Sakrapport

Övervakning av metaller och organiska miljögifter i marin biota, 2010

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Comments Concerning the National Swedish Contaminant Monitoring Programme in Marine Biota, 2010

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PAHs
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1 Introduction

This report gives a summary of the monitoring activities within the national Swedish contaminant programme in marine biota. It is the result from the joint efforts of: the Department of Applied Environmental Science at Stockholm University (analyses of organochlorines, brominated flame retardants and perfluorinated substances), the Department of Environmental Assessment at Swedish University of Agricultural Sciences (analyses of heavy metals), Department of Chemistry at Umeå University (analyses of PCDD/PCDF), IVL – Swedish Environmental Research Institute (analyses of polycyclic aromatic hydrocarbons) 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 marine biota could be summarised as follows:

- to estimate the levels and the normal variation of various contaminants in marine biota from several representative sites, uninfluenced by local sources, along the Swedish coasts. 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 marine 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 PFC’s as well as the ratios between various contaminants.

- the time series are also relevant for human consumption since important commercial fish species like herring and cod are sampled. A co-operation with the Swedish Food Administration is established. Sampling is also co-ordinated with SSI (Swedish Radiation Protection Authority) for analysing radionuclides in fish and blue mussels (HELCOM, 1992).
• 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 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), liver somatic index (LSI) and fat content are monitored at all sites. At a few sites, integrated monitoring with fish physiology and population are running in co-operation with the University of Gothenburg and the Swedish Board of Fisheries.

• experiences from the national programme with several 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 the ongoing model building activities concerning marine ecosystems in general and in the Baltic and North Sea environment in particular.

• the contaminant programme in marine biota constitute an integrated part of the national monitoring activities in the marine environment as well as of the international programmes within ICES, OSPARCOM, HELCOM and EU.

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 and, for some contaminants, differences in geometric mean concentration between various species caught at the same site. Sometimes notes of seasonal variation and differences in concentration between tissues in the same species are given. This information could say something about the relative appropriateness of the sampled matrix and be of help in designing monitoring programmes. In the temporal trend part, an extract of the relevant findings is summarised in the 'conclusion'-paragraph. It should be stressed though, that geographical differences may not reflect antropogenic influence but may be due to factors like productivity, temperature, salinity etc.

The report is continuously updated. The date of the latest update is reported at the beginning of each chapter. The creation date of each figure is written in the lower left corner.
2 Summary 2008/09

A short summary of the results up to year 2008/09 is given below. Graphical presentations, tables and details are given in the following chapters.

- The condition of herring in the Baltic is decreasing, together with the fat content in herring muscle, in all autumn and spring time series except at Ängskärsklubb (autumn and spring (for which it is increasing)). During recent years this decrease has stopped at Landsort and Utlångan and the condition and fat content have improved somewhat.

- Due to a change of method for metal analysis in 2004, values after 2003 are not presented, since the values are uncertain. A change of analytical laboratory for metal analysis took place during 2009, but the new results are not ready to be presented within 2010 years report.

- Lead concentrations in herring, cod and perch livers are decreasing in almost all time series, both on the Swedish west coast and in the Baltic.

- The increasing trends of cadmium concentrations in herring liver from the Baltic Proper and from the Bothnian Sea reported for the period 1980 to 1997 seems to have turned into a decreasing trend during recent years. The levels are however not lower than in the beginning of the 1980-ies.

- Cadmium concentrations in blue mussels from the Baltic Proper are about 5 times higher than the suggested background levels for the North Sea and 3 times higher than in blue mussels from the Swedish west coast.

- CB-153 is decreasing in herring (accept for Utlångan and Ängskärsklubb spring), perch and guillemot from the Baltic sampling sites and also in herring and blue mussel from Fladen and Väderöarna at the Swedish west coast.

- CB-153 shows significantly higher concentrations in herring (generally more than three times) from the Baltic Proper and the Bothnian Sea compared to the Swedish west coast.

- DDE is decreasing in herring, perch, cod and blue mussel from all sampling sites.

- HCH’s are decreasing at almost all sites with time series long enough to permit a statistical trend analysis.

- HCB is decreasing in herring, cod, perch and guillemot from all sampling sites and also in blue mussel from Väderöarna at the Swedish west coast.

- There was a significant decrease of TCDD/TCDF in guillemot eggs from St Karlsö between 1970 and the middle of the 80-ies, after which the decrease has levelled out. In herring there is no decrease in TCDD-equivalents during the investigated time period 1990-2008.
- TCDD/TCDF shows clearly higher concentrations in herring from the Baltic Proper, the Bothnian Sea and the Bothnian Bay compared to the Swedish west coast.

- HBCD is *increasing* in guillemot eggs from the Baltic Proper, but it is *decreasing* in herring from Utlängan (Baltic Proper) and from Fladen (cod liver and herring muscle) and Väderöarna at the Swedish west coast.

- PFOS is *increasing* in guillemot eggs from the Baltic Proper.

- The sum of PAHs is *decreasing* in blue mussels from Väderöarna at the Swedish west coast.
3 Sampling

3.1 Sampling area
The sampling area is generally defined by a central co-ordinate surrounded by a circle of 3 nautical miles. The exact sampling location should be registered at collection. General demands on sampling sites within the national contaminant monitoring programme are defined in chap. 5.

3.2 Collected specimens
For many species adult specimens are less stationary than sub-adults and represent a more recent picture of the contaminant load since many contaminants accumulates over time. To increase comparability between years, young specimens are generally collected. However, the size of the individual specimens has to be big enough to allow individual chemical analysis. Thus the size and age of the specimens vary between species and sites (see chap. 4). To avoid possible contribution of between-year variance due to sex differences the same sex (females) is analysed each year in most timeseries. In the past both sexes were used and thus, at least for the oldest time series, both sexes appear. To achieve the requested number of individual specimens of the prescribed age range and sex, about 50 - 100 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.

3.3 Number of samples and sampling frequency
In general 10-12 individual specimens from the old Baltic sites (reported to HELCOM) and the old Swedish westcoast sites (reported to OSPARCOM) are analysed annually from each site/species. At the new Baltic and west coast sites 2 pools of 12 individuals are analysed from each site/species. For guillemot eggs and perch (old sites), 10 individual specimens are analysed. Organochlorines in blue mussels are analysed in pooled samples containing about 20 individual specimens in each pool. Since 1996, samples from 12 individual specimens are analysed which is proposed in the revised guidelines for HELCOM and OSPARCOM.

The sampling recommendation prescribes a narrow age range for sampled species. In a few cases it has not been possible to achieve the required number of individuals within that range. In order to reduce the between-year variation due to sample differences in age composition, only specimens within the range of age classes given in brackets after species name in the figures, are selected in this presentation.

Sampling is carried out annually in all timeseries. A lower frequency would result in a considerable loss in statistical and interpretational power.
3.4  Sampling season
Sampling of the various fish species and blue mussels is carried out in autumn, outside the spawning season. However, from two sites; Ångskärsklubb and Utlångan, herring is also sampled in spring. The two spring series started already in 1972. In the beginning only organochlorines where analysed but since 1996 metals have been analysed on a yearly basis. This provides a possibility to study seasonal differences and, when possible, to adjust for these differences and improve the resolution of the time series. It also gives an opportunity study possible changes in the frequencies of spring and autumn spawners.

Guillemot eggs are collected in the beginning-middle of May. A second laid egg (due to a lost first egg) should not be collected and are avoided by sampling early laid eggs (see 4.6).

3.5  Sample preparation and registered variables
A short description of the various sampling matrices and the type of variables that are registered are given below. See TemaNord (1995) for further details.

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

Muscle samples are taken from the middle dorsal muscle layer. The epidermis and subcutaneous fatty tissue are carefully removed. Samples of 10 g muscle tissue are prepared for organochlorine/bromine analysis, 20 g for analysis of PCDD/F and 1.5 g for mercury analysis.

The liver is completely removed and weighted in the sample container. Samples of 0.5 – 1g are prepared for metal analyses and 0.5 g for analysis of perfluorinated substances.

3.5.2  Blue mussel
For each specimen total shell length, shell and soft body weight are registered. Trace metals are analysed in individual mussels whereas samples for organochlorine/bromine determination and PAH’s are analysed in pools of about 20 specimens.

3.5.3  Guillemot egg
Length, width and total weight are recorded. Egg contents are blown out. Embryo tissue is separated from the yolk and white that are homogenised.

Weight of the empty and dried eggshell is recorded. The eggshell thickness is measured at the blowing hole using a modified micrometer.

2 g of the homogenised egg content is prepared for mercury analyses and another to 2 g for the other analysed metals. 10 g is prepared for analyses of organochlorines/bromines, 30 g for analysis of PCDD/F and 1 g for perfluorinated substances.
3.6 Data registration

Data are stored in a flat ASCII file in a hierarchical fashion where each individual specimen represents one level. Each measured value is coded and the codes are defined in a code list (Danielsson and Nyberg, 2008). 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

The sample database provides the basic information for this report and contains data of contaminant concentrations in biota from individual specimens of various species.

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

<table>
<thead>
<tr>
<th>Species</th>
<th>N of individual specimen</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring</td>
<td>5228</td>
<td>50</td>
</tr>
<tr>
<td>Cod</td>
<td>1072</td>
<td>10</td>
</tr>
<tr>
<td>Perch</td>
<td>928</td>
<td>9</td>
</tr>
<tr>
<td>Eelpout</td>
<td>514</td>
<td>5</td>
</tr>
<tr>
<td>Dab</td>
<td>346</td>
<td>3</td>
</tr>
<tr>
<td>Flounder</td>
<td>340</td>
<td>3</td>
</tr>
<tr>
<td>Guillemot</td>
<td>587</td>
<td>6</td>
</tr>
<tr>
<td>Blue mussel</td>
<td>1518</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>10 533</td>
<td></td>
</tr>
</tbody>
</table>

4.1 Herring (*Clupea harengus*)

Herring is a pelagic species that feeds mainly on zooplankton. It becomes sexually mature at about 2-3 years in the Baltic and at about 3-4 years at the Swedish west coast. It is the most dominating commercial fish species in the Baltic. It is important not only for human consumption but essential also for several other predators in the marine environment.

Herring is the most commonly used indicator species for monitoring contaminants in biota within the BMP (Baltic Monitoring Programme) in the HELCOM convention area and is sampled by Finland, Estonia, Poland and Sweden.

Herring muscle tissue is fat and thus very appropriate for analysis of fat-soluble contaminants i.e. hydrocarbons.

Herring samples are collected each year from seventeen sites along the Swedish coasts: Rånefjärden, Harufjärden, Kinnebäcksfjärden (Bothnian Bay), Holmöarna, Örefjärden, Gaviks fjärden, Långvinds fjärden, Ångskärsklubb (Bothnian Sea), Lagnö, Landsort (northern Baltic Proper), Byxelkrok, Abbekås, Hanö bukten, Utlängan (southern Baltic Proper), Kullen, Fladen (Kattegatt) and at Väderöarna (Skagerack). Herring (collected by the Swedish board of Fisheries in 2008) from 2 sites in the open sea, Baltic Proper and Bothnian Sea, are presented in this report (spatial staple maps).

Herring liver tissue is analysed for lead, cadmium, copper, zinc and perflourinated substances. 1995 analyses of chromium and nickel were added to the programme. Herring muscle tissue is analysed for mercury, organochlorines (DDT’s, PCB’s, HCH’s, HCB, PCDD/PCDF) and polybrominated flameretardants. Herring muscle from spring caught specimens from Ångskärsklubb and Utlängan are analysed for organochlorines and polybrominated flameretardants and from 1996 also for the metals mentioned above. Herring samples from various sites within the marine monitoring programme have also been analysed for dioxins/dibenzo furans, co-planar CB’s, polybrominated diphenyl ethers.
(Sellström, 1996) and fat composition in pilot studies. Monitoring of Cs-135 is also carried out on herring from these sites by the Swedish Radiation Protection Institute.

The herring specimens are age determined by scales. The analysed specimens are females between 2 - 5 years. Total body weight, liver weight, total length and maturity of gonads is also recorded.

Table 4.2. The range of weeks when collection of samples has been carried out in all (or almost all) years at the old locations and the age classes selected in the presented time series below. The 95% confidence intervals for the yearly means of total body weight, total length, liver weight and liver and muscle dry weight are also given.

<table>
<thead>
<tr>
<th>Sampling week</th>
<th>age (year)</th>
<th>body weight (g)</th>
<th>length (cm)</th>
<th>liver weight (g)</th>
<th>liver dry weight (%)</th>
<th>muscle dry weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harufjärden</td>
<td>38-42</td>
<td>3-4</td>
<td>28-31</td>
<td>16-17</td>
<td>0.32-0.39</td>
<td>20-35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22-23</td>
<td></td>
</tr>
<tr>
<td>Ångskärsklubb</td>
<td>38-42</td>
<td>3-5</td>
<td>33-42</td>
<td>17-18</td>
<td>0.38-0.56</td>
<td>20-35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21-23</td>
<td></td>
</tr>
<tr>
<td>- “ - spring</td>
<td>20-24</td>
<td>2-5</td>
<td>25-33</td>
<td>16-17</td>
<td>0.31-0.54</td>
<td>19-23</td>
</tr>
<tr>
<td>Landsort</td>
<td>41-48</td>
<td>3-5</td>
<td>38-50</td>
<td>18-20</td>
<td>0.46-0.66</td>
<td>20-32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22-24</td>
<td></td>
</tr>
<tr>
<td>Karlskrona</td>
<td>41-46</td>
<td>2-4</td>
<td>38-48</td>
<td>17-19</td>
<td>0.36-0.51</td>
<td>22-35</td>
</tr>
<tr>
<td>- “ - spring</td>
<td>18-23</td>
<td>2-3</td>
<td>51-65</td>
<td>19-22</td>
<td>0.30-0.55</td>
<td>17-20</td>
</tr>
<tr>
<td>Fladen</td>
<td>35-45</td>
<td>2-3</td>
<td>47-61</td>
<td>19-20</td>
<td>0.55-0.70</td>
<td>22-38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25-27</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>38-40</td>
<td>2-3</td>
<td>50-90</td>
<td>18-24</td>
<td>0.40-1.0</td>
<td>27-39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24-35</td>
<td></td>
</tr>
</tbody>
</table>

The growth rate varies considerably at the different sites, see Table 4.3 below.

Table 4.3. Average length at the age of three and age at the length of 16 cm at the old sites

<table>
<thead>
<tr>
<th></th>
<th>Average length (cm) at 3 years</th>
<th>Average age (years) at 16 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harufjärden</td>
<td>15.91</td>
<td>3.07</td>
</tr>
<tr>
<td>Ångskärsklubb</td>
<td>16.87</td>
<td>2.24</td>
</tr>
<tr>
<td>- “ - spring</td>
<td>16.79</td>
<td>2.42</td>
</tr>
<tr>
<td>Landsort</td>
<td>17.28</td>
<td>2.17</td>
</tr>
<tr>
<td>Karlskrona</td>
<td>18.20</td>
<td>1.19</td>
</tr>
<tr>
<td>Fladen</td>
<td>20.32</td>
<td>0.82</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>21.73</td>
<td>0.53</td>
</tr>
</tbody>
</table>

4.2 Cod (Gadus morhua)

The Baltic cod lives below the halocline feeding on bottom organisms. It becomes sexually mature when 2-6 years old in Swedish waters. The spawning takes place during the period May - August (occasionally spawning specimens could be found in March or September). The cod requires a salinity of at least 11 PSU and an oxygen content of at least 2 ml/l (Nissling, 1995) for the spawning to be successful. The population shows great fluctuations and has decreased dramatically during the period 1984-1993. Cod fishing for human consumption is economically important.

Cod is among the ‘first choice species’ recommended within the JAMP (Joint Assessment and Monitoring Programme) and BMP (Baltic Monitoring Programme).

Cod is collected in the autumn from two sites: south east of Gotland and from Fladen at the Swedish west coast. Cods are age determined by otoliths. Specimens of both sexes, between 3-4 years from Gotland and between 2-4 years from Fladen, are analysed.
The cod liver is fat and organic contaminants are often found in relatively high concentrations. For that reason, it is a very appropriate matrix for screening for ‘new’ contaminants.

Cod liver tissue is analysed for lead, cadmium, copper and zinc as well as for organochlorines. 1995 analyses of chromium and nickel were added and analysis for brominated substances and HBCD in 1999. Cod muscle tissue is analysed for mercury.

Before 1989, 20 individual samples from south east of Gotland and 25 samples from Kattegatt were analysed for organochlorines. Between 1989-1993 one pooled sample from each site, each year was analysed. Since 1994, 10 individual cod samples are analysed at the two sites each year.

Table 4.4. The range of weeks when collection of samples has been carried out in all (or almost all) years at a specific location, the age classes selected in the presented time series below. The 95% confidence intervals for the yearly means of total body weight, total length, liver weight and liver dry weight are also given.

<table>
<thead>
<tr>
<th>Sampling week</th>
<th>age</th>
<th>body weight (g)</th>
<th>Length (cm)</th>
<th>liver weight (g)</th>
<th>liver dry weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE Gotland</td>
<td>35-39</td>
<td>3-4</td>
<td>310-455</td>
<td>32-35</td>
<td>16-41</td>
</tr>
<tr>
<td>Fladen</td>
<td>37-42</td>
<td>2-3</td>
<td>240-345</td>
<td>29-33</td>
<td>4-10</td>
</tr>
</tbody>
</table>

4.3 Dab (*Limanda limanda*)

Dab is a bottom living species feeding on crustaceans, mussels, worms, echinoderms and small fishes. The males become sexually mature between 2-4 years and the females between 3-5 years. The spawning takes place during the period April – June shallow coastal waters. The dab tends to migrate to deeper water in late autumn.

Dab is among the ‘first choice species’ recommended within the JAMP (Joint Assessment and Monitoring Programme).

Because of reduced analytical capacity, organochlorines in dab were annually analysed in one pooled sample from 1989 to 1995. Since 1995 samples of dab are no longer analysed but are still collected and stored in the Environmental Specimen Bank.

Dab is collected from Kattegatt (Fladen) in the autumn. Liver tissue samples have been analysed for lead, cadmium, copper and zinc and muscle tissue samples for organochlorines and mercury. The dab specimens are age determined by otoliths. Specimens between 3-5 years have been analysed.

Table 4.5. The range of weeks when collection of samples has been carried out in all (or almost all) years, the age classes selected in the presented time series below. The 95% confidence intervals for the yearly means of total body weight, total length, liver weight and liver dry weight are also given.

<table>
<thead>
<tr>
<th>Sampling week</th>
<th>age</th>
<th>body weight (g)</th>
<th>length (cm)</th>
<th>liver weight (g)</th>
<th>liver dry weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fladen</td>
<td>37-44</td>
<td>2-6</td>
<td>50-250</td>
<td>15-30</td>
<td>0.5-2</td>
</tr>
</tbody>
</table>
4.4 Flounder (*Platichthys flesus*)

Flounder is a bottom living species feeding on crustaceans, mussels, worms, echinoderms and small fishes. The males in the Skagerack become sexually mature between 3-4 years of age and the females one year later. The spawning in the Skagerack takes place during the period January – April in shallow coastal waters. The flounder tends to migrate to deeper waters in late autumn.

Flounder is among the ‘second choice species’ recommended within the JAMP (Joint Assessment and Monitoring Programme). Because of reduced analytical capacity, organochlorines in flounder were annually analysed in one pooled sample from 1989 to 1995. Since 1995 samples of flounder are no longer analysed but are still collected and stored in the Environmental Specimen Bank.

Flounder is collected from the Skagerack (Väderöarna) in the autumn. Liver tissue samples have been analysed for lead, cadmium, copper and zinc and muscle tissue samples for organochlorines and mercury. The flounder specimens are age determined by otoliths. Specimens between 4-6 years have been analysed.

**Table 4.6.** The range of weeks when collection of samples has been carried out in all (or almost all) years, the age classes selected in the presented time series below. The 95% confidence intervals for the yearly means of total body weight, total body length, liver weight and liver dry weight are also given.

<table>
<thead>
<tr>
<th>Sampling week</th>
<th>age (year)</th>
<th>body weight (g)</th>
<th>length (cm)</th>
<th>liver weight (g)</th>
<th>liver dry weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Väderöarna</td>
<td>37-44</td>
<td>3-6</td>
<td>100-400</td>
<td>20-35</td>
<td>18-30</td>
</tr>
</tbody>
</table>

4.5 Blue mussel (*Mytilus edulis*)

Blue mussels are one of the most common used organisms for monitoring contaminants in biota. Adult mussels are sessile and hence it is easier to define the area the samples represent, compared to fish.

Blue mussel is among the ‘first choice species’ recommended within the JAMP (Joint Assessment and Monitoring Programme).

Blue mussels are collected from the Kattegatt (Fladen, Nidingen), from the Skagerack (Väderöarna) and from Kvädöfjärden in the Baltic Proper. The mussels are sampled in the autumn. Sampling depth varies between the sampling sites.

Soft body tissue is analysed for lead, cadmium, copper, zinc, mercury and organochlorines. In 1995 analyses of chromium and nickel were added and in 2000 analysis of brominated substances. From 1995 samples from Kvädöfjärden were included in the analysis. Hitherto, samples from this site had only been collected and stored (since 1981). Organochlorines in blue mussels are analysed in pooled samples from each site and year whereas the trace metals are analysed in 25 individual samples per year and site (15 from 1996). PAH’s has been analysed retrospectively (start 1984/87) in mussels from all three localities and are since 2003 analysed on a yearly basis in pooled samples.
Table 4.7. The range of weeks when collection of samples has been carried out in all (or almost all) years at a specific location, the shell length interval selected in the presented time series below. The 95% confidence intervals for the yearly means of soft body weight and shell weight are also given.

<table>
<thead>
<tr>
<th>Location</th>
<th>Sampling week</th>
<th>Sampling depth</th>
<th>Shell length</th>
<th>Shell weight</th>
<th>Soft body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kvädojärden</td>
<td>38-43</td>
<td>2-10</td>
<td>2-3</td>
<td>0.4-0.6</td>
<td>1-2</td>
</tr>
<tr>
<td>Fladen, Nidingen</td>
<td>37-51</td>
<td>0.5</td>
<td>5-8</td>
<td>5-25</td>
<td>2-10</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>42-51</td>
<td>2</td>
<td>6-10</td>
<td>10-30</td>
<td>5-25</td>
</tr>
</tbody>
</table>

4.6 **Guillemot (Uria aalge)**

Guillemots are appropriate for monitoring of contaminants in the Baltic Sea since most of them do not migrate further than to the southern parts of the Baltic proper during the winter season. They feed mainly on sprat (Sprattus sprattus) and herring (Clupea harengus). The guillemot breed for the first time at the age of 4-5 years and the egg is hatched after about 32 days.

The egg content is fat (11-13%) and thus very appropriate for analysis of fat-soluble contaminants i.e. hydrocarbons.

Normally the guillemot lay just a single egg but if this egg is lost, it may lay another. It has been shown that late laid eggs of guillemot contain significantly higher concentrations of organochlorines compared to early laid eggs (Bignert et al., 1995). In this presentation only early laid eggs are included except for dioxins where the results from all collected eggs are included. 10 guillemot eggs, collected between week 19-21(22), are analysed each year.

Guillemot egg contents from St Karlsö are analysed for mercury, organochlorines, perflourinated compounds (Holmström et al., 2005) and polybrominated compounds (Sellström, 1996). From 1996, the concentrations of Pb, Cd, Ni, Cr, Cu and Zn are also analysed. The timeserver has also been analysed for PCC (Wideqvist et al. 1993). Various shell parameters e.g. shell weight, thickness and thickness index is also monitored. The weights of several hundreds of fledglings are normally recorded each year at St Karlsö. Eggs have also been collected for some years from Bonden in the northern parts of the Bothnian Sea but so far only results (organochlorines) for 1991 are available.

4.7 **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 0.8% fat.

Integrated monitoring with fish physiology and population development is running on perch in co-operation with the University of Gothenburg and the Swedish Board of Fisheries. Perch is also used as an indicator species for contaminant monitoring within the national monitoring programme of contaminants in freshwater biota.

Perch muscle tissue samples from two coastal sites, Holmöarna and Kvädojärden in the Baltic, are analysed for organochlorines and mercury. In 1995 analyses of lead, cadmium, chromium, nickel, copper and zinc in perch liver were added to the programme and in 2006 PCDD/F.
Table 4.8. The range of weeks when collection of samples has been carried out in all (or almost all) years at the old sites, the age classes selected in the presented time series below. The 95% confidence intervals for the yearly means of total body weight, total body length, liver weight and liver dry weight are also given.

<table>
<thead>
<tr>
<th>Perch</th>
<th>Sampling week</th>
<th>age (year)</th>
<th>body weight (g)</th>
<th>length (cm)</th>
<th>liver weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holmöarna</td>
<td>33-42</td>
<td>3-5</td>
<td>77-88</td>
<td>17-21</td>
<td>0.86-1.5</td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>31-40</td>
<td>3-5</td>
<td>56-67</td>
<td>15-20</td>
<td>0.50-0.73</td>
</tr>
</tbody>
</table>

4.8 Eelpout, viviparous blenny (*Zoarces viviparus*)

The eelpout is considered as a more or less stationary species living close to the bottom, feeding on insect larvae, molluscs, crustaceans, worms, hard roe and small fishes. It becomes sexually mature when 2 years old at a length of 16 - 18 cm. The spawning takes place during August - September. After 3-4 weeks the eggs hatch inside the mothers body where the fry stay for about three months. The possibility to measure the number of eggs, fertilized eggs, the size of the larvae and the embryonic development makes the species suitable for integrated studies of contaminants and reproduction (Jacobsson et al., 1993). Integrated monitoring with fish physiology and population development is running on eelpout in co-operation with the University of Gothenburg and the Swedish Board of Fisheries.

Eelpout specimens have been collected from Väderöarna in the Skagerack since 1988. In this time series analyses of various PCB congeners are available. Since 1995, eelpout is also collected from Holmöarna and Kvädöfjärden. Liver tissue is analysed for lead, cadmium, chromium, nickel, copper and zinc whereas muscle tissue is analysed for mercury and organochlorines. Contaminant analysis in eelpout from Holmöarna ended in 2007.

Table 4.9. The range of weeks when collection of samples has been carried out in all (or almost all) years at a specific location, the age classes selected in the presented time series below. The 95% confidence intervals for the yearly means of total body weight, total body length, liver weight and liver and muscle dry weight are also given.

<table>
<thead>
<tr>
<th>Sampling week</th>
<th>age (year)</th>
<th>total weight (g)</th>
<th>length (cm)</th>
<th>liver weight (g)</th>
<th>liver dry weight (%)</th>
<th>muscle dry weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holmöarna</td>
<td>47</td>
<td>3-6</td>
<td>21-26</td>
<td>18-20</td>
<td>0.20-0.50</td>
<td>13-26</td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>46</td>
<td>3-6</td>
<td>28-39</td>
<td>19-22</td>
<td>0.20-0.60</td>
<td>18-25</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>(36), 45-47</td>
<td>3-6</td>
<td>35-70</td>
<td>20-25</td>
<td>0.40-1.00</td>
<td>14-32</td>
</tr>
</tbody>
</table>
5 Sampling sites

The location and names of the sample sites are presented in Figure 5. The sampling sites are located in areas regarded as locally uncontaminated and, as far as possible, uninfluenced by major river outlets or ferry routes and not too close to heavy populated areas.

The Swedish sampling stations are included in the net of HELCOM stations in the Baltic and in the Oslo and Paris Commissions’ Joint Monitoring Programme (OSPAR, JMP) station net in the North Sea. Denmark (plaice), Estonia (herring, perch), Finland (herring), Germany (perch, cod, herring), Latvia (perch), Lithuania (herring, cod, flounder) and Poland (herring) reports contaminant data within HELCOM. Within JMP time series of various contaminants in biota are reported from Belgium, Denmark, France, Germany, Iceland, The Netherlands, Norway, Spain, Sweden, Ireland and UK. All the countries within HELCOM and OSPAR submit the data directly to ICES.

During 2007 the National Swedish marine monitoring programme has been expanded, herring from 10 new sites have been added. Name and location of these sites are found under figure 5. From 2007 and onward herring has also been collected by the Swedish board of Fisheries from a number of sites in the open sea (Baltic). 2 sites, one from the Baltic Proper and one from the Bothnian Sea (fish from 2008) has been analysed for various contaminants within the national monitoring programme.

5.1 Rånefjärden, Bothnian Bay, north
Co-ordinates: 65 45’ N, 22 25’ E within a radius of 3’, ICES 60H2 93
County: Norrbottens län

Surface salinity: <3 PSU
Average air temperature: January: -10° / April: -1° / July: 15° / October: 2°

Sampling matrix: Baltic herring and perch (only sampling), autumn
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’s.
5.2 Harufjärden, Bothnian Bay, north
Co-ordinates: 65 35’ N, 22 53’ E within a radius of 3’, ICES 60H2 93
County: Norrbottens län

Surface salinity: <3 PSU
Average air temperature: January: -10° / April: -1° / July: 15° / October: 2°

Sampling matrix: Baltic herring, autumn

5.3 Kinnebäcksfjärden, Bothnian Bay
Co-ordinates: 64 50’ N, 21 16’ E within a radius of 3’, ICES 58H1
County: Norrbottens län

Average air temperature: January: -10° / April: -1° / July: 15° / October: 2°

Sampling matrix: Baltic herring and perch, autumn
Start: Only sampling

5.4 Holmöarna, Bothnian Bay, south, coastal site
Co-ordinates: 63 41’ N, 20 53’ E, ICES 56H0
County: Västerbottens län

Surface salinity: c 4 PSU
Average air temperature: January: -5° / April: 0° / July: 15° / October: 4°

Start year for various contaminants and species:

<table>
<thead>
<tr>
<th>Contaminant/Species</th>
<th>PCB/DDT</th>
<th>HCH/HCB</th>
<th>Hg</th>
<th>Pb/Cd/Cu/Zn</th>
<th>Cr/Ni</th>
<th>PCDD/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perch</td>
<td>1980</td>
<td>(19(89)95)</td>
<td>19(91)95</td>
<td>1995</td>
<td>1995</td>
<td>2007</td>
</tr>
</tbody>
</table>

Both species are collected during the autumn. Baltic herring is also sampled (since 2007).

At Holmöarna the contaminant monitoring is integrated with fish population and physiology monitoring, carried out by the Swedish Board of Fisheries and the University of Gothenburg.

5.5 Örefjärden, Bothnian Bay, south
Co-ordinates: 63 25’ N, 19 24’ E within a radius of 3’, ICES 55G9
County: Västernorrlands län

Average air temperature: January: -10° / April: -1° / July: 15° / October: 2°

Sampling matrix: Baltic herring and perch, autumn
Start: Only sampling

5.6 Gaviksfjärden, Bothnian Bay, south
Co-ordinates: 63 07’ N, 18 38’ E within a radius of 3’, ICES 55G8
County: Västernorrlands län

Average air temperature: January: -10° / April: -1° / July: 15° / October: 2°

Sampling matrix: Baltic herring and perch (only sampling), autumn
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’s

5.7 Långvindsfjärden, Bothnian Sea
Co-ordinates: 61 46’ N, 17 27’ E within a radius of 3’, ICES 52G7
County: Gävleborgs län

Average air temperature: January: -3° / April: 2° / July: 15° / October: 6°

Sampling matrix: Baltic herring and perch (only sampling), autumn
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’s

5.8 Ängskärsklubb, Bothnian Sea
Co-ordinates: 60 44’ N, 17 52’ E, ICES 50G7 83
County: Gävleborgs län / Uppsala län

Surface salinity: c 6 PSU
Average air temperature: January: -3° / April: 2° / July: 15° / October: 6°

Sampling matrix: Baltic herring, spring/autumn
Start, spring: 1972 DDT/PCB, 1972-75 Hg, 1988 HCH’s/HCB, 1979 PCDD/F, 2005 PFC

In 1996 collection and analyses of herring samples from four other sites in the region were financed by the county board of Gävleborgs län. This investigation is valuable to estimate the representativeness of the well established sample site at Ängskärsklubb. It also gives information on small scale geographical variation in general.

5.9 Lagnö, Baltic Proper, north
Co-ordinates: 59 25’ N, 18 37’ E, ICES 47G8
County: Stockholms län

Surface salinity: c 6-7 PSU
Average air temperature: January: -1° / April: 3° / July: 16° / October: 7°

Sampling matrix: Baltic herring and perch (only sampling), autumn
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’s

5.10 Landsort, Baltic Proper, north
Co-ordinates: 58 42’ N, 18 04’ E, ICES 46G8 23
County: Stockholms län / Södermanlands län
Surface salinity: c 6-7 PSU
Average air temperature: January: -1° / April: 3° / July: 16° / October: 7°

Sampling matrix: Baltic herring, autumn

Herring samples have also been collected to analyse the metallothionein concentration and to compare the fat composition in old versus young herring specimen.

