer, particularly in running waters. These algae are also a good indicator of water quality. Analysis of periphyton algae may therefore serve to supplement or replace chemical or other biological studies. Periphyton algae may be the only feasible biological indicator in slow-flowing waters.

The assessment is confined to watercourses and is based on two indices, both designed to reflect the degree of eutrophication and general pollution impact.

Assessment of current conditions

TABLE 38.

CURRENT CONDITIONS: index, diatoms

Class	Description	IPS index or IDG index
1	Very high index figure	≥ 17.5
2	High index figure	14 – 17.5
3	Moderate index figure	10.5 – 14
4	Low index figure	7 – 10.5
5	Very low index figure	< 7

The IPS (Indice de polluo-sensibilité) and IDG (Indice diatomique génerique) indices are calculated as:

$$\sum A_i I_i V_i / \sum A_i V_i$$

where Ai is the relative abundance of taxon i, expressed as a percentage, V_i is the indicator value of taxon i (1 – 3) and I_i is the sensitivity to pollution of taxon i (1 – 5). The result obtained using the above formula is converted into a scale of 1 – 20 as follows:

4.75 · original index value –3.75.

The genera in question and their trophic ranking scores and sensitivity to pollution are listed in the method description in the EPA Environmental Monitoring Handbook; indices can be calculated using the Omnidia software.

The class boundaries essentially reflect the state of the watercourse as follows:

Class 1. Highly oligotrophic to oligotrophic state and no or insignificant pollution.

Class 2. Oligotrophic to eutrophic state and/or slight pollution.

Class 3. Eutrophic to highly eutrophic state and/or obvious pollution.

Class 4. Severe pollution.

Class 5. Very severe pollution.

This classification is based on European studies and have been adapted to Swedish conditions in terms of pollution levels and algal occurrence. It has been tested on limited Swedish data from various ecotypes.

Assessment of deviation from reference values

There is no background data from which to determine reference values and therefore no proposed assessment of deviation is described here.

Comments

Experience in Sweden of water quality assessment using diatoms is limited and the model criteria in this chapter are therefore largely based on experience in other countries. Class boundaries and other aspects may be adjusted as more is learnt about Swedish conditions.

The assessment must be based on samples taken and analyses made in accordance with the Swedish EPA Environmental Monitoring Handbook and analyses made in accordance with the Swedish standard.

References

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Benthic fauna

Introduction

Benthic fauna is an important element in the biological diversity of lakes and watercourses. These organisms are also an important food resource for fish and play an important part in breaking down organic matter. Methods of classifying and assessing lakes and watercourses based on benthic fauna are in general use.

The model criteria given here cover a selection of parameters for various types of habitat and various quality aspects. Diversity (here calculated as Shannon-Wiener's diversity index) is high if there are many species and several of them are dominant, and low if there are few species, one or more being very dominant. The ASPT index is a "clean water index", mainly indicating the presence of sensitive groups (high values) or tolerant ones (low values). The impact on fauna of eutrophication and organic pollutants is assessed using the Danish fauna index (watercourses and the littoral zone of lakes), the BQI index and the O/C index (profundal zone in lakes). The Danish fauna index is used to ascertain whether animals belonging to various key groups with varying tolerance are present in the samples. Depending on the groups occurring, samples are classified according to a scale from high (sensitive species) to low values (tolerant species). The BQI index is a quality index based on chironomid species. High values indicate that species preferring clean water and well-oxygenated water dominate; low values indicate the presence of tolerant species. The O/C index expresses the relationship between the number of oligochaete worms and chironomid midge larvae and is a further measure of oxygen conditions and the degree of organic load on lake beds. A high index (ratio) shows a predominance of oligochaete worms, ie, relatively low oxygen levels and/or high organic load. Finally, acidification is reflected by the acidity index, which is based on the occurrence of species possessing differing degrees of pH tolerance. High values indicate predominantly species sensitive to acidification. The methods of calculating the various indices are shown in Appendix 2.

Assessment of current conditions

TABLE 39.

CURRENT CONDITIONS: bottom fauna index, watercourses (riffle areas)

Class	Description	Shannon's diversity index	ASPT-index	Danish fauna-index	Acidity index
1	Very high index	> 3.71	> 6.9	7	> 10
2	High index	2.97 – 3.71	6.1 – 6.9	6	6 – 10
3	Moderately high index	2.22 – 2.97	5.3 – 6.1	5	4 – 6
4	Low index	1.48 – 2.22	4.5 – 5.3	4	2 – 4
5	Very low index	≤ 1.48	≤ 4.5	≤ 3	≤ 2

TABLE 40.

CURRENT CONDITIONS: bottom fauna index, littoral zone of lakes (exposed shores)

Class	Description	Shannon's diversity index	ASPT-index	Danish fauna-index	Acidity index
1	Very high index	> 3.00	> 6.4	> 5	> 8
2	High index	2.33 – 3.00	5.8 – 6.4	5	6 – 8
3	Moderately high index	1.65 – 2.33	5.2 – 5.8	4	3 – 6
4	Low index	0.97 – 1.65	4.5 – 5.2	3	1 – 3
5	Very low index	≤ 0.97	≤ 4.5	≤ 2	≤ 1

Apart from the acidity index, class boundaries are based on statistical breakdowns, where classes 1 and 5 are delimited by the 90th and 10th percentiles (O/C index 10th and 90th) and where the other class boundaries are divided evenly between the extremes. The class boundaries for the acidity index reflect the occurrence of various species along a pH gradient (see Appendix 2).

TABLE 41.

CURRENT CONDITIONS: bottom fauna index, profundal zone in lakes

Class	Description	BQI-index	O/C-index*
1	Very high/very low index	> 4	≤ 0.5
2	High/low index	3.0 – 4.0	0.5 – 4.7
3	Moderately high/low index	2.0 – 3.0	4.7 – 8.9
4	Low/high index	1.0 – 2.0	8.9 – 13
5	Very low/very high index	≤ 1.0	> 13

* Adjusted for sampling depth (see Appendix 4)

Assessment of deviation from reference values

TABLE 42.

DEVIATION from reference value: bottom fauna index, lakes and watercourses

Class	Description	Recorded value/reference value	
		O/C index	Other index
1	No or slight deviation	< 0.3	> 0.9
2	Moderate deviation	0.3 – 0.6	0.8 – 0.9
3	Significant deviation	0.6 – 0.8	0.6 – 0.8
4	Large deviation	0.8 – 0.9	0.3 – 0.6
5	Very large deviation	> 0.9	< 0.3

This classification is based on the EC white paper prior to the framework directive on water (Nixon et al., 1996), which describes each class as follows (with some modifications).

Class 1. No or insignificant effects of disturbance. No or only insignificant anthropogenic impact on communities of organisms or their habitat. The macro invertebrate community resembles that normally occurring in the type of habitat under undisturbed conditions.

Class 2. Moderate effects of disturbance. The benthic fauna shows signs of disturbance but only deviates slightly from its undisturbed state.

Class 3. Clear effects of disturbance. Substantial impact on assemblages of organisms and their habitat. The bottom fauna deviates moderately from its normal undisturbed state.

Class 4. Pronounced effects of disturbance. The community deviates markedly from its undisturbed state.

Class 5. Very great effects of disturbance. Only a few tolerant species occur.

Reference values specific to a given locality should be used as far as possible. These may be derived in several ways. They can be estimated on the basis of historical surveys carried out in the area or they may be obtained from surveys made in similar but unaffected lakes or watercourses in the vicinity. If this is not possible, the reference values given in Table 43 may be used.

TABLE 43.

Reference values for differing habitats and natural geography. Reference values comprise the 25th percentile (75th percentile for O/C index) in data from lakes and watercourses included in the 1995 survey of lakes and watercourses, which, as far as possible, are unaffected. The data used is described in detail in the background report. The boundaries between the natural geographical regions are shown in Figure 3. The figures given for the profundal zone of lakes are not specific to regions.

	Natural geographical region					
	Arctic/ alpine	Northern boreal	Middle boreal	Southern boreal	Boreo-nemoral	Nemoral
Watercourses						
Shannon-Wiener's diversity index	1.96	2.56	2.34	2.11	1.97	1.89
ASPT-index	5.8	6.2	6.0	5.5	4.7	4.8
Danish fauna index*	5	5	5	5	5	5
Acidity index	6	6	6	6	6	6
Littoral zone of lakes						
Shannon's-Wiener's diversity index	1.00	1.06	1.46	1.98	2.15	2.01
ASPT-index	4.6	5.0	5.0	5.0	5.1	4.5
Danish fauna index	3	4	4	4	4	4
Acidity index	6	6	6	6	6	6
Profundal zone in lakes						
BQI-index	2					
O/C-index	8.5					

* Reference values for regions 4, 5 and 6 have been adjusted upwards (from 4 to 5) in response to comments received from consultants, county administrative boards etc working in these regions.

