



Naturhistoriska
riksmuseet

Comments Concerning the National Swedish Contaminant Monitoring Programme in Fresh Water Biota 2009

Överenskommelse NR 216 0916

dnr 235-2294-09Mm

Report nr 4:2010

Swedish Museum of Natural History
Department of Contaminant Research
P.O.Box 50 007
SE-104 05 Stockholm
Sweden



Comments Concerning the National Swedish Contaminant Monitoring Programme in Freshwater Biota 2009

2010-05-31

Nicklas Gustavsson, Anders Bignert, Elin Boalt, Elisabeth Nyberg, Julia Stempa Tocca
The Department of Contaminant Research, Swedish Museum of Natural History

Chemical analysis:

Organochlorines/bromines and perfluorinated substances
Department of Applied Environmental Science, Stockholm University

PCDD/PCDF
Department of Chemistry, Umeå University

Contents

1	INTRODUCTION	6
2	SUMMARY	8
3	SAMPLING	9
3.1	Collected specimens	9
3.2	Number of samples and sampling frequency	9
3.3	Sample preparation and registered variables	10
3.4	Age determination	10
3.5	Data registration	10
4	SAMPLE MATRICES	11
4.1	Pike (<i>Esox lucius</i>)	11
4.2	Arctic char (<i>Salvelinus alpinus</i>)	12
4.3	Perch (<i>Perca fluviatilis</i>)	12
5	SAMPLING SITES	14
6	ANALYTICAL METHODS	17
6.1	Organochlorines and brominated flame retardants	17
6.1.1	Quality assurance	17
6.1.2	Standards	17
6.1.3	Detection limits and the uncertainty in the measurements	17
6.1.4	Validation	18
6.1.5	Reference Material	18
6.1.6	Intercalibration and certifications	19
6.2	Dioxins, dibenzofurans and dioxinlike PCB's	19
6.3	Perfluorinated substances	19
6.3.1	Sample preparation and instrumental analysis	19
6.3.2	Quality control	20
7	STATISTICAL TREATMENT AND GRAPHICAL PRESENTATION	21
7.1	Trend detection	21
7.1.1	Log-linear regression analyses	21
7.1.2	Non-parametric trend test	21
7.1.3	Non-linear trend components	22
7.2	Outliers and values below the detection limit	22

7.3	Legend to the plots	22
8	THE POWER OF THE PROGRAMME	25
9	ASSESSMENT CRITERIA	28
9.1	Classification	28
9.2	Selection of thresholds	29
9.3	Comments to thresholds	31
9.3.1	PCB	31
9.3.2	PFAs	31
9.3.3	Dioxins	31
9.3.4	PBDEs	32
9.3.5	HBCD	32
9.3.6	HCHs	32
9.3.7	HCB	32
9.3.8	DDTs	32
10	FAT CONTENT	33
10.1	Temporal variation	33
11	PCBS, POLYCHLORINATED BIPHENYLS	34
11.1	Spatial variation	34
11.2	Comparison to thresholds	35
11.3	Temporal variation	35
12	PFAS, PERFLUOROALKYL SUBSTANCES	40
12.1	Spatial variation	40
12.2	Comparison to thresholds	41
12.3	Temporal variation	41
13	PCDD/PCDF, POLYCHLORINATED DIOXINS AND DIBENZOFURANS	45
13.1	Spatial variation	45
13.2	Comparison to thresholds	46
13.3	Temporal variation	46
14	POLYBROMINATED FLAME RETARDANTS	51
14.1	Spatial variation	51
14.2	Comparison to thresholds	51

14.3	Temporal variation	51
15	PESTICIDES (DDE; DDD; DDT; HCHS; HCB)	55
15.1	Spatial variation	55
15.2	Comparison to thresholds	55
15.3	Temporal variation	56
16	REFERENCES	63
17	ANNEX 1	66

1 Introduction

This report gives a summary of the monitoring activities within the national Swedish contaminant programme in freshwater biota. It is the result from the joint efforts of: the *Department of Applied Environmental Science* at Stockholm University (analyses of organochlorines, flame retardants and perfluorinated compounds), *Department of Chemistry* at Umeå University (analyses of PCDD/PCDF) and the *Department of Contaminant Research* at the Swedish Museum of Natural History (co-ordination, sample collection administration, sample preparation, recording of biological variables, storage of frozen biological tissues in the Environmental Specimen Bank for retrospective studies, data preparation and statistical evaluation). The monitoring programme is financed by the *Environmental Protection Agency* (EPA) in Sweden.

The data of concern in this report represent the bioavailable part of the investigated contaminants i.e. the part that has virtually passed through the biological membranes and may cause toxic effects. The objectives of the monitoring program in freshwater biota could be summarised as follows:

- to estimate the levels and the normal variation of various contaminants in freshwater biota from several representative sites spread throughout the country, uninfluenced by local sources. The goal is to describe the general contaminant load and to supply reference values for regional and local monitoring programmes
- to monitor long term time trends and to estimate the rate of found changes.
quantified objective: to detect an annual change of 10% within a time period of 10 years with a power of 80% at a significance level of 5%.
- to estimate the response in biota of measures taken to reduce the discharges of various contaminants
quantified objective: to detect a 50% decrease within a time period of 10 years with a power of 80% at a significance level of 5%.
- to detect incidents of regional influence or widespread incidents of ‘Chernobyl’-character and to act as watchdog monitoring to detect renewed usage of banned contaminants.
quantified objective: to detect an increase of 200% a single year with a power of 80% at a significance level of 5%.
- to indicate large scale spatial differences
quantified objective: to detect differences of a factor 2 between sites with a power of 80% at a significance level of 5%.
- to explore the development and regional differences of the composition and pattern of e.g. PCB’s, HCH’s, DDT’s, PCDD/F, PBDE/HBCD, PAH’s and PFA’s as well as the ratios between various contaminants.

- the measured concentrations are also relevant for human consumption since the sampled fish species are important within recreational fishing and are commonly used as food.
- all analysed, and a large number of additional specimens, of the annually systematically collected material are stored frozen in *the Environmental Specimen Bank*. This invaluable material enables future retrospective studies of contaminants unknown or impossible to analyse today as well as control analyses of suspected analytical errors.
- although the programme is focused on contaminant concentration in biota, also the development of biological variables like e.g. condition factor (CF) and fat content are monitored at all sites.
- some of the monitored lakes are chosen because of additional investigations of water chemistry and fish population carried out by the Swedish University of Agricultural Sciences and the Swedish board of fisheries respectively. These lakes still fulfil the original selection criteria, see chapter 6.
- experiences from the national programme with time series of over 30 years can be used in the design of regional and local monitoring programmes.
- the perfectly unique material of high quality and long time series is further used to explore relationships among biological variables and contaminant concentrations in various tissues; the effects of changes in sampling strategy, the estimates of variance components and the influence on the concept of power *etc.*
- the accessibility of high quality data collected and analysed in a consistent manner is an indispensable prerequisite to evaluate the validity of hypothesis and models concerning the fate and distribution of various contaminants. It could furthermore be used as input of 'real' data in model building activities concerning freshwater ecosystems.
- by using assessment criteria, the results from the investigations can be used as a tool to prioritize among pollutants and to find localities where there is a risk for effects on biota.

The present report displays the timeseries of analysed contaminants in biota and summarises the results from the statistical treatment. It does *not* in general give the background or explanations to significant changes found in the timeseries. Increasing concentrations thus, urge for intensified studies. Short comments are given for temporal trends as well as for spatial variation. It should be stressed though, that geographical differences may not reflect anthropogenic influence but may be due to factors like productivity, temperature, pH *etc.*

One of the 16 national goals for the environment in Sweden is an environment free of pollutants. The definition of this goal can be translated roughly as follows; The environment shall be free from substances and metals that have been created or extracted by society and that can threaten human health or biological diversity. The national monitoring programs are a part of this ambition and the results are important in the follow up work.

2 Summary

A short summary of the results up to year 2007/08 is given below. Graphical presentations, tables and details are given in the following chapters.

- The fat content of pike in Lake Bolmen and Lake Storvindeln show *decreasing* trends with an annual decrease of 0.98-1.2%. No change can be detected for Char in Lake Abiskojaure.
- CB-153 is *decreasing* in char from Lake Abiskojaure and in pike from Lake Bolmen and Lake Storvindeln. In Lake Bolmen this can only be seen in the last 10 years.
- In most of the monitored lakes, the concentrations of CB-118 and CB-180 are below threshold levels. For CB-153 most lakes show concentrations above threshold.
- For PFOS, the threshold is exceeded in 75% of the monitored lakes. No time series are available.
- There is a significant *decrease* of TCDD/TCDF in perch from Lake Skärgölen for the whole time period 1980-2008. During the last ten years, no changes in concentrations are detected.
- The threshold for TCDD equivalents is not exceeded in any lake.
- Concentrations of the BDE-47, BDE-153 and BDE-154 demonstrate *increasing* trends over the last 40 years, but with a shorter time perspective, trends are *decreasing*. The decrease is rapid with a mean annual change of 8.5-13%.
- The threshold for PBDE is not exceeded in any lake and the concentrations are over 200 times below threshold. For HBCD this margin is even larger.
- HCH's are *decreasing* at all sites with time series long enough to permit a statistical trend analysis. All analyses after year 1998 show concentrations below LOD.
- The threshold for Lindane is not exceeded in any lake
- HCB is *decreasing* in char from Lake Abiskojaure and in pike from Lake Bolmen and Lake Storvindeln. In Lake Bolmen this can only be seen in the last 10 years.
- The threshold for HCB equivalents is not exceeded in any lake.
- DDT, DDE and DDD all show significant *decreasing* trends over the monitored time period.

3 Sampling

3.1 Collected specimens

In general, older specimens show a greater within-year variance compared to younger ones and to increase the comparability between years relatively young specimens are collected. For many species, adult specimens are also less stationary than sub-adults. The specimen need however to be of a certain size to allow individual chemical analysis and thus the size and age of the specimens vary between species and sites (see chap. 4).

To be able to make a selection of individuals of equal size and weight for analysis, about 50 specimens are collected at each site.

Only healthy looking specimens with undamaged skin are selected.

The collected specimens are placed individually in polyethene plastic bags, deep frozen as soon as possible and transported to the sample preparation laboratory.

Collected specimens, not used for the annual contaminant monitoring programme are stored in the Environmental Specimen Bank (see Odsjö 1993 for further information). These specimens are thoroughly registered and biological information and notes of available amount of tissue together with a precise location in the cold-store are accessible from a database. These specimens are thus available for retrospective analyses or for control purposes.

Sampling of perch is carried out in the autumn (August-October) outside the spawning season. Char is also sampled in the autumn (August-November) which usually means during spawning. Pike is collected in spring (April-May) during or close after spawning.

Earlier in the programmes existence, Roach was collected from a number of lakes. This was either prior to or during the same time as the collection of Perch. Since 2007, collection of Roach has decreased. In figure 5.1 and 5.2 these lakes are shown.

3.2 Number of samples and sampling frequency

In general 10 specimens are analysed annually from each lake, either individually or as a pooled sample. Historically, individual samples were common but this has changed and pooling of samples is nowadays done more or less exclusively for organic pollutants. This is mostly due to greater cost-effectiveness which in turn allows analyses of additional localities and substances.

The sampling recommendation prescribes a range for age and/or weight of the samples. In a few cases it has not been possible to achieve the required number of individuals within that range. Sampling is carried out annually in all time series. A lower frequency would certainly result in a considerable loss of statistical and interpretational power. During a period of reduced analytical capacity, several of the collected samples were not analysed but stored in the Environmental Specimen Bank. This has however changed and since 2007 most of the material is analysed for most substances.

3.3 Sample preparation and registered variables

For each specimen total body weight, total length, body length, sex, age (see chapter 4 for various age determination methods depending on species), gonad weight, state of nutrition, liver weight and sample weight are registered.

The epidermis and subcutaneous fatty tissue are carefully removed. Muscle samples are taken from the middle dorsal muscle layer.

The liver is completely removed and weighted in the sample container.

See TemaNord (1995) for further details about sample preparation.

Fish muscle tissue are analysed for organochlorines (DDT's, PCB's, HCH's ,HCB and Dioxins), PBDE (Poly Brominated Diphenyl Ethers), HBCD and PAH (Polycyclic Aromatic Hydrocarbons). Fish liver is used for PFAs (Perfluoroalkyl substances).

In addition to the analyses above, muscle samples are analysed for mercury and liver samples for lead, cadmium, nickel, chromium, copper, zinc and arsenic. These results are not reported here but can be found at the Swedish Environmental Research Institute which is the national data host for environmental data (www.ivl.se).

3.4 Age determination

The age determination in Pike is made by reading the age of the cleithrum. In Char and Perch, the otoliths are used for age determination. After determination, the material is stored in room temperature filed under the same number as the specimen it came from. This allows redetermination or a second opinion if there are uncertainties.

3.5 Data registration

Data are stored in a flat ASCII file in a hierarchical fashion where each individual specimen represents one level. Each measured value are coded and the codes are defined in a codelist. The primary data files are processed through a quality control program. Suspected values are checked and corrected if appropriate. Data are retrieved from the primary file into a table format suitable for further import to database or statistical programs.

4 Sample matrices

Pike is the species that has been collected over the longest period of time. Perch is most numerous both in numbers of collected individuals but also from the majority of lakes.

Table 4. Number of individual specimen of various species sampled for analysis of contaminants within the base program

Species	N of individual specimen	Percent of total %
Pike	1115	34
Char	363	11
Perch	1799	55
Total	3277	100

4.1 Pike (*Esox lucius*)

The pike males become sexually mature between 1-3 years and the females between 2-5 years. The spawning takes place during the period March - May. The adult pike feeds on fish but also on snakes, frogs and young birds. Pike is a lean fish with an average muscle fat content of 0.58 % (geometric mean of all samples).

Pike are collected from two sites: L. Bolmen (Småland) since 1967 and from L. Storvindeln (Västerbotten) since 1968. These two time series are probably the longest series of frozen stored fish in the world and has been used for retrospective studies of contaminant concentrations for several contaminants.

The specimens from L. Bolmen are collected during March - May. From L. Storvindeln, the specimens are collected in the middle of May with few exceptions.

Table 4.1. Number of samples, n of years and geometric mean of weight, age and length with 95% confidence interval for the pikes collected at L. Bolmen and L. Storvindeln.

	Bolmen	95% c.i	Storvindeln	95% c.i
n tot	491	-	624	.-
n of years	42	-	41	-
Age (years)	4.8	4.6-4.9	5.1	4.9-5.3
Length (cm)	54.7	54.0-55.4	58.8	57.6-60.0
Weight (g)	1052	1011-1094	1109	1051-1171

4.2 Arctic char (*Salvelinus alpinus*)

The arctic char becomes sexually mature between 3-5 years. The spawning takes place during the period August - October. Arctic Char muscle tissue is the fattest of the three species sampled with an average fat content of 1.41 % (geometric mean of all samples).

Arctic char are collected in the autumn from three sites: L. Abiskojaure (Norrbotten) since 1981, L. Tjulträsk (Västerbotten) since 1982 and from lake Stor-Björnsjön since 2007.

Table 4.2. Number of samples, n of years and geometric mean of weight, age and length with 95% confidence interval for the Char collected at L. Abiskojaure, L. Tjulträsk and L. Stor-Björnsjön.

	Abiskojaure (95% c.i)	Tjulträsk (95% c.i)	Stor-Björnsjön (95% c.i)% c.i
n tot	264	93	6
n of years	29	28	3
Age (years)	5.1 (4.9-5.2)	5.3 (5.2-5.5)	6.2 (5.5-7.0)
Length (cm)	26.7 (26.2-27.3)	24.7 (24.0-25.4)	30.0 (28.8-31.3)
Weight (g)	185 (172-198)	134 (121-148)	239 (204-279)

4.3 Perch (*Perca fluviatilis*)

Perch is an omnivorous, opportunistic feeding predatory fish. Male perch become sexually mature between 2-4 years and the females between 3-6 years of age. The spawning takes place during the period April - June when the water temperature reaches about 7-8 degrees. Perch muscle tissue is lean and contains only about 0.65 % fat (geometric mean of all samples).

The collection of samples takes place in the period August – October.

Table 4.3. Number of samples, n of years and geometric mean of age, length and weight with 95% confidence intervals for Perch collected within the monitoring programme.

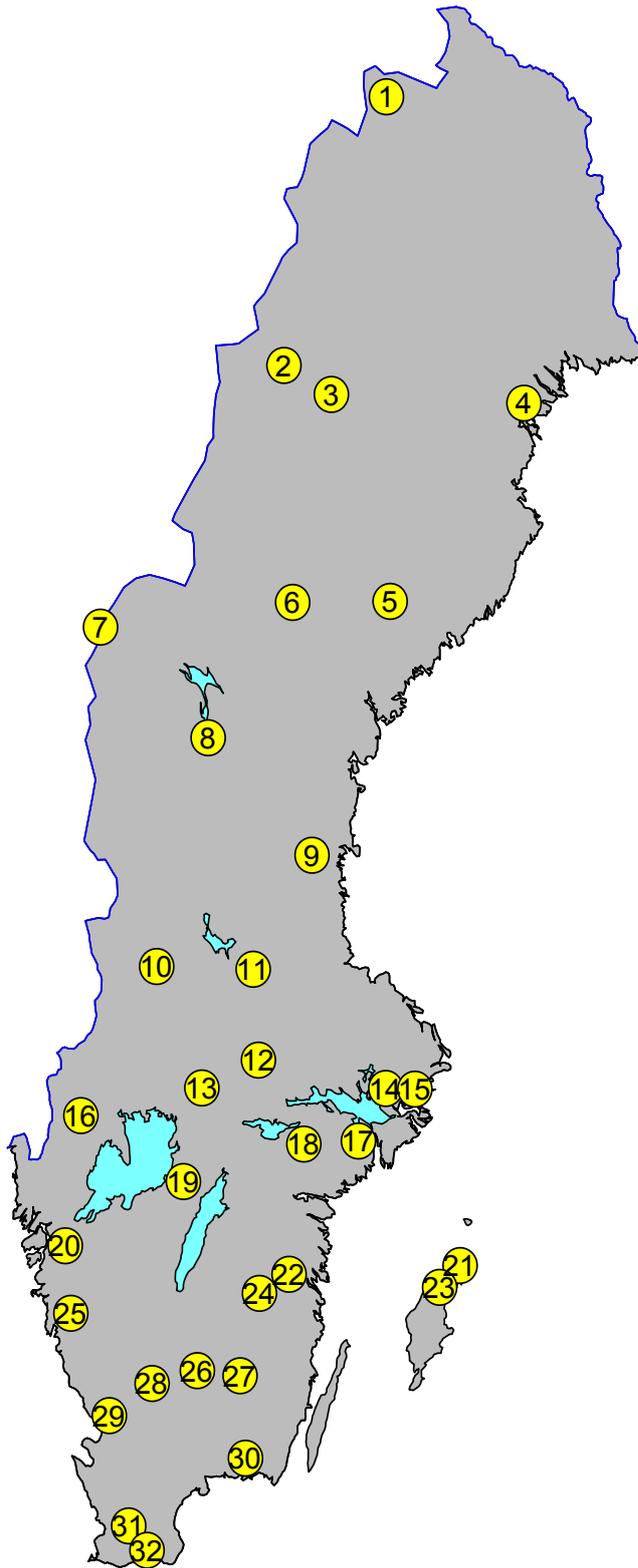
LAKE	N TOT	N OF YEARS	AGE (YEARS)	LENGTH (CM) 95% C.I.	WEIGHT (G) 95% C.I.
Allgjuttern	32	7	4.5 (4.3-4.8)	18.5 (18.1-19.0)	61.2 (56.3-66.5)
Bränträsket	19	6	7.3 (6.6-8.1)	19.0 (18.1-19.9)	66.0 (56.4-77.4)
Bysjön	70	10	5.3 (5.0-5.5)	17.7 (17.4-18.0)	56.4 (53.6-59.4)
Bästräsk	19	6	3.6 (3.2-3.9)	17.7 (17.2-18.3)	55.7 (51.2-60.6)
Degervattnet	68	10	6.0 (5.7-6.4)	17.4 (17.2-17.7)	55.2 (52.9-57.5)
Fiolen	59	10	4.9 (4.7-5.3)	17.9 (17.5-18.3)	59.5 (55.7-63.5)
Fräcksjön	13	5	5.7 (5.3-6.0)	16.8 (16.4-17.1)	45.1 (42.1-48.3)
Fysingen	20	5	4.2 (3.7-4.8)	16.4 (15.9-16.9)	42.5 (39.7-45.4)
Gipsjön	19	6	6.0 (5.6-6.4)	17.1 (16.5-17.6)	54.1 (47.7-61.3)
Hjärtsjön	69	10	4.3 (4.0-4.6)	18.6 (18.3-18.8)	64.6 (61.7-67.6)
Horsan	211	5	4.9 (4.6-5.3)	17.3 (16.8-17.7)	50.2 (46.3-54.4)
Krageholmsjön	69	10	3.2 (2.9-3.4)	17.6 (17.2-18.1)	61.6 (55.9-68.0)
Krankesjön	199	4	3.0 -	18.0 (17.3-18.8)	67.6 (58.2-77.7)
Lilla Öresjön	19	6	5.1 (4.8-5.4)	18.0 (17.0-19.1)	56.8 (47.6-67.7)
Limmingsjön	19	5	4.9 (4.7-5.1)	17.8 (17.4-18.3)	54.0 (49.9-58.4)
Remmarsjön	58	10	6.3 (6.0-6.6)	18.6 (18.1-19.1)	65.0 (59.6-70.9)
Skärgölen	368	29	4.4 (4.3-4.6)	14.9 (14.7-15.1)	34.8 (33.4-36.2)
Spjutsjön	18	3	3.3 (3.1-3.5)	17.7 (17.1-18.3)	55.8 (49.4-63.1)
Stora Envättern	69	10	5.9 (5.6-6.2)	17.3 (16.9-17.7)	52.4 (48.9-56.3)
Stensjön	100	13	6.6 (6.4-6.9)	18.2 (18.0-18.3)	56.6 (54.9-58.3)
Stora Skärsjön	39	9	6.4 (6.0-6.7)	16.7 (16.3-17.2)	50.7 (45.9-55.9)
Stor-Backsjön	19	6	6.2 (5.9-6.5)	18.5 (18.2-18.9)	63.9 (60.1-68.0)
Svartsjön	77	28	5.9 (5.8-6.1)	15.9 (15.0-16.9)	42.7 (34.6-52.6)
Sännen	19	6	5.6 (5.3-6.0)	17.4 (17.0-17.8)	51.5 (47.2-56.1)
Tärnan	49	10	6.0 (5.4-6.6)	16.7 (16.2-17.2)	45.5 (41.6-49.7)
Älgsjön	19	5	5.4 (4.8-6.0)	16.8 (16.2-17.3)	46.3 (41.5-51.6)
Övre Skärsjön	59	10	7.1 (6.5-7.8)	17.9 (17.7-18.2)	57.6 (55.1-60.1)

5 Sampling sites

The location and names of the sample sites are presented in figure 5.1. The sampling sites are selected following a number of criteria:

- The lakes must not be influenced by local contamination
- The land use in the areas surrounding the lake should be under control and intensive rural areas avoided
- The lake should preferably be placed high in the drainage system
- Influence of liming activities should be avoided
- The lakes should have some protection against future exploitation
- In general, fish from eutrophic lakes would show a slower response to changes in the amount of discharges to the lakes compared to oligotrophic ones which are thus preferred for monitoring activities
- To facilitate regional comparisons the selected lakes should preferably be as similar as possible concerning factors that could influence the concentration of various contaminants in the analysed biological tissues

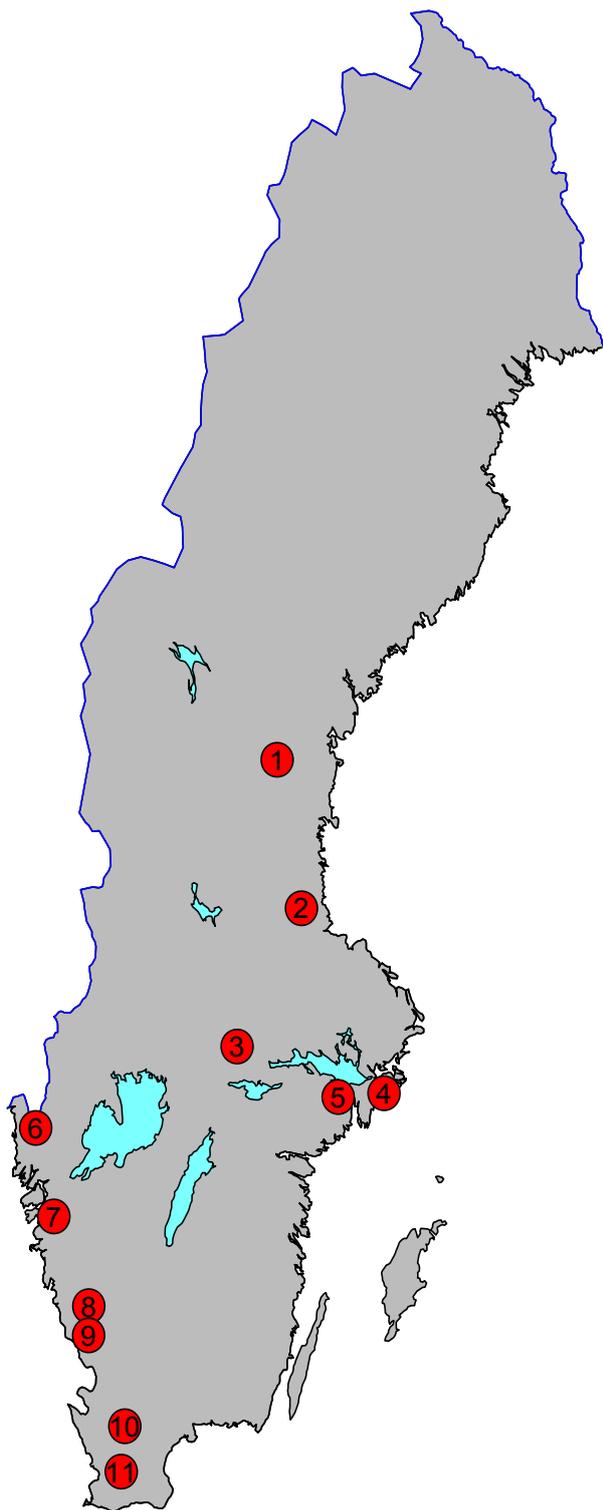
Collection of samples is carried out in 32 lakes (2009) distributed from north to south in Sweden, see table and map in figure 5.1. Lakes from where samples were collected earlier but are no more are shown in figure 5.2. The reason for this discontinued collection is mostly due to intentional changes, e.g. liming. The samples from these locations are however still available in the environmental specimen bank and could be used for comparisons and retrospective analyses. In annex 1, more information about the lakes currently sampled in the programme is listed.