5.11      Kvädöfjärden, Baltic Proper, coastal site
Co-ordinates: 58 2’ N, 16 46’ E, ICES 45G6
County: Östergötland / Kalmar

Surface salinity: c 6-7 PSU
Average air temperature: January: -1° / April: 4° / July: 17° / October: 7°

Start year for various contaminants and species:

<table>
<thead>
<tr>
<th>Contaminant/Species</th>
<th>PCB/DDT</th>
<th>HCH/HCB</th>
<th>Hg</th>
<th>Pb/Cd/Cu/Zn</th>
<th>Cr/Ni</th>
<th>PAH</th>
<th>PCDD/F</th>
</tr>
</thead>
</table>

All species are collected during the autumn.

At Kvädöfjärden the contaminant monitoring is integrated with fish population and -physiology monitoring, carried out by the Swedish Board of Fisheries and the University of Gothenburg.

Neuman et al. (1988) report decreasing Secchi depths during the invested period; somewhat below 6 m 1980 to somewhat above 4 m in the middle of the eighties.

5.12      Byxelkrok, Baltic Proper
Co-ordinates: 57 19’ N, 17 309’ E, ICES 43G6
County: Kalmar län

Surface salinity: c 7 PSU
Average air temperature: January: 0° / April: 3° / July: 16° / October: 8°

Sampling matrix: Baltic herring, autumn
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’s
5.13  **St Karlsö, Baltic Proper**  
Co-ordinates: 57 11’ N, 17 59’ E, ICES 43G7  
County: Gotland

St Karlsö is situated about 7 km west of the island Gotland and about 80 km east of the Swedish Baltic coast.

Surface salinity: c 7 PSU  
Average air temperature: January: 0° / April: 3° / July: 16° / October: 8°

Sampling matrix: Guillemot egg, May  
Start: 1968 DDT/PCB, 1969 Hg, 1988 HCH’s/HCB

5.14  **South east of Gotland, Baltic Proper**  
Co-ordinates: 56 53’ N / 18 38’ E, ICES 42G8 43  
County: Gotland

Surface salinity: c 7-8 PSU  
Average air temperature: January: 0° / April: 3° / July: 16° / October: 8°

Sampling matrix: Cod, autumn  

5.15  **Utlängan, Karlskrona archipelago, Baltic Proper, south**  
Co-ordinates: 55 57’ N, 15 47’ E, ICES 40G5 73  
County: Blekinge

Surface salinity: c 8 PSU  
Average air temperature: January: 0° / April: 4° / July: 16° / October: 8°

Start year for analysis of various contaminants in herring spring/autumn:

<table>
<thead>
<tr>
<th>Contaminant/Species</th>
<th>PCB/DDT</th>
<th>HCH/HC</th>
<th>Hg</th>
<th>Pb/Cd/Cu/Zn</th>
<th>Cr/Ni</th>
<th>PBDE/HBCD</th>
<th>PCDD/F</th>
<th>PFC</th>
</tr>
</thead>
</table>

In 1997 collection and analyses of herring samples from one site rather close to the reference site and two sites in Hanöbukten were financed by the Environmental Protection Agency. This investigation is valuable to estimate the representativeness of the well-established sample site at Utlängan. It will also give information on small-scale geographical variation in general.
5.16 Västra Hanöbukten, Baltic Proper, south  
Co-ordinates: 55 45’ N, 14 17’ E, ICES 40G4  
County: Skåne  
Surface salinity: c 8 PSU  
Average air temperature: January: 0° / April: 4° / July: 16° / October: 8°  
Sampling matrix: Baltic herring, autumn  
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’s

5.17 Abbekås, Baltic Proper, south  
Co-ordinates: 55 18’ N, 13 36’ E, ICES 39G3  
County: Skåne  
Surface salinity: c 8 PSU  
Average air temperature: January: 0° / April: 4° / July: 16° / October: 8°  
Sampling matrix: Baltic herring, autumn  
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’

5.18 Kullen, Kattegatt, Swedish west coast  
Co-ordinates: 56 19’ N / 12 23’ E, ICES 41G2  
County: Skåne  
Surface salinity: c 20-25 PSU  
Average air temperature: January: 0° / April: 5° / July: 16° / October: 8°  
Sampling matrix: Herring, autumn  
Start: 2007 DDT/PCB, Hg, Pb/Cd/Cu/Zn/Cr/Ni, HCH’s/HCB, PBDE/HBCD, PCDD/F and PFC’

5.19 Fladen, Kattegatt, Swedish west coast  
Co-ordinates: 57 14’ N / 11 50’ E, ICES 43G1 83, JMP J34  
County: Halland  
Surface salinity: c 20-25 PSU  
Average air temperature: January: 0° / April: 5° / July: 16° / October: 8°  
Start year for various contaminants and species:

<table>
<thead>
<tr>
<th>Contaminant/Species</th>
<th>PCB/DDT</th>
<th>HCH/HCB</th>
<th>Hg</th>
<th>Pb/Cd/Cu/Zn</th>
<th>Cr/Ni</th>
<th>PAH</th>
<th>PBDE/HBCD</th>
<th>PCDD/F</th>
<th>PFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dab</td>
<td>1981</td>
<td>1988</td>
<td>1981</td>
<td>1981</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All species are collected during the autumn.
5.20 Nidingen, Kattegatt, Swedish west coast

Since 1987 blue mussels have been collected at Nidingen about 10 km NNE of Fladen.

5.21 Väderöarna, Skagerack, Swedish west coast

Co-ordinates: 58°31’ N, 10°54’ E ICES 46G0 93, JMP J33
County: Göteborgs- o Bohus län

Surface salinity: c 25-30 PSU
Average air temperature: January: 0°C / April: 5°C / July: 16°C / October: 8°C

Start year for various contaminants and species:

<table>
<thead>
<tr>
<th>Contaminant/Species</th>
<th>PCB/PCB</th>
<th>HCH/HCB</th>
<th>Hg</th>
<th>Pb/Cd/Cu/Zn</th>
<th>Cr/Ni</th>
<th>PAH</th>
<th>PBDE/HBCD</th>
<th>PCDD/F</th>
<th>PFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flounder</td>
<td>1980</td>
<td>1988</td>
<td>1980</td>
<td>1981</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All species are collected during the autumn.

5.22 Fjällbacka, Skagerack, Swedish west coast

Eelpout and blue mussels are collected at Musön, Fjällbacka at the coast (about 10 km east of Väderöarna).

5.23 Bonden, northern Bothnian Sea

Co-ordinates: 63°25’ N, 20°02’ E, ICES 55H0
County: Västerbotten

Surface salinity: c 5 PSU
Average air temperature: January: -5°C / April: 0°C / July: 15°C / October: 4°C

Sampling matrix: Guillemot egg (only rotten eggs), summer
Start: 1991 DDT/PCB

The collection of egg samples has been more or less sporadic however, since the population development has been low.
6 Analytical methods

6.1 Trace metals

The analyses of trace metals are carried out at the Department of Environmental Assessment at Swedish University of Agricultural Sciences. Analytical methods for metals in liver are described by Borg et al., 1981, for mercury by May & Stoepppler, 1984, and Lindsted & Skare, 1971. The laboratory participates in the periodic QUASIMEME intercallibration rounds. It has also participated in the programme for sampling quality control, QUASH.

CRM’s used for mercury are:
and for the other metals:

Due to a change of method for metal analysis in 2004, values after 2003 are not presented in this section. The new method is under investigation, since the values are uncertain.

6.2 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).

6.2.1 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 ICO/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.
6.2.2 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 were introduced. The standards were made from solutions where the concentrations of each compound had lower uncertainty (±5%) compared with the old standards (±10%).

6.2.3 Detection limits and the uncertainly 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 6833 PCB and pesticides values from control samples during 16 years. The uncertainly in the measurements is expressed as two relative standard deviations and is less the 36% in the interval 0.04-0.5 ng/g, less then 22% in the interval 0.5-5 ng/g and less then 16% when higher then 5 ng/g. The uncertainly 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 1411 values from control samples during 9 years.

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

6.2.4 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.

Coeluation 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. Coeluation 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 find 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.

6.2.5 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.

6.2.6 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. 608 of the 635 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 forth following intercalibration exercises have shown improved results. As a total, 67 of the 81 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.

6.3 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.

6.4 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.

6.4.1 Sample preparation and instrumental analysis
A sample aliquot of 0.5 to 1.5 g homogenized tissue was transferred to a polypropylene (PP)-centrifuge tube, and spiked with 10 ng each of a suite of mass-labelled internal standards (18O- or 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. A volume of 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 15 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.

6.4.2 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 (PFSAs), including perfluorooctane sulfonamide (PFOSA), were determined to 70–95%. Furthermore, mean method recoveries of the mass labelled internal standard compounds were between 51% and 109%. Method quantification limits (MQLs) for all analytes were determined on the basis of blank extraction experiments and ranged between 0.2 and 0.6 ng/g wet weight (w.w.) for the different compounds. 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 15% for all 7 compounds quantified in the ILC.

6.5 Polycyclic Aromatic Hydrocarbons

The analysis of PAH are carried out at IVL Swedish Environmental Research Institute. The extraction and analysis of the samples were performed according to IVLs accredited method for PAH.

The biota samples were spiked with recovery standard, homogenised in acetone and extracted in an ultrasonic bath. The extract was safeguarded and the samples were extracted once more with acetone and twice with pentane/ether. The extracts were combined and the organic compounds were extracted to an organic phase by liquid/liquid extraction with water and pentane and further concentrated under nitrogen.

The samples were hydrolyzed and pre-treatment procedures, such as fractionation of the organic compounds on silica were performed as additional "clean-up" procedures. Laboratory blanks followed the same procedures as the samples in the analytical work.

The determination of the PAH components was carried out using a high performance liquid chromatograph (HPLC, type Varian Prostar 240, M410) with a 5 μm C_{18}-column (Chromosphere PAH 100* 3 mm, Chrompack). A linear gradient elution program was used, starting with acetonitrile/water 50:50 and ending with 100 % acetonitrile (Rathburne HPLC-grade) at a flow rate of 1 ml min^{-1}. A fluorescence detector (Varian Prostar 363) with a wavelength program optimized for each PAH was used for detection. The peak heights were registered with a chromatographic system from Varian (Star). The concentrations of 16 different PAH compounds were calculated by comparison to a certified standard, NIST, SRM 1647.

All the standards used (both internal standard and quantification standards) are certified with known purity and precision.
7 Statistical treatment, 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.

<table>
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<th>2%</th>
<th>3%</th>
<th>4%</th>
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<td>4</td>
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<td>10</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

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 Adjustments for covariables
It has been shown that metal concentrations in cod liver are influenced by fat content (Grimås et al., 1985). Consequently the metal concentrations in cod liver are adjusted for fat content. In some occasions (when the average fat content differs between years) this is of major importance and might change the direction of the slope and decrease the between-year variation considerable. For the same reasons, mercury concentrations are adjusted for body weight and organochlorines in spring caught herring muscle tissue are adjusted for fat content (Bignert et al., 1993) where appropriate (indicated in the header text of the figures).

7.3 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_{0.05} distribution with n-2 degrees of freedom. When calculating the i\textsuperscript{th} standardised residual the current observation is left out implying that the i\textsuperscript{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.

7.4 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, no time series are 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, age class and sampling locality. Age class may be replaced by shell length for blue mussels. Sampling locality is in a few cases in a coded form to save space; C1=herring, Harufjärden, C2=herring, Ångskärsklubb, C3=herring, Landsort, C4=herring, Utlångan, C6=herring, Fladen, V2=spring caught herring, Ångskärsklubb, V4=spring caught herring, Karlskrona archipelago, U8=guillemot egg, St Karlsö, G5=cod south east of Gotland, G6=cod, Fladen, P2=perch, Kvädöfjärden, M6=blue mussel, Fladen/Nidingen, M3=blue mussel, Väderöarna, L6=dab, Fladen, P3=flounder, Väderöarna. 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 9.
reports the coefficient of determination ($r^2$) together with a p-value for a two-sided test (H0: slope = 0) i.e. a significant value is interpreted as a true change, provided that the assumptions of the regression analysis is fulfilled.

reports the concentration estimated from the regression line for the last year together with a 95% confidence interval, e.g. $y(96)=2.55(2.17,3.01)$ is the estimated concentration of year 1996 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.

reports Kendall's $\tau$, and the corresponding p-value.

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 $\tau$ are reported.

7.5 Legend to the three dimensional maps

The height of the bars represents a geometric mean of the last 5 years or less if results are not available
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 asterix 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. As an example, the time series of lead concentrations in fish liver seem to suffer from occasional outliers, especially in the beginning of the investigated period 1981-1984. The estimated median sensitiveness of these series is 12.5% a year. If a few outliers, identified by means of objective statistical criteria’s, are deleted, the calculated median sensitiveness improves to 5.8%. In the presented results suspected outliers are included which means that the power and sensitiveness might be underestimated.

Due to a change of method for metal analysis in 2004, values after 2003 are not presented. Metals will be analysed by a new laboratory from 2009/2010 (material from 2007) and an intercalibration will be conducted to provide comparable results for the timeseries.

Table 8.1. reports the number of years that various contaminants have been analysed and detected from the monitored sites. Generally the monitoring of trace metals has continued for about 25-30 years, PCB and DDT for about 25-30 years (spring caught herring and guillemot egg however, more than 35 years), HCH, HCB and PCDD/PCDF for about 20 years and PBDE/HBCD only for about 10 years.
### Table 8.1.
Number of years that various contaminants have been analysed and detected.

|          | C1 | C2 | V2 | C3 | C4 | V4 | C6 | G5 | G6 | P1 | P2 | Z1 | Z2 | Z3 | M2 | M6 | M3 | L6 | P3 | U8 |
|----------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Hg**     | 26 | 26 | 15 | 27 | 27 | 14 | 27 | 11 | 28 | 28 | 12 | 24 | 11 | 12 | 11 | 12 | 11 | 24 | 26 | 15 | 34 |
| Pb*      | 21 | 22 | 8  | 23 | 23 | 5  | 23 | 9  | 23 | 23 | 9  | 8  | 9  | 8  | 9  | 9  | 8  | 9  | 21 | 22 | 14 | 14 | 8  |
| Cd*      | 22 | 22 | 2  | 8  | 23 | 23 | 7  | 23 | 9  | 23 | 23 | 9  | 7  | 9  | 8  | 9  | 7  | 8  | 9  | 21 | 22 | 14 | 14 | 8  |
| Ni*      | 9  | 9  | 8  | 9  | 9  | 7  | 9  | 9  | 9  | 9  | 9  | 8  | 8  | 7  | 9  | 8  | 9  | 8  | 9  | 9  | 8  | 8  |
| Cr*      | 9  | 9  | 8  | 9  | 9  | 7  | 9  | 9  | 9  | 9  | 8  | 7  | 8  | 8  | 9  | 9  | 9  | 8  | 9  | 9  | 8  | 8  |
| Cu*      | 22 | 22 | 8  | 23 | 23 | 7  | 23 | 9  | 23 | 23 | 9  | 8  | 7  | 9  | 8  | 9  | 7  | 9  | 8  | 9  | 21 | 22 | 14 | 14 | 8  |
| Zn*      | 21 | 21 | 8  | 22 | 22 | 7  | 22 | 9  | 22 | 22 | 9  | 8  | 7  | 9  | 8  | 8  | 9  | 21 | 21 | 13 | 13 | 8  |
| sPCB     | 31 | 29 | 35 | 30 | 29 | 34 | 29 | -  | 29 | 28 | 21 | 25 | -  | -  | -  | -  | 22 | 23 | 13 | 15 | 37 |
| CB-153   | 20 | 19 | 20 | 22 | 21 | 20 | 21 | 13 | 20 | 19 | 14 | 14 | 11 | 14 | 14 | 11 | 14 | 14 | 21 | 20 | 5  | 6  |
| DDE      | 29 | 28 | 35 | 30 | 29 | 24 | 29 | 13 | 28 | 28 | 22 | 26 | 11 | 14 | 14 | 14 | 14 | 23 | 23 | 23 | 14 | 15 | 37 |
| α-HCH    | 11 | 16 | 16 | 22 | 21 | 18 | 14 | 7  | 20 | 19 | 5  | 14 | 6  | 8  | 4  | 13 | 14 | 14 | 14 | 12 | 16 | 15 | 6  |
| β-HCH    | 10 | 17 | 20 | 22 | 21 | 20 | 18 | 10 | 2  | 20 | 12 | 4  | 3  | 6  | 11 | 2  | 12 | 9  | 5  | -  | -  | 21 |
| γ-HCH    | 13 | 15 | 17 | 21 | 20 | 18 | 14 | 7  | 19 | 16 | 5  | 9  | 5  | 8  | 8  | 12 | 16 | 15 | 6  | 16 | 6  | 13 |
| HCB      | 20 | 18 | 20 | 21 | 21 | 20 | 21 | 12 | 20 | 19 | 14 | 17 | 11 | 14 | 14 | 14 | 9  | 10 | 6  | 6  | 22 |
| TCDD-     | 18 | -  | -  | -  | 18 | -  | 19 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 38 |
| eqvBDE-47| 10 | 9  | 7  | 10 | 10 | 6  | 10 | 9  | 10 | 10 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 34 |
| HBCD     | 10 | 9  | 7  | 10 | 10 | 7  | 10 | 9  | 10 | 7  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 35 |

- * values until 2003
- ** values until 2006

Table 8.1 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.
Number of years required to detect an annual change of 5% with a power of 80%. C1=herring, Harufjärden, C2=herring, Ängskärsklubb, C3=herring, Landsort, C4=herring, Utlångan, C6=herring, Fladen, V2=spring caught herring, Ängskärsklubb, V4=spring caught herring, Karlskrona archipelago, U8=guillemot egg, St Karlsö.

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<th>C4</th>
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<th>G6</th>
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### Other trace metals

**Based on geometric means on a dry weight basis**

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</tbody>
</table>

- * values until 2003
- ** values until 2006
### Organochlorines

Based on geometric means on a lipid weight basis

|     | C1 | C2 | C3 | C4 | C6 | C7 | V2 | V4 | U8 | G5 | G6 | P1 | P2 | M2 | M6 | M3 | Median |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-------|
| sPCB | 7  | 5  | 5  | 15 | 14 | -  | 18 | 16 | 12 | *1 | *2 | *1 | *2 | -  | *1 | *1 | 16.5  |
| DDE  | *2 | 16 | 17 | *1 | 18 | 18 | 19 | 16 | *1 | 16 | *1 | *1 | *2 | 17 | 20 | 18 | 18    |
| α-HCH | 10 | 14 | 12 | 8  | 7  | 8  | 9  | *1 | 15 | 10 | *1 | 8  | 16 | 17 | 13 | 18 | 11    |
| β-HCH | 10 | *1 | 12 | 13 | *2 | -  | 10 | *1 | 10 | 25 | -  | -  | 15 | 23 | 17 | 14    |
| γ-HCH | *1 | 16 | 12 | *1 | *1 | 22 | *1 | *1 | 32 | 11 | *1 | 15 | *1 | 14 | *1 | *1 | 15.5  |
| HCB  | 14 | 20 | 19 | 19 | 15 | 17 | 17 | *1 | 17 | 18 | 15 | 21 | 16 | 16 | *2 | 17    |
| TCDD-eqv | 20 | -  | -  | 16 | 18 | -  | -  | -  | *1 | -  | -  | -  | -  | -  | -  | -  | 17    |
| BDE-47 | 19 | 15 | 16 | *1 | 11 | 15 | 24 | 20 | *2 | 15 | 18 | -  | -  | -  | -  | -  | 16    |
| HBCD | 23 | 23 | 15 | 20 | 17 | 17 | 22 | *2 | *1 | *2 | 21 | -  | -  | -  | -  | -  | 20    |

* indicates a significant non-linear trend component

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. The table shows that the sensitiveness for Pb and Cd is approximately the same (10%-20%) whereas for Zn and Cu it is somewhat better (5-10%). For PCB, DDE, HCH and HCB the estimated sensitiveness is about 5-12%. For the TCDD-eqv the estimated median sensitiveness 12% and for BDE-47 and HBCD 11-16%. Biological variables like the condition index for herring, cod and perch show a sensitiveness of about 1-2%.

**Table 8.3.** Lowest detectable trend within a 10-year period with a power of 80% for various variables in various matrices at various sites. The top row for every substance gives the figure based on the residual variance for the whole period, whereas the bottom row gives the figure for the last ten years of the time series. If no figure is given for the last 10 year period this indicates that the time series show a significant non-linear trend component. The figure for the whole time period is calculated considering the non-linear trend component.
### Mercury
Based on geometric means on a fresh weight basis

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<th>G6</th>
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### Other trace metals
Based on geometric means on a dry weight basis

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* values until 2003
** values until 2006

### Organochlorines
Based on geometric means on a lipid weight basis

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### Biological variables

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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. For the shorter time series of HCH’s and HCB however, about 80-100%. For the series of α- and γ-HCH though, the decreasing rate has been considerable (about 15-20% a year) leading to statistically significant results from most sites.
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.

**Mercury**
Based on annual geometric mean concentrations on a fresh weight basis

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**Other trace metals**
Based on annual geometric mean concentrations on a dry weight basis

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**Organochlorines**
Based on annual geometric mean concentrations on a lipid weight basis

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| TCDD-equiv | .68 | - | - | - | .98 | - | .9 | - | - | - | - | *1.0 | - | - | - 
| BDE-47 | .17 | .25 | .07 | .26 | *.2 | .07 | .72 | .23 | .34 | .20 | - | - | *.10 | - | - | - 
| HBCD | .11 | .10 | .06 | .31 | .15 | *0 | .17 | .13 | *1 | .08 | - | - | *1.0 | - | - | - 

* indicates a significant non-linear trend component
9 Condition

The stoutness of fish, i.e. weight against length is a common measure of the ‘degree of well-being’ of an individual or a population.

In this report the commonly used ‘condition factor’, K, (Vibert & Lagler, 1961) is used:

\[ K = 100 \frac{W}{L^3} \]

where the weight (W) is given in grams and the length (L) in centimetres.

9.1 Temporal variation

Significant decreasing trends for the condition factor of herring are observed from Harufjärden, Landsort and Utlängan (autumn and spring) while it increases at Ängskärsklubb in spring caught herring for the whole time series and in autumn caught herring during the last ten years. The increase at Ängskärsklubb may be explained by an unintentional increase of the average age over time in the collected samples. A significant increase is also seen in herring from Fladen for the last ten years.

The condition factor estimated for cod show significant upward trends at both Gotland and Fladen over the whole investigated period, but for the recent 5-10 years indications of a decreasing trend is observed at both locations. The observed increase might be explained by the simultaneous decrease in population density during the investigated period.

Significantly decreasing trends for the condition factor are observed at Holmöarna for perch and eelpout. The overall trend for perch at Kvädöfjärden is increasing significantly (only 0.14%), but for the last ten years a steeper upward trend is observed (1%).

9.2 Spatial variation

The average condition factor, estimated over a period of over 20 years is slightly lower in herring sampled at Harufjärden in the northern parts of the Bothnian Bay compared to samples from Fladen and Väderöarna at the Swedish west coast.
Condition factor, cod and perch

Cod (3-4), SE Gotland

- Condition factor: 0.5 to 1.0
- Fisheries: 1980 to 1995
- Number of data: 433
- Slope: 0.978 to 1.04
- SD: 6.4% to 8.5%
- Power: 1.0%
- \( r^2 = 0.16 \), p < 0.030

Cod (2-3), Fladen

- Condition factor: 0.5 to 1.0
- Fisheries: 1980 to 1995
- Number of data: 499
- Slope: 0.959 to 1.01
- SD: 5.9% to 8.5%
- Power: 1.0%
- \( r^2 = 0.24 \), p < 0.006

Perch, Holmoarna

- Condition factor: 0.5 to 1.0
- Fisheries: 1980 to 1995
- Number of data: 305
- Slope: 1.17 to 1.22
- SD: 3.7% to 6.5%
- Power: 1.0%
- \( r^2 = 0.23 \), p < 0.020

Kvadofjarden (3-4)

- Condition factor: 0.5 to 1.0
- Fisheries: 1980 to 1995
- Number of data: 308
- Slope: 1.19 to 1.23
- SD: 2.6% to 6.0%
- Power: 1.0%
- \( r^2 = 0.12 \), p < 0.070

Condition factor, eelpout

Holmoarna

- Condition factor: 0.5 to 1.0
- Fisheries: 1994 to 1998
- Number of data: 109
- Slope: 0.31 to 1.1
- SD: 4.5% to 11%
- Power: 1.0%
- \( r^2 = 0.44 \), p < 0.018

Kvadofjarden

- Condition factor: 0.5 to 1.0
- Fisheries: 1994 to 1998
- Number of data: 123
- Slope: 0.09 to 1.1
- SD: 11% to 13%
- Power: 0.77%
- \( r^2 = 0.06 \), p < 0.074

Vaderoarna

- Condition factor: 0.5 to 1.0
- Fisheries: 1990 to 2000
- Number of data: 237
- Slope: -0.12 to 1.1
- SD: 15% to 13%
- Power: 4.9%
- \( r^2 = 0.06 \), p < 0.074
10 Fat content

The fat content is determined in samples that are analysed for organochlorines i.e. herring, eelpout (dab and flounder) muscle, cod liver and blue mussel soft body. A strong negative correlation between concentrations of organochlorines (expressed on a fat weight basis) and fat content in spring caught herring has been shown (Bignert et al. 1993) but also between the concentration of various metals and fat content in cod liver (Grimås et al. 1985). The analysed concentrations of these contaminants are hence adjusted for varying fat content.

In general, an extremely low fat content, due to e.g. starvation, may cause elevated concentrations of organo chlorines expressed on a fat weight basis.

The sample fat content is determined after extraction with acetone and hexane with 10% ether without heating (Jensen et al. 1983) in the present investigation.

The result of the fat determination may vary considerable depending on the extraction method used.

In herring muscle tissue, the subcutaneous fat layer is removed before the samples are prepared. Analyses of fat content including skin and subcutaneous fat shows at least 1.5 times higher fat content.

10.1 Temporal variation

In the Baltic, decreasing trends of fat in herring muscle tissue are indicated from Harufjärden, Landsort and Utlängan (autumn and spring). The fast decrease at Landsort and Utlängan (autumn) seems to have ceased during the past decade (with an exception of last three years when the fat content was down to really low levels, less than 2%). An increasing trend is observed for fat in herring muscle from Fladen for the past ten years.

Overall increasing trends in fat content are found in cod liver from south east of Gotland and Fladen, but during the past ten years the fat content has decreased in cod liver south east of Gotland. The fluctuating fat content in cod has to be considered when evaluating the time series of trace metals in cod liver (see above).

Decreasing trends of fat content in perch muscle are indicated at both Holmöarna and Kvädöfjärden in the Baltic. Eelpout from Holmöarna in the Baltic proper and Väderöarna on the west coast is also showing a decline in fat content.

The time series of blue mussel from Väderöarna shows a decrease in fat content during the past ten years.

10.2 Spatial variation

Today, the fat content in autumn caught herring from the Baltic is rather similar in muscle tissue from all investigated sites. In the beginning of the eighties however, the samples
from Ängskärsklubb in the Bothnian Sea and Harufjärden in the Bothnian Bay were lower compared to samples from the Baltic Proper. The fat content in herring from Skagerack varies and can sometimes be about twice as high compared to herring muscle from the Baltic and the Kattegatt. This is not surprising since Atlantic herring muscle tissue may contain more than 15% fat.

The fat content in cod liver is highly variable even between specimens caught at the same time at the same place. The geometric mean fat content over time in samples from SE of Gotland is more than 2.5 times higher compared to cod livers from the Kattegatt. This difference is significant.

10.3 Seasonal variation
Fat content in spring caught herring from Ängskärsklubb show approximately the same mean value as herring from the same site caught in the autumn whereas herring from Karlskrona archipelago caught in the autumn show about 30% higher mean fat content compared to spring caught herring from the same area.
Table 10.1. Trend (in %) for concentration of fat (%) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The total number of analyses and the number of years are also presented. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>N yrs</th>
<th>Year</th>
<th>trend (95% ci)</th>
<th>last year (95% ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>586</td>
<td>29</td>
<td>78-08</td>
<td>-1.4 (-2.7,-.46)*</td>
<td>2.3 (1.9-2.7)</td>
</tr>
<tr>
<td>Ängskärskl. aut.</td>
<td>3-5</td>
<td>462</td>
<td>28</td>
<td>78-07</td>
<td>2.3 (1.9-2.8)</td>
<td></td>
</tr>
<tr>
<td>” spring</td>
<td>2-5</td>
<td>644</td>
<td>35</td>
<td>72-08</td>
<td>2.7 (2.3-3.2)</td>
<td></td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>460</td>
<td>30</td>
<td>78-08</td>
<td>-1.5 (-2.9,-.17)*</td>
<td>2.8 (2.2-3.5)</td>
</tr>
<tr>
<td>Utlängan, aut.</td>
<td>2-4</td>
<td>593</td>
<td>29</td>
<td>80-08</td>
<td>-3.8 (-5.1,-2.5)*</td>
<td>1.7 (1.4-2.1)</td>
</tr>
<tr>
<td>” spring</td>
<td>2-3</td>
<td>595</td>
<td>34</td>
<td>72-08</td>
<td>-2.3 (-3.2,-1.4)*</td>
<td>1.4 (1.1-1.7)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>639</td>
<td>29</td>
<td>80-08</td>
<td>-2.3 (-3.2,-1.4)*</td>
<td>1.4 (1.1-1.7)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>262</td>
<td>13</td>
<td>95-08</td>
<td>95-08</td>
<td>5.5 (3.4-8.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Cod liver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>421</td>
<td>29</td>
<td>80-08</td>
<td>1.8 (.81, 2.7)*</td>
<td>68 (58-79)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>470</td>
<td>29</td>
<td>80-08</td>
<td>2.4 (.25, 4.5)*</td>
<td>26 (19-37)</td>
</tr>
<tr>
<td><strong>Perch muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td>281</td>
<td>22</td>
<td>80-07</td>
<td>80-08</td>
<td>-.91 (-1.2,-.58)*</td>
<td>.67 (.63-.70)</td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>310</td>
<td>27</td>
<td>80-08</td>
<td>80-08</td>
<td>-.84 (-1.4,-.33)*</td>
<td>.63 (.58-.68)</td>
</tr>
<tr>
<td><strong>Eelpout muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td>97</td>
<td>11</td>
<td>95-07</td>
<td>95-08</td>
<td>-4.7 (-8.2, -1.3)*</td>
<td>.55 (.44-.70)</td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>123</td>
<td>14</td>
<td>95-08</td>
<td>95-08</td>
<td>-.84 (-1.4,-.33)*</td>
<td>.59 (.49-.71)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>238</td>
<td>17</td>
<td>88-08</td>
<td>88-08</td>
<td>-3.1 (-5.8,-.35)*</td>
<td>.53 (.40-.71)</td>
</tr>
<tr>
<td><strong>Dab muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>3-6</td>
<td>158</td>
<td>13</td>
<td>81-94</td>
<td>-3.7 (-5.2,-2.2)*</td>
<td>.61 (.54-.68)</td>
</tr>
<tr>
<td><strong>Flounder muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>4-6</td>
<td>190</td>
<td>15</td>
<td>80-94</td>
<td>-3.4 (-5.7,-1.0)*</td>
<td>.60 (.50-.73)</td>
</tr>
<tr>
<td><strong>Blue mussel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>99</td>
<td>26</td>
<td>81-08</td>
<td>81-08</td>
<td>.89 (.61-1.3)</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>106</td>
<td>28</td>
<td>80-08</td>
<td>80-08</td>
<td>1.5 (1.1-2.0)</td>
<td></td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>74</td>
<td>14</td>
<td>95-08</td>
<td>95-08</td>
<td>1.4 (1.1-1.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Guillemot egg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td>412</td>
<td>38</td>
<td>69-08</td>
<td>69-08</td>
<td>12 (11-13)</td>
<td></td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05
**Fat %, cod liver and perch muscle**

**Cod (3-4), SE Gotland**
- n(tot)=421, n(yrs)=29
- m=52.8 (48.5, 58.1)
- slope=1.9% (1.6, 2.2)
- SD(i)=17%, 14%, 13 yr
- power=1.0, 0.47, 0.05
- y(08)=67.5 (57.9, 77.8)
- r=0.16, p=0.02

**Cod (2-3), Fladen**
- n(tot)=470, n(yrs)=29
- m=18.7 (15.5, 22.6)
- slope=2.4% (0.3, 4.5)
- SD(i)=39%, 3.0%, 21 yr
- power=1.0, 0.13, 0.05
- y(08)=26.1 (18.5, 36.8)
- r=0.20, NS

**Perch**
- n=704 (689, 741)
- slope=-88% (-1.2, -5.4)
- SD(i)=61%, 70%, 7 yr
- power=1.0
- y(08)=67.1 (63.7, 70.8)
- r=0.19, p=0.01

**Holmoarna**
- n(tot)=281, n(yrs)=22
- m=152 (149, 156)
- slope=2.9% (1.5, 4.5)
- SD(i)=52%, 3.0%, 21 yr
- power=1.0
- y(08)=65.2 (59.4, 72.5)
- r=0.19, NS

**Kvadofjarden**
- n(tot)=312, n(yrs)=27
- m=18.7 (16.5, 21.5)
- slope=3.1% (2.2, 4.1)
- SD(i)=42%, 3.0%, 21 yr
- power=1.0
- y(08)=26.1 (18.5, 36.8)
- r=0.20, NS

**Fat %, blue mussel soft body**

**Fladen**
- n(tot)=99, n(yrs)=26
- m=1.08 (0.8, 1.3)
- slope=-1.4% (-4.0, 1.1)
- SD(i)=39%, 3.0%, 21 yr
- power=1.0
- y(08)=0.89 (0.6, 1.2)
- r=0.05, NS

**Vaderoarna**
- n(tot)=106, n(yrs)=28
- m=1.33 (1.1, 1.6)
- slope=0.8% (-0.8, 2.6)
- SD(i)=32%, 2.7%, 19 yr
- power=1.0
- y(08)=1.50 (1.2, 2.0)
- r=0.04, NS

**Kvadofjarden**
- n(tot)=75, n(yrs)=14
- m=1.27 (1.1, 1.4)
- slope=0.1% (-2.3, 4.4)
- SD(i)=20%, 4.8%, 14 yr
- power=1.0
- y(08)=1.27 (0.9, 1.6)
- r=0.04, NS
Fat %, Eelpout

Holmoarna
- \( n(tot) = 97, n(\text{yrs}) = 11 \)
- \( m = 0.722 (0.608, 0.858) \)
- Slope = -4.7\% (-8.2, -1.3)
- \( \text{SD}(\text{lr}) = 17\%, 5.8\%, 12 \text{ yr} \)
- \( r^2 = 0.52, p < 0.012 \)
- \( \text{SD}(\text{sm}) = 19\%, 8.9\%, 13 \text{ yr} \)

Kvadofjarden
- \( n(tot) = 123, n(\text{yrs}) = 14 \)
- \( m = 0.588 (0.535, 0.645) \)
- Slope = 0.03\% (-2.4, 2.5)
- \( \text{SD}(\text{lr}) = 16\%, 3.5\%, 12 \text{ yr} \)
- \( r^2 = 0.00, \text{NS} \)
- \( \text{SD}(\text{sm}) = 29, 5.5\%, 5 \text{ yr} \)

Vaderoarna
- \( n(tot) = 238, n(\text{yrs}) = 17 \)
- \( m = 0.693 (0.581, 0.826) \)
- Slope = -3.1\% (-5.8, -0.35)
- \( \text{SD}(\text{lr}) = 26\%, 4.6\%, 16 \text{ yr} \)
- \( r^2 = 0.28, p = 0.039 \)
- \( \text{SD}(\text{sm}) = 92, 13\%, 5 \text{ yr} \)

Fat %, guillemot egg, early laid

- \( n(tot) = 414, n(\text{yrs}) = 38 \)
- \( m = 12.1 (11.7, 12.5) \)
- Slope = -0.5\% (-0.36, 0.25)
- \( \text{SD}(\text{lr}) = 7.4\%, 50\%, 9 \text{ yr} \)
- \( r^2 = 0.11, \text{NS} \)
- \( \text{SD}(\text{sm}) = 3.5, 13\%, 5 \text{ yr} \)

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The graphs show the distribution of fat percentages for different populations over time, with statistical measures for each population.
Due to a change of laboratory for metal analysis in 2008, values after 2006 are not presented in this section.

