Time series of DDT- and PCB-substances, Hg, Cd, Pb, Cu and Zn in starling (Sturnus vulgaris) from reference areas in Sweden

Swedish monitoring programme in terrestrial biota

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INTRODUCTION
National and regional monitoring of pollution of contaminants in the Swedish environment comprises studies of the body burden of bio-accumulated substances in biota from terrestrial and freshwater reference areas in the Swedish mainland and from the surrounding seas and coastal areas (Odsjö and Olsson 1979a,b). Primarily the monitoring of pollutants aims at studying long-term changes of concentrations in the environment (trend monitoring) as well as spatial variation. Trend monitoring is considered as an important instrument for studies of the general bioaccumulation due to national and international use as well as measures against use of different pollutants in order to minimise pollution of nature. By use of data from a net of localities, the transport and geographical distribution of contaminants is possible to study.

As a matrix for monitoring of bio-accumulating substances in terrestrial environments in Sweden, tissues of starling (*Sturnus vulgaris*) have been used since the 1960s. The former OECD Monitoring Programmes carried out in 1966-75, were later extended on a national level. In 1981 the current Contaminant Monitoring Programme started in Sweden as part of the National Swedish Environmental Monitoring Programme (PMK). The network of sampling sites were changed and extended the following years. Krankesjön in the southernmost part of Sweden is the oldest and still existing locality from earlier time (see Table 1). Results from the programme have earlier been reported (Odsjö and Olsson 1989).

Starling was chosen as a terrestrial species for monitoring of chemical residues in wildlife also in USA in the National Contaminant Biomonitoring Program. Monitoring of starlings at 110 predetermined locations started in 1967 (Jacknow *et al.* 1986). Nestling of starling have also been collected and analysed for contaminants in Finland since the end of the 1960s (Paasivirta *et al.* 1985).

MATERIALS AND METHODS

Material
The starling is a migratory species breeding in connection to agricultural areas all over the country of Sweden. However, population density decreases to the north and north-west. Due to the migration behaviour, young starlings only have been collected from nesting boxes. Collection has normally been carried out in late May-early June at an age of the young of about three weeks, i.e. shortly before they were fledged. Starlings have been collected from eight reference areas in Sweden. In order to achieve homogeneity in the material between years, only live young have been picked up from the boxes. No alterations of collection areas have been done during the period. From a contaminant monitoring point of view, young starlings are considered as representative for the area in which they were collected since they were raised by food, chiefly inveterbrates, from the vicinity of the nest. Shortly after the capture, the starlings were frozen at an temperature of about -20 °C (some at -80 °C) and were transported frozen to the laboratory.

Localities
The localities referred to in this presentation cover the central and southern part of Sweden. Sampling localities are indicated in Figure 1. Due to the generally sparse populations of starlings in northern Sweden and a recent population decrease, it has been difficult or impossible to collect material from the northern part of Sweden. The sampling sites are all locally uncontaminated i.e. there are no local outlets in the vicinity of the sampling area that might constitute a major influence on the measured concentrations in the studied material.

Table 1. Sampling sites and provinces, start of collection of young starlings.

<table>
<thead>
<tr>
<th>Sampling Site</th>
<th>Province</th>
<th>Start of Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Svartedalen, Västergötland</td>
<td>started 1982</td>
<td>Boa Berg, Halland;  started 1985</td>
</tr>
<tr>
<td>Tiveden, Östergötland; started 1983</td>
<td>Norra Kvill, Småland; started 1982</td>
<td></td>
</tr>
<tr>
<td>Grimsö, Västmanland; started 1981</td>
<td>Fleringe, Gotland; started 1983</td>
<td></td>
</tr>
<tr>
<td>Tyresta, Södermanland; started 1983</td>
<td>Krankesjön, Skåne; started 1967</td>
<td></td>
</tr>
</tbody>
</table>

Analysis

Chemical analysis of DDT- and PCB-substances were originally performed by use of packed column gas chromatography (LRGC) according to a method described by Jensen et al. 1983. This method was substituted in 1988 by capillary column gas chromatography (HRGC), according to methods described by Eriksson et al. 1993. About 10 g of breast muscle tissue were prepared from each individual for separate analysis. The analyses were performed at the Laboratory for Analytical Environmental Chemistry at the Institute for Applied Environmental Research, Stockholm University.

To be able to combine earlier results obtained from analysis by use of LRGC with those obtained by use of HRGC, samples from three areas, Grimsö, Fleringe and Krankesjön from three, three and two years, respectively, were analysed parallel by both methods (Table 3). The ratio between levels derived from the two, separate methods of analysis was used to recalculate the levels of DDT-substances obtained by HRGC to levels comparable to LRGC levels. In the cases where the ratios have been studied they were in general close to 1 except for Krankesjön where the ratio was increased, which may depend on a small material. In the time series presented below the ratio of 1 has been used.

Concentrations of sPCB analysed by packed column GC (LRGC) were estimated from 13 peaks in the chromatogram, while analysis by capillary column GC (HRGC) is based on estimation of seven selected individual congeners (CB-28, CB-52, CB-101, CB-118, CB-138, CB-153 and CB-180). Concentration of peak 10 (PCB10) derived from the LRGC chromatogram equals that of CB-138 + CB-163 + minor amounts of unidentified components derived from the HRGC chromatogram. This has been used to calculate ratios between the two categories of concentrations to combine results derived by the two methods from the actual period. The sum of PCBs (sPCB) is estimated from the concentration of peak 10 (PCB10) in the chromatogram from LRGC using the ratio $R_1 = \text{PCB10}/\text{sPCB}$. From capillary column GC (HRGC) the PCB10 concentrations have been estimated using the ratio $R_2 = (\text{CB-138 + CB-163})/\text{PCB10}$. Thus, depending on method of analysis used, the sum of PCBs (sPCB) are estimated either by:

\[
\text{sPCB} = \frac{\text{PCB10}}{R_1}
\]

or

\[
\text{sPCB} = \frac{(\text{CB-138 + CB-163})}{(R_1 \times R_2)}
\]

Separate ratios have been calculated and used for starlings from different localities as shown in Table 2.
The chemical analysis of metals comprised Hg, Cd, Pb, Cu and Zn (Table 2). The analyses were performed at the Department of Environmental Assessment, Swedish University of Agricultural Sciences. For analysis of Hg about 1 g of breast muscle tissue was prepared for individual analyses. For the other metals about 1 g of kidney tissue was prepared. The Hg concentration in the oldest series of material, from Krankesjön, was analysed by NAA method during the period 1967-1983. Prior to analyses, the tissue samples were freeze-dried. The concentrations of metals have been determined by flame-less atomic absorption spectroscopy (Borg et al. 1981, Lindsted et al. 1971, May and Stoeppler 1984). The analytical procedures have also been reported by Åslund (1993). Each annual sample consists of 10 individually analysed specimens.

