

# Metals (lead, cadmium and mercury)

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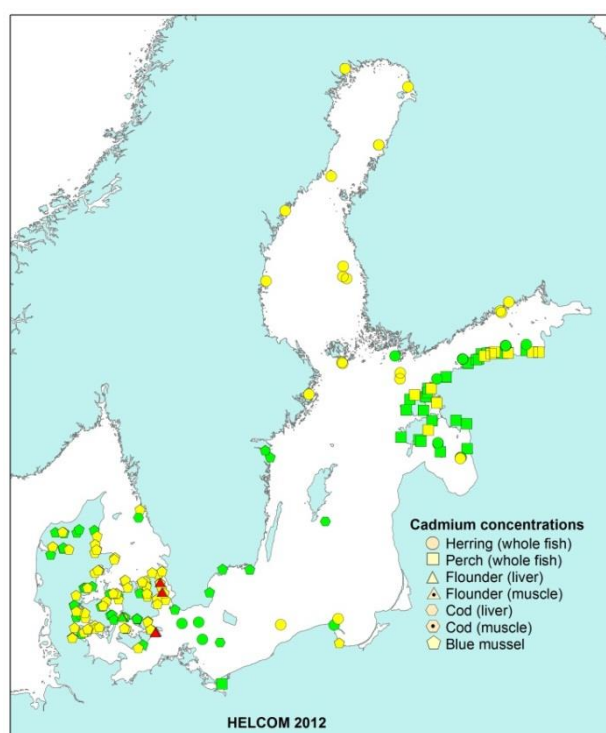
## Key messages

Cadmium concentrations in the entire Baltic Sea indicate worrying levels, which is also shown as 'moderate' or 'bad' status classifications. The blue mussels in the Danish straits and the perch in the Estonian coast show also Good Environmental Status, perhaps indicating more local conditions.

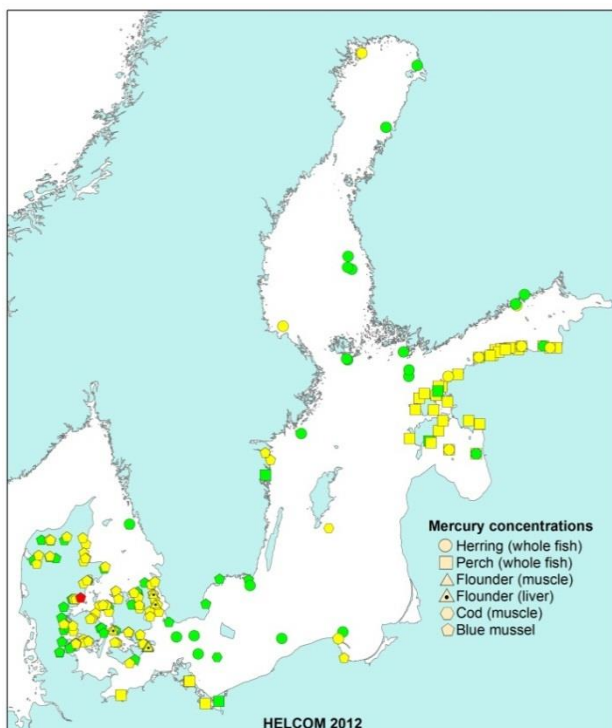
Mercury concentrations are generally worse in the Danish straits and the Estonian coast, whereas the Gulf of Bothnia seems to be in a better status.

Lead concentrations are generally high and indicate moderate or bad environmental status in many sub-basins of the Baltic Sea. Only the southwestern Baltic Sea has sites with Good Environmental Status in blue mussels.

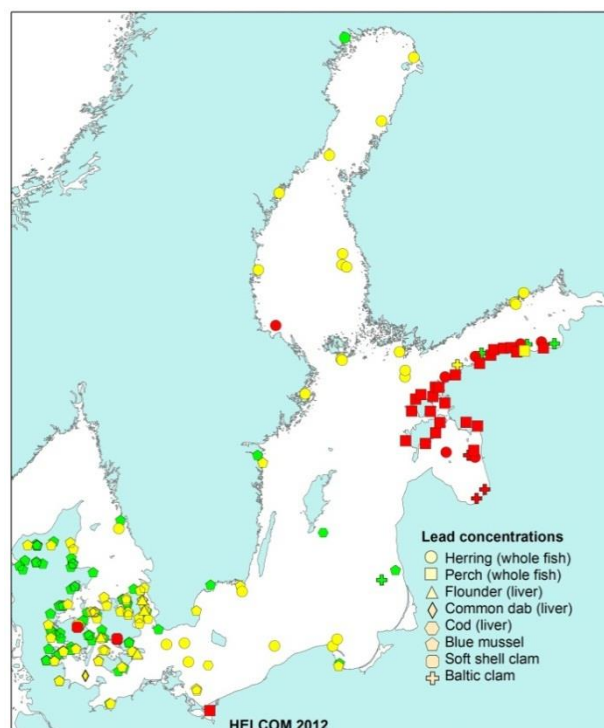
Time series graphs show that no consistent trends are visible for the three metals in the Baltic Sea; increases or decreases are seen depending on site.



**Figure 1.** Status of cadmium in relation to the cadmium GES boundary in different fish species and the blue mussel in 2005-2010. In herring and perch the liver samples have been converted to whole fish concentrations (note that there are conversion factors for herring and perch muscle concentrations, see Methods). Green colour denotes 'good environment status', yellow denotes 'moderate' and red 'bad'. For the boundaries, see Methods.



**Figure 2.** Status of mercury in relation to the mercury GES boundary in different fish species and the blue mussel in 2005–2010. Herring and perch concentrations were converted to whole fish concentrations. For explanations, see Fig 1.



**Figure 3.** Status of lead in relation to the lead GES boundary in different fish species and the blue mussel in 2005–2010. Herring and perch concentrations were converted to whole fish concentrations. For explanations, see Fig 1.

## Current status in the Baltic Sea

### Cadmium

The 6-year averages of cadmium concentrations in Baltic fish and blue mussels (2005–2010) are spatially varying. In general, elevated concentrations are found from all parts of the Baltic Sea, but particularly the Gulf of Bothnia has poorer status than other sub-basins of the region (Figure 1). The status of cadmium does not seem to depend on species, but concentrations measured from perch and blue mussels represent more local conditions and hence show higher variability.

### Mercury

The 6-year averages of mercury concentrations show elevated status in several sites in the Baltic Sea (Figure 2). The blue mussel and flounder data from the Danish Straits and Kattegat indicate several locations of sub-GES status and the perch data from the Estonian coast indicates even more clearly the same. The herring and cod data from Gulf of Bothnia and the Baltic Proper indicates GES. It seems that the status classes depend on sampled species; for example, perch has accumulated generally higher concentrations of mercury than the fattier herring.

### Lead

The 6-year averages of lead concentrations in Baltic fish and bivalves show a variation from bad status in the Gulf of Finland and Baltic Proper to a moderate or good environmental status in the Danish Straits and Kattegat (Figure 3). In the Gulf of Bothnia, the status is most likely better than elsewhere, but the high detection limit of the herring liver

samples leaves some uncertainty to the status classification in the Finnish side of the sub-basin; the status may be better than shown in Figure 3.

## General Information

### General properties

Metals are naturally occurring substances that have been used by humans since the iron age. The metals Cd, Pb and Hg are the most toxic and regulated metals today, and have no biological function. Mercury is bioaccumulated, mainly in its organic form (Methyl-mercury) and due to high evaporation pressure can be transported from soil to the Baltic, and concentrate in the arctic.

### Main impacts on the environment and human health

Lead and mercury have been connected to impaired learning curves for children, even at small dosage. Lead can cause increased blood pressure and cardio-vascular problems in adults. Acute metal poisoning generally results in vomiting. Long term exposures of high levels of lead and mercury can affect the neurological system. Mercury can lead to birth defects as seen in Minimatta bay among fishermen in a mercury polluted area, and also after ingestion of methylmercury treated corn in Iran. Cadmium is concentrated in the kidney, and can result in impaired kidney function, and cadmium can exchange for calcium in bones and produce bone fractures (Itai-Itai disease).

The HELCOM thematic assessment of hazardous substances (HELCOM 2010) showed high concentrations of mercury and cadmium in biota and sediment all over the Baltic Sea. Lead was not assessed.

## Policy relevance

### Status of the indicator on international priority lists and other policy relevance

Mercury and cadmium are included in the HELCOM Baltic Sea Action Plan. All the three metals are included in the EU WFD (Pb and Cd in water, Hg in biota) and EU shellfish directive in shellfish. Part of EU food directives, limits set in a range of fish species, shellfish and other seafood. In the OSPAR CEMP to be measured on a mandatory basis in fish, shellfish and sediment (OSPAR 2010).