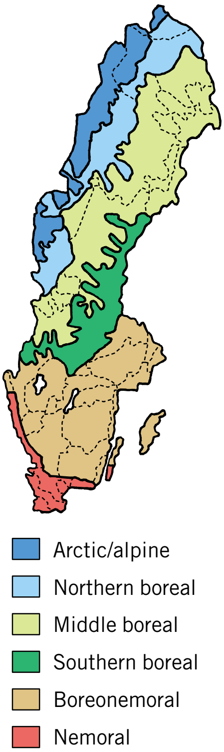

Figure 3. Natural geographical regions used to calculate reference values (from Nordic Council of Ministers, 1984).

Comments

The assessment must be based on samples taken (SS-EN 27828) and analyses made in accordance with the Swedish EPA Environmental Monitoring Handbook.

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Fish

Introduction

Fish form an essential part of freshwater ecosystems and it is therefore important to assess the status of fish communities and any changes in them. A considerable amount is known about the life cycles and habitat requirements of individual species, which means that the structure and function of fish communities is also a useful tool for assessing whether any changes have occurred in the habitat.

The assessments in this chapter are based on a large number of biologically relevant parameters, weighed together to form an overall index. All parameters indicate various kinds of change in the biota. Hence, the overall index gives a mean indication of the status of the fish community, whereas the individual parameters combine to form a profile indicating the factors of particular importance to the status of the community.

The system is to some extent founded on a tried and tested US system, used to assess deviation from original status with the help of fish (Index of Biotic Integrity – IBI). The original IBI and most subsequent applications have classified impact in relation to unaffected references, which requires good knowledge of the pristine fish fauna in each instance. An approach of this kind is scarcely possible in Sweden. Although waters directly affected by acidification, liming and point sources, for example, can indeed be identified, it is not usually possible to distinguish waters affected in other ways, eg, by changes in land use, introduction of non-native species etc. The reference values presented here therefore constitute ”typical” values for each parameter in relation to the two national fish databases used, rather than values for ”pristine state”. The analyses performed show that this approach is still well able to distinguish waters displaying documented impact from evidently pristine waters.

Historical migrations of fish and interaction between species determine their presence in lakes and watercourses. Regional adjustments have therefore been made by describing parameters on the basis of local conditions such as height above sea level and lake size. This approach has yielded better results than did previous attempts at division into natural geographical regions.

Lake assessment is based on the following parameters, which are weighed together to give an overall index.

1. Number of native fish species
2. Species diversity of native fish species based on weight
3. Relative biomass of native fish species (weight/effort)
4. Relative number of individuals of native fish species (number/effort)
5. Proportion of piscivorous (fish-eating) percids out of the total catch based on weight
6. Proportion of cyprinids out of the total catch based on weight
7. Presence of species and stages sensitive to acidification
8. Proportion of biomass of species tolerant of low oxygen concentrations
9. Proportion of biomass of alien species

Parameters 1 – 5 are used to assess current conditions. All nine parameters are used to assess deviation from reference values.

Watercourse assessment is based on the following parameters, which are weighed together to give an overall index.

1. Number of native fish species
2. Biomass of native fish species
3. Number of individuals of native fish species
4. Proportion of salmonids based on number
5. Reproduction of native salmonids
6. Presence of species and stages sensitive to acidification
7. Proportion of alien species based on number

Parameters 1 – 5 are used to assess current conditions. All seven parameters are used to assess deviation from reference values.

Assessment of current conditions

The class boundaries of the individual parameters and of the overall assessment (Table 44) are based on statistical distributions of existing data on fish fauna in Swedish lakes and watercourses. With a few isolated exceptions, the 95th, 75th, 25th and 5th percentiles have been used as

TABLE 44.

CURRENT CONDITIONS: fish, lakes

Class	Description	No. of species[1]	Species diversity[2]	Biomass[3]	Number[3]
1	Very high number of species, etc	≥ 10	> 0.65	> 4000	> 95
2	High number of species, etc	6 – 9	0.55 – 0.65	1800 – 4000	35 – 95
3	Moderate number of species, etc	3 – 5	0.28 – 0.55	650 – 1800	13 – 35
4	Low number of species, etc	2	0.11 – 0.28	250 – 650	5 – 13
5	Very low number of species, etc	≤ 1	≤ 0.11	≤ 250	≤ 5

Class	Description	Proportion of piscivorous fish[4]
1	Very high proportion of pisc. fish	> 0.82
2	High proportion of pisc. fish	0.54 – 0.82
3	Moderately high proportion of pisc. fish	0.24 – 0.54
4	Low proportion of pisc. fish	0.09 – 0.24
5	Very low proportion of pisc. fish	≤ 0.09

Class	Description	Overall index[5]
1	Very low overall index	< 2.2
2	Low overall index	2.2 – 2.6
3	Moderately high overall index	2.6 – 3.4
4	High overall index	3.4 – 4.2
5	Very high overall index	≤ 4.2

1 Only fish species native to Sweden are included (see list of species in Appendix 3).
2 Species diversity is calculated as Shannon-Wiener's H' = $[W_{tot}\log_{10}(W_{tot}) - \Sigma W_i\log_{10}(W_i)] / W_{tot}$, where W_{tot} is the total weight per effort and Wi is the weight per effort for each species. An effort constitutes one night's fishing with a net using a standard method.
3 Biomass and number are expressed as grams and number per effort, respectively.
4 Piscivorous percids includes zander (*Sander lucioperca*) and perch (*Perca fluviatilis*) more than 150 mm in length. The parameter is only calculated for lakes where perch and/or zander are caught.
5 The overall index is calculated as the mean of the class figures for all parameters included.

class boundaries. In most cases, this means that 50 per cent of existing data will fall within class 3.

Class 1 in the overall index indicates that the fish fauna of the lake consists of a large number of species with high diversity, many fish with a high proportion of piscivorous fish, ie, a rich and diverse fish community.

TABLE 45.

CURRENT CONDITIONS: fish, watercourses

Class	Description	No. of species[1]	Biomass[2]	Number[2]	Proportion of salmonids[3]
1	Very high number of species, etc	≥ 5	≥ 2200	≥ 222	1.00
2	High number of species, etc	3 – 4	640 – 2200	64 – 222	0.90 – 1.00
3	Moderate number of species, etc	2	260 – 640	23 – 64	0.73 – 0.90
4	Low number of species, etc	1	95 – 260	6 – 23	0.16 – 0.73
5	Very low number of species, etc	0	< 95	< 6	< 0.16

Class	Description	Salmonid reproduction[3]
1	Very high salmonid reproduction	1.00
2	High salmonid reproduction	0.67 – 1.00
3	Moderately salmonid reproduction	0.50 – 0.67
4	Low salmonid reproduction	0.33 – 0.50
5	Very low salmonid reproduction	< 0.33

Class	Description	Overall index[4]
1	Very low overall index	< 2.0
2	Low overall index	2.0 – 2.5
3	Moderately high overall index	2.5 – 3.6
4	High overall index	3.6 – 4.0
5	Very high overall index	> 4.0

1 Only fish species native to Sweden are included (see list of species in Appendix 3).
2 Biomass and number are expressed per 100 m^2.
3 At localities where salmonids occur (char, grayling, trout or salmon), a calculation of the number of these four species having yearlings (recruitment) is ascertained. The number of breeding species is divided by the number of salmonid species.
4 Calculated as the mean of the class figures for all parameters included.

Class 3 represents average conditions for fish communities in Swedish lakes (see above).

As with lakes, the class boundaries of the individual parameters and of the overall assessment for watercourses are based on statistical distributions of existing data on fish fauna in Swedish lakes and watercourses. With a few isolated exceptions, the 95th, 75th, 25th and 5th percentiles have been used as class boundaries. In most cases, this means that 50 per cent of existing data will fall within class 3.

Class 1 in the overall index indicates that the fish fauna of the watercourse consists of a large number of species with high diversity, many fishes with a high proportion of salmonids having a high reproduction level. A classification around class 3 indicates a watercourse close to the median for Swedish watercourses. Class 5 indicates an ecosystem poor in species and individuals and with an absence of salmonids.

Assessment of deviation from reference values

Note that deviation from reference values for lakes (Table 46) is not calculated for the parameters ”Presence of species and stages sensitive to acidification”, ”Proportion of tolerant fish species” and ”Proportion of alien species”, the deviation can instead be obtained directly by comparing the recorded value with the classes in table 46. In these cases the value for class 1 is the result obtained in waters with no or insignificant impact.

Class boundaries have been adjusted to existing parameters and background data. With a few isolated exceptions, the 50th, 25th, 10th and 5th percentiles have been used for one-sided parameters, which means that 50 per cent of the background data will fall within class 1. The 2nd, 5th, 10th and 25th percentiles and the 75th, 90th, 95th and 98th percentiles, respectively, have been used for double-sided parameters. Here, too, 50 per cent of the background data falls within class 1.

Note that reference values for watercourses are only calculated for the ”Number of species” parameter. The parameters ”Weight/100 m^2” to ”Proportion of alien fish species” are calculated as described in the footnote. In these cases the value for class 1 is the result obtained in waters with no or insignificant impact.