NR	Sampling site	Species	Since
1	Abiskojaure	Char	1981-
2	Tjulträsk	Char	1982-
3	Storvindeln	Pike	1968-
4	Bränträsket	Perch	2004-
5	Remmarsjön	Perch	2000-
6	Degervattnet	Perch	2000-
7	Stor-Björnsjön	Char	2007-
8	Stor-Backsjön	Perch	2004-
9	Stensjön	Perch	1997-
10	Gipsjön	Perch	2004-
11	Spjutsjön	Perch	2007-
12	Övre Skärsjön	Perch	2000-
13	Limmingsjön	Perch	2005-
14	Fysingen	Perch	2005-
15	Tärnan	Perch	2000-
16	Bysjön	Perch	2000-
17	Stora Envättern	Perch	2000-
18	Älgsjön	Perch	2005-
19	Svartsjön*	Perch	1982-
20	Fräcksjön	Perch	2005-
21	Bästräsk	Perch	2004-
22	Allgjutten	Perch	97-99,06-
23	Horsan*	Perch	2005-
24	Skärgölen	Perch	1981-
25	Lilla Öresjön	Perch	2004-
26	Fiolen	Perch	2000-
27	Hjärtsjön	Perch	2000-
28	Bolmen	Pike	1967-
29	Stora Skärsjön	Perch	97-99,04-
30	Sännen	Perch	2004-
31	Krankesjön*	Perch	2006-
32	Krageholmsjön	Perch	2000-

4 12:35, KNC LIMN

Figure 5.1. Map and table showing the location of the sampled sites within the monitoring programme. At locations marked with *, Roach has been collected before and/or at the same time as Perch.



NR	Sampling site	Species	Year
1	Stormyrtjärn	Perch	1990-1996
2	Bysjön, Ockelbo	Perch	2005-2006
3	Ämten	P,R,P	1982-2000
4	Bylsjön	Perch	1982-96, 2006
5	Norra Yngern	Perch	2005-2006
6	Rotehogstjärn	Perch	1997-99
7	Kvarnsjön	Perch	1981-96
8	Stora Bälgsjön	Perch	1984-96
9	Stora Pipsjön	Perch	1987-96
10	Fåglasjön	Perch	2005-2006
11	Krankesjön	Roach	1980-2007

0.03.04 15:41, KNC LIMN DC

Figure 5.2. Map and table showing the location of discontinued sampled sites. In Lake Ämten, Perch, Roach and Pike was collected during the stated years.

6 Analytical methods

6.1 Organochlorines and brominated flame retardants

The analyses of organochlorines and brominated flame retardants are carried out at the Laboratory for Analytical Environmental Chemistry at the Institute of Applied Environmental Research (ITM) at Stockholm University. The analytical methods applied are described elsewhere. The organochlorines are presently determined by high resolution gas chromatography (Jensen /et al./, 1983, Eriksson /et al./, 1994). The brominated substances are analysed by GC connected to a mass spectrometer operating in the electron capture /negative ion mode (Sellström et al., 1998). This year a few complementary analysis concerning the higher brominated substances BDE 196, 197, 203, 205, 206, 207 and 209 in herring from Harufjärden has been carried out. The analyse is similar to the one for the lower brominated ones except for the use of a shorter column, 15m, with a thinner phase, 0.1mm.

6.1.1 Quality assurance

The Quality control for organochlorines has continuously improved the last ten years and resulted in an accreditation 1999. Assessment is performed once a year by the accreditation body SWEDAC and was last done in the autumn of 2007. The laboratory is fulfilling the obligation in SS-EN ISO/IEC 17025. The accreditation is valid for CB 28, 52, 101, 118, 153, 138, 180, DDEpp, DDDpp, DDTpp, HCB and α - β - γ -HCH in biological tissues. So far the brominated flame retardants (BFRs) are not accredited but the analysis of BDE 47, 99, 100, 153, 154 and HBCD are in many ways performed with the same quality aspects as the organochlorines.

The Quality Assurance program is built on the Quality Manual, SOPs and supplements. The annual audit includes a review of the qualifications of the staff, internal quality audit (vertical), SOPs, internal quality controls, filing system, proficiency testing, up-to-date record of the training of the staff (to be able to perform their assigned tasks), accredited methods and audit of the quality program.

6.1.2 Standards

The original of all standards are certified with known purity and precision. The concentrations are calculated for each individual congener. In April 2005 a new PBDE-standard as well as HBCD-standard was introduced. The standards were made from solutions where the concentrations of each compound had lower uncertainty ($\pm 5\%$) compared with the old standards ($\pm 10\%$).

6.1.3 Detection limits and the uncertainty in the measurements

The uncertainty in the measurement is found to follow the theory stated by Horwitz in 1982. With increasing level follows decreasing relative standard deviation (Horwitz et al., 1989). These relative standard deviations are calculated from 6321 PCB and pesticides values from control samples during 15 years. The uncertainty in the measurements is expressed as two relative standard deviations and is less than 36% in the interval 0.04-0.5

ng/g, less than 22% in the interval 0.5-5 ng/g and less than 16% when higher than 5 ng/g. The uncertainty in the measurements for BFRs is expressed in the same way as for the PCBs, and are in the same range (20-36%) in the interval 0.005-5 ng/g. The standard deviation for the five BDEs and HBCD are calculated from 1240 values from control samples during 8 years.

Detection limits and other comments are reported under each contaminant description.

6.1.4 Validation

To have the possibility to control impurities in solvents, equipments and glasswares, one blank sample is extracted together with each batch of environmental samples.

Coelution of congeners in GC analysis is dependent upon instrumental conditions such as column type, length, internal diameter, film thickness and oven temperature etc. Some potentially coeluting PCB congeners on a column with the commonly used phase DB-5 are CB-28/-31, CB-52/-46/-49, CB-101/-84/-90, CB-118/-123/-149, CB-138/-158/-163, CB-153/-132/-105 and CB-180/-193 (Schantz et al., 1993). To minimize those problems a column with a more polar phase is used in parallel.

Coelution with other PCBs then the seven can then be avoided on at least one column, with the exception for CB-138, which coelutes with CB-163 (Larsen et al., 1990). Therefore CB-138 is reported as CB-138+163.

In order to verify possibly coelutions with HCHs, DDTpp and DDDpp one representative sample extract are also treated with potassium hydroxide after the treatment with sulphuric acid. The two extracts are analysed and the chromatograms compared. No remaining peaks at the same retention time as the analytes indicates no coelutions.

When introducing a new matrix one of the samples is re-extracted with a mixture of more polar solvents for control of no remaining contaminants in the matrix residual. Samples from new matrixes and samples from already established matrixes from new sampling location are also examined for suitable internal standard.

From 2005 to 2008 ITM took part in the EU project NORMAN where one of the issues of the project was to provide protocols for validation for harmonisation and dissemination of chemical monitoring methods and a final version of this protocol can be found on the website www.norman-network.net.

During 2008 the laboratory has moved into a new building. The analysis of both organochlorines and BFRs has been validated with respect to blank samples and re-analysed old samples with good results.

6.1.5 Reference Material

Two laboratory reference materials (LRM) are used as extraction controls, chosen with respect to their lipid content and level of organic contaminants. The controls consist of herring respectively salmon muscle, homogenised in a household mixer and stored in aliquots of 10 gram of herring respectively 3 gram of salmon in air tight bags of aluminium laminate at -80°C. At every extraction event one extraction control is extracted as well.

From 1998 CRM 349, cod liver oil was analysed twice a year for PCBs. During 2003 the laboratory changed to CRM 682 and 718, mussel (whole body) respectively herring (muscle), being better representants since they cover the whole extraction procedure. One of those samples are analysed once a year. Until now no CRM exist for BFRs.

6.1.6 Intercalibration and certifications

Concerning PCBs and pesticides, the laboratory has participated in the periodic QUASIMEME intercalibration exercise since 1993, with two rounds every year, each one containing two samples. 565 of the 591 values that the laboratory has produced during the years have been satisfactory according to QUASIMEME, meaning they have falling within +/- 2 sd of the assigned value. In 2000, the laboratory participated in the first interlaboratory study ever performed for BFR and since 2001 the BFRs are incorporated in the QUASIMEME scheme. From the beginning there was one yearly exercise but after 2006 this was changed to two exercises per year with one sample each time. The laboratory has performed with good results for these studies until 2007. The reason for this less good performance was limited access to the instrument, with not enough time for cleaning and pre-tests. However, during 2008 a new instrument has been bought and validated. The two following intercalibration exercises have shown improved results. As a total, 59 of the 73 values the laboratory has produced during the years have been satisfactory according to QUASIMEME.

The laboratory has since 1998 participating in three certification exercises, concerning PCBs, pesticides and BFRs. In two of this the laboratory was involved as a co-organizer. As a total, 494 of the 534 reported values were accepted and could be used as a part of the certification. The laboratory has also participated in the programme for sampling quality control, QUASH.

6.2 Dioxins, dibenzofurans and dioxinlike PCB's

The analyses of dioxins and dioxin-like PCBs are carried out at the Department of Chemistry, Umeå University. The extraction method is described by Wiberg et al., 1998, the clean-up method by Danielsson et al. 2005, and the instrumental analysis (GC-HRMS) by Liljelind et al. 2003. The laboratory participates in the annual FOOD intercallibration rounds, and include a laboratory reference material (salmon tissue) with each set of samples.

6.3 Perfluorinated substances

The analyses of perfluorinated substances are carried out at the Analytical Environmental Chemistry Unit at the Department of Applied Environmental Science (ITM), University of Stockholm.

6.3.1 Sample preparation and instrumental analysis

A sample aliquot of approximately 0.5 g homogenized tissue was spiked with 5 ng each of a suite of mass-labelled internal standards (¹³C-labelled perfluorinated sulfonates and carboxylic acids). The samples were extracted twice with 5 mL of acetonitrile in an ultrasonic bath. Following centrifugation, the supernatant extract was removed and the combined acetonitrile phases were concentrated to 1 mL under a stream of nitrogen. The concentrated extract underwent dispersive clean-up on graphitized carbon and acetic acid. Approximately 0.5 mL of the cleaned-up extract was added to 0.5 mL of aqueous ammonium acetate. Precipitation occurred and the extract was centrifuged before the clear supernatant was transferred to an autoinjector vial for instrumental analysis and the volume standards BTPA and bPFDCa were added.

Aliquots of the final extracts were injected automatically on a high performance liquid chromatography system (HPLC; Alliance 2695, Waters) coupled to a tandem mass spectrometer (MS-MS; Quattro II, Micromass). Compound separation was achieved on an Ace 3 C₁₈ column (150 x 2.1 mm, 3 µm particles, Advanced Chromatography Technologies) with a binary gradient of ammonium acetate buffered methanol and water. The mass spectrometer was operated in negative electrospray ionization mode with the following optimized parameters: Capillary voltage, 2.5 kV; drying and nebuliser gas flow (N₂), 300 and 20 L/h, respectively; desolvation and source temperature, 150 and 120 °C, respectively. Quantification was performed in selected reaction monitoring chromatograms using the internal standard method.

6.3.2 Quality control

The extraction method employed in the present study (with the exception of the concentration step) has previously been validated for biological matrices and showed excellent analyte recoveries ranging between 90 and 110% for PFCAs from C6 to C14 (Powley and Buck, 2005). Including extract concentration, we determined recoveries between 70 and 90% for C6- to C10-PFCAs and 65–70% for C11-C14 PFCAs. Extraction efficiencies for perfluorosulfonates (PFSS), including perfluorooctane sulfonamide (PFOSA), were determined to 70–95%. Furthermore, mean method recoveries of the mass labelled internal standard compounds were between 52% and 102%. Method quantification limits (MQLs) for all analytes were determined on the basis of blank extraction experiments and ranged between 0.2 and 1.0 ng/g wet weight (w.w.) for the different compounds. Two herring liver samples were analysed in duplicates in different batches on different days. The obtained values varied <15% for all of the 14 paired results (7 detected analytes in two samples). A fish tissue sample used in an international inter-laboratory comparison (ILC) study in 2007 (van Leeuwen et al., 2009) was analyzed along with the samples. The obtained concentrations deviated from the mean concentration from the ILC study by less than 10% for all 7 compounds quantified in the ILC.

7 Statistical treatment and graphical presentation

7.1 Trend detection

One of the main purposes of the monitoring programme is to detect trends. The trend detection is carried out in three steps.

7.1.1 Log-linear regression analyses

Log-linear regression analyses are performed for the *entire investigated time period* and also for the *recent ten years* for longer time series.

The slope of the line describes the yearly percentual change. A slope of 5% implies that the concentration is halved in 14 years whereas 10% corresponds to a similar reduction in 7 years and 2% in 35 years. See table 7.1 below.

Table 7.1. The approximate number of years required to double or half the initial concentration assuming a continuous annual change of 1, 2, 3, 4, 5, 7, 10, 15 or 20% a year.

	1%	2%	3%	4%	5%	7%	10%	12%	15%	20%
Increase	70	35	24	18	14	10	7	6	5	4
Decrease	69	35	23	17	14	10	7	6	4	3

7.1.2 Non-parametric trend test

The regression analysis presupposes, among other things, that the regression line gives a good description of the trend. The leverage effect of points in the end of the line is also a well-known fact. An exaggerated slope, caused 'by chance' by a single or a few points in the end of the line, increases the risk of a false significant result when no real trend exist. A non-parametric alternative to the regression analysis is the Mann-Kendall trend test (Gilbert, 1987, Helsel & Hirsch, 1995, Swertz, 1995). This test has generally lower power than the regression analysis and does not take differences in magnitude of the concentrations into account; it only counts the number of consecutive years where the concentration increases or decreases compared with the year before. If the regression analysis yields a significant result but not the Mann-Kendall test, the explanation could be either that the latter test has lower power or that the influence of endpoints in the time series has become unwarrantable great on the slope. Hence, the eighth line reports Kendall's ' τ ', and the corresponding p-value. The Kendall's ' τ ' ranges from 0 to 1 like the traditional correlation coefficient ' r ' but will generally be lower. 'Strong' linear correlations of 0.9 or above corresponds to τ -values of about 0.7 or above (Helsel and Hirsch, 1995, p. 212). This test was recommended by the Swedish EPA for use in water quality monitoring programmes with annual samples, in an evaluation comparing several other trend tests (Loftis *et al.* 1989).

7.1.3 Non-linear trend components

An alternative to the regression line in order to describe the development over time is a kind of smoothed line. The smoother applied here is a simple 3-point running mean smoother fitted to the annual geometric mean values. In cases where the regression line is badly fitted the smoothed line may be more appropriate. The significance of this line is tested by means of an Analysis of Variance where the variance explained by the smoother and by the regression line is compared with the total variance. This procedure is used at assessments at ICES and is described by Nicholson *et al.*, 1995.

7.2 Outliers and values below the detection limit

Observations further from the regression line than what is expected from the residual variance around the line is subjected to special concern. These deviations may be caused by an atypical occurrence of something in the physical environment, a changed pollution load or errors in the sampling or analytical procedure. The procedure to detect suspected outliers in this presentation is described by Hoaglin and Welsch (1978). It makes use of the *leverage coefficients* and the *standardised residuals*. The standardised residuals are tested against a $t_{.05}$ distribution with $n-2$ degrees of freedom. When calculating the i th standardised residual the current observation is left out implying that the i th observation does not influence the slope nor the variance around the regression line. The suspected outliers are merely indicated in the figures and are included in the statistical calculations except in a few cases, pointed out in the figures.

Values reported below the detection limit is substituted using the ‘robust’ method suggested by Helsel & Hirsch (1995) p 362, assuming a log-normal distribution within a year.

7.3 Legend to the plots

The analytical results from each of the investigated elements are displayed in figures. A selection of sites and species are presented in plots, time series shorter than 4 years.

The plot displays the geometric mean concentration of each year (circles) together with the individual analyses (small dots) and the 95% confidence intervals of the geometric means.

The overall geometric mean value for the time series is depicted as a horizontal, thin line.

The trend is presented by one or two regression lines (plotted if $p < 0.10$, two-sided regression analysis); one for the whole time period in red and one for the last ten years in pink (if the time series is longer than ten years). Ten years is often too short a period to statistically detect a trend unless it is of considerable magnitude. Nevertheless the ten year regression line will indicate a possible change in the direction of a trend. Furthermore, the residual variance around the line compared to the residual variance for the entire period will indicate if the sensitivity have increased as a result of e.g. an improved sampling technique or that problems in the chemical analysis have disappeared.

A smoother is applied to test for non-linear trend components (see 7.1.3). The smoothed line in blue is plotted if $p < 0.10$. A broken line or a dashed line segment indicates a gap in the time series with a missing year.

The log-linear regression lines fitted through the geometric mean concentrations follow smooth exponential functions.

A cross inside a circle, indicate a suspected outlier, see 7.3. The suspected outliers are merely indicated in the figures and are included in the statistical calculations except in a few cases, pointed out in the figures.

Each plot has a header with species name and sampling locality. Below the header of each plot the results from several statistical calculations are reported:

n(tot)= The first line reports the total number of analyses included together with the number of years (**n(yrs)**=).

m= The overall geometric mean value together with its 95% confidence interval is reported on the second line of the plot (N.B. d.f.= n of years - 1).

slope= reports the slope, expressed as the yearly percentual change together with its 95% confidence interval.

sd(lr)= reports the coefficient of variation around the regression line, as a measure of between-year variation, together with the lowest detectable change in the current time series with a power of 80%, one-sided test, $\alpha=0.05$. The last figure on this line is the estimated number of years required to detect an annual change of 5% with a power of 80%, one-sided test, $\alpha=0.05$.

power= reports the power to detect a log-linear trend in the time series (Nicholson & Fryer, 1991). The first figure represent the power to detect an annual change of 5% with the number of years in the current time series. The second figure is the power estimated as if the slope where 5% a year and the number of years were ten. The third figure is the *lowest detectable change* (given in percent per year) for a ten year period with the current between year variation at a power of 80%. The results of the power analyses from the various time series are summarised in chapter 8.

r²= reports the coefficient of determination (r^2) together with a p-value for a two-sided test (H_0 : slope = 0) i.e. a significant value is interpreted as a true change, provided that the assumptions of the regression analysis is fulfilled.

y(06)= reports the concentration estimated from the regression line for the last year together with a 95% confidence interval, e.g. $y(06)=2.55(2.17,3.01)$ is the estimated concentration of year 2006 where the residual variance around the regression line is used to calculate the confidence interval. Provided that the regression line is relevant to describe the trend, the residual variance might be more appropriate than the within-year variance in this respect.

tao= reports Kendall's ' τ ', and the corresponding p-value.

sd(sm)= reports the coefficient of variation around the smoothed line. The significance of this line could be tested by means of an Analysis of Variance (see 7.1.3). The p-value is reported for this test. A significant result will indicate a non-linear trend component. After the p-value, the minimum trend (%/year), likely to be detected, at a power of 80%, during

a period of 10 years, should a log-linear trend occur, is shown. This estimate is compensated for the loss of degrees of freedom, considering the smoother.

Below these nine lines are additional lines with information concerning the regression of the last ten years.

In some few cases where an extreme outlying observation may hazard the confidence in the regression line, the ordinary regression line is replaced by the 'Kendall-Theil Robust line', see Helsel and Hirsch (1995) page 266. In these cases only the 'Theil'-slope and Kendall's ' τ ' are reported.

8 The power of the programme

Before starting to interpret the result from the statistical analyses of the time series it is essential to know with what power temporal changes can be detected (i.e. the chance to reveal true trends with the investigated matrices). It is crucial to know whether a negative result of a trend test indicate a stable situation or if the monitoring programme is too poor to detect even serious changes in the contaminant load to the environment. One approach to this problem is to estimate the power of the time series based on the 'random' between-year variation. Alternatively the lowest detectable trend could be estimated at a fixed power to represent the sensitiveness of the time series.

The first task would thus be to estimate the 'random' between-year variation. In the results presented below this variation is calculated using the residual distance from a log-linear regression line. In many cases the log-linear line, fitted to the current observations, seems to be an acceptable 'neutral' representation of the true development of the time series. In cases where a significant 'non-linear' trend has been detected (see above), the regression line may not serve this purpose; hence the sensitiveness- or power-results based on such time series are marked with an asterisk in the tables below. These results are also excluded from estimations of median performances.

Another problem is that a single outlier could ruin the estimation of the between-year variation. In the presented results suspected outliers are included which means that the power and sensitiveness might be underestimated.

Table 8.1 reports the number of years that various contaminants have been analysed and detected from the monitored sites.

Table 8.1 Number of years that various contaminants have been analysed and detected.

Contaminant	Abiskojaure	Bolmen	Skärgölen	Storvindeln
CB-153	19	17	-	18
DDT	12	31	-	32
DDE	23	38	-	37
DDD	4	36	-	21
γ -HCH	12	12	-	20
HCB	19	17	-	34
TCDD	-	-	13	-
TCDF	-	-	13	-
BDE-47	-	32	-	-
BDE-153	-	31	-	-
BDE-154	-	29	-	-

Table 8.2 reports the number of years required to detect an annual change of 5% with a power of 80 %. The power is to a great extent dependent of the length of the time series and the possibility to statistically verify an annual change of 5% at a power of 80% generally requires 15-20 years for the organic substances.

Table 8.2 The number of years required to detect an annual change of 5% with a power of 80 %

Contaminant	Abiskojaure	Bolmen	Skärgölen	Storvindeln
CB-153	17	17	-	13
DDT	22	30	-	23
DDE	20	19	-	15
DDD	9	20	-	19
γ -HCH	25	21	-	28
HCB	13	19	-	18
TCDD	-	-	16	-
TCDF	-	-	11	-
BDE-47	-	32	-	-
BDE-153	-	31	-	-
BDE-154	-	31	-	-

In table 8.3 the lowest trend possible to detect within a 10-year period with a power of 80 % is presented both for the entire time series and for the latest 10-year period.