### Status of restrictions, bans or use

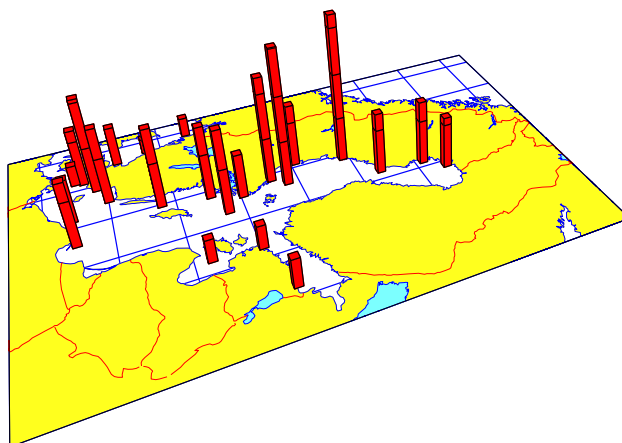
All three metals have been used for centuries, but in the last decades have been banned for most uses. Today, the main area of usage of cadmium and mercury is in rechargeable batteries, and for mercury additionally, low energy light sources. Main source of all three metals are burning of fossil fuels. The air deposition is mainly long range transport from outside the Baltic Sea catchment area (60–84 %). Sources of mercury used in amalgams for dentist have been reduced by installing mercury traps in sinks and generally reducing amalgams in dental works, as electrodes in paper bleaching, in thermometers and mercury switches and a range of other products that have been phased out. Current legal use include batteries and low energy light sources. For lead, the main source was leaded fuels until their ban in Europe in the 1990ies. Both cadmium and lead have hotspots in connection with metal processing facilities, and cadmium is coexisting with all zinc ores, and typically present at levels of 0,5 –2 % in the final products. Weathering of outdoor zinc-products thus leads to cadmium pollution. Current legal use of cadmium and lead includes rechargeable Ni-Cd batteries and for lead car batteries.

## Concentrations and time series of metals in the Baltic Sea

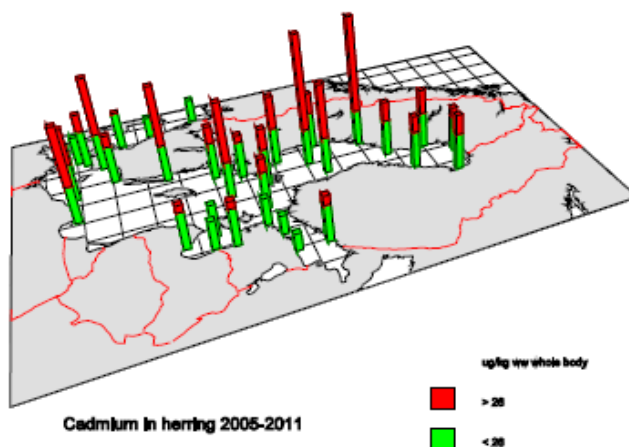
### Concentrations of metals

#### Cadmium

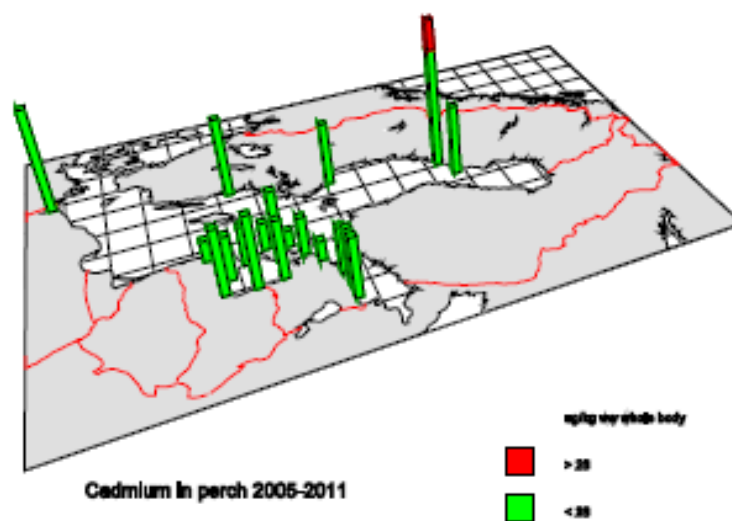
Cadmium concentrations in the herring liver range between 0.35–3.6 mg kg<sup>-1</sup> dw (Figure 4a). The highest concentrations are found from the Bothnian Sea.



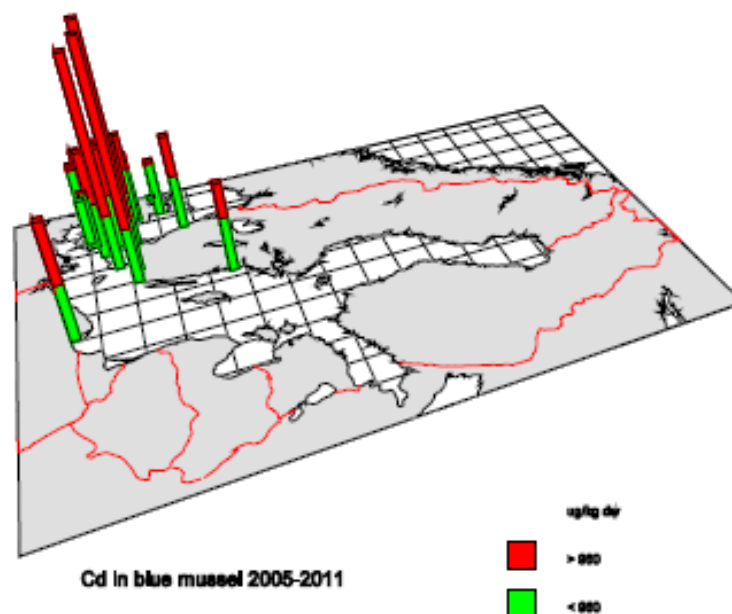
**Figure 4a.** Spatial variation in arithmetic mean concentration (2008–2010 in µg/g dry weight) of cadmium in herring liver. The highest concentration (around 3.6 mg/kg) was found in the northern Bothnian Sea (Gaviksfjärden), the lowest (around 0.35 mg/kg) in Kattegat (Fladen). The Swedish data originates from the Swedish national monitoring programme and are analysed at the Department of Applied Environmental Science, Stockholm University. Additional data is obtained from ICES database.



**Figure 4b.** Spatial variation in arithmetic mean concentration (2005–2011 in µg/kg wet weight) of cadmium in herring whole body. Sites closer than 50 km are fused together to an arithmetic mean concentration. The highest bar represents a concentration of 94 µg/kg. Red columns represent concentrations above 26 µg/kg.

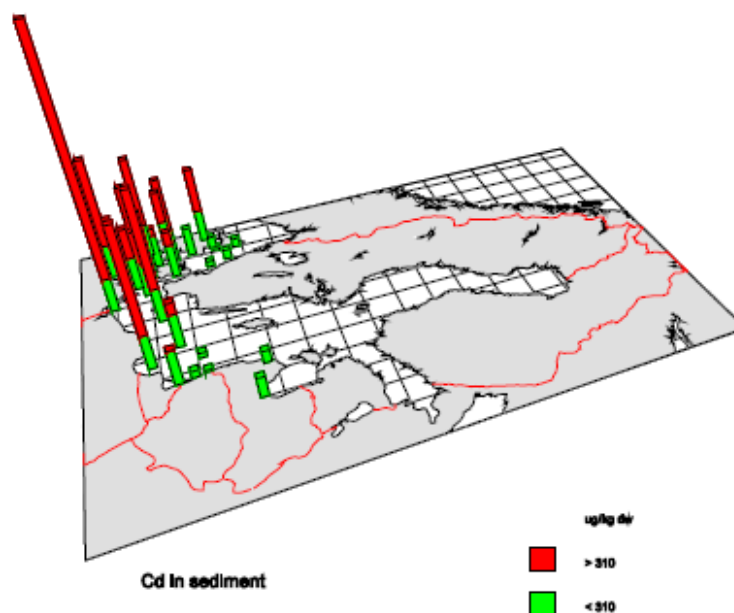


**Figure 4c.** Spatial variation in arithmetic mean concentration (2005–2011 in  $\mu\text{g/kg}$  wet weight) of cadmium in perch whole body. Sites closer than 50 km are fused together to an arithmetic mean concentration. The highest bar represents a concentration of 32  $\mu\text{g/kg}$ . Red columns represent concentrations above 26  $\mu\text{g/kg}$ .



**Figure 4d.** Spatial variation in arithmetic mean concentration (2005–2011 in  $\mu\text{g/kg}$  dry weight) of cadmium in blue mussel. The highest bar represents a value of 4 100  $\mu\text{g/kg}$  dw. Red columns represent concentrations above 960  $\mu\text{g/kg}$ .

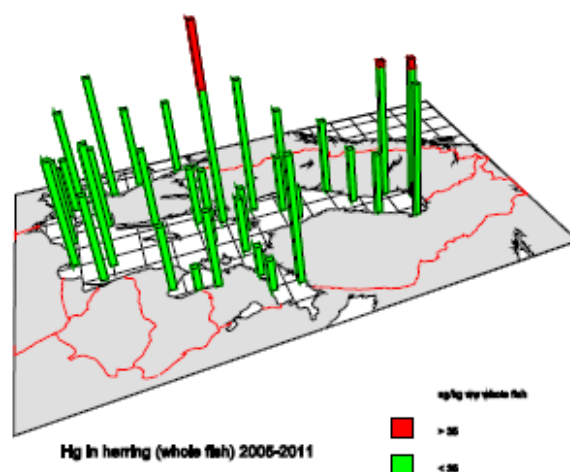




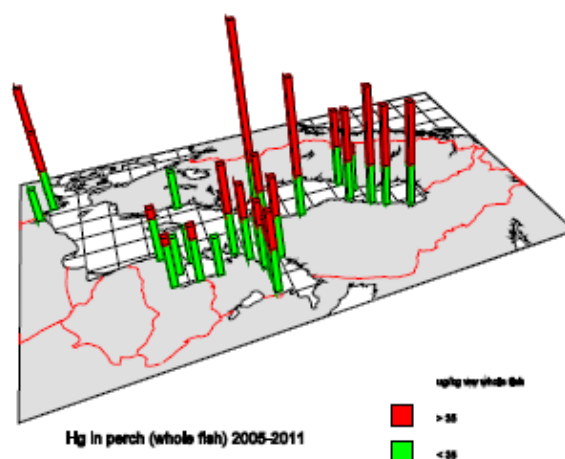
**Figure 4e.** Spatial variation in arithmetic mean concentration (2005–2011 in  $\mu\text{g}/\text{kg}$  dry weight) of cadmium in sediment. The highest bar represents a value of 2 480  $\mu\text{g}/\text{kg}$  dw. Red columns represent concentrations above 960  $\mu\text{g}/\text{kg}$ .