Comments

The assessments must be based on fish surveys carried out in accordance with the instructions given in the Swedish EPA Environmental Monitoring Handbook. Hence, lakes having a surface area of less than 10 ha should not be included. Assessment of current conditions and deviations should also be made with a degree of insight. This is particularly so where the absence of species and stages forms part of the assessment (eg, proportion of species sensitive to acidification and proportion of alien species). In exceptional cases, natural variations may lead to erroneous interpretations. Assessment of lakes over 500 m above sea level should be made with great caution owing to the absence of data on high altitude lakes and lakes with predominantly salmonid assemblages. The background data on watercourses in lowland areas is similarly limited. Help with calculations may be obtained from the data host for fish (Institute of Freshwater Research, National Board of Fisheries).

TABLE 46.

DEVIATION from reference value, lakes. For the time being, calculations should only be made for lakes below 500 m above sea level. Background data on higher altitude lakes is too limited for reliable assessment. Calculations are only made for lakes that can be assumed to contain, or have contained, fish.

Class	Description	Recorded value/reference value			
		No. of species[1]	Species diversity[1]	Biomass[1]	Number[1]
1	No or insignif. deviation	> 0.80	> 1.00	0.65 – 1.50	0.60 – 1.40
2	Slight deviation	0.62 – 0.80	0.83 – 1.00	0.45 – 0.65 or 1.50 – 2.15	0.37 – 0.60 or 1.40 – 2.15
3	Significant deviation	0.42 – 0.62	0.60 – 0.83	0.28 – 0.45 or 2.15 – 2.70	0.22 – 0.37 or 2.15 – 2.80
4	Large deviation	0.32 – 0.42	0.38 – 0.60	0.10 – 0.28 or 2.70 – 3.40	0.10 – 0.22 or 2.80 – 3.50
5	Very large deviation	≤ 0.32	≤ 0.38	< 0.10 or > 3.40	< 0.10 or > 3.50

Class	Description	Recorded value/reference value			
		Proportion pisc.[1]	Proportion cyprinids[1]	Proportion species and stages sensitive to acidification[2]	Proportion tolerant species[3]
1	No or insignificant deviation	1.00	1.00	a)	< 0.10
2	Slight deviation	0.65 – 1.00	1.00 – 1.28		0.10 – 0.25
3	Significant deviation	0.40 – 0.65	1.28 – 1.67	b)	0.25 – 0.50
4	Large deviation	0.23 – 0.40	1.67 – 1.89		0.50 – 1.00
5	Very large deviation	< 0.23	> 1.89	c)	1.00

Class	Description	Proportion alien species[4]	Overall index[5]
1	No or insignificant deviation	0	≤ 1.7
2	Slight deviation	0 – 0.10	1.7 – 2.1
3	Significant deviation	0.10 – 0.20	2.1 – 2.6
4	Large deviation	0.20 – 0.50	2.6 – 3.0
5	Very large deviation	> 0.50	> 3.0

1 The deviation is calculated as the ratio between recorded value and the reference value. The reference value is set with reference to Table 47.

2 a) Presence of spined loach (*Cobitis taenia*) or crayfish or juvenile roach (*Rutilus rutilus*), minnow (*Phoxinus phoxinus*), burbot (*Lota lota*), char (Salvelinidae), whitefish (Coregonidae) or vendace (*Coregonus albula*).
b) Presence of perch (*Perca fluviatilis*), trout (*Salmo trutta*), bullhead (Cottidae), ruffe (*Gymnocephalus cernuus*), burbot (*Lota lota*), grayling (*Thymalus thymalus*) char, whitefish or vendace (*Coregonus albula*).
c) Species absent (have disappeared) or only mature/large individual specimens of perch or pike are present.

3 Calculated as percentage by weight of crucian carp (*Carassius carassius*) and/or tench (*Tinca tinca*) out of the total catch. This parameter is only used in lakes where one of these species has been caught.

4 Calculated as percentage by weight of fish species not native to Sweden out of the total catch.

5 The overall assessment of deviation is obtained by calculating the mean class value for all parameters included (maximum 9 parameters).

TABLE 47.

CALCULATION OF REFERENCE VALUES for lakes.

Parameter	Height (m)	Reference value
Number of fish species[1]	0 – 100	$J = 2.44 \cdot \text{Lake area}^{0.233}$
	101 – 300	$J = 2.07 \cdot \text{Lake area}^{0.218}$
	> 300	$J = 1.68 \cdot \text{Lake area}^{0.171}$
Species diversity[2]	all	$J = -0.0414 + 0.331 \cdot \ln$ (No. of fish species)
Weight per effort[3]	0 – 100	$J = 3981 \cdot \text{Maximum depth}^{-0.383}$
	101 – 300	$J = 2511 \cdot \text{Maximum depth}^{-0.383}$
	> 300	$J = 1995 \cdot \text{Maximum depth}^{-0.383}$
Number per effort[3]	0 – 100	$J = 77.0 - 35.6 \cdot \log_{10}(\text{maximum depth})$
	101 – 300	$J = 36.0 - 13.1 \cdot \log_{10}(\text{maximum depth})$
	> 300	$J = 19.8 - 6.1 \cdot \log_{10}(\text{maximum depth})$
Proportion of piscivorous percids[4]	all	$J = 0.481 - 0.0000615 \cdot$ (total weight/effort)
Proportion of piscivorous cyprinids[5]	all	$J = 0.283 + 0.0000694 \cdot$ (total weight/effort)

1 Only fish species native to Sweden are included (see list of species). Lake area is expressed in hectares.

2 Species diversity is calculated as Shannon-Wiener's $H' = [W_{tot}\log_{10}(W_{tot}) - \Sigma W_i \log_{10}(W_i)] / W_{tot}$ where W_{tot} is the total weight per effort and W_i is the weight per effort for each species.

3 Biomass and number are expressed as grams and number per effort, respectively. An effort constitutes one night's fishing with a net using a standard method. Depth is expressed in metres.

4 Piscivorous percids includes zander (*Sander lucioperca*) and perch (*Perca fluviatilis*) more than 150 mm in length. The parameter is only calculated for lakes where perch and/or zander are caught.

5 The following species are classified as cyprinids: asp (*Aspius aspius*), bleak (*Alburnus alburnus*), silver bream (*Abramis bjoerkna*, alt. *Blicca bjoerkna*), bream (*Abramis brama*), minnow (*Phoxinus phoxinus)*, Zope (*Abramis ballerus*), ide (*Leuciscus idus*), roach (*Rutilus rutilus*), crucian carp (*Carassius carassius*), rudd (*Rutilus erythrophthalmus*, alt. *Scardinius erythrophthalmus*), dace (*Leuciscus leuciscus*), tench (*Tinca tinca*) and Baltic vimba (*Abramis vimba* alt *Vimba vimba*). The parameter is only calculated for lakes where cyprinids are caught.

TABLE 48.

DEVIATION from reference value, watercourses, used only for watercourses that can be assumed to contain, or have contained, fish.

Number of species[1]

Class	Description	Recorded value/reference value
1	No or insignificant deviation	≥ 0.85
2	Slight deviation	0.70 – 0.85
3	Significant deviation	0.50 – 0.70
4	Large deviation	0.50 – 0.35
5	Very large deviation	< 0.35

Weight[2]/100 m[2]

Class	Description	0 – 99 m ab.	100 – 299 m ab.	300 – 700 m ab.	> 700 m ab.
1	No or insign. deviat.	≥ 525	≥ 250	≥ 105	≥ 65
2	Slight deviation	350 – 525	175 – 250	75 – 105	45 – 65
3	Significant deviation	225 – 350	100 – 175	45 – 75	25 – 45
4	Large deviation	80 – 225	35 – 100	15 – 45	10 – 25
5	Very large deviation	< 80	< 35	< 15	< 10

Number[2]/100m[2]

Class	Description	0 – 99 m ab.	100 – 299 m ab.	300 – 700 m ab.	> 700 m ab.
1	No or insign. deviat.	≥ 1.70	≥ 1.34	≥ 0.98	≥ 0.84
2	Slight deviation	1.50 – 1.70	1.05 – 1.34	0.80 – 0.98	0.60 – 0.84
3	Significant deviation	1.24 – 1.50	0.85 – 1.05	0.53 – 0.80	0.40 – 0.60
4	Large deviation	0.67 – 1.24	0.34 – 0.85	0.30 – 0.53	0.30 – 0.40
5	Very large deviation	< 0.67	< 0.34	< 0.30	< 0.30

Proportion of salmonids (flow = < 0.2 m/s – Calm)

Class	Description	0 – 99 m ab.	100 – 299 m ab.	300 – 700 m ab.	> 700 m ab.
1	No or insign. deviat.	≥ 0.77	≥ 0.31	≥ 0.86	≥ 0.95
2	Slight deviation	0.53 – 0.77	0.15 – 0.31	0.54 – 0.86	0.80 – 0.95
3	Significant deviation	0.23 – 0.53	0.10 – 0.15	0.16 – 0.54	0.61 – 0.80
4	Large deviation	0.05 – 0.23	0.05 – 0.10	0.05 – 0.16	0.40 – 0.61
5	Very large deviation	< 0.05	< 0.05	< 0.05	< 0.40

Contd. ➤

TABLE 48.