Table 2. Mean ratio ($R_1$) between PCB10 and sPCB derived from packed column gas chromatography (LRGC) and mean ratios ($R_2$) between CB-138+CB-163 and PCB10 derived from capillary column gas chromatography (HRGC).

<table>
<thead>
<tr>
<th>Area</th>
<th>$n_1$</th>
<th>$R_1$</th>
<th>CV</th>
<th>$n_2$</th>
<th>$R_2$</th>
<th>CV</th>
<th>$R_1 \times R_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grimsö</td>
<td>93</td>
<td>.19</td>
<td>20.7</td>
<td>32</td>
<td>.76</td>
<td>24.4</td>
<td>.15</td>
</tr>
<tr>
<td>Fleringe</td>
<td>50</td>
<td>.16</td>
<td>14.9</td>
<td>36</td>
<td>.65</td>
<td>18.9</td>
<td>.11</td>
</tr>
<tr>
<td>Krankesjön</td>
<td>120</td>
<td>.18</td>
<td>15.4</td>
<td>9</td>
<td>.72</td>
<td>19.1</td>
<td>.13</td>
</tr>
<tr>
<td>Svartedalen</td>
<td>60</td>
<td>.20</td>
<td>24.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norra Kvill</td>
<td>60</td>
<td>.19</td>
<td>24.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyresta 46</td>
<td>.20</td>
<td>7.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boa Berg</td>
<td>30</td>
<td>.19</td>
<td>27.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tiveden</td>
<td>39</td>
<td>.18</td>
<td>15.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$n_1 = \text{number of analyses, } n_2 = \text{number of analyses}$  
R$_1 = \text{PCB10/sPCB, } R_2 = \text{CB-138+CB-163/PCB10, CV = Coefficient of Variation}$

Statistical treatment and graphical presentation  
(According to A. Bignert, 1998)

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

Log-linear regression analyses
Log-linear regression analyses is performed both for the entire investigated time period and for time series longer than ten years, also for the recent ten years. The slope of the line describes the yearly percentage 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 1 below.
Table 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>
<thead>
<tr>
<th></th>
<th>1%</th>
<th>2%</th>
<th>3%</th>
<th>4%</th>
<th>5%</th>
<th>7%</th>
<th>10%</th>
<th>12%</th>
<th>15%</th>
<th>20%</th>
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</thead>
<tbody>
<tr>
<td>Increase</td>
<td>70</td>
<td>35</td>
<td>24</td>
<td>18</td>
<td>14</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Decrease</td>
<td>69</td>
<td>35</td>
<td>23</td>
<td>17</td>
<td>14</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Non-parametric trend test

The regression analyses presupposes, among other thing, 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 \( \tau \), and the corresponding p-value. The Kendall's \( \tau \) ranges from 0 to 1 like the traditional correlation coefficient \( r \) but will generally be lower. ‘Strong’ linear correlation of 0.9 or above corresponds to \( \tau \)-values of about 0.7 or above (Helsel and Hirsch, 1995, p. 212). EPA recommended this test for use in water quality monitoring programmes with annual samples, in an evaluation comparing several other trend tests (Loftis et al. 1989).

Non-linear trend components

An alternative to the regression line in order to describe the development over time would be some 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).

Outliers and values below the detection limit

Observations too far from the regression line considering from what could be 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 \( i \)th standardised residual the current observation is left out implying that the \( i \)th observation does not influence the slope or the variance around the regression line. The suspected outliers are merely indicated in the figures and are included 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 lognormal distribution within a year.

**Legend to the plots**

The analytical results from each of the investigated elements are displayed in figures. A separate plot except for time series shorter than 4 years represents each site/species.

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, dashed 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 and one for the last ten years (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. The smoothed line 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, indicates a suspected outlier, see above. The suspected outliers are merely indicated in the figures and are included the statistical calculations except in a few cases, pointed out in the figures.

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

- $n(tot)$ = The first line reports the total number of analyses included together with the number of years ($n(yrs)$).
- $m$ = The overall geometric mean value together with its 95% confidence interval is reported on the second line of the plot (N.B. d.f. := $n$ of years - 1).
- $\text{slope}$ = reports the slope, expressed as the yearly percentage change together with its 95% confidence interval.
- $\text{sd(lr)}$ = reports the square root of the residual variance 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 represents 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 were 5% a year and the number of years were ten. The third figure is the lowest detectable change for a ten-year period with the current between year variation at a power of 80%.

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

$y(98)$ = reports the concentration estimated from the regression line for the last year together with a 95% confidence interval, e.g. $y(98)=2.55(2.17,3.01)$ is the estimated concentration of year 1997 where the residual variance around the regression line is used to calculate the confidence interval. Provided that the regression line is relevant to describe the trend, the residual variance might be more appropriate than the within-year variance in this respect.

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

**sd(sm)** = reports the square root of the residual variance around the smoothed line. The significance of this line could be tested by means of an Analysis of Variance. The p-value is reported for this test. A significant result will indicate a non-linear trend component.

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

**RESULTS**

**Long-term trends of metals and organochlorines in muscle and kidney of starlings**

The analytical results are displayed in Figure 2-15, which visualise the trend in concentrations and the statistics of DDT- and PCB-substances and Hg in muscle and Cd, Pb, Cu, and Zn in kidney of starling. The time series is continuously updated once a year when new material is collected and analysed.

**Organochlorines**

**DDE**

**Svartedalen (Figure 2a).**
The DDE concentrations in muscle of starlings from Svartedalen show no significant log-linear or linear change during the period ($p<0.822$).
The number of years required to detect an annual change of 5% is 21 years for muscle of starlings. The overall geometric mean value of DDE in muscle is 0.194 µg/g (lipid weight) for the period 1982-1987.

**Grimsö (Figure 2a + 2b).**
The DDE concentrations in muscle of starlings from Grimsö show no significant log-linear or linear change during the period ($p<0.697$).
The number of years required to detect an annual change of 5% is 23 years for muscle of starlings. The overall geometric mean value of DDE in muscle is 0.216 µg/g (lipid weight) for the period 1981-1995.
Analytical results from area 1 (Morskoga/Grimsö) are separated from the results from the other three areas 2-4 (Grimsö village, Fännsäter/Grimsö och Bergshyttan/Grimsö) and visualized in Fig. 2b. The reason is the higher concentrations of DDE in Morskoga and the greater difference between year. DDE concentrations in muscle of starlings neither from Morskoga nor from the other three sites show any significant log-linear or linear change during the period (p<0.914 and p<0.236). The overall geometric mean values of DDE in muscle are 1.06 and 0.140 µg/g (lipid weight), respectively for the period 1984-1995 and 1981-1995, respectively.