## Mercury

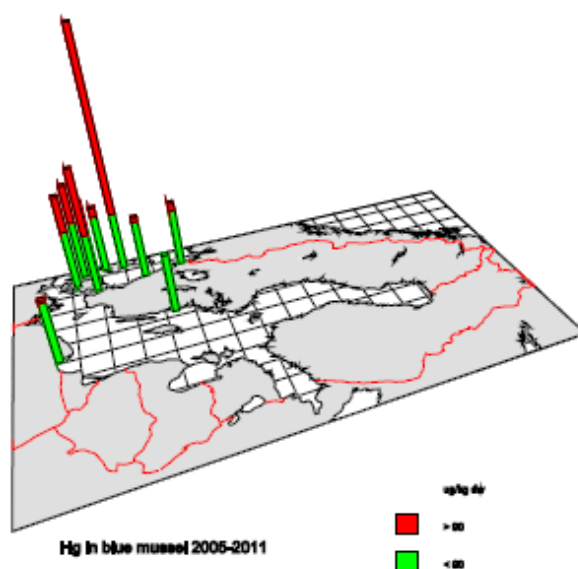
The mercury concentrations in perch are clearly higher than in herring and somewhat higher than in blue mussels (Figures 5–7). The concentrations are high almost everywhere in the Baltic Sea, but lower concentrations may exist in the eastern Bothnian Sea and the Archipelago Sea. Similar result was also shown in the HELCOM Thematic Assessment (HELCOM 2010) and by Bignert et al. (2011). The high mercury concentrations in the Bothnian Bay and eastern Gulf of Finland are also seen in the sediment data (HELCOM 2010).



**Figure 5.** Concentrations of mercury ( $\mu\text{g}/\text{kg}$  ww) in herring muscle, converted to whole fish concentrations (see Annex 1 of this indicator report). The green part of the bars represent a concentration of 35  $\mu\text{g}/\text{kg}$  ww, which is the EQS for fish. Sites closer than 50 km are fused together to an arithmetic mean concentration.



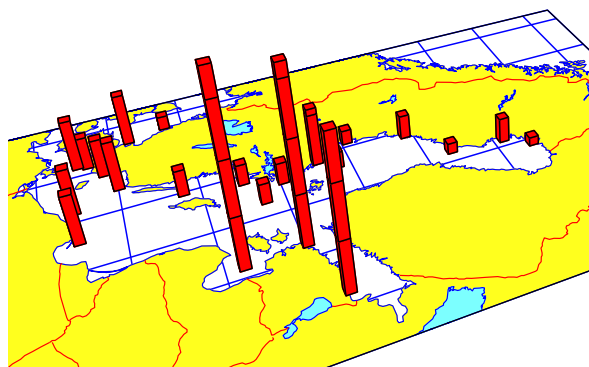
**Figure 6.** Concentrations of mercury ( $\mu\text{g/kg ww}$ ) in perch muscle, converted to whole fish concentrations (see Annex 2 of this indicator report). The green part of the bars represent a concentration of  $35 \mu\text{g/kg ww}$ , which is the EQS for fish. Sites closer than 50 km are fused together to an arithmetic mean concentration.



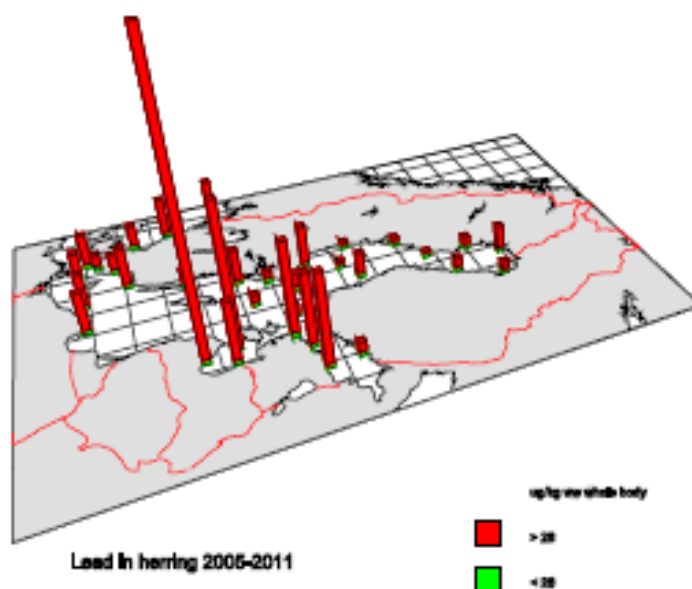
**Figure 7.** Concentrations of mercury ( $\mu\text{g/kg dw}$ ) in blue mussels. The green part of the bars represent a concentration of  $90 \mu\text{g/kg dw}$ , which is the EAC in blue mussels. Sites closer than 50 km are fused together to an arithmetic mean concentration.

## Lead

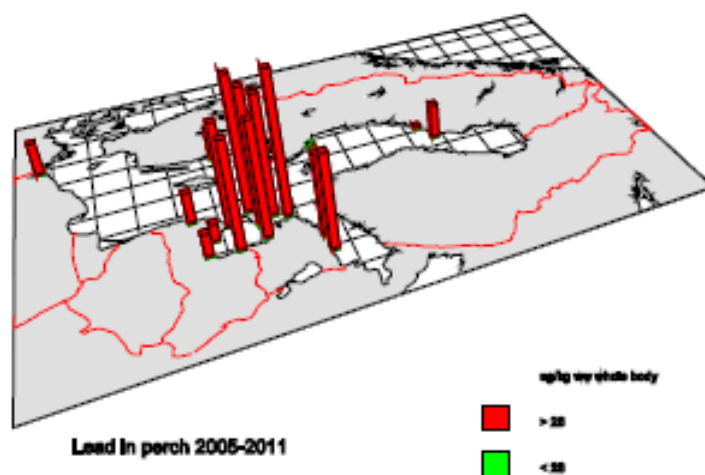
Lead concentrations in herring liver are highest in the Estonian coastal waters in Gulf of Finland, Northern Baltic Proper and Gulf of Riga (Figure 8). The lowest concentrations are from the Gulf of Bothnia.



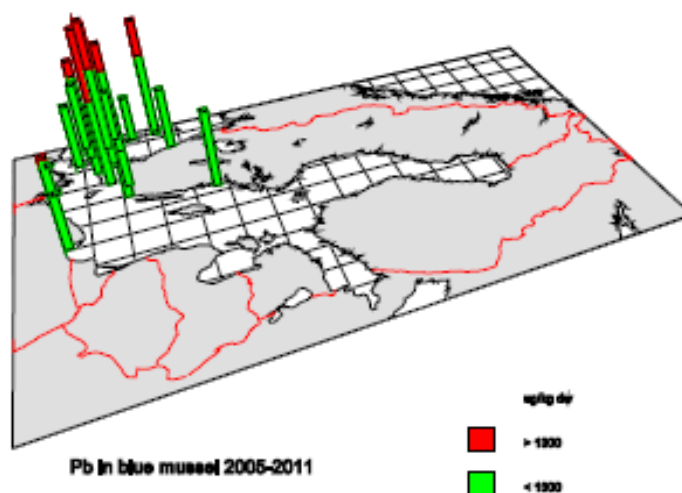
**Figure 8a.** Spatial variation in arithmetic mean concentration (2008–2010 in ng/g dry weight) of lead in herring liver. The highest concentration (around 423 ng/g ) was found in the Gulf of Riga, the lowest (around 20 ng/g) in the Bothnian Bay (Harufjärden). The Swedish data originates from the Swedish national monitoring programme and are analysed at the Department of Applied Environmental Science, Stockholm University. Additional data is obtained from ICES database.



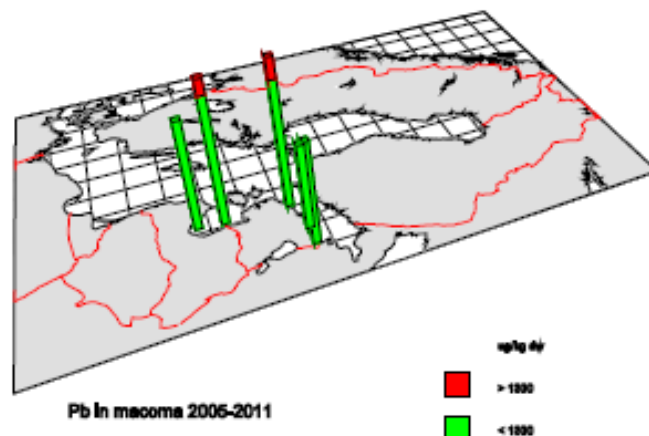
**Figure 8b.** Spatial variation in arithmetic mean concentration (2005–2011 in µg/gg wet weight) of lead in herring whole body. The highest concentration of 1644 µg/kg was found in the Gulf of Riga. The green part of the bars represent a concentration of 26 µg/kg ww.



**Figure 8c.** Spatial variation in arithmetic mean concentration (2005–2011 in  $\mu\text{g/gg}$  wet weight) of lead in perch whole body. The highest bar represents a concentration of  $1607 \mu\text{g/kg}$ . The green part of the bars represent a concentration of  $26 \mu\text{g/kg ww}$ .