Mercury is one of the mandatory contaminants that should be analysed and reported within both the OSPARCOM and HELCOM conventions.

The concentration of mercury in fish muscle and blue mussel soft body is determined using a ‘Mercury Monitor LCD 3200’ detector at the Department of Environmental Assessment at Swedish University of Agricultural Sciences. The detection limit is estimated to approximately 10 ng/g dry weight.

Table 11.1. Mean divergence from standard value of analysed CRM (Certified Reference Material). The last column shows the mean deviation from the standard, including the sign.

<table>
<thead>
<tr>
<th>Year</th>
<th>CRM</th>
<th>n</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>94</td>
<td>DORM-2</td>
<td>16</td>
<td>4.6</td>
<td>-0.2</td>
</tr>
<tr>
<td>95</td>
<td>DORM-2</td>
<td>38</td>
<td>3.6</td>
<td>-0.6</td>
</tr>
<tr>
<td>96</td>
<td>DORM-2</td>
<td>20</td>
<td>3.9</td>
<td>2.6</td>
</tr>
<tr>
<td>97</td>
<td>DORM-2</td>
<td>4</td>
<td>5.0</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

The uncertainty of a single analytical value is estimated to be between 3-5% in average. The deviation of the mean value (including the sign) of the analysed CRM samples, from the standard value is less than 3%.

In 1992, new analytical equipment was introduced and great efforts have been made to intercalculate the new method by reanalysing old samples both dried extracts and samples from the Environmental Specimen Bank.

11.1 Temporal variation

11.1.1 Conventions, aims and restrictions

The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the mercury discharges are to be reduced by 70% between 1985 and 1995, using 1985 as a base year.

The Minister Declaration from 1988, within HELCOM, calls for a reduction of the discharges of mercury to air and water by 50% by 1995 with 1987 as a base year.

The use of mercury in the paper pulp industries has been banned in Sweden since 1966.

According to a governmental proposition (1993/94:163) the aim is that all mercury usage should have ceased the year 2000 in Sweden.
11.1.2 This investigation

There is no common general trend for mercury in herring muscle for the investigated time series. The time series from Landsort show a significant increasing trend of about 2% per year for the whole time period, but during the last ten years the concentrations have decreased. Mercury was monitored in spring caught herring from Ängskärsklubb and Karlskrona for four years in the beginning of the seventies, and these series were continued in 1996. Both series show a significant decrease. Both time series from the Swedish west coast (Fladen and Väderöarna) show a significant increase of between 1 and 6%.

The time series from Ängskärsklubb in the Bothnian Sea shows a very large between-year variation. Although the sampling site at Ängskärsklubb is located rather far off the coast, the mercury concentration in the herring samples could be influenced by local discharges. Ängskärsklubb may thus not be representative of the Bothnian Sea. During 1995-1996 the estimated mean concentration in herring muscle from Ängskärsklubb were on the same level as measured in comparable samples from Landsort. However, in 1997 and 1999 the geometric mean concentrations increased to the same level that was recorded in the beginning of the eighties.

The number of years required to detect an annual change of 5% varied between 13 to 19 (25 for Ängskärsklubb) years for the herring time series. The power to detect a 5% annual change is close to 100% for most of the long herring and cod series. The large between-year variation in Ängskärsklubb lowers the power of that specific time series to about 85%.

Perch muscle samples from Kvädöfjärden in the Baltic Proper show a significant decreasing trend.

Cod from SE of Gotland show a significant increasing linear trend.

Mercury concentration in eelpout showed a significant increasing trend at Väderöarna.

The mercury concentration in blue mussels from Kvädöfjärden in the Baltic Proper has increased significantly during the last ten years. A similar pattern can also be seen in blue mussels from Väderöarna and Fladen on the Swedish west coast.

Guillemot eggs from St Karlsö in the Baltic proper show a significant decreasing trend of about 1.5% a year in mercury concentration. It should be noted that the mercury analyses in this time series have been carried out in a retrospective study i.e. all analyses have been performed at one occasion at the same laboratory.

11.1.3 Conclusion

The results concerning the development of mercury concentration in the investigated matrices are not consistent. The mercury concentration in guillemot egg decreases whereas the concentration in herring from the northern Baltic Proper seems to increase or fluctuate. The future development of mercury has to be studied carefully and possible analytical problems thoroughly investigated.
11.2 Spatial variation

Figure 11.1. Spatial variation in concentration (w.w.) of mercury in herring liver.

Herring muscle from Ängskärsklubb show the highest mercury concentrations of all herring samples. This might be due to local discharges. Samples collected during the eighties from Ängskärsklubb are thus most probably not representative of the Bothnian Sea, regarding the mercury concentration. In the beginning of the eighties the mercury concentrations in herring from Ängskärsklubb ranged from 60-180 ng/g. Finnish mercury analyses of herring muscle samples between 1980-83 from the eastern part of the Bothnian Sea show concentrations around 20 ng/g (ICES, 1995), i.e. the same level as the results from Ängskärsklubb in 1994-1996.

Among the other herring sites, Harufjärden show the highest mercury concentration over time, significantly higher than Landsort, Utlängan and Fladen. The time series from Utlängan in the southern Baltic proper shows the lowest mercury concentrations in the Baltic with a geometric mean concentration about 17 ng/g.

Cod muscle tissue from Fladen in the Kattegatt (56 ng/g) show significantly higher concentrations than samples from south east of Gotland (40 ng/g). Finnish data of mercury in cod from the Bothnian Sea and from the mouth of the Gulf of Finland show concentrations in the same range as the Swedish data from Gotland (ICES, 1995). The mercury concentration in cod muscle from Fladen is however within the same range as in cod muscle from the same age class from reference stations along the Norwegian coast (Green & Rönningen, 1994) analysed at NIVA.
Perch muscle samples from Holmöarna in the Quark show significantly higher concentrations (64 ng/g) compared to perch samples from Kvädöfjärden (24 ng/g) at the coast of the Baltic Proper. The estimated geometric mean concentration for Holmöarna 2006 is about 3 times higher than for Kvädöfjärden 2006.

The mercury concentration in flounder from the Skagerack show values in the same range as Danish flounder samples from the Belt Sea but significantly lower compared to Danish flounder samples from the Sound (ICES, 1995).

Mercury in blue mussels from Fladen in Kattegatt and Väderöarna in Skagerack show no spatial variation. The overall mean concentration in blue mussel samples from the two sites, exceed the upper limit of the range of ‘present background concentrations in pristine areas within the OSPAR Convention Area’ proposed to be between 5-10 ng/g wet weight (ICES, 1997).

The estimated mean concentrations for 2006 in herring and cod muscle (except for cod from Fladen (56 ng/g), perch and eelpout from Holmöarna (64 and 72 ng/g respectively) and eelpout from Kvädöfjärden (76 ng/g)); all fall inside the range proposed as the ‘present background concentrations in pristine areas within the OSPAR Convention Area’ (10-50 ng/g fresh weight in round fish, ICES, 1997).

11.3 Seasonal variation
No significant differences in mercury concentrations were found between spring and autumn caught herring from Ångskärsklubb and Karlskrona.

11.4 Species differences
Significant differences in mean mercury concentration (ng/g w.w.), in fish muscle and blue mussel soft body, were found between various species at the Swedish west coast.

Holmöarna: Eelpout(82) > Perch(65)
Kvädöfjärden: Eelpout(77) > Blue mussel(25) - Perch(24)
Fladen: Cod(53) > Herring(30) > Blue mussel(14)
Väderöarna: Eelpout(44) - Herring(34) - > Blue mussel(15)

The mercury concentration in blue mussel is in general lower than in fish muscle. The levels found in guillemot eggs are 3 to 20 times higher compared to the levels in fish muscle.

The concentration in fish muscle from the various sites all fall below the suggested limit (by the Swedish National Food Administration – SNFA) for human consumption (500 ng/g fresh weight) by a factor 6-25. However, the suggested limit for children’s food is 50 ng/g, which is close to the overall mean concentration in fish muscle from most of the investigated sites (SLVFS, 1993). The limit within the European Community for several fish species is set to 500 ng/g fresh weight (EG, 2001).
Table 11.2. Estimated geometric mean concentrations of mercury (ng/g fresh weight) for the last sampled year in various matrices and sites during the investigated time period. The trend is reported, if p<0.1. The age interval for fish, and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age interval</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend (95% ci)</th>
<th>last year (95% ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring muscle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>412</td>
<td>26</td>
<td>80-06</td>
<td>39 (35-43)</td>
<td></td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>427</td>
<td>26</td>
<td>80-06</td>
<td>55 (43-70)</td>
<td></td>
</tr>
<tr>
<td>Ängskärskl. aut.</td>
<td>(spring)</td>
<td>210</td>
<td>15</td>
<td>72-75,96-06</td>
<td>-2.8 (-3.9,-1.7)*</td>
<td>24 (19-29)</td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>406</td>
<td>27</td>
<td>80-06</td>
<td>1.6 (-.12, 3.3)</td>
<td>35 (27-46)</td>
</tr>
<tr>
<td>Utlångan, aut.</td>
<td>(spring)</td>
<td>424</td>
<td>27</td>
<td>80-06</td>
<td>17 (15-20)</td>
<td>18 (15-21)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>489</td>
<td>27</td>
<td>80-06</td>
<td>1.4 (0.05, 2.7)*</td>
<td>30 (25-37)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td></td>
<td>220</td>
<td>11</td>
<td>95-05</td>
<td>5.6 (1.1, 10)*</td>
<td>34 (26-44)</td>
</tr>
<tr>
<td>Cod muscle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>402</td>
<td>28</td>
<td>79-06</td>
<td>2.2 (1.1, 3.3)*</td>
<td>40 (34-48)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>447</td>
<td>28</td>
<td>79-06</td>
<td>53 (49-58)</td>
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<tr>
<td>Perch muscle</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Holmöarna</td>
<td>3-6</td>
<td>134</td>
<td>12</td>
<td>91,95-06</td>
<td>65 (55-76)</td>
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<tr>
<td>Kvädöfjärden</td>
<td>3-6</td>
<td>236</td>
<td>24</td>
<td>81-06</td>
<td>-3.3 (-5.2, -1.4)*</td>
<td>24 (18-32)</td>
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<tr>
<td>Eelpout muscle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td></td>
<td>107</td>
<td>11</td>
<td>95-06</td>
<td>82 (70-96)</td>
<td></td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td></td>
<td>119</td>
<td>12</td>
<td>95-06</td>
<td>77 (65-91)</td>
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<td>120</td>
<td>12</td>
<td>95-06</td>
<td>44 (28-68)</td>
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<td>Dab muscle</td>
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<tr>
<td>Fladen</td>
<td>3-6</td>
<td>278</td>
<td>14</td>
<td>81-94</td>
<td>78 (52-115)</td>
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<tr>
<td>Flounder muscle</td>
<td></td>
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<tr>
<td>Väderöarna</td>
<td>4-6</td>
<td>248</td>
<td>14</td>
<td>81-94</td>
<td>46 (25-83)</td>
<td></td>
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<tr>
<td>Blue mussel</td>
<td>shell 1</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Fladen</td>
<td></td>
<td>473</td>
<td>24</td>
<td>81-06</td>
<td>14 (13-16)</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td></td>
<td>499</td>
<td>26</td>
<td>80-06</td>
<td>15 (13-17)</td>
<td></td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td></td>
<td>107</td>
<td>11</td>
<td>95-05</td>
<td>25 (18-37)</td>
<td></td>
</tr>
<tr>
<td>Guillemot egg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlslö</td>
<td></td>
<td>255</td>
<td>34</td>
<td>69-06</td>
<td>-1.5 (-2.3, -0.82)</td>
<td>260 (230-310)</td>
</tr>
</tbody>
</table>

# confidence interval based on only two-three years d.f = n of obs. -1, in all other cases d.f.= n of years -1
* significant trend, p < 0.05
The blue lines indicate the suggested limit in children food by SNFA.

Hg, ng/g fresh wt., herring muscle

HGC

Angskarsklubb (3-5)

n(tot)=412, n(yrs)=26

m=38.7 (34.7, 43.1)
slope=-.20% (-1.6, 1.2)
SD(lr)=7.48, 2.1%, 16 yr
power=1.0/.29/10%
y(06)=37.7 (30.5, 46.6)
r2=.00, NS
tao=.03, NS
SD(sm)=8.59, NS, 12%
slope=2.3% (-6.1, 11)
SD(lr)=9.37, 12%, 18 yr
power=.21/.21/12%
r2=.05, NS

gHg, ng/g fresh wt., herring muscle

Angskarsklubb, spring

n(tot)=210, n(yrs)=15

m=33.0 (26.1, 41.9)
slope=-2.8% (-3.9, -1.7)
SD(lr)=7.01, 4.5%, 15 yr
power=.88/.35/9.0%
y(06)=23.5 (19.4, 28.5)
r2=.70, p<.001 *
tao=-.54, p<.005 *
SD(sm)=8.20, NS, 11%
slope=-.70% (-7.0, 5.6)
SD(lr)=7.65, 9.1%, 15 yr
power=.34/.34/9.1%
r2=.01, NS

gHg, ng/g fresh wt., herring muscle

Karlskrona, spring

n(tot)=176, n(yrs)=14

m=20.1 (17.6, 23.0)
slope=-1.0% (-1.9, -.15)
SD(lr)=6.38, 4.0%, 13 yr
power=.95/.53/7.0%
y(06)=17.6 (15.0, 20.7)
r2=.35, p<.025 *
tao=-.45, p<.025 *
SD(sm)=6.80, NS, 7.4%
slope=.47% (-5.4, 6.3)
SD(lr)=7.56, 9.7%, 14 yr
power=.31/.41/8.1%
r2=.01, NS

Fladen (2-3)

n(tot)=489, n(yrs)=27

m=25.2 (22.5, 28.2)
slope=1.4% (.05, 2.7)
SD(lr)=8.21, 1.9%, 15 yr
power=1.0/.30/9.7%
y(06)=30.3 (24.7, 37.1)
r2=.15, p<.040 *
tao=.28, p<.043 *
SD(sm)=6.97, p<.070, 8.2%
slope=5.9% (-.92, 13)
SD(lr)=8.23, 9.8%, 15 yr
power=.30/.30/9.8%
r2=.33, p<.079

Utlangan (2-4)

n(tot)=424, n(yrs)=27

m=17.3 (14.9, 20.1)
slope=.51% (-1.4, 2.5)
SD(lr)=13.4, 2.8%, 19 yr
power=1.0/.17/14%
y(06)=18.5 (13.8, 24.8)
r2=.01, NS
tao=.09, NS
SD(sm)=11.0, p<.043, 12%
slope=1.9% (-8.7, 12)
SD(lr)=14.6, 16%, 20 yr
power=.15/.15/16%
r2=.02, NS

Vaderoarna

n(tot)=220, n(yrs)=11

m=25.4 (21.1, 30.4)
slope=5.6% (1.1, 10)
SD(lr)=6.43, 6.4%, 13 yr
power=.59/.46/7.6%
y(05)=33.5 (25.7, 43.7)
r2=.47, p<.020 *
tao=.42, p<.073
SD(sm)=5.18, p<.091, 6.1%

The blue lines indicate the suggested limit in children food by SNFA.
The blue lines indicate the suggested limit in children food by SNFA.

The blue lines indicate the suggested limit in children food by SNFA.
The blue lines indicate the suggested limit in children food by SNFA.

Hg, ng/g fresh weight, eelpout

Holmoarna

n(tot)=107, n(yrs)=11
m=81.6 (68.7, 95.6)
slope=-3.4% (-7.3, 2.4)
SD(lr)=5.29, 7.2%, 14 yr
power=49.3/68.5%
y(06)= 62.2 (54.1, 98.8)
tao=-12, NS
SD(sm)=45.71, NS, 9.2%

Kvadofjarden

n(tot)=119, n(yrs)=12
m=76.9 (64.6, 91.4)
slope=17.5% (5.5, 5.2)
SD(lr)=6.59, 7.7%, 16 yr
power=45.2/27/11%
y(06)= 76.1 (54, 108)
tao=00, NS
SD(sm)=5.07, p<.001, 8.5%

Vaderoarna

n(tot)=120, n(yrs)=12
m=25.2 (18.3, 33.8)
slope=10% (3.1, 17)
SD(lr)=11.1, 10%, 19 yr
power=1.0/8.5%
y(06)=16.0 (12.6, 20.2)
r2=0.07, NS
SD(sm)=8.62, p<.001, 6.7%

The blue lines indicate background concentration in OSPAR areas.
Hg, ng/g fresh w., guillemot eggs, early laid

n(tot)=255, n(yrs)=34
m=350 (317, 386)
slope=-1.5% (-2.3, -0.82)
SD(lr)=3.85, 1.2%, 14 yr
power=1.0/40/8.2%
y(06)= 264 (227, 308)
r²=.37, p<.001 *
tao=-.45, p<.001 *
SD(sm)=2.57, p<.001, 5.4%
slope=.04% (-4.4, 4.5)
SD(lr)=3.05, 3.3%, 12 yr
power=.61/.61/6.3%
r²=.00, NS
12 Lead

Due to a change of method for metal analysis in 2004, values after 2003 are not presented in this section. The new method is under investigation, since the values are uncertain.

The toxic effects of lead involve several organ system and biochemical activities and the major risk is its toxicity to the nervous system. The risk is highest for Children and unborn, partly because of higher permeability of the blood-brain barrier (Klaassen & Rozman, 1991).

Lead is known to concentrate in liver tissue but to an even greater extent in the bone matrix. Approximately 90% of the total amount of lead in humans are found in the skeleton (Klaassen & Rozman, 1991). The lead concentration in liver from Baltic herring is about 4 times higher (wet wt.) than the concentration reported for the edible parts of herring. For cod, the concentration in liver is about 2.5 times higher and for perch about 2 times. Concentrations in edible parts are reported by Jorhem and Sundström, 1993.

Lead is one of the mandatory contaminants that should be analysed and reported within both the OSPARCOM and HELCOM conventions.

The concentration of lead in fish liver and blue mussel soft body is determined using an atomic absorption spectrophotometer with graphite furnace at the Department of Environmental Assessment at Swedish University of Agricultural Sciences. The detection limit is estimated to approximately 10 ng/g dry weight which implies that the concentrations in herring, flounder and dab are approximately 10-20 times above the detection limit.

The estimated residual variance is higher in the beginning of the time series. 1982 seems to be lower than the surrounding years in all series but one, indicating an analytical problem.

Table 12.1. Mean divergence from standard value of analysed CRM (Certified Reference Material). The last column shows the mean deviation from the standard, including the sign.

<table>
<thead>
<tr>
<th>Year</th>
<th>CRM</th>
<th>n</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>DOLT-1</td>
<td>12</td>
<td>14</td>
<td>-6.1</td>
</tr>
<tr>
<td>91</td>
<td>DOLT-1</td>
<td>12</td>
<td>13</td>
<td>-8.1</td>
</tr>
<tr>
<td>93</td>
<td>DOLT-2</td>
<td>17</td>
<td>7.4</td>
<td>-1.7</td>
</tr>
<tr>
<td>94</td>
<td>DOLT-2</td>
<td>12</td>
<td>6.9</td>
<td>3.6</td>
</tr>
<tr>
<td>95</td>
<td>DOLT-2</td>
<td>3</td>
<td>4.5</td>
<td>1.5</td>
</tr>
<tr>
<td>97</td>
<td>SLRS-3</td>
<td>9</td>
<td>9.0</td>
<td>1.8</td>
</tr>
</tbody>
</table>

The uncertainty of a single analytical value is thus estimated to be between 5-15%. The mean deviation (including the sign) of the analysed CRM samples, from the standard value is between 1-10%.
12.1  Temporal variation

12.1.1  Conventions, aims and restrictions
The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the lead discharges are to be reduced by 70% between 1985 and 1995, using 1985 as a base year.

The Minister Declaration from 1988, within HELCOM, calls for a reduction of the discharges of lead to air and water by 50% by 1995 with 1987 as a base year.

12.1.2  Other investigations
Jorhem and Sundström (1993) found about 75% lower levels of lead in fish samples (Baltic herring, cod and pike) from the period 1983-90 compared to a previous study from the period 1973-82 (Jorhem et al. 1984).

12.1.3  This investigation
At Harufjärden, Ängskärsklubb (autumn), Landsort, Utlängan and Fladen, the investigated time series in herring liver show significant decreasing trends.

The number of years required to detect an annual change of 5% varied between 9 to 19 years for the herring time series with a power to detect a 5% annual change ranging from 0.19 (shorter series) to 1.0 (longer series). An annual change greater than 10% would likely be detected.

Lead concentrations in cod liver (after adjusting for varying fat content) showed decreasing trends from SE Gotland and Fladen.

Lead concentrations in the shorter time series of perch liver showed decreasing trends from Kvädöfjärden but not for Holmöarna.

The short time series (8 years) of lead in guillemot eggs show a significant decreasing trend.

The lead concentration in blue mussel soft body from Fladen showed a significant decreasing trend and the short time series from Kvädöfjärden a significant increasing trend.

12.1.4  Conclusion
The decrease of lead in most matrices at most sampling sites probably reflects a general decrease of lead in the environment.
12.2 Spatial variation
The lead concentration in blue mussels from the Swedish west coast is not significantly higher compared to blue mussel samples of similar length from a reference site at Kobbeffjord, Greenland (Riget et al 1993). Mussel samples from all three sites show mean levels below the ‘background concentration at diffuse loading’ in blue mussels for lead of <5 μg/g dry weight, proposed by Knutzen and Skie (1992).

12.3 Species differences
 Significant differences in mean lead concentration (μg/g dry weight), in fish liver and blue mussel soft body, were found between the species marked with ‘>‘:

Holmøarna: Eelpout(0.14) > Perch(0.04)
Kvädöfjärden: Blue mussel (4.3) > Eelpout(0.18) > Perch(0.033)
Fladen: Blue mussel(0.86) > Herring(0.08) > Cod(0.04)
Väderöarna: Blue mussel(1.1) > Eelpout(0.14) > Herring(0.044)

The lead concentration in blue mussel soft body tissue is thus generally much higher than concentration in fish liver. The concentration in eelpout liver is about three to five times higher than perch liver in the analysed samples.

The recommended limit for children’s food is set by the Swedish Food Administration to 50 ng/g fresh weight (SLVFS, 1993). Within the European Community the limit in fish muscle is set to 0.2 ug/g and in mussels to 1.5 ug/g. (EG, 2002).
Table 12.2. Estimated geometric mean concentrations of lead (ug/g dry weight) for the last sampled year in various matrices and sites during the investigated time period. The age interval for fish, and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend (95% ci)</th>
<th>last year (95% ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring liver</strong></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>357</td>
<td>21</td>
<td>81-03</td>
<td>-5.2 (-7.2, -3.3)*</td>
<td>0.064 (.050-.083)</td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>383</td>
<td>22</td>
<td>81-03</td>
<td>-4.2 (-6.2, -2.1)*</td>
<td>0.099 (.077-.13)</td>
</tr>
<tr>
<td>&quot; spring</td>
<td>3-6</td>
<td>80</td>
<td>8</td>
<td>96-03</td>
<td>.18 (.15-.21)</td>
<td></td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>370</td>
<td>23</td>
<td>81-03</td>
<td>-5.1 (-7.1, -3.1)*</td>
<td>.11 (.081-.14)</td>
</tr>
<tr>
<td>Utlängan, aut.</td>
<td>2-4</td>
<td>307</td>
<td>23</td>
<td>81-03</td>
<td>-2.2 (-4.8, .35)</td>
<td>.15 (.11-.21)</td>
</tr>
<tr>
<td>&quot; spring</td>
<td>0-4</td>
<td>47</td>
<td>5</td>
<td>96-03</td>
<td>.19 (.17-.21)</td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>443</td>
<td>23</td>
<td>81-03</td>
<td>-4.2 (-6.6, -1.8)*</td>
<td>.080 (.059, 0.11)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>2-4</td>
<td>180</td>
<td>9</td>
<td>95-03</td>
<td>.056 (.044-.072)</td>
<td></td>
</tr>
<tr>
<td><strong>Cod liver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>339</td>
<td>23</td>
<td>81-03</td>
<td>-7.2 (-9.9, -4.5)*</td>
<td>.021 (.014-.030)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-4</td>
<td>425</td>
<td>23</td>
<td>81-03</td>
<td>-5.1 (-7.8, -2.4)*</td>
<td>.040 (.029-.057)</td>
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<td><strong>Perch liver</strong></td>
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<td></td>
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<tr>
<td>Holmöarna</td>
<td>0-7</td>
<td>90</td>
<td>9</td>
<td>95-03</td>
<td>.048 (.035-.065)</td>
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<tr>
<td>Kvädöfjärden</td>
<td>3-7</td>
<td>80</td>
<td>8</td>
<td>95-03</td>
<td>-10 (-17,-3.0)*</td>
<td>.033 (.023-.047)</td>
</tr>
<tr>
<td><strong>Eelpout liver</strong></td>
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<td></td>
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</tr>
<tr>
<td>Holmöarna</td>
<td>67</td>
<td>7</td>
<td>95-03</td>
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<td>.16 (.12-.20)</td>
<td></td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>89</td>
<td>9</td>
<td>95-03</td>
<td></td>
<td>.19 (.17-.21)</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>79</td>
<td>8</td>
<td>95-03</td>
<td></td>
<td>.13 (.10-.17)</td>
<td></td>
</tr>
<tr>
<td><strong>Dab liver</strong></td>
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</tr>
<tr>
<td>Fladen</td>
<td>3-6</td>
<td>257</td>
<td>14</td>
<td>81-94</td>
<td>.77 (-3.0, 4.6)*</td>
<td>221 (165-296)</td>
</tr>
<tr>
<td><strong>Flounder liver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>4-6</td>
<td>239</td>
<td>14</td>
<td>81-94</td>
<td>-0.06 (-5.4,5.3)*</td>
<td>173 (115-260)</td>
</tr>
<tr>
<td><strong>Blue mussel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Fladen</td>
<td>5-8</td>
<td>396</td>
<td>21</td>
<td>81-03</td>
<td>-4.4 (-8.6,-12)*</td>
<td>.86 (.51-1.5)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>6-10</td>
<td>412</td>
<td>22</td>
<td>81-03</td>
<td>1.4 (1.1-1.8)</td>
<td></td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>88</td>
<td>9</td>
<td>95-03</td>
<td>19 (1.3, 36)*</td>
<td>4.3 (1.9-9.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Guillemot egg</strong></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>St. Karlsö</td>
<td>80</td>
<td>8</td>
<td>96-03</td>
<td>-13 (-18,-8.7)*</td>
<td>.030 (.025-.037)</td>
<td></td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05
Pb, ug/g dry w., cod liver
Fat adjusted geometric means

Cod, SE Gotland (3-4)

- n(tot)=339, n(yrs)=23
- slope=7.2%(-9.9,-4.5)
- SD(lr)=13.3,9.2,20 yr
- power=11/11/21%
- r²=17, NS

Cod, SE Gotland (3-4)

- n(tot)=339, n(yrs)=23
- slope=7.2%(-21.5,9.9)
- SD(lr)=15.3,21%,23 yr
- power=11/11/21%
- r²=17, NS

Slope=-7.2% (-9.9,-4.5)
SD(lr)=13.3,9.2,20 yr
Power=11/11/21%
R²=17, NS

Slope=-7.2% (-21.5,9.9)
SD(lr)=15.3,21%,23 yr
Power=11/11/21%
R²=17, NS

Pb, ug/g dry w. perch

Holmoarna

- age=0-7
- n(tot)=90, n(yrs)=9
- m=.048 (.035, 0.065)
- SD(lr)=12.3, 17%, 19 yr
- power=14/17/14%
- r²=.22, NS
- tao=-.22, NS

Kvadofjarden

- age=3-7
- n(tot)=80, n(yrs)=8
- m=.050 (.038, 0.068)
- SD(lr)=7.32, 12%, 14 yr
- power=22/42/8.0%
- r²=.67, p<.014 *
- tao=-.71, p<.013 *

Slope=-6.7% (-18,4.7)
SD(lr)=12.3,17%,19 yr
Power=14/17/14%
R²=.22, NS
Tao=-.22, NS

Slope=-10% (-17,-3.0)
SD(lr)=7.32,12%,14 yr
Power=22/42/8.0%
R²=.67, p<.014 *
Tao=-.71, p<.013 *
Pb, ug/g wet w., blue mussel softbody
Shell lengths in brackets

Fladen (5-8 cm)

<table>
<thead>
<tr>
<th>length</th>
<th>n(tot)</th>
<th>n(yrs)</th>
<th>m</th>
<th>slope</th>
<th>SD(lr)</th>
<th>power</th>
<th>r²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8 cm</td>
<td>396</td>
<td>21</td>
<td>0.202 (.147-.279)</td>
<td>6.1%(-10.2)</td>
<td>37.0 .6.4,25%</td>
<td>0.58</td>
<td>0.05</td>
<td>&lt;.005 *</td>
</tr>
</tbody>
</table>

Vaderoarna (6-10 cm)

<table>
<thead>
<tr>
<th>length</th>
<th>n(tot)</th>
<th>n(yrs)</th>
<th>m</th>
<th>slope</th>
<th>SD(lr)</th>
<th>power</th>
<th>r²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-10 cm</td>
<td>412</td>
<td>22</td>
<td>0.229 (.186-281)</td>
<td>1.5%(-4.5,1.5)</td>
<td>31.5</td>
<td>5.4,7,21</td>
<td>0.31</td>
<td>0.052</td>
</tr>
</tbody>
</table>

Kvadofjarden

<table>
<thead>
<tr>
<th>length</th>
<th>n(tot)</th>
<th>n(yrs)</th>
<th>m</th>
<th>slope</th>
<th>SD(lr)</th>
<th>power</th>
<th>r²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 cm</td>
<td>88</td>
<td>9</td>
<td>0.257 (.204-323)</td>
<td>19%(-11,27)</td>
<td>31.3</td>
<td>1.2,18</td>
<td>0.12</td>
<td>&lt;.013</td>
</tr>
</tbody>
</table>

The blue lines indicate background concentration in OSPAR areas.