Table 8.3 The lowest trend possible to detect (in %) within a 10-year period with a power of 80 % for the entire time series and for the latest 10 years [in brackets]

Contaminant	Abiskojaure	Bolmen	Skärgölen	Storvindeln
CB-153	12 [4.2]	12 [8.7]	-	7.4 [4.9]
DDT	18 [9.5]	31 [23]	-	20 [20]
DDE	15 [4.9]	15 [6.4]	-	9.8 [7.4]
DDD	4.0[4.0]	16 [5.8]	-	14 [4.9]
γ -HCH	26 [21]	9.6 [9.4]	-	29
HCB	7.2 [3.9]	14 [8.8]	-	13 [3.0]
TCDD	-	-	11 [12]	-
TCDF	-	-	5.7 [7.2]	-
BDE-47	-	35 [11]	-	-
BDE-153	-	34 [11]	-	-
BDE-154	-	34 [8]	-	-

Table 8.4 reports the power to detect an annual change of 5% covering the monitoring period, i.e. the length of the time series varies depending on site and investigated contaminant. For the long time series the estimated power is close to 100% in most cases.

Table 8.4. Power to detect an annual change of 5% covering the entire monitoring period. The length of the time series varies depending on site and investigated contaminant. In cases where considerable increased power has been achieved during the recent ten years period, this value has been used. * indicates a significant non-linear trend.

Contaminant	Abiskojaure	Bolmen	Skärgölen	Storvindeln
CB-153	0.92	0.81	-	1.0
DDT	0.19	0.88	-	1.0
DDE	0.96	1.0	-	1.0
DDD	0.10	1.0	-	0.94
γ -HCH	0.12	0.52	-	0.36
HCB	1.0	0.70	-	1.0
TCDD	-	-	0.52	-
TCDF	-	-	0.97	-
BDE-47	-	0.83	-	-
BDE-153	-	0.82	-	-
BDE-154	-	0.72	-	-

9 Assessment criteria

When conducting environmental monitoring as described earlier in this report the results tells us something about the concentrations present in the environment, how large the variation is and also about the geographical differences. Repeated measurements over time will also give us the possibility to detect trends in the material. What it does not say is what possible effects the measured concentrations have on the environment and on the organisms living there and especially at what levels these effects appear. To be able to evaluate our results in this respect, we need a defined limit to which we can relate them to. A variety of these limits are available but for a rather small group of substances and many of them are developed in both different ways and with different endpoints in mind.

These limits have different names depending on which organisation that developed them. In this report we focus mostly on the EQS (Environmental Quality Standards) and EAC (Environmental Assessment Criteria) values developed by EU and OSPAR respectively. The methods used when deriving these values are more or less the same and produce comparable results. Together, the two organisations cover some but not all of the substances investigated in this report and thus in the Swedish national monitoring program.

In addition to the EU list of priority substances the Swedish EPA asked the Swedish Chemical Agency to derive proposals for environmental quality standards for a number of pollutants of importance in Sweden. These proposals (Naturvårdsverket, 2008) are used in this report when applicable. For some of the substances that are measured, no limits, standards or criteria are available.

The way a EQS value is derived and how uncertainty is handled is described in a technical guidance document (TGD, 2009)

9.1 Classification

The EU Water Framework Directive (WFD) classification scheme for water quality includes five status classes (high, good, moderate, poor and bad). These classes corresponds to a colour where blue indicate high status, green=good, yellow=moderate, orange=poor and red=bad.

The transition from high to good status is the detection limit for the chemical analysis (for anthropogenic substances) or background concentrations for natural elements (such as metals). The transition from good to moderate is the threshold value i.e. the EQS. In this report a similar approach is used. The same transition criteria are used except that for the classes that indicate levels above the EQS/EAC the colours indicate exponentially increasing concentrations, figure 9.1.

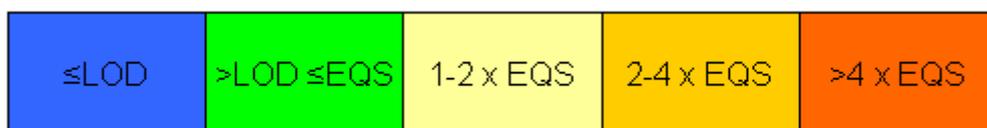


Figure 9.1 Class limits used in this report. Blue represents high status and is used when measured concentrations are below LOD (Limit Of Detection). Green represents good status and thus concentrations above LOD but below EQS/EAC. Light yellow (moderate) is used for concentrations between 1-2 times the EQS/EAC, dark yellow for concentrations between 2-4 times the EQS/EAC and orange when the concentration exceeds 4 times the EQS/EAC.

It is important to keep in mind that the three classes that indicate concentrations above the EQS/EAC (light/dark yellow and orange) cannot be used as a toxicologically relevant measurements or effect prediction. Depending on the substance of interest, the dose-response curves are very different. Therefore, a concentration of e.g. 4 x EQS can induce relatively harmless effects for one substance but cause adverse effects for another. By the reason stated above, the colours above threshold are more used as indicators of possible effects and to show geographical differences in concentration. The ideal situation would be to have several scientifically based endpoints for each substance.

To be able to evaluate substances for which no threshold values can be found, the lower 5th percentile of all measurements in the dataset is used as a transition between concentrations regarded as acceptable and unacceptable. The LOD is still used to indicate high status. To illustrate that different methods have been used and that these values have been derived without toxicological background information, the colors used in the maps are different, fig 9.2.

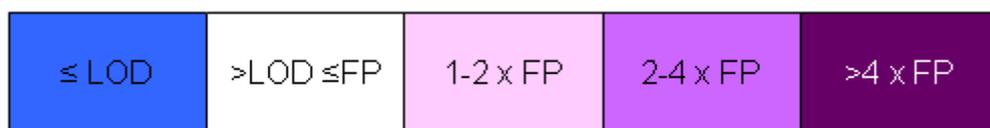


Figure 9.2 Class limits used in this report for substances without a predefined assessment criteria. FP stands for Fifth Percentile and it is derived from the dataset by calculating the lower 5th percentile of the measurements in the dataset. The following classes are used for concentrations above this level according to the numbers in the figure.

9.2 Selection of thresholds

In this report the principle of precaution is used when more than one threshold value is available. This conduct is also in accordance with the recommendation in the WFD guidelines.

The results presented in this report are extremely dependent on the threshold used. For some substances this may lead to an incorrect or biased picture of the actual exposure and risk scenario. It is however of importance to begin the process of implementing these thresholds in assessments. This is a way to more efficiently find and give priority to those substances of most concern. In table 9.1, a list of the thresholds used in this report is presented along with the value chosen as transition between high and good status.

The transition used for high status is the LOD (Limit Of Detection) for the chemical analysis as mentioned earlier in this chapter. This limit varies from run to run and on instrumental conditions but the variation is however not a critical factor. In this report, the lowest LOD from the latest analysis is chosen as a transition point. The LOD in itself is not related to risk but indicate low levels provided that the analytical method is appropriate and of high quality. Should a known effect level be lower than the LOD, the effect level is used instead.

As a comparison to the thresholds, the 5th percentile for all measurements of each substance is included in the table. These are often expressed on lipid weight basis instead of wet weight which means that they are generally about a factor 60-200 higher than the corresponding wet weight value (depends on fat content).

Table 9.1 List of thresholds used in this report.

Substance	LOD (ng/g ww)	Treshold (ng/g ww)	5 th percentile (ng/g lw)	Reference to threshold
CB-118	0.05	24 (lw)	5	OSPAR, 2009
CB-153	0.05	0.25	12	OSPAR, 2005
CB-180	0.05	480 (lw)	5	OSPAR, 2009
PFOS	0.5	6	1.79 (ww)	Naturvårdsverket, 2008
PFOA	0.5	6	-	
PFNA	0.1	6	0.23 (ww)	
PFTriA	0.1	6	0.84 (ww)	
PFOSA	0.3	6	0.09 (ww)	
TCDD	0.005 (pg/g)	1.25 (pg/g)	3.45 (pg/g)	EU, 2006
TCDD*	0.005 (pg/g)	1.25 (pg/g)	0.68 (pg/g)	
TCDF*	0.005 (pg/g)	12.5 (pg/g)	5.33 (pg/g)	
CB-77*	0.005 (pg/g)	12.5 (pg/g)	76 (pg/g)	
CB-126*	0.005 (pg/g)	12.5 (pg/g)	50.75 (pg/g)	
BDE-47	0.01		1.08	
BDE-99	0.01		0.60	
BDE-100	0.003	247	0.34	IVL, 2010
BDE-153	0.003		0.18	
BDE-154	0.003		0.22	
BDE-209	0.02	20 (pg/g)	-	NRM
HBCD	0.02	1500	0.80	Naturvårdsverket, 2008
HCH (Lindane)	0.04	26	3	IVL, 2010
HCB	0.04	10	5	EU (CIRCA)
DDT	0.06	-	12	NRM
DDE	0.03	-	19	NRM
DDD	0.07	-	8	NRM

* Calculated from the TCDD threshold.

9.3 Comments to thresholds

9.3.1 PCB

The threshold values for PCB have been thoroughly reviewed before use. The problems with these are that the thresholds available differ in magnitude depending on what studies that are used as a scientific basis. For CB-118 and CB-180 the only available thresholds comes from OSPAR and for CB-153 there is also a consumption based limit from the Swedish national food administration.

In the latest agreement on assessment criteria that are to be used in the 2010 QSR (OSPAR, 2009), OSPAR lists EAC values for the mentioned CB congeners in biota (fish). In a publication from ICES prior to these values (ICES, 2008) the proposed EACs for PCBs are reviewed and the conclusion was that the values “seem to be extreme and environmentally unrealistically high for biota”. This comment specifically addressed the proposed CB-153 EAC of 3200 ug/kg ww but is valid for all CB congeners. The reason that these values are so high is due to toxicological tests with only one single congener at a time. The results of these tests are that the PCB toxicity is severely underestimated since single congeners do not appear by themselves in the environment. Therefore, even if the concentrations of CB-153 are clearly below threshold, this is not a guarantee that effects does not appear due to other more toxic congeners. In this way of thinking, the congeners that are presented here are more seen as a proxy for the total load of PCB and not as individually relevant thresholds.

In the latest agreement this EAC was changed to an EAC^{passive} of 1600 ug/kg lw in fish liver. This is lower but still seems unreasonably high. Therefore, an old value for CB-153 is used in this report until this is further investigated.

The thresholds for CB-118 and CB-180 are still used here in lack of other values. These thresholds are expressed on lipid weight in liver while the measurements here are made in muscle. The differences between these tissues are not considered here. It is however desirable to derive new thresholds for these compounds where consideration is taken for additive and synergistic effects.

9.3.2 PFAs

The threshold for PFA used in this report is taken from a report ordered by the Swedish EPA (Naturvårdsverket, 2008). The value is derived for PFOS by the method described in the TGD but is in this report used for all the PFAs. Consideration and comparison between toxicity for different PFAs is not done here and hence the appropriateness of using this threshold for other compounds than PFOS is not known.

9.3.3 Dioxins

The threshold for maximum concentrations of TCDDEQ in fish used for feed is used in this report (1.25 pg/g ww; EU, 2006). The reason for using this value and not the consumption based value (4 pg/g ww) is that there need to be a safety margin for top predators and sensitive species. For TCDD, TCDF, CB-77 and CB-126 a threshold was calculated from the TCDDEQ value using TEF factors of 1, 0.1, 0.0001 and 0.1 respectively (Van den Berg *et al*, 2006). These values should only be used as indications

since they represent the maximum concentration of the compound that would not lead to the threshold being exceeded, if the compound in question was the single contributor to the TEQ.

9.3.4 PBDEs

The threshold for polybrominated flame retardants is set with human health as endpoint and holds for the sum of BDE 28, 47, 99, 100, 153, 154. The threshold is calculated from the EQS for water (IVL, 2010). For the analyses used in this report, no measurements of BDE-28 are available. The result is a underestimation of the sum of the congeners mentioned above. No attempts to correct for this are carried out here.

No thresholds are available for BDE-209 and the measurements exceeding the LOD are so few that a 5th percentile value is misleading. Therefore, the LOD is used as a threshold.

9.3.5 HBCD

The HBCD value originates from the same report as PFOS (Naturvårdsverket, 2008). This is a high value but the only one that could be found.

9.3.6 HCHs

The threshold refers to Lindane which is the most toxic HCH and is therefore considered appropriate for all HCHs in this report. The threshold is calculated from the EQS for water (IVL, 2010).

9.3.7 HCB

This threshold is from the EU list of priority substances. (CIRCA's website)

9.3.8 DDTs

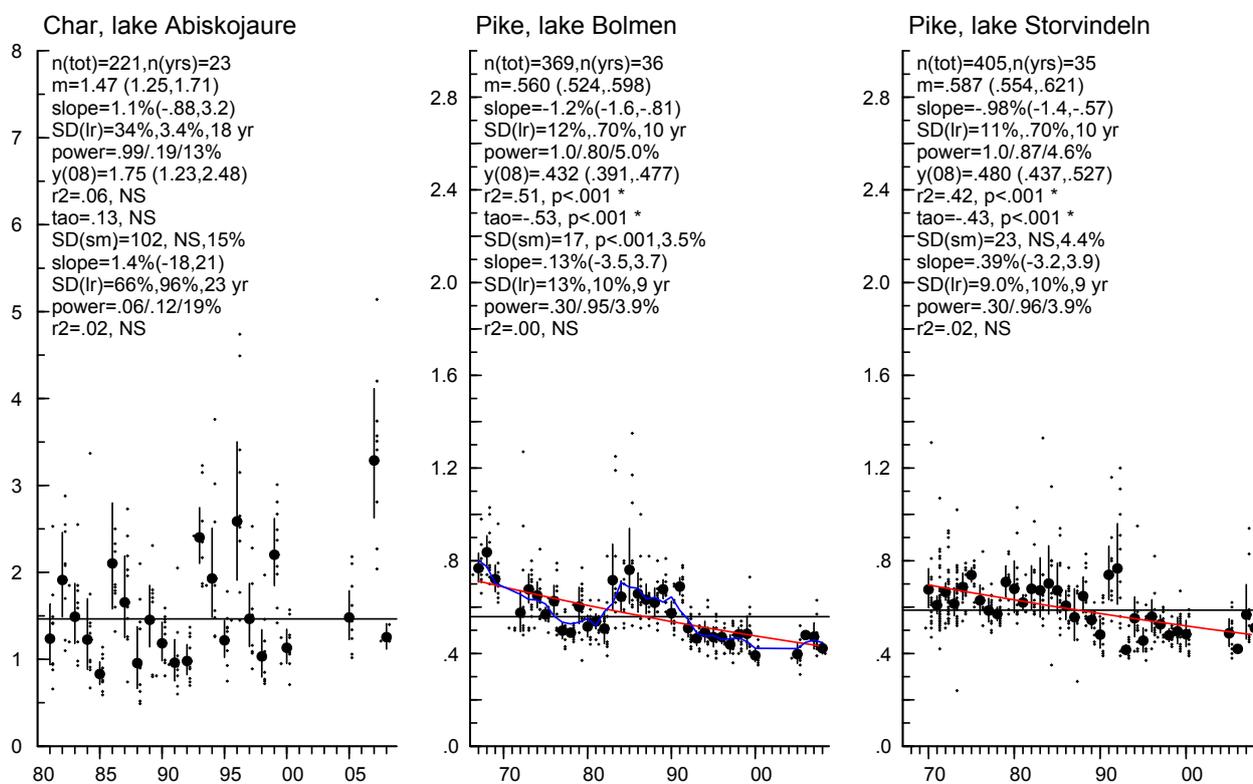
No thresholds could be found for this group and hence the 5th percentile from all the available measurements was used instead.

10 Fat content

10.1 Temporal variation

Fat content in pike from lake Bolmen and lake Storvindeln demonstrated significant decreasing trends during the time period 1967/68 – 2008 (figure 10.1). The annual decrease varied between 0.98-1.2%. No such trends could be detected in char from Lake Abiskojaure during the somewhat shorter monitoring period between 1980 – 2008.

Fat %



pia - 10.05.25 13:51, Fat

Figure 10.1 Temporal variation of fat content in Char and Pike from three lakes within the Swedish national monitoring programme

11 PCBs, Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) consist of two linked benzene rings with chlorine atoms substituted for one or more hydrogen atoms. 209 congeners are possible and twenty of these have non-ortho chlorine substitutions and so can attain a planar structure similar to the highly toxic polychlorinated dibenzo-*p*-dioxins and dibenzofurans (McKinney *et al.* 1985, Serico *et al.* 1991). PCBs are synthetic chemicals that have been used in a wide variety of manufacturing processes especially as plasticizers and as insulators and fire retardants. It is widely distributed in the environment through inappropriate handling of waste material or e.g. leakage from large condensers and hydraulic systems.

PCBs can influence human health by affecting multiple organ systems (ATSDR 2000, Carpenter 1998, Carpenter 2006) and their toxicological effects e.g. on reproduction in mink is well documented (Aulerich *et al.* 1977, Jensen *et al.* 1977 and Bleavins *et al.* 1980).

The Helsinki Convention (HELCOM) has imposed special bans and restrictions on transport, trade, handling, use and disposal of PCBs. The Minister Declaration from 1996, within HELCOM, and the declaration in Esbjerg 1995, calls for measures for toxic, persistent, bioaccumulating substances like PCBs to have ceased completely in the year 2020. Seven PCB congeners (CB-28, CB-52, CB-101, CB-118, CB-138, CB-153 and CB-180, IUPAC) are listed as mandatory contaminants that should be analysed and reported within both the OSPARCOM and the HELCOM conventions. In the proposed revised guidelines for OSPARCOM (1996) the congeners CB-105 and CB-156 are added to this list.

The concentration of the PCB's in fish muscle, is determined using a gas chromatograph (GC) equipped with an electron capture detector.

Coelution of congeners in GC analysis is dependent upon instrumental conditions such as column type, length, internal diameter, film thickness and oven temperature etc. Some potentially coeluting PCB congeners are CB-28/-31, CB-52/-49, CB-101/-90, CB-138/-163/-164 and CB-153/-132/-105 (Schantz *et al.*,1993). During recent years it has been discovered that congener CB-163, and possibly also CB-164, has interfered with CB-138 (see also Roos *et al.* 1989). This implies that the reported concentration of CB-138 also includes a minor contribution from CB-163 and possibly also from CB-164.

11.1 Spatial variation

The pattern of the spatial variation of CB-118, 153 and 180 is very much the same, figure 11.1 and 11.2. In general, higher concentrations can be seen in the southern parts of the country and in the areas surrounding the major cities. The highest concentration of CB-118 was measured in lake Fysingen (270 ng/g lw) and the lowest in lake Tjulträsk (4.6 ng/g lw). The same comparison for CB-153 shows the highest concentration in lake Fräcksjön (680 ng/g lw, 3.63 ng/g ww) and the lowest in lake

11.2 Comparison to thresholds

In addition to information about geographical variation, the maps contain information about the measured concentrations in relation to threshold levels. Figure 11.3 and 11.4 show these threshold values compared to the range of the measured concentrations. Table 11.1 show the distribution of classes per substance.

When using this set of thresholds, a majority of the measured concentrations of CB-118 and CB-180 lies within the blue and green classes. For CB-153 the situation is different but this can be explained by the proportionately restrictive threshold used.

11.3 Temporal variation

During the last ten year period, concentrations of CB-153 show significant decreasing trends in all three lakes, Abiskojaure, Bolmen and Storvindeln with an annual change of 4-9%, figure 11.5. Similar decreasing trends for the entire monitoring period 1985-2008 and 1980-2008 are also found in Lake Storvindeln and Lake Abiskojaure with a decrease of 3.5-4.4% per year. These trends are consistent with and of similar magnitude as other time series for PCB in marine biota (Bignert *et al.* 2010).

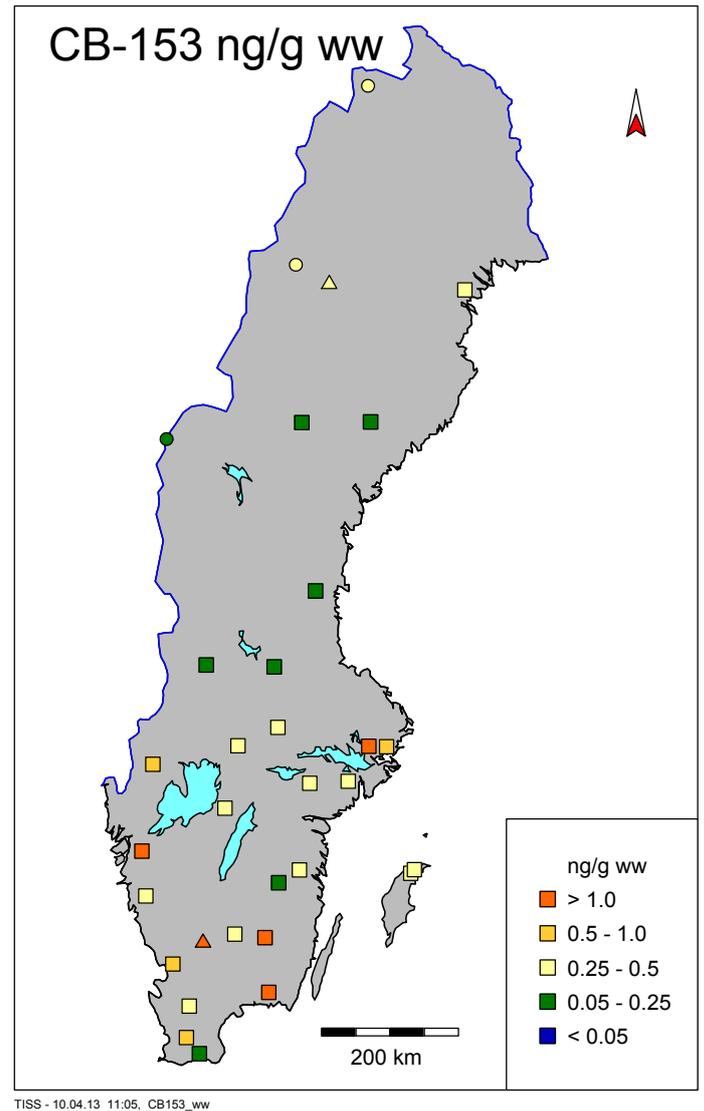
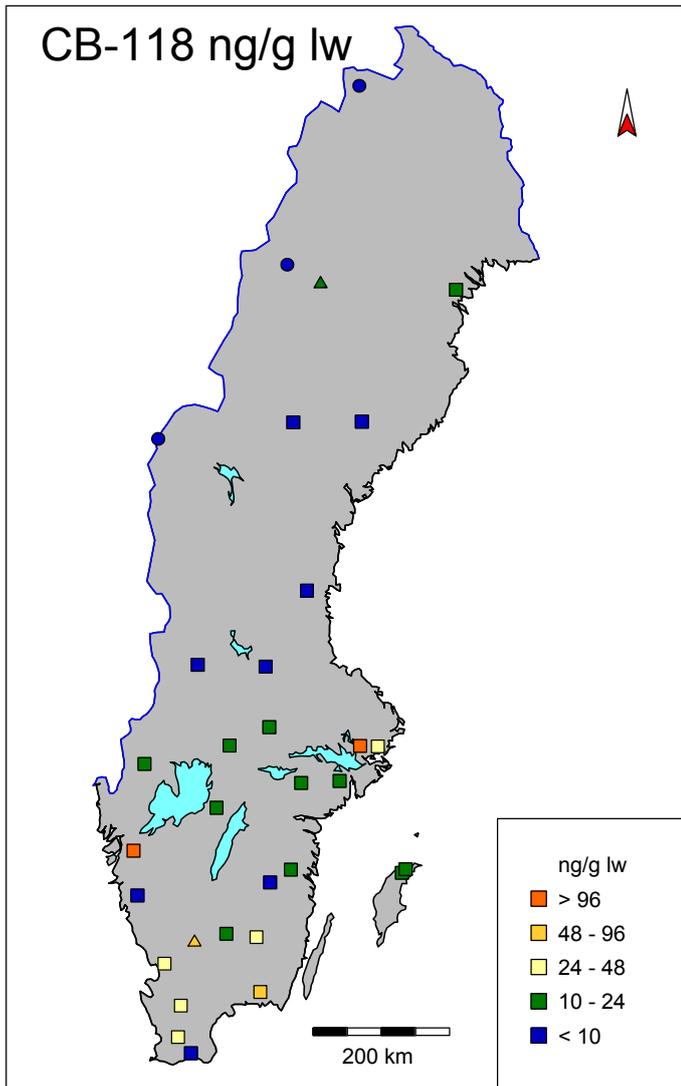


Figure 11.1. Spatial variation of CB-118 and CB-153 respectively. The squares represents the concentration interval of average measured concentrations in fish muscle between 2000-2008 from lakes within the monitoring programme. Threshold used for CB-118 = 24 ng/g lw and for CB-153= 0.25 ng/g ww