**Tyresta (Figure 2a).**
The DDE concentrations in muscle of starlings from Tyresta show no significant log-linear or linear change during the period (p<0.358).
The number of years required to detect an annual change of 5% is 20 years for muscle of starlings. The overall geometric mean value of DDE in muscle is 0.275 µg/g (lipid weight) for the period 1983-1987.

**Tiveden (Figure 2a).**
The DDE concentrations in muscle of starlings from Tiveden show no significant log-linear or linear change during the period (p<0.122).
The number of years required to detect an annual change of 5% is 13 years for muscle of starlings. The overall geometric mean value of DDE in muscle is 0.149 µg/g (lipid weight) for the period 1984-1987.

**Boa Berg (Figure 3).**
The DDE concentrations in muscle of starlings from Boa Berg show no significant log-linear or linear change during the period (p<0.213).
The number of years required to detect an annual change of 5% is 15 years for muscle of starlings. The overall geometric mean value of DDE in muscle is 0.118 µg/g (lipid weight) for the period 1985-1987.

**Norra Kvill (Figure 3).**
The DDE concentrations in muscle of starlings from Norra Kvill show no significant log-linear or linear change during the period (p<0.711).
The number of years required to detect an annual change of 5% is 18 years for muscle of starlings. The overall geometric mean value of DDE in muscle is 0.183 µg/g (lipid weight) for the period 1982-1987.

**Fleringe (Figure 3).**
The DDE concentrations in muscle of starlings from Fleringe show no significant log-linear or linear change during the period (p<0.223).
The number of years required to detect an annual change of 5% is 17 years for muscle of starlings. The overall geometric mean value of DDE in muscle is 1.31 µg/g (lipid weight) for the period 1983-1995. Thus, the highest mean level of DDE in muscle of starling is found in this area.

**Krankesjön (Figure 3).**
The DDE concentrations in muscle of starlings from Krankesjön show no significant log-linear or linear change during the period (p<0.098).
The number of years required to detect an annual change of 5% is 20 years for muscle of starlings.

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*Note: The figures and details provided are for illustrative purposes and may not reflect the actual content of the document.*
The overall geometric mean value of DDE in muscle is 0.460 µg/g (lipid weight) for the period 1976-1995.

**PCB10 (CB-138 + 163)**

**Svartedalen (Figure 4).**
The concentrations of PCB10 in muscle of starlings from Svartedalen show no significant log-linear or linear change during the period (p<0.806). The number of years required to detect an annual change of 5% is 20 years for muscle of starlings. The overall geometric mean value of PCB10 in muscle is 0.078 µg/g (lipid weight) for the period 1982-1987.

**Grimsö (Figure 4).**
The concentrations of PCB10 in muscle of starlings from Grimsö show a significant decreasing log-linear trend during the period (p<0.000). The annual decrease is 9.5% during the period 1981-95. The number of years required to detect an annual change of 5% is 16 years for muscle of starlings. The overall geometric mean value of PCB10 in muscle is 0.045 µg/g (lipid weight) for the period 1981-1995.

**Tyresta (Figure 4).**
The concentrations of PCB10 in muscle of starlings from Tyresta show no significant log-linear or linear change during the period (p<0.803). The number of years required to detect an annual change of 5% is 17 years for muscle of starlings. The overall geometric mean value of PCB10 in muscle is 0.064 µg/g (lipid weight) for the period 1983-1987.

**Tiveden (Figure 4).**
The concentrations of PCB10 in muscle of starlings from Tiveden show no significant log-linear or linear change during the period (p<0.078). The number of years required to detect an annual change of 5% is 13 years for muscle of starlings. The overall geometric mean value of PCB10 in muscle is 0.035 µg/g for the period 1984-1987.

**Boa Berg (Figure 5).**
The concentrations of PCB10 in muscle of starlings from Boa Berg show no significant log-linear or linear change during the period (p<0.270). The number of years required to detect an annual change of 5% is 18 years for muscle of starlings. The overall geometric mean value of PCB10 in muscle is 0.035 µg/g (lipid weight) for the period 1985-1987.

**Norra Kvill (Figure 5).**
The concentrations of PCB10 in muscle of starlings from Norra Kvill show no significant log-linear or linear change during the period (p<0.592). The number of years required to detect an annual change of 5% is 19 years for muscle of starlings. The overall geometric mean value of PCB10 in muscle is 0.039 µg/g (lipid weight) for the period 1982-1987.

**Fleringe (Figure 5).**
The concentrations of PCB10 in muscle of starlings from Fleringe show no significant log-linear or linear change during the period (p<0.703).
The number of years required to detect an annual change of 5% is 15 years for muscle of starlings. The overall geometric mean value of PCB10 in muscle is 0.069 µg/g (lipid weight) for the period 1983-1995.

**Krankesjön (Figure 5).**
The concentrations of PCB10 in muscle of starlings from Krankesjön show a significant decreasing log-linear trend during the period (p<0.030). The annual decrease is 4.1% during the period 1976-1995.
The number of years required to detect an annual change of 5% is 19 years for muscle of starlings. The ANOVA test showed that the smoothed line for concentrations of PCB10 in muscle indicates a significant non-linear trend component (p<0.003).
The overall geometric mean value of PCB10 in muscle is 0.077 µg/g (lipid weight) for the period 1976-1995.

**Metals**

**Mercury**

**Svartedalen (Figure 6a).**
The mercury concentrations in muscle of starlings from Svartedalen show no significant log-linear or linear change during the period (p<0.429).
The number of years required to detect an annual change of 5% is 18 years for muscle of starlings. The ANOVA test showed that the smoothed line for concentrations of mercury in muscle indicates a significant non-linear trend component (p<0.010).
The overall geometric mean value of mercury in muscle is 12.2 ng/g (fresh weight) for the period 1982-1994.

**Grimsö (Figure 6a + 6b).**
The mercury concentrations in muscle of starlings from Grimsö show no significant log-linear or linear change during the period (p<0.386).
The number of years required to detect an annual change of 5% is 23 years for muscle of starlings. The overall geometric mean value of mercury in muscle is 19.6 ng/g (fresh weight) for the period 1982-1999.
Due to great variation in levels of mercury in starlings from one of the four sub-sites, analytical results from area 2 (Grimsö village) are separated from results from the other three areas 1, 3 and 4 (Morskoga/Grimsö, Fännäsätter/Grimsö och Bergshyttan/Grimsö). Separated results are visualized in Fig. 6b. Mercury concentrations in muscle of starlings neither from area 2 nor from areas 1, 3 and 4 show any significant log-linear or linear change during the period (p<0.068 and p<0.724, respectively). The overall geometric mean values of mercury in muscle from area 2 and areas 1, 3 and 4 were 30.6 and 14.5 ng/g (fresh weight), respectively.