(Contd.)

Proportion of salmonids (flow = < 0.2 - 0.7 m/s – Flowing)

Class	Description	0 – 99 m ab.	100 – 299 m ab.	300 – 700 m ab.	> 700 m ab.
1	No or insign. deviat.	≥ 0.76	≥ 0.62	≥ 0.90	≥ 0.99
2	Slight deviation	0.58 – 0.76	0.34 – 0.62	0.68 – 0.90	0.90 – 0.99
3	Significant deviation	0.38 – 0.58	0.15 – 0.34	0.40 – 0.68	0.88 – 0.90
4	Large deviation	0.17 – 0.38	0.05 – 0.15	0.14 – 0.40	0.54 – 0.88
5	Very large deviation	< 0.17	< 0.05	< 0.14	< 0.54

Proportion of salmonids (flow = < 0.7 m/s – Fast-flowing)

Class	Description	0 – 99 m ab.	100 – 299 m ab.	300 – 700 m ab.	> 700 m ab.
1	No or insign. deviat.	≥ 0.78	≥ 0.43	≥ 0.95	≥ 0.98
2	Slight deviation	0.60 – 0.78	0.25 – 0.43	0.80 – 0.95	0.90 – 0.98
3	Significant deviation	0.37 – 0.60	0.11 – 0.25	0.45 – 0.80	0.50 – 0.90
4	Large deviation	0.19 – 0.37	0.05 – 0.11	0.16 – 0.45	0.25 – 0.50
5	Very large deviation	< 0.19	< 0.05	< 0.16	< 0.25

Salmonid reproduction[3]

Class	Description	
1	No or insignificant deviation	1.00
2	Slight deviation	0.67 – 1.00
3	Significant deviation	0.50 – 0.67
4	Large deviation	0.33 – 0.50
5	Very large deviation	< 0.33

Presence of species and stages sensitive to acidification[4]

Class	Description	
1	No or insignificant deviation	a)
2	Slight deviation	b)
3	Significant deviation	c)
4	Large deviation	d)
5	Very large deviation	e)

Contd. ➤

TABLE 48.

(Contd.)

Proportion of alien species[5]

Class	Description	
1	No or insignificant deviation	0
2	Slight deviation	0 – 0.01
3	Significant deviation	0.01 – 0.02
4	Large deviation	0.02 – 0.05
5	Very large deviation	> 0.05

Overall index[6]

Class	Description	
1	No or insignificant deviation	< 2.8
2	Slight deviation	2.8 – 3.3
3	Significant deviation	3.3 – 4.5
4	Large deviation	4.5 – 4.9
5	Very large deviation	≥ 4.9

1 Only fish species native to Sweden are included. The reference value (J) is calculated as follows: $J = 1.19 + 0.71 \cdot [\mathrm{Log}_{10}\ (\mathrm{Width})] + 0.419 \cdot [\mathrm{Catchment}] + 0.142 \cdot [\mathrm{Lake\ percentage}] - 0.0019 \cdot [\mathrm{Height\ above\ sea\ level}]$ using the class values below for the catchment areas and percentage of lakes. Width and height are expressed in metres.

Class	Catchment	Percentage of catchment upstream comprising lakes
1	< 10 km^2	< 1 %
2	< 100 km^2	< 5 %
3	< 1000 km^2	< 10 %
4	> 1000 km^2	> 10 %

The deviation is then calculated as the ratio between the recorded value and the reference value.

2 Biomass and number are expressed per 100 m^2.

3 At localities where salmonids occur (char, grayling, trout or salmon), a calculation of the number these four species having yearlings (recruitment) is ascertained. The number of breeding species is divided by the number of species of salmonids.

4 Presence of species and stages sensitive to acidification.
a) High density of yearling trout and/or presence of yearling salmon, roach or minnow.
b) Presence of cyprinids, gudgeon (*Cottus gobio*), stone loach (*Noemacheilus barbatulus*), spined loach, Wels (*Siluris glanis*) or crayfish and/or occurrence of yearling burbot, grayling or char.
c) Presence of bullhead, ruffe, burbot, grayling, char, whitefish, vendace, salmon or eel (*Anguilla anguilla*) and/or presence of yearling trout or perch.
d) Only fish present are perch, pike or mature trout (older than yearlings).
e) Absence of species.

5 Calculated as percentage by weight of fish species not native to Sweden out of the total catch.

6 The overall assessment of deviation is obtained by calculating the mean class value for all parameters included (maximum 7 parameters).

Fish species have been transferred from one part of the country to another since Viking times and many transferred species now form a natural part of the fish fauna. Thus, it is not biologically relevant to attempt to define transferred Swedish fish species as alien on the basis of administrative boundaries. For the time being, the term ”alien fish species” is therefore defined as species introduced into Sweden, eg, rainbow trout (*Onchorhynchus mykiss*), lake trout (*Salvelinus namaycush*) brook trout (*Salvelinus fontinalis*), sockeye salmon (*Onchorhynchus nerka*) and other species (see the list of species in Appendix 3).

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Presentation of data

When using these Environmental Quality Criteria, it is essential to present the data used and any adjustments that have been made to reference values. If the background data does not meet the sampling frequency and other requirements specified in each chapter (eg, the number of samples differs from the recommended number), this should be stated.

Colour coding of classes 1 – 5 should use blue, green, yellow, orange and red, as follows.

Class 1

Class 2

Class 3

Class 4

Class 5

List of species with trophic ranking scores for aquatic plants

(cf Palmer et al. 1992). Where no indicator value is given, this is because none has been set.

Submerged plants	
Isoetids	
Crassula aquatica	3
Baldellia ranunculoides	4
Isoetes echinospora	4
Subularia aquatica	4
Isoetes lacustris	5
Lobelia dortmanna	5
Limosella aquatica	5.3
Peplis portula	5.3
Ranunculus reptans	5.3
Pilularia globulifera	5.5
Elatine hydropiper	6
Littorella uniflora	6.7
Eleocharis acicularis	8.5
Elodeids	
Alisma gramineum	
Callitriche brutia (pedunculata)	
Callitriche cophocarpa	
Callitriche platycarpa	
Najas intermedia	
Najas minor	
Ranunculus fluitans	
Ruppia maritima	
Ruppia spiralis	
Sagittaria natans	
Utricularia australis (neglecta)	
Utricularia ochroleuca	
Potamogeton polygonifolius	3
Sparganium angustifolium	3
Juncus bulbosus	3.7
Scirpus fluitans	4
Sparganium friesii	4
Utricularia intermedia	4
Utricularia minor	4
Callitriche hamulata	5
Callitriche palustris (verna)	5
Myriophyllum alterniflorum	5.5
Nitella spp.	5.5
Potamogeton alpinus	5.5
Utricularia vulgaris	5.5
Potamogeton berchtoldii (pusillus)	7.3
Potamogeton gramineus	7.3
Potamogeton obtusifolius	7.3
Potamogeton perfoliatus	7.3
Potamogeton praelongus	7.3
Callitriche stagnalis	7.7
Hippuris vulgaris	7.7
Potamogeton compressus (zosterif.)	7.7
Callitriche obtusangula	8.5
Callitriche hermaphroditica	8.5
Chara spp.	8.5
Ceratophyllum submersum	8.5
Elodea canadensis	8.5
Potamogeton crispus	8.5
Ranunculus aquatilis	8.5
Ranunculus peltatus	8.5
Ranunculus trichophyllus	8.5
Hottonia palustris	9.0
Stratiotes aloides	9.0

Ceratophyllum demersum	10
Elodea nuttallii	10
Myriophyllum spicatum	10
Myriophyllum verticillatum	10
Najas flexilis	10
Najas marina	10
Oenanthe aquatica	10
Potamogeton acutifolius	10
Potamogeton filiformis	10
Potamogeton friesii (mucron.)	10
Potamogeton lucens	10
Potamogeton pectinatus	10
Potamogeton rutilus	10
Potamogeton trichoides	10
Ranunculus baudotii	10
Ranunculus circinatus	10
Zanichellia palustris	10

Floating-leaved plants

Sparganium angustifolium	3
Sparganium hyperboreum	3
Nuphar pumila	6
Glyceria fluitans	6.3
Nymphaea alba	6.7
Nymphaea candida	6.7
Potamogeton natans	6.7
Alopecurus aequalis	7.7
Nuphar lutea	8.5
Sparganium gramineum	8.5
Persicaria amphibium	9
Sagittaria sagittifolia	9

Free-floating plants

Lemna minor	8.5
Hydrocharis morsus-ranae	9
Lemna gibba	10
Lemna trisulca	10
Nymphoides peltata	10
Spirodela polyrrhiza	10