**Figure 8d.** Spatial variation in arithmetic mean concentration (2005–2011 in  $\mu\text{g/gg}$  dry weight) of lead in blue mussel. The highest bar represents a concentration of  $2300 \mu\text{g/kg}$ . The green part of the bars represent a concentration of  $1300 \mu\text{g/kg dw}$ .



**Figure 8e.** Spatial variation in arithmetic mean concentration (2005–2011 in  $\mu\text{g/gg}$  dry weight) of lead in *Macoma balthica*. The highest bar represents a concentration of 1514  $\mu\text{g/kg}$ . The green part of the bars represent a concentration of 1300  $\mu\text{g/kg ww}$ .

### Temporal trends

The temporal trends for metals in biota are inconclusive, as there are both areas with increasing trends of mercury and cadmium, and areas with decreasing trends (Figures 9–16; see also HELCOM 2010 and Jensen 2012).

#### Cadmium

Cadmium concentrations in herring are generally showing significant increasing trends followed by decreasing trends (Figure 9). Cadmium concentration in liver tissue from various species show coherent trends of similar magnitudes from various regions. Cadmium concentrations in cod liver samples (adjusted for varying fat content) from south east of Gotland and Fladen, however, show significant decreasing trends (Figure 10).

In general, the recent levels are not significantly lower compared to the concentrations measured at the beginning of the 80s, despite measures taken to reduce discharges of cadmium to the environment.

#### Mercury

There is no common general trend for mercury in herring muscle for the investigated time series. The concentration in herring from the northern Baltic Proper seems to increase during the investigated time period until the mid-90s but with a decreasing trend the last 15 years (Figure 11). The annual mean concentrations in herring muscle during the investigated time period are all below 100  $\mu\text{g/kg}$  except for a few years at Ängskärsklubb. The concentrations in the eggs of Common Guillemot have decreased since 1970s (Figure 12).

The time series for autumn-caught herring 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.

Mercury was monitored in spring-caught herring from Ängskärsklubb and Karlskrona for four years in the beginning of the seventies, and these series were taken up again in 1996. The Ängskärsklubb time series shows significantly lower concentrations during the recent time period compared to the concentrations in the early seventies and this decrease is about 60%.

#### Lead

Lead is showing significant declining trends in almost all investigated biotic matrices of sufficient length, obviously as a result of measures taken to reduce discharges of lead to the environment (Figures 13–16). The investigated time

series in herring liver show significant decreasing trends at Harufjärden (-5.9 %), Ängskärsklubb (autumn, -4.5 %), Landsort (-5.7 %), and Utlängan (autumn, -2.8 %). Lead concentrations in cod liver (after adjusting for varying fat content) showed decreasing trends from SE Gotland (-5.3 %) and Fladen (about -2.8 %). Perch liver from the coastal sites Holmöarna (Bothnian Sea) and Kvädöfjärden (Baltic Proper) show decreasing concentrations of lead at an annual rate of -8.9 % and -7.1 % respectively.

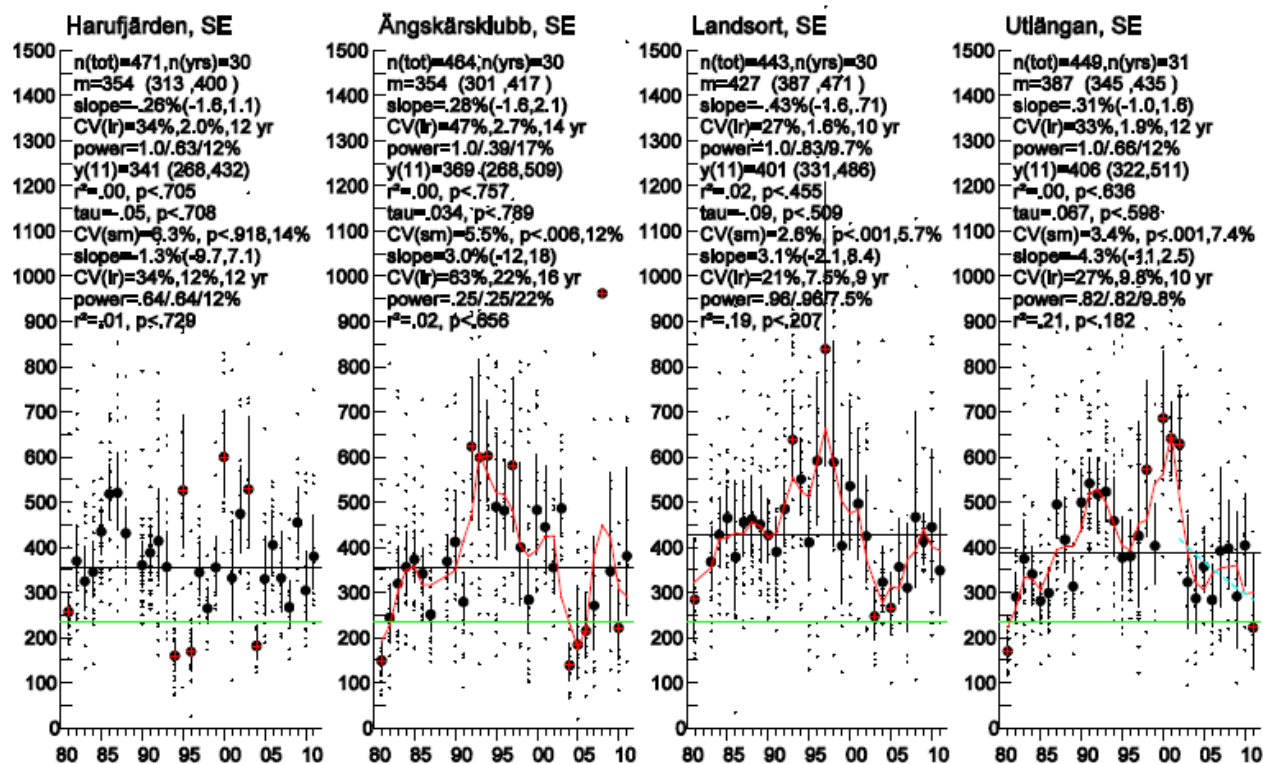
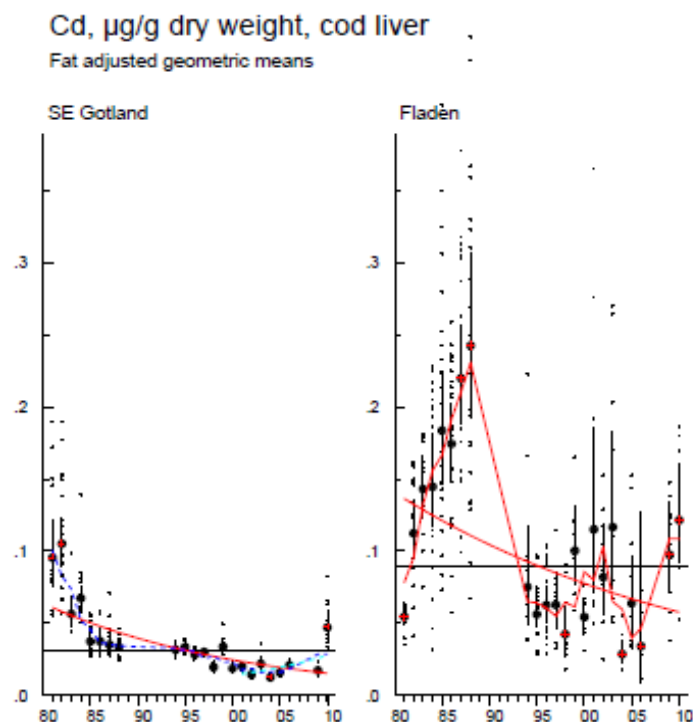
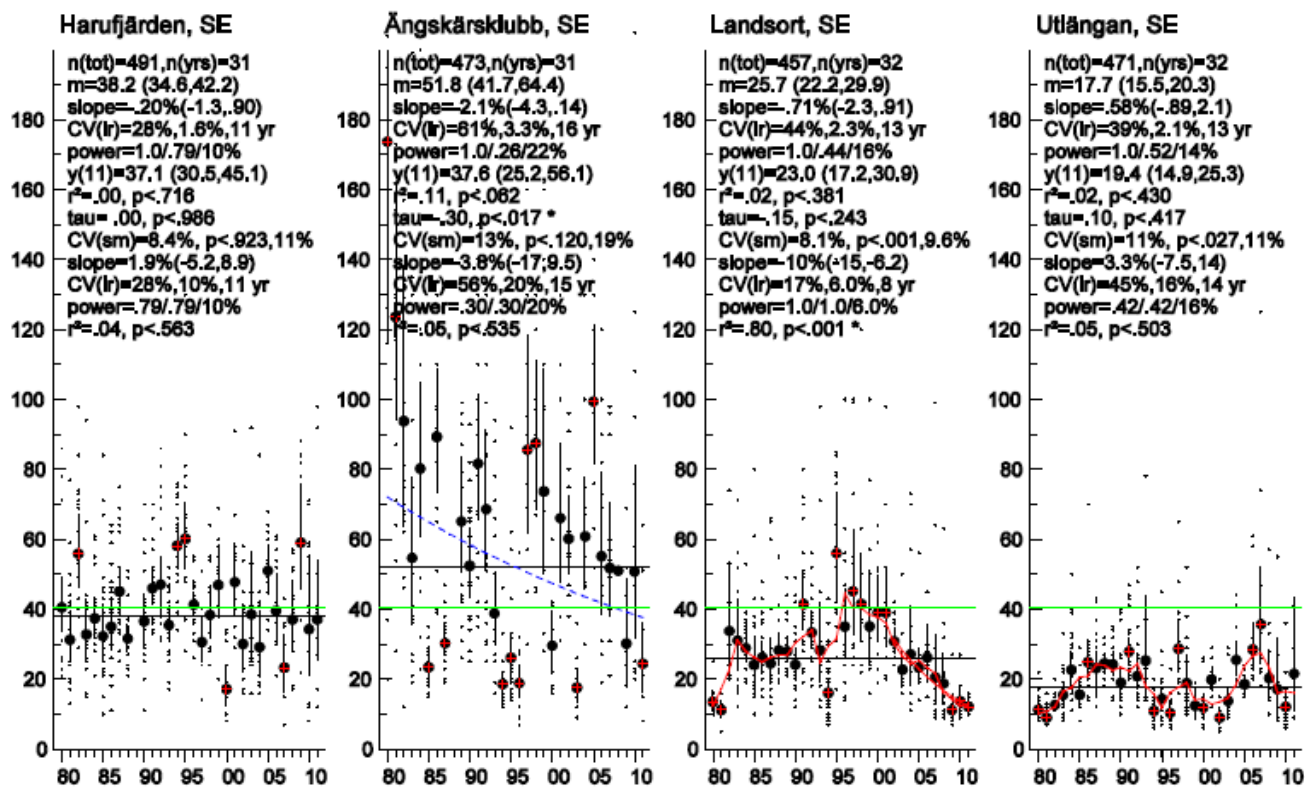