**Tyresta (Figure 6a).**
The mercury concentrations in muscle of starlings from Tyresta show no significant log-linear or linear change during the period (p<0.872).
The number of years required to detect an annual change of 5% is 17 years for muscle of starlings. The ANOVA test showed that the smoothed line for concentrations of mercury in muscle indicates a significant non-linear trend component (p<0.001).
The overall geometric mean value of mercury in muscle is 11.0 ng/g (fresh weight) for the period 1983-1994.

**Tiveden (Figure 6a).**
The mercury concentrations in muscle of starlings from Tiveden show no significant log-linear or linear change during the period (p<0.432). The number of years required to detect an annual change of 5% is 23 years for muscle of starlings. The ANOVA test showed that the smoothed line for concentrations of mercury in muscle indicates a significant non-linear trend component (p<0.005). The overall geometric mean value of mercury in muscle is 32.4 ng/g (fresh weight) for the period 1984-1994.

**Boa Berg (Figure 7).**
The mercury concentrations in muscle of starlings from Boa Berg show no significant log-linear or linear change during the period (p<0.236). The number of years required to detect an annual change of 5% is 21 years for muscle of starlings. The ANOVA test showed that the smoothed line for concentrations of mercury in muscle indicates a significant non-linear trend component (p<0.024). The overall geometric mean value of mercury in muscle is 7.51 ng/g (fresh weight) for the period 1985-1994.

**Norra Kvill (Figure 7).**
The mercury concentrations in muscle of starlings from Norra Kvill show no significant log-linear or linear change during the period (p<0.152). The number of years required to detect an annual change of 5% is 28 years for muscle of starlings. The overall geometric mean value of mercury in muscle is 11.6 ng/g (fresh weight) for the period 1982-1994.

**Fleringe (Figure 7).**
The mercury concentrations in muscle of starlings from Fleringe show no significant log-linear or linear change during the period (p<0.194). The number of years required to detect an annual change of 5% is 12 years for muscle of starlings. The ANOVA test showed that the smoothed line for concentrations of mercury in muscle indicates a significant non-linear trend component (p<0.004). The overall geometric mean value of mercury in muscle is 19.4 ng/g (fresh weight) for the period 1983-1999.

**Krankesjön (Figure 7).**
The mercury concentrations in muscle of starlings from Krankesjön show a significant decreasing log-linear trend during the period (p<0.012). The annual decrease is 2.6% during the period 1967-1999. The number of years required to detect an annual change of 5% is 21 years for muscle of starlings. The ANOVA test showed that the smoothed line for concentrations of mercury in muscle indicates a significant non-linear trend component (p<0.002). The overall geometric mean value of mercury in muscle is 15.3 ng/g (fresh weight) for the period 1967-1999.

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**Cadmium**
Svartedalen (Figure 8).
The cadmium concentrations in kidney of starlings from Svartedalen show no significant log-linear or linear change during the period (p<0.862).
The number of years required to detect an annual change of 5% is 21 years for kidney of starlings. The ANOVA test showed that the smoothed line for concentrations of cadmium in kidney indicates a significant non-linear trend component (p<0.005).
The overall geometric mean value of cadmium in kidney is 0.124 µg/g (dry weight) for the period 1982-1994.

Grimsö (Figure 8).
The cadmium concentrations in kidney of starlings from Grimsö show a significant decreasing log-linear trend during the period (p<0.049). The annual decrease is 3.5% during the period 1981-1999. The number of years required to detect an annual change of 5% is 18 years for kidney of starlings. The overall geometric mean value of cadmium in kidney is 0.146 µg/g (dry weight) for the period 1981-1999.

Tyresta (Figure 8).
The cadmium concentrations in kidney of starlings from Tyresta show no significant log-linear or linear change during the period (p<0.909). The number of years required to detect an annual change of 5% is 19 years for kidney of starlings. The overall geometric mean value of cadmium in kidney is 0.164 µg/g (dry weight) for the period 1983-1994.

Tiveden (Figure 8).
The cadmium concentrations in kidney of starlings from Tiveden show no significant log-linear or linear change during the period (p<0.351). The number of years required to detect an annual change of 5% is 17 years for kidney of starlings. The ANOVA test showed that the smoothed line for concentrations of cadmium in kidney indicates a significant non-linear trend component (p<0.036). The overall geometric mean value of cadmium in kidney is 0.096 µg/g (dry weight) for the period 1984-1994.

Boa Berg (Figure 9).
The cadmium concentrations in kidney of starlings from Boa Berg show no significant log-linear change (p<0.068). The number of years required to detect an annual change of 5% is 16 years for kidney of starlings. The ANOVA test showed that the smoothed line for concentrations of cadmium in kidney indicates a significant non-linear trend component (p<0.035). The overall geometric mean value of cadmium in kidney is 0.163 µg/g (dry weight) for the period 1985-1994.

Norra Kvill (Figure 9).
The cadmium concentrations in kidney of starlings from Norra Kvill show no significant log-linear or linear change during the period (p<0.872). The number of years required to detect an annual change of 5% is 16 years for kidney of starlings.
The overall geometric mean value of cadmium in kidney is 0.092 µg/g (dry weight) for the period 1982-1994.

_Fleringe (Figure 9)._  
The cadmium concentrations in kidney of starlings from Fleringe show no significant log-linear or linear change during the period (p<0.422).  
The number of years required to detect an annual change of 5% is 21 years for kidney of starlings.  
The overall geometric mean value of cadmium in kidney is 0.422 µg/g (dry weight) for the period 1983-1999, which also is the highest mean value of all localities.

_Krankesjön (Figure 9)._  
The cadmium concentrations in kidney of starlings from Krankesjön show no significant log-linear or linear change during the period (p<0.899).  
The number of years required to detect an annual change of 5% is 24 years for kidney of starlings.  
The overall geometric mean value of cadmium in kidney is 0.171 µg/g (dry weight) for the period 1973-1999.

**Lead**

_Svartedalen (Figure 10)._  
The lead concentrations in kidney of starlings from Svartedalen show a significant decreasing log-linear trend during the period (p<0.002). The annual decrease is 12% during the period 1982-1994.  
The number of years required to detect an annual change of 5% is 17 years for kidney of starlings.  
The overall geometric mean value of lead in kidney is 1.04 µg/g (dry weight) for the period 1982-1994.