Emergent plants

Alisma lanceolatum	
Scutellaria galericulata	
Eriophorum angustifolium	2.5
Carex limosa	4
Carex rostrata	4.3
Carex nigra	4.7
Menyanthes trifoliata	5.3
Ranunculus flammula	5.3
Carex aquatilis	5.5
Carex lasiocarpa	5.5
Juncus effusus	5.5
Lysimachia thyrsiflora	5.5
Peucedanum palustre	5.5
Potentilla palustris	5.5
Sparganium minimum (natans)	5.5
Agrostis stolonifera	5.7
Veronica scutellata	6.3
Equisetum fluviatile	7
Hydrocotyle vulgaris	7
Calla palustris	7.3
Caltha palustris	7.3
Carex vesicaria	7.3
Eleocharis mammilata	7.3
Eleocharis palustris	7.3
Galium palustre	7.3
Myosotis scorpioides	7.3
Phragmites australis	7.3
Scirpus lacustris	7.3
Myosotis laxa	7.7
Alisma plantago aquatica	8.5
Carex elata	8.5
Cicuta virosa	8.5
Cladium mariscus	8.5
Iris pseudacorus	8.5
Mentha aquatica	8.5
Phalaris arundinacea	8.5
Ranunculus hederaceus	8.5
Sparganium erectum (ramosum)	8.5
Typha latifolia	8.5
Acorus calamus	9
Ranunculus lingua	9
Sium latifolium	9
Apium inundatum	10
Berula erecta	10

Bidens cernua	10
Bidens tripartita	10
Bolboschoenus maritimus	10
Butomus umbellatus	10
Carex acuta	10
Carex acutiformis	10
Carex pseudocyperus	10
Carex riparia	10
Glyceria maxima	10
Nasturtium officinale	10
Polygonum hydropiper	10
Ranunculus sceleratus	10
Rorippa amphibia	10
Rumex hydrolapathum	10
Scirpus tabernaemontani	10
Solanum dulcamara	10
Sparganium emersum (simpl.)	10
Typha angustifolia	10
Veronica anagallis-aquatica	10
Veronica beccabunga	10

Calculation of index and other parameters for assessing benthic fauna

(1) *Shannon-Wiener's diversity index (Shannon, 1948)* is calculated as:

$$H' = -\sum_{i=1}^{s} \frac{n_i}{N} \log_2 \frac{n_i}{N}$$

where N = the total number of individuals, and n_i = the number of individuals of the "i"th species.

(2) The ASPT index (average score per taxon) (Armitage et al., 1983) is calculated by identifying organisms found in the sample at family (taxon) level (class for Oligochaeta). Each family is given a point score representing its tolerance to pollution (see below). The scores are added up and the total divided by the total number of families recorded

The following families score 10:
Siphlonuridae, Heptageniidae, Leptophlebiidae, Ephemerellidae, Potamanthidae, Ephemeridae, Taeniopterygidae, Leuctridae, Capniidae, Perlodidae, Perlidae, Chloroperlidae, Aphelocheiridae, Phyrganeidae, Molannidae, Beraeidae, Odontoceridae, Leptoceridae, Goeridae, Lepidostomatidae, Brachycentridae, Sericostomatidae.

The following families score 8:
Astacidae, Lestidae, Agriidae, Gomphidae, Cordulegasteridae, Aeshnidae, Corduliidae, Libellulidae, Psychomyiidae, Philopotamidae.

The following families score 7:
Caenidae, Nemouridae, Rhyacophilidae, Polycentropodidae, Limnephilidae.

The following families score 6:
Neritidae, Viviparidae, Ancylidae, Hydroptilidae, Unionidae, Corophiidae, Gammaridae, Platycnemididae, Coenagriidae.

The following families score 5:
Mesoveliidae, Hydrometridae, Gerridae, Nepidae, Naucoridae,

Notonectidae, Pleidae, Corixidae, Haliplidae, Hygrobiidae, Dytiscidae, Gyrinidae, Hydrophilidae, Clambidae, Heledidae, Dryopidae, Elminthidae, Chrysomelidae, Curculionidae, Hydropsychidae, Tipulidae, Simuliidae, Planariidae, Dendrocoelidae.

The following families score 4:
Baetidae, Sialidae, Piscicolidae.

The following families score 3:
Valvatidae, Hydrobiidae, Lymnaeidae, Physidae, Planorbidae, Sphaeriidae, Glossiphoniidae, Hirudidae, Erpobdellidae, Asellidae.

The following families score 2:
Chironomidae.

The following families score 1:
Oligochaeta.

(3) Danish fauna index (Skriver et al., in press) is calculated by

- calculating the number of diversity groups (positive minus negative) using Table 1a below;
- the fauna index is found using Table 1b below; the table is read from the top down, the index figure is that for the first group containing a genus or family found in the sample.

Table 1a. Basis for calculating diversity groups

Positive	Negative
Tricladida	Oligochaeta ≥ 100 individuals
Gammarus	*Helobdella*
All Plecoptera genera	*Erpobdella*
All Ephemeroptera genera	*Asellus*
Elmis	*Sialis*
Limnius	Psychodidae
Elodes	*Chironomus*
Rhyacophilidae	Eristalinae
All cased Trichoptera families	*Sphaerium*
Ancylus	*Lymnaea*

Table 1b. Indicator genera for determining the Danish fauna index. The index is given inversely to the original version (Kirkegaard et al., 1992).

	No. of diversity groups	≤ –2	–1 – 3	4 – 9	≥ 10
Group 1	≥ 2 genera	-	5	6	7
	1 taxon	-	4	5	6
Brachyptera					
Capnia					
Leuctra					
Isogenus					
Isoperla					
Isoptena					
Perlodes					
Protonemura					
Siphonoperla					
Ephemeridae					
Limnius					
Glossomatidae					
Sericomatidae					
Group 2		4	4	5	5
Amphinemura					
Taeniopteryx					
Ametropodidae					
Ephemerellidae					
Heptageniidae					
Leptophlebiidae					
Siphlonuridae					
Elmis					
Elodes					
Rhyacophilidae					
Goeridae					
Ancylus					
If ≥ 5 individuals of *Asellus* go to group 3					
If ≥ 5 individuals of *Chironomus*, go to group 4					
Group 3		3	4	4	4
≥ 10 individuals of *Gammarus*					
Caenidae					
If ≥ 5 individuals of other Trichoptera than in group 2					
Or ≥ 5 individuals of *Chironomus*, go to group 4					

Group 4	≥ 2 genera	3	3	4	-
	1 taxon	2	3	-	-
≥ 10 individuals of *Gammarus*					
Asellus					
Caenidae					
Sialis					
Other Trichoptera than in preceding groups					
Group 5	≥ 2 genera	2	3	3	-
	1 taxon	2	2	3	-
< 10 individuals of *Gammarus*					
Baetidae					
≥ 25 individuals of Simuliidae					
If ≥ 100 individuals of Oligochaeta, go to group 5, 1 taxon					
If ≥ 2 individuals of Eristalinae, go to group 6					
Group 6		1	1	-	-
Tubificidae					
Psychodidae					
Chironomidae					
Eristalinae					

(4) Acidity index (Henrikson & Medin, 1996) is calculated as the sum of the highest scores obtained for each of the criteria I – V below.

I. Presence of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddis-flies (Trichoptera) with differing pH tolerance

Genera having an indicator value of 3 (pH ≥ 5.4) score 3 points
Genera having an indicator value of 2 (pH 4.8 – 5.4) score 2 points
Genera having an indicator value of 1 (pH 4.5 – 4.8) score 1 point
Genera having an indicator value of 0 (pH ≤ 4.5) score 0 points

Genus	Indicator value	Genus	Indicator value
EPHEMEROPTERA	1	*Heptagenia fuscogrisea*	0
Baetis rhodani	1	*Leptophlebia vespertina*	0
Baetis niger	1	*Leptophlebia marginata*	0
Baetis digitatus	3	*Ephemera danica*	3
Baetis muticus	3	*Ephemera vulgata*	2
Heptagenia sulphurea	1	*Ephemera* sp.	2

Genus	Indicator value
Caenis robusta	3
Caenis rivulorum	3
Caenis horaria	2
Caenis luctuosa	3
Centroptilum luteolum	1
Procloeon bifidum	3
Ephemerella ignita	2
Siphlonurus lacustris	1
PLECOPTERA	
Brachyptera risi	0
Taeniopteryx nebulosa	1
Amphinemura sulcicollis	0
Amphinemura borealis	1
Nemurella pictetii	0
Nemoura cinerea	0
Nemoura avicularis	1
Nemoura flexuosa	0
Protonemura meyeri	0
Leuctra hippopus	0
Leuctra nigra	0
Leuctra digitata	0
Diura nanseni	1
Isoperla grammatica	0
Isoperla difformis	0
Perlodes dispar	1
Siphonoperla burmeisteri	1
Dinocras cephalotes	3
TRICHOPTERA	
Rhyacophila nubila	0
Rhyacophila fasciata	1
Chimarra marginata	3
Philoptemus montanus	3
Neureclipsis bimaculata	0
Polycentropus flavomaculatus	0
Polycentropus irroratus	0
Plectrocnemia conspersa	0
Cyrnus trimaculatus	1
Cyrnus flavidus	1
Holocentropus dubius	1
Lype reducta	1
Tinodes waeneri	3
Wormaldia subnigra	3
Cheumatopsyche lepida	3
Hydropsyche siltalai	0
Hydropsyche pellucidula	1
Hydropsyche angustipennis	0
Ceratopsyche silvenii	2
Ithytrichia sp.	2
Hydroptila sp.	2
Oxyethira sp.	1
Agapetus ochripes	2
Oligostomis reticulata	1
Lepidostoma hirtum	1
Molanodes tinctus	2
Sericostoma personatum	1
Silo pallipes	1
Goera pilosa	1
Beraeodes minutus	1
Brachycentrus subnubilus	3
Micrasema sp.	1
Athripsodes cinereus	3
Athripsodes aterrimus	1
Ceraclea annulicornis	3
Oecetis testacea	2
Oecetis sp.	1
Trianodes sp.	2
Mystacides azurea	2

II. Presence of amphipods

Amphipods score 3 points.