Pb, ug/g dry w. Guillemot egg

Stora Karloso

<table>
<thead>
<tr>
<th>length</th>
<th>n(tot)</th>
<th>n(yrs)</th>
<th>m</th>
<th>slope</th>
<th>SD(lr)</th>
<th>power</th>
<th>r²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 cm</td>
<td>80</td>
<td>8</td>
<td>0.048 (.043-.055)</td>
<td>15.7%(-18.8)</td>
<td>15.7</td>
<td>7.0,22</td>
<td>0.30</td>
<td>&lt;.001 *</td>
</tr>
</tbody>
</table>

The blue lines indicate background concentration in OSPAR areas.
Due to a change of method for metal analysis in 2004, values after 2003 are not presented in this section. The new method is under investigation, since the values are uncertain.

Cadmium is an important metal in many industrial applications. It has been excessively used until the end of the seventies, in electroplating or galvanising because of its noncorrosive properties. It is has also been used (and is still used to some extent) as a cathode material for nickel-cadmium batteries and as a colour pigment for paints and plastics. Its industrial use has however decreased considerable during recent years. In 1982, Sweden as the first country in the world introduced a principal ban for certain industrial applications. Cadmium does also reach the environment as a by-product of zinc and lead mining and smelting and as an undesired element in fertilisers.

Cadmium is one of the mandatory contaminants that should be analysed and reported within both the OSPARCOM and the HELCOM conventions.

The time series of cadmium concentration in fish liver and blue mussel soft body, presented below, start 1981. It is determined using an atomic absorption spectrophotometer with graphite furnace at the Department of Environmental Assessment at Swedish University of Agricultural Sciences. The detection limit is estimated to approximately 5 ng/g dry weight.

**Table 13.1.** Mean divergence from standard value of analysed CRM (Certified Reference Material). The last column shows the mean deviation from the standard, including the sign.

<table>
<thead>
<tr>
<th>Year</th>
<th>CRM</th>
<th>n</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>Dolt-1</td>
<td>4</td>
<td>6.3</td>
<td>6.3</td>
</tr>
<tr>
<td>91</td>
<td>Dolt-1</td>
<td>15</td>
<td>4.0</td>
<td>-0.5</td>
</tr>
<tr>
<td>93</td>
<td>Dolt-2</td>
<td>20</td>
<td>4.1</td>
<td>0.5</td>
</tr>
<tr>
<td>94</td>
<td>Dolt-2</td>
<td>21</td>
<td>3.3</td>
<td>1.7</td>
</tr>
<tr>
<td>95</td>
<td>Dolt-2</td>
<td>22</td>
<td>2.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>96</td>
<td>Dolt-2</td>
<td>24</td>
<td>5.5</td>
<td>2.4</td>
</tr>
<tr>
<td>97</td>
<td>Dolt-2</td>
<td>6</td>
<td>4.9</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

The uncertainty of a single analytical value is thus estimated to be around ±5% on average and has not changed over time. The mean deviation (including the sign) of around 20 samples from the standard value is (except for 1990) less than 2.5% and shows no systematic deviation. Although the concentration of cadmium in Dolt2 is about 10 to 15 times higher compared to the levels in the investigated herring livers, there is no reason, sofar, to believe that the impact from analytical errors on the evaluation of the time series is important.
13.1 Temporal variation

13.1.1 Conventions, aims and restrictions
The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the cadmium discharges are to be reduced by 70% between 1985 and 1995, using 1985 as a base year.

The Minister Declaration from 1988, within HELCOM, calls for a reduction of the discharges of cadmium to air and water by 50% by 1995 with 1987 as a base year.

The Swedish Parliament has agreed on a general reduction of cadmium discharges aiming at a reduction of 70% between 1985 and 1995. Further, that all use of cadmium that implies a risk of discharges to the environment, in a longer term perspective, will cease (prop 1990/91:90, JoU 30, rskr.343).

In 1982, the use of cadmium in electroplating and as a thermal stabilisor was banned in Sweden.

A fee on batteries containing cadmium was introduced 1987 in Sweden. This fee was raised considerably in 1991.

The content of cadmium in fertilisers was restricted to 100g/ton phosphorus, 1993.01.01 in Sweden.

13.1.2 Input
The discharges of cadmium to the environment in Sweden have been estimated to have decreased with approximately 45% between 1985 and 1990 while the airborne cadmium load during the same period is estimated to have decreased with approximately 15% (SNV, Rapport 4135). The river discharges to the Baltic from Sweden have decreased considerably during the recent decades while from Poland, Russia and the Baltic countries the discharges are still very high. The estimated cadmium burden (in tons) 1990 from Sweden compared to all countries was, to; the Bothnian Bay and the Bothnian Sea, 2/17; the Baltic proper 0.41/110; the Kattegatt, 0.5/6(Widell, 1990,1992).

13.1.3 Proposed processes
a) Decreased contaminant load may cause a corresponding decrease in the amount bioavailable cadmium.

b) Bengtsson (1975) among others, suggested that decreasing salinity increase the bioavailability of cadmium. Studies by Danielsson et al.(1983), Mart et al.(1985) and Nolting (1986) show that cadmium is desorbed from particulate material during transition from fresh to more saline water. Hence, plankton may gain in adsorption capacity as salinity decrease. Decreasing levels of salinity during the period have been reported from several stations in the Baltic (Bergström & Matthäus, 1995) but also in the Bothnian Bay. Herring feeding on plankton may thus be exposed to increasing levels of bioavailable cadmium (Harms, 1995).

c) Increased mobility of Cd-ions due to acidification may cause an increased cadmium concentration in the run off (e.g. Borg et al, 1989).
d) Cadmium can be bound to metallothionein (MT) (da Silva and Williams, 1994). It is further known that various compounds can induce (and possibly also inhibit) the formation of MT in fish liver (Bouquegneau et al., 1975). A change in the amount of MT, due to induction, inhibition or ceased induction or inhibition, might thus change the metal concentration in the analysed liver tissue.

13.1.4 Other investigations

Concentrations of dissolved and particulate cadmium were determined in seawater from several sites in the Baltic proper for nine years during the time period 1980 to 1993 (Pohl, 1994, Schneider & Pohl, 1995). The material was separated into two regions. A decrease of approximately 7% per year was found in the Mecklenburg Bight/Arkona Sea and in surface waters of the Bornholm Sea/Gotland Sea. The time series are however based on data from various seasons and the analytical technique has changed over time.

Cadmium concentration analysed in herring muscle between 1979 to 1993 from three Finnish sites: western and eastern Gulf of Finland and southern Bothnian Bay show decreasing trends of between 10 to 12% a year (ICES, 1995). However, the analysed cadmium concentrations are close to, and for several years below, the detection limit.

Cadmium concentration in herring muscle has also been reported from three sites along the Polish coast between 1974-1988 (Protasowicki et al. 1975) and during 1991-1993 (Polak-Juszczak and Domagala, 1994) where the mean values indicate a decrease. Polish data of Cd concentrations analysed in herring muscle and liver from three sites were also reported to HELCOM and assessed by ICES but were found too short to disclose any trends (ICES, 1995).

A general remark for extra cautiousness is appropriate when interpreting analyses of low concentrations near the detection level as in water or muscle samples. An improved analytic technique may lead to decreasing concentrations due to less risk of sample contamination.

13.1.5 This investigation

Cadmium concentrations in herring liver from Utlängan (autumn) in the Baltic proper show a significant increasing log-linear trend. The total increase in cadmium concentration during 1981-95 at Ångskärsklubb, Landsort and Utlängan is about 2.5 times. During recent years the increases have levelled out and also turned to a decrease at least at Landsort and Ångskärsklubb.

Cadmium concentrations in cod liver samples (adjusted for varying fat content) from south east of Gotland and Fladen show significant decreasing trends.

Cadmium concentrations in eelpout samples from Holmöarna, Kvädöfjärden and Väderöarna all show significant increasing trends (the between year variation at Holmöarna and Kvädöfjärden is large though).

The number of years required to detect an annual change of 5% varied between 10 to 19 years for the herring time series with a power to detect a 5% annual change ranging from 0.46 to 1.0. (Since it is not appropriate to fit a log-linear trend at Ångskärsklubb and Utlängan, these sites were excluded from the power calculations.)

The geometric mean concentration of cadmium in dab liver was extremely high in 1988, about 5 times the overall mean concentration.
13.1.6 Conclusion
The rapid increase of cadmium concentrations at Ängskärsklubb and Landsort seems to have stopped and is now turning downward. Cadmium is concentrated in internal organs, i.e. liver, why the concentration in muscle tissue is very low. Analysed values for perch and herring muscle are 0.5 and 4 ng/g dry weight respectively (unpublished data). The average cadmium concentration in potatoes (in a sample of 8, during 1987-1990) was reported to 17 ng/g (Jorhem and Sundström, 1993). The cadmium concentrations of 0.5 to 4 ng/g indicates that there is no immediate risk for human consumption, since the EU limit suggested for human consumption of fish is 50 ng/g fresh weight (EG nr 221/2002).

13.2 Spatial variation

13.2.1 Other investigations
Cadmium analysed in kidney cortex from juvenile harbour seals showed significantly lower values in samples from the Baltic compared to comparable samples from the west coast (Frank et al. 1992)

13.2.2 This investigation
The overall mean Cd-concentrations in herring liver from the Baltic show significantly higher cadmium concentrations compared to Fladen in the Kattegatt and Väderöarna in the Skagerack at the Swedish west coast. All sampling sites in the Baltic show significantly higher levels, estimated 2000, compared to Fladen. The geometric mean concentration in herring liver, for the period 1981-2003, from Harufjärden (Bothnian Bay) and Ladsort (Baltic proper) show about 3 respectively 3.5 times higher values compared to samples from the Kattegatt.

Eelpout livers from Holmöarna in the southern Bothnian Bay and Kvädöfjärden in the Baltic Proper show about 3 to 4 times higher geometric mean Cd-concentrations (dry weight) compared to samples from Väderöarna in the Skagerack.

Blue mussels from Kvädöfjärden, analysed 1995-03, show about 3 times higher concentrations compared to blue mussel samples from the Swedish west coast. The samples from the Swedish west coast show mean levels similar to what is found in blue mussels from the Belgian coast (Vyncke et al. 1999) and do not exceed the ‘high background concentration at diffuse loading’ for cadmium in blue mussels of <2 μg/g dry weight, proposed by Knutzen and Skie (1992) whereas the samples from Kvädöfjärden does. All blue mussel samples exceed the range of ‘present background concentrations in pristine areas within the OSPAR Convention Area’ proposed to 0.070-0.11 μg/g wet weight (ICES, 1997). The estimated geometric mean concentration from Kvädöfjärden exceeds this concentration by about 4 times.

Cadmium concentrations in cod livers from Fladen in the Kattegatt, are significantly higher (about 3 times on a dry weight basis and about 2 times on a fresh weight basis) compared to samples from south east of Gotland. This may be explained by the fact that the average fat content in cod liver from Gotland is about 2.5 times higher compared to the samples from the Kattegatt. The Swedish data from SE of Gotland are in the same range as Finnish data of cod liver from the Gulf of Finland and the Bothnian Sea.
Herring liver from Fladen in the Kattegatt show significantly higher concentrations compared to Väderöarna in the Skagerack.

### 13.3 Species differences

Significant differences in mean cadmium concentration (μg/g dry weight), in fish liver and blue mussel soft body, were found between the species marked with ‘>’:

- Holmöarna: Eelpout(1.8) > Perch(0.47)
- Kvädfjärden: Blue mussel(4.3) > Eelpout(2.1) > Perch(0.60)
- Fladen: Blue mussel(0.96) > Herring(0.54) > Cod(0.12)
- Väderöarna: Blue mussel(1.1) > Herring(0.33) - Eelpout(0.49)

The cadmium concentration in blue mussel soft body tissue is thus about 2 to 9 times the concentration found in fish liver and the concentration in eelpout liver is about twice as high as in perch liver in the analysed samples. The concentration found in guillemot egg is extremely low, at least 500 times lower (dry weight) compared to herring liver.

### Table 13.2. Geometric mean concentrations of cadmium (μg/g dry weight) in various matrices and sites during the whole investigated time period and the estimated mean concentration for the last year. The age interval for fish, and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend (95% ci)</th>
<th>last year (95% ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring liver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>364</td>
<td>22</td>
<td>81-03</td>
<td>1.4 (1.2-1.7)</td>
<td></td>
</tr>
<tr>
<td>Angskärskl. aut.</td>
<td>3-5</td>
<td>382</td>
<td>22</td>
<td>81-03</td>
<td>3.0 (.75, 5.2)*</td>
<td>2.3 (1.7-3.1)</td>
</tr>
<tr>
<td>” spring</td>
<td>3-6</td>
<td>80</td>
<td>8</td>
<td>96-03</td>
<td>3.9 (3.3-4.7)</td>
<td></td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>370</td>
<td>23</td>
<td>81-03</td>
<td>1.8 (-.25, 3.9)</td>
<td>2.3 (1.8-3.1)</td>
</tr>
<tr>
<td>Utlångan, aut.</td>
<td>3-4</td>
<td>287</td>
<td>23</td>
<td>81-03</td>
<td>3.1 (1.3, 4.8)*</td>
<td>2.4 (1.9-3.0)</td>
</tr>
<tr>
<td>” spring</td>
<td>0-4</td>
<td>70</td>
<td>7</td>
<td>96-03</td>
<td>2.4 (2.1-2.7)</td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>443</td>
<td>23</td>
<td>95-03</td>
<td>.54 (.48-.59)</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>2-4</td>
<td>180</td>
<td>9</td>
<td>95-03</td>
<td>.33 (.29-.38)</td>
<td></td>
</tr>
<tr>
<td>Cod liver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>343</td>
<td>23</td>
<td>81-03</td>
<td>-6.4 (-8.3,-4.5)*</td>
<td>.027 (.021-.035)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-4</td>
<td>426</td>
<td>23</td>
<td>81-03</td>
<td>-3.5 (-6.4,-6.60)*</td>
<td>.12 (.079-.17)</td>
</tr>
<tr>
<td>Perch liver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td>0-7</td>
<td>90</td>
<td>9</td>
<td>95-03</td>
<td>.47 (.35-.62)</td>
<td></td>
</tr>
<tr>
<td>Kvädfjärden</td>
<td>90</td>
<td>9</td>
<td>95-03</td>
<td>.60 (.47-.77)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eelpout liver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td>67</td>
<td>7</td>
<td>95-03</td>
<td>11 (4.7, 17)*</td>
<td>1.8 (1.4-2.3)</td>
<td></td>
</tr>
<tr>
<td>Kvädfjärden</td>
<td>2-9</td>
<td>89</td>
<td>9</td>
<td>95-03</td>
<td>10 (4.7, 16)*</td>
<td>2.1 (1.6-2.7)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>3-8</td>
<td>79</td>
<td>8</td>
<td>95-03</td>
<td>11 (5.6, 17)</td>
<td>.49 (.38-.63)</td>
</tr>
<tr>
<td>Dab liver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>3-6</td>
<td>257</td>
<td>14</td>
<td>81-94</td>
<td>3.7 (-4.8,12)*</td>
<td>0.81 (.42-1.5)</td>
</tr>
<tr>
<td>Flounder liver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>4-6</td>
<td>239</td>
<td>14</td>
<td>81-94</td>
<td>1.7 (-3.7,7.0)*</td>
<td>0.53 (.35-.80)</td>
</tr>
<tr>
<td>Blue mussel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>5-8</td>
<td>396</td>
<td>21</td>
<td>81-03</td>
<td>-1.3 (-2.7,-.19)</td>
<td>.96 (80-1.2)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>6-10</td>
<td>413</td>
<td>22</td>
<td>81-03</td>
<td>1.1 (.94-1.2)</td>
<td></td>
</tr>
<tr>
<td>Kvädfjärden</td>
<td>0-3</td>
<td>88</td>
<td>9</td>
<td>95-03</td>
<td>4.3 (3.8-4.8)</td>
<td></td>
</tr>
<tr>
<td>Guillemot egg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td>78</td>
<td>8</td>
<td>96-03</td>
<td>-16 (-25,-7.1)*</td>
<td>.001 (.001-.002)</td>
<td></td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05
**Cd, ug/g dry w., cod liver**

Fat adjusted geometric means

### Cod, SE Gotland (3-4)

- $n_{\text{tot}}=343$, $n_{\text{yrs}}=23$
- $m=.055$ (0.044, 0.069)
- $SD(m)=10.0$, $2\%$, 16 yr
- $y(03)=.027$ (.021, .035)
- $\tau=7.1\%$ (-12.2, 2.5)
- $SD(y)=55.6\%$, 12 yr
- $r^2=.61$, $p=.007$
- $power=1.0/1.0/11\%$
- $r^2=.70$, $p<.001$
- $\frac{\text{power}}{\text{y(03)}}=.027$

### Cod, Fladen (2-4)

- $n_{\text{tot}}=426$, $n_{\text{yrs}}=23$
- $m=.169$ (0.136, 0.209)
- $SD(m)=24.9$, 4.2%, 21 yr
- $y(03)=.115$ (.079, .167)
- $\tau=.68$, $p<.001$
- $SD(y)=5.4\%$, 12 yr
- $r^2=.61$, $p<.007$
- $power=.57/1.0/17\%$

### Holmoarna

- $n_{\text{tot}}=90$, $n_{\text{yrs}}=9$
- $m=.465$ (0.349, 0.620)
- $SD(m)=48.4$, 17%, 19 yr
- $y(03)=.573$ (.334, .981)
- $\tau=.17$, NS
- $r^2=.14$, NS
- $power=.14/1.0/14\%$

### Kvadofjarden

- $n_{\text{tot}}=90$, $n_{\text{yrs}}=9$
- $m=.602$ (0.470, 0.771)
- $SD(m)=67.5$, 15%, 18 yr
- $y(03)=.63$ (.38, 1.04)
- $\tau=.06$, NS
- $r^2=.01$, NS
- $power=.15/6.6/13\%$

---

*Figure* - 08.02.19 10:34, CDP
Cd, ug/g dry w., Eelpout

Holmoarna

n(tot)=67, n(yrs)=7
m=1.25 (1.05, 1.48)
SD(μ)=297.12%, 1.6 yr
power=1.0 (0.925%)
y(03)=1.77 (1.37, 2.26)
r2=0.66, p<0.001 *
tao=.29, p<0.001 *

Kvadofjarden

age=2-9
n(tot)=89, n(yrs)=9
m=1.38 (1.18, 1.60)
slope=11% (4.7, 16)
SD(μ)=210.80%, 27 yr
power=1.0 (0.926%)
y(03)=2.07 (1.59, 2.68)
r2=.14, p<0.001 *
tao=.34, p<0.001 *

Vaderoarna

age=3-8
n(tot)=79, n(yrs)=9
m=1.20 (1.05, 1.35)
slope=10% (4.7, 16)
SD(μ)=55.8, 26 yr
power=1.0 (0.929%)
y(03)=4.08 (3.80, 6.69)
r2=.18, p<0.001 *
tao=.29, p<0.001 *

The blue lines indicate background concentration in OSPAR areas.
14 Nickel

Due to a change of method for metal analysis in 2004, values after 2003 are not presented in this section. The new method is under investigation, since the values are uncertain.

The concentration of nickel in fish liver is determined using an atomic absorption spectrophotometer with graphite furnace at the Department of Environmental Assessment at Swedish University of Agricultural Sciences. The detection limit is estimated to approximately 0.1 μg/g dry weight.

The analysis started on samples collected 1995.

14.1 Temporal variation
The time series of herring from Landsort, Fladen and Väderöarna, cod liver from SE Gotland and Fladen, perch liver from Holmöarna and eelpout from Kvädöfjärden and Väderöarna, all show significant decreasing trends.

Nickel has only been analysed since 1995 (eight years) and therefore the possibilities to detect time trends are limited. For herring the number of years required to detect an annual change of 5 % varies between 13 to 26 years. The power to detect an annual change of 5 % range from 0.08 to 0.36.

14.2 Spatial variation
Significantly lower nickel concentrations were observed in herring liver from Väderöarna compared to the samples from Landsort and Karlskrona archipelago.

Mussels from all three sites show mean levels below the upper limit of the ‘high background concentration at diffuse loading’ in blue mussels for nickel of <5 μg/g dry weight, proposed by Knutzen and Skie (1992).
Table 14.1. Geometric mean concentrations of nickel (µg/g dry weight) in various matrices and sites during the time period and the estimated mean concentration for the last year. The age interval for fish, and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Age Interval</th>
<th>n (total)</th>
<th>n (years)</th>
<th>Year</th>
<th>Trend % (95% CI)</th>
<th>Last Year (95% CI)</th>
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<tr>
<td><strong>Herring liver</strong></td>
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<td>.15 (.087-.26)</td>
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<td>3-5</td>
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<td>95-03</td>
<td>-11 (-22, 0.7)</td>
<td>.11 (.066-.20)</td>
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<tr>
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<td>3-6</td>
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<td>96-03</td>
<td>-8.8 (-19, 1.7)</td>
<td>.20 (.13-.31)</td>
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<td>123</td>
<td>9</td>
<td>95-03</td>
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<td>-20 (-32,-7.9)*</td>
<td>.061 (.035-.11)</td>
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<tr>
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<td>-14 (-20,-7.9)*</td>
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<td>SE Gotland</td>
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<td>-8.8 (-16,-2)*</td>
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<td>-9.5 (-19,.07)*</td>
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<td><strong>Blue mussel</strong></td>
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<tr>
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<td>St. Karlsö</td>
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<td>8</td>
<td>96-03</td>
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<td>.076 (.048-.12)</td>
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</table>

*significant trend, p < 0.05

**Ni, ug/g dry w., herring liver**

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Age Interval</th>
<th>n (total)</th>
<th>n (years)</th>
<th>Year</th>
<th>Trend % (95% CI)</th>
<th>Last Year (95% CI)</th>
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</tbody>
</table>

---

*significant trend, p < 0.05
Ni, ug/g dry weight, herring liver

### Angskarsklubb, spring
- **Age:** 3-6
- **n(tot):** 70, **n(yrs):** 8
- **m:** 0.271 (0.205, 0.359)
- **SD:** 8.8%
- **SD(lr):** 21.2, 15%
- **Power:** 0.16, 0.28, 0.10
- **y(03):** 0.163 (0.129, 0.309)
- **r^2:** 0.41
- **t** = 0.41, *p* < 0.003

### Karlshkona, spring
- **Age:** 0-4
- **n(tot):** 70, **n(yrs):** 7
- **m:** 0.286 (0.226, 0.353)
- **SD:** 8.5%
- **SD(lr):** 15.6, 14%
- **Power:** 0.19, 0.51, 0.07
- **y(02):** 0.222 (0.158, 0.312)
- **r^2:** 0.52
- **t** = 0.52, *p* < 0.008

### Fladen (2-3)
- **Age:** 0-6
- **n(tot):** 121, **n(yrs):** 9
- **m:** 0.134 (0.081, 0.222)
- **SD:** 8.8%
- **SD(lr):** 19.4, 18%
- **Power:** 0.13, 0.16, 0.09
- **y(03):** 0.061 (0.035, 0.107)
- **r^2:** 0.69
- **t** = 0.69, *p* < 0.006

### Vaderaorna
- **Age:** 2-4
- **n(tot):** 180, **n(yrs):** 9
- **m:** 0.087 (0.063, 0.121)
- **SD:** 8.8%
- **SD(lr):** 8.19, 8.8%
- **Power:** 0.36, 0.49, 0.12
- **y(03):** 0.050 (0.037, 0.066)
- **r^2:** 0.81
- **t** = 0.81, *p* < 0.004

Ni, ug/g dry w., cod liver

### SE Gotland
- **Age:** 0-6
- **n(tot):** 110, **n(yrs):** 9
- **m:** 0.092 (0.072, 0.118)
- **SD:** 8.8%
- **SD(lr):** 23.2, 16%
- **Power:** 0.30, 0.40, 0.13
- **y(03):** 0.065 (0.047, 0.090)
- **r^2:** 0.57
- **t** = 0.57, *p* < 0.016

### Fladen
- **Age:** 0-5
- **n(tot):** 110, **n(yrs):** 9
- **m:** 0.176 (0.131, 0.237)
- **SD:** 8.8%
- **SD(lr):** 17.7, 14%
- **Power:** 0.18, 0.24, 0.11
- **y(03):** 0.121 (0.077, 0.188)
- **r^2:** 0.45
- **t** = 0.45, *p* < 0.048
Ni, ug/g dry w., perch liver

Holmoarna (4-7)
- n(tot)=76, n(yrs)=8
- m=104 (105, 196)
- slope=20% (38, 1.5)
- SD(y)=24.7, 33%, 24 yr
- y(03)=0.45 (0.16, 1.12)
- r(2)=.54, p=.038 *
- SD(sm)=11.4, p<.005, 9.5%

Kvadojarden (3-6)
- n(tot)=79, n(yrs)=8
- m=106 (108, 192)
- slope=16% (36, 3.9)
- SD(y)=28.7, 36%, 25 yr
- y(03)=0.54 (0.20, 1.45)
- r(2)=.39, p=.038 *
- SD(sm)=8.97, p<.001, 7.3%

Ni, ug/g dry w., eelpout liver

Holmoarna (3-6)
- n(tot)=19, n(yrs)=7
- m=.186 (.103, .338)
- slope=2.5% (-25, 30)
- SD(y)=41.8, 59%, 28 yr
- y(03)=.202 (.065, .625)
- r(2)=.01, NS
- SD(sm)=35.7, NS, 23%

Kvadojarden (2-6)
- n(tot)=66, n(yrs)=9
- m=.213 (.142, .320)
- slope=-16% (-25, -7.2)
- SD(y)=19.4, 13%, 16 yr
- y(03)=.111 (.072, .172)
- r(2)=.72, p<.004 *
- SD(sm)=18.0, NS, 10%

Vaderoarna (3-5)
- n(tot)=71, n(yrs)=8
- m=.248 (.160, .387)
- slope=-16% (-26, -5.1)
- SD(y)=23.0, 18%, 17 yr
- y(03)=.138 (.086, .224)
- r(2)=.69, p<.011 *
- SD(sm)=18.6, NS, 9.6%
15 Chromium

Due to a change of method for metal analysis in 2004, values after 2003 are not presented in this section. The new method is under investigation, since the values are uncertain.

The concentration of chromium in fish liver is determined using an atomic absorption spectrophotometer with graphite furnace at the Department of Environmental Assessment at Swedish University of Agricultural Sciences. The detection limit is estimated to approximately 0.1 μg/g dry weight.

The analysis started on samples collected 1995.

15.1 Temporal variation
Chromium decrease significantly in herring from Ängskärsklubb (autumn), Utlängan (autumn), Karlskona (spring), Fladen and Väderöarna, in cod and blue mussels from Fladen, in perch from Holmöarna and in guillemot eggs.

The required minimum years to detect an annual change of 5 % varies between 10 and 33 years for herring. The power to detect an annual change of 5 % ranges between 0.06 and 0.64.

15.2 Spatial variation
The chromium concentration in blue mussel samples from the Kattegatt varies between years and shows a geometric mean concentration in the same range as mussels from the Baltic Proper. These concentrations are about 2-3 times higher compared to samples from the Skagerack and close to or above the ‘high background concentration at diffuse loading’ in blue mussels for chromium of <3 μg/g dry weight, proposed by Knutzen and Skie (1992). The samples from the Skagerack are well below this value.
Table 15.1. Geometric mean concentrations of chromium (μg/g dry weight) in various matrices and sites during the time period and the estimated mean concentration for the last year. The age interval for fish, and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend</th>
<th>% (95% ci)</th>
<th>last year (95% ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring liver</strong></td>
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<td>Harufj. autumn</td>
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<td>Ångskärskl.aut.</td>
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<td>96-03</td>
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<tr>
<td>Landsort</td>
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<td>95-03</td>
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<td>.21 (0.17-.24)</td>
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<tr>
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<td>95-03</td>
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<tr>
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<td>95-03</td>
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<td>* significant trend, p &lt; 0.05</td>
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**Cr, ug/g dry w., herring liver**

Harufjärden (3-4)

\[
\begin{array}{cccccccc}
\text{n(tot)=124, n(yrs)=9} \\
\text{m=-.279 (.255,.304)} \\
\text{SD(lr)=27.5, 16%, 18 yr} \\
\text{r2=.42, p<.056} \\
\text{tao=-.50, p<.061} \\
\end{array}
\]

Angskärsklubb (3-5)

\[
\begin{array}{cccccccc}
\text{n(tot)=122, n(yrs)=9} \\
\text{m=-.235 (.207,.267)} \\
\text{SD(lr)=34.4, 24%, 20 yr} \\
\text{r2=.52, p<.028} \\
\text{tao=.56, p<.037} \\
\end{array}
\]

Landsort (3-5)

\[
\begin{array}{cccccccc}
\text{n(tot)=122, n(yrs)=9} \\
\text{m=-.206 (.174,.244)} \\
\text{SD(lr)=56.8, 48%, 33 yr} \\
\text{r2=.67, p<.012} \\
\text{tao=-.17, NS} \\
\end{array}
\]

Utlångan (3-4)

\[
\begin{array}{cccccccc}
\text{n(tot)=110, n(yrs)=9} \\
\text{m=-.246 (.213,282)} \\
\text{SD(lr)=40, 33%, 29 yr} \\
\text{r2=.47, p<.041} \\
\text{tao=-.67, p<.012} \\
\end{array}
\]
**Cr, ug/g dry weight, herring liver**

- **Angskarsklubb, spring**
  - age=3-6
  - n(tot)=80, n(yrs)=8
  - m=.341 (.297, .391)
  - slope=-4.7% (-9.5, .23)
  - SD(lr)=12.9, 6.8%, 10 yr
  - power=.53, .86, 4.7%
  - y(03)=.289 (.236, .355)
  - r²=.48, p<.057*
  - tao=-.50, p<.083

- **Karlskrona, spring**
  - age=0-4
  - n(tot)=70, n(yrs)=7
  - m=.300 (218, 412)
  - slope=-12% (-24, -1.57)
  - SD(lr)=19.9, 17%, 14 yr
  - power=.14, .36, 8.8%
  - y(02)=.208 (.136, .316)
  - r²=.59, p<.043*
  - tao=-.62, p<.051

- **Fladen (2-3)**
  - n(tot)=121, n(yrs)=9
  - m=.203 (.094, .437)
  - slope=-26% (-49, -2.8)
  - SD(lr)=47.3, 37%, 29 yr
  - power=.07, .08, 30%
  - y(03)=.072 (.024, .216)
  - r²=.50, p<.032*
  - tao=-.67, p<.012*

- **Vaderoarna**
  - age=2-4
  - n(tot)=136, n(yrs)=9
  - m=.302 (.172, .529)
  - slope=-22% (-35, -9.5)
  - SD(lr)=35.2, 19%, 20 yr
  - power=.12, .15, 16%
  - y(03)=.123 (.067, .228)
  - r²=.71, p<.005*
  - tao=.42, p<.002*

**Cr, ug/g wet w., blue mussel softbody**

- **Kvadofjarden**
  - length=0-3
  - n(tot)=88, n(yrs)=9
  - m=.284 (.263, .306)
  - slope=-3.5% (-6.3, -.67)
  - SD(lr)=27.1, 50%, 18 yr
  - power=1.0, 20%, 13%
  - y(03)=.247 (.217, .282)
  - r²=.07, p<.015*
  - tao=.42, p<.002*

- **Fladen (5-8 cm)**
  - n(tot)=130, n(yrs)=9
  - m=.302 (.172, .529)
  - slope=-22% (-35, -.95)
  - SD(lr)=35.2, 19%, 20 yr
  - power=.12, 15%, 16%
  - y(03)=.123 (.067, .228)
  - r²=.61, p<.022*
  - tao=.61, p<.002*
  - SD(sm)=38.9, NS, 13%

- **Vaderoarna (6-10)**
  - n(tot)=130, n(yrs)=9
  - m=.155 (.128, .187)
  - slope=1.3% (-6.6, 9.2)
  - SD(lr)=13.9, 12%, 15 yr
  - power=.24, .32, 9.5%
  - y(03)=.163 (.112, .237)
  - r²=.50, p<.037
  - tao=.66, NS
  - SD(sm)=10.5, p<.064, 7.1%

---

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16 Copper

Due to a change of method for metal analysis in 2004, values after 2003 are not presented in this section. The new method is under investigation, since the values are uncertain.