_Grimsö (Figure 10)._  
The lead concentrations in kidney of starlings from Grimsö show a significant decreasing log-linear trend during the period (p<0.003). The annual decrease is 7.5% during the period 1984-1999.  
The number of years required to detect an annual change of 5% is 17 years for kidney of starlings.  
The overall geometric mean value of lead in kidney is 0.720 µg/g (dry weight) for the period 1984-1999.

_Tyresta (Figure 10)._  
The lead concentrations in kidney of starlings from Tyresta show a significant decreasing log-linear trend during the period (p<0.041). The annual decrease is 7.6% during the period 1984-1994.  
The number of years required to detect an annual change of 5% is 16 years for kidney of starlings.  
The ANOVA test showed that the smoothed line for concentrations of lead in kidney indicates a significant non-linear trend component (p<0.000).  
The overall geometric mean value of lead in kidney is 1.46 µg/g (dry weight) for the period 1984-1994.

_Tiveden (Figure 10)._  
The lead concentrations in kidney of starlings from Tiveden show a significant decreasing log-linear trend during the period (p<0.005). The annual decrease is 9.7% during the period 1984-1994.  
The number of years required to detect an annual change of 5% is 14 years for kidney of starlings.  
The overall geometric mean value of lead in kidney is 0.678 µg/g (dry weight) for the period 1984-1994.
**Boa Berg (Figure 11).**
The lead concentrations in kidney of starlings from Boa Berg show no significant log-linear or linear change during the period (p<0.187). The number of years required to detect an annual change of 5% is 20 years for kidney of starlings. The overall geometric mean value of lead in kidney is 1.91 µg/g (dry weight) for the period 1985-1994.

**Norra Kvill (Figure 11).**
The lead concentrations in kidney of starlings from Norra Kvill show no significant log-linear or linear change during the period (p<0.159). The number of years required to detect an annual change of 5% is 17 years for kidney of starlings. The ANOVA test showed that the smoothed line for concentrations of lead in kidney indicates a significant non-linear trend component (p<0.002). The overall geometric mean value of lead in kidney is 0.854 µg/g (dry weight) for the period 1982-1994.

**Fleringe (Figure 11).**
The lead concentrations in kidney of starlings from Fleringe show a significant decreasing log-linear trend during the period (p<0.000). The annual decrease is 7.8% during the period 1984-1999. The number of years required to detect an annual change of 5% is 14 years for kidney of starlings. The overall geometric mean value of lead in kidney is 0.672 µg/g (dry weight) for the period 1984-1999.

**Krankesjön (Figure 11).**
The lead concentrations in kidney of starlings from Krankesjön show a significant decreasing log-linear trend during the period (p<0.016). The annual decrease is 6.2% during the period 1980-1999. The number of years required to detect an annual change of 5% is 21 years for kidney of starlings. The overall geometric mean value of lead in kidney is 1.51 µg/g (dry weight) for the period 1980-1999.

**Copper**

**Svartedalen (Figure 12).**
The copper concentrations in kidney of starlings from Svartedalen show no significant log-linear or linear change during the period (p<0.468). The number of years required to detect an annual change of 5% is 13 years for kidney of starlings. The overall geometric mean value of copper in kidney is 14.8 µg/g (dry weight) for the period 1982-1994.

**Grimsö (Figure 12).**
The copper concentrations in kidney of starlings from Grimsö show a significant decreasing log-linear trend during the period (p<0.041). The annual decrease is 1.1% during the period 1984-1999. The number of years required to detect an annual change of 5% is 8 years for kidney of starlings. The ANOVA test showed that the smoothed line for concentrations of copper in kidney indicates a significant non-linear trend component (p<0.002). The overall geometric mean value of copper in kidney is 18.1 µg/g (dry weight) for the period 1984-1999.
Tyresta (Figure 12).
The copper concentrations in kidney of starlings from Tyresta show no significant log-linear or linear change during the period (p<0.375).
The number of years required to detect an annual change of 5% is 12 years for kidney of starlings. The overall geometric mean value of copper in kidney is 17.1 µg/g (dry weight) for the period 1984-1994.

Tiveden (Figure 12).
The copper concentrations in kidney of starlings from Tiveden show no significant log-linear or linear change during the period (p<0.148).
The number of years required to detect an annual change of 5% is 10 years for kidney of starlings. The overall geometric mean value of copper in kidney is 16.5 µg/g (dry weight) for the period 1984-1994.

Boa Berg (Figure 13).
The copper concentrations in kidney of starlings from Boa Berg show no significant log-linear or linear change during the period (p<0.484).
The number of years required to detect an annual change of 5% is 13 years for kidney of starlings. The overall geometric mean value of copper in kidney is 16.4 µg/g (dry weight) for the period 1985-1994.

Norra Kvill (Figure 13).
The copper concentrations in kidney of starlings from Norra Kvill show no significant log-linear or linear change during the period (p<0.178).
The number of years required to detect an annual change of 5% is 8 years for kidney of starlings. The overall geometric mean value of copper in kidney is 17.6 µg/g (dry weight) for the period 1982-1994.

Fleringe (Figure 13).
The copper concentrations in kidney of starlings from Fleringe show a significant decreasing log-linear trend during the period (p<0.019). The annual decrease is 2.1% during the period 1984-1999. The number of years required to detect an annual change of 5% is 10 years for kidney of starlings. The overall geometric mean value of copper in kidney is 18.8 µg/g (dry weight) for the period 1984-1999.

Kranke sjön (Figure 13).
The copper concentrations in kidney of starlings from Krankesjön show no significant log-linear or linear change during the period (p<0.116). The number of years required to detect an annual change of 5% is 10 years for kidney of starlings. The overall geometric mean value of copper in kidney is 17.0 µg/g (dry weight) for the period 1980-1999.

Zinc

Svartedalen (Figure 14).
The zinc concentrations in kidney of starlings from Svartedalen show no significant log-linear or linear change during the period (p<0.907).
The number of years required to detect an annual change of 5% is 12 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 84.7 µg/g (dry weight) for the period 1982-1994.

**Grimsö (Figure 14).**
The zinc concentrations in kidney of starlings from Grimsö show no significant decreasing log-linear or linear change during the period (p<0.912).
The number of years required to detect an annual change of 5% is 11 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 82.2 µg/g (dry weight) for the period 1984-1999.

**Tyresta (Figure 14).**
The zinc concentrations in kidney of starlings from Tyresta show no significant log-linear or linear change during the period (p<0.902).
The number of years required to detect an annual change of 5% is 12 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 84.2 µg/g (dry weight) for the period 1984-1994.

**Tiveden (Figure 14).**
The zinc concentrations in kidney of starlings from Tiveden show no significant log-linear or linear change during the period (p<0.815).
The number of years required to detect an annual change of 5% is 12 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 85.9 µg/g (dry weight) for the period 1984-1994.