III. Presence of groups sensitive to acidification such as leeches (Hirudinea), water beetles, (Elmididae) snails (Gastropoda) and mussels (Bivalvia)

1 point per group.

IV. Ratio between number of species of mayflies of the *Baetis* genus and stoneflies (Plecoptera)

Ratio > 1 scores 2 points
Ratio 0.75 – 1 scores 1 point
Ratio < 0.75 scores 0 points

V. Number of genera present from the Table below (the number according to the original index has been adapted in line with the Swedish EPA national survey of lakes and watercourses in 1995 and the genera included therein)

≥ 32 genera scores 2 points
17 – 31 genera scores 1 point
≤ 16 genera scores 0 points

1	Porifera	23	*Marstoniopsis scholtzi*
2	Spongillidae	24	Valvatidae
3	Coelentrata	25	*Valvata cristata*
4	Hydrozoa	26	*Valvata macrostoma*
5	Plathelminthes	27	*Valvata piscinalis*
6	Turbellaria	28	*Valvata sibirica*
7	Planaridae	29	*Acroloxus lacustris*
8	Dendrocoelidae	30	Lymnaeidae
9	Nematoda	31	*Myxas glutinosa*
10	Nemathelminthes	32	*Lymnaea* sp.
11	Nematomorpha	33	*Lymnaea stagnalis*
12	Mollusca	34	*Stagnicola* sp.
13	Gastropoda	35	*Stagnicola palustris*-gr.
14	Neritidae	36	*Stagnicola corvus*
15	*Theodoxus fluviatilis*	37	*Stagnicola glabra*
16	Viviparidae	38	*Galba truncatula*
17	*Viviparus contectus*	39	*Radix* sp.
18	*Viviparus viviparus*	40	*Radix peregra*
19	*Bithynia leachi*	41	*Radix peregra/ovata*
20	*Bithynia tentaculata*	42	Ancylidae
21	Hydrobiidae	43	*Ancylus fluviatilis*
22	*Hydrobia/Potamopyrgus*	44	Planorbidae

45 *Planorbis* sp.
46 *Anisus vortex*
47 *Anisus vorticulus*
48 *Anisus spirorbis*
49 *Bathyomphalus contortus*
50 *Gyraulus* sp.
51 *Gyraulus acronicus/ albus/laevis*
52 *Gyraulus riparius*
53 *Gyraulus crista*
54 *Hippeutis complanatus*
55 *Segmentina nitida*
56 *Planorbarius corneus*
57 Physidae
58 *Physa fontinalis*
59 *Physella acuta*
60 *Aplexa hypnorum*
61 Bivalvia
62 *Margaritifera margaritifera*
63 Unionidae
64 *Unio* sp.
65 *Anodonta/Pseudoanodonta*
66 *Dreissena polymorpha*
67 Sphaeriidae
68 *Sphaerium* sp.
69 *Musculinum lacustre*
70 *Pisidium* sp.
71 Annelida
72 Oligochaeta
73 Hirudinea
74 Piscicolidae
75 *Piscicola geometra*
76 Glossiphonidae
77 *Theromyzon maculosum*
78 *Theromyzon tessulatum*
79 *Hemiclepsis marginata*
80 *Glossiphonia/Batrachobdella*
81 *Glossiphonia complanata*
82 *Helobdella stagnalis*
83 Hirudinidae
84 *Haemopis sanguisuga*
85 *Hirudo medicinalis*
86 Erpobdellidae
87 *Erpobdella octoculata*
88 *Erpobdella testacea*
89 *Dina lineata*
90 Crustacea
91 *Branchinecta paludosa*
92 *Polyartemia forcipata*
93 *Tanymastix stagnalis*
94 *Lepidurus arcticus*
95 *Lepidurus apus*
96 *Argulus* sp.
97 *Mysis relicta*
98 Asellidae
99 *Asellus aquaticus*
100 *Monoporeia affinis*
101 Gammaridae
102 *Relictacanthus lacustris*
103 *Pallasea quadrispinosa*
104 *Gammarus* sp.
105 *Gammarus duebeni*
106 *Gammarus pulex*
107 *Gammarus lacustris*
108 Astacidae
109 *Astacus astacus*
110 *Pacifastacus leniusculus*
111 Arachnida
112 *Argyroneta aquatica*
113 Hydracarina
114 Insecta
115 Ephemeroptera
116 Baetidae
117 *Acentrella lapponica*
118 *Baetis* sp.
119 *Baetis buceratus*
120 *Baetis digitatus*
121 *Baetis niger*
122 *Baetis liebenauae*
123 *Baetis muticus*
124 *Baetis rhodani*
125 *Baetis vernus*-gr.
126 *Baetis macani/bundaye*
127 *Baetis fuscatus*-gr.
128 *Baetis fuscatus*
129 *Centroptilum luteolum*

130 *Cloeon dipterum*-gr.
131 *Cloeon simile*-gr.
132 *Procloeon bifidum*
133 Siphlonuridae
134 *Ameletus inopinatus*
135 *Parameletus* sp.
136 *Siphlonurus alternatus*
137 *Siphlonurus armatus*
138 *Siphlonurus lacustris/aestivalis*
139 *Metretopus alter*
140 *Metretopus borealis*
141 Heptagenidae
142 *Arthroplea congener*
143 *Ecdyonurus joernensis*
144 *Heptagenia dalecarlica*
145 *Heptagenia fuscogrisea*
146 *Heptagenia orbiticola*
147 *Heptagenia sulphurea*
148 *Rhithrogena* sp.
149 Leptophlebidae
150 *Leptophlebia* sp.
151 *Paraleptophlebia* sp.
152 Ephemeridae
153 *Ephemera* sp.
154 *Ephemera danica*
155 *Ephemera glaucops*
156 *Ephemera vulgata*
157 Ephemerellidae
158 *Ephemerella* sp.
159 *Ephemerella aurivillii*
160 *Ephemerella ignita*
161 *Ephemerella mucronata*
162 Caenidae
163 *Brachycercus harrisellus*
164 *Caenis* sp.
165 *Caenis horaria*
166 *Caenis lactea*
167 *Caenis rivulorum*
168 *Caenis robusta*
169 *Caenis luctuosa/macrura*
170 *Prosopistoma foliaceum*
171 Plecoptera
172 Perlodidae
173 *Arcynopteryx compacta*
174 *Diura bicaudata*
175 *Diura nanseni*
176 *Isogenus* sp.
177 *Isogenus nubecula*
178 *Perlodes dispar*
179 *Isoperla* sp.
180 *Isoperla difformis*
181 *Isoperla grammatica*
182 *Isoperla obscura*
183 *Dinochras cephalotes*
184 Chloroperlidae
185 *Isoptena* sp.
186 *Isoptena serricornis*
187 *Xanthoperla apicalis*
188 *Siphlonoperla* sp.
189 *Siphlonoperla burmeisteri*
190 Taeniopterygidae
191 *Taeniopteryx* sp.
192 *Taeniopteryx nebulosa*
193 *Brachyptera* sp.
194 *Brachyptera risi*
195 *Brachyptera braueri*
196 Nemouridae
197 *Amphinemura* sp.
198 *Amphinemura borealis*
199 *Amphinemura standfussi/sulcicollis*
200 *Amphinemura sulcicollis*
201 *Nemoura* sp.
202 *Nemoura avicularis*
203 *Nemoura cinerea*
204 *Nemurella pictetii*
205 *Protonemura* sp.
206 *Protonemura meyeri*
207 Capniidae
208 *Capnia* sp.
209 *Capnopsis schilleri*
210 Leuctridae
211 *Leuctra* sp.
212 *Leuctra fusca/digitata/hippopus*
213 *Leuctra fusca*