The concentration of copper in fish liver is determined using an atomic absorption spectrophotometer with graphite furnace at the Department of Environmental Assessment at Swedish University of Agricultural Sciences.

Copper is a nutritionally essential metal and the concentration is regulated by homeostatic mechanisms. The free copper is effectively controlled by metallothionein synthesis (da Silva and Williams, 1994) induced by copper itself or by other substances. Although copper is not believed to accumulate with continued exposure, changes found in biological tissues may still reflect changes in concentration of the ambient water.

The copper concentration in liver from Baltic herring is about 4.5 times higher than the concentration reported from the edible parts of herring. For cod the concentration in the liver is about 40-60 times higher and for perch about 12-14 times. Concentrations in edible parts are reported by Jorhem and Sundström, 1993.

The concentration of copper in fish liver and blue mussel soft body is determined using an atomic absorption spectrophotometer with graphite furnace. The detection limit is estimated to approximately 10 ng/g dry weight.

16.1 Temporal variation

16.1.1 Conventions, aims and restrictions
The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the copper discharges are to be reduced by 50% between 1985 and 1995, using 1985 as a base year.

The Minister Declaration from 1988, within HELCOM, calls for a reduction of the discharges of copper to air and water by 50% by 1995 with 1987 as a base year.

16.1.2 This investigation
A significant upward trend of copper in herring was found at Utlängan and significantly decreasing trends at Fladen for herring and blue mussels.

The number of years required to detect an annual change of 5% varied between 12 to 15 years for the herring time series at a power of 80%.
16.2 Spatial variation
No significant differences in mean copper concentration in herring between the sampling sites were found.

The copper concentration in blue mussels from the Swedish west coast is not significantly different compared to blue mussel samples of similar length from a reference site at Kobbefjord, Greenland (Riget et al 1993). Mussel samples from all three sites show mean levels below the ‘high background concentration at diffuse loading’ in blue mussels for copper of $<10 \, \mu g/g$ dry weight, proposed by Knutzen and Skie (1992).

16.3 Species differences
Significant differences in mean copper concentration, in fish liver and blue mussel soft body, were found between the species marked with ‘>’: 

Kvädöfjärden: Eelpout(22) > Perch(13) > Blue mussel (7.9)
Fladen: Cod(17) > Herring(10) > Blue mussel(5.4)
Väderöarna: Eelpout(31) > Herring(9.2) > Blue mussel(5.2)
Table 16.1. Geometric mean concentrations of copper (μg/g dry weight) in various matrices and sites during the time period and the estimated mean concentration for the last year. The age interval for fish, and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>yrs</th>
<th>year</th>
<th>trend</th>
<th>last year</th>
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<td>Harufj. autumn</td>
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<td>22</td>
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<td>Ångskärskl. aut.</td>
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<td>1.6 (.35, 2.9)</td>
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<tr>
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<td>80</td>
<td>8</td>
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<td>13 (11-15)</td>
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<td>287</td>
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<td>1.4 (.00, 2.8)*</td>
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<tr>
<td>** spring</td>
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<td>69</td>
<td>7</td>
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<td>14 (10-18)</td>
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</tr>
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<td>23</td>
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<td>9.2 (8.4-10)</td>
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<td>23</td>
<td>81-03</td>
<td>16 (15-18)</td>
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<tr>
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<td>23</td>
<td>81-03</td>
<td>17 (14-21)</td>
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<td>Perch liver</td>
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<tr>
<td>Holmöarna</td>
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<td>90</td>
<td>9</td>
<td>95-03</td>
<td>11 (8.6-13)</td>
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</tr>
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<td>Kvädojärden</td>
<td>3-7</td>
<td>80</td>
<td>8</td>
<td>95-03</td>
<td>13 (10-15)</td>
<td></td>
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<tr>
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<td>67</td>
<td>7</td>
<td>95-03</td>
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<td>9</td>
<td>95-03</td>
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<td>95-03</td>
<td>31 (28-35)</td>
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<td>Dab liver</td>
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<td></td>
</tr>
<tr>
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<td>3-5</td>
<td>257</td>
<td>14</td>
<td>81-94</td>
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<td>Flounder liver</td>
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</tr>
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<td>Väderöarna</td>
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<td>239</td>
<td>14</td>
<td>81-94</td>
<td>51 (35-74)</td>
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<tr>
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<td>5-8</td>
<td>396</td>
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<td>-1.1 (-2.2, .03)</td>
<td>5.4 (4.7-6.2)</td>
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<td>Väderöarna</td>
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<td>22</td>
<td>81-03</td>
<td>5.2 (4.9-5.6)</td>
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</tr>
<tr>
<td>Kvädojärden</td>
<td></td>
<td>88</td>
<td>9</td>
<td>95-03</td>
<td>7.9 (7.2-8.7)</td>
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<tr>
<td>Guillemot egg</td>
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<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td>80</td>
<td>8</td>
<td>96-03</td>
<td>2.9 (2.7-3.2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05

Cu, μg/g dry w., herring liver
Cu, ug/g dry w., herring (liver)

Angskarskl., spring

n(tot)=80, n(yrs)=8
m=13.1 (11.4,15.1)
slope=-2.4%(-4.7,4.0)
SD(r)=6.65,11%,12 yr
dr=34,646.1%%
y(03)=12.1 (9.3,15.8)
r2=.12, NS

tao=.03, NS

Karlskrona, spring

n(tot)=69, n(yrs)=7
m=13.6 (10.3,17.8)
slope=-8.2%(-21,4.3)
SD(r)=9.8,18%,15 yr
dr=65,329.4%%
y(02)=10.6 (6.8,16.6)
r2=.36, NS

tao=-.43, NS

Fladen, (2-3)

n(tot)=443, n(yrs)=23
m=12.3 (10.9,13.8)
slope=-1.5%(-3.2,1.3)
SD(r)=10.2,2.4%,15 yr
dr=17,329.3%%
y(03)=10.4 (8.4,12.8)
r2=.15, p<.066

tao=-.29, p<.054

Vaderoama

n(tot)=180, n(yrs)=9
m=9.17 (8.42,10.0)
slope=-1.1%(-4.6,2.3)
SD(r)=9.5,4.9%,15 yr
dr=64,329.3%%
y(03)=8.8 (7.4,10.3)
r2=.25, NS

tao=.17, NS

Cu, ug/g dry w., perch liver

Holmoarna

age=0-7
n(tot)=90, n(yrs)=9
m=10.6 (8.63,13.0)
slope=-4.5%(-12,3.4)
SD(r)=10.8,11%,15 yr
dr=24,329.4%%
y(03)= 8.9 ( 6.1,12.9)
r2=.21, NS

tao=-.39, NS

Kvadofjarden

age=3-7
n(tot)=80, n(yrs)=8
m=12.5 (10.3,15.2)
slope=-3.6%(-11.3,8)
SD(r)=9.99,12%,14 yr
dr=21,408.3%%
y(03)=10.7 ( 7.4,15.6)
r2=.19, NS

tao=-.21, NS
Cu, ug/g wet w., blue mussel softbody

Shell lengths in brackets

The blue lines indicate background concentration in OSPAR areas.
17 Zinc

Updated 08.03.28

Due to a change of method for metal analysis in 2004, values after 2003 are not presented in this section. The new method is under investigation, since the values are uncertain.

The time series of zinc concentration in fish liver and blue mussel soft body, presented below, start 1981. It is determined using an atomic absorption spectrophotometer with graphite furnace at the Department of Environmental Assessment at Swedish University of Agricultural Sciences.

Zinc is a nutritionally essential metal and the concentration is regulated by homeostatic mechanisms. Hence, zinc is not believed to accumulate with continued exposure but changes found in biological tissues may still reflect changes in concentration of the ambient water.

The zinc concentration in liver from Baltic herring is about 1.5 times higher than the concentration reported from the edible parts of herring. For cod the concentration in the liver is about 6 - 8 times higher and for perch about 3.5 times. Concentrations in edible parts are reported by Jorhem and Sundström, 1993.

The concentration of zinc in fish liver and blue mussel soft body is determined using an atomic absorption spectrophotometer with graphite furnace. The detection limit is estimated to approximately 100 ng/g dry weight.

17.1 Temporal variation

17.1.1 Conventions, aims and restrictions
The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the zinc discharges are to be reduced by 50% between 1985 and 1995, using 1985 as a base year.

The Minister Declaration from 1988, within HELCOM, calls for a reduction of the discharges of zinc to air and water by 50% by 1995 with 1987 as a base year.

17.1.2 This investigation
Significant downward trends are shown in herring liver from Landsort (the past ten years) and in guillemot eggs during the whole analysed time period. Significant upward trends are found for herring from Harufjärden and Fladen for the whole period and also for Utlångan the last ten years.

The number of years required to detect an annual change of 5% varied between 9 to 13 years for the herring time series with a power to detect a 5% annual change ranging from
0.43 for the shorter time series to 1.0 for the longer ones. (Since it is not appropriate to fit a log-linear trend at Harufjärden and Utlängan, these sites were excluded from the power calculations.)

### 17.2 Spatial variation
No significant differences in mean zinc concentration are observed in herring among the sampling sites in the Baltic Sea and the Swedish west coast.

The zinc concentration in cod liver from Fladen is significantly higher than in cod liver from the site SE of Gotland. This may be explained by the significantly lower fat content in cod liver from Fladen since zinc concentration is negatively correlated with fat content.

The zinc concentration in blue mussels from the Swedish west coast is not significantly different compared to blue mussel samples of similar length from a reference site at Kobbefjord, Greenland (Riget et al. 1993). The zinc concentrations in blue mussels from all the three investigated sites are below the proposed background concentrations for the North Sea (ICES, 1997)

### 17.3 Differences among various species
Significant differences in mean zinc concentration, in fish liver and blue mussel soft body, were found between the species marked with ‘>’:

- Holmöarna: Eelpout(158) > Perch(102)
- Kvädöfjärden: Eelpout(189) > Perch(114)
- Fladen: Blue mussel(112) > Herring(105) > Cod(71)
- Väderöarna: Blue mussel (108) > Herring(107)

### 17.4 Seasonal variation
The concentrations in spring caught herring from Ängskärsklubb and Utlängan is considerable higher compared to samples from the same areas in the autumn (table 17.1).
Table 17.1. Geometric mean concentrations of zinc (μg/g dry weight) in various matrices and sites during the time period and the estimated mean concentration for the last year. The age interval for fish, and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend (95% ci)</th>
<th>last year</th>
</tr>
</thead>
<tbody>
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<td><strong>Herring liver</strong></td>
<td></td>
<td></td>
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<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
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<td>21</td>
<td>81-03</td>
<td>1.6 (.22, 3.0)*</td>
<td>110 (96-140)</td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>363</td>
<td>21</td>
<td>81-03</td>
<td>100 (94-110)</td>
<td></td>
</tr>
<tr>
<td>”</td>
<td>3-6</td>
<td>80</td>
<td>8</td>
<td>96-03</td>
<td>150 (130-170)</td>
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</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>352</td>
<td>22</td>
<td>81-03</td>
<td>93 (87-100)</td>
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<tr>
<td>Utlängan, aut.</td>
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<td>270</td>
<td>22</td>
<td>81-03</td>
<td>100 (94-110)</td>
<td></td>
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<td>”</td>
<td>0-4</td>
<td>70</td>
<td>7</td>
<td>96-03</td>
<td>130 (100-150)</td>
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<td>Fladen</td>
<td>418</td>
<td>22</td>
<td>81-03</td>
<td>1.0 (.25, 1.8)*</td>
<td>110 (95-120)</td>
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<tr>
<td>Väderöarna</td>
<td>2-4</td>
<td>180</td>
<td>9</td>
<td>95-03</td>
<td>110 (94-120)</td>
<td></td>
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<tr>
<td><strong>Cod liver</strong></td>
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</tr>
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<td>SE Gotland</td>
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<td>325</td>
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<td>81-03</td>
<td>34 (30-39)</td>
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<td>81-03</td>
<td>71 (66-77)</td>
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<td>Holmöarna</td>
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<td>8</td>
<td>95-03</td>
<td>110 (92-140)</td>
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<td>9</td>
<td>95-03</td>
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<td>95-03</td>
<td>190 (150-240)</td>
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<td>9</td>
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<td>220 (180-270)</td>
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<td><strong>Dab liver</strong></td>
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</tr>
<tr>
<td>Fladen</td>
<td>3-5</td>
<td>234</td>
<td>13</td>
<td>81-94</td>
<td>88 (77-101)</td>
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<tr>
<td><strong>Flounder liver</strong></td>
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<td>13</td>
<td>81-94</td>
<td>183 (149-223)</td>
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<td>9</td>
<td>95-03</td>
<td>130 (120-150)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Guillemot egg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td>80</td>
<td>8</td>
<td>96-03</td>
<td>-2.8 (-5.3,-3.3)*</td>
<td>43 (38-47)</td>
<td></td>
</tr>
</tbody>
</table>

NL = non-linear trend components
* significant trend, p < 0.05
Zn, ug/g dry weight, herring liver

Harufjarden (3-4)

- n(tot)=344, n(yrs)=21
- m=86.8 (106.6, 66.0)
- slope=1.3% (22.3, 3.0)
- y(03)=113 (90, 135)
- tao=39, p<0.013
- SD(sm)=3.1, p=0.012

Angskarsklubb (3-5)

- n(tot)=363, n(yrs)=21
- m=95.9 (86.6, 106.0)
- slope=.7% (-.22, 3.0)
- y(03)=91 (60, 154)
- tao=42, p<0.013
- SD(sm)=3.4, p=0.012

Landsort (3-5)

- n(tot)=352, n(yrs)=22
- m=93.2 (87.0, 100.0)
- slope=-.2% (-1.3, .85)
- y(03)=97 (80, 125)
- tao=42, p<0.013
- SD(sm)=3.4, p<0.012

Utlangan (3-4)

- n(tot)=270, n(yrs)=22
- m=101 (94.1, 108.0)
- slope=.79% (-.24, 1.8)
- y(03)=97 (80, 125)
- tao=42, p<0.013
- SD(sm)=3.1, p=0.012

Zn, ug/g dry weight, herring liver

Angskarsklubb, spring

- age=3-6
- n(tot)=80, n(yrs)=8
- m=146 (129, 165)
- slope=-2.0% (-7.6, 3.6)
- y(03)=108 (108, 154)
- tao=42, p<0.013

Karlskrona, spring

- age=0-4
- n(tot)=70, n(yrs)=7
- m=125 (102, 153)
- slope=-4.2% (-15, 6.3)
- y(02)=75 (75, 161)
- tao=42, p<0.013

Fladen (2-3)

- age=2-3
- n(tot)=418, n(yrs)=22
- m=93.9 (88.5, 100.0)
- slope=1.0% (.25, 1.8)
- y(03)=95 (95, 115)
- tao=42, p<0.013

Vaderoarna

- age=2-4
- n(tot)=180, n(yrs)=9
- m=107 (94.3, 121)
- slope=-1.5% (-6.9, 3.2)
- y(03)=97 (78, 126)
- tao=42, p<0.013
The blue lines indicate background concentration in OSPAR areas.
18 PCB's, Polychlorinated biphenyles

PCB’s 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. 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 number of possible congeners is 209, having one to ten chlorines. 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).

Seven CB-congeners (CB-28, CB-52, CB-101, CB-118, CB-138, CB-153 and CB-180) 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, cod liver, blue mussel soft body and guillemot egg is determined using a gas chromatograph (GC) equipped with an electron capture detector.

Before 1988, PCB’s were analysed by a packed column GC and the total sum of PCB was estimated from 14 peaks after calibration with Aroclor 1254 (Jensen et al. 1983). During 1988, analyses on capillary column were introduced, admitting analysis of individual congeners (Eriksson et al., 1994).

Although the relative abundance of the various CB-congeners is considered to be fairly constant, both geographical differences and temporal changes in the ratios between the investigated congeners can be shown, see below.

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. 1990). This implies that the reported concentration of CB-138 also includes a minor contribution from CB-163 and possibly also from CB-164.

The sum of PCB’s (sPCB), presented in this report, is estimated from the concentration of peak 10 (PCB10) in the chromatogram from packed column chromatography using the ratio, R1=PCB10/sPCB. PCB10 constitute approximately 11-14% of the total amount of PCB in herring, 13-15% in cod, 16-17% in perch, 12 % in blue mussel and 18% in guillemot egg. Thus, the ratio varies between matrices but is very stable within the same matrix at the same sampling site - the coefficient of variation is found, with few exceptions, to be between 3.5 - 6%, see CV1 in table 18.1. From 1989 and forward, PCB10 concentrations have been estimated using the ratio, R2=(CB-138 + CB-163)/PCB10. CB-138 + CB-163 constitute about 60-80% of PCB10 and 7-12% of the total sum of PCB’s in herring. The mean ratios are given in table 18.1, below.
The sum of PCB’s is until 1988 estimated according to:

\[ s_{PCB} = \frac{PCB10}{R_1} \]

and after 1988:

\[ s_{PCB} = \frac{(CB-138+CB-163)}{(R_1 \cdot R_2)} \]

**Table 18.1.** Mean ratios between peak 10 and the total sum of PCB’s, from packed column gas chromatography (GC) \((R_1)\) and mean ratios between CB-138+CB-163 (capillary GC) and PCB10 \((R_2)\). Also the number of analyses \((n)\) and the Coefficient of Variation \((CV)\) for the two ratios are given.

<table>
<thead>
<tr>
<th></th>
<th>(n_1)</th>
<th>(R_1)</th>
<th>(CV_1)</th>
<th>(n_2)</th>
<th>(R_2)</th>
<th>C.I.</th>
<th>(CV_2)</th>
<th>(R_1 \cdot R_2)</th>
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<td><strong>Herring</strong></td>
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<td></td>
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<tr>
<td>Harufjärden</td>
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<td>.14</td>
<td>4.0</td>
<td>19</td>
<td>.73</td>
<td>.67-.76</td>
<td>9.1</td>
<td>.098</td>
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<td>Ångskärsklubb</td>
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<td>.14</td>
<td>5.1</td>
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<td>.83</td>
<td>.79-.88</td>
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<td>.12</td>
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<tr>
<td>spring</td>
<td>397</td>
<td>.13</td>
<td>5.1</td>
<td>25</td>
<td>.79</td>
<td>.75-.82</td>
<td>11</td>
<td>.10</td>
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<tr>
<td>Landsort</td>
<td>159</td>
<td>.12</td>
<td>5.2</td>
<td>29</td>
<td>.61</td>
<td>.59-.63</td>
<td>7.4</td>
<td>.070</td>
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<td>Utängan</td>
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<td>.12</td>
<td>5.4</td>
<td>20</td>
<td>.65</td>
<td>.62-.68</td>
<td>9.8</td>
<td>.075</td>
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<tr>
<td>spring</td>
<td>371</td>
<td>.12</td>
<td>5.3</td>
<td>10</td>
<td>.67</td>
<td>.64-.69</td>
<td>5.4</td>
<td>.080</td>
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<tr>
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<td>.13</td>
<td>5.3</td>
<td>25</td>
<td>.82</td>
<td>.79-.86</td>
<td>10</td>
<td>.11</td>
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<td><strong>Cod</strong></td>
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</tr>
<tr>
<td>Gotland</td>
<td>152</td>
<td>.14</td>
<td>4.0</td>
<td>11</td>
<td>.69</td>
<td>.65-.72</td>
<td>7.3</td>
<td>.093</td>
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<tr>
<td>Fladen</td>
<td>176</td>
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<td>10</td>
<td>.85</td>
<td>.81-.89</td>
<td>6.9</td>
<td>.13</td>
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<td><strong>Perch</strong></td>
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</tr>
<tr>
<td>Holmöarna</td>
<td>140</td>
<td>.17</td>
<td>5.3</td>
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<td>Kvädojärden</td>
<td>108</td>
<td>.16</td>
<td>6.0</td>
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<td><strong>Dab</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>153</td>
<td>.18</td>
<td>5.9</td>
<td>10</td>
<td>.71</td>
<td>18</td>
<td></td>
<td>.13</td>
</tr>
<tr>
<td><strong>Flounder</strong></td>
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<td></td>
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<td></td>
</tr>
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<td>Väderöarna</td>
<td>137</td>
<td>.13</td>
<td>9.8</td>
<td>5</td>
<td>.74</td>
<td>11</td>
<td></td>
<td>.096</td>
</tr>
<tr>
<td><strong>Blue mussel</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>5</td>
<td>.12</td>
<td>11.</td>
<td>1</td>
<td>.74</td>
<td>-</td>
<td></td>
<td>.087</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>9</td>
<td>.12</td>
<td>5.6</td>
<td>1</td>
<td>.95</td>
<td>-</td>
<td></td>
<td>.11</td>
</tr>
<tr>
<td><strong>Guillemot</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td>211</td>
<td>.18</td>
<td>3.5</td>
<td>30</td>
<td>.77</td>
<td>.74-.80</td>
<td>9.8</td>
<td>.14</td>
</tr>
</tbody>
</table>

**Table 18.2.** Approximate detection limit (capillary column, GC) for the analysed CB-congeners.

<table>
<thead>
<tr>
<th>Congener</th>
<th>ng/g, fat weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB-28 (2,4,4'-tri CB)</td>
<td>4</td>
</tr>
<tr>
<td>CB-52 (2,2',5,5'-tetra CB)</td>
<td>4</td>
</tr>
<tr>
<td>CB-101 (2,2',4,5,5'-penta CB)</td>
<td>4</td>
</tr>
<tr>
<td>CB-118 (2,3',4,4',5-penta CB)</td>
<td>5</td>
</tr>
<tr>
<td>CB-138 (2,2',3,4,4',5-hexa CB)</td>
<td>5</td>
</tr>
<tr>
<td>CB-153 (2,2',4,4',5,5'-hexa CB)</td>
<td>5</td>
</tr>
<tr>
<td>CB-180 (2,2',3,4,4',5,5'-hepta CB)</td>
<td>4</td>
</tr>
</tbody>
</table>
18.1 Temporal variation

18.1.1 Conventions, aims and restrictions
The Helsinki Convention (HELCOM) revised 1992 especially names PCB for which special bans and restrictions on transport, trade, handling, use and disposal are imposed. The Minister Declaration from 1988, within HELCOM, calls for a reduction of stable organic substances by 50% by 1995 with 1987 as a base year.

The Minister Declaration from 1996, within HELCOM, and the declaration in Esbjerg 1995, calls for measures for toxic, persistent, bioaccumulating substances to have ceased completely in the year 2020.

The use of PCB was banned in Sweden in 1973, except for sealed systems. In 1978, all new use of PCB was forbidden.

18.1.2 This investigation
The concentration of sPCB (sum of PCB’s estimated from CB-138 or peak 10 from packed column chromatography) in herring muscle from all herring sites in the Baltic and at the west coast show significant decreasing trends during the time period 1978/80-2008. The average rate varies between -5 and -10% per year. A similar significant decrease within the same range (5 and 10% a year) was also found in the two time series of spring caught herring, 1972-2008. This implies a total decrease of about 70% at Ängskärsklubb and about 90% at Karlskrona, of the PCB-concentration in herring muscle, since the beginning of the seventies. CB-153 show the same decreasing trends as sPCB at all sites except for Utlängan where no trend is observed.

An extremely high concentration of PCB’s was recorded at Landsort 1996. This could most probably be explained by the very low fat content in herring this year.

The two cod time series from south east of Gotland in the Baltic Proper and Fladen at the west coast show significant decreasing trends for sPCB. A significant decrease of CB-153 is observed for the last ten years in cod from Fladen.

Also in the time series of perch the sPCB concentrations have decreased as well as in blue mussel from the west coast and in guillemot eggs (1969-2008). The latter trend corresponds to a total decrease of almost 90% since the beginning of the seventies. CB-153 shows the same decreasing trends as sPCB at all perch and mussel sites.

The number of years required to detect an annual change of 5% varied between 14 to 22 years for the herring, perch, mussel and cod time series.
18.1.3 Conclusion
The concentration of PCB has decreased approximately with 5-10% per year, in herring and cod from the Baltic Sea and Kattegatt as well as in guillemot eggs and perch from the Baltic Sea, since the end of the seventies.

18.2 Spatial variation

![Spatial variation in concentration (l.w.) of CB-153 in herring muscle. (N.B., the bar in the most northern part of the Bothnian Bay represents the site Rånefjärden, Harufjärden shows lower concentrations but is hidden behind)](image)

The figure 18.1 indicates that herring muscle from Ängskärsklubb in the Bothnian Sea, Lagnö, Utlängan and Hanö Bay in the Baltic Proper show elevated concentrations of CB-153 compared to Harufjärden and Kinnbäcksfjärden in the Bothnian Bay, the off shore sampling site in the Baltic Proper and Fladen and Väderöarna (l lipid weight) at the west coast. Yet only two years are presentetd for the new sampling sites and only one year for the off shore sampling sites.

The estimated concentration of CB-153 (wet weight) for year 2008 from Harufjärden in the Bothnian Bay show similar, or in fact lower concentrations compared to Fladen in the Kattegatt and Väderöarna in the Skagerack, and significantly lower than herring samples from the Bothnian Sea and the Baltic Proper.

The ratio CB-118/CB-153 is significantly lower at Ängskärsklubb compared to all the other sites. Herring from Landsort has the highest ratio.
A significant difference was found between CB-153 (lipid weight) concentrations analysed in cod liver from south east of Gotland (higher) and the Kattegatt (lower).

**Table 18.3** Trend (in %) for sPCB (μg/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend (95% ci)</th>
<th>last year (95% ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring msc.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haruť. autumn</td>
<td>3-4</td>
<td>394</td>
<td>29</td>
<td>78-08</td>
<td>-8.9 (-10,-7.6)*</td>
<td>.17 (.13-.21)</td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>353</td>
<td>28</td>
<td>78-07</td>
<td>-7.7 (-8.9,-6.6)*</td>
<td>.35 (.29-.43)</td>
</tr>
<tr>
<td>” spring</td>
<td>2-5</td>
<td>633</td>
<td>35</td>
<td>72-08</td>
<td>-5.0 (-6.1,-3.8)*</td>
<td>1.1 (0.87-1.4)</td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>394</td>
<td>30</td>
<td>78-08</td>
<td>-5.5 (-6.6,-4.4)*</td>
<td>.60 (.50-.73)</td>
</tr>
<tr>
<td>Utlängan, aut.</td>
<td>3-4</td>
<td>295</td>
<td>29</td>
<td>80-08</td>
<td>-5.5 (-6.6,-4.4)*</td>
<td>.50 (.42-.61)</td>
</tr>
<tr>
<td>” spring</td>
<td>2-4</td>
<td>624</td>
<td>34</td>
<td>72-08</td>
<td>-9.5 (-10,-8.6)*</td>
<td>.62 (.52-.75)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>481</td>
<td>29</td>
<td>80-08</td>
<td>-7.7 (-8.8,-6.7)*</td>
<td>.14 (.12-.17)</td>
</tr>
<tr>
<td><strong>Cod liver</strong></td>
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<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>315</td>
<td>29</td>
<td>80-08</td>
<td>-5.8 (-7.3,-4.3)*</td>
<td>.94 (.74-1.2)</td>
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<tr>
<td>Fladen</td>
<td>2-3</td>
<td>332</td>
<td>28</td>
<td>80-08</td>
<td>-6.0 (-8.1,-3.9)*</td>
<td>1.2 (.85-1.7)</td>
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<td><strong>Perch muscle</strong></td>
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</tr>
<tr>
<td>Holmōarna</td>
<td>4-7</td>
<td>269</td>
<td>21</td>
<td>80-07</td>
<td>-8.9 (-11,-7.1)*</td>
<td>.23 (.18-.31)</td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>3-4</td>
<td>232</td>
<td>25</td>
<td>80-08</td>
<td>-8.9 (-11,-6.6)*</td>
<td>.11 (.076-.16)</td>
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<td><strong>Dab muscle</strong></td>
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<tr>
<td>Fladen</td>
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<td>158</td>
<td>13</td>
<td>81-94</td>
<td>-4.6 (-12,2.8)</td>
<td>0.72 (.40-1.3)</td>
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<tr>
<td>Väderöarna</td>
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<td>15</td>
<td>80-94</td>
<td>-2.8 (-7.4,1.8)</td>
<td>1.7 (1.2-2.6)</td>
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<tr>
<td><strong>Blue mussel</strong>**</td>
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</tr>
<tr>
<td>Fladen</td>
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<td>22</td>
<td>84-08</td>
<td>-7.4 (-9.3,-5.6)*</td>
<td>.19 (.15-.24)</td>
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<td>Väderöarna</td>
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<td>23</td>
<td>84-08</td>
<td>-7.2 (-9.3,-5.1)*</td>
<td>.23 (.17-.31)</td>
<td></td>
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<tr>
<td><strong>Guillemot egg</strong></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>St. Karlsö</td>
<td>390</td>
<td>37</td>
<td>69-08</td>
<td>-8.9 (-9.5,-8.4)*</td>
<td>12 (10-13)</td>
<td></td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05  
** Pooled samples
Table 18.4. Trend (in %) for CB-153 (μg/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if \( p < 0.1 \) or from the mean if no trend is present. The age interval for fish and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
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<th>n tot</th>
<th>n yrs</th>
<th>year</th>
<th>trend</th>
<th>last yr</th>
</tr>
</thead>
<tbody>
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<td><strong>Herring msc.</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>278</td>
<td>20</td>
<td>87-08</td>
<td>-4.5 ( -7.4, -1.6)*</td>
<td>.031 (.023 -.043)</td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>287</td>
<td>19</td>
<td>89-07</td>
<td>-5.9 ( -8.6, -3.1)*</td>
<td>.075 (.056 -.10)</td>
</tr>
<tr>
<td>” spring</td>
<td></td>
<td>269</td>
<td>20</td>
<td>89-08</td>
<td></td>
<td>.18 (.12 -.26)</td>
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<tr>
<td>Landsort</td>
<td>3-5</td>
<td>315</td>
<td>22</td>
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<td>-4.8 ( 7.9, -1.8)*</td>
<td>.062 (.043 -.090)</td>
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<tr>
<td>Utlångan, aut.</td>
<td>3-4</td>
<td>279</td>
<td>21</td>
<td>88-08</td>
<td></td>
<td>.075 (.055 -.10)</td>
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<td>” spring</td>
<td></td>
<td>264</td>
<td>20</td>
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<td>-4.8 ( -7.4, -2.2)*</td>
<td>.11 (.082 -.15)</td>
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<tr>
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<td>2-3</td>
<td>336</td>
<td>21</td>
<td>88-08</td>
<td>-6.5 ( -8.5, -4.6)*</td>
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<td>243</td>
<td>13</td>
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<td>.016 (.011 -.023)</td>
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<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>163</td>
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<td>.16 (.13 -.20)</td>
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<td>19</td>
<td>89-08</td>
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<td>.40 (.28 -.56)</td>
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<td><strong>Perch muscle</strong></td>
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<tr>
<td>Holmöarna</td>
<td></td>
<td>139</td>
<td>14</td>
<td>89,95-07</td>
<td>-11 ( -16, -5.6)*</td>
<td>.10 (.065 -.135)</td>
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<tr>
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<td>211</td>
<td>21</td>
<td>84,89-08</td>
<td>-6.2 ( -9.9, -2.6)*</td>
<td>.027 (.018 -.040)</td>
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<tr>
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<td>11</td>
<td>95,97-07</td>
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<td>.12 (.059 -.25)</td>
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<td>14</td>
<td>95-08</td>
<td>-9.6 ( -15, -4.4)*</td>
<td>.093 (063-.14)</td>
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<tr>
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<td>123</td>
<td>14</td>
<td>95-08</td>
<td></td>
<td>.28 (.16 -.51)</td>
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<td><strong>Dab muscle</strong></td>
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<tr>
<td>Fladen</td>
<td>3-6</td>
<td>5</td>
<td>5</td>
<td>89-94</td>
<td></td>
<td>-</td>
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<td><strong>Flounder msc</strong></td>
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<tr>
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<td>6</td>
<td>6</td>
<td>89-94</td>
<td></td>
<td>-</td>
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<td><strong>Blue mussel</strong></td>
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<tr>
<td>Fladen</td>
<td>84</td>
<td>21</td>
<td>88-08</td>
<td>-7.5 ( -9.0, -6.0)*</td>
<td>.024 (.020 -.028)</td>
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<td>Väderöarna</td>
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<td>20</td>
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<td>-6.0 ( -8.7, -3.3)*</td>
<td>.028 (.021 -.039)</td>
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<tr>
<td>Kvädöfjärden</td>
<td>69</td>
<td>14</td>
<td>95-08</td>
<td>-2.0 ( -3.7, -2.3)*</td>
<td>.053 (.047 -.060)</td>
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<td><strong>Guillemot egg</strong></td>
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<td>St. Karlsö</td>
<td>208</td>
<td>21</td>
<td>88-08</td>
<td>-7.1 ( -8.3, -5.8)*</td>
<td>2.1 (1.8-2.4)</td>
<td></td>
</tr>
</tbody>
</table>