Figure 9. Temporal development of cadmium concentrations ( $\mu\text{g kg}^{-1} \text{ ww}$ ) in herring liver in Bothnian Bay (Harufjärden), Bothnian Sea (Ängskärsklubb), Northern Baltic Proper (Landsort) and Bornholm Basin (Utlängan). The green line denotes the GES boundary.

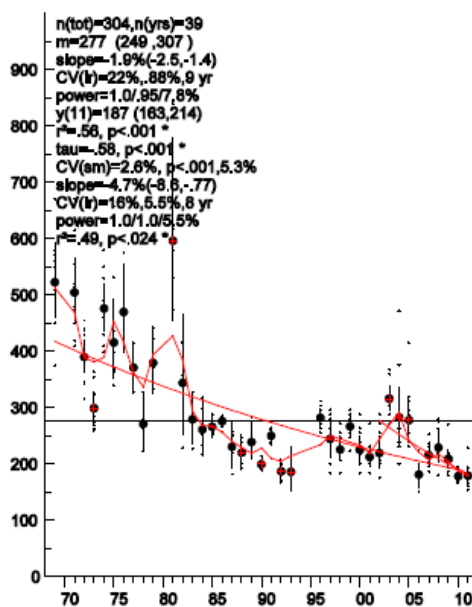


**Figure 10.** Temporal trends of cadmium concentration ( $\text{mg kg}^{-1}$  dry weight) in cod liver (1981–2010) from the Eastern Gotland Basin (SE Gotland) and from Kattegatt (Fladen). The red linear lines and dashed light blue linear line presented in the figures are based on a log-linear regression analysis. The red lines shows decreasing trends of  $-4.8$  and  $-3.0$  % per year respectively ( $p < 0.05$ ) and the light blue line shows an increasing trend for the last ten years ( $0.05 < p < 0.15$ ). The red non-linear line ( $p < 0.05$ ) and the dashed blue non-linear line ( $0.05 < p < 0.1$ ) are simple 3-point running mean smoothers fitted to the annual geometric mean values. The horizontal line is the mean concentration over the whole period. A red cross represents a suspected outlier.





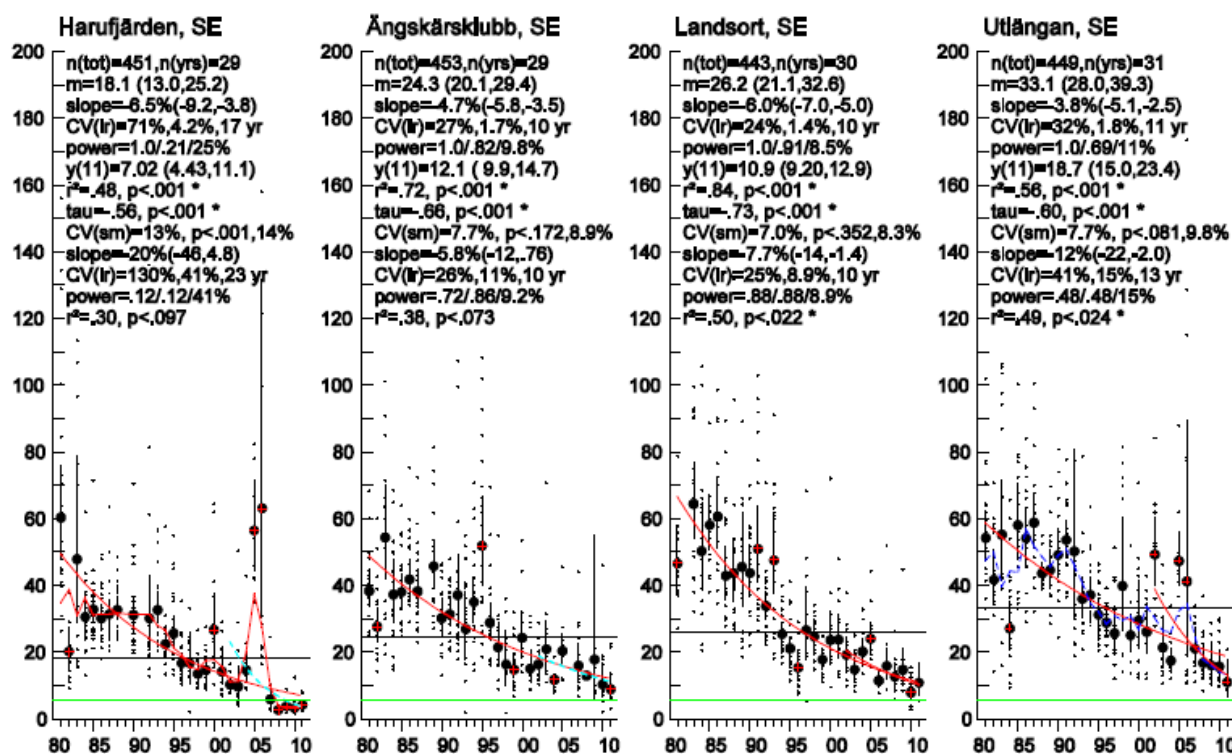
**Figure 11.** Temporal development of mercury concentrations ( $\mu\text{g kg}^{-1} \text{ ww}$ ) in herring liver in Bothnian Bay (Harufjärden), Bothnian Sea (Ängskärsklubb), Northern Baltic Proper (Landsort) and Bornholm Basin (Utlängan). The green line denotes the GES boundary.



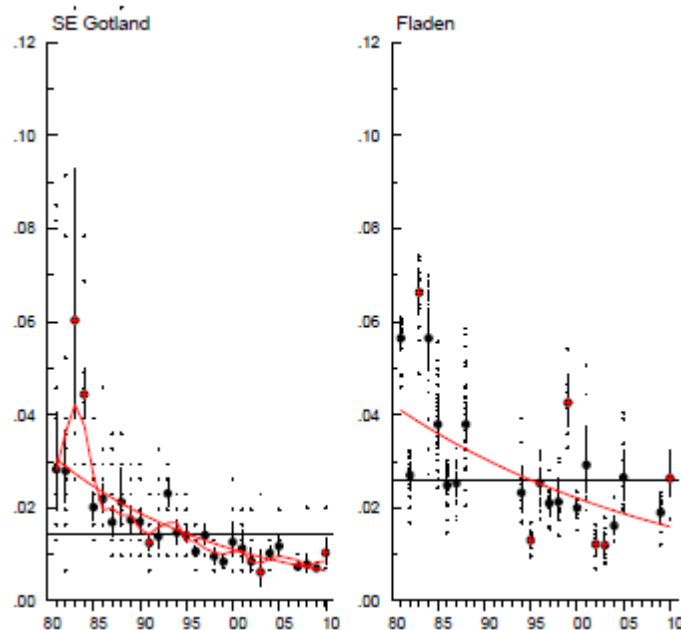
**Figure 12.** Temporal development of mercury concentrations ( $\mu\text{g kg}^{-1} \text{ dw}$ ) in eggs of Common Guillemot in Stora Karlsö, Gotland.



