AMAP Faroe Islands Heavy metals and POPs Core programme 2004

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Contents

Preface

The present report is part of the national contribution to the international Arctic Monitoring and Assessment Programme, AMAP, as operated under the auspices of the Arctic Council. The report summarises the results of the core programme monitoring of heavy metals and persistent organic pollutants in terrestrial, freshwater and marine environments of the Faroe Islands. The monitoring is done according to guidelines adopted by AMAP, with adaptations that reflect the special Faroese pollution issues and the experience gained from earlier work.

Úrtak og niðurstøða

(Týtt hevur Marjun A. Simonsen)

Ulkulivrar úr Føroyum vórðu kannaðar í sambandi við AMAP-kanningina í 2004 eins og í trimum fylgjandi árum, frá 1999 til 2001. Kyksilvurmegnið í ulkulivrum skifti nógv frá einum ári til tað næsta, og árligu miðaltølini fyri bólkin upp á 20-25 cm skifti frá 0,05 mg/kg í 2001 til 1,4 mg/kg í 2000. Kyksilvurmegnið, ið var 0,08 mg/kg í 2004, er tí í lægra endanum á tí, ið higartil er mátað. Eisini kadmiummegnið hevur verið heldur skiftandi frá einum lágum megni upp á 0,20 mg/kg í 1999 og 2001, til 0,38 mg/kg í 2000. Kadmiummegnið í ulkulivrum í 2004 er tí úr miðal til lágt í hesum mátingum. Tó sýnist selenmegnið at vera rættiliga støðugt á økinum 1,3 til 1,6 mg/kg av livur í bólkinum, ið er 20-25 cm til støddar.

Samanborið við úrslit av kanningum, ið áður eru gjørdar av teistaeggjum, er kyksilvurnøgdin í sýnunum frá 2004 á sama stigi sum tær, ið vórðu funnar í sýnunum í 1999 og eitt sindur størri enn í árunum 2000-2001. Verður metalmegnið í teistalivur borið saman, tá ið fuglarnir verða bólkaðir eftir kyni og nøringarstøðu, er rakt við, at kyksilvur- og selenmegnið er ymist ímillum hesar bólkar. Kyksilvurmegnið vísir seg at vera størri í kallfugli enn í kvennfugli, eisini í ungum kallfugli. Ein samsvarskanning av 20 einstøkum pørum av metaldátum bendir á, at tað er eitt frámerkjandi negativt samband millum Hg og Se í teistalivur.

Kyksilvur, kadmium og selen varð kannað í hvalasýnum, ið vórðu tikin í Vestmanna 2001. Tá ið roknað varð út eitt normalisað kyksilvurmiðaltal fyri at fáa eina heildarmynd av kyksilvurnøgdini, ið er til staðar í eini grind, vísti tað seg, at kyksilvurmegnið í vøddunum í hesi ávísu grind, ið var 1,68 mg/kg, var í lægra enda á tí, sum rakt varð við, síðan eftirlitið byrjaði í 1997. Sum ofta áður er staðfest, øktist kyksilvurmegnið bæði í vøddum og livrum eftir hvalalongd. Selen, sum ikki samsvaraði við hvalalongd, tá ið megnið í vøddunum varð kannað, samsvaraði við longd, tá ið selenmegnið í livrini varð kannað. Henda seinna eygleiðingin kann hava samband við, at kyksilvur- og selenmegn í livur samsvaraði sera frámerkjandi. Selen og kadmium í livur samsvaraðu eisini, eins og kadmium- og kyksilvurmegnið. Kadmium í vøddum samsvaraði ikki frámerkjandi við kadmiummegnið, hvørki í livur ella nýrum, sjálvt um kadmiummegnið í livur og nýrum samsvaraðu.

Kyksilvurmegnið í harulivur í mettum bólkum av ungum harum (n=9), vaksnum kvennharum (n=6) og vaksnum kallharum (n=6) var ávikavist 0,05, 0,13 og 0,06 mg/kg, og kadmiummegnið var 0,10, 0,37 og 0,25 mg/kg fyri somu bólkar. Atvoldin til munin millum metalmegnið í haru í 1999 og 2001 er at finna í vaksna kvennharubólkinum, har kyksilvurmegnið í hesum bólki frá 2001