* significant trend, \( p < 0.05 \)
** Pooled samples
sPCB, ug/g lipid w., herring muscle

Fat adjusted geometric means (spring)

**Angskarsklubb (2-5) spring**
- \( n(tot) = 633, n(yrs) = 35 \)
- \( m = 2.63 \) (2.11, 3.29)
- \( \text{slope} = -5.0\% (-6.1, -3.8) \)
- \( \text{SD(lr)} = 29\% \)
- \( \text{power} = 1.0 \)
- \( r^2 = .71, p < .001 * \)
- \( \text{SD(sm)} = 39, \ NS \)

**Karlskrona (2-4) spring**
- \( n(tot) = 624, n(yrs) = 34 \)
- \( m = 3.27 \) (2.24, 4.77)
- \( \text{slope} = -9.5\% (-10.8, -8.6) \)
- \( \text{SD(lr)} = 25\% \)
- \( \text{power} = 1.0 \)
- \( r^2 = .94, p < .001 * \)
- \( \text{SD(sm)} = 21, \ NS \)

**Fladen (2-3)**
- \( n(tot) = 481, n(yrs) = 29 \)
- \( m = 0.409 \) (0.314, 0.534)
- \( \text{slope} = -7.7\% (-8.8, -6.7) \)
- \( \text{SD(lr)} = 20\% \)
- \( \text{power} = 1.0 \)
- \( r^2 = .57, p < .001 * \)

**Harufjarden (3-4)**
- \( n(tot) = 394, n(yrs) = 29 \)
- \( m = 1.03 \) (0.783, 1.37)
- \( \text{slope} = -5.5\% (-6.6, -4.4) \)
- \( \text{SD(lr)} = 24\% \)
- \( \text{power} = 1.0 \)
- \( r^2 = .78, p < .001 * \)

**Landsort (3-5)**
- \( n(tot) = 394, n(yrs) = 30 \)
- \( m = 1.34 \) (1.09, 1.65)
- \( \text{slope} = -5.5\% (-6.6, -4.4) \)
- \( \text{SD(lr)} = 24\% \)
- \( \text{power} = 1.0 \)
- \( r^2 = .78, p < .001 * \)

**Utlangan (3-4)**
- \( n(tot) = 481, n(yrs) = 29 \)
- \( m = 0.409 \) (0.314, 0.534)
- \( \text{slope} = -7.7\% (-8.8, -6.7) \)
- \( \text{SD(lr)} = 20\% \)
- \( \text{power} = 1.0 \)
- \( r^2 = .57, p < .001 * \)
sPCB, ug/g lipid w., blue mussel

**Fladen**
- $n_{(tot)}=83$, $n_{(yrs)}=22$
- $m=438.4$ (336.0, 570.0)
- slope=-7.4% (-9.3, -5.6)
- $SD(y)=24.2$%, 16 yr
- $SD(x)=1.02$%
- $y_{(08)}=190$ (149, 243)
- $t_2=7.8$, $p<0.001^*$
- $tao=73$, $p<0.001^*$
- $SD(sm)=20$, $p<0.001.5.9$
- slope=-8.8% (-14, -3.5)
- $SD(y)=18.8$%, 12 yr
- $power=42$/56/6.7%

**Vaderoarna**
- $n_{(tot)}=84$, $n_{(yrs)}=23$
- $m=551.1$ (416.7, 730.0)
- slope=-7.2% (-9.3, -5.1)
- $SD(y)=32.4$%, 18 yr
- $SD(x)=1.01$%
- $y_{(08)}=233$ (173, 313)
- $t_2=7.1$, $p<0.001^*$
- $tao=56$, $p<0.001^*$
- $SD(sm)=27$, $p<0.001.5.8$
- slope=-47% (-4.3, 5.3)
- $SD(y)=15.7$%, 12 yr
- $power=.49$/64/6.1%

---

sPCB, ug/g lipid w., Guillemot eggs, early laid. St Karlso

**St Karlso**
- $n_{(tot)}=390$, $n_{(yrs)}=37$
- $m=64.2$ (45.4, 90.9)
- slope=-8.9% (-9.5, -8.4)
- $SD(y)=15.0$%, 12 yr
- $power=1.0$/59/6.5%
- $y_{(08)}=11.7$ (10.4, 13.1)
- $t_2=97$, $p<0.001^*$
- $tao=.92$, $p<0.001^*$
- $SD(sm)=3.9$, NS (5.8)
- slope=-10% (-16, -4.3)
- $SD(y)=20.8$%, 13 yr
- $power=.37$/50/7.2%
- $t_2=7.1$, $p<0.004^*$

---

96
CB-153, ug/g lipid w., herring muscle

Harufjarden (3-4)
- n(tot)=279, n(yrs)=20
- m=0.048 (.039, .060)
- slope=-4.5% (-7.4, -1.6)
- SD(lr)=34%, 4.3%, 18 yr
- power=.92/.18/14%
- y(08)=.031 (.023, .043)
- r^2=.38, p<.004 *
- tao=-.42, p<.009 *
- SD(sm)=12, NS, 13%
- slope=-4.8% (-14, 4.9)
- SD(lr)=38%, 14%, 19 yr
- power=.17/.17/14%
- r^2=.14, NS

Angskarsklubb (3-5)
- n(tot)=287, n(yrs)=19
- m=.127 (.103, .158)
- slope=-5.9% (-8.6, -3.1)
- SD(lr)=27%, 3.9%, 17 yr
- power=.95/.23/12%
- y(07)=.075 (.056, .101)
- r^2=.54, p<.001 *
- tao=-.49, p<.039, 8.9%
- SD(sm)=12, p<.039, 8.9%
- slope=-7.6% (-13, -1.8)
- SD(lr)=21%, 8.3%, 14 yr
- power=.40/.40/8.3%
- r^2=.53, p<.016 *

Landsort (3-5)
- n(tot)=315, n(yrs)=22
- m=.103 (.081, .130)
- slope=-4.8% (-7.9, -1.8)
- SD(lr)=40%, 4.4%, 21 yr
- power=.91/.14/16%
- y(08)=.062 (.043, .090)
- r^2=.36, p<.003 *
- tao=-.45, p<.019, 12%
- SD(sm)=14, p<.019, 12%
- slope=-7.2% (-15, .16)
- SD(lr)=29%, 11%, 16 yr
- power=.26/.26/11%
- r^2=.39, p<.052

Utlangan (3-4)
- n(tot)=279, n(yrs)=21
- m=.093 (.079, .111)
- slope=-2.2% (-4.9, .51)
- SD(lr)=33%, 3.9%, 18 yr
- power=.96/.19/13%
- y(08)=.075 (.055, .103)
- r^2=.13, NS
- tao=-.17, NS
- SD(sm)=10, p<.006, 8.7%
- slope=.95% (-7.2, 9.1)
- SD(lr)=31%, 12%, 17 yr
- power=.22/.22/12%
- r^2=.01, NS

Vaderoarna
- n(tot)=243, n(yrs)=13
- m=.021 (.017, .027)
- slope=-6.5% (-8.5, -4.6)
- SD(lr)=32%, 7.6%, 17 yr
- power=.95/22/12%
- y(08)=.022 (.018, .028)
- r^2=.73, p<.001 *
- tao=.70, p<.001 *
- SD(sm)=8.6, NS, 9.9%
- slope=-13% (-18, -7.7)
- SD(lr)=19%, 7.3%, 13 yr
- power=.49/49/7.3%
- r^2=.81, p<.001 *
CB-153, ug/g lipid w., cod liver

SE Gotland (3-4)

\[ \text{y}(08) = 162 \pm 1.0 \text{(130, 201)} \]

Fladen (2-3)

\[ \text{y}(08) = 399 \pm 3.0 \text{(281, 566)} \]

Holmoarna

\[ \text{SD(sm)} = 307 \pm 5.0 \text{(300, 310)} \]

Kvadofjarden

\[ \text{SD(sm)} = 3874 \pm 5.0 \text{(3600, 4150)} \]

\[ \text{SD(sm)} = 3874 \pm 5.0 \text{(3600, 4150)} \]

\[ \text{SD(sm)} = 3874 \pm 5.0 \text{(3600, 4150)} \]

\[ \text{SD(sm)} = 3874 \pm 5.0 \text{(3600, 4150)} \]

\[ \text{SD(sm)} = 3874 \pm 5.0 \text{(3600, 4150)} \]
CB-153, µg/g lipid w.

### Holmoarna

- **n(tot):** 96
- **n(yrs):** 11
- **m:** 0.145 (0.099, 0.212)
- **slope:** -3.0% (-14, 7.7)
- **SD(n):** 62, 19, 1023
- **y(08):** 0.122 (0.092, 0.253)
- **SD(sm):** 56, 29, 25
- **power:** 0.14 (0.09, 0.21)

### Kvadofjarden

- **n(tot):** 123
- **n(yrs):** 14
- **m:** 0.174 (0.128, 0.236)
- **slope:** -9.6% (-15, -4.4)
- **SD(n):** 35, 7.5, 18
- **y(08):** 0.093 (0.063, 0.139)
- **SD(sm):** 30, 13, 18
- **power:** 0.24 (0.11, 0.20)

### Vaderoarna

- **n(tot):** 123
- **n(yrs):** 14
- **m:** 0.275 (0.205, 0.370)
- **slope:** 0.48% (-7.2, 8.2)
- **SD(n):** 38, 11, 23
- **y(08):** 0.021 (0.021, 0.028)
- **SD(sm):** 21, 6, 12
- **power:** 0.02 (0.01, 0.04)

### Fladen

- **n(tot):** 84
- **n(yrs):** 21
- **m:** 0.051 (0.040, 0.063)
- **slope:** -7.5% (-9.0, -6.0)
- **SD(n):** 18, 2.2, 13
- **y(08):** 0.024 (0.020, 0.028)
- **SD(sm):** 7.5, 0.86, 0.71
- **power:** 1.0 (0.48, 0.73)

### Vaderoarna

- **n(tot):** 81
- **n(yrs):** 20
- **m:** 0.051 (0.040, 0.065)
- **slope:** -6.0% (-8.7, -3.3)
- **SD(n):** 29, 4.1, 18
- **y(08):** 0.028 (0.021, 0.039)
- **SD(sm):** 4.1, 0.011
- **power:** 1.0 (0.48, 0.73)

### Kvadofjarden

- **n(tot):** 70
- **n(yrs):** 14
- **m:** 0.060 (0.056, 0.064)
- **slope:** -1.9% (-3.6, -0.23)
- **SD(n):** 21, 50, 16
- **y(08):** 0.053 (0.047, 0.060)
- **SD(sm):** 20, 0.001
- **power:** 1.0 (0.48, 0.73)
CB-153, ug/g lipid w., guillemot egg

St Karlso

n(tot)=208, n(yrs)=21
m=4.26 (3.44,5.28)
slope=7.1% (-8.3,-5.8)
SD(r)=13%, 1.8%, 12 yr
power=1.0/.64/6.1%
y(08)=2.10 (1.81,2.44)
r²=88, p<.001 *
tao=.83, p<.001 *
SD(sm)=15, NS, 8.1%
slope=7.0% (-13,-.83)
SD(r)=23%, 8.9%, 15 yr
power=.35/.35/8.9%

r²=.46, p<.030 *

p=10.05.18 13:16, 153u
The concentration of DDT’s in fish muscle and blue mussel soft body is determined using a gas chromatograph (GC) equipped with an electron capture detector.

Before 1988 DDT’s (DDT, DDE, DDD) were analysed on a packed column GC. During 1988, analyses on capillary column were introduced. The two methods give slightly different results for the various DDT-compounds. In table 19.1 the mean ratio: ‘capillary column results’ / ‘packed column results’ from various sites and matrices are presented. When the concentrations are close to the detection limit (D.L.) for packed column GC the results seem to be underestimated. This is particularly true for the estimated sum of DDT’s (sDDT) since DDT and DDD may fall below D.L. and hence only DDE will constitute the sum. To avoid this bias at low levels, only samples with DDE concentrations above 0.2 μg/g have been selected to calculate the ratios given below. Only analyses where DDE, DDD and DDT were all present in levels above D.L. are included in the sDDT ratio. When it has been possible to estimate these ratios, they are in general close to 1. There are a few exceptions; at Landsort both the DDE and DDT ratios are lower than 1, indicating overestimated concentrations from the packed column, possible due to interference with other compounds in the DDE and DDT peaks in the packed column chromatogramme. At Fladen the DDE ratio is significantly above 1 indicating underestimated DDE concentration from the packed column GC.

In the time series presented below DDE is shown for herring, cod perch, eelpout and blue mussel and sDDT for flounder, dab and guillemot where the ratio of 1 has been used.

Table 19.1. Ratios of DDE, DDT, DDD and sDDT analysed on a capillary column versus the same samples analysed on a packed column gas chromatography (GC) and the corresponding 95% confidence interval.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>DDE 95% C.I.</th>
<th>n</th>
<th>DDT 95% C.I.</th>
<th>n</th>
<th>DDD 95% C.I.</th>
<th>n</th>
<th>sDDT 95% C.I.</th>
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<td><strong>Herring muscle</strong></td>
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<td>Harufjärden</td>
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<td>1.1 .99-1.2</td>
<td>6</td>
<td>.96 .89-1.0</td>
<td>4</td>
<td>1.5 1.1-2.0</td>
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<td>1.1 .98-1.2</td>
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<td>.63 .55-70</td>
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<td>.75 .67-81</td>
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<td>SE Gotland</td>
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</table>

The detection limit (capillary column, GC) is estimated to approximately 7 ng/g fat weight for DDE, 4 ng/g for DDD and 3 ng/g for DDT.
19.1 Temporal variation

19.1.1 Conventions, aims and restrictions
The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the DDT discharges are to be reduced by 50% between 1985 and 1995, using 1985 as a base year.

The Helsinki Convention (HELCOM) revised 1992 especially names the DDTs for which special bans and restrictions on transport, trade, handling, use and disposal are imposed. The Minister Declaration from 1988, within HELCOM, calls for a reduction of stable organic substances by 50% by 1995 with 1987 as a base year.

In Sweden, DDT was partially banned as a pesticide in 1970, and completely banned in 1975 due to its persistence and environmental impact.

19.1.2 This investigation
DDE concentrations in herring muscle, cod, perch and blue mussels from all investigated sites and in eelpout from Kvädöfjärden, decreased significantly during the time period 1980-2008. The rate varies between 2 and 11% a year. The time series of guillemot eggs (1969-2008) show a significant trend of -10% a year for DDE.

The discharge of fresh DDT during 1983-84 (Bignert et al, 1990) is clearly noticeable in the time series from Landsort and Utlängan in the Baltic proper and Fladen at the Swedish west coast.

The number of years required to detect an annual change of 5% for DDE in herring varied between 16 to 21 years. The variation of DDE is somewhat less between years in general compared to DDT and DDD. When comparing the power of the time series of DDT's with other contaminants it should be noted that the DDT incident 1983-84 deteriorate the power of the time series calculated from the log-linear regression lines.

The ratio of DDT/sDDT is decreasing significantly at all herring sites except for Väderöarna where there is not enough data points to detect a possible change.

19.1.3 Conclusion
The concentration of DDE has decreased at a rate of approximately 4-11% per year (in herring), in the Baltic as well as in the Kattegatt, since the end of the seventies. The DDT has generally decreased faster than the sum of DDT’s.
19.2 Spatial variation

Figure 19.1. Spatial variation in concentration (l.w.) of DDE in herring muscle.

The highest concentrations of DDE in herring (lipid weight) is found at Hanöbukten (figure 19.1, yet only two years are presented for the new localities and one year for the off shore sampling sites) in the Baltic Proper, significantly higher than from Harufjärden (Bothnian Bay) and at the localities at the Swedish west coast.

The DDE concentrations in cod from the Baltic Proper (southeast of Gotland) are about twice as high, compared to cod from Fladen at the Swedish west coast.

Table 19.2. Trend (in %) for DDE (μg/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

For dab and flounder sDDT is estimated (μg/g lipid weight).

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103
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**Cod liver**

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**Perch muscle**

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**Blue mussel**

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</table>

* significant trend, p < 0.05
** Pooled samples
DDE, ug/g lipid w., herring muscle

Fat adjusted spring herring samples

**Hårufjarden (3-4)**
- n(tot)=444, n(yrs)=29
- m=0.93 (0.64, 1.34)
- slope=6.0% (-12.7, 7.7)
- SD(lr)=39%, 2.9%, 21 yr power=1.0/141%
- y(08)=.80, p<.001 *
- tao=.07, p<.001 *
- SD(sm)=15, p<.071, 14%

**Angskarsklubb (3-5)**
- n(tot)=456, n(yrs)=28
- m=.209 (0.155, 0.282)
- slope=-8.3% (-9.6, -7.0)
- SD(lr)=25%, 2.0%, 16 yr power=1.0/27%
- y(07)=.066 (.053, .081)
- tao=.07, p<.001 *
- SD(sm)=11, NS, 13%

**Landsort (3-5)**
- n(tot)=447, n(yrs)=30
- m=.380 (0.308, 0.467)
- slope=-5.1% (-6.5, -3.7)
- SD(lr)=30%, 2.0%, 17 yr power=1.0/21%
- y(08)=.180 (.142, .228)
- tao=.07, p<.001 *
- SD(sm)=31, NS, 11%

**Utlangan (3-4)**
- n(tot)=361, n(yrs)=29
- m=.326 (.272, .379)
- slope=-6.7% (-17, 3.5)
- SD(lr)=30%, 2.0%, 17 yr power=1.0/15%
- y(07)=.178 (.142, .223)
- tao=.07, p<.001 *
- SD(sm)=24, NS, 13%

**Vadoerama (2-3)**
- n(tot)=242, n(yrs)=13
- m=.023 (.018, .030)
- slope=-6.6% (-12, -1.4)
- SD(lr)=34%, 7.5%, 18 yr power=42/20/13%
- y(08)=.015 (.010, .022)
- tao=.07, p<.016 *
- SD(sm)=19, NS, 13%
- slope=-11%, 2.3, 17 yr power=17/22/12%
- tao=.08, p<.013 *
DDE, ug/g lipid w., cod liver and perch muscle.

Geometric means, fat adjusted for cod

**Cod (3-4), SE Gotland**
- n(tot)=296, n(yrs)=28
- m=0.657 (0.538, 0.803)
- SD(yr)=22%, 19%, 16 yr
- y(08)=0.272 (0.246, 0.304)
- r²=68, p=0.001 *
- tao=68, p=0.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.28/10%
- r²=.72, p<.001 *
- tao=-.68, p<.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.28/10%
- r²=.72, p<.001 *
- tao=-.68, p<.001 *

**Cod (2-3), Fladen**
- n(tot)=332, n(yrs)=28
- m=0.386 (0.310, 0.480)
- SD(yr)=29%, 22%, 17 yr
- y(08)=0.190 (0.161, 0.222)
- r²=68, p=0.001 *
- tao=68, p=0.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.22/12%
- r²=.68, p<.001 *
- tao=-.63, p<.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.22/12%
- r²=.68, p<.001 *
- tao=-.63, p<.001 *

**Holmoarna**
- n(tot)=279, n(yrs)=22
- m=0.103 (0.063, 0.166)
- SD(yr)=34%, 29%, 19 yr
- y(08)=0.074 (0.051, 0.101)
- r²=68, p=0.001 *
- tao=68, p=0.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.21/12%
- r²=.12, NS
- tao=-.63, p<.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.21/12%
- r²=.12, NS
- tao=-.63, p<.001 *

**Kvadofjarden (3-4)**
- n(tot)=243, n(yrs)=26
- m=0.093 (0.069, 0.145)
- SD(yr)=61%, 54%, 25 yr
- y(08)=0.063 (0.040, 0.086)
- r²=68, p=0.001 *
- tao=68, p=0.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.23/12%
- r²=.15, NS
- tao=-.64, p<.001 *
- SD(sm)=80, NS, 12%
- power=1.0/.23/12%
- r²=.15, NS
- tao=-.64, p<.001 *

**DDE, ug/g lipid w., Eelpout muscle**

**Holmoarna**
- n(tot)=95, n(yrs)=11
- m=0.112 (0.084, 0.150)
- SD(yr)=41%, 33%, 21 yr
- y(07)=0.053 (0.026, 0.079)
- r²=51, p=0.004 *
- tao=51, p=0.004 *
- SD(sm)=4734, p<.001, 100%
- power=1.0/.13/17%
- r²=.03, NS
- tao=.13, NS
- SD(sm)=4734, p<.001, 100%
- power=1.0/.13/17%
- r²=.03, NS
- tao=.13, NS

**Kvadofjarden**
- n(tot)=122, n(yrs)=14
- m=0.162 (0.111, 0.238)
- SD(yr)=42%, 36%, 22 yr
- y(08)=0.078 (0.046, 0.110)
- r²=51, p=0.004 *
- tao=51, p=0.004 *
- SD(sm)=5689, p<.001, 100%
- power=1.0/.12/18%
- r²=.51, p<.001 *
- tao=.12, NS
- SD(sm)=5689, p<.001, 100%
- power=1.0/.12/18%
- r²=.51, p<.001 *
- tao=.12, NS

**Vaderoarna**
- n(tot)=121, n(yrs)=14
- m=0.084 (0.066, 0.108)
- SD(yr)=42%, 36%, 22 yr
- y(08)=0.077 (0.048, 0.108)
- r²=51, p=0.004 *
- tao=51, p=0.004 *
- SD(sm)=4194, p<.001, 100%
- power=1.0/.12/18%
- r²=.02, NS
- tao=.12, NS
- SD(sm)=4194, p<.001, 100%
- power=1.0/.12/18%
- r²=.02, NS
DDE, ug/g lipid w., guillemot egg, early laid

Fladen
- n(tot)=82, y=23
- m=0.01 (0.07, 0.07)
- slope=7.5% (9.9, 5.2)
- SD(y)=39%, 4.0%, 20 yr
- power=55%, 15% (16%, 15%)
- y(08)=0.020 (0.14, 0.28)
- r=0.68, p<0.001
- SD(sm)=17, 98, 19%
- slope=-8.6% (20, 38)
- SD(y)=36%, 16%, 18 yr
- power=14.16/13%
- tao=-0.68, p<0.001

Vadenoarna
- n(tot)=84, y=23
- m=0.05 (0.026, 0.048)
- slope=8.1% (10, -6.1)
- SD(y)=31%, 3.3%, 18 yr
- power=48%, 19%, 13%
- y(08)=0.013 (0.10, 0.11)
- r=0.77, p<0.001
- SD(sm)=9.9, 98, 12%
- slope=4.7% (12, 19)
- SD(y)=36%, 16%, 18 yr
- power=28%, 38%, 8.0%
- tao=-0.67, p<0.001

Kvadofjarden
- n(tot)=70, y=14
- m=0.07 (0.062, 0.073)
- slope=2.5% (4.4, -5.5)
- SD(y)=25%, 30%, 17 yr
- power=1.0, 22%, 17%
- y(08)=0.057 (0.056)
- r=0.10, p<0.012
- SD(sm)=9.9, 98, 12%
- slope=-5.3% (9.3, 1.3)
- SD(y)=30%, 1.2%, 18 yr
- power=1.0, 18%, 14%
- tao=-0.41, p<0.001

DDE, ug/g lipid w., blue mussel

- n(tot)=390, y=37
- m=62.1 (41.6, 92.9)
- slope=-10% (-11, -9.3)
- SD(y)=25%, 1.4%, 17 yr
- power=1.0, 24/11%
- y(08)=8.9 (7.3, 9.9)
- r=0.94, p<0.001
- tao=-0.92, p<0.001
- SD(sm)=4.0, 0.0, p<0.001
- slope=-7.1% (-13, -1.6)
- SD(y)=18%, 8.6%, 13 yr
- power=38, 51/7.1%
- r=0.87, p<0.019

- n(tot)=70, y=14
- m=0.07 (0.062, 0.073)
- slope=2.5% (4.4, -5.5)
- SD(y)=25%, 30%, 17 yr
- power=1.0, 22%, 17%
- y(08)=0.057 (0.056)
- r=0.10, p<0.012
- SD(sm)=9.9, 98, 12%
- slope=-5.3% (9.3, 1.3)
- SD(y)=30%, 1.2%, 18 yr
- power=1.0, 18%, 14%
- tao=-0.41, p<0.001

20 HCH’s, Hexachlorocyclohexanes

Updated 10.05.30

Technical HCH contains various isomers: 60-75% α-HCH, 15% γ-HCH (lindane), 7-10% β-HCH, δ-HCH 7%, ε-HCH 1-2% and came into general use in 1950 (Gaul, 1992). The γ-isomer is the most toxic isomer of the HCH’s, 500 to 1000 times as potent as the α-isomer (White-Stevens, 1971). The use of technical HCH stopped in the countries around the Baltic between 1970-1980. Since 1980, use of lindane in Europe has been allowed only as an insecticide. It was still used to a great extent in France and Italy 1990 (Yi-Fan et al. 1996). The isomers: α-HCH, β-HCH and γ-HCH i.e. Lindane have been analysed in muscle tissue for various fish species (liver tissue for cod), blue mussel soft body and guillemot eggs since 1988, see table below. Samples from 1987 at Harufjärden and Landsort have been retrospectively analysed. The concentrations of β-HCH are in many cases close to the detection limit, which implies analytical problems. The detection limit is estimated to approximately 2 ng/g fat weight for α-HCH, 3 ng/g for β-HCH and 3 ng/g for γ-HCH.

20.1 Temporal variation

20.1.1 Conventions, aims and restrictions

The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the discharges of HCHs are to be reduced by 50% between 1985 and 1995, using 1985 as a base year.

The Minister Declaration from 1988, within HELCOM, calls for a reduction of stable organic substances by 50% by 1995 with 1987 as a base year.

In Sweden, the use of lindane was severely restricted 1970, subsequently prohibited for use in agriculture 1978 because of its suspected carcinogenic properties and persistence. Remaining use was banned 1988/89.

20.1.2 This investigation

The variance for concentrations of α-HCH in herring muscle is generally low. Decreasing trends with an annual decrease of about 13-19% are found for herring from all sites. The concentrations in cod liver are also decreasing significantly both in the time series from south east of Gotland and Fladen (in Kattegatt at the Swedish west coast). Concentrations...
of α-HCH are also decreasing in perch from Kvädöfjärden and Holmöarna, in eelpout from the same sampling sites as perch as well as in eelpout from Väderöarna, in guillemot eggs from St Karlsö and in blue mussels from all sampled sites (Baltic and West coast).

The number of years required to detect an annual change of 5% is about 10-12 years for cod and varies between 7 to 14 years for the herring time series.

Concentrations of β-HCH are generally decreasing, and are now approaching the detection limit. This makes the substance less fitted for use in this kind of study. The concentrations of β-HCH in some matrices are however still detectable and show significant decreasing trends, for example in herring from Ängskärsklubb, Landsort and Utlängan, in cod from SE Gotland and in guillemot eggs (St Karlsö).

The concentration of lindane (γ-HCH) has decreased significantly in all analysed matrices at all sampling sites except for guillemot eggs (St Karlsö) and herring from Väderöarna. The decrease is in the magnitude of 10 to 18% for herring, perch, and blue mussel and 15 to 20% for cod and eelpout.

The ratio α-HCH/lindane in herring, show significant decreasing trends from Harufjärden, Landsort and Utlängan.

20.1.3 Conclusion

In general, the concentration of HCH's seems to have decreased at a rate of about 9.5% or more per year, in various species from the Baltic as well as at the Swedish west coast, since the end of the eighties. From ten time series on herring, cod and guillemot eggs for the period 1987-95, a median decrease of 65 % (38-88%) could be estimated. α-HCH is in general decreasing faster than lindane.

Measures taken to fulfil the aim of the North Sea Conference and the HELCOM Convention of a 50% reduction of the discharges of HCHs, 1995 with 1985 and 1987 respectively as base years, thus seems to have had a measurable effect in biota.
20.2 Spatial variation

Figure 20.1. Spatial variation in concentration (l.w.) of b-HCH in herring muscle.

Somewhat higher concentrations of HCH's (lipid weight) are found in the herring samples from the Baltic Proper compared to the Bothnian Bay and the Kattegatt even after the rapid decrease mentioned above, see tables 20.1 and 20.2.

Figure 20.1 also show higher concentrations of b-HCH in herring from the Baltic Proper than in herring from the Bothnian Sea and the Swedish West Coast. Bare in mind that results from the new sampling sites are based on analysis from two years only (off shore sites one year).

The ratio lindane/α-HCH is higher in the Kattegatt compared to the Baltic in both herring and cod. This could reflect that in the former east-bloc countries mainly technical HCH were used whereas the use of lindane (γ-HCH) was more common in western countries.