## Pb, ng/g wet w., herring liver

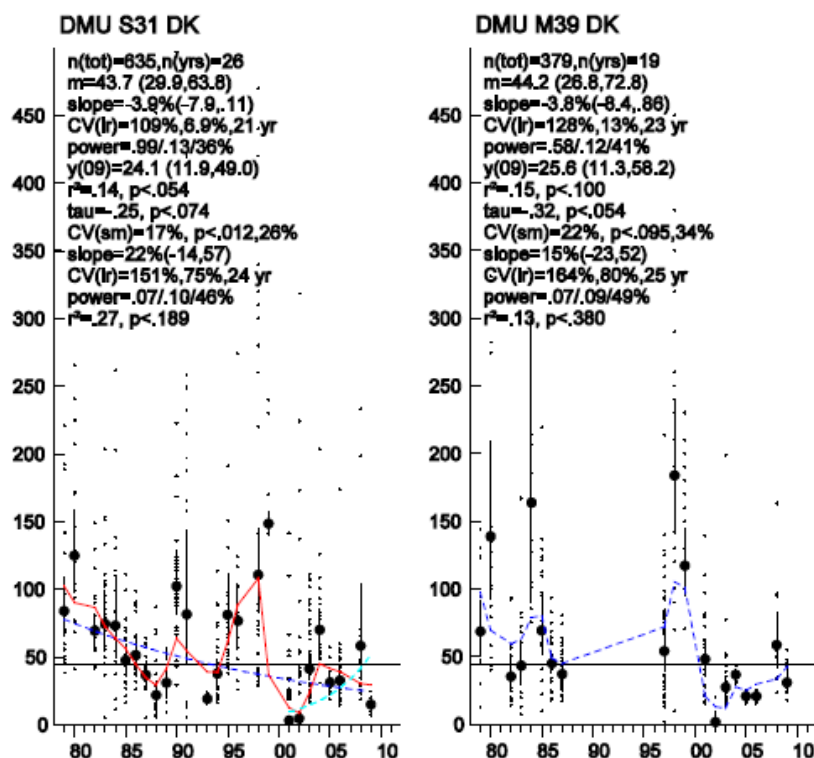


**Figure 13.** Lead concentrations ( $\mu\text{g}/\text{kg}$  ww) in herring liver in Bothnian Bay (Harufjärden), Bothnian Sea (Ängskärsklubb), Northern Baltic Proper (Landsort) and Bornholm Basin (Utlängan) between 1981–2010. The linear red lines ( $p<0.05$ ) and dashed light blue lines ( $0.05<p<0.15$ ) presented in the figures are based on a log-linear regression analyses and the red lines show decreasing trends of about 3–6 % per year for the whole time period. Decreasing trends for the last ten years are indicated at a majority of the sites. The non-linear red line ( $p<0.05$ ) and the dashed blue line ( $0.05<p<0.1$ ) are simple 3-point running mean smoothers fitted to the annual geometric mean values. The horizontal line is the mean concentration of the analysed period. A red cross represents a suspected outlier. The green line denotes the GES boundary.

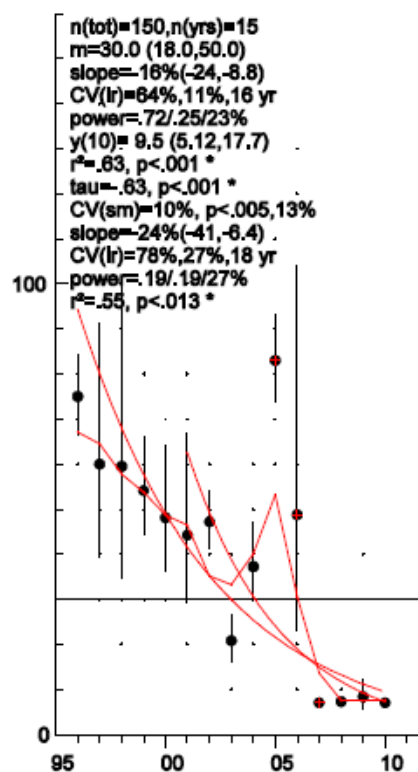


**Figure 14.** Temporal trends of lead concentration ( $\text{mg kg}^{-1} \text{ dw}$ ) in cod liver (1981–2010) from Eastern Gotland Basin (SE Gotland) and from Kattegatt (Fladen). The red linear lines presented in the figures are based on a log-linear regression analysis and show decreasing trends of -5.3 and -2.8 % per year respectively and the red non-linear line is a simple 3-point running mean smoother fitted to the annual geometric mean values. The horizontal line is the mean concentration over the whole period. A red cross represents a suspected outlier.

### Pb, ng/g wet weight, flounder liver



**Figure 15** Temporal development of lead concentrations ( $\mu\text{g/kg ww}$ ) in flounder liver in the Sound (S31) and Great Belt (S39).



**Figure 16.** Temporal development of lead concentrations ( $\mu\text{g/kg dw}$ ) in eggs of Common Guillemot in Stora Karlsö, Gotland

## Metadata

### Data source

ICES database of the monitoring data of the HELCOM Contracting Parties, complemented by the EIONET database and National Swedish Monitoring Programme of Contaminants in Biota Description of data

### Description of data

The average of the time period 2005–2010 was used to produce the status maps. Conversions of data to wet-weight – based or dry-weight –based concentrations were made by the lipid weight or dry weight percentage to have the same unit as the GES boundary.

For time series graphs: stations with long time series were selected. If data was in similar format per station, no conversion was made. As station names have changed in long time series and sampling per station name varies spatially a bit, the values were aggregated per 0.1 degree square.

### Cadmium

Trend (in %) assessed from the annual geometric mean of concentrations of cadmium ( $\mu\text{g/g dry weight}$ ) in various matrices and sites during the time period 1981–2010 and the estimated mean concentration for the last year (2010). The trend is reported, if  $p < 0.1$ . The age interval, the total number of analyses and the number of years are also presented. The numbers presented in brackets are the 95 % confidence intervals.

| Matrix               | age | n analyses | n yrs | year  | trend (95 % ci)   | mean concentration of last year (95 % ci) |
|----------------------|-----|------------|-------|-------|-------------------|---|
| <b>Herring liver</b> |     |            |       |       |                   |   |
| Harufjärden          | 3–5 | 459        | 29    | 81–10 |                   | 1.2 (.90-1.6)                             |
| Ängskärsklubb        | 3–5 | 452        | 29    | 81–10 |                   | 1.4 (.96-2.0)                             |
| Landsort             | 3–5 | 445        | 30    | 81–10 |                   | 1.6 (1.3-2.1)                             |
| Utlängan             | 3–4 | 444        | 30    | 81–10 | 1.4 (.12, 2.7)*   | 1.8 (1.4-2.2)                             |
| Fladen               | 2–3 | 527        | 30    | 81–10 |                   | .39 (.32-.46)                             |
| <b>Cod liver</b>     |     |            |       |       |                   |   |
| SE Gotland           | 3–4 | 393        | 23    | 81–10 | -4.8 (-6.6,-3.0)* | .015 (.011-.021)                          |
| Fladen               | 2–4 | 334        | 23    | 81–10 | -3.0 (-5.5,.43)   | .058 (.037-.0898)                         |

\* significant trend,  $p < 0.05$ .

### Mercury

Trend (in %) assessed from the annual geometric mean of concentrations of mercury (ng/g fresh weight) in various matrices and sites during the time period 1971/80-2010 and the estimated mean concentration for the last year (2010). The trend is reported, if  $p < 0.1$ . The age interval, the total number of analyses and the number of years are also presented. The numbers presented in brackets are the 95% confidence intervals.

| Matrix                | age | n analyses | n yrs | year  | trend (95 % ci)   | mean concentration of last year (95 % ci) |
|-----------------------|-----|------------|-------|-------|-------------------|---|
| <b>Herring muscle</b> |     |            |       |       |                   |   |
| Harufjärden           | 3–5 | 479        | 30    | 80–10 |                   | 37 (30–46)                                |
| Ängskärsklubb         | 3–5 | 461        | 30    | 80–10 |                   | 41 (27–61)                                |
| Ängskärsklubb, spring |     | 234        | 19    | 72–10 | -2.5 (-3.4,-1.6)* | 23 (19–26)                                |
| Landsort              | 3–5 | 451        | 31    | 80–10 |                   | 25 (19–34)                                |
| Utlängan              | 2–4 | 466        | 31    | 80–10 |                   | 19 (15–25)                                |
| Utlängan, spring      |     | 232        | 18    | 72–10 | -.73 (-1.6,-.12)  | 19 (16–22)                                |

significant trend,  $p < 0.05$

### Lead

Trend (in %) assessed from the annual geometric mean of concentrations of lead ( $\mu\text{g/g}$  dry weight) in various matrices and sites during the time period 1981-2010 and the estimated mean concentration for the last year (2010). The trend is reported, if  $p < 0.1$ . The age interval, the total number of analyses and the number of years are also presented. The numbers presented in brackets are the 95% confidence intervals.

| Matrix               | age | n analyses | n yrs | year  | trend (95 % ci)    | mean concentration of last year (95 % ci) |
|----------------------|-----|------------|-------|-------|--------------------|---|
| <b>Herring liver</b> |     |            |       |       |                    |   |
| Harufjärden          | 3–5 | 439        | 28    | 81–10 | -5.9 (-9.0, -2.8)* | .029 (.017–.048)                          |
| Ängskärsklubb        | 3–5 | 441        | 28    | 81–10 | -4.5 (-5.8, -3.2)* | .050 (.040–.0622)                         |
| Landsort             | 3–5 | 445        | 30    | 81–10 | -5.7 (-6.8, -4.6)* | .045 (.038–.055)                          |
| Utlängan             | 2–4 | 432        | 29    | 81–10 | -2.8 (-4.0, -1.6)* | .085 (.069–.10)                           |
| <b>Cod liver</b>     |     |            |       |       |                    |   |
| SE Gotland           | 3–4 | 402        | 29    | 81–10 | -5.3 (-6.6, -4.0)* | .007 (.005–.008)                          |
| Fladen               | 2–4 | 470        | 31    | 81–10 | -2.8 (-4.8, -.87)* | .016 (.011–.022)                          |
| <b>Perch liver</b>   |     |            |       |       |                    |   |
| Holmöarna            | 3–7 | 150        | 15    | 95–10 | -8.9(-15,-2.9)*    | .008 (.004–.013)                          |
| Kvädöfjärden         | 3–7 | 135        | 15    | 95–10 | -7.1(-12,-2.1)*    | .010 (.007–.016)                          |