214 *Leuctra hippopus*
215 *Leuctra nigra*
216 Odonata
217 *Calopteryx splendens*
218 *Calopteryx virgo*
219 Lestidae
220 *Lestes* sp.
221 *Sympecma fusca*
222 *Platycnemis pennipes/ Pyrrhosoma nymphula*
223 Platycnemidae
224 *Platycnemis pennipes*
225 Coenagrionidae
226 *Pyrrhosoma nymphula*
227 *Erythromma najas*
228 *Coenagrion* sp.
229 *Enallagma cyathigerum*
230 *Ischnura* sp.
231 Aeshnidae
232 *Aeshna* sp.
233 *Brachytron pratense*
234 Gomphidae
235 *Gomphus vulgatissimus*
236 *Ophiogomphus* sp.
237 *Onychogomphus forcipatus*
238 Cordulegasteridae
239 *Cordulegaster boltoni*
240 Corduliidae
241 *Cordulia aenea*
242 *Somatochlora* sp.
243 Libellulidae
244 *Leucorrhinia* sp.
245 *Libellula* sp.
246 *Orthetrum* sp.
247 *Sympetrum* sp.
248 Coleoptera
249 Gyrinidae
250 *Gyrinus* sp.
251 *Orectochilus villosus*
252 Haliplidae
253 *Noterus* sp.
254 Dytiscidae
255 *Copelatus* sp.
256 *Hydroglyphus* sp.
257 *Hygrotus* sp.
258 *Coelambus* sp.
259 *Hyphydrus* sp.
260 *Hydroporus* sp.
261 *Porhydrus* sp.
262 *Graptodytes* sp.
263 *Oreodytes* sp.
264 *Suphrodytes* sp.
265 *Deronectes* sp.
266 *Scarodytes* sp.
267 *Stictotarsus* sp.
268 *Nebrioporus* sp.
269 *Platambus* sp.
270 *Ilybius* sp.
271 *Agabus* sp.
272 *Rhantus* sp.
273 *Colymbetes* sp.
274 *Laccophilus* sp.
275 *Hydaticus* sp.
276 *Graphoderus* sp.
277 *Acilius* sp.
278 *Dytiscus* sp.
279 Dryopidae
280 *Dryops* sp.
281 Elmidae
282 *Stenelmis* sp.
283 *Stenelmis canaliculata*
284 *Elmis* sp.
285 *Elmis aenea*
286 *Esolus* sp.
287 *Esolus angustatus*
288 *Oulimnius* sp.
289 *Oulimnius troglodytes/ tuberculatus*
290 *Oulimnius troglodytes*
291 *Oulimnius tuberculatus*
292 *Limnius* sp.
293 *Limnius volckmari*
294 *Normandia* sp.
295 *Normandia nitens*
296 *Riolus* sp.
297 *Riolus cupreus*

298 Scirtidae
299 *Elodes* sp.
300 *Microcara* sp.
301 *Cyphon* sp.
302 *Trionocyphon* sp.
303 *Scirtes* sp.
304 Chrysomelidae
305 *Plateumaris* sp.
306 *Donacia* sp.
307 Hydraenidae
308 *Ochtebius* sp.
309 *Hydraena* sp.
310 *Limnebius* sp.
311 Hydrochidae
312 *Hydrochus* sp.
313 Spercheidae
314 *Spercheus* sp.
315 Helophoridae
316 *Helophorus* sp.
317 Hydrophilidae
318 *Berosus* sp.
319 *Chaetarthria* sp.
320 *Anacaena* sp.
321 *Laccobius* sp.
322 *Helochares* sp.
323 *Enochrus* sp.
324 *Hydrobius* sp.
325 *Cercyon* sp.
326 Hygrobiidae
327 Clambidae
328 Helodidae
329 *Helodes* sp.
330 Curculionidae
331 Hemiptera
332 Mesoveliidae
333 *Mesovelia* sp.
334 Hydrometridae
335 *Hydrometra* sp.
336 *Velia caprai*
337 *Velia saulii*
338 *Microvelia* sp.
339 Gerridae
340 Nepidae
341 *Nepa cinerea*
342 *Ranatra linearis*
343 Aphelocheiridae
344 *Aphelocheirus aestivalis*
345 Notonectidae
346 *Notonecta* sp.
347 Corixidae
348 Neuroptera
349 Sialidae
350 *Sialis* sp.
351 *Sialis fuliginosa/nigripes*
352 *Sialis lutaria*-gr.
353 *Sisyra* sp.
354 Lepidoptera
355 Trichoptera
356 Rhyacophilidae
357 *Rhyacophila* sp.
358 *Rhyacophila fasciata*
359 *Rhyacophila obliterata/nubila*
360 *Rhyacophila nubila*
361 Glossosomatidae
362 *Glossosoma intermedium*
363 *Glossosoma* sp.
364 *Agapetus* sp.
365 Hydroptilidae
366 *Agraylea* sp.
367 *Hydroptila* sp.
368 *Ithytrichia* sp.
369 *Ithytrichia lamellaris*
370 *Orthotrichia* sp.
371 *Oxyethira* sp.
372 *Tricholeiochiton* sp.
373 *Tricholeiochiton fagesii*
374 Philopotamidae
375 *Philopotamus montanus*
376 *Wormaldia subnigra*
377 *Wormaldia occipitalis*
378 *Chimarra marginata*
379 Psychomyiidae
380 *Lype phaeopa*
381 *Lype reducta*
382 *Psychomyia pusilla*
383 *Tinodes pallidulus*

384 *Tinodes waeneri*
385 *Ecnomus tenellus*
386 Polycentropidae
387 *Cyrnus* sp.
388 *Cyrnus flavidus*
389 *Cyrnus insolutus*
390 *Cyrnus trimaculatus*
391 *Cyrnus crenaticornis*
392 *Holocentropus* sp.
393 *Holocentropus dubius*
394 *Holocentropus insignis*
395 *Holocentropus picicornis*
396 *Holocentropus stagnalis*
397 *Neureclipsis bimaculata*
398 *Plectrocnemia* sp.
399 *Plectrocnemia conspersa*
400 *Polycentropus* sp.
401 *Polycentropus flavomaculatus*
402 *Polycentropus irroratus*
403 Hydropsychidae
404 *Cheumatopsyche lepida*
405 *Ceratopsyche silfvenii*
406 *Ceratopsyche nevae*
407 *Hydropsyche angustipennis*
408 *Hydropsyche contubernalis*
409 *Hydropsyche pellucidula*
410 *Hydropsyche saxonica*
411 *Hydropsyche siltalai*
412 *Arctopsyche ladogensis*
413 Phryganeidae
414 *Agrypnetes crassicornis*
415 *Agrypnia* sp.
416 *Oligostomis reticulata*
417 *Oligotricha* sp.
418 *Phryganea bipunctata*
419 *Phryganea grandis*
420 *Semblis atrata*
421 *Semblis phalaenoides*
422 *Trichostegia minor*
423 Brachycentridae
424 *Brachycentrus subnubilus*
425 *Micrasema gelidum*
426 *Micrasema setiferum*
427 Lepidostomatidae
428 *Crunoecia irrorata*
429 *Lepidostoma hirtum*
430 Limnephilidae
431 *Ironoquia dubia*
432 *Apatania* sp.
433 *Ecclisopteryx dalecarlica*
434 *Chaetopteryx/Anitella*
435 Limnephilidae
436 *Anabolia* sp.
437 *Glyphotaelius pellucidus*
438 *Grammotaulius* sp.
439 *Limnephilus* sp.
440 *Nemotaulius punctato/ lineatus*
441 *Phacopteryx brevipennis*
442 *Halesus* sp.
443 *Hydatophylax infumatus*
444 *Micropterna lateralis*
445 *Micropterna sequax*
446 *Potamophylax* sp.
447 *Stenophylax permistus*
448 Goeridae
449 *Goera pilosa*
450 *Silo pallipes*
451 Beraeidae
452 *Beraea maurus*
453 *Beraea pullata*
454 *Beraeodes minutus*
455 Sericostomatidae
456 *Sericostoma personatum*
457 *Notidobia ciliaris*
458 Odontoceridae
459 *Odontocerum albicorne*
460 Molannidae
461 *Molanna albicans*
462 *Molanna angustata*
463 *Molanna submarginalis*
464 *Molanna nigra*
465 *Molannodes tinctus*
466 Leptoceridae
467 *Adicella reducta*
468 *Athripsodes* sp.

469 *Athripsodes albifrons/ commatatus/cinereus*
470 *Athripsodes aterrimus*
471 *Ceraclea* sp.
472 *Ceraclea alboguttata*
473 *Ceraclea annulicornis*
474 *Ceraclea dissimilis*
475 *Ceraclea excisus*
476 *Ceraclea fulva*
477 *Ceraclea nigronervosa*
478 *Ceraclea perplexa*
479 *Ceraclea senilis*
480 *Erotesis baltica*
481 *Leptocerus tineiformis*
482 *Mystacides* sp.
483 *Mystacides longicornis/nigra*
484 *Mystacides azurea*
485 *Oecetis furva*
486 *Oecetis lacustris*
487 *Oecetis notata*
488 *Oecetis ochracea*
489 *Oecetis testacea*
490 *Setodes argentipunctellus*
491 *Triaenodes* sp.
492 *Ylodes* sp.
493 Diptera
494 Brachysera
495 Psychodidae
496 *Pericoma* sp.
497 Culicidae
498 *Chaoborus* sp.
499 Simuliidae
500 Ceratopogonidae
501 Chironomidae
502 *Chironomus* sp.
503 Tabanidae
504 *Atherix ibis*
505 *Ibisia marginata*
506 Dolichopodidae
507 Empididae
508 *Eristalis* sp.
509 Sciomyzidae
510 Ephydridae
511 Muscidae
512 Tipulidae
513 Limoniidae
514 *Ptychoptera* sp.
515 *Phalacrocera* sp.
516 *Triogma* sp.
517 *Dixa* sp.