20.3 Seasonal variation

Unlike the PCB’s, the DDT’s and HCB, the HCH’s show no significant seasonal difference in concentrations between herring caught in the spring and in the autumn.
Table 20.1. Trend (in %) for α-HCH (μg/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

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<tr>
<th>Matrix</th>
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<th>n yrs</th>
<th>year</th>
<th>trend (95% ci)</th>
<th>Last year (95% ci)</th>
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<tr>
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</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>168</td>
<td>11</td>
<td>87</td>
<td>90-99# -16 (-19,-13)*</td>
<td>**</td>
</tr>
<tr>
<td>Ängskärskl. aut.</td>
<td>3-5</td>
<td>243</td>
<td>16</td>
<td>89</td>
<td>04# -20 (-23,-17)*</td>
<td>**</td>
</tr>
<tr>
<td>” spring</td>
<td>2-4</td>
<td>197</td>
<td>16</td>
<td>89</td>
<td>07 -18 (-19,-17)*</td>
<td>.003 (.003-.003)</td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>306</td>
<td>22</td>
<td>87</td>
<td>04 -17 (-19,-16)*</td>
<td>.003 (.003-.004)</td>
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<tr>
<td>Utlångan, aut.</td>
<td>3-4</td>
<td>253</td>
<td>21</td>
<td>88</td>
<td>08 -18 (-19,-17)*</td>
<td>.003 (.002-.003)</td>
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<tr>
<td>” spring</td>
<td>2-3</td>
<td>212</td>
<td>18</td>
<td>87</td>
<td>07 -18 (-19,-17)*</td>
<td>.003 (.003-.004)</td>
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<tr>
<td>Fladen</td>
<td>2-3</td>
<td>243</td>
<td>14</td>
<td>88-01# -16 (-17,-15)*</td>
<td>**</td>
<td></td>
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<tr>
<td>Väderöarna</td>
<td>107</td>
<td>7</td>
<td></td>
<td>95-99,03# -13 (-17,-9.6)*</td>
<td>**</td>
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</tr>
<tr>
<td>Cod liver</td>
<td></td>
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</tr>
<tr>
<td>SE Gotland</td>
<td>175</td>
<td>20</td>
<td></td>
<td>89</td>
<td>08 -19 (-20,-18)*</td>
<td>.003 (.003-.003)</td>
</tr>
<tr>
<td>Fladen</td>
<td>138</td>
<td>19</td>
<td></td>
<td>89</td>
<td>08 -16 (-17,-14)</td>
<td>.001 (.001-.002)</td>
</tr>
<tr>
<td>Perch muscle</td>
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<tr>
<td>Holmöarna</td>
<td>43</td>
<td>5</td>
<td></td>
<td>89</td>
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</tr>
<tr>
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<td>84</td>
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<td>Holmöarna</td>
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<td>95</td>
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<tr>
<td>Kvädöfjärden</td>
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<td>8</td>
<td></td>
<td>95</td>
<td>02# -16 (-21,-9.8)*</td>
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</tr>
<tr>
<td>Väderöarna</td>
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<td>4</td>
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<td>95</td>
<td>96,98,05# -13 (-17,-13)*</td>
<td>.004 (.001-.013)</td>
</tr>
<tr>
<td>Blue mussel***</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>60</td>
<td>12</td>
<td></td>
<td>95</td>
<td>07# -15 (-18,-13)*</td>
<td>.004 (.004-.005)</td>
</tr>
<tr>
<td>Fladen</td>
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<td>14</td>
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<td>88</td>
<td>01# -15 (-18,-12)*</td>
<td>**</td>
</tr>
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<td>Väderöarna</td>
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<td>14</td>
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<td>88</td>
<td>04# -13 (-17,-9.6)*</td>
<td>**</td>
</tr>
<tr>
<td>Guillemot egg</td>
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<tr>
<td>St. Karlsö</td>
<td>168</td>
<td>18</td>
<td></td>
<td>88</td>
<td>08 -14 (-17,-12)*</td>
<td>.002 (.001-.003)</td>
</tr>
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</table>

# All values at or below detection limit during recent years
* significant trend, p < 0.05
** No estimated value because of concentrations at or below detection limit
*** Pooled samples
Table 20.2. Trend (in %) for of γ-HCH (μg/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend (95% ci)</th>
<th>Last year (95% ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring msc.</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>183</td>
<td>13</td>
<td>87, 90-01#</td>
<td>-10 (-13,-7.7)*</td>
<td>**</td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>229</td>
<td>15</td>
<td>89-03#</td>
<td>-16 (-19,-12)*</td>
<td>**</td>
</tr>
<tr>
<td>” spring</td>
<td>2-5</td>
<td>214</td>
<td>17</td>
<td>89-05#</td>
<td>-14 (-16,-12)*</td>
<td>**</td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>286</td>
<td>21</td>
<td>87-08</td>
<td>-13 (-14,-12)*</td>
<td></td>
</tr>
<tr>
<td>Utölingen, aut.</td>
<td>2-4</td>
<td>280</td>
<td>20</td>
<td>88-08</td>
<td>-14 (-15,-13)*</td>
<td>.004 (.003-.004)</td>
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<tr>
<td>” spring</td>
<td>2-3</td>
<td>204</td>
<td>18</td>
<td>87-06#</td>
<td>-16 (-17,-14)*</td>
<td>.005 (.004-.005)</td>
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<tr>
<td>Fladen</td>
<td>2-3</td>
<td>252</td>
<td>14</td>
<td>88-01#</td>
<td>-9.9 (-14,-5.6)*</td>
<td>**</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>120</td>
<td>7</td>
<td>95-01#</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cod liver</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>150</td>
<td>19</td>
<td>89-08</td>
<td>-15 (-16,-14)*</td>
<td>.003 (.003-.004)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>106</td>
<td>16</td>
<td>89-06#</td>
<td>-18 (-21,-14)*</td>
<td>.002 (.002-.003)</td>
</tr>
<tr>
<td><strong>Perch muscle</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td>41</td>
<td>5</td>
<td>89,95-98#</td>
<td>-14 (-26,-3.1)*</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>Kvådöfjärden</td>
<td>72</td>
<td>9</td>
<td>89,94-01#</td>
<td>-11 (-20,-2.9)*</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td><strong>Eelpout</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Holmöarna</td>
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<td>5</td>
<td>95,97,99,01-02#</td>
<td>-17 (-32,-3.2)*</td>
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<td>60</td>
<td>8</td>
<td>95-02#</td>
<td>-18 (-21,-15)*</td>
<td>**</td>
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<tr>
<td>Väderöarna</td>
<td>69</td>
<td>8</td>
<td>95-02,05#</td>
<td>-20 (-28,-12)*</td>
<td>**</td>
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<tr>
<td><strong>Blue mussel</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kvådöfjärden</td>
<td>57</td>
<td>12</td>
<td>95-06#</td>
<td>-16 (-20,-12)*</td>
<td>.004 (.003-.006)</td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>53</td>
<td>16</td>
<td>81,83,88-01#</td>
<td>-9.5 (-12,-6.5)*</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>50</td>
<td>15</td>
<td>83,88-04#</td>
<td>-12 (-16,-8.5)*</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td><strong>Guillemot egg</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td>96</td>
<td>13</td>
<td>88-91,93-97,00-01,07#</td>
<td>.006 (.003-.011)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# all values below detection limit during recent years
* significant trend, p < 0.05
** no estimated value because of concentrations at or below detection limit
*** Pooled samples

Table 20.3. The estimated proportion of α-, β-, γ- HCH (%) in various matrices and sites.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n yrs</th>
<th>n yrs</th>
<th>year</th>
<th>α</th>
<th>β</th>
<th>γ</th>
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</thead>
<tbody>
<tr>
<td><strong>Herring msc.</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>7</td>
<td>87,90-95</td>
<td>57</td>
<td>16</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>7</td>
<td>89-95</td>
<td>49</td>
<td>22</td>
<td>28</td>
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</tr>
<tr>
<td>” spring</td>
<td>2-5</td>
<td>7</td>
<td>89-95</td>
<td>48</td>
<td>26</td>
<td>26</td>
<td></td>
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<tr>
<td>Landsort</td>
<td>3-5</td>
<td>9</td>
<td>87-95</td>
<td>47</td>
<td>25</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Utölingen, aut.</td>
<td>2-4</td>
<td>8</td>
<td>88-95</td>
<td>43</td>
<td>27</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>” spring</td>
<td>2-3</td>
<td>7</td>
<td>87-95</td>
<td>43</td>
<td>24</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>7</td>
<td>87-95</td>
<td>37</td>
<td>10</td>
<td>53</td>
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<tr>
<td><strong>Cod liver</strong></td>
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<td></td>
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</tr>
<tr>
<td>SE Gotland</td>
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<td>87-95</td>
<td>45</td>
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<td>27</td>
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<td>7</td>
<td>87-95</td>
<td>37</td>
<td>11</td>
<td>52</td>
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<td><strong>Blue mussel</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>10</td>
<td>2</td>
<td>81-95</td>
<td>32</td>
<td>11</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>8</td>
<td>9</td>
<td>83-95</td>
<td>31</td>
<td>9</td>
<td>60</td>
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</tr>
</tbody>
</table>
a-HCH, ug/g lipid w., herring muscle

Harufjarden (3-4)

- n(tot)=168, n(yrs)=11
- mn=020 (013.030)
- slope=-16% (-19, -13)
- SD(lr)=15%, 4.1%, 10 yr
- power=.93/84.8%
- r2=.94, p<.001 *
- ta0=-.93, p<.001 *

Angskarsklubb (3-5)

- n(tot)=243, n(yrs)=16
- mn=018 (010.030)
- slope=-20% (-23, -17)
- SD(lr)=18%, 3.7%, 14 yr
- power=.85/85.4%
- r2=.93, p<.001 *
- ta0=-.90, p<.001 *

Landsort (3-5)

- n(tot)=306, n(yrs)=22
- mn=020 (012.032)
- slope=-17% (-19, -16)
- SD(lr)=18%, 1.7%, 12 yr
- power=1.0/67%
- r2=.97, p<.001 *
- ta0=-.94, p<.001 *

Utlangan (3-4)

- n(tot)=252, n(yrs)=21
- mn=016 (010.026)
- slope=-16% (-19, -15)
- SD(lr)=7.5%, 2.8%, 8 yr
- power=1.0/1.0%
- r2=.97, p<.001 *
- ta0=-.98, p<.001 *

Angskarsklubb, spring (2-4)

- n(tot)=197, n(yrs)=16
- mn=015 (008.027)
- slope=-18% (-19, -17)
- SD(lr)=10%, 1.8%, 9 yr
- power=1.0/95%
- r2=.99, p<.001 *
- ta0=-.98, p<.001 *

Karlskrona, spring (2-3)

- n(tot)=212, n(yrs)=18
- mn=018 (010.030)
- slope=-18% (-19, -17)
- SD(lr)=12%, 1.8%, 10 yr
- power=1.0/88%
- y(07)=.003 (003.003)
- ta0=.97, p<.001 *

Fladen (2-3)

- n(tot)=243, n(yrs)=14
- mn=018 (010.030)
- slope=-15% (-18, -14)
- SD(lr)=9.0%, 2.8%, 8 yr
- power=1.0/1.0%
- r2=.97, p<.001 *

Vaderoarna

- n(tot)=107, n(yrs)=7
- mn=006 (004.008)
- slope=-13% (-17, -9.5)
- SD(lr)=11%, 6.0%, 8 yr
- power=.68/99%
- y(03)=.003 (003.004)
- ta0=.98, p<.001 *

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a-HCH, ug/g lipid w., cod liver and perch muscle

Cod, SE Gotland

<table>
<thead>
<tr>
<th>n(tot)</th>
<th>Slope</th>
<th>Y(01)</th>
<th>R2</th>
<th>p</th>
<th>SD (lr)</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>175</td>
<td>1.06</td>
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<td>.99</td>
<td>&lt;.001</td>
<td>11%</td>
<td>.91</td>
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</table>

Cod (2-3), Fladen

<table>
<thead>
<tr>
<th>n(tot)</th>
<th>Slope</th>
<th>Y(01)</th>
<th>R2</th>
<th>p</th>
<th>SD (lr)</th>
<th>Power</th>
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</thead>
<tbody>
<tr>
<td>138</td>
<td>1.06</td>
<td>0.00</td>
<td>.99</td>
<td>&lt;.001</td>
<td>11%</td>
<td>.91</td>
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Perch, Holmoarna

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<th>Y(01)</th>
<th>R2</th>
<th>p</th>
<th>SD (lr)</th>
<th>Power</th>
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</thead>
<tbody>
<tr>
<td>43</td>
<td>1.06</td>
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<td>.99</td>
<td>&lt;.001</td>
<td>11%</td>
<td>.91</td>
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Perch, Kvadofjarden

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<th>Y(01)</th>
<th>R2</th>
<th>p</th>
<th>SD (lr)</th>
<th>Power</th>
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<tbody>
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<td>115</td>
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<td>.99</td>
<td>&lt;.001</td>
<td>11%</td>
<td>.91</td>
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a-HCH, ug/g lipid w., blue mussel

Fladen

<table>
<thead>
<tr>
<th>n(tot)</th>
<th>Slope</th>
<th>Y(01)</th>
<th>R2</th>
<th>p</th>
<th>SD (lr)</th>
<th>Power</th>
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<tbody>
<tr>
<td>48</td>
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<td>11%</td>
<td>.91</td>
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Vaderoarna

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<th>Y(01)</th>
<th>R2</th>
<th>p</th>
<th>SD (lr)</th>
<th>Power</th>
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<tbody>
<tr>
<td>48</td>
<td>1.06</td>
<td>0.00</td>
<td>.99</td>
<td>&lt;.001</td>
<td>11%</td>
<td>.91</td>
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Kvadofjarden

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<th>R2</th>
<th>p</th>
<th>SD (lr)</th>
<th>Power</th>
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<tbody>
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<td>65</td>
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<td>.99</td>
<td>&lt;.001</td>
<td>11%</td>
<td>.91</td>
</tr>
</tbody>
</table>
b-HCH, ug/g lipid w., guillemot egg, early laid

\[ n(tot)=208, n(yrs)=21 \]
\[ m=0.393, (0.299, 0.517) \]
\[ SD(lr)=16\%, 1.9\%, 12\ yr \]
\[ power=1.0/6.0/3.3\% \]
\[ y(08)=155, (133, 181) \]
\[ r^2=.92, p<.001^* \]
\[ tao=8.1, p<.001^* \]
\[ SD(sm)=16, <.071, 1.5\% \]

Lindane, ug/g lipid w., herring muscle

Harufjarden (3-4)
\[ n(tot)=183, n(yrs)=13 \]
\[ m=0.010, (0.008, 0.013) \]
\[ slope=-10\%, (-13.7, -7.7) \]
\[ SD(lr)=14\%, 3.7\%, 11\ yr \]
\[ power=.97/.68/5.8\% \]
\[ y(01)=.005, (0.004, 0.006) \]
\[ r^2=.88, p<.001^* \]
\[ tao=-8.7, p<.001^* \]
\[ SD(sm)=2.4, <.040, 4.0\% \]

Angskarsklubb (3-5)
\[ n(tot)=220, n(yrs)=15 \]
\[ m=0.013, (0.008, 0.019) \]
\[ slope=-16\%, (-19, 12) \]
\[ SD(lr)=20\%, 5.2\%, 16\ yr \]
\[ power=.78/.28/10\% \]
\[ y(03)=.004, (0.004, 0.006) \]
\[ r^2=.87, p<.001^* \]
\[ tao=-9.0, p<.001^* \]
\[ SD(sm)=4.1, <.050, 13\% \]

Landsort (3-5)
\[ n(tot)=286, n(yrs)=21 \]
\[ m=0.017, (0.012, 0.025) \]
\[ slope=-13\%, (-14, 12) \]
\[ SD(lr)=15\%, 6.2\%, 12\ yr \]
\[ power=.58/.74/4.7\% \]
\[ y(08)=.004, (0.004, 0.006) \]
\[ r^2=.92, p<.001^* \]
\[ tao=-9.2, p<.001^* \]
\[ SD(sm)=4.1, <.050, 6.1\% \]

Utliangan (2-5)
\[ n(tot)=279, n(yrs)=20 \]
\[ m=0.016, (0.011, 0.024) \]
\[ slope=-14\%, (-15, 13) \]
\[ SD(lr)=11\%, 1.5\%, 10\ yr \]
\[ power=1.0/.85/7.4\% \]
\[ y(05)=.004, (0.004, 0.006) \]
\[ r^2=.96, p<.001^* \]
\[ tao=-9.6, p<.001^* \]
\[ SD(sm)=2.5, <.050, 3.7\% \]
Lindane, ug/g lipid w., blue mussel

\[ n(tot)=57, n(yrs)=12 \]
\[ m=0.10 (.007,.015) \]
\[ \text{slope}=-16\%(-20,-12) \]
\[ SD(lr)=22\%,6.0\%,14 \text{ yr} \]
\[ power=.65/40/8.2\% \]
\[ y(06)=.004 (.003,.006) \]
\[ r^2=.67, p<.001 \] * 
\[ \text{SD(sm)}=5.1, \text{NS}, 8.5\% \]
\[ \text{slope}=-15\%(-21,-9.8) \]
\[ r^2=.83, p<.001 \] * 

\[ n(tot)=53, n(yrs)=16 \]
\[ m=.025 (.018,.035) \]
\[ \text{slope}=-9.5\%(-12,-6.5) \]
\[ SD(lr)=27\%,5.2\%,17 \text{ yr} \]
\[ power=.77/23/12\% \]
\[ y(01)=.012 (.009,.016) \]
\[ r^2=.77, p<.001 \] * 
\[ \text{SD(sm)}=4.6, p<.005/6.1\% \]

\[ n(tot)=50, n(yrs)=15 \]
\[ m=.022 (.014,.033) \]
\[ \text{slope}=-12\%(-16,-8.5) \]
\[ SD(lr)=33\%,6.3\%,18 \text{ yr} \]
\[ power=.50/20/13\% \]
\[ y(04)=.007 (.005,.010) \]
\[ r^2=.81, p<.001 \] * 
\[ \text{SD(sm)}=5.5, p<.016/7.6\% \]
\[ \text{slope}=-20\%(-29,-12) \]
\[ SD(lr)=26\%,16\%,16 \text{ yr} \]
\[ power=.15/28/10\% \]
\[ r^2=.84, p<.002 \] * 

\[ n(tot)=57, n(yrs)=12 \]
\[ m=0.10 (.007,.015) \]
\[ \text{slope}=-16\%(-20,-12) \]
\[ SD(lr)=22\%,6.0\%,14 \text{ yr} \]
\[ power=.65/40/8.2\% \]
\[ y(06)=.004 (.003,.006) \]
\[ r^2=.67, p<.001 \] * 
\[ \text{SD(sm)}=5.1, \text{NS}, 8.5\% \]
\[ \text{slope}=-15\%(-21,-9.8) \]
\[ r^2=.83, p<.001 \] *
21 HCB, Hexachlorobenzene

The use of the highly persistent HCB as a fungicide is banned in the Baltic countries and although it may still reach the environment as a by-product of many chlorinating processes e.g. pentachlorophenol and vinyl chloride monomer production, we have reasons to expect a decrease in biological samples from the Baltic.

HCB has been analysed in various species, see table below, since 1988. At Harufjärden and Landsort samples from 1987 have been retrospectively analysed.

The detection limit is estimated to approximately 1 ng/g fat weight.

21.1 Temporal variation

21.1.1 Conventions, aims and restrictions
The North Sea Conference (1984, 1987, 1990) that covers all routes of pollution to the North Sea, states that the HCB discharges are to be reduced by 50% between 1985 and 1995, using 1985 as a base year.

The Minister Declaration from 1988, within HELCOM, calls for a reduction of stable organic substances by 50% by 1995 with 1987 as a base year.

HCB was withdrawn from market 1980 in Sweden, because of its carcinogenic effects on experimental animals and it persistence.

21.1.2 This investigation
In the Baltic proper there are significant decreases in concentrations of HCB in all analysed fish species and in guillemot eggs. Decreasing trends are also found on the Swedish west coast, in herring and cod from Fladen and blue mussels and eelpout from Väderöarna.

In blue mussels from the Swedish west coast the concentrations are very low. Since the year 2000 values are at or below detection limit and hence blue mussels are not considered to be a good matrice for monitoring of HCB’s in this region.

The number of years required to detect an annual change of 5% varied between 14 to 20 years for the herring time series.
21.1.3 Conclusion
The concentration of HCB in herring, cod, dab and guillemot egg has decreased at a rate of about 5-10% per year from the Baltic Proper since 1988. The aim of the North Sea Conference and the HELCOM Convention of a 50% reduction of HCB, 1995 with 1985 and 1987 respectively as a base year thus seems to be fulfilled.

21.2 Spatial variation

![HCB Concentration Map](image)

Figure 21.1. Spatial variation in concentration (l.w.) of HCB in herring muscle.

Herring muscle from Landsort and Utlängan in the Baltic Proper represent the highest HCB concentrations of the herring samples, significantly higher compared to the other sites in the late eighties. However, since the concentrations have decreased considerably in the samples from the Baltic Proper and the variance from the Bothnian Bay and the Baltic Sea are large, no significant differences can be shown in the estimated concentrations for 2008 in the autumn caught herring from the various sites in the Baltic and the Kattegatt, although the estimated concentrations from 2008 is more than twice as high in the Baltic compared to the Swedish west coast.

The results from eelpout and blue mussel samples from Kvädöfjärden that were analysed for HCB for the first time 1995, indicate about twice as high concentrations or more in the Baltic compared to the Kattegatt and the Skagerack. This difference is significant for blue mussels and for eelpout when comparing Holmöarna and Väderöarna.
21.3 Differences among various species
At some of the sampling sites, specimens of various species are collected within the same area. HCB is analysed in fish muscle tissue except for cod where the liver is used whereas whole soft body is analysed in blue mussels. The mean concentrations (last year) (ng/g lipid weight) found are listed in decreasing order. Differences in geometric mean HCB concentration among the species samples from the same area are marked with ‘>’:

Holmöarna: Eelpout(16) > Perch(7)
Kvädöfjärden: Eelpout(11) > Perch(6)- Blue mussel(5)
Fladen: Cod(9) - Herring(6) >Blue mussel(<3)
Väderöarna: Eelpout(8) - Herring(5) > Blue mussel(<3)

The lowest concentrations are found in blue mussels whereas the highest are found in guillemot eggs.

21.4 Seasonal variation
Herring caught in the spring show 2-3 times higher HCB-concentrations on a lipid weight basis compared to samples collected in the autumn.
Table 21.1. Trend (in %) for of HCB (μg/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n</th>
<th>n yrs</th>
<th>year</th>
<th>trend</th>
<th>last yr</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring msc.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>278</td>
<td>20</td>
<td>87-08</td>
<td>-3.6 (-5.4,-1.8)*</td>
<td>.014</td>
<td>(.011-.017)</td>
</tr>
<tr>
<td>Ångskärskl. aut.</td>
<td>3-5</td>
<td>275</td>
<td>18</td>
<td>89-07</td>
<td>-8.4 (-12,-4.7)*</td>
<td>.009</td>
<td>(.006-.014)</td>
</tr>
<tr>
<td>Fladder spring</td>
<td>269</td>
<td>20</td>
<td>89-08</td>
<td>-6.1 (-8.8,-3.4)*</td>
<td>.039</td>
<td>(.029-.053)</td>
<td></td>
</tr>
<tr>
<td>Landsort spring</td>
<td>3-5</td>
<td>303</td>
<td>21</td>
<td>87-08</td>
<td>-6.0 (-8.6,-3.4)*</td>
<td>.018</td>
<td>(.013-.025)</td>
</tr>
<tr>
<td>Utlångan, aut.</td>
<td>3-4</td>
<td>279</td>
<td>21</td>
<td>88-08</td>
<td>-6.9 (-9.8,-4.1)*</td>
<td>.016</td>
<td>(.011-.022)</td>
</tr>
<tr>
<td>Fladder spring</td>
<td>225</td>
<td>20</td>
<td>87-08</td>
<td>-9.3 (-11,-7.2)*</td>
<td>.022</td>
<td>(.017-.028)</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>2-3</td>
<td>336</td>
<td>21</td>
<td>88-08</td>
<td>-7.4 (-9.3,-5.6)*</td>
<td>.006</td>
<td>(.005-.007)</td>
</tr>
<tr>
<td><strong>Cod liver</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>163</td>
<td>20</td>
<td>89-08</td>
<td>-7.1 (-9.8,-4.5)*</td>
<td>.018</td>
<td>(0.013-.024)</td>
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<tr>
<td>Fladder</td>
<td>2-3</td>
<td>155</td>
<td>19</td>
<td>89-08</td>
<td>-5.4 (-8.4,-2.5)*</td>
<td>.009</td>
<td>(.007-.013)</td>
</tr>
<tr>
<td><strong>Perch muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td>112</td>
<td>14</td>
<td>89,95</td>
<td>07</td>
<td>-5.7 (-8.8,-2.7)*</td>
<td>.007</td>
<td>(.005-.009)</td>
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<tr>
<td>Kvädöfjärden</td>
<td>142</td>
<td>17</td>
<td>84,89</td>
<td>00,03,07,08</td>
<td>-3.6 (-7.3,-23)*</td>
<td>.006</td>
<td>(.003-.009)</td>
</tr>
<tr>
<td><strong>Eelpout muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Holmöarna</td>
<td>95</td>
<td>11</td>
<td>95-07</td>
<td>97</td>
<td>-9.7 (-18,-1.1)*</td>
<td>.016</td>
<td>(.009-.029)</td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>114</td>
<td>14</td>
<td>95-08</td>
<td>-3.0 (-6.4,-44)*</td>
<td>.011</td>
<td>(.008-.014)</td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>99</td>
<td>14</td>
<td>95-08</td>
<td>-2.2 (-4.4,-02)*</td>
<td>.008</td>
<td>(.006-.009)</td>
<td></td>
</tr>
<tr>
<td><strong>Dab muscle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fladder</td>
<td>3-5</td>
<td>6</td>
<td>6</td>
<td>89-94</td>
<td>.004 (.003-.006)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flounder msc</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>4-6</td>
<td>6</td>
<td>6</td>
<td>89-94</td>
<td>.004 (.001-.028)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Blue mussel</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fladen</td>
<td>32</td>
<td>9</td>
<td>88-00#</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Väderöarna</td>
<td>31</td>
<td>10</td>
<td>88-00#</td>
<td>**</td>
<td>-7.9 (-16,-.05)*</td>
<td>.005</td>
<td>(.003-.007)</td>
</tr>
<tr>
<td>Kvädöfjärden</td>
<td>65</td>
<td>14</td>
<td>95-08</td>
<td>95</td>
<td>.005 (.003-.007)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Guillemot egg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td>218</td>
<td>22</td>
<td>79,88</td>
<td>08</td>
<td>-6.4 (-8.2,-4.7)*</td>
<td>.59</td>
<td>(.48-.72)</td>
</tr>
</tbody>
</table>
# all values below detection limit during recent years
* significant trend, p < 0.05
** no estimated value because of concentrations at or below detection limit
*** Pooled samples
HCB, ng/g lipid w., blue mussel

Kvadofjarden

- n(tot)=66, n(yrs)=14
- m=5.62 (4.95-6.28)
- SD(tot)=26%, 6.1%, 16 yr
- power=63%, 25%, 11%
- y(08)=4.69 (3.38, 6.50)
- r2=.19, NS
- slope=-3.6%(-11.3, 7.7)
- SD(tot)=28%, 11%, 16 yr
- power=63%, 25%, 11%

Fladen

- n(tot)=32, n(yrs)=9
- m=2.50 (2.02, 3.09)
- SD(tot)=28%, 12%, 16 yr
- power=63%, 25%, 11%
- y(08)=2.16 (1.45, 3.23)
- r2=.13, NS
- slope=-2.7%(-9.0, 3.6)
- SD(tot)=28%, 11%, 16 yr
- power=63%, 25%, 11%

Vaderoarna

- n(tot)=31, n(yrs)=10
- m=2.92 (2.01, 4.23)
- SD(tot)=43%, 16%, 20 yr
- power=14%, 14%, 16%
- y(08)=1.93 (1.14, 3.24)
- r2=.40, p<.050 *
- slope=-7.8%(-16.0, .05)
- SD(tot)=43%, 16%, 20 yr
- power=14%, 14%, 16%

HCB, ug/g lipid w., guillemot egg, early laid

St. Karlso

- n(tot)=218, n(yrs)=22
- m=1.12 (.908, 1.38)
- SD(tot)=6.4%(-8.2, -4.7)
- power=1.0/.40/8.3%
- y(08)=.587 (.480, .718)
- r2=.76, p<.001 *
- slope=-5.4%(-8.4, -1.6)
- SD(tot)=12%, 4.8%, 10 yr
- power=.84/.84/4.8%
- r2=.59, p<.009 *

Vaderoarna

- n(tot)=31, n(yrs)=10
- m=2.92 (2.01, 4.23)
- SD(tot)=43%, 16%, 20 yr
- power=14%, 14%, 16%
- y(08)=1.93 (1.14, 3.24)
- r2=.40, p<.050 *
- slope=-7.8%(-16.0, .05)
- SD(tot)=43%, 16%, 20 yr
- power=14%, 14%, 16%

Kvadofjarden

- n(tot)=66, n(yrs)=14
- m=5.62 (4.95-6.28)
- SD(tot)=26%, 6.1%, 16 yr
- power=63%, 25%, 11%
- y(08)=4.69 (3.38, 6.50)
- r2=.19, NS
- slope=-3.6%(-11.3, 7.7)
- SD(tot)=28%, 11%, 16 yr
- power=63%, 25%, 11%

Fladen

- n(tot)=32, n(yrs)=9
- m=2.50 (2.02, 3.09)
- SD(tot)=28%, 12%, 16 yr
- power=63%, 25%, 11%
- y(08)=2.16 (1.45, 3.23)
- r2=.13, NS
- slope=-2.7%(-9.0, 3.6)
- SD(tot)=28%, 11%, 16 yr
- power=63%, 25%, 11%

Vaderoarna

- n(tot)=31, n(yrs)=10
- m=2.92 (2.01, 4.23)
- SD(tot)=43%, 16%, 20 yr
- power=14%, 14%, 16%
- y(08)=1.93 (1.14, 3.24)
- r2=.40, p<.050 *
- slope=-7.8%(-16.0, .05)
- SD(tot)=43%, 16%, 20 yr
- power=14%, 14%, 16%
Dioxins are unintentionally created during combustion of organic materials. They are highly toxic and carcinogenic.

Dioxins in guillemot eggs from St. Karlsö have been retrospectively analysed in a time series back to 1968. Herring muscle tissue has also been analysed during recent years.

22.1 Conventions aims and restrictions
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

22.2 Temporal variation

22.2.1 This investigation
The dioxin content of fat fish from the Baltic often exceeds the prescribed maximum limit (4 WHO-PCDD/F pg/g or 8 WHO-PCDD/F-PCBTEQ pg/g fresh weight) within the European Union, and therefore Sweden and Finland are currently only allowed to sell on the domestic market or to non member states (EC 2375/2001, EC 201/2002, EC 199/2006, EC 1881/2006). However, the TEQ levels in herring from the reference sites in this investigation do not exceed the prescribed maximum.

In guillemot eggs significant decreasing trends are observed for TCDD, TCDF and TCDD-equivalents during the whole period. However there is a difference over time between PCDD and PCDF. PCDF does not show the same decreasing trend during the recent 10 years as PCDD. This might explain the ceased trend for TCDD-equivalents during the last 20 years. The number of years required to detect an annual change of 5% varied between 12 and 17 years in the time series of guillemot.
There are no significant changes in concentration over time in herring muscle. In 2007 an increasing trend was observed at Harufjärden, but the very low level of TCDD-eqv in 2008 years herring eliminated the trend. The exceptionally low level of TCDD-eqv can not be explained by fat content, weight or length (these parameters were normal) so further investigations are needed. The number of years required to detect an annual change of 5% varied between 16 and 20 years for these time series.

22.3 Spatial variation

![Spatial variation in concentration (l.w.) of TCDD-equivalents in herring muscle.]

The TCDD-eqv in figure 22.1 (only two years are presented for the new sampling sites, one year for the off shore sites) are elevated in herring muscle from Harufjärden (Bothnian Bay) and Gaviksjärden and Ängskärsklubb (Bothnian Sea) compared to localities in the Baltic Proper and at the Swedish west coast.
Table 22.1. Trend (in %) for of TCDD-eqv. (pg/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish is also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n tot</th>
<th>n yrs</th>
<th>year</th>
<th>trend</th>
<th>last yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring msc. **</td>
<td>3-4</td>
<td>135</td>
<td>18</td>
<td>90-08</td>
<td></td>
<td>36 (24-54)</td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>181</td>
<td>19</td>
<td>88, 90, 92-08</td>
<td></td>
<td>26 (20-34)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utlängan</td>
<td>2-3</td>
<td>136</td>
<td>19</td>
<td>90-08</td>
<td></td>
<td>8.1 (5.8-11)</td>
</tr>
<tr>
<td>Guillemot egg**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-2.9 (-3.5, -2.2)*</td>
<td>.83 (.72-0.96)</td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05
** Pooled samples

Table 22.2. Trend (in %) for of TCDD-eqv. (pg/g fresh weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish is also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n tot</th>
<th>n yrs</th>
<th>year</th>
<th>trend</th>
<th>last yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring msc. **</td>
<td>3-4</td>
<td>135</td>
<td>18</td>
<td>90-08</td>
<td></td>
<td>.77 (.52-.1.1)</td>
</tr>
<tr>
<td>Harufj. autumn</td>
<td>3-4</td>
<td>175</td>
<td>18</td>
<td>90, 92-08</td>
<td></td>
<td>.65 (.46-.91)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.44 (.32-.61)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>136</td>
<td>19</td>
<td>90-08</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05
** Pooled samples
PCDD/PCDF in guillemot egg

TCDD, pg/g fat

- $n_{(tot)}=120$, $n_{(yrs)}=34$
- $m=265$ (213, 330)
- slope: $-5.2\%$ ($-5.7, -4.7$)
- SD(lr): $16\%$, $30\%$, $12$ yr
- power: $1.0 / 0.2 / 0.4$
- $y(08) = 92$ (82, 104)
- $r^2 = 0.93$, $p < 0.001$ *
- SD(sm): $1.8$, $p < 0.01$, $3.7\%$
- slope: $-7.1\%$ ($-8.8, -11$)
- $SD(sm) = 4.8$, $p < 0.01$, $7.2\%$
- power: $18 / 32 / 9.3\%$
- $r^2 = 0.69$, $p < 0.001$ *
- SD(sm): $37$, $p < 0.01$, $4.9\%$
- slope: $-1.3\%$ ($-5.8, 3.1$)
- $SD(sm) = 60.6$, $p < 0.001$ *

TCDF, pg/g fat

- $n_{(tot)}=120$, $n_{(yrs)}=34$
- $m=51.3$ (45.2, 58.3)
- slope: $-1.4\%$ ($-2.4, -0.35$)
- SD(lr): $27\%$, $1.7\%$, $17$ yr
- power: $1.0 / 0.2 / 0.4$
- $y(08) = 39.0$ (30.9, 49.3)
- $r^2 = 0.19$, $p < 0.01$ *
- SD(sm): $1.8$, $p < 0.01$, $3.7\%$
- slope: $0.79\%$ ($-8.8, 10$)
- $SD(sm) = 4.9$, $p < 0.01$, $7.0\%$
- power: $18 / 32 / 9.3\%$
- $r^2 = 0.69$, $p < 0.001$ *
- SD(sm): $37$, $p < 0.01$, $4.9\%$
- slope: $-1.3\%$ ($-5.8, 3.1$)
- $SD(sm) = 60.6$, $p < 0.001$ *

TCDD-equivalents, ng/g fat

- $n_{(tot)}=163$, $n_{(yrs)}=38$
- $m=1.44$ (1.27, 1.65)
- slope: $-2.9\%$ ($-3.5, -2.2$)
- SD(lr): $20\%$, $1.0\%$, $14$ yr
- power: $1.0 / 0.3 / 0.2$
- $y(08) = 0.830$ (0.718, 0.960)
- $r^2 = 0.69$, $p < 0.001$ *
- SD(sm): $1.8$, $p < 0.01$, $3.7\%$
- slope: $-1.3\%$ ($-5.8, 3.1$)
- $SD(sm) = 60.6$, $p < 0.001$ *

---

pia - 10:36:15 07:57, 11AU
Polybrominated flame retardants in guillemot eggs from St. Karlsö have been retrospectively analysed in a time series back to 1968. Herring muscle tissue has also been analysed during recent years.

23.1 Temporal variation

23.1.1 This investigation
Significant increasing concentrations of BDE-47, BDE-99 and BDE-100, in guillemot eggs, from the late sixties until the early nineties are followed by decreasing values during the recent period.

Decreasing concentrations of BDE-47 can also be observed in herring from Harufjärden, Ängskärsklubb (autumn), Landsort, Utlängan (autumn) and Väderöarna and in cod and herring from Fladen.