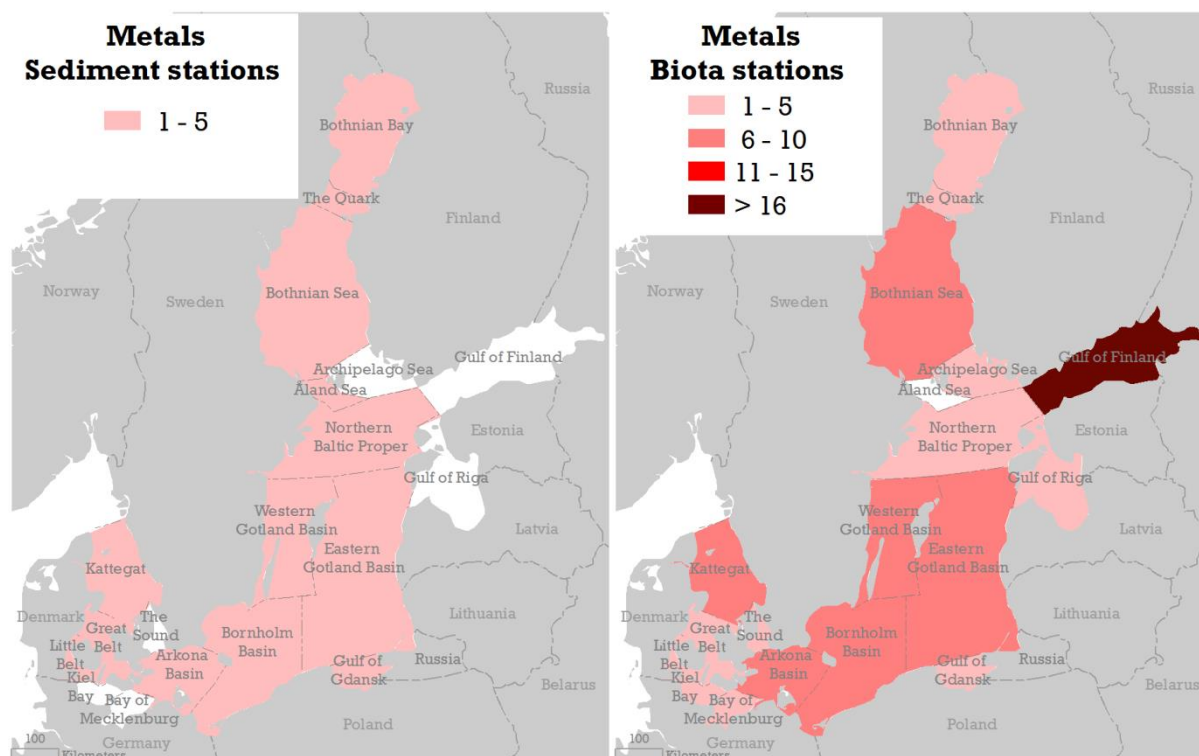
\* significant trend,  $p < 0.05$

## Geographic coverage

### Current monitoring network

Cadmium, mercury and lead are being monitored in all the Baltic Sea countries. In addition to long-term monitoring stations of herring, cod, perch, flounder and eelpout, there is a fairly dense grid of monitoring stations for mussels and perch at the shoreline, but very few stations in the open Baltic Sea. The monitoring is, however, considered as representative.

**Annex 1** gives an overview of the current monitoring.



### Geographical relevance in the monitoring of metals

Cadmium, mercury and lead concentrations are spatially highly varying in the Baltic Sea. Therefore, a dense network of monitoring stations is needed to have reliable overviews of the state of the environment. The monitoring should contain both long-lived and mobile species (herring, cod, flounder) and more local species (perch and shellfish).

Sediment monitoring can complement the assessment.

Monitoring of cadmium, mercury and lead is relevant in the entire sea area.

### Temporal aspects

Cadmium. In the Swedish monitoring programme, the non-linear trends found in the cadmium series makes it difficult to estimate the quality in terms of power. From the linear parts of the trends the number of years required to detect an annual change of 10 % with a power of 80 % varied between 11 to 15 years.

Mercury. The number of years required to detect an annual change of 10 % with a power of 80 % varied between 9 and 16 years for the herring time series.

Lead. In the Swedish monitoring programme, the number of years required to detect an annual change of 10 % with a power of 80 % varied between 10 to 18 years for the herring time-series. The number of years required to detect an annual change of 10 % with a power of 80 % were 11 and 14 years for the cod time-series (Bignert et al. 2012)

### Methodology and frequency of data collection

See HELCOM COMBINE manual.

HELCOM and OSPAR guidelines for measuring metals in biota and sediment exist. Guideline for monitoring in water is being developed. Quality assurance in form of international workshops and intercalibrations has been organized yearly by QUASIMEME since 1993, with two rounds each year for water, sediment and biota.

### Methodology of data analyses

Data analyses were carried out by the *Department of Contaminant Research* at the Swedish Museum of Natural History, Stockholm.

Concentrations in herring and perch were converted from muscle and liver to 'whole fish concentrations' according to the constants in Annex 2. The rationale behind the conversion was to better meet the GES boundary, which was interpreted to reflect the mean concentration of a whole fish.

A dry weight percentage of 35 percent in herring liver has been assumed when information on dry weight content was missing in the ICES database.

### Preferred matrix

Shellfish or sediment for local surveys.

Fish muscle (Hg) and liver (Cd, Pb) for regional surveys.

### Determination of GES boundary

Metals have been assessed since the beginning of OSPAR and HELCOM conventions, and the OSPAR assessment criteria are available for cadmium, lead and mercury. In this core indicator GES boundary (between Good



Environmental Status and a 'moderate status') is the Background Assessment Criterion (BAC) of OSPAR (2009). The reason for the use of BACs instead of OSPAR Environmental Assessment Criteria (EAC), is that EACs – which ensure that no chronic effects occur below that level – are (EACs for Cd and Pb in sediment, Hg in mussels and Hg and Cd in fish) actually lower than BACs for metals in fish. Following the decision for the OSPAR Quality Status Report 2010 (see Law et al. 2010 for discussion), also HELCOM core indicators will use BACs for all three metals as GES boundaries.

The threshold concentration to indicate a 'bad status' in mussels and fish is the Food Safety Limit of European Union (EU/1881/2006) and in sediment the Effect-Range –low (ERL) value from US EPA (see OSPAR 2009). The EU food safety limits are meant for fish meat (i.e. muscle samples) only and therefore the liver concentrations, which are higher than muscle concentrations, follow the food safety limits of bivalves. This follows the OSPAR (2010) approach (see Law et al. 2010 for discussion).

**Table 1.** Assessment criteria of this core indicator for cadmium, mercury and lead.

|    | Sediment<br>(µg/kg dry weight) |       | Mussels<br>(µg/kg dry weight) |                   | Fish<br>(µg/kg wet weight) |  |
|----|--------------------------------|-------|-------------------------------|-------------------|----------------------------|--|
|    | GES boundary                   | ERL   | GES boundary                  | EU food           | GES boundary               | EU food  |
| Cd | 310 <sup>5</sup>               | 1200  | 960                           | 5000 <sup>1</sup> | 26                         | Muscle: 50 (100 <sup>3</sup> )<br>Liver: 1000 <sup>2</sup> |
| Hg | 70 <sup>5</sup>                | 150   | 90                            | 2500 <sup>1</sup> | 35                         | Muscle: 500 (1000 <sup>4</sup> )                           |
| Pb | 38000 <sup>5</sup>             | 47000 | 1300                          | 7500 <sup>1</sup> | 26                         | Muscle: 300<br>Liver: 1500 <sup>2</sup>                    |

<sup>1</sup>) converted from 1881/2006/EU by the factor 5 (see OSPAR 2009, Law et al. 2010), <sup>2</sup>) bivalve value, see Law et al. 2010 for discussion, <sup>3</sup>) eel, <sup>4</sup>) pike and eel, <sup>5</sup>) BACs are normalized to 5% Aluminium.

**Table 2.** EU environmental quality standards for metals (EC proposal to the revised EQS Directive).

|    | Water<br>(µg/l)   |            | Biota<br>(µg/kg wet weight) |         | Sediment<br>(µg/kg dry weight) |         |
|----|-------------------|------------|-----------------------------|---------|--------------------------------|---------|
|    | AA-EQS            | Mac-EQS    | AA-EQS                      | Mac-EQS | AA-EQS                         | Mac-EQS |
| Cd | 0.08–0.25/0.2     | 0.45 – 1.5 | n.a.                        | n.a.    | n.a.                           | n.a.    |
| Hg | 0.05 <sup>1</sup> | 0.07       | 20 <sup>2</sup>             | n.a.    | n.a.                           | n.a.    |
| Pb | 1.3               | 14         | n.a.                        | n.a.    | n.a.                           | n.a.    |

<sup>1</sup>) If memberstates don't use biota AA-EQS, the water AA-EQS should have the same protection power as the biota AA-EQS. <sup>2</sup>) one can add the background concentration.

n.a.: Not applicable

Shellfish are available in the whole of the HELCOM area, but assessment criteria are based on *Mytilus edulis*, available in the more saline parts. The GES boundary values for other species should be verified against *Mytilus edulis*, and it should also be noted that different *Mytilus* species exists in the Baltic Sea (*Mytilus trossulus*), that is more adapted to low salinity waters. Other species used for monitoring is *Macoma baltica*.

The EU directive on environmental quality standards (2008/105/EC), Article 3, states that also long-term temporal trends should be assessed for substances that accumulate in sediment and/or biota.