**Boa Berg (Figure 15).**
The zinc concentrations in kidney of starlings from Boa Berg show no significant log-linear or linear change during the period (p<0.386).
The number of years required to detect an annual change of 5% is 9 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 78.6 µg/g (dry weight) for the period 1986-1994.

**Norra Kvill (Figure 15).**
The zinc concentrations in kidney of starlings from Norra Kvill show a significant decreasing log-linear trend during the period (p<0.014). The annual decrease is 2.4% for the period 1982-1994.
The number of years required to detect an annual change of 5% is 8 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 84.0 µg/g (dry weight) for the period 1982-1994.

**Fleringe (Figure 15).**
The zinc concentrations in kidney of starlings from Fleringe show no significant log-linear or linear change during the period (p<0.926).
The number of years required to detect an annual change of 5% is 12 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 81.1 µg/g (dry weight) for the period 1984-1999.
Krankesjön (Figure 15).
The zinc concentrations in kidney of starlings from Krankesjön show no significant log-linear or linear change during the period (p<0.820).
The number of years required to detect an annual change of 5% is 12 years for kidney of starlings. The overall geometric mean value of zinc in kidney is 80.1 µg/g (dry weight) for the period 1980-1999.
REFERENCES


Fig 1. The Swedish Monitoring Programme of Contaminants in Terrestrial Biota. Sampling localities for starlings.
Table 2. Sampling sites for collection of young starlings. Annual scheme for analysis of metals and organochlorines

<table>
<thead>
<tr>
<th>Year</th>
<th>Svartedalen, Västergötland</th>
<th>Norra Kvill, Småland</th>
<th>Grimsö, Västmanland</th>
<th>Tyresta, Södermanland</th>
<th>Boa Berg, Halland</th>
<th>Tiveden, Östergötland</th>
<th>Fleringe, Gotland</th>
<th>Krankesjön, Skåne</th>
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Hg=Mercury, Cd=Cadmium, ME=metals, LR=LRGC (packed column), HR=HRGC (capillary column)
LR=analysis carried out at RSL (Swed. Mus. of Natural Hist.)
Figure 2a. DDE, µg/g, lipid weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.
Figure 2b. DDE, \(\mu g/g\), lipid weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

**Morskoga**
- \(n_{tot}=52, n_{yrs}=11\)
- \(m=1.06 (0.70, 1.60)\)
- slope=28% (-12, 13)
- \(sd(lr)=0.65, 18\% , 24 \text{ yr}\)
- \(r^2=0.00, p<.914\)
- \(sd(sm)=0.67, \text{n.s.}\)
- \(tao=-.09, p<.755\)

**Gimso village + Fannsater + Bergshyttan**
- \(n_{tot}=180, n_{yrs}=15\)
- \(m=.140 (.108, .183)\)
- slope=-3.5% (-9.5, 2.6)
- \(sd(lr)=.47, 7.5\% , 20 \text{ yr}\)
- \(r^2=.11, p<.236\)
- \(sd(sm)=.37, \text{n.s.}\)
- \(tao=.22, p<.276\)
Figure 3. DDE, μg/g, lipid weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.
Figure 4. PCB10 (CB-138 + 163), µg/g, lipid weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

<table>
<thead>
<tr>
<th>Location</th>
<th>Sample Size (n)</th>
<th>Mean (µg/g)</th>
<th>Slope (%)</th>
<th>SD (µg/g)</th>
<th>R²</th>
<th>Significance</th>
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<tbody>
<tr>
<td>Svartedalen</td>
<td>60 (6 yrs)</td>
<td>0.078 (0.050, 0.122)</td>
<td>5.3% (28, 34)</td>
<td>0.47% (20)</td>
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<td>Grimso</td>
<td>232 (15 yrs)</td>
<td>0.045 (0.034, 0.061)</td>
<td>9.9% (14, 51)</td>
<td>0.34% (16)</td>
<td>0.63</td>
<td>p&lt;.000 *</td>
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<td>Tyresta</td>
<td>46 (5 yrs)</td>
<td>0.064 (0.042, 0.098)</td>
<td>0.0% (-35, 41)</td>
<td>0.38% (17)</td>
<td>0.02</td>
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<td>Tiveden</td>
<td>39 (4 yrs)</td>
<td>0.035 (0.016, 0.080)</td>
<td>0.0% (-8.0, 81)</td>
<td>0.23% (13)</td>
<td>0.67</td>
<td>p&lt;.308</td>
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Contaminant Research Group/Swedish Museum of Natural History and Inst. of Appl. Environmental Research/Stockholm University
Figure 5. PCB10 (CB-138 + 163), µg/g, lipid weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

Boa Berg
n(tot)=30, n(yrs)=3
m=.035 (.005,.225)
slope=-69%(*,*,.310)
SD(lr)=.42,%,18 yr
power=.13/.24/13%
y(87)=.02 (.00,2.34)
r²=.84, p<.270

Norra Kvill
n(tot)=60, n(yrs)=6
m=.039 (.025,.059)
slope=6.2%(-23,36)
SD(lr)=.44,%,19 yr
power=.12/.23/14%
y(87)=.045 (.018,.110)
r²=.84, p<.270

Fleringe
n(tot)=130, n(yrs)=13
m=.069 (.058,.083)
slope=-.89%(-5.9,4.1)
SD(lr)=.31,6.1%,15 yr
power=.65/.37/9.5%
y(95)=.066 (.046,.094)
r²=.84, p<.270

Krankesjon
n(tot)=200, n(yrs)=20
m=.077 (.060,.097)
slope=-4.1%(-7.8,-.40)
SD(lr)=.46,4.6%,19 yr
power=.86/.22/14%
y(95)=.052 (.034,.078)
r²=.84, p<.270
Figure 6a. Hg, ng/g, fresh weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

Svartedalen
- $n_{(tot)}=130$, $n_{(yrs)}=13$
- $m=12.2$ (9.5, 15.6)
- slope=-2.5%(-9.2,4.2)
- $SD(lr)=.41$, 8.2%, 18 yr
- $y(94)=10.5$ (6.5, 16.8)
- $r^2=.06$, $p<.429$
- $SD(sm)=.25$, p<.010*

Grimso
- $n_{(tot)}=277$, $n_{(yrs)}=18$
- $m=19.6$ (14.5, 26.4)
- slope=-2.5%(-8.3,3.3)
- $SD(lr)=.60$, 7.2%, 23 yr
- $y(99)=15.9$ (8.9, 28.3)
- $r^2=.05$, $p<.429$
- $SD(sm)=.58$, n.s.