■ = Perch ● = Char ▲ = Pike

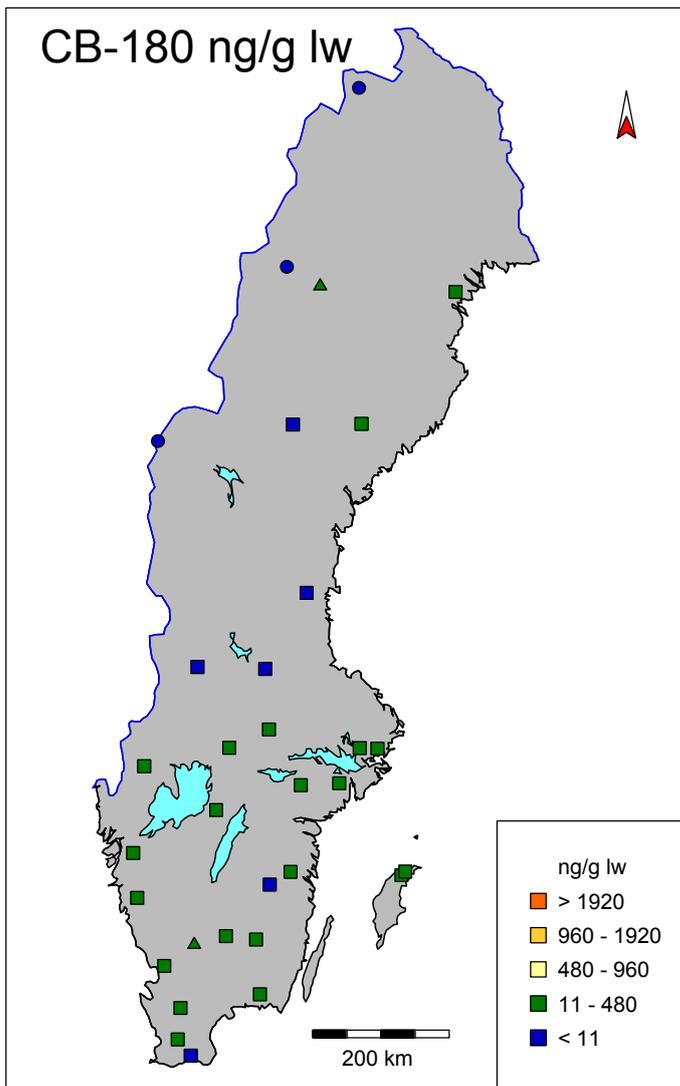


Figure 11.2. Spatial variation of CB-180. The squares represents the average measured concentrations in fish muscle between 2000-2008 from lakes within the monitoring programme. Threshold used for CB-180 = 480 ng/g lw

■ = Perch ● = Char ▲ = Pike

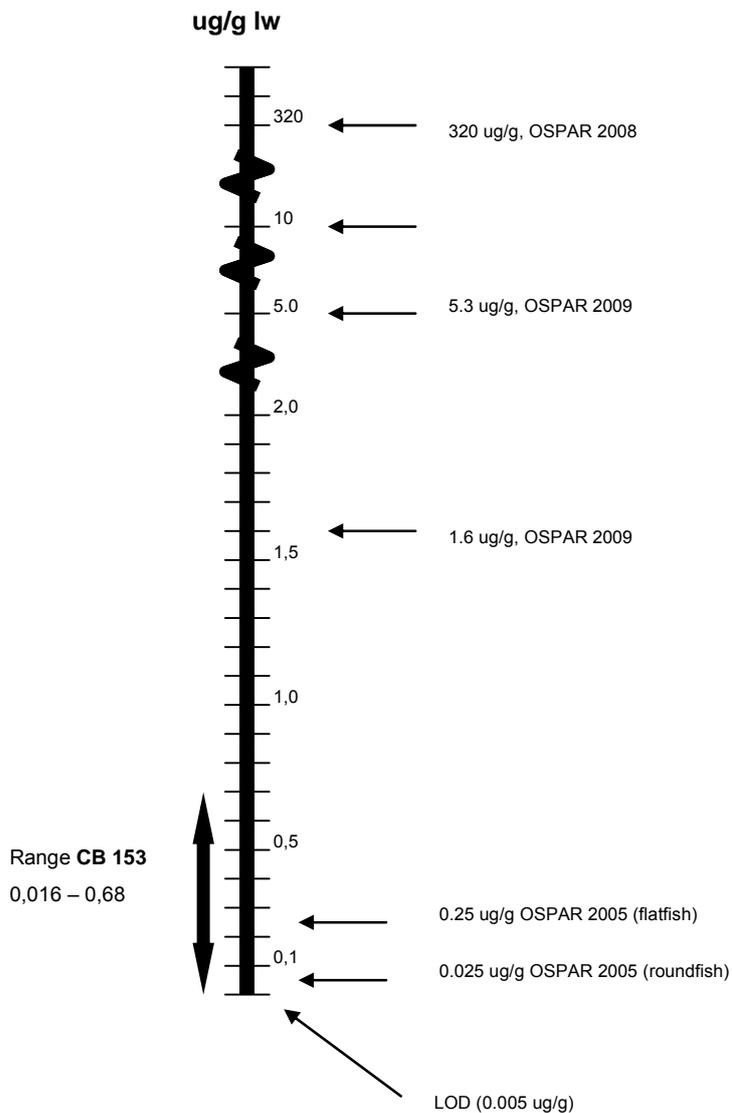


Figure 11.3 Comparison between the range of average analysed concentrations of CB-153 in fish muscle 2000-2008 and different threshold concentrations available in literature. All thresholds are expressed on lipid weight basis using the assumption of 1 % fat content.

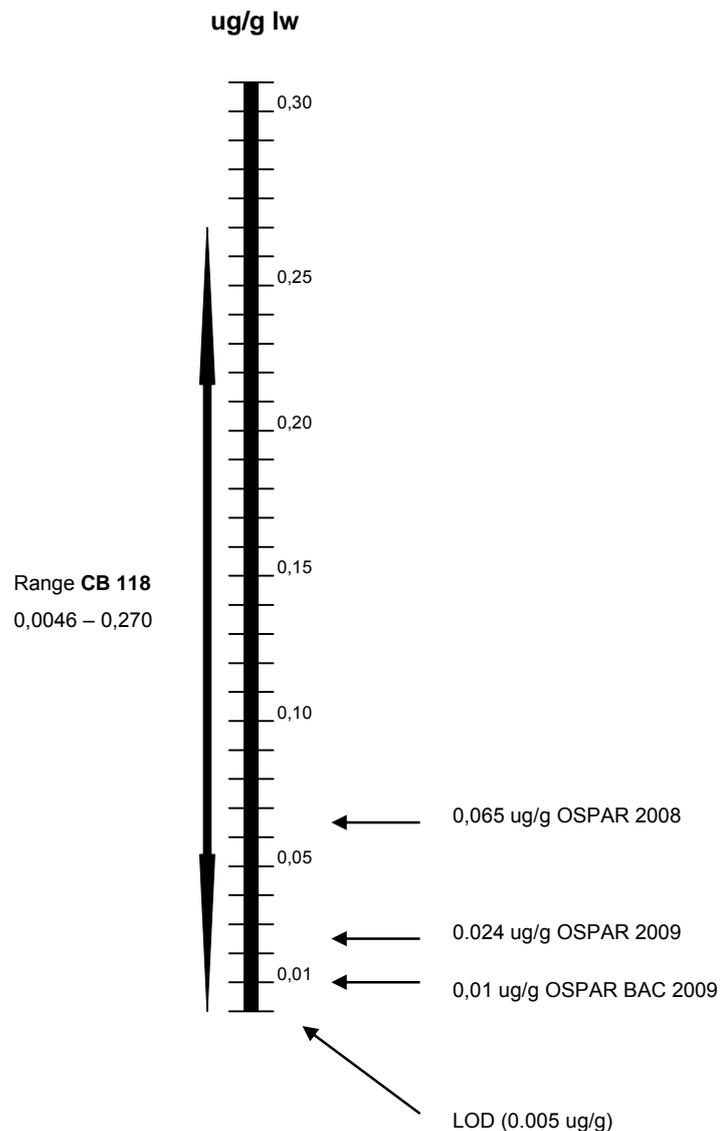
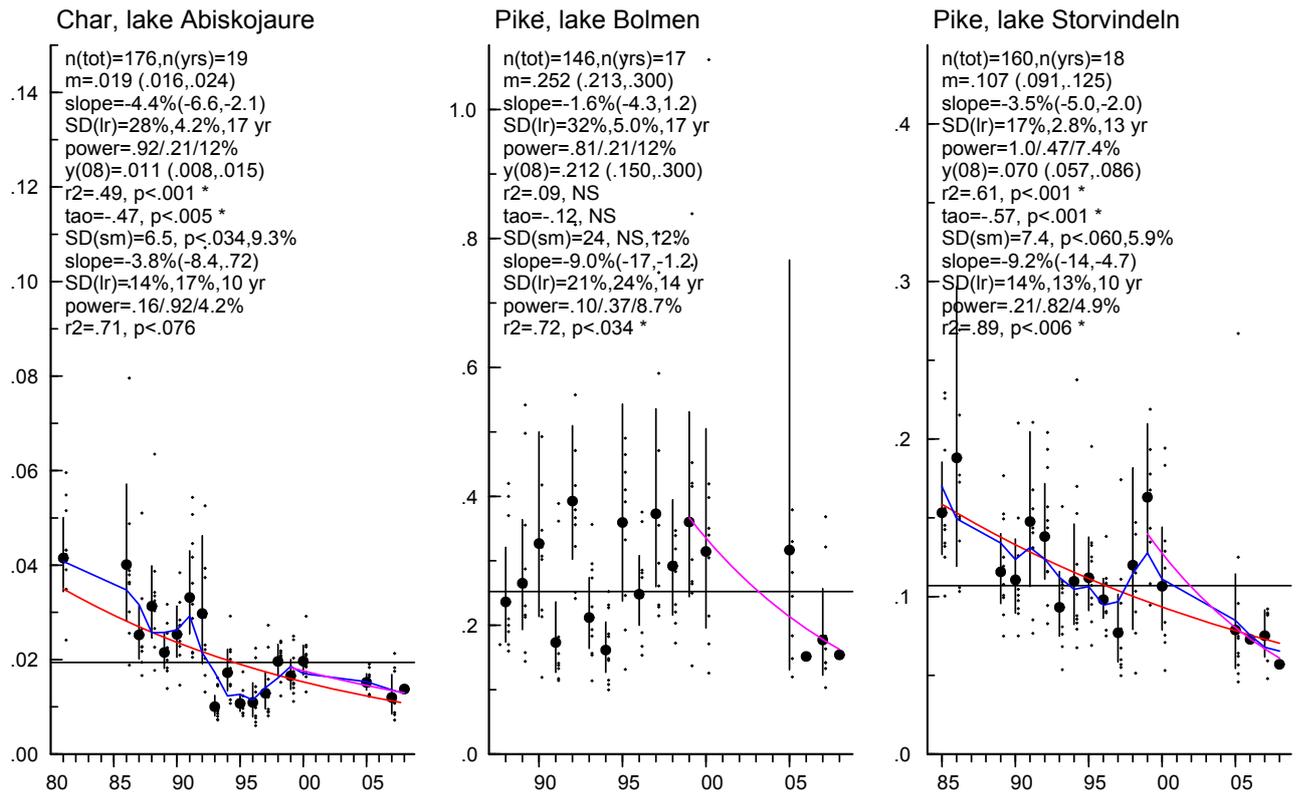


Figure 11.4 Comparison between the range of average analysed concentrations of CB-118 in fish muscle 2000-2008 and different threshold concentrations available in literature. All thresholds are expressed on lipid weight basis using the assumption of 1 % fat content.

Table 11.1 Class distribution of measured substances compared to threshold levels in percent of total

Substance	n	%	%	%	%	%
CB-118	32	34,4	37,5	15,6	6,3	6,3
CB- 153	32	-	25	40,6	18,8	15,6
CB-180	32	28,1	71,9	-	-	-

CB-153 ug/g lipid w.



pia - 10.05.25 13:52, PCB153

Figure 11.5 Temporal variation of CB-153 in Char and Pike from three lakes within the Swedish national monitoring programme.

12 PFAs, Perfluoroalkyl substances

Perfluoroalkyl substances (PFAs) are anthropogenic surfactants with exceptional stability and surface tension lowering potential. PFA's have been used industrially (e.g. production of fluoropolymers) and commercially (water and stain proofing agents and fire-fighting foams) since the beginning of the 1950s. It was not until recently (2000) that the main producer, 3M, started to phase out their production of the main compound of concern, perfluorooctane sulfonate (PFOS) and PFOS-related chemicals (Key et al., 1997 and Holmström et al., 2005).

Environmental PFA contamination has multiple emission sources. These include primary emissions of PFAs to air and water from industrial production and application as well as secondary emissions from consumer products or sewage treatment plant effluents.

Exponentially increasing concentrations of some PFAs in wildlife has been reported during the 1990s (Holmström et al., 2005). In biota, PFAs tend to accumulate in protein rich tissues such as blood, liver and eggs. Toxic effects in humans include weight loss, liver enlargement, immunotoxicity and a number of developmental effects such as postnatal mortality. Intake of contaminated fish from the Baltic Sea is a source of human exposure to PFAs (Berger et al., 2009). Production and use of PFOS is regulated in some countries (e.g. Canada and the EU), but large scale production continues in other parts of the world.

The different PFAs that are monitored in the freshwater programme are PFHxA, PFHpA, PFOA, PFNA, PFDcA, PFUnA, PFDoA, PFTriA, PFTeA, PFPeDA, PFBS, PFHxS, PFOS, PFDcS and PFOSA.

Due to their concentrations and/or temporal trends, PFOS, PFOA and PFNA are currently the PFAs of most concern for the Baltic Sea environment (HELCOM Commission in press). Based on their documented relevance for the marine environment, those mentioned above, PFTriA and PFOSA are the PFA's included in this report

12.1 Spatial variation

PFOS is the substance that can be found in the highest concentrations of the fifteen that are measured. PFOA was only found in concentrations exceeding the detection limit on two locations; lake Abiskojaure and Lake Stor-Björnsjön. In both these lakes the measurements were performed on arctic char. PFOSA was found in 3 lakes, PFNA in 30 and PFTriA in all lakes (Figures 12.1; 12.2; 12.3)

For PFOS, a pattern of increasing concentrations from north to south can be found. The only exception to this is Lake Degervattnet and Lake Brännträsket. The highest levels are found in the south and south-western parts of the country. The highest measured concentration was found in Lake Fysingen (168 ng/g ww) and the lowest in Lake Storvindeln (1.65 ng/g ww). For PFTriA the pattern is similar with higher concentrations in the southern parts of the country. No general pattern can be seen for the three other compounds presented here.

12.2 Comparison to thresholds

The threshold used in this assessment is 6 ng/g ww. This is used for all the PFAs shown in this report although it originally is intended for PFOS only. The variability in toxicity between the different compounds is not considered here. The result of this comparison is that for PFOA, PFOSA and PFNA, all the measured concentrations are below the threshold and many are under the detection limit (Table 12.1).

For PFOS the situation is different. A total of 66.7% percent of the measured concentrations exceed the threshold. In Lake Fysingen, which have the highest burden (168.1 ng/g ww), the limit is exceeded by a factor 28. It is yet unknown what possible effects this might have on the biota but measures to reduce this burden should be taken. For PFTriA the situation is similar but no exceptionally high concentrations were detected, the highest was Lake Fräcksjön with 17.4 ng/g ww.

12.3 Temporal variation

No time series or retrospective data are available regarding temporal variation for PFAs in the monitored lakes. For most of the lakes, retrospective analyses are possible.

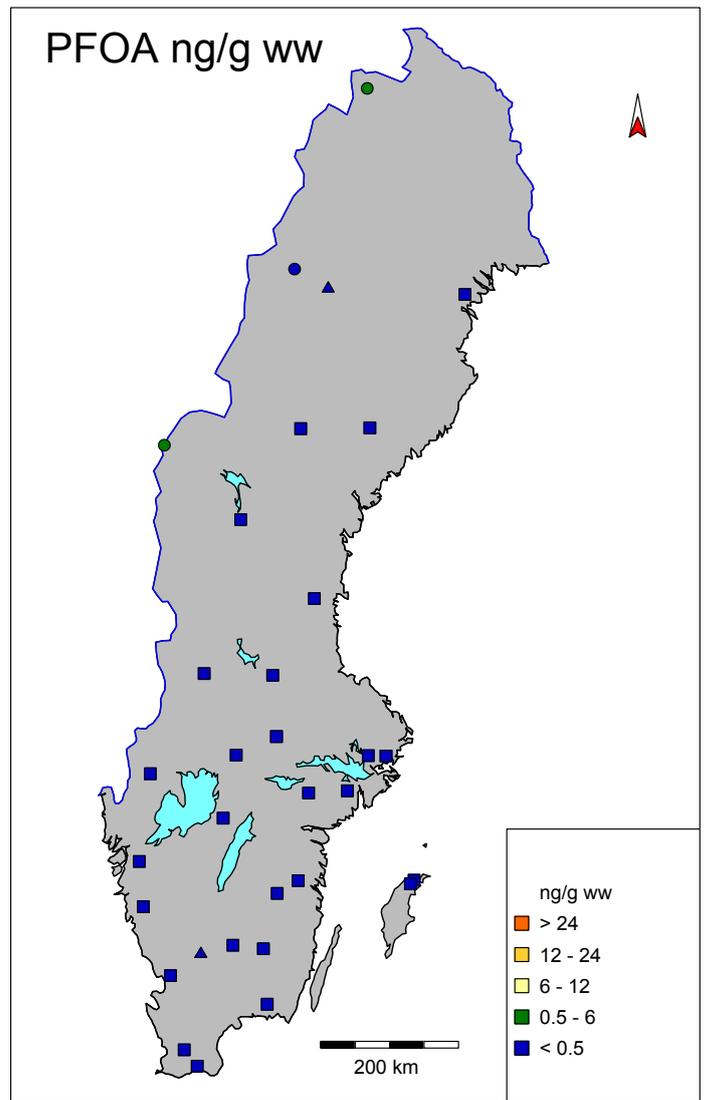
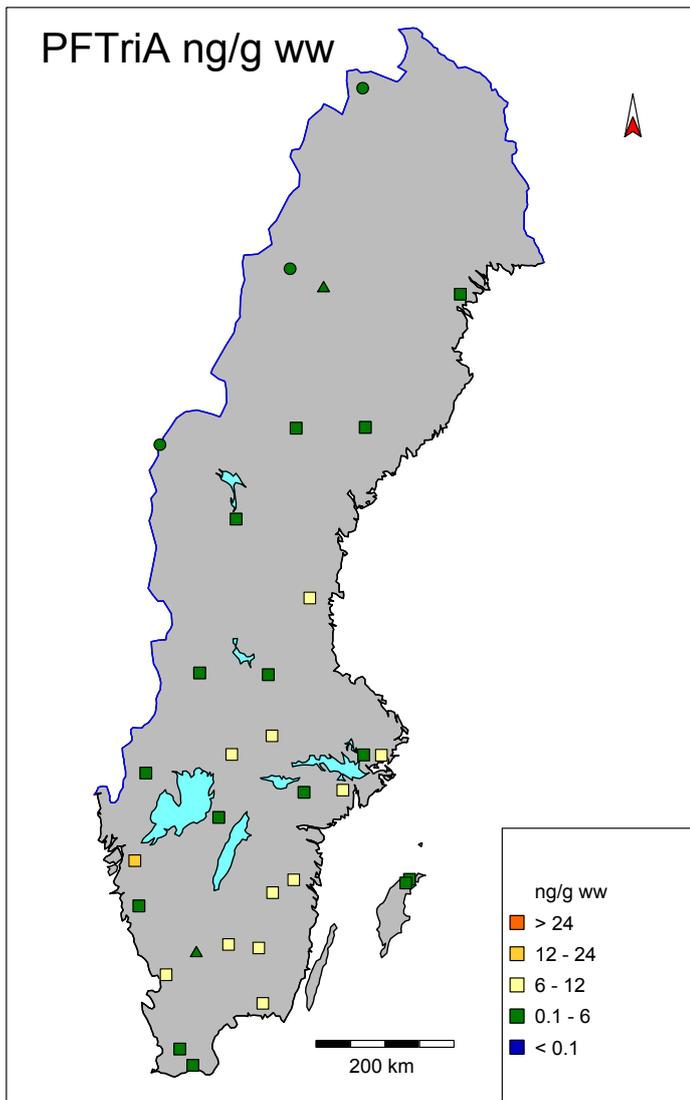


Figure 12.1. Spatial variation of PFTrIA and PFOA respectively. The squares represents the concentration interval of average measured concentrations in fish liver between 2007-2008 from lakes within the Swedish national monitoring programme. ■ = Perch ● = Char ▲ = Pike

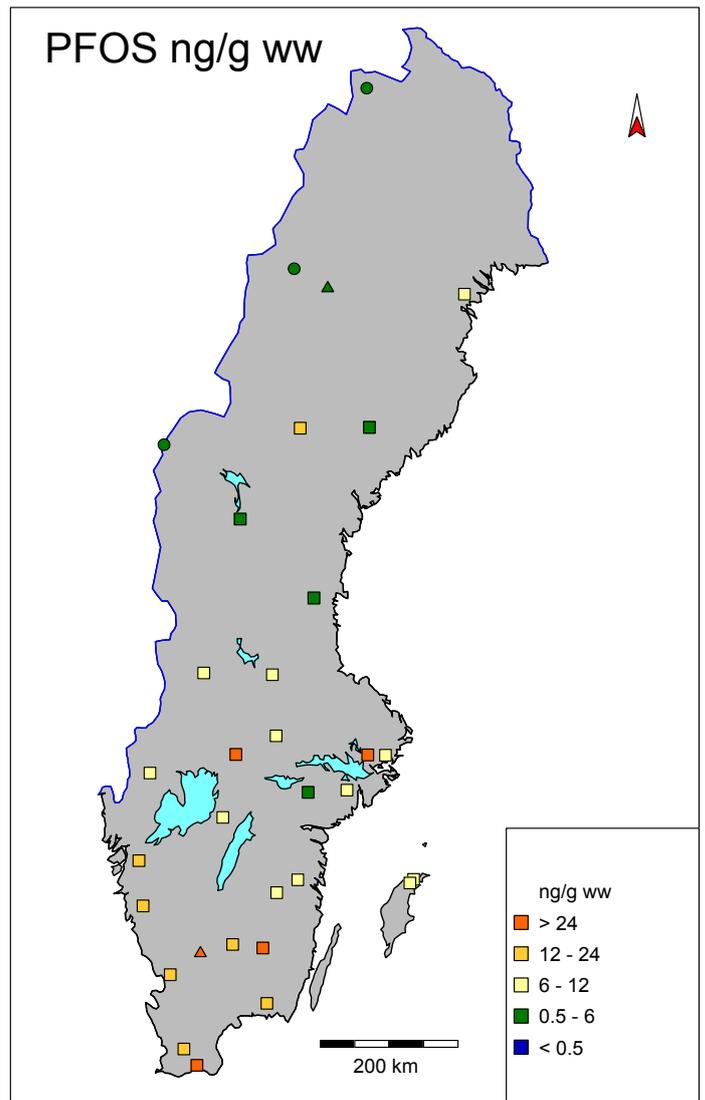
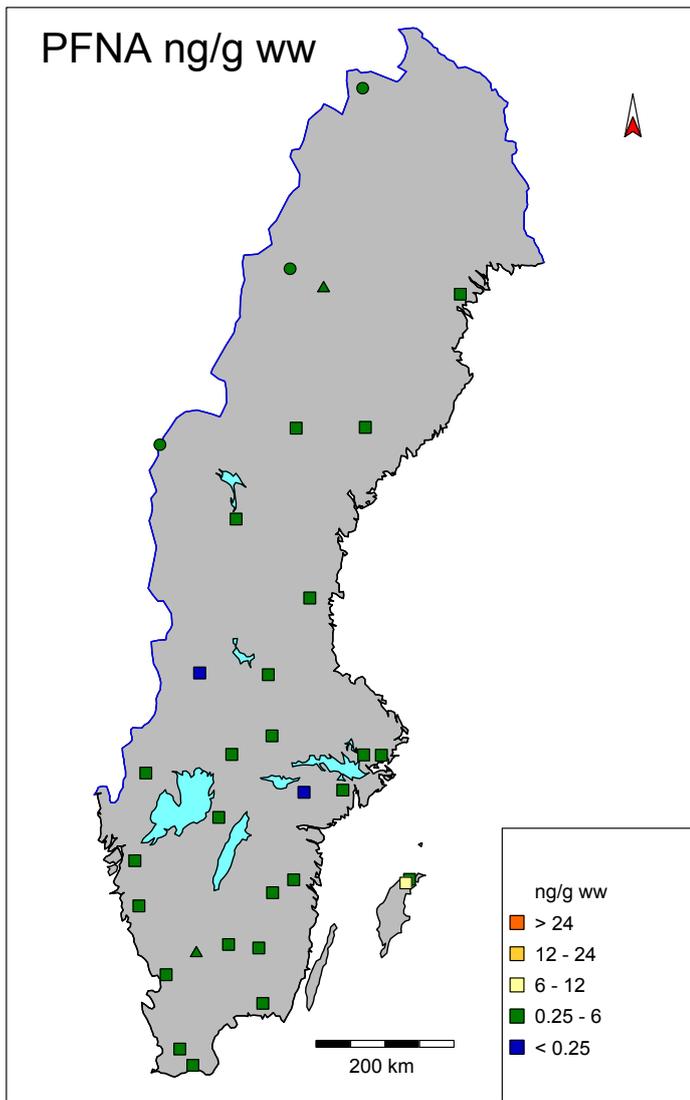