### Thresholds in the time series

In the time series figures no data conversion has been made but a line indicating the GES has been added, which has required, in some cases, a conversion of the GES boundary. In Figure 11, the GES boundary has been converted from whole fish concentrations to muscle concentration according to Annex 2. The EQS for whole fish has been recalculated to fit the muscle values in the time series for herring using the recalculation factor of 0.86 (Annex 2 of this indicator report). In Figure 12, the GES boundary of the mercury in blue mussel and Baltic clam (BAC of 90 µg/kg dw) was recalculated to wet weight basis using the mean dry weight of the blue mussels (15 %). The recalculated BAC is  $90 \text{ mg/kg dw} \times 0.15 = 13.5 \text{ µg/kg ww}$ .

### Strengths and weaknesses of data

The data on metal concentrations in fish and bivalves is spatially adequate and time series are available for several stations. The sampling of several species may be seen as an advantage, but the comparability of status classes and concentrations is difficult between different species as seen in the case of mercury.

### Further work required

The conversion factors from tissue-specific concentrations to whole fish concentrations require careful thinking, but may be the right direction to go in future. More studies are, however, required to solve geographical and species-specific differences in conversion factors.

Further studies are needed for establishing the interspecies correlations for mussels.

Existing data of sediment cores from the different regions of the Baltic Sea should be evaluated, and used to establish regional background concentrations.

Normalization of sediment data to same level of TOC/clay-silt content should be tested.

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## Annex 1.

Cadmium, mercury and lead in national monitoring programmes in sediment and biota. Number of stations and frequency of monitoring (interval in years) is shown for each sub-basin.  
Species key: her=herring, per=perch, flo=flounder, eelp=eelpout, sal=salmon, mus=mussel

| Subbasin           | Sweden |                        | Germany |                          | Estonia |                  | Poland              |                                      | Lithuania         |               | Latvia |       | Finland |                                  | Denmark |                            |
|--------------------|--------|------------------------|---------|--------------------------|---------|------------------|---------------------|--------------------------------------|-------------------|---------------|--------|-------|---------|----------------------------------|---------|----------------------------|
|                    | Sedim. | Biota                  | Sedim.  | Biota                    | Sedim.  | Biota            | Sedim.              | Biota                                | Sedim.            | Biota         | Sedim. | Biota | Sedim.  | Biota                            | Sedim.  | Biota                      |
| Archipelago Sea    |        |                        |         |                          |         |                  |                     |                                      |                   |               |        |       |         | 1 her,<br>1per                   |         |                            |
| Arkona Basin       | 1      | 1 her                  |         | 1 her, 2<br>mus,<br>1cod |         |                  |                     |                                      |                   |               |        |       |         |                                  | ~3      | 1 flo<br>1 mus             |
| Bay of Mecklenburg |        |                        |         | 4 mus                    |         |                  |                     |                                      |                   |               |        |       |         |                                  |         |                            |
| Bornholm Basin     | 1      | 2 her                  |         | 2                        |         |                  | 3 (2)<br>(inter. 5) | 1 her+ 1 flo+<br>1 mus<br>(inter. 1) |                   |               |        |       |         |                                  |         | 1 mus                      |
| Bothnian Bay       | 2      | 3 her                  |         |                          |         |                  |                     |                                      |                   |               |        |       |         | 1 her,<br>3per<br>1 her,<br>1per |         |                            |
| Bothnian Sea       | 2      | 4 her                  |         |                          |         |                  |                     |                                      |                   |               |        |       |         |                                  |         |                            |
| Eastern Gotland    | 2      | 1 cod                  |         |                          |         |                  | 1<br>(inter. 5)     | 1 her<br>(inter. 1)                  | 25 (every<br>3 y) | 5 (freq<br>1) |        | 1     |         |                                  |         |                            |
| Great Belt         |        |                        |         |                          |         |                  |                     |                                      |                   |               |        |       |         |                                  | ~6      | 1 flo,<br>11 mus<br>5 eelp |
| Gulf of Finland    |        |                        |         |                          |         | 2 her,<br>12 per |                     |                                      |                   |               |        |       |         | 2 her,<br>2per                   |         |                            |
| Gulf of Gdansk     |        |                        |         |                          |         |                  | 2<br>(inter. 5)     | 1 mus+1 flo<br>(inter. 1)            |                   |               |        |       |         |                                  |         |                            |
| Gulf of Riga       |        |                        |         |                          |         | 1 her, 3<br>per  |                     |                                      |                   |               |        | 7     |         |                                  |         |                            |
| Kattegat           | 1      | 2 her, 1<br>cod, 1 mus |         |                          |         |                  |                     |                                      |                   |               |        |       |         |                                  | ~5      | 6 mus<br>4 eelp            |
| Kiel Bay           |        |                        |         | 1 dab                    |         |                  |                     |                                      |                   |               |        |       |         |                                  |         |                            |
| Little Belt        |        |                        |         | 1                        |         |                  |                     |                                      |                   |               |        |       |         |                                  | ~4      | 2-8 mus<br>2 eelp          |
| N Baltic Proper    | 2      | 3 her                  |         |                          |         | 4 per            |                     |                                      |                   |               |        |       |         |                                  |         |                            |
| The Quark          |        | 1 her, 2 per           |         |                          |         |                  |                     |                                      |                   |               |        |       |         | 1 her,<br>1per                   |         |                            |

## HELCOM Core Indicator of Hazardous Substances Metals (lead, cadmium and mercury)

[illegible]

## Annex 2

### Metals in different parts of fish,

In the report “Cadmium, lead, and mercury concentrations in whole-fish, liver, and muscle concentrations of herring (*Clupea harengus*) and perch (*Perca fluviatilis*)”, many concentrations for lead and cadmium were reported below the level of quantification. This led to overestimations of concentrations in the liver and muscle and influenced the conversion factors (Table 1). As chemical concentrations of cadmium in the muscle are expected to be low this may be a more pronounced problem for the conversion factors for liver. The aim of this Annex is to use data material for liver and muscle concentrations in herring and perch from previous studies conducted the Department of Contaminant Research at NRM.

Estimates of whole-fish concentrations are based on carcass homogenate concentrations from herring and perch collected from Gaviksfjärden in the autumn 2011, liver concentrations from herring and perch at Harufjärden (herring) and Kvädöfjärden (perch) collected in the autumn 2009 and 2010. Muscle concentrations are from herring at Harufjärden and perch at Kvädöfjärden collected in the autumn 2000-2006. As some of the data sets are based on pooled samples, averages for all weights and concentrations were used. Concentrations below detection limit are estimated as reported concentrations divided by two. All concentrations and calculations are based on concentrations expressed as µg/g (mg/kg) dry weight (DW). DW% for perch muscles at Kvädöfjärden were not available, instead DW% from the Gaviksfjärdens data was used. Whole-fish concentrations were estimated using the following formula:

$$C_{wf} = (C_c \cdot W_c + C_l \cdot W_l + C_m \cdot W_m) / (W_c + W_l + W_m)$$

There were no significant correlations between carcass and liver concentrations and fish age, body weight or length. No such biological data was available for the data set from which the muscle concentrations were collected. Results are provided in table 2.

### Conclusions

We recommend that metal conversion factors between different organs are based on a combination of results (Table 3). Conversion factors between whole fish / liver for cadmium and lead as well as between whole fish and muscle for mercury are based on individual samples from one station and one year (Table 1). (These values differ slightly from results presented in “Cadmium, lead, and mercury concentrations in whole-fish, liver, and muscle concentrations of herring (*Clupea harengus*) and perch (*Perca fluviatilis*)”, as the values have been recalculated on a dry weight basis). Conversion factors between whole fish / liver concentrations for cadmium and lead in herring and perch are based on pooled sampled means from various geographic location and years (Table 2). The latter should be regarded as temporary and can hopefully be improved.

**Table A1.** Conversion factors between whole fish to liver and muscle concentrations for cadmium, mercury, and lead in herring and perch. Based on individual samples from one station and one year. Conversion factors for lead whole fish/liver are probably biased due lots of levels below quantification.

| Conversion factors from liver or muscle to whole-fish concentrations |         |         |      |                   |
|--|---------|---------|------|-------------------|
| Whole fish/liver   |         |         |      | Whole fish/muscle |
| Species  | Cadmium | Mercury | Lead | Mercury           |
| Herring  | 0.11    | 0.52    | 1.07 | 0.86              |
| Perch  | 0.16    | 1.63    | 2.96 | 0.72              |

**Table A2.** Conversion factors between whole fish to liver and muscle concentrations for cadmium and lead in herring and perch. Based on pooled sampled means from various geographic location and years.

| Conversion factors from liver to whole-fish concentrations |                  |       |
|--|------------------|-------|
| Species  | Whole fish/liver |       |
|  | Cadmium          | Lead  |
| Herring  | 0.08             | 4.58  |
| Perch  | 0.11             | 12.18 |

**Table A3.** Conversion factors between whole fish, liver, and muscle concentrations for cadmium and lead in herring and perch. Factors for cadmium and mercury are based on individual samples from one station and one year. Factors for lead are based on pooled sampled means from various geographic location and years and should be regarded as temporary.

| Conversion factors from liver or muscle to whole-fish concentrations |             |             |       |                   |
|--|-------------|-------------|-------|-------------------|
| Whole fish/liver   |             |             |       | Whole fish/muscle |
| Species  | Cadmium     | Mercury     | Lead  | Mercury           |
| Herring  | <b>0.11</b> | <b>0.52</b> | 4.58  | <b>0,86</b>       |
| Perch  | <b>0.16</b> | <b>1.63</b> | 12.18 | <b>0.72</b>       |