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(5) BQI index (Benthic Quality Index) (modified after Wiederholm, 1980) is calculated as:

$$BQI = \sum_{i=0}^{5} \frac{k_i \; n_i}{N}$$

where $K_i = 5$ for *Heterotrissocladius subpilosus*, 4 for *Paracladopelma* sp., *Microspectra* sp., *Heterotanytarsus apicalis, Heterotrissocladius grimshawi, Heterotrissocladius marcidus* and *Heterotrissocladius maeaeri*, 3 for *Sergentia coracina, Tanytarsus* sp. and *Stictochironomus* sp., 2 for *Chironomus anthracinus*, 1 for *Chironomus plumosus* and 0 if these indicator species are absent; ni = number of individuals of each indicator group; N = total number of individuals of all indicator groups.

(6) O/C index (Wiederholm, 1980) is calculated as:

the density of oligochaetes divided by the density of oligochaetes and sediment-living chironomids (not including non-sediment-living species such as *Procladius* sp.), expressed as a percentage. Values are depth-corrected by dividing the ratio obtained above by the sampling depth.

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List of Swedish freshwater fish species

R = reproduces annually CP = commonly present Ex = previously, annual reproduction, but not present since 1850 (i) = introduced * = not present year-round in inland waters

Family English name	Swedish name	*Scientific name*	
Petromyzontidae	**Nejonögon**		
Lampern	Flodnejonöga	*Lampetra fluviatilis* (Linnaeus, 1758)	R
Brook lamprey	Bäcknejonöga	*Lampetra planeri* (Linnaeus, 1758)	R
Lamprey	Havsnejonöga	*Petromyzon marinus* (Bloch, 1748)	R
Acipenseridae	**Störfiskar**		
Sturgeon	Stör	*Acipenser sturio* (Linnaeus, 1758)	Ex
Anguillidae	**Ålfiskar**		
Eel	Ål	*Anguilla anguilla* (Linnaeus, 1758)	CP
Clupeidae	**Sillfiskar**		
Allis shad	Majsill	*Alosa alosa* (Linnaeus, 1758)	R*
Twaite shad	Staksill	*Alosa fallax* (La Cépéde, 1800)	CP*
Cyprinidae	**Karpfiskar**		
Zope	Faren	*Abramis ballerus* (Linnaeus, 1758)	R
Silver bream	Björkna	*Abramis bjoerkna* (Linnaeus, 1758)	R
Bream	Braxen	*Abramis brama* (Linnaeus, 1758)	R
Baltic vimba	Vimma	*Abramis vimba* (Linnaeus, 1758)	R
Bleak	Benlöja	*Alburnus alburnus* (Linnaeus, 1758)	R
Asp	Asp	*Aspius aspius* (Linnaeus, 1758)	R
Crucian carp	Ruda	*Carassius carassius* (Linnaeus, 1758)	R
Carp	Karp	*Cyprinus carpio* (Linnaeus, 1758)	R (i)
Gudgeon	Sandkrypare	*Gobio gobio* (Linnaeus, 1758)	R
Moderlieschen	Groplöja	*Leucaspius delineatus* (Heckel, 1758)	R
Chub	Färna	*Leuciscus cephalus* (Linnaeus, 1758)	R
Ide	Id	*Leuciscus idus* (Linnaeus, 1758)	R

Dace	Stäm	*Leuciscus leuciscus* (Linnaeus, 1758)	R
Ziege	Skärkniv	*Pelecus cultratus* (Linnaeus, 1758)	CP*
Eurpean minnow	Elritsa	*Phoxinus phoxinus* (Linnaeus, 1758)	R
Rudd	Sarv	*Rutilus erythrophtalamus* (Linnaeus, 1758)	R
Roach	Mört	*Rutilus rutilus* (Linnaeus, 1758)	R
Tench	Sutare	*Tinca tinca* (Linnaeus, 1758)	R
Cobitidae	**Nissögefiskar**		
Spined loach	Nissöga	*Cobitis taenia* (Linnaeus, 1758)	R
Balitoridae	**Grönlingfiskar**		
Stone loach	Grönling	*Barbatula barbatula* (Linnaeus, 1758)	R
Siluridae	**Egentliga malar**		
Wels catfish	Mal	*Silurus glanis* (Linnaeus, 1758)	R
Esocidae	**Gäddfiskar**		
Pike	Gädda	*Esox lucius* (Linnaeus, 1758)	R
Osmeridae	**Norsfiskar**		
Smelt	Nors	*Osmerus eperlanus* (Linnaeus, 1758)	R
Salmonidae	**Laxfiskar**		
Cutthroat trout	Strupsnittöring	*Oncorhynchus clarki* (Richardson, 1836)	R(i)
Rainbow trout	Regnbåge	*Oncorhynchus mykiss* (Walbaum, 1792)	R(i)
Sockeye salmon	Indianlax	*Oncorhynchus nerka* (Walbaum, 1792)	R(i)
Salmon	Lax	*Salmo salar* (Linnaeus, 1758)	R
Brown trout	Öring	*Salmo trutta* (Linnaeus, 1758)	R
Arctic char	Fjällröding	*Salvelinus alpinus* (Linnaeus, 1758)	R
Brook trout	Bäckröding	*Salvelinus fontinalis* (Mitchill, 1855)	R (i)
Lake trout	Kanadaröding	*Salvelinus namaycush* (Walbaum, 1792)	R(i)
-	Storröding	*Salvelinus umbla* (Linnaeus, 1758)	R
Grayling	Harr	*Thymallus thymallus* (Linnaeus, 1758)	R
Coregonidae	**Sikfiskar**		
Vendace	Siklöja	*Coregonus albula* (Linnaeus, 1758)	R
-	Älvsik	*Coregonus maraena* (Bloch, 1779)	R
-	Storsik	*Coregonus maxillaris* (Günter, 1866)	R
Lacustrine fluvial whitefish	Blåsik	*Coregonus megalops* (Widegren, 1863)	R
-	Planktonsik	*Coregonus nilssoni* (Valenciennes, 1848)	R
-	Aspsik	*Coregonus pallasi* (Valenciennes, 1848)	R
Peled	Storskallesik	*Coregonus peled* (Gmelin, 1789)	R

-	Vårsiklöja	*Coregonus trybomi* (Svärdson, 1979)	R
Walaam whitefish	Sandsik	*Coregonus widegreni* (Malmgren, 1863)	R
Lotidae	**Lakefiskar**		
Burbot	Lake	*Lota lota* (Linnaeus, 1758)	R
Gasterosteidae	**Spiggfiskar**		
Three-spined stickleback	Storspigg	*Gasterosteus aculeatus* (Linnaeus, 1758)	R
Nine-spined stickleback	Småspigg	*Pungitius pungitius* (Linnaeus, 1758)	R
Cottidae	**Simpor**		
Bullhead	Stensimpa	*Cottus gobio* (Linnaeus, 1758)	R
Bullhead	Rysk simpa	*Cottus koshewnikowi* (Gratzianow, 1907)	R
Alpine bullhead	Bergsimpa	*Cottus poecilopus* (Heckel, 1836)	R
Fourhorn sculpin	Hornsimpa	*Triglopsis quadricornis* (Linnaeus, 1758)	R
Percidae	**Abborrfiskar**		
Perch	Abborre	*Perca fluviatilis* (Linnaeus, 1758)	R
Zander	Gös	*Sander lucioperca* (Linnaeus, 1758)	R
Ruffe	Gärs	*Gymnocephalus cernuus* (Linnaeus, 1758) R	
Pleuronectidae	**Flundrefiskar**		
Flounder	Skrubbskädda	*Platichthys flesus* (Linnaeus, 1758)	*

Revised by M. Appelberg on the basis of
– Sven O. Kullander 1999. Swedish Fishes: Check list of Swedish Freshwater Fishes. www electronic publication; Swedish Museum of Natural History.
– Froese, R., and D. Pauly, Eds 1999. FisBase 99. www electronic publication, 28 March, 2000, Fishbase.

REPORT 5050

Environmental Quality Criteria

Lakes and Watercourses

SWEDEN HAS AN ABUNDANCE OF LAKES AND WATERCOURSES but the biological diversity in many of them has unfortunately declined. Many lakes have been hard hit by acidification and eutrophication. Locally, elevated concentrations of metals is a major problem. The environmental state of lakes and watercourses can be interpreted using the model criteria in this report.

The report is one of a series of six reports published by the Swedish Environmental Protection Agency under the heading ENVIRONMENTAL QUALITY CRITERIA. The reports are intended to be used by local and regional authorities, as well as other agencies, but also contain useful information for anyone with responsibility for, and an interest in, good environmental quality.

Reports available in English are:

	Report No.
• Groundwater	5051
• Coasts and Seas	5052
• Contaminated Sites	5053

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