Tyresta
- $n_{(tot)}=116$, $n_{(yrs)}=12$
- $m=11.0$ (8.87, 13.7)
- slope=.37%(-6.4,7.1)
- $SD(lr)=.36$, 8.3%, 17 yr
- $y(94)=11.3$ (7.3, 17.4)
- $r^2=.00$, $p<.872$
- $SD(sm)=.16$, p<.001*

Tiveden
- $n_{(tot)}=99$, $n_{(yrs)}=10$
- $m=32.4$ (21.2, 49.6)
- slope=4.9%(-8.7,18)
- $SD(lr)=.61$, 20%, 23 yr
- $y(94)=41.8$ (18.2, 96.2)
- $r^2=.08$, $p<.432$
- $SD(sm)=.31$, p<.005*

Contaminant Research Group/Swedish Museum of Natural History and Dept. of Env. Assessment/Swe. University of Agricultural Science.
Figure 6b. Hg, ng/g, fresh weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

Grimso village
- $n(tot)=87$, $n(yrs)=17$
- $m=30.6$ (20.0, 47.0)
- slope $=-7.1\%$ (-15, .67)
- $SD(lr)=.77$, 10%, 27 yr
- $y(99)=17.2$ (8.1, 36.3)
- $r^2=.20$, $p<.068$
- $SD(sm)=.82$, n.s.

Fannsater + Morskoga + Bergshyttan
- $n(tot)=190$, $n(yrs)=16$
- $m=14.5$ (11.6, 18.2)
- slope $=.82\%$ (-4.1, 5.7)
- $SD(lr)=.44$, 6.3%, 19 yr
- $y(99)=15.6$ (9.7, 25.0)
- $r^2=.01$, $p<.724$
- $SD(sm)=.40$, n.s.
Figure 7. Hg, ng/g, fresh weight, in muscle of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.
Figure 8. Cd, µg/g, dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated.

Smoother: 3-point running mean, unweighted is drawn when significant.

Svartedalen
- n(tot)=125, n(yrs)=13
- m=0.124 (.093, .167)
- slope=-52% (-7.8, 8.8)
- SD(lr)=.51, 10%, 21 yr
- power=.33/.20/16%
- y(94)=.128 (.071, .231)
- r2=.00, p<.862
tao=.10, p=.669
SD(sm)=.29, p=.005 *

Grimso
- n(tot)=272, n(yrs)=19
- m=.146 (.118, .180)
- slope=-3.5% (-7.1, .03)
- SD(lr)=.40, 4.4%, 18 yr
- power=.89/.26/13%
- y(94)=.106 (.073, .154)
- r2=.21, p<.049 *
tao=.26, p=.124
SD(sm)=.33, p=.067

Tyresta
- n(tot)=111, n(yrs)=12
- m=.164 (.125, .216)
- slope=-.22% (-8.6, 8.2)
- SD(lr)=.45, 10%, 19 yr
- power=.32/.23/14%
- y(94)=.162 (.094, .280)
- r2=.00, p=.909
tao=-.09, p=.732
SD(sm)=.47, n.s.

Tiveden
- n(tot)=99, n(yrs)=10
- m=.096 (.074, .126)
- slope=3.6% (-4.8, 12)
- SD(lr)=.37, 12%, 17 yr
- power=.28/.28/13%
- y(94)=.116 (.070, .195)
- r2=.11, p=.351
tao=.24, p=.371
SD(sm)=.26, p=.036 *
Figure 9. Cd, µg/g, dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

Boa Berg
- n(tot) = 100, n(yrs) = 10
- m = 1.63 (1.12, 2.13)
- slope = 7.4% (-15, 75)
- SD(lr) = 32.9% (16 yr)
- power = 35%-35%/9.9%
- y(94) = 11.7 (7.6, 190)
- r² = .35, p < .008
- tao = .24, p < .371
- SD(sm) = .22, p < .035 *

Norra Kvill
- n(tot) = 124, n(yrs) = 13
- m = .092 (0.77, 1.11)
- slope = .29% (-4.9, 5.5)
- SD(lr) = 32.6% (16 yr)
- power = 62%/35%/9.9%
- y(94) = .094 (0.65, 136)
- r² = .00, p < .951
- tao = .03, p < .951
- SD(sm) = .31, n.s.

Fleringe
- n(tot) = 155, n(yrs) = 16
- m = .422 (0.32, 0.556)
- slope = -2.3% (-8.1, 3.6)
- SD(lr) = 32.7% (21 yr)
- power = 49% (17%/9.9%
- y(99) = .349 (198, 613)
- r² = .05, p < .422
- tao = .10, p < .620
- SD(sm) = .48, n.s.

Krankesjon
- n(tot) = 210, n(yrs) = 24
- m = .171 (0.13, 0.223)
- slope = -13% (-3.8, 3.6)
- SD(lr) = 64.4% (24 yr)
- power = 82% (21%/16%
- y(99) = .168 (101, 281)
- r² = .00, p < .899
- tao = .01, p < .941
- SD(sm) = .58, n.s.
Figure 10. Pb, µg/g, dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

Svartedalen
n(tot)=117, n(yrs)=12
m=1.04 (.730, 1.49)
slope=-12%(-18,-5.7)
sd(lr)=.35, 8.1%, 17 yr
power=.45/.30/11%
y(94)=.534 (.350, .813)
tao=.64, p<.005 *
sd(sm)=.24, p<.136

Grimsö
n(tot)=255, n(yrs)=16
m=.720 (.547, .947)
slope=-7.5%(-12,-3.0)
sd(lr)=.39, 5.5%, 17 yr
power=.73/27/12%
y(99)=.411 (.277, .609)
tao=.48, p<.003 *
sd(sm)=.24, p<.429

Tyresta
n(tot)=105, n(yrs)=11
m=1.46 (1.11, 1.93)
slope=-7.6%(-15,-.34)
sd(lr)=.34, 8.9%, 16 yr
power=.40/.32/11%
y(94)=1.00 (.65, 1.54)
tao=.45, p<.041 *
sd(sm)=.11, p<.000 *

tiveden
n(tot)=98, n(yrs)=10
m=.678 (.505, .910)
slope=-9.7%(-15,-3.9)
sd(lr)=.26, 7.9%, 16 yr
power=.47/47/7.9%
y(94)=.410 (.288, .584)
tao=.64, p<.012 *
sd(sm)=.25, p<.809

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Figure 11. Pb, µg/g, dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

Boa Berg
n(tot)=100, n(yrs)=10
m=1.91 (1.32, 2.77)
slope=-7.7% (-20.4, 7.0)
sd(lr)=49.16%, 20 yr
power=.21/21/16%
y(94)=1.35 (.69, 2.62)
r2=.20, p<.187
tao=.38, p<.152
sd(sm)=.50, n.s.