Figure 12.2. Spatial variation of PFNA and PFOS respectively. The squares represents the concentration interval of average measured concentrations in fish liver 2007-2008 from lakes within the Swedish national monitoring programme. ■ = Perch ● = Char ▲ = Pike

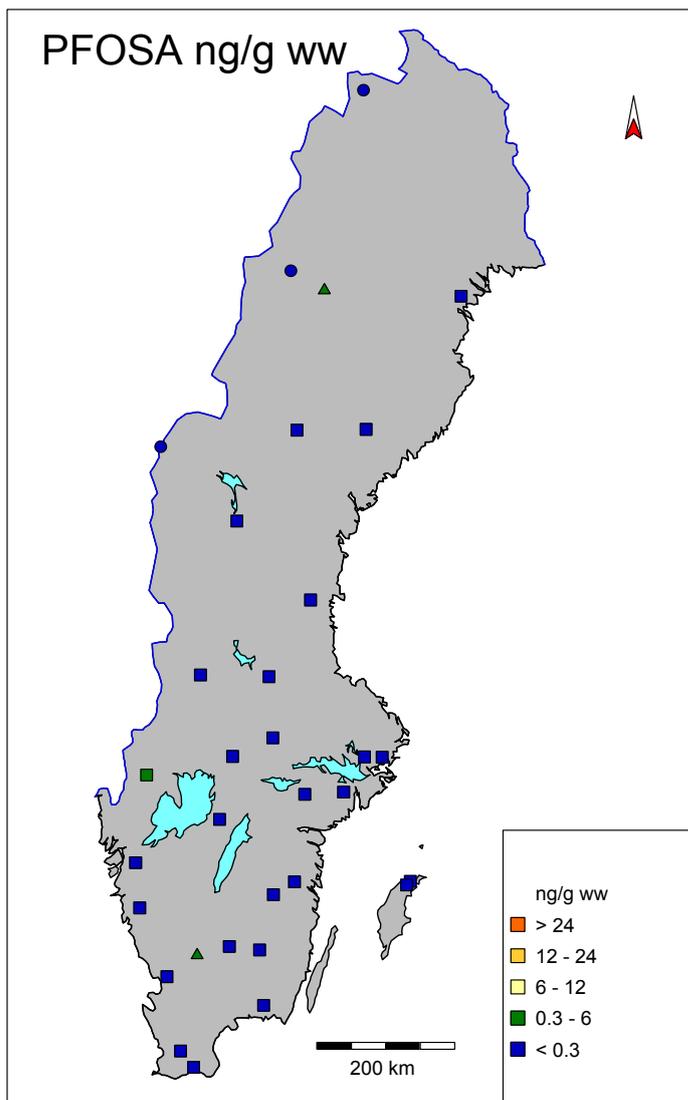


Figure 12.3. Spatial variation of PFOSA. The squares represent the concentration interval of average measured concentrations in fish liver 2007-2008 from lakes within the Swedish national monitoring programme.

■ = Perch ● = Char ▲ = Pike

Table 12.1. Class distribution of measured substances compared to threshold levels in percent of total

Substance	n	%	%	%	%	%
PFOA	32	93,7	6,3	-	-	-
PFNA	32	6,3	90,6	3,1	-	-
PFOS	32	-	25,0	37,5	21,9	15,6
PFOSA	32	90,6	9,4	-	-	-
PFTriA	32	-	62,5	34,4	3,1	-

13 PCDD/PCDF, Polychlorinated Dioxins and Dibenzofurans

Polychlorinated dibenzo-*p*-dioxins (PCDD) and dibenzofurans (PCDF) consist of 17 congeners considered to be of toxicological importance (210 congeners in total). PCDD/Fs are unintentionally created and are formed in several industrial processes and from most combustion processes (municipal waste incineration and small scale burning in poorly controlled conditions). The use of chlorine gas during pulp bleaching processes was formerly an important producer of PCDD/Fs.

Atmospheric deposition is the most important active source of PCDD/Fs to the Baltic Sea today (Sellström et al. 2009). The origin of the substances in air is, however, not fully known, although there are indications of strong impact of long-range atmospheric transport from south-western and southern Europe. It is also uncertain how historical emissions and secondary sources contribute and how PCDD/Fs are accumulated in the food chain.

The most relevant toxic effects of PCDD/Fs and DL-PCBs are developmental toxicity, carcinogenicity and immunotoxicity. The most relevant health effect seems to be developmental effects in children where exposure can take place both during pregnancy and during breast-feeding. As a positive effect of restrictions and prohibitions of PCDD are that levels are decreasing in mother's milk in Sweden (Norén and Meironyté 2000).

Releases of dioxins, from industrial installations are mainly regulated by the IPPC Directive and the Waste Incineration Directive. Dioxins are comprised by the objective of HELCOM's strategy for hazardous substances that is to continuously reduce discharges, emissions and losses of hazardous substances, with a goal of their eventual cessation by the year 2020. The ultimate aim is to achieve concentrations in the environment near background values for naturally occurring substances and close to zero for man-made synthetic substances. This objective was adopted in 1998 and dioxin has been selected as one of the priority substances for immediate action. The Stockholm Convention on Persistent Organic Pollutants (POPs) is an international agreement, requiring measures for reducing or preventing releases of dioxins to the environment.

A for dioxins and PCBs strategy including actions in the area of feed and food contamination and actions related to the environment including release reduction was adopted by the EU in 2001.

13.1 Spatial variation

There are no spatial variation patterns for the dioxins. This is mostly due to low concentrations at all measured locations (Fig 13.1; 13.2; 13.3). For TCDD, most of the lakes with concentrations under LOD are located in the north. The highest concentrations of TCDF (0.27 pg/g ww) was measured in lake Bolmen, TCDDEQ in Lake Sännen (0.20 pg/g ww), TCDD in Lake Allgjuttern (0.028 pg/g ww), CB-126 in Lake Fräcksjön (5.35 pg/g ww) and CB-77 in Lake Fysingen (13.11 pg/g ww). This investigation has only been done once, (2008) and therefore the variation is unknown.

13.2 Comparison to thresholds

Compared to the threshold of 1.25 pg/g ww for TCDDDEQ none of the measured concentrations exceed it (Table 13.1). The highest concentration that was measured in lake Sannen was 0.2 pg/g ww and hence a factor ~6 from threshold levels. The result is similar for the other congeners and the PCBs. Fish from these lakes seems to be safe to eat in a dioxin perspective.

13.3 Temporal variation

Levels of both TCDD, PCDF and TCDD-equivalents demonstrates significant decreasing trends in Lake Skärgölen during the time period 1980 - 2008 with a mean annual decrease of 2.4 – 2.7% (Fig 13.4). During the last ten year period, no changes in concentrations are detected. This time series is the only one available for dioxins and it is the result of a retrospective analysis that was performed 2008.

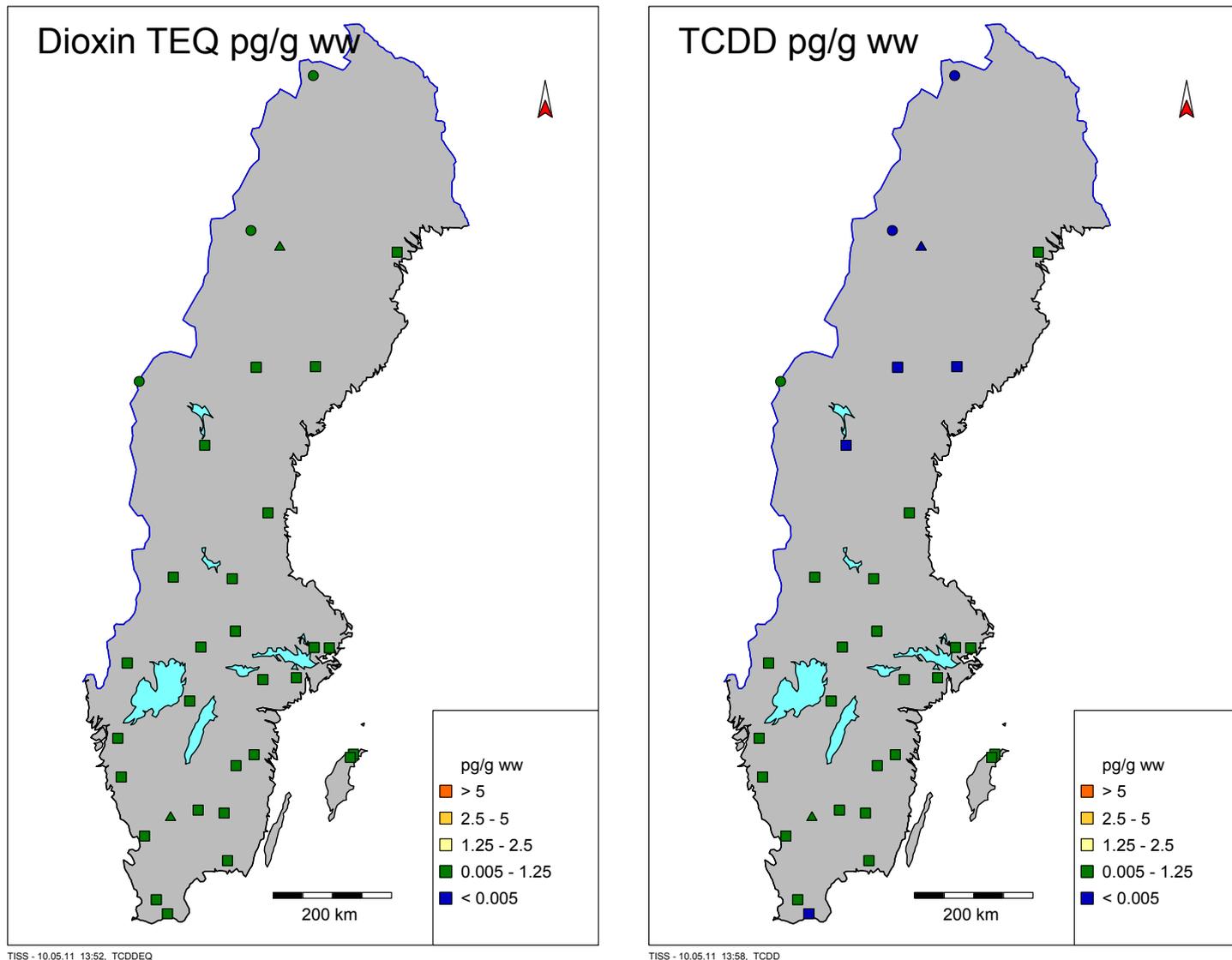


Fig 13.1. Spatial variation of TCDD equivalents and TCDD respectively. The squares represents the measured concentrations in fish muscle 2008 in lakes within the monitoring programme.

■ = Perch ● = Char ▲ = Pike

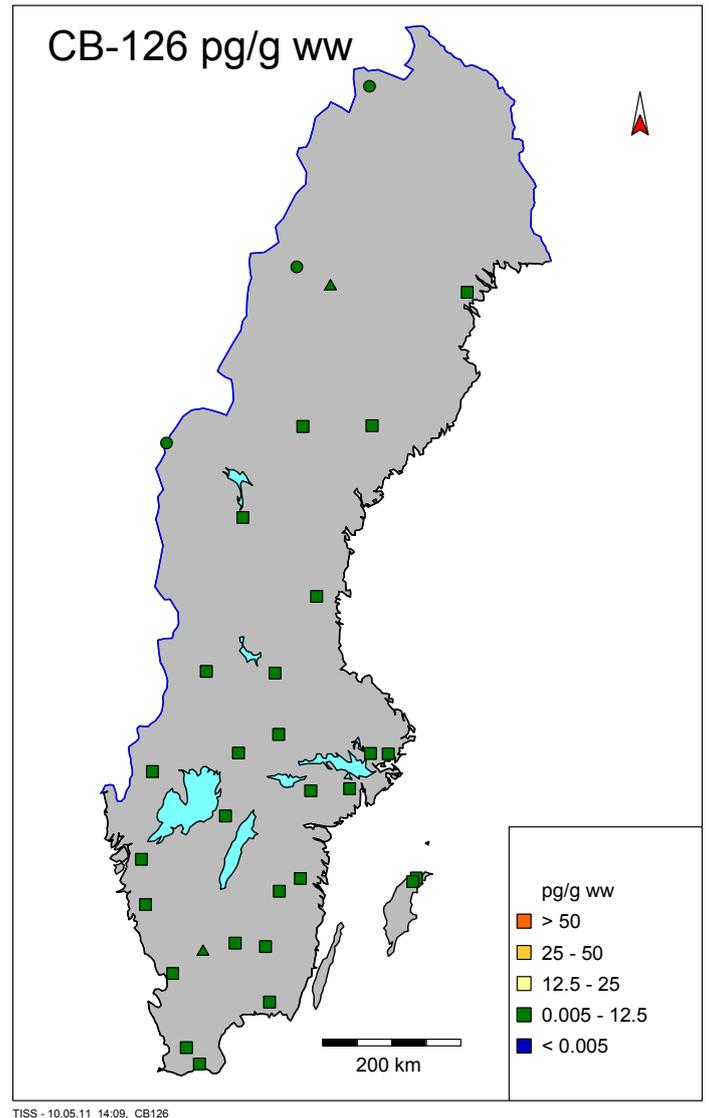
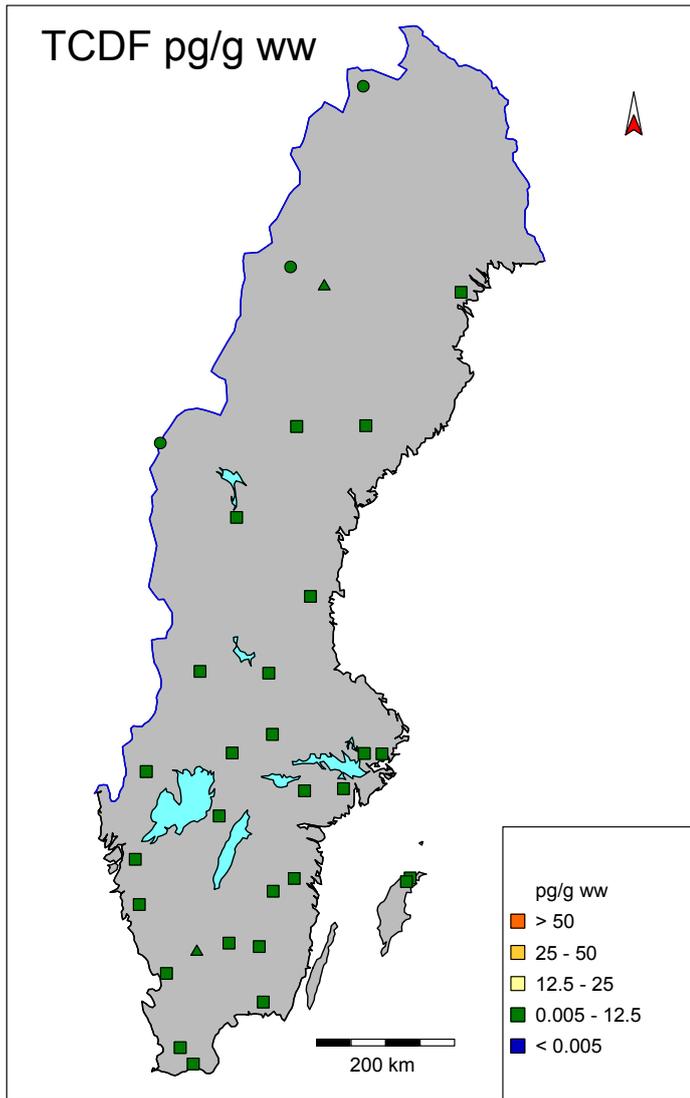
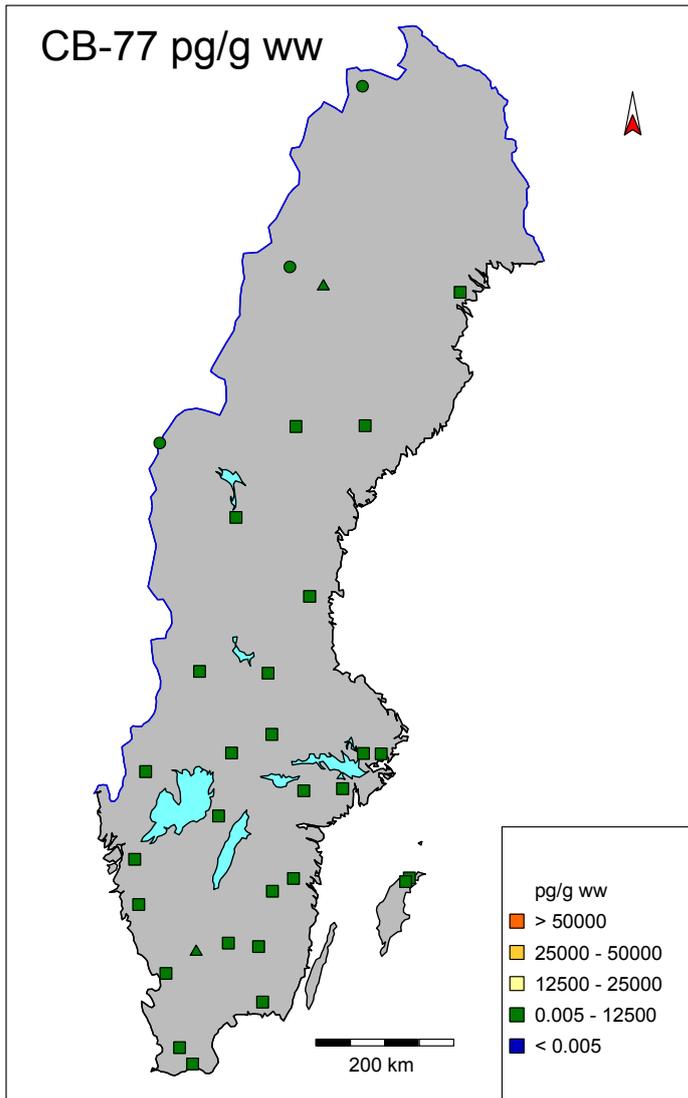


Fig 13.2. Spatial variation of TCDF and CB-126 respectively. The squares represent the measured concentrations in fish muscle 2008 in lakes within the monitoring programme.
 ■ = Perch ● = Char ▲ = Pike



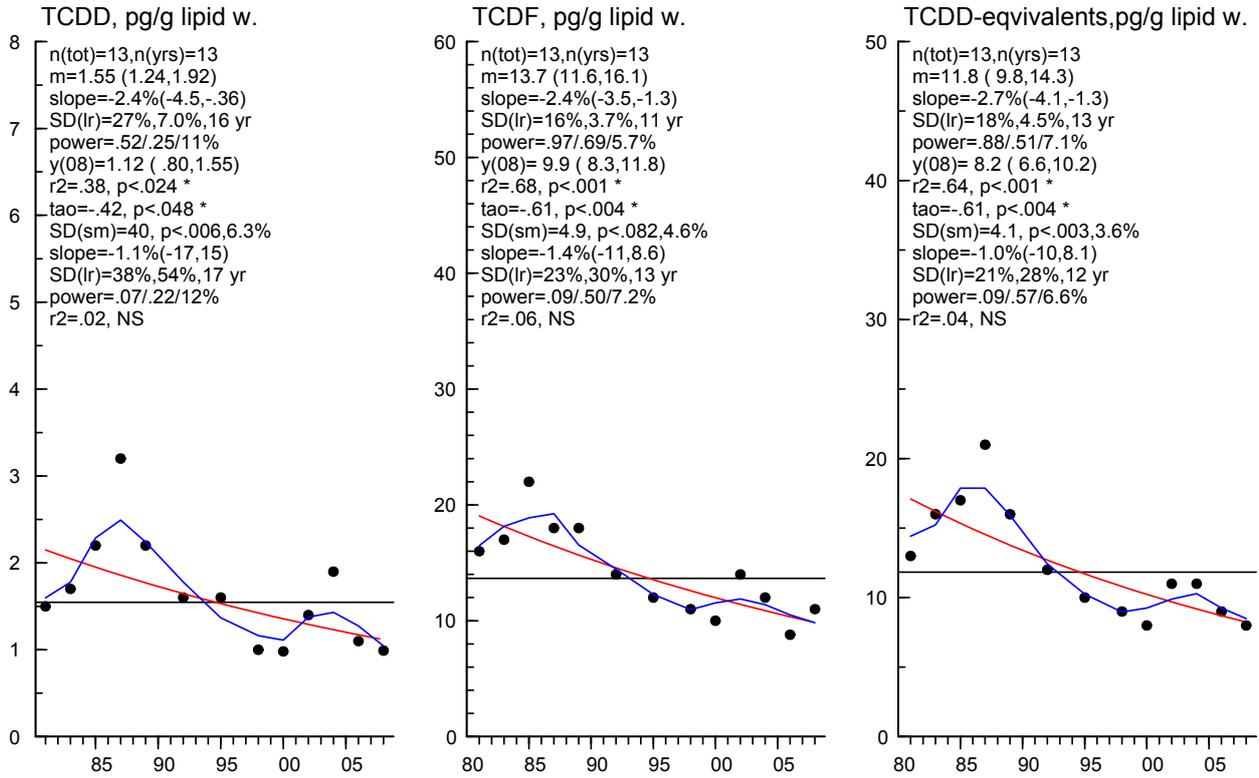
TISS - 10.05.11 14:12, CB77

Fig 13.3. Spatial variation of CB-77. The squares represent the measured concentrations in fish muscle 2008 in lakes within the monitoring programme. ■ = Perch ● = Char ▲ = Pike

Table 13.1. Class distribution of measured substances compared to threshold levels in percent of total

Substance	n	%	%	%	%	%
TCDD	32	21.9	78.1	-	-	-
TCDF	32	-	100	-	-	-
TCDEQ	32	-	100	-	-	-
CB-126	32	-	100	-	-	-
CB-77	32	-	100	-	-	-

PCDD/PCDF in perch, lake Skargölen



pia - 10.05.25 13:55, DIOXIN

Figure 13.4 Temporal variations of TCDD, TCDF and TCDD- equivalents in perch from Lake Skargölen 1980-2008

14 Polybrominated flame retardants

Polybrominated diphenyl ethers and HBCD are used as additive brominated flame retardants (BFR) in plastics, textile and electronics. PBDEs leak out to the environment during production, use, or disposal of such products. PBDEs are mainly spread diffuse distribution via atmosphere and rivers. HBCDD is bioaccumulative, lipophilic and persistent and accumulates in the food-web.

Several negative effects after PBDE exposure have been reported. In mammals, behaviour, learning (Eriksson et al. 2006) and effects on hormonal functions have been reported (Legler 2008). In birds, several aspects regarding reduced reproductive success has been documented (Fernie et al. 2009). Chemical products and goods containing concentrations over a certain level of these BDE's are banned in EU.

14.1 Spatial variation

No geographical trends for PBDE can be seen in the material (Fig 14.1). This is mainly due to the thresholds used. For HBCD, most lakes with concentrations above LOD are located in the southern part of the country. In many of these lakes, the concentrations are however very close to detection levels. For BDE-209, measurable concentrations seem to be most common in the middle parts of the country but no trends are visible (Fig 14.2).