For HBCD a significant increasing trend is shown in guillemot eggs. The concentrations of HBCD are increasing in guillemot eggs with about 3% per year. In herring on the contrary HBCD is decreasing at Utlängan (9.6% per year) in the Baltic Proper and at Fladen (17% per year) and Väderöarna (16% per year) at the Swedish west coast.

The number of years required to detect an annual change of 5%, in the concentration of BDE-47, is 11 to 20 years for herring and cod (except for herring caught at Ängskärsklubb in spring) and for HBCD 15 to 23 years,
23.2 Spatial variation

Figure 23.1. Spatial variation in concentration (l.w.) of HBCD in herring muscle.

Figure 23.1 indicate elevated concentrations of HBCD (lipid weight) at the sampling sites in the south Baltic Proper (only two years are presented for the new sampling sites and one year for the off shore sites). The figure 23.2 and the time series for herring indicate elevated concentrations of some of the substances at Karlskrona in the southern Baltic Proper. In general the PBDE’s and HBCD seem to be more evenly distributed among sites compared to e.g. PCB.
Table 23.1. Trend (in %) for of BDE-47 (ng/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish is also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n tot</th>
<th>n yrs</th>
<th>year</th>
<th>trend</th>
<th>Mean (last year if trend)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring msc.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harufj.</td>
<td>3-4</td>
<td>118</td>
<td>10</td>
<td>99-08</td>
<td>-8.3 (-18,1.3)*</td>
<td>4.3 (2.6-7.1)</td>
</tr>
<tr>
<td>Ångskärsklubb</td>
<td>3-5</td>
<td>108</td>
<td>9</td>
<td>99-07</td>
<td>-11 (-19,-3.1)*</td>
<td>3.8 (2.6-5.5)</td>
</tr>
<tr>
<td>autumn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ångskärsklubb</td>
<td>2-5</td>
<td>67</td>
<td>7</td>
<td>02-08</td>
<td></td>
<td>12 (4.7-33)</td>
</tr>
<tr>
<td>spring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>114</td>
<td>10</td>
<td>99-08</td>
<td>-9.7 (-17,-2.3)*</td>
<td>4.4 (3.0-6.5)</td>
</tr>
<tr>
<td>Utlängan</td>
<td>3-4</td>
<td>113</td>
<td>10</td>
<td>99-08</td>
<td>-5.9 (-13,1.1)</td>
<td>6.8 (4.7-9.9)</td>
</tr>
<tr>
<td>autumn</td>
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<tr>
<td>Utlängan</td>
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<td>58</td>
<td>6</td>
<td>03-08</td>
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<td>13 (5.5-29)</td>
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<tr>
<td>spring</td>
<td>2-3</td>
<td>120</td>
<td>10</td>
<td>99-08</td>
<td>-17 (-21,-13)*</td>
<td>1.7 (1.4-2.1)</td>
</tr>
<tr>
<td>Fladen</td>
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<td>164</td>
<td>9</td>
<td></td>
<td>-16 (-23,-8.7)*</td>
<td>2.0 (1.3-3.0)</td>
</tr>
<tr>
<td><strong>Cod liver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>97</td>
<td>10</td>
<td>99-08</td>
<td></td>
<td>17 (12-24)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>96</td>
<td>10</td>
<td>99-08</td>
<td>-18 (-27,-9.6)*</td>
<td>11 (6.6-17)</td>
</tr>
<tr>
<td><strong>Güillemot egg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td></td>
<td>197</td>
<td>34</td>
<td>68-08</td>
<td></td>
<td>49 (25-95)</td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05

Table 23.2. Trend (in %) for of HBCD (ng/g lipid weight) assessed from the annual geometric mean in various matrices and the estimated mean concentration for the last year. Last years values are estimated from trend if p<0.1 or from the mean if no trend is present. The age interval for fish and the length interval for blue mussels are also presented together with the total number of analyses and the number of years of the various time-series. The numbers presented in brackets are the 95% confidence intervals.

<table>
<thead>
<tr>
<th>Matrix</th>
<th>age</th>
<th>n tot</th>
<th>n yrs</th>
<th>year</th>
<th>trend</th>
<th>Mean (last year if trend)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herring msc.</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Harufj.</td>
<td>3-4</td>
<td>118</td>
<td>10</td>
<td>99-08</td>
<td></td>
<td>9.4 (4.6-20)</td>
</tr>
<tr>
<td>Ångskärsklubb</td>
<td>3-5</td>
<td>105</td>
<td>9</td>
<td>99-07</td>
<td></td>
<td>3.5 (1.7-7.3)</td>
</tr>
<tr>
<td>autumn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ångskärsklubb</td>
<td>2-5</td>
<td>67</td>
<td>7</td>
<td>02-08</td>
<td></td>
<td>22 (10-47)</td>
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<tr>
<td>spring</td>
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<td></td>
</tr>
<tr>
<td>Landsort</td>
<td>3-5</td>
<td>114</td>
<td>10</td>
<td>99-08</td>
<td>-9.6 (-20,1.1)</td>
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<td>99-08</td>
<td>-16 (-23,-8.7)*</td>
<td>10 (5.7-18)</td>
</tr>
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<td>autumn</td>
<td></td>
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<tr>
<td>Utlängan</td>
<td>2-4</td>
<td>66</td>
<td>7</td>
<td>02-08</td>
<td></td>
<td>27 (14-50)</td>
</tr>
<tr>
<td>Fladen</td>
<td>2-3</td>
<td>117</td>
<td>10</td>
<td>99-08</td>
<td>-16 (-24,-8.7)</td>
<td>2.7 (1.8-2.0)</td>
</tr>
<tr>
<td>Väderöarna</td>
<td>154</td>
<td>9</td>
<td>02-08</td>
<td>-17 (-25,-8.9)</td>
<td>2.1 (1.3-3.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Cod liver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Gotland</td>
<td>3-4</td>
<td>96</td>
<td>10</td>
<td>99-08</td>
<td></td>
<td>19 (9.7-35)</td>
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<tr>
<td>Fladen</td>
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<td>60</td>
<td>7</td>
<td>99-08</td>
<td>-11 (-24,1.0)*</td>
<td>5.1 (2.6-10)</td>
</tr>
<tr>
<td><strong>Güillemot egg</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Karlsö</td>
<td></td>
<td>207</td>
<td>35</td>
<td>68-08</td>
<td></td>
<td>2.9 (1.9,3.9)*</td>
</tr>
</tbody>
</table>

* significant trend, p < 0.05
Brominated contaminants in Guillemot egg, ng/g lipid w.

Figure 23.2: Spatial variation of some polybrominated flame retardants. 1=Haruľjärden (Bothnian Bay), 2=Ängskärsklubb (S. Gulf of Bothnia), 3=Landsort (N. Baltic Proper), 4=Karlskrona (S.Baltic Proper), 6=Fladen (Kattegatt), 7=Väderöarna (Skagerack)
**BDE-47, ng/g lipid w., cod liver**

SE Gotland

- **n(tot)**=97, **n(yrs)**=10
- **m**=18.8 (15.7, 22.1)
- **slope**=-1.8% (-8.1, 4.4)
- **SD(lr)**=21%, 9.0%, 15 yr
- **y(08)**=17.2 (12.3, 24.0)
- **r2**=.05, **NS**
- **SD(sm)**=9.5, **NS, 10%**

Fladen

- **n(tot)**=96, **n(yrs)**=10
- **m**=24.3 (15.1, 33.7)
- **slope**=-5% (-11.9, 1.1)
- **SD(lr)**=20%, 13%, 18 yr
- **y(08)**=10.5 (6.6, 16.6)
- **r2**=.75, **p<.001** *
- **SD(sm)**=12, **NS, 14%**

**HBCD, ng/g lipid w., herring muscle**

Harufjarden

- **n(tot)**=118, **n(yrs)**=10
- **m**=8.09 (5.60, 11.7)
- **slope**=3.4% (10.1, 7)
- **SD(lr)**=55%, 21%, 23 yr
- **y(06)**=9.4 (4.6, 19.5)
- **r2**=.04, **NS**
- **SD(sm)**=21, **NS, 17%**

Angskarsklubb (3-5)

- **n(tot)**=106, **n(yrs)**=9
- **m**=9.96 (3.30, 17.4)
- **slope**=-8.8% (-24, 6.7)
- **SD(lr)**=47%, 24%, 23 yr
- **y(07)**=3.49 (1.68, 7.28)
- **r2**=.21, **NS**
- **SD(sm)**=40, **NS, 25%**

Landsort (3-5)

- **n(tot)**=114, **n(yrs)**=10
- **m**=12.2 (10.2, 14.5)
- **slope**=.67% (-7.3, 5.9)
- **SD(lr)**=24%, 9.5%, 15 yr
- **y(08)**=11.8 (8.3, 16.8)
- **r2**=.35, **p<.071** *
- **SD(sm)**=9.5, **NS, 8.7%**

Utlangan (3-4)

- **n(tot)**=112, **n(yrs)**=10
- **m**=15.5 (10.9, 22.0)
- **slope**=-9.6% (-20, 1.1)
- **SD(lr)**=41%, 16%, 20 yr
- **y(08)**=10.1 (5.7, 17.8)
- **r2**=.38, **p<.071** *
- **SD(sm)**=17, **NS, 17%**
HBCD in Guillemot egg, ng/g lipid w.

- Angskarsklubb, spring
  - n(tot)=67, n(yrs)=17
  - m=5.55 (3.70, 8.31)
  - slope=-16% (-24, -8.7)
  - SD(lr)=26%, 11%, 16 yr
  - SD(sm)=18, NS, 20%
  - y(08)=2.67 (1.79, 3.99)
  - r²=.76, p<.001 *
  - tao=-.64, p<.009 *
  - SD(sm)=20, NS, 13%

- Karlshkona, spring
  - n(tot)=66, n(yrs)=9
  - m=4.75 (3.00, 7.54)
  - slope=-17% (-25, -8.9)
  - SD(lr)=28%, 14%, 17 yr
  - SD(sm)=24, NS, 14%
  - y(08)=2.09 (1.32, 3.32)
  - r²=.78, p<.002 *
  - tao=-.78, p<.004 *
  - SD(sm)=24, NS, 14%

- Fladen
  - n(tot)=117, n(yrs)=10
  - m=5.55 (3.70, 8.31)
  - slope=-16% (-24, -8.7)
  - SD(lr)=26%, 11%, 16 yr
  - SD(sm)=20, NS, 13%
  - y(08)=2.67 (1.79, 3.99)
  - r²=.76, p<.001 *
  - tao=-.64, p<.009 *
  - SD(sm)=20, NS, 13%

- Vadoerna
  - n(tot)=154, n(yrs)=9
  - m=4.75 (3.00, 7.54)
  - slope=-17% (-25, -8.9)
  - SD(lr)=26%, 14%, 17 yr
  - SD(sm)=20, NS, 14%

- HBCD in Guillemot egg, ng/g lipid w.
  - n(tot)=207, n(yrs)=35
  - m=33.3 (23.8, 46.7)
  - slope=2.9% (1.9, 3.9)
  - SD(lr)=27%, 1.7%, 18 yr
  - power=1.0/.20/13%
  - y(08)= 170 ( 137, 211)
  - r²=.51, p<.001 *
  - SD(sm)=4.7, p<.001, 8.0%
  - slope=1.3% (-3.5, 6.2)
  - SD(lr)=17%, 6.9%, 13 yr
  - power=.53/.53/6.9%
  - r²=.05, NS
24 PAHs, Polyaromatic Hydrocarbons

Polyaromatic Hydrocarbons have been retrospectively analysed in blue mussels from Kvådöfjärden in the Baltic and Fladen and Väderöarna at the Swedish west coast in time series from 1987 to 2003, 1987 to 2003 and 1984 to 2003, respectively. PAHs are since 2003 analysed on a yearly basis from these three blue mussel sampling sites. The PAHs analysed are: Naphthalene, Acenaphtene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd)pyrene.

The source of PAHs is either pyroliytic or petrogenic and can be evaluated by molecule indexes and is based on concentration relationships between individual PAHs (Pikkarainen 2004). Metabolic capacity of the species sampled has to be considered.

24.1 Temporal variation

24.1.1 This investigation

All PAHs analysed (except acenapthene, which rarely was found over the detection limit) are presented as time series below. Significant decreasing trends are found in the time series for sPAH, Chrysene, Fluoranthene and Pyrene (Väderöarna) and Naphthalene (Kvådöfjärden) for the whole time period. Significant increasing trends for the last ten years are observed for Anthracene and Fluoranthene (Väderöarna) and for Benzo(a)anthracene and Fluorene (Kvådöfjärden).

The number of years required to detect an annual change of 5%, in the concentration varies a lot with type of PAH and sampling site. Generally the statistical power to detect trends is low compared to other contaminants. It lies between 22 and 37 years.

Some of the PAHs (e.g. Anthracene and Fluoranthene) are extremely high in concentration certain years compared to the average concentrations. These results could possibly be considered to be true outliers. The power and number of years required to detect a trend would improve if these outliers were excluded.
24.2 Spatial variation

Figure 24.1. Spatial variation in concentration (d.w.) of sPAH in blue mussle soft body.

Blue mussel soft body from Kvädöfjärden in the Baltic Proper represent the highest sPAH concentration of the blue mussel samples (figure 24.1). The retrospective studies show that the PAHs are not all systematically higher at Kvädöfjärden. Flouranthene and Pyrene for example show higher concentrations at Väderöarna.
sPAH, ng/g dry w., blue mussel

Fladen
- n(tot)=15, n(yrs)=15
- m=42.8 (27.7, 66.1)
- slope=-2.1% (-8.6, 4.7)
- SD(lr)=102%, 15%, 30 yr
- y(08)=35.5 (16.7, 75.1)
- r²=0.03, NS
- SD(sm)=23, NS, 35%
- slope=-24% (-27.2, 28)
- SD(lr)=141%, 49%, 34 yr
- power=.06/.07/40%

Vaderoarna
- n(tot)=17, n(yrs)=16
- m=66.1 (48.3, 84.2)
- slope=-4.0% (-8.5, 5.6)
- SD(lr)=61%, 11%, 26 yr
- y(08)=44.9 (25.9, 77.9)
- r²=0.20, p<0.078
- SD(sm)=13, NS, 20%
- slope=6.4% (0.23)
- SD(lr)=64%, 24%, 23 yr
- power=19.1/19%

Kvadofjarden
- n(tot)=17, n(yrs)=17
- m=108 (85.0, 137)
- slope=-50% (-42.3, 3.8)
- SD(lr)=45%, 7.3%, 22 yr
- y(08)=102 (63, 164)
- r²=0.01, NS
- SD(sm)=12, NS, 21%

Anthracene, ng/g dry w., blue mussel

Fladen
- n(tot)=17, n(yrs)=15
- m=.224 (.127, .397)
- slope=-3.7% (-12, 5.1)
- SD(lr)=136%, 20%, 36 yr
- y(08)=.162 (.061, .428)
- r²=0.06, NS
- SD(sm)=64, NS, 40%
- slope=11% (-22, 45)
- SD(lr)=177%, 64%, 39 yr
- power=.06/.06/51%

Vaderoarna
- n(tot)=17, n(yrs)=16
- m=.429 (.327, .562)
- slope=-1.6% (-5.4, 2.1)
- SD(lr)=41%, 8.6%, 23 yr
- y(08)=.366 (.232, .579)
- r²=0.06, NS
- SD(sm)=40, p<.009, 13%
- slope=14% (3.8, 24)
- SD(lr)=29%, 16%, 18 yr
- power=15%.19/13%

Kvadofjarden
- n(tot)=17, n(yrs)=17
- m=.358 (.210, .611)
- slope=2.3% (-5.8, 11)
- SD(lr)=198%, 17%, 36 yr
- y(08)=.47 (.16, 1.35)
- r²=0.02, NS
- SD(sm)=119, p<.009, 53%
- slope=16% (-26, 57)
- SD(lr)=168%, >99%, 37 yr
- power=.05/.06/46%
Benzo(a)anthracene, ng/g dry w., blue mussel

Fladen
- \( n(tot) = 14 \), \( n(yrs) = 13 \)
- \( m = 2.95 \) (2.15, 4.05)
- slope = -29% (-6.0, 5.5)
- power = 19/11/21%
- \( y(09) = 2.89 \) (1.68, 4.97)
- \( r^2 = 0.00 \), NS

Fladen
- \( n(tot) = 17 \), \( n(yrs) = 16 \)
- \( m = 3.73 \) (2.67, 5.23)
- slope = -2.7% (-7.3, 1.6)
- power = 26/11/49%
- \( y(08) = 1.65 \) (1.05, 4.97)
- \( r^2 = 0.11 \), NS

Vaderoarna
- \( n(tot) = 14 \), \( n(yrs) = 13 \)
- \( m = 3.94 \) (3.18, 5.70)
- slope = -32% (-9.4, 7.7)
- power = 15/11/21%
- \( y(09) = 1.91 \) (1.04, 3.77)
- \( r^2 = 0.00 \), NS

Kvadofjarden
- \( n(tot) = 14 \), \( n(yrs) = 13 \)
- \( m = 5.94 \) (3.96, 8.92)
- slope = 3.8% (1.3, 11)
- power = 16/10/27%
- \( y(09) = 1.6 \) (0.3, 2.1)
- \( r^2 = 0.00 \), NS

Benzo(a)pyrene, ng/g dry w., blue mussel

Fladen
- \( n(tot) = 16 \), \( n(yrs) = 14 \)
- \( m = 0.58 \) (0.34, 0.98)
- slope = -0.86% (-9.4, 7.7)
- power = 10/07/39%
- \( y(08) = 0.53 \) (0.20, 1.42)
- \( r^2 = 0.00 \), NS

Vaderoarna
- \( n(tot) = 17 \), \( n(yrs) = 16 \)
- \( m = 1.11 \) (0.66, 1.84)
- slope = -2.5% (-9.6, 4.6)
- power = 13/07/40%
- \( y(08) = 287 \) (36, 2.06)
- \( r^2 = 0.04 \), NS

Kvadofjarden
- \( n(tot) = 17 \), \( n(yrs) = 17 \)
- \( m = 4.08 \) (2.93, 5.68)
- slope = 1.2% (2.9, 8.6)
- power = 28/09/26%
- \( y(08) = 4.65 \) (2.40, 9.01)
- \( r^2 = 0.00 \), NS
Benzo(k)fluoranthene, ng/g dry w., blue mussel

Fladen
- n(tot)=17, n(yrs)=15
- m=1.16 (0.73, 1.62)
- slope=56% (-6.7, 8)
- SD(r)=106%, 16%, 31 yr
- y(08)=1.22 (-55, 2.70)
- r²=0.0, NS
- SD(sm)=69%, NS, 36%
- SD(lr)=156%, 55%, 36 yr
- power=.06/0.44%, NS

Vaderoarna
- n(tot)=17, n(yrs)=16
- m=1.76 (1.09, 2.82)
- slope=-2.9% (-0.5, 3.6)
- SD(r)=69%, 16%, 32 yr
- y(08)=1.32 (-5.9, 2.93)
- r²=0.0, NS
- SD(sm)=138, NS, 31
- SD(lr)=84%, 39%, 30 yr
- power=.07/0.32%, NS

Kvadofjarden
- n(tot)=17, n(yrs)=17
- m=5.59 (4.30, 7.27)
- slope=-.52% (-4.6, 0.35)
- SD(r)=47%, 8%, 23 yr
- y(08)=5.28 (3.12, 8.93)
- r²=0.01, NS
- SD(sm)=138, NS, 31
- SD(lr)=58%, NS, 36 yr
- power=.06/0.11/20%

Chrysene, ng/g dry w., blue mussel

Fladen
- n(tot)=17, n(yrs)=15
- m=4.42 (2.84, 6.88)
- slope=-2.2% (-9.1, 4.7)
- SD(r)=103%, 16%, 31 yr
- y(08)=3.63 (1.69, 7.78)
- r²=0.04, NS
- SD(sm)=59, NS, 36%
- SD(lr)=151%, 53%, 35 yr
- power=.06/0.43%, NS

Vaderoarna
- n(tot)=17, n(yrs)=16
- m=6.72 (4.13, 10.9)
- slope=-5.5% (-12.65)
- SD(r)=65%, 16%, 31 yr
- y(08)=3.92 (1.85, 8.32)
- r²=0.02, NS
- SD(sm)=37, p<0.090, 30
- SD(lr)=55%, 29%, 30 yr
- power=.06/0.29%, NS

Kvadofjarden
- n(tot)=17, n(yrs)=17
- m=9.07 (6.90, 11.9)
- slope=-1.7% (-5.8, 2.4)
- SD(r)=50%, 8%, 23 yr
- y(08)=7.5 (4.4, 12.8)
- r²=0.06, NS
- SD(sm)=23, NS, 19%
- SD(lr)=65%, 52%, 22 yr
- power=.06/0.13/18%

pia - 10.06.03 14:10, SKF

pia - 10.06.03 14:10, CHR
Fluoranthene, ng/g dry w., blue mussel

<table>
<thead>
<tr>
<th>Location</th>
<th>n(tot)</th>
<th>n(yrs)</th>
<th>m (95% CI)</th>
<th>slope (95% CI)</th>
<th>SD(lr)</th>
<th>SD(sm)</th>
<th>r^2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fladen</td>
<td>17</td>
<td>15</td>
<td>6.32 (3.62,11.0)</td>
<td>-2.8% (-12.59)</td>
<td>4.9 (1.9,12.8)</td>
<td>0.04</td>
<td>26, NS</td>
<td>0.00</td>
</tr>
<tr>
<td>Vadoarna</td>
<td>16</td>
<td>15</td>
<td>7.5 (11.5,26.0)</td>
<td>4.6% (9.5,24)</td>
<td>10.9 (5.9,20.1)</td>
<td>0.058</td>
<td>22, NS</td>
<td>0.00</td>
</tr>
<tr>
<td>Kvadofjarden</td>
<td>17</td>
<td>17</td>
<td>11.8 (8.02,17.4)</td>
<td>3.8% (7.4,10)</td>
<td>1.27 (0.51,3.15)</td>
<td>0.01</td>
<td>66, NS</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Indeno(1,2,3-cd)pyrene, ng/g dry w., blue mussel

<table>
<thead>
<tr>
<th>Location</th>
<th>n(tot)</th>
<th>n(yrs)</th>
<th>m (95% CI)</th>
<th>slope (95% CI)</th>
<th>SD(lr)</th>
<th>SD(sm)</th>
<th>r^2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fladen</td>
<td>13</td>
<td>13</td>
<td>1.12 (.669,1.89)</td>
<td>1.5% (7.4,10)</td>
<td>1.27 (51.3,15)</td>
<td>0.1</td>
<td>06, NS</td>
<td>0.00</td>
</tr>
<tr>
<td>Vadoarna</td>
<td>13</td>
<td>12</td>
<td>2.01 (1.29,3.13)</td>
<td>3.0% (-3.1,9.2)</td>
<td>2.77 (1.25,6.16)</td>
<td>0.11</td>
<td>27, NS</td>
<td>0.00</td>
</tr>
<tr>
<td>Kvadofjarden</td>
<td>17</td>
<td>17</td>
<td>8.15 (6.31,10.5)</td>
<td>0.03% (4.0,3.9)</td>
<td>8.1 (4.8,13.6)</td>
<td>0.06</td>
<td>07, NS</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Naphtalene, ng/g dry w., blue mussel

Fladen

\[ n(tot)=17, n(yrs)=15 \]
\[ m=2.59 (1.76,3.82) \]
\[ SD(tr)=2.2\% (4.3,3.8) \]
\[ SD(tr)=71\%, 14\%, 28\ yr \]
\[ power=18/(0.028\%) \]
\[ y(08)=2.12 \]
\[ r^2=0.05, NS \]
\[ SD(sm)=71\% \]
\[ slope=-2.2\% (-8.3,3.8) \]
\[ SD(sm)=71\% \]

Vaderoarna

\[ n(tot)=16, n(yrs)=15 \]
\[ m=2.75 (1.81,4.17) \]
\[ SD(tr)=3.1\% (8.8,2.5) \]
\[ SD(tr)=78\%, 14\%, 29\ yr \]
\[ power=17/(0.030\%) \]
\[ y(08)=2.00 \]
\[ r^2=0.01, NS \]
\[ SD(sm)=81\% \]
\[ slope=-3.1\% (-8.8,2.5) \]
\[ SD(sm)=81\% \]

Kvadofjarden

\[ n(tot)=17, n(yrs)=17 \]
\[ m=11.8 (7.2,19.3) \]
\[ SD(tr)=11\% (-16.7,1.1) \]
\[ SD(tr)=54\%, 8.6\%, 24\ yr \]
\[ power=36/(10.2\%) \]
\[ y(08)=3.0 \]
\[ r^2=0.01, NS \]
\[ SD(sm)=20\% \]
\[ slope=-11\% (-16,-7.1) \]
\[ SD(sm)=20\% \]

Phenantrene, ng/g dry w., blue mussel

Fladen

\[ n(tot)=17, n(yrs)=15 \]
\[ m=6.71 (4.03,11.2) \]
\[ SD(tr)=125\%, 19\%, 34\ yr \]
\[ power=12/(0.0739\%) \]
\[ y(08)=5.8 \]
\[ r^2=0.01, NS \]
\[ SD(sm)=50\% \]
\[ slope=-1.6\% (-9.7,6.4) \]
\[ SD(sm)=50\% \]

Vaderoarna

\[ n(tot)=17, n(yrs)=16 \]
\[ m=7.45 (4.96,11.2) \]
\[ SD(tr)=59\%, 14\%, 30\ yr \]
\[ power=18/(0.0832\%) \]
\[ y(08)=7.2 \]
\[ r^2=0.00, NS \]
\[ SD(sm)=44\% \]
\[ slope=-0.29\% (-6.1,5.5) \]
\[ SD(sm)=44\% \]

Kvadofjarden

\[ n(tot)=17, n(yrs)=17 \]
\[ m=7.36 (4.71,10.6) \]
\[ SD(tr)=13\% (-7.5,4.9) \]
\[ SD(tr)=103\%, 13\%, 30\ yr \]
\[ power=20/(0.0732\%) \]
\[ y(08)=6.1 \]
\[ r^2=0.01, NS \]
\[ SD(sm)=47\% \]
\[ slope=-1.3\% (-7.5,4.9) \]
\[ SD(sm)=47\% \]
Pyrene, ng/g dry w., blue mussel

Fladen

- n(tot)=17, n(yrs)=15
- m=7.35 (4.97,10.9)
- slope=-3.7% (-0.6, 2.1)
- SD(lr)=78%, 13%, 27 yr
- r²=13, NS
- SD(sm)=39, NS, 31%
- power=.19/.08/27%

Vaderoarna

- n(tot)=17, n(yrs)=16
- m=11.5 (8.09, 16.4)
- slope=-4.8% (-9.1, -.63)
- SD(lr)=55%, 97%, 25 yr
- r²=.13, NS
- SD(sm)=19, p<.048
- power=.30/.10/22%

Kvadofjarden

- n(tot)=17, n(yrs)=17
- m=6.19 (4.15, 9.21)
- slope=2.8% (-3.2, 8.7)
- SD(lr)=89%, 12%, 30 yr
- r²=.22, NS
- SD(sm)=47, NS, 35%
- power=.05/.08/32%
25 PFCs, Perfluorinated compounds

Perfluorinated substances have been used industrially and commercially since the beginning of the 1950s and 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).

PFOS has been retrospectively analysed in guillemot eggs from St. Karlsö in a time series starting 1968. Additionally, a selection of perfluorinated substances has been analysed in herring liver tissue during the last three years. These comprised perfluorinated carboxylates (PFCAs): perfluorohexanoate (PFHxA), perfluorooctanoate (PFHxO), perfluorononanoate (PFNA), perfluorodecanoate (PFDoC), perfluoroundecanoate (PFUnA), perfluorododecanoate (PFDoD), perfluorotridecanoate (PFTrA), perfluorotetradecanoate (PFTeA), perfluoropentadecanoate (PFPeDA) as well as perfluorinated sulfonates (PFSs): perfluorobutane sulfonate (PFBS), perfluorohexane sulfonate (PFHxS), perfluoroctane sulfonate (PFOS), perfluorodecane sulfonate (PFDoS), perfluorooctane sulfonamide (PFOSA) and 6:2 fluorotelomer sulfonate (6:2 FTS).

25.1 Temporal variation

25.1.1 This investigation

A significant increasing trend is observed for PFOS in guillemot eggs with 7-10% per year, which is equal to an increase to 25-30 times higher levels in the early 2000s as compared to the late 1960ties. Due to change of the analytical method between 2003 and 2004 and relatively high inter-annual variations, the future trend for PFOS concentrations in the Baltic marine environment cannot be predicted. Further monitoring will reveal if the phase out by 3M will make a difference for the PFOS concentrations in biota.
**PFOS, ng/g fresh w., guillemot egg, St Karlso**

Data source: ITM, Urs Berger, Katrin Holmstrom  10.06.15  09:01, pfos08

![Graph](image)

**Figure 25.1** Temporal trend of PFOS concentrations in guillemot eggs (ng/g w.w.). The mean annual PFOS value shown as red dot in the figure of the time series is based on pooled samples or mean values of individual samples.

25.2 **Spatial variation**

25.2.1 **This investigation**

So far only three years (2005-08) of analysis in herring liver are available (pooled samples, 12 fish in each) at the old sampling sites and only two years at the new sampling sites (one year at the off shore sites). Therefore, the obtained results have to be interpreted carefully. However, it has been shown that the individual variation of perfluorinated substances is relatively small compared to classical POPs (Verreault et al., 2007). The spatial variations of 7 perfluorinated substances (three PFSs in Figure 25.2: PFHxS, PFOS and PFOSA and four PFCAs in Figure 25.3: PFNA, PFDCa, PFUnA and PFTriA) are presented below. The selection was based on number of results above LOQ.
Figure 25.2 Spatial variation in concentration (w.w.) of A) PFHxS, B) PFOS and C) PFOSA in herring liver. Highest concentration of PFHxS and PFOS were 2.2 ng/g and 19.0 ng/g, respectively. Highest concentration of PFOSA (6.8 ng/g) was found at Fladen in the Kattegatt.

PFHxS and PFOS show a quite similar spatial pattern, but PFOS concentrations were approximately 45 times higher than PFHxS levels. This was as expected, since PFHxS has not been produced intentionally, but only occurred as by-product in technical PFOS. Furthermore, the distribution of PFOS is quite homogenous along the Swedish coast (with the exception of Lagnö and the off shore sampling site in the Baltic Proper), which is a result of the extraordinary persistency of the compound and the long history of use (three decades). Elevated levels may be expected at sites with a higher population density and associated current emissions from consumer products still containing technical PFOS. PFOSA, however, is not persistent, but a precursor compound to PFOS. The high concentrations at the west coast reflect a current source probably located around the North Sea. The relatively short environmental half-life of PFOSA does not allow it to diffuse into the Baltic, due to the low water exchange between the two seas. Degradation of PFOSA to PFOS might also contribute to higher PFOS concentrations. Taken into account that liver generally contains about 5 times higher concentrations than fish muscle, PFOS levels in herring liver are in agreement with levels found in other fish species from the Baltic (Swedish Environmental Protection Agency, 2007). PFOS concentrations in guillemot eggs from 2005, however, are about 200 times higher than in herring liver (herring and sprat...
being the main prey of guillemot), showing the high retention of this compound in guillemot and the transport potential to the forming egg.

A) PFNA

B) PFDcA

C) PFUnA

D) PFTriA

Figure 25.3 Spatial variation in PFCA concentrations (w.w.) of A) PFNA, B) PFDcA, C) PFUnA and D) PFTriA in herring liver. Highest concentrations of PFNA (3.30 ng/g) was found at Byxelkrok (in Kalmar sund) in the south Baltic Proper. Highest concentrations of PFUnA (4.63 ng/g), PFDcA (3.34 ng/g and PFTriA (5.20 ng/g) were found at Harufjärden in the Bothnian Bay.

PFCAs in the environment can have two types of sources, direct sources (from manufacturing and use of PFCAs) and indirect sources (from degradation of volatile precursor compounds) (Prevedouros et al., 2006). PFNA is intentionally produced and therefore probably originates mainly from direct sources (production and use of consumer products containing PFNA, such as PTFE products) and waterborne transport to remote locations. This may partly explain the spatial variations of PFNA in this study, as sewage treatment plant effluents from industry or larger cities could represent hot-spots. In contrast, PFUnA and PFTriA are unintentionally produced substances, and their presence in the environment is probably due to both direct sources (impurities in PFOA and PFNA productions) and indirect sources (atmospheric transport and degradation of precursors). The fact that the odd-chained PFUnA and PFTriA are higher concentrated than PFDoA and the homogenous spatial distribution of these compounds supports the theory that indirect sources are important for these long-chain PFCAs. Also levels and compound patterns of
PFCAs are in good agreement with concentrations in other Baltic fish (Swedish Environmental Protection Agency, 2007).
26 References


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