Norra Kvill
n(tot)=119, n(yrs)=12
m=.854 (.667, 1.09)
slope=-4.5% (-11.2, 1.1)
sd(lr)=37.84%, 17 yr
power=.43/29/12%
y(94)=.67 (.43, 1.03)
r2=.19, p<.159
tao=.30, p<.193
sd(sm)=.13, p<.002 *

Fleringe
n(tot)=150, n(yrs)=15
m=.672 (.525, .862)
slope=-7.8% (-11, -4.4)
sd(lr)=.27, 4.3%, 14 yr
power=.90/43/8.4%
y(99)=.365 (.269, .496)
r2=.66, p<.000 *
tao=.58, p<.003 *
sd(sm)=.23, p<.363

Krankesjön
n(tot)=180, n(yrs)=18
m=1.51 (1.11, 2.06)
slope=-6.2% (-11, -1.3)
sd(lr)=.53, 6.4%, 21 yr
power=.61/19/17%
y(99)=.88 (.54, 1.46)
r2=.31, p<.016 *
tao=-.37, p<.034 *
Figure 12. Cu, \( \mu g/g \), dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

<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) (95% CI)</th>
<th>Power (95% CI)</th>
<th>( y(94) ) (95% CI)</th>
<th>( r^2 )</th>
<th>p-value</th>
<th>tao (95% CI)</th>
<th>sd (sm) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Svartedalen</td>
<td>120</td>
<td>12</td>
<td>14.8 (12.8, 17.1)</td>
<td>-1.4% (-5.6, 2.8)</td>
<td>0.23, 5.3% (13 yr)</td>
<td>0.76, 53/7.2%</td>
<td>13.7 (10.3, 18.1)</td>
<td>0.06, p&lt; 0.468</td>
<td>-0.15, p&lt; 0.537</td>
<td>0.25, n.s.</td>
<td></td>
</tr>
<tr>
<td>Grimso</td>
<td>257</td>
<td>16</td>
<td>18.1 (17.1, 19.1)</td>
<td>-1.1% (-2.1, -0.04)</td>
<td>0.09, 1.3% (8 yr)</td>
<td>1.0, 0/1.0/2.7%</td>
<td>16.6 (15.2, 18.3)</td>
<td>0.15, p&lt; 0.041</td>
<td>-0.25, p&lt; 0.192</td>
<td>0.04, p&lt; 0.002 *</td>
<td></td>
</tr>
<tr>
<td>Tyresta</td>
<td>106</td>
<td>11</td>
<td>17.1 (15.0, 19.6)</td>
<td>-1.8% (-6.1, 2.5)</td>
<td>0.20, 5.2% (12 yr)</td>
<td>1.0, 0/1.0/6.1%</td>
<td>15.7 (12.1, 20.2)</td>
<td>0.09, p&lt; 0.375</td>
<td>-0.38, p&lt; 0.120</td>
<td>0.18, n.s.</td>
<td></td>
</tr>
<tr>
<td>Tiveden</td>
<td>99</td>
<td>10</td>
<td>16.5 (14.7, 18.5)</td>
<td>2.3% (-1.0, 5.6)</td>
<td>0.15, 4.5% (10 yr)</td>
<td>0.78, 0.87/4.5%</td>
<td>18.6 (15.2, 22.9)</td>
<td>0.24, p&lt; 0.148</td>
<td>-0.29, p&lt; 0.283</td>
<td>0.15, n.s.</td>
<td></td>
</tr>
</tbody>
</table>

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Figure 13. Cu, µg/g, dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated.

Smoother: 3-point running mean, unweighted is drawn when significant.

**Boa Berg**
- n(tot)=100, n(yrs)=10
- m=16.4 (14.0,19.3)
- slope=-1.9% (-7.6,3.9)
- sd(lr)=.23,7.0%, 13 yr
- power=55/35/7.0%
- y(94)=15.1 (11.1,20.6)
- r²=.06, p<.484
- tao=-.11, p<.721
- sd(sm)=.26, n.s.

**Norra Kville**
- n(tot)=119, n(yrs)=12
- m=17.6 (16.3,19.0)
- slope=1.3% (-72,3.4)
- sd(lr)=.12,6%, 8 yr
- power=1.0/98/3.5%
- y(94)=18.9 (16.5,21.7)
- r²=.17, p<.178
- tao=2.1, p=.373
- sd(sm)=.09, n.s.

**Fleringe**
- n(tot)=150, n(yrs)=15
- m=18.8 (17.1,20.6)
- slope=-2.1% (-3.9,-.40)
- sd(lr)=.14,2.2%, 10 yr
- power=1.0/90/4.3%
- y(99)=15.9 (13.6,18.6)
- r²=.35, p<.019 *
- tao=-.35, p<.075
- sd(sm)=.10, p<.108

**Kranesjön**
- n(tot)=180, n(yrs)=18
- m=17.0 (15.8,18.4)
- slope=-1.1% (-2.4,.31)
- sd(lr)=.15,1.8%, 10 yr
- power=1.0/87/4.6%
- y(99)=15.5 (13.5,17.9)
- r²=.14, p<.116
- tao=.28, p<.112

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Figure 14. Zn, µg/g, dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated.

Smoother: 3-point running mean, unweighted is drawn when significant.
Figure 15. Zn, µg/g, dry weight, in kidney of starling. Log-linear regression on geometric means, suspected outliers indicated. Smoother: 3-point running mean, unweighted is drawn when significant.

bo: Berg
n(tot)=90, n(ys)=9
m=78.6 (71.3, 86.7)
slope=-1.5% (-5.4, 2.4)
sd(lr)=.13, 4.6%, 9 yr
data=.6 (9/5/3.9)
y(94)=74.0 (61.4, 89.1)
r2=.11, p=.386
sd(sm)=.11, n.s.

Norra Kvill
n(tot)=109, n(ys)=11
m=84.0 (77.0, 91.5)
slope=-2.4% (-4.2, -62)
sd(lr)=.09, 2.5%, 8 yr
data=1.0 (1/0/2.9)
y(94)=73.9 (65.9, 82.9)
r2=.51, p=.014*
sd(sm)=.09, n.s.

Fleringe
n(tot)=140, n(ys)=14
m=81.1 (72.8, 90.4)
slope=-.04% (-2.6, 2.6)
sd(lr)=.19, 3.4%, 12 yr
data=.98, .68/5.9%
y(99)=78.7 (64.0, 96.9)
r2=.00, p=.926
sd(sm)=.15, n.s.

Krankesjon
n(tot)=170, n(ys)=17
m=80.1 (71.8, 89.4)
slope=-10% (-2.3, 1.9)
sd(lr)=.22, 2.9%, 12 yr
data=1.0, 5/8/6.7%
y(99)=78.7 (64.0, 96.9)
r2=.00, p=.820
tao=.07, p<.711

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