14.2 Comparison to thresholds

For PBDE, the result shown here is an underestimation of the total concentration that the threshold is valid for due to the lack of data for BDE-28. This is however of less importance since the margin up to these levels is very large. The highest mean concentration that was measured was 0.95 ng/g ww in Lake Abiskojaure which is a factor 260 from the threshold. The situation is similar for HBCD but the margin is even larger. The highest concentration of HBCD (0.30 ng/g ww) was measured in Lake Svartsjön and hence the margin to threshold is 5000. No threshold is available for BDE-209, therefore the detection limit is used as threshold. In Lake Remmarsjön and Lake Skärgölen the highest levels were measured and the concentrations there exceed 100 pg/g ww. Table 14.1 show the distribution of classes per substance.

14.3 Temporal variation

Concentrations of BDE-47, BDE-153 and BDE-154 demonstrate increasing trends over the last 40 years, but with a shorter time perspective, trends are decreasing (Fig 14.3). For time series from the late 1960's and onwards, BDE-47, BDE-153, BDE-154, concentrations are increasing with an annual mean of 4-7.6%. However, during the last decade all concentrations have decreased rapidly with a mean annual change of 8.5-13%.

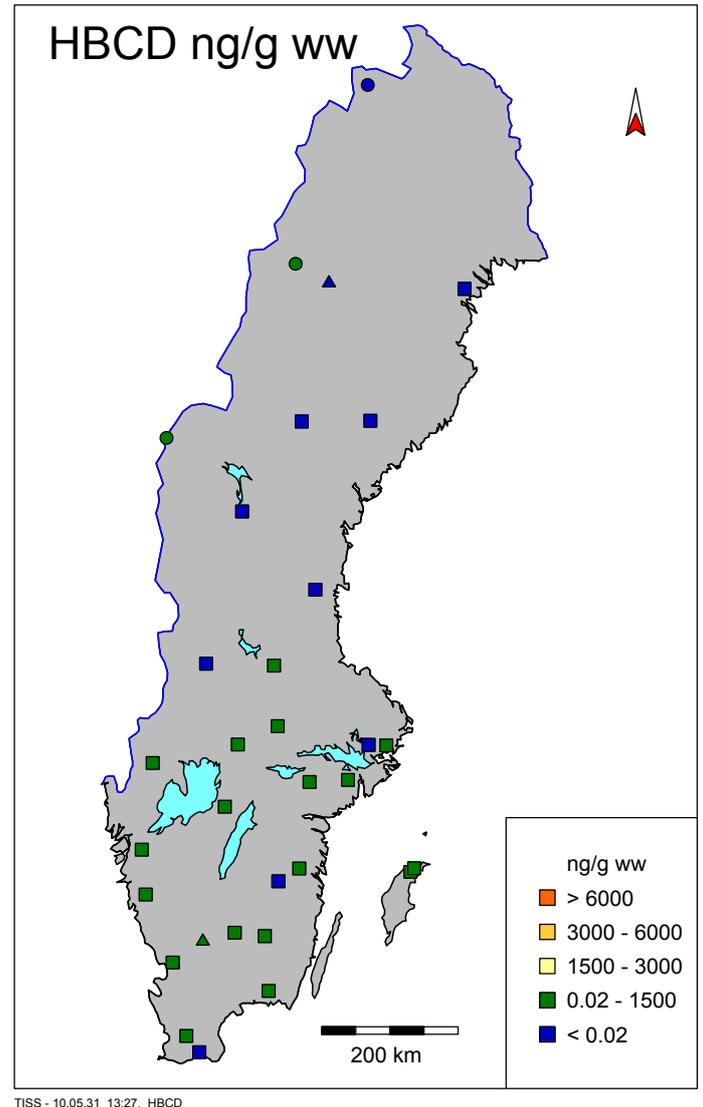
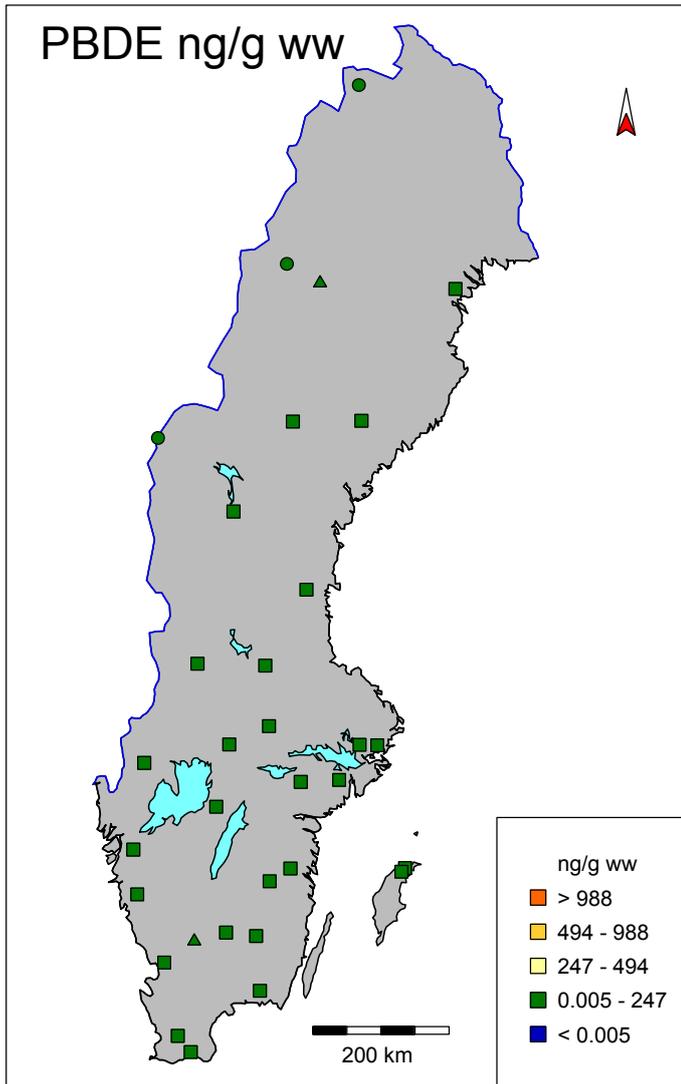


Fig 14.1. Spatial variation of PBDE (sum of BDE-47, 99, 100, 153, 154) and HBCD respectively. The squares represent the average measured concentrations in fish muscle 2001 – 2008 (2005-2008 for HBCD) in lakes within the monitoring programme. ■ = Perch ● = Char ▲ = Pike

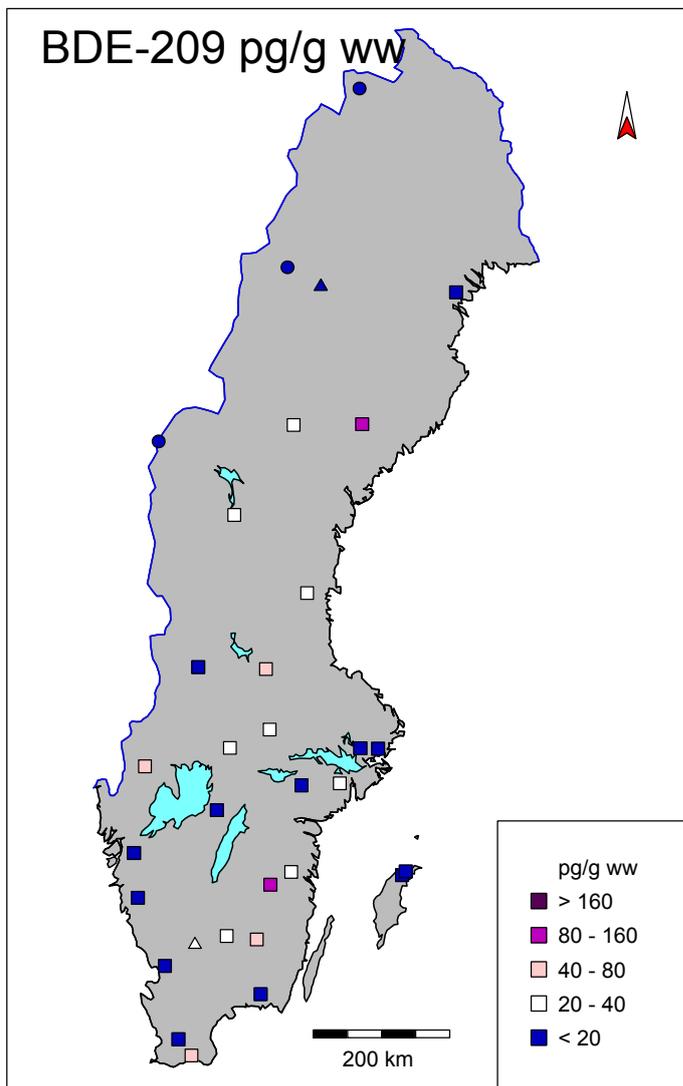
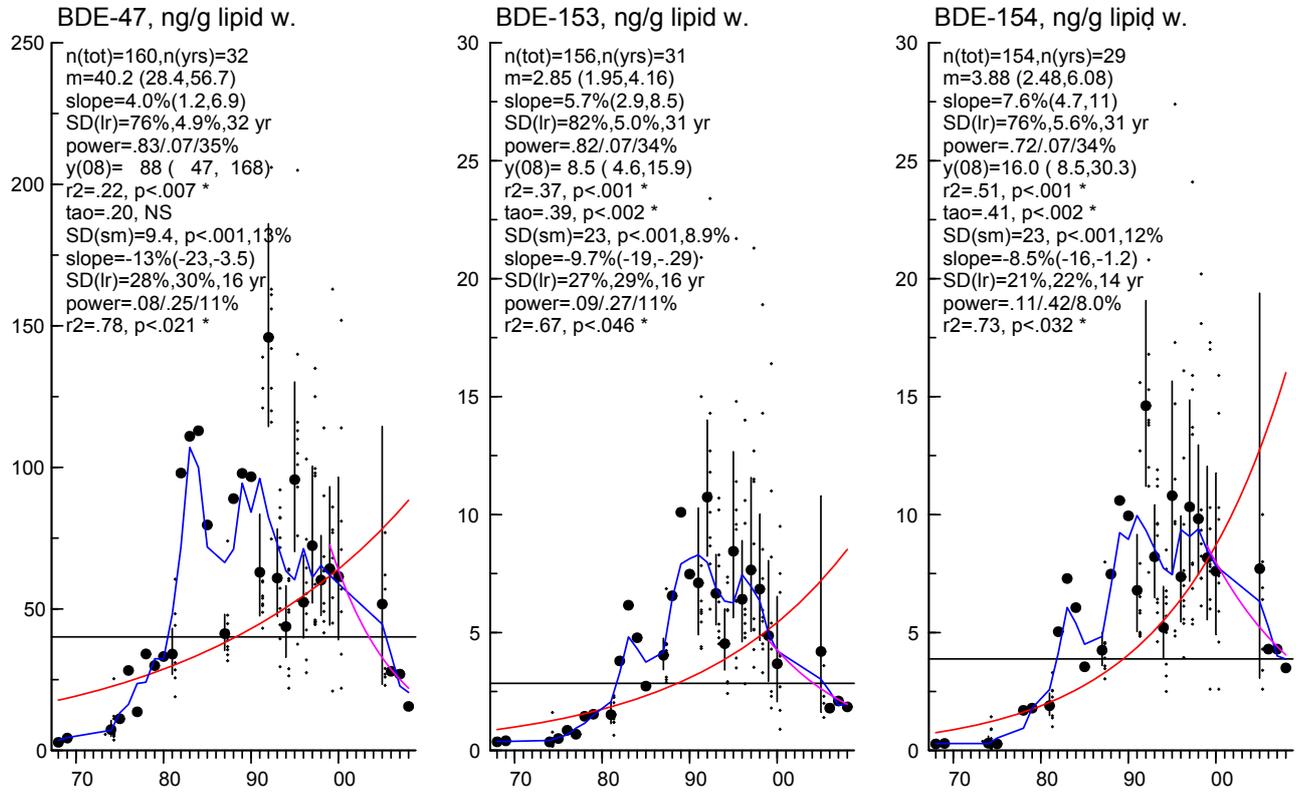


Fig 14.2. Spatial variation of BDE-209. The squares represent the average measured concentrations in fish muscle 2005 – 2008 in lakes within the monitoring programme.
 ■ = Perch ● = Char ▲ = Pike

Table 14.1. Class distribution of measured substances compared to threshold levels in percent of total

Substance	n	%	%	%	%	%
PBDE	32	-	100	-	-	-
HBCD	32	34.4	65.6	-	-	-
Substance	n	%	%	%	%	%
BDE-209	32	53.1	28.1	12.5	6.3	-

Brominated contaminants in pike, lake Bolmen



pia - 10.05.25 13:56, BFR

Figure 14.3 Temporal variations of BDE-47, BDE-153 and BDE-154 in Lake Bolmen

15 Pesticides (DDE; DDD; DDT; HCHs; HCB)

DDT is a persistent synthetic pesticide that primarily degrades to DDE and DDD. It is still used in some countries as an effective pesticide against mosquitoes and hence malaria. The presence of DDT and its metabolites in the Arctic area indicates long range transport (Welch et al. 1991). DDT has severe health effects on wildlife. In fish eating birds, reduced reproductive success is widely documented. This is due to several factors such as failure to return to nesting sites, egg shell thinning, ability of eggs to hatch, reduced number of reproducing pairs and nestling brood size (Hamlin et al. 2010, Helander et al. 2008). Also, embryo mortality, thyroid malfunction, and immunosuppression have been documented (Hamlin et al. 2010).

In western European countries the use of DDT ceased around 1990, although heavy use was banned between 1970 and 1975 in most countries bordering the Baltic Sea. Exposure to DDT cause severe health effects in wildlife such as reduced productivity in top predator white-tailed sea eagle (Helander *et al.* 2008)

HCB has been used for agricultural purpose and as a wood preservation agent. The main source of HCB to surface waters in EU is through leakage from industry where HCB occurs as unintentional by-product. Leakage from contaminated land may also be significant source in some areas. Production of HCB is globally banned by the Stockholm Convention since 2004.

15.1 Spatial variation

No pattern in spatial variation is visible for Lindane, HCB or DDT (Fig 15.1; 15.2) and the concentrations are generally low throughout the country. For DDE the concentrations are higher in the southern and middle parts of the country and the substance is detectable in all lakes (Fig 15.2). The pattern for DDD is similar to that of DDE but with fewer lakes in the highest class and some in which the concentrations are below LOD (Fig 15.3).

15.2 Comparison to thresholds

The thresholds for Lindane and HCB are not exceeded in any of the sampled lakes. The highest concentration of HCB was found in Lake Abiskojaure (0.27 ng/g ww) which is a factor 37 from the threshold level. In many of the lakes the concentrations are very close to or below the detection level.

The concentrations of Lindane are below detection in all lakes. If the LOD is changed slightly to 0.04 ng/g instead of 0.09 ng/g, all locations but one turn green. The detection limit has varied over the years and has sometimes been lower than 0.09 ng/g but it would be misleading to display the concentrations as green where the original result was under LOD.

For the DDTs, the maps are based on comparison to the 5th percentiles (FP) of all measurements. In most of the lakes, the concentrations of DDT are below the FP. The highest concentration was found in Lake Storvindeln (19 ng/g lw).

For both DDE and DDD most concentrations are higher than FP. The highest concentration of DDE was measured in Lake Bolmen (506 ng/g lw) and for DDD in Lake Fågslasjön (49 ng/g lw). Table 15.1 show the distribution of classes per substance.

15.3 Temporal variation

In Lake Abiskojaure and Lake Storvindeln, trends of HCB are decreasing significantly during 1978/81-2008, whereas no such trend is detectible in Lake Bolmen.(figure 15.5) However, during the last decade trends are decreasing significantly in all three lakes with an average of 4 -7.5% annually. This period only includes data from five years though (2001-2004 are missing).

Concentrations of Lindane show decreasing trends in Lake Abiskojaure and Lake Bolmen with an annual rate of 17% and 6.1% respectively (Figure 15.4) Since 1998 no concentrations are above the detection limit.

Concentrations of DDT, DDD, and DDE in char from Lake Abiskojaure and in pike from Lake Bolmen and Lake Storvindeln show similar patterns (Fig 15.6; 15.7; 15.8). The pesticide has decreased significantly during the period 1967/68/81-2008 with an annual change of between 4.9-8.4% in Lake Abiskojaure, 7-12 % in Lake Bolmen and 8.4-12% in Lake Storvindeln. During the last ten year period, the decreasing trends seem to have stagnated and concentrations stabilized

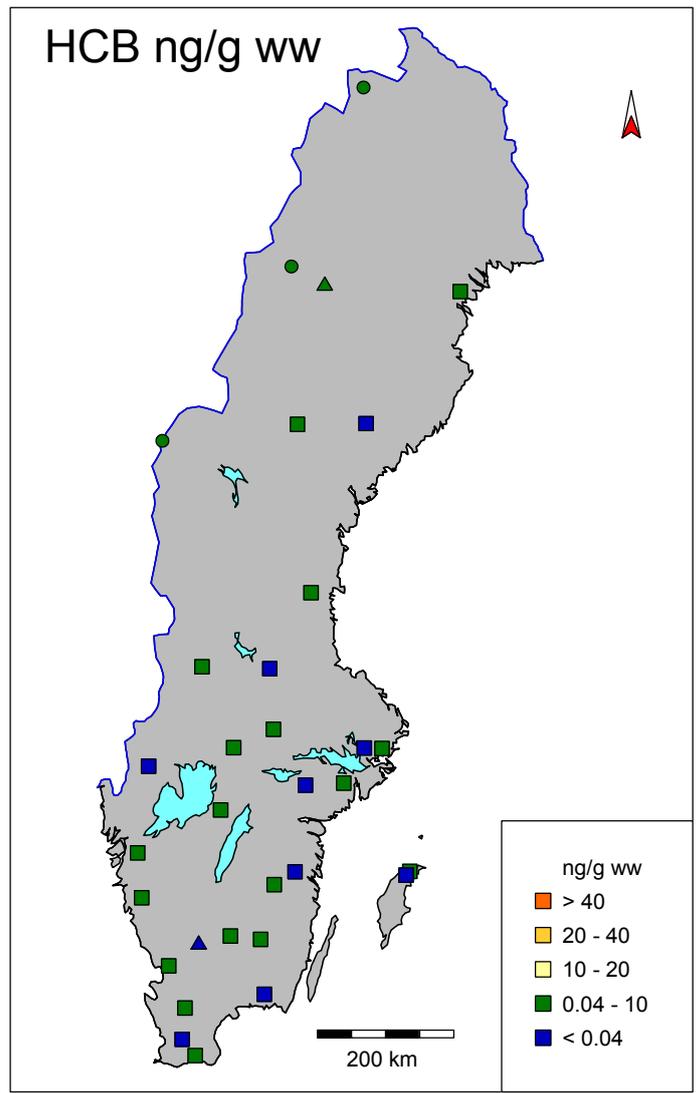
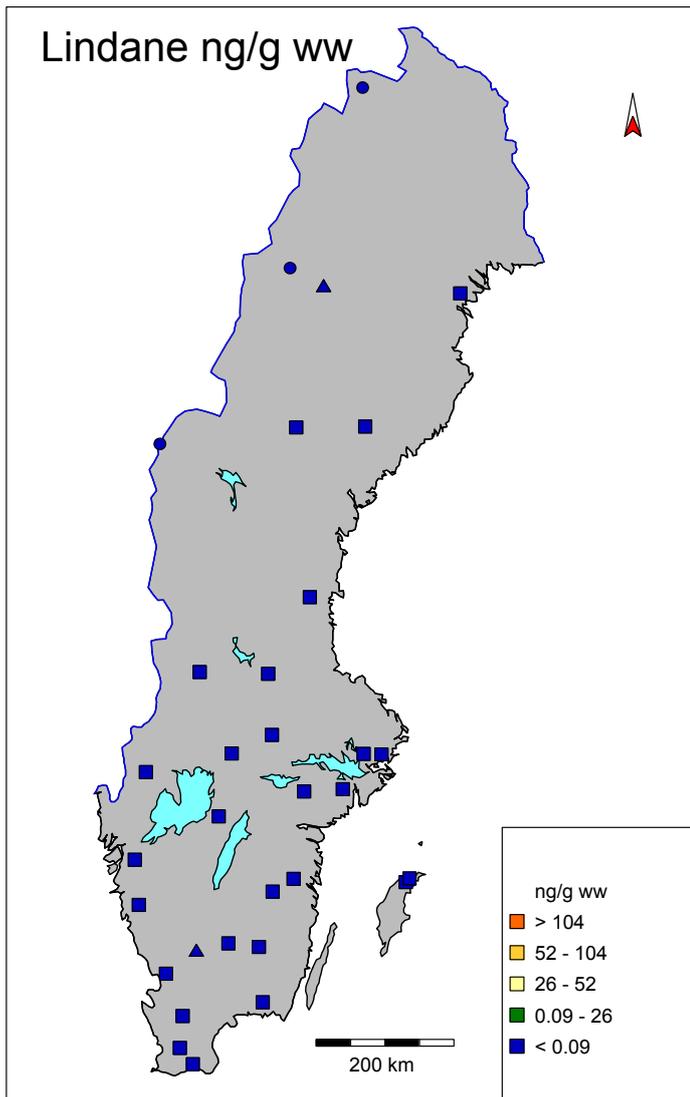


Figure 15.1. Spatial variation of Lindane and HCB respectively. The squares represents the concentration interval of average measured concentrations in fish muscle between 2000-2008 from lakes within the Swedish national monitoring programme. ■ = Perch ● = Char ▲ = Pike

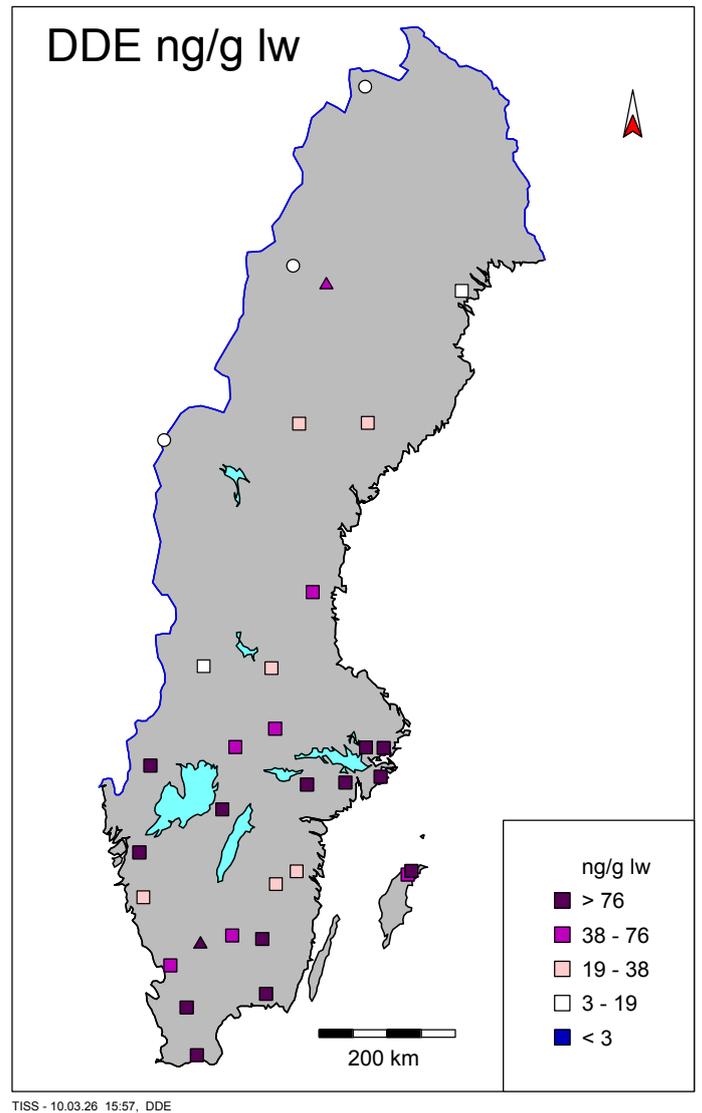
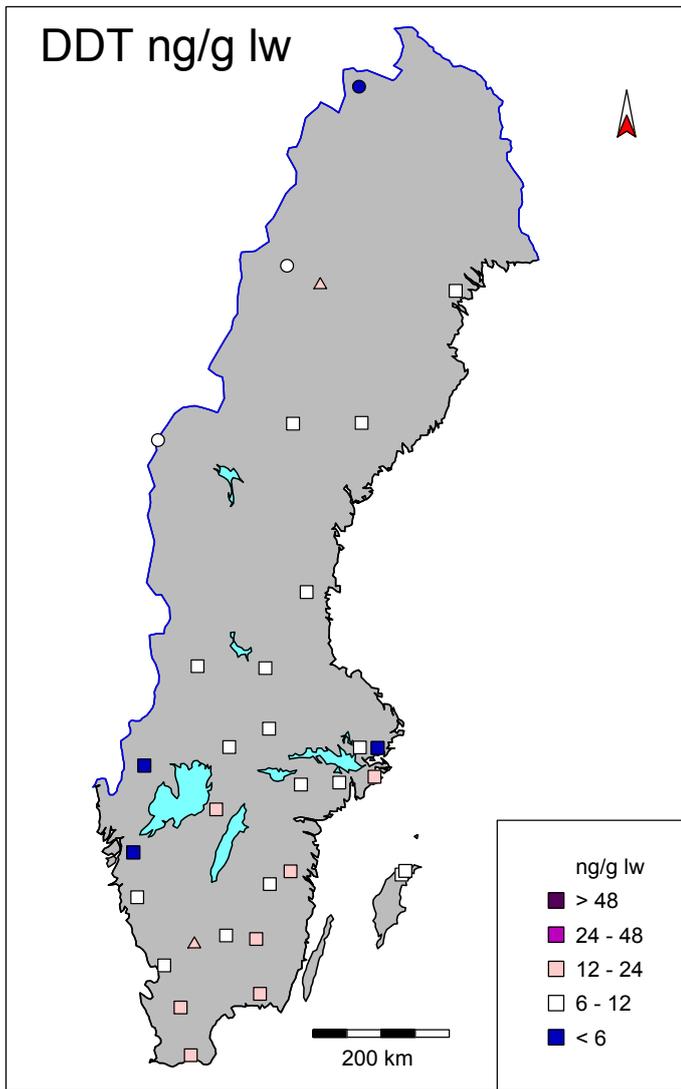
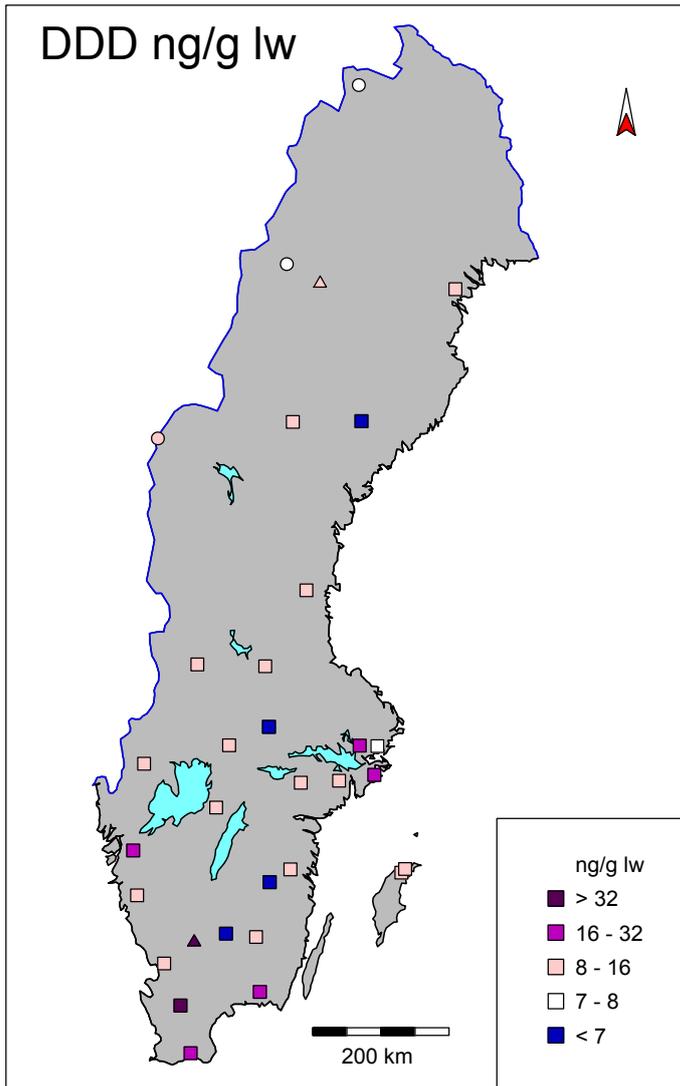


Figure 15.2. Spatial variation of DDT and DDE respectively. The squares represents the concentration interval of average measured concentrations in fish muscle between 2000-2008 from lakes within the Swedish national monitoring programme. ■ = Perch ● = Char ▲ = Pike



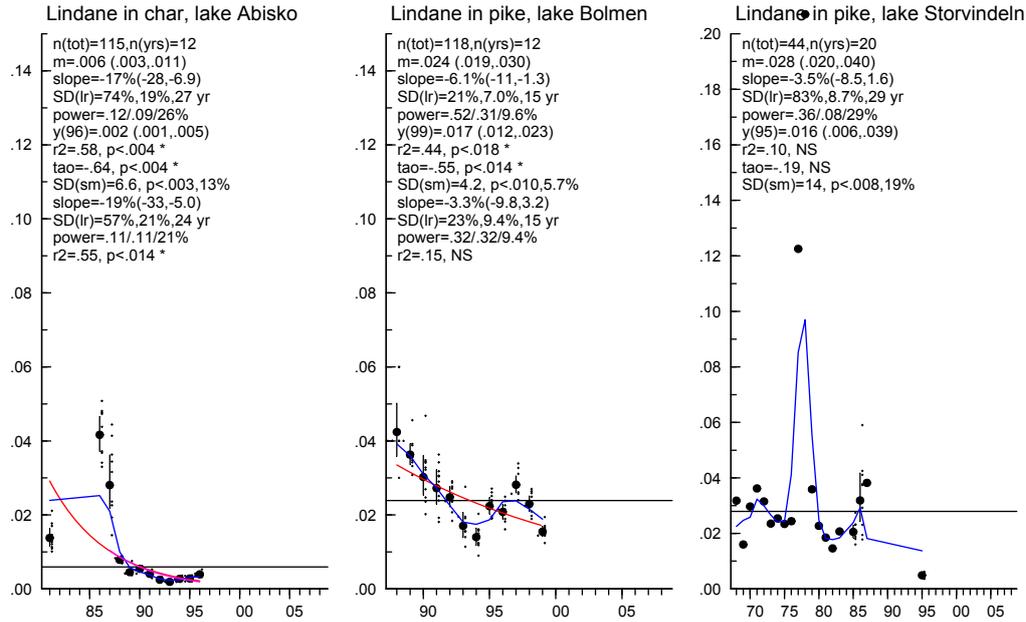
TISS - 10.03.26 16:06, DDD

Figure 15.3. Spatial variation of DDD. The squares represents the concentration interval of average measured concentrations in fish muscle between 2000-2008 from lakes within the Swedish national monitoring programme. ■ = Perch ● = Char ▲ = Pike

Table 15.1. Class distribution of measured substances compared to threshold levels in percent of total

Substance	n	%	%	%	%	%
HCB	32	31.3	68.7	-	-	-
Lindane	32	100	-	-	-	-
Substance	n	%	%	%	%	%
DDT	32	12.5	59.4	28.1	-	-
DDE	32	-	15.6	18.8	21.9	43.8
DDD	32	12.5	9.4	56.3	15.6	6.3

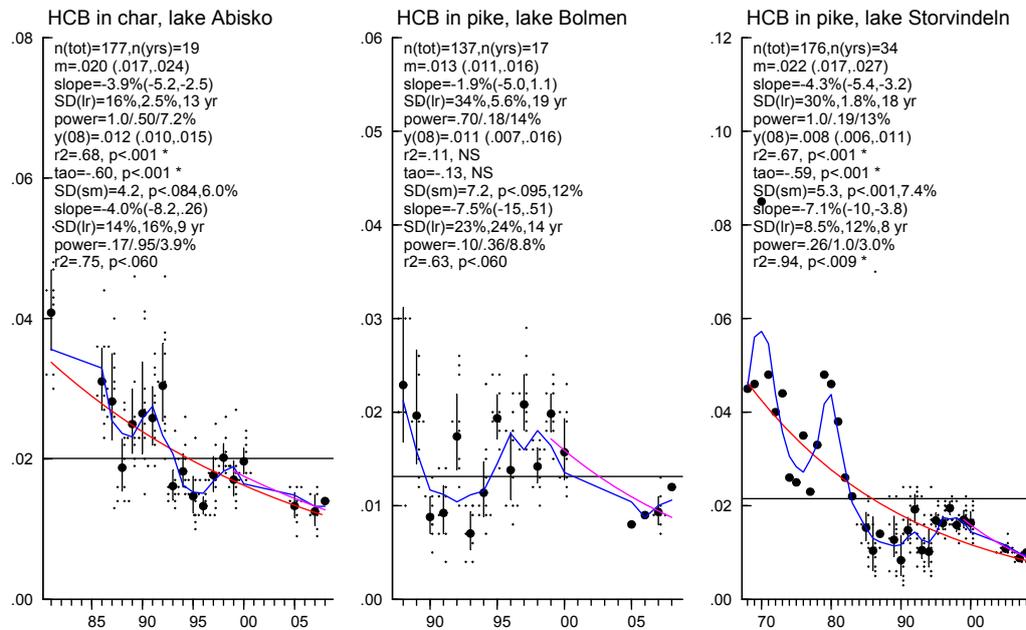
Lindane ug/g lipid w.



pia - 10.05.25 14:11, Lindane

Figure 15.4 Temporal variation of Lindane in Char and Pike from lakes within the Swedish national monitoring programme.

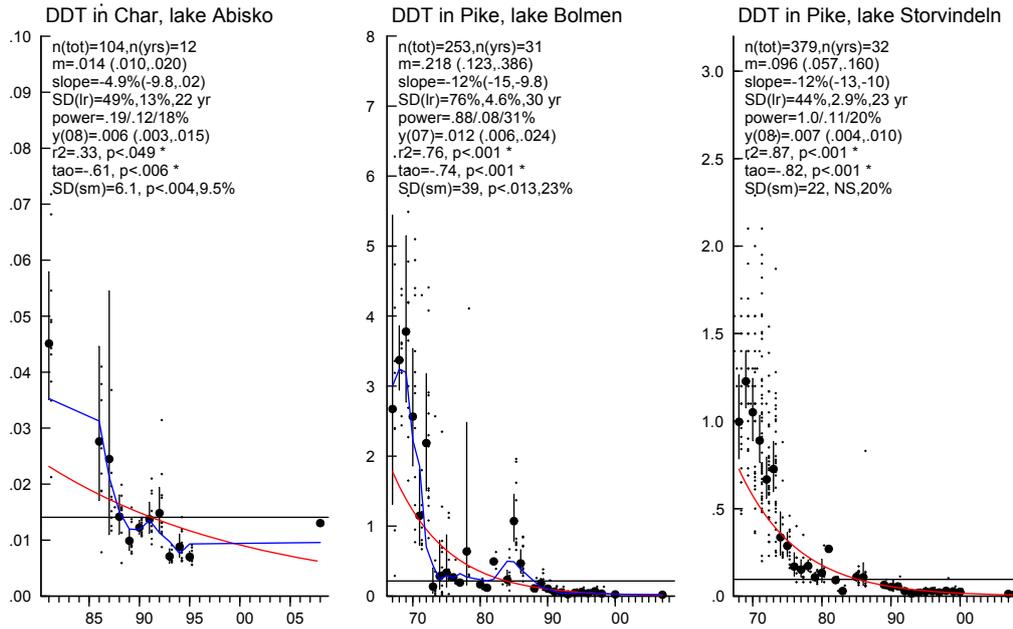
HCB ug/g lipid w.



pia - 10.05.25 14:10, HCB

Figure 15.5 Temporal variation of HCB in Char and Pike from lakes within the Swedish national monitoring programme

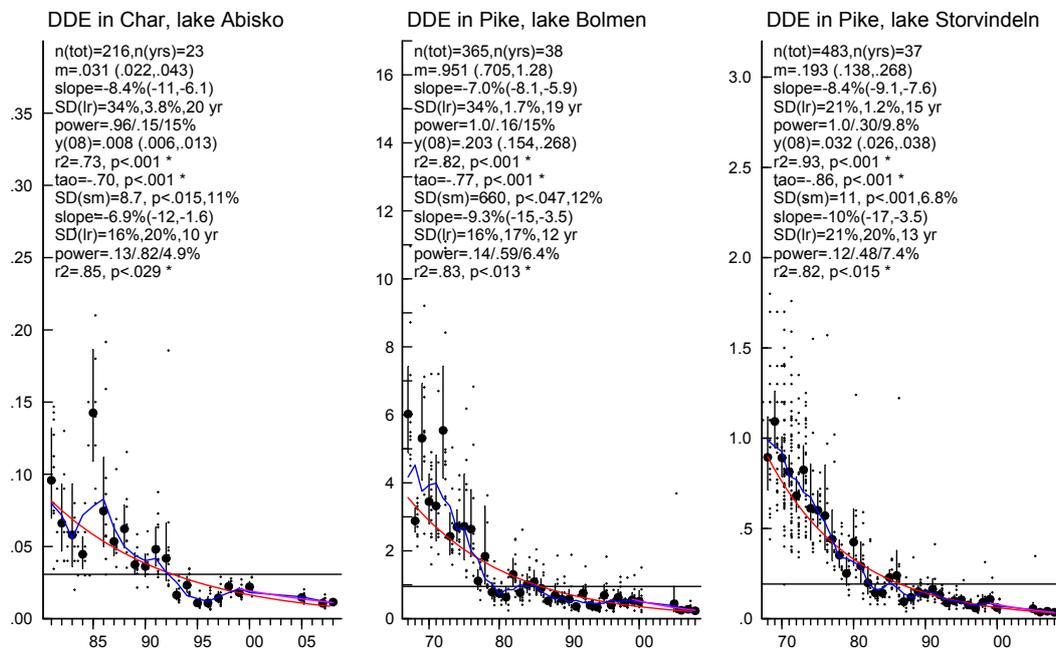
DDT ug/g lipid w.



pia - 10.05.25 14:22, DDT

15.6 Temporal variation of DDT in Char and Pike from lakes within the Swedish national monitoring programme

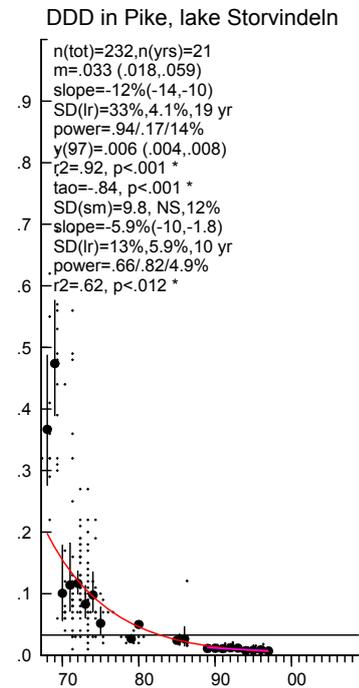
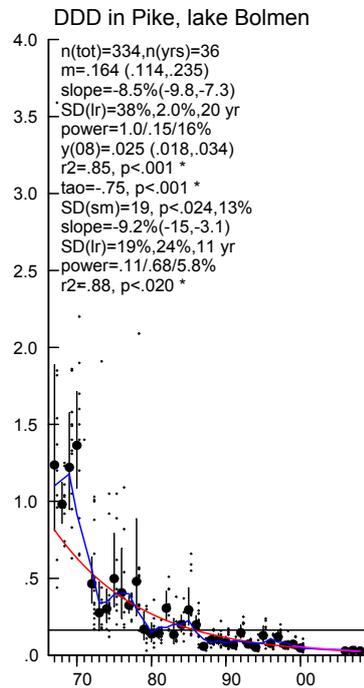
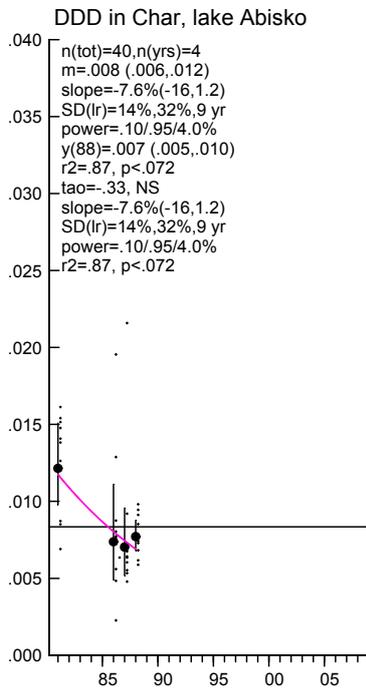
DDE ug/g lipid w.



pia - 10.05.25 14:13, DDE

15.7 Temporal variation of DDE in Char and Pike from lakes within the Swedish national monitoring programme

DDD ug/g lipid w.



pia - 10.05.26 11:22, DDD

15.8 Temporal variation of DDD in in Char and Pike from lakes within the Swedish national monitoring programme.

16 References

- Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological profile for polychlorinated biphenyls. Atlanta: US Department of Health and Human Services. 1-758
- Aulerich, R. J., and Ringer, R. K. 1977. Current status of PCB toxicity to mink, and effect on their reproduction. *Arch. Environm. Contam. Toxicol.* 6: 279-292.
- Berger, U., Glynn, A., Holmström, K. E., Berglund, M., Halldin Ankarberg, E., and Törnkvist, A. 2009. Fish consumption as a source of human exposure to perflourinated alkyl substances in Sweden – Analysis of edible fish from Lake Vättern and the Baltic Sea. *Chemosphere.* 76(6): 799-804.
- Bignert, A., Danielsson, S., Nyberg, E., Asplund, L., Eriksson, U., Berger, U. & Haglund, P. 2010. Comments Concerning the National Swedish Contaminant Monitoring Programme in Marine Biota, 2010. Report to the Swedish Environmental Protection Agency. Report nr 1:2010 154 pp
- Bleavins, M. R., Aulerich, R.J., and Ringer, R.K. 1980. Polychlorinated biphenyls (Aroclors 1016 and 1242): Effects on survival and reproduction in mink and ferrets. *Arch. Environm. Contam. Toxicol.* 10: 1432-0703.
- Carpenter, D.O., 1998. Polychlorinated biphenyls and human health. *Int J Occup Med Environ Health.* 11, 291-303.
- Carpenter, D.O., 2006. Polychlorinated Biphenyls (PCBs): Routes of Exposure and Effects on Human Health. *Rev Environ Health.* 21(1), 1-23.
- CIRCAs website 2010-05-11 Substance data sheet, priority substance No. 16 Hexachlorobenzene http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/i-priority_substances/supporting_background/substance_sheets/hxchlbenzene_eqsdatashee/EN_1.0_&a=d
- Danielsson C., Wiberg K., Korytar P., Bergek S., Brinkman U.A., Haglund P. 2005. Trace analysis of polychlorinated dibenzo-p-dioxins, dibenzofurans and WHO polychlorinated biphenyls in food using comprehensive two-dimensional gas chromatography with electron-capture detection. *Journal of Chromatography A*, 2005, Vol. 1086: 61-70.
- Eriksson, P., Fischer, C., and Fredriksson, A. 2006. Polybrominated diphenyl ethers, a group of brominated flame retardants, can interact with polychlorinated biphenyls in enhancing developmental neurobehavioural defects. *Toxi. Sci.* 94(2): 302-309.
- Eriksson U., Johansson A., Litzén K., Häggberg L., Winberg A., Zakrisson S. 1994. Analysmetod för bestämning av klorerade organiska miljögifter i biologiskt material. ITM rapport 18
- EU 2006. Directive 2006/12/EG of the European parliament and of the council of 3 February 2006
- Fernie, K. J., Shutt, J. L., Letcher, R. J., Ritchie, I. J, and Bird, D. M. 2009. Environmentally relevant concentrations of DE-71 and HBCD alter eggshell thickness and reproductive success of American kestrels. *Environ. Sci. Technol.* 43:2124-2130.
- Gilbert R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold, New York.
- Hamlin, H. J. and Guillette Jr, L. J. 2010. Wildlife as sentinels of environmental impacts on reproductive health and fertility. In :Woodruff, T. J., Janssen, S., Guillette L. J. (Eds), *Environmental impacts on reproductive health and fertility.* Cambridge University Press, New York, pp 103-110.

- Helander, B., Bignert, A., Asplund, L. 2008. Using raptors as environmental sentinels: monitoring the White-tailed sea eagle *Haliaeetus albicilla* in Sweden. *AMBIO*. 37(6): 425-431.
- HELCOM Commission. Hazardous substances in the Baltic Sea. An intergrated thematic assessment of hazardous substances in the Baltic Sea. In press.
- Helsel, D.R. & R.M. Hirsch. 1995. *Statistical Methods in Water Resources*, Studies in Environmental Sciences 49. Elsevier, Amsterdam
- Hoaglin D.C. & R.E. Welsch. 1978. The hat matrix in regression and ANOVA. *Amer. Stat.* 32:17-22.
- Holmström K., Järnberg U., Bignert A. 2005. Temporal trends of PFOS and PFOA in Guillemot Eggs from the Baltic Sea, 1968-2003. *Environ. Sci. Technol.* 39 (1): 80-84.
- ICES. 2008. Report of the working group on biological effects of contaminants (WGBEC). ICES CM 2008/MHC:07
- IVL. 2010. Bedömning av miljögiftspåverkan i vattenmiljö. IVL Rapport B 1891
- Jensen, S., Renberg, L., and Reutergårdh, L. 1977. Residue analysis of sediment and sewage sludge for organochlorides in the presence of element sulfur. *Anal. Chem.* 49: 316-318.
- Jensen, S., Reutergårdh, L. and Jansson, B. 1983. Analytical methods for measuring organochlorines and methyl mercury by gas chromatography. *FAO Fish. Technical paper*, 212, 21-33.
- Key B.D., Howell R.D. and Criddle C.S. 1997. Fluorinated Organics in the Biosphere. *Environ. Sci. Technol.* 31 (9):2445-2454.
- Liljelind P., Soederstroem G., Hedman B., Karlsson S., Lundin L., Marklund S. 2003. Method for Multiresidue Determination of Halogenated Aromatics and PAHs in Combustion-Related Samples *Environmental Science and Technology*, 2003, Vol. 37: 3680-3686.
- Loftis J.C., Ward R.C., Phillips R.D. 1989. An Evaluation of Trend Detection Techniques for Use in Water Quality Monitoring Programs. EPA/600/3-89/037. 139 p.
- Naturvårdsverket. 2008. Förslag till gränsvärden för särskilt förorenande ämnen. Stöd till vattenmyndigheterna vid statusklassificering och fastställande av MKN. Rapport 5799.
- Nicholson M.D. & R. Fryer. 1991. The Power of the ICES Cooperative Monitoring Programme to Detect Linear Trends and Incidents. In: Anon. Report of the Working Group on Statistical Aspects of Trend Monitoring. ICES Doc CM 1991.
- Nicholson M.D., R. Fryer and J.R. Larsen. 1995. A Robust Method for Analysing Contaminant Trend Monitoring Data. *Techniques in Marine Environmental Sciences*. ICES.
- Norén, K., and Meironyté, D. 2000. Certain organochloride and organobromine contaminants in Swedish human milk in perspective of past 20-30 years. *Chemosphere*. 40(9-11):1111-1123.
- Odsjö T. 1993. The Swedish Environmental Specimen Bank with reference to the National Contaminant Monitoring Programme in Sweden. *The Science of the Total Environment*, 139/140; 147-156.
- OSPARCOM (1996). *OSPARCOM—Oslo and Paris Conventions for the Prevention of Marine Pollution* (1996).
- OSPAR (2005) Assessment of data collected under the Co-ordinated Environmental Monitoring Programme. Publication Number : 2005/235.
- OSPAR (2009) Agreement on CEMP Assessment Criteria for the QSR 2010. Agreement number: 2009-2.

Powley, C. R.; Buck, R. C. 2005. Matrix-effect free analytical methods for determination of perfluorinated carboxylic acids in biological samples. Poster presented at the Society of Environmental Toxicology and Chemistry (SETAC), 15th Annual Meeting of SETAC Europe, Lille, France, May 22–26, 2005.

Roos A., Kienhuis P., Traag W. and Tuistra W. 1989. Problems encountered in the determination of 2,3,4-2',4',5' hexachlorobiphenyl (CB-138) in environmental samples. *Intern. J. Env. Anal. Chem.*, 36:155.

Schantz M.M., Parris R.M., Kurz J., Ballschmiter K. and Wise S.A. 1993. Comparison of methods for the gas-chromatographic determination of PCB congeners and chlorinated pesticides in marine reference materials. *Fresenius Z. Anal. Chem.*, 346:766-78.

Swertz O. 1995. Trend assessment using the Mann-Kendall test. Report of the Working Group on Statistical Aspects of Trend Monitoring. ICES CM 1995/D:2.

Sällström, U., Egebäck, A-L., McLachlan, M. S. 2009. Identifying source regions for the atmospheric input of PCDD/Fs to the Baltic Sea. *Atmos. Env.* 43: 1730-1736.

Technical Guidance for Deriving Environmental Quality standards (TGD EQS). 2009. Chemicals and the water framework directive; Revised draft July 2009

TemaNord 1995:543. Manual for Nordic Environmental Specimen Banking

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. Review: The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds. *Tox Sci* 93(2), 223-241 (2006)

Van Leeuwen S.P.J., Swart C.P., van der Veen I., de Boer J. 2009. Significant improvements in the analysis of perfluorinated compounds in water and fish: Results from an interlaboratory method evaluation study. *Journal of Chromatography A*, 1216 (2009) 401–409.

Welch, H. E., Muir, D. C., Billeck, B. N., Lockhart, W. L., Brunskill, G. J., and Kling, H. J. 1991. Brown snow: a long-range transport event in the Canadian Arctic. *Sci. Technol.* 25(2): 280-286.

Wiberg K., Oehme M., Haglund P., Karlsson H., Olsson M., Rappe C. 1998. Enantioselective analysis of organochlorine pesticides in herring and seal from the Swedish marine environment. *Marine Pollution Bulletin*, 1998, Vol. 36: 345-353.

17 Annex 1

1) Lake Abiskojaure

County	Norrbottn
Main catchment area.	Torne älv river (1000)
Physical geographic regions.	Alpine-northern boreal zone. High mountain region of Lapland (36B)
Coordinates, RAK	X 7582080, Y 1617490 (30I6d 2584)
Altitude	487 m
Lake surface	2.98 sq. km
Max. depth	35 m
Volume	31 Mm ³
Protection	National park
Sample matrix	Char
Start	1981
Other monitoring	Fish population investigated (FiV)
pH / alkalinity	6.9 / 0.16 mekv/L
vegetation	lacking vegetation, surrounded by heath
nutrient status	poor in nutrients, totP = 5.9 ug/L +- 2,6
other	rocky beaches and lake floor. secchi depth = 9m

2) Lake Tjulträsk

County	Västerbotten County
Main catchment area.	Ume älv river
Physical geographic regions.	alpine-northern boreal zone
Coordinates, RAK	X 7317990, Y 1511960 (25G3b 2422)
Altitude	539 m
Lake surface	5.25 sq. km
Max. depth	38 m
Volume	114 Mm ³
Protection	Nature reserve
Sample matrix	Roach
Start	1982
pH / alkalinity	ca 7 / approximately 0.3 mekv/L
vegetation	The Vindelå valley is in south-east constituted of coniferous forest with elements of birch which further north-west passes into moors, with birthforests, rich in mosses. Dispersed are also meadows with birchforest, with high herbs, grasses and ferns with mires and dry bogs.
nutrient status	ca 5 ug/L totP (1999), i.e. oligotrophic
other	Very clear alpine lake with a rich bird life

3) Lake Storvindeln

County	Västerbotten County
Main catchment area.	Ume älv river / Vindelälven river (28000)
Physical geographic regions.	Alpine-northern boreal zone
Coordinates, RAK	X 7282710, Y 157578 (24H7c 2422)
Altitude	342 m
Lake surface	53 sq. km
Max. depth	29 m
Volume	No information found
Sample matrix	Pike
Start	1968
pH / alkalinity	
vegetation	
nutrient status	
other	Hard-bottom lake with beaches rich in species. Together with L. Bolmen, the longest time series of contaminants in freshwater fish, in the world.

4) Lake Brännträsket

County	Norrbottn County
Main catchment area.	Rosån river
Physical geographic regions.	Intermediate boreal
Coordinates, RAK	X 7280950, Y 1759260
Altitude	82 m
Lake surface	0.81 sq. km
Max. depth	6.5 m
Volume	1.87 Mm ³
Sample matrix	Perch
Start	2004
pH / alkalinity	ca 6.5 / 0.118 mekv/L
vegetation	Very sparse vegetation
nutrient status	totP = 12 µg/L
other	Lake Brännträsket consists mainly of spruce with elements of pine. The area has mobile soil water and is rich in lime.

5) Lake Remmarsjön

County	Västernorrland County
Main catchment area.	Gideälven river (34000)
Physical geographic regions.	Intermediate boreal
Coordinates, RAK	X 7086190, Y 1621320
Altitude	234 m
Lake surface	1.29 sq. km
Max. depth	14.4 m
Volume	7.02 Mm ³
Sample matrix	Perch
Start	2000
Other monitoring	
pH / alkalinity	Close 6.5 / 0.05-0.2 mekv / L (i.e. close to neutral with rather good buffer capacity).
vegetation	1 / 3 of the lake is richly overgrown, the rest consists of steep rocky edges. Lined with wide belts common reed, common club-rush and water horsetail. In the lake, chickweed and plants with floating foliage, can also be found.
nutrient status	Moderately rich in nutrients.
other	Surrounded by coniferous forest, with elements of the cultural landscape. Species-rich in fish.

6) Lake Degervattnet

County	Jämtland County
Main catchment area.	Ångermanälven river (38000)
Physical geographic regions.	intermediat boreal
Coordinates, RAK	X 7085120, Y 1520860
Altitude	852 m
Lake surface	1.6 sq. km
Max. depth	20 m
Volume	
Protection	
Sample matrix	Perch
Start	2000
pH / alkalinity	pH close to 7 / alkalinity 0.15-0.25 mekv/L
Vegetation	Moderate, mostly clumps of reed i the in- and outlets. Surrounded by coniferous forests. (Wilander 1999)
Nutrient status	Poor in nutrients, totP = below 8 ug/L
Other	narrow with steep and rocky beaches except in the south where there is one sandy beach.

7) Lake Stor-Björnsjön

County	Jämtland County
Main catchment area.	Indalsälven river
Physical geographic regions.	Alpine-Northern Boreal
Coordinates, RAK	X 7060830, Y 1322870
Altitude	567 m
Lake surface	35 ha
Max. depth	15 m
Volume	
Protection	
Other monitoring	
Sample matrix	Char
Start	2007
pH / alkalinity	7 / 0.15-0,25 mekv/L
vegetation	Sedge is growing around the shallow areas and the lake floor is covered by plants, however these are not classified.
nutrient status	Nutrient-poor, totP < 10 µg/L
other	Lake Stor-Björnsjön is surrounded alternately by mires and slightly hilly terrain with mixed coniferous and deciduous forest.

8) Lake Stor-Backsjön

County	Jämtland County
Main catchment area.	Indalsälven river (40000)
Physical geographic regions.	Intermediate boreal
Coordinates, RAK	X 6952200, Y 1433830
Altitude	426 m
Lake surface	2.09 sq. km
Max. depth	5 m
Volume	3 279
Sample matrix	Perch
Start	2004
pH / alkalinity	High buffering capacity, pH 7.4 Alkalinitet 0.31 mekv/L
vegetation	No information
nutrient status	High Secchi depth
other	Parts of the area consists of virgin forest of both coniferous and deciduous nature. West of the lake is an alkaline fen, with common reed, mountain bladder-fern and early marsh-orchid.

9) Lake Stensjön

County	Gävleborgs County
Main catchment area.	Ljusnan river
Physical geographic regions.	Southern boreal
Coordinates, RAK	X 6836730, Y 1540830
Altitude	268 m
Lake surface	0.53 sq. km
Max. depth	8.5 m
Volume	2,4 Mm ³
Sample matrix	Perch
Start	1997
pH / alkalinity	ca 6/0.05 mekv/L
vegetation	Sparse, mostly common reed, unbranched bur-reed, water lilies and chickweed, along with isoetids along the beaches. Lake surrounded by pine forest.
nutrient status	TotP = 11-12 ug/L
other	Bogs, mires, and the quagmire in close vicinity of the lake. Irregular lake bed with rocky beaches.

10) Lake Gipsjön

County	Dalarna County
Main catchment area.	Göta älv river (108000), consisting in equal parts of mires and coniferous forest.
Physical geographic regions.	Intermediate boreal
Coordinates, RAK	X 6727290, Y 1380820
Altitude	376 m
Lake surface	67 ha
Max. depth	14 m
Volume	
Sample matrix	Perch
Start	2004
pH / alkalinity	pH 5-6 / 0 mekv/L
vegetation	Sparse, composed primarily of greater bladderwort, yellow and white water lily, broad-leaved pondweed, common club-rush and common reed.
nutrient status	totP = 12.4 ug/L
other	Diversified lake floor profile, with several depths and shallows. Water very rich in humus, with several quagmires along the water's edge. Secchi depth about 1m.

11) Lake Spjutsjön

County	Dalarna County
Main catchment area.	Dalälven river
Physical geographic regions.	Southern Boreal
Coordinates, RAK	X 6724670, Y 1480310
Altitude	
Lake surface	0.4 sq. km
Max. depth	21.3 m
Volume	
Protection	
Other monitoring	
Sample matrix	Perch
Start	2007
pH / alkalinity	
vegetation	
nutrient status	
other	

12) Övre Skärsjön

County	Västmanland County
Main catchment area.	Norrström river (61000)
Physical geographic regions.	boreonemoral - southern boreal
Coordinates, RAK	X 6635320, Y 1485710
Altitude	219 m
Lake surface	1.70 sq. km
Max. depth	32 m
Volume	9.9 Mm ³
Sample matrix	Perch
Start	2000
pH / alkalinity	ca 5.3 / ca 0.003 mekv/L
vegetation	Surrounded by mixed deciduous and coniferous forest and some mires. Sparse lake vegetation. Mostly sedge, yellow and white water lilies, as well as isoetids and mosses (Fontinalis).
nutrient status	totP = 8-9 ug/L
other	Water rich in humus, coloured brown. Surrounded by undulating landscape. Undulating lake floor.

13) Lake Limmingssjön

County	Örebro County
Main catchment area.	Gullspångsälven
Physical geographic regions.	Southern boreal
Coordinates, RAK	X 6608040, Y 1590000
Altitude	234 m
Lake surface	1.08 sq. km
Max. depth	
Volume	
Protection	
Other monitoring	A part of the environmental monitoring programme “Nationella tidsserier i referens-sjöar” since 1983.
Sample matrix	Perch
Start	2005
pH / alkalinity	6.67 / 0.091 mekv/L
vegetation	Lake Limmingssjön is surrounded by pine forests with elements of mixed deciduous and coniferous forest as well as mires.
nutrient status	Poor in nutrients, totP = 5 ug/L
other	Several areas with deforestation can be found in the catchment area, including some very large ones just north of the lake. Secchi depth 3.79 m. South of the lake is a polluted area, that is an old mine.

14) Lake Fysingen

County	Stockholm County
Main catchment area.	Oxundaån river
Physical geographic regions.	Boreonemoral
Coordinates, RAK	X 6607490, Y 1618850
Altitude	1.8 m
Lake surface	4.76 km ²
Max. depth	4.5
Volume	10 milj m ³
Protection	-
Other monitoring	-
Sample matrix	Perch
Start	2005
pH / alkalinity	7.9 / 2.05 mekv/L
vegetation	The vegetation around the lake is dominated by grasslands and deciduous trees
nutrient status	totP = 18 ug/L
other	Lake situated on a plain with shore meadows and mighty reed belts. The area around the lake consists mainly of forest, but also some agricultural land.

15) Lake Tärnan

County	Stockholm County
Main catchment area.	Coastal region (59060)
Physical geographic regions.	Boreonemoral
Coordinates, RAK	X 6606880, Y 1644780
Altitude	40 m
Lake surface	1.06 sq. km
Max. depth	12 m
Volume	ca 5.1 mM3
Sample matrix	Perch
Start	2000
pH / alkalinity	ca 7 / 0.35 mekv/L
vegetation	High diversity of bryophytes, isoetides and elodeides. Have been classified as class 2 regarding species richness, where class 1 is very rich in species and class 5 is species poor. Surrounded by common reed, sedge, bulrush, amphibious bistort, water horsetail, rosette plants, Myriophyllum sp. and water lilies.
nutrient status	totP = 10 ug/L
other	Surrounded by older mixed deciduous and coniferous forest (spruce, pine and aspen), arable land and a mire.

16) Lake Bysjön

County	Värmland
Main catchment area.	Göta älv river (108000)
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6580860, Y 1302640
Altitude	123 m
Lake surface	1.18 sq. km
Max. depth	12.7 m
Volume	8.25 Mm ³
Protection	
Sample matrix	Perch
Start	2000
pH / alkalinity	6.5 / 0.1 mekv/L
vegetation	Abundant in some places. Comprised mostly of sedge, common reed and common clubrush, marsh cinquefoil, water horsetail, chickweed, Myriophyllum sp., and yellow- and white water lily.
Nutrients status	moderat in nutrients. totP = 12-20 ug/L
other	Surrounding farmland and mixed deciduous and coniferous wood, very close to E18. Divided into two pools.

17) Lake Stora Envättern

County	Stockholm County
Main catchment area.	Trosaån river (63000)
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6555870, Y 1588690
Altitude	62 m
Lake surface	0.38 sq. km
Max. depth	11.2 m
Volume	1.85 Mm ³
Sample matrix	Perch
Start	2000
pH / alkalinity	6-7 / just over 0.05 mekv/L (close to neutral with low buffering capacity).
vegetation	Surrounded by pine forests and outcrops. Sparse water vegetation, except in the bays where bulrush, common club-rush, water horsetail, common reed, waterlilies and chickweed can be found. Isoetids can be found along the beaches.
nutrient status	Poor in nutrients with high Secchi depth. TotP < 25 ug/L
other	Relatively poor in species.

18) Lake Älgsjön

County	Södermanland County
Main catchment area.	Nyköpingsån river
Physical geographic regions.	Southern boreal
Coordinates, RAK	X 6552750, Y 1532340
Altitude	49
Lake surface	0.36 sq. km
Max. depth	7 m
Volume	1,31 Mm ³
Protection	
Other monitoring	
Sample matrix	Perch
Start	2005
pH / alkalinity	6-7 / 0.2 mekv/L
vegetation	Surrounded for the most part of mixed coniferous and deciduous forest. In the north part there are two shallow bays overgrown with water lilies, common reed and common club-rush.
nutrient status	totP = 20-30 ug/L
other	Secchi depth ca 2 m. Lake Älgsjön is a long narrow lake where the water is coloured brown due to humic substances. The lake floor profile is reminiscent of a soap cup; the beaches descend steep downhill to flatten out against the middle of the lake.

19) Lake Svartsjön

County	Västra Götaland County
Main catchment area.	Motala Ström River (108138)
Physical geographic regions.	Boreonemoral zone
Coordinates, RAK	X 6516090, Y 1408390 (09E3b 1663)
Altitude	125 m
Lake surface	0.07 sq. km
Max. depth	5 m
Volume	
Sample matrix	Roach
Start	1982
pH / alkalinity	6.9 / 0.27 mekv/L (high alkalinity)

vegetation
nutrient status
other

Surrounding mires (colours the water)
dystrophic, totP = 21 ug/L (high amounts of phosphorous)
Secchi depth = 0.8 m. Strongly colored water with high levels
ammonium. There is probably a lack of oxygen on the bottom for
much of the year, which may be a reason behind the ammonium
levels.

20) Lake Fräcksjön

County
Main catchment area.
Physical geographic regions.
Coordinates, RAK
Altitude
Lake surface
Max. depth
Volume

Västra Götaland County
Göta älv river (?)
boreonemoral
X 6452890, Y 1286650
63 m
0.27 sq. km
15m

Protection

Other monitoring

Sample matrix
Start
pH / alkalinity

Perch
2005

Since the early 1980s, the pH has often
been around 6,5 and alkalinity 0.05 mekv/L

vegetation

Surrounded by mixed coniferous and deciduous forest. The
water vegetation is abundant in the bays and consists of yellow-
and white water lilies, various species of chickweed, isoetids,
common reed, common club-rush and sedge.

nutrient status
other

totP = 9.8 ug/L

Humic forest lake, consisting of two pools that are separated by a
narrow strait. The rocky beaches are steep and there are no larger
shallows in the area.

21) Bästeträsk

County	Gotland County
Main catchment area.	Coastal region (118117)
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6425550, Y 1685530
Altitude	6 m
Lake surface	0.67 sq. km
Max. depth	4.5 m
Volume	No information
Protection	Nature reserve
Sample matrix	Perch
Start	2004
pH / alkalinity	8.2 / 2.3 mekv/L
vegetation	The lake lacks higher water vegetation to a large extent, but stands of reed and great fen-sedge occurs both in the south-west of the lake, and north of the Stor- and Lillholmen. Large parts of the central lake have vegetation consisting of charales.
nutrient status	totP = 6,9 ug/L. Nutrientpoor lake with higher Secchi depth, than maximum depth.
other	The lake floor consists in part of rocky hard-bottom and in part of suspension-bottom with a sediment layer up to 1.5 meters in thickness. The lake is surrounded by limestone outcrops, pine forests, mires with great fen-sedge growing in them, and ephemeral water bodies.

22) Lake Allgjuttern

County	Kalmar County
Main catchment area.	Botorpströmmen
Physical geographic regions.	Boreonemoral
Coordinates, RAK	X 6424870, Y 1517240
Altitude	131 m
Lake surface	18 ha
Max. depth	40 m
Volume	
Protection	
Other monitoring	
Sample matrix	Perch
Start	2006
pH / alkalinity	6,5 – 7 / 0,05 mekv/L
vegetation	The vegetation can mainly be found in the shallow bays and consists primarily of common reed, common club-rush and common chickweed.
nutrient status	totP = 10 ug/L
other	

23) Lake Horsan

County	Gotland County
Main catchment area.	Coastal region (118117), dominated by forest
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6420080, Y 1680130 (07J4g 0980)
Altitude	5 m
Lake surface	0.56 sq. km
Max. depth	1.5 m
Volume	
Sample matrix	Roach, Perch
Start	1980
pH / alkalinity	Ca 8.2 / ca 2.2 mekv/L
vegetation	Very sparse, consisting mainly of reeds and green fen-sedge. Primarily charales sp. below the water surface. Pine forest around the lake.
Nutrient status	Low in nutrients
Other	Suspension-bottom, with elements of hard bottom along the shores. The lake consists of two pools. Secchi depth exceeding maximum depth.

24) Lake Skärgölen

County	Kalmar County
Main catchment area.	Motala ström river (67000)
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6406090, Y 1486730 (07F1h 0884)
Altitude	72 m
Lake surface	16 hectare
Max. depth	13
Volume	1.08 Mm ³
Sample matrix	Perch
Start	1981
Other monitoring	
pH / alkalinity	Close to 7 / close to 0.15 mekv/L
vegetation	Surrounded by mires and coniferous forest. Sparce veg at the beach edge, however, the rich in species of common reed, bulrush, chickweed, yellow and white waterlily, sedge and isoetids.
nutrient status	Poor in nutrients, totP often below 10 ug/L
other	Becomes deep very quickly, which might affect the amount of vegetation along the shores.

25) Lake Lilla Öresjön

County	Halland County
Main catchment area.	Rolfsån river (106000)
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6952200, Y 1433830
Altitude	107 m
Lake surface	0.61 sq. km
Max. depth	17 m
Volume	
Sample matrix	Perch
Start	2004
pH / alkalinity	ca 5.5 - 6 / 0.2 – 0.25 mekv/L
vegetation	No information
nutrient status	5 ug/L
other	Secchi depth about 3.8 m. Forest lake, poor in nutrients.

26) Lake Fiolen

County	Kronobergs county
Main catchment area.	Mörrumsån river (86000)
Physical geographic regions.	Boreonemoral
Coordinates, RAK	X 6330250, Y 1422670
Altitude	226 m
Lake surface	1.55 sq. km
Max. depth	10
Volume	6.21 Mm ³
Protection	
Sample matrix	Perch
Start	2000
pH / alkalinity	6,5 / 0,05 mekv/L
vegetation	Moderate but with plants like shoreweed and quillwort, reed and waterlilies.
Nutrient status	Poor in nutrients
other	Surrounded by coniferous forests, farmland and mires.

27) Lake Hjärtsjön

County	Kronobergs County
Main catchment area.	Alsterån river (75)
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6325150, Y 1466750
Altitude	274 m
Lake surface	1.37 sq. km
Max. depth	7 m
Volume	4.6 Mm ³
Protection	
Sample matrix	Perch
Start	2000
pH / alkalinity	below 5.5 / under 0 mekv/L
Vegetation	Moderat, mostly rosette plants, yellow and white waterlilies and bogbeans.
nutrient status	Poor in nutrients, totP often below 10 ug/L
Other	Surrounded by coniferous forestes and mires. Secchi depht above 6m

28) Lake Bolmen

County	Kronobergs, Hallands, Jönköpings län
Main catchment area.	Lagan river (98000) /Bolmån river
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6295110, Y 1368660
Altitude	141 m
Lake surface	184 sq. km
Max. depth	37 m
Volume	1260 Mm ³
Protection	
Sample matrix	Pike
Start	1967
Other monitoring	
pH / alkalinity	ca 7 / 0.14-0.18 mekv/L
vegetation	
nutrient status	moderat in nutrients. totP = 0.009-0.011 mg/L
other	Lake floors poor in oxygen. Secchi depth = 2-3m in august

29) Lake Stora Skärsjön

County	Halland County
Main catchment area.	Genevadsån river (99000)
Physical geographic regions.	boreonemoral
Coordinates, RAK	X 6286060, Y 1332050
Altitude	60 m
Lake surface	0.28 sq. km
Max. depth	11.5 m
Volume	1.172 Mm ³
Sample matrix	Perch
Start	1997
pH / alkalinity	pH close to 7 / alkalinity about 0.1 mekv/L (i.e. fairly good buffer capacity)
vegetation	Abundant with common reed, common club-rush, Myriophyllum spp. and water lilies. Isoetides along the water's edge. The surrounding pine forests.
nutrient status	Relatively high Secchi depth.
other	Several deeps and shallows. Not a good reference lake, near an incinerating plant.

30) Lake Sännen

County	Blekinge County
Main catchment area.	Coastal region (81082)
Physical geographic regions.	nemoral - boreonemoral
Coordinates, RAK	X 6244210, Y 1472340
Altitude	62.7 m
Lake surface	0.99 sq. km
Max. depth	13 m
Volume	3.9 Mm ³
Sample matrix	Perch
Start	2004
pH / alkalinity	ca 5-6 / ca 0.02 – 0.04 mekv/L. Lake Sännen is an acidified, limed lake.
vegetation	Surrounded largely by mixed coniferous and deciduous forest. Bunches of common reed, common spike- and club-rush as well as bottle- and slender sedge occurs sparingly.
nutrient status	totP = 15 - 21 ug/L
other	Secchi depth 4.7 m.

31) Lake Krankesjön

County	Scania County
Main catchment area.	Kävlingeån river (92000)
Physical geographic regions.	nemoral
Coordinates, RAK	X 6177970, Y 1353390 (02D5a 1281)
Altitude	19 m
Lake surface	3.31 sq. km
Max. depth	3 m
Volume	
Protection	Nature reserve
Sample matrix	Roach
Start	1980
Other monitoring	
pH / alkalinity	No information
vegetation	Lake surrounded by willow and swamp forest consisting of birch and alder, lined with common reed. Very rich bentic vegetation with chickweed and charales.
nutrient status	Eutrophicated, totP = ca 40 ug/L
other	One of the country's richest bird lakes.

32) Lake Krageholmssjön

County	Scania County
Main catchment area.	Coastal region (89090)
Physical geographic regions.	nemoral
Coordinates, RAK	X 6153750, Y 1370870
Altitude	43 m
Lake surface	2.05 sq. km
Max. depth	9 m
Volume	
Protection	Nature reserve
Sample matrix	Perch
Start	2000
Other monitoring	
pH / alkalinity	No information
vegetation	Surrounded by beech forest. Varied vegetation. Dominated by plants growing above water surface. Abundant in common chickweed and two species Charales.
nutrient status	Extremely rich in nutrients, totP = 91 ug/L
other	Affected by agriculture however, one of Scania's least affected lakes. Very high natural value. Rich in fish. Surrounding land is the mostly agricultural land and mires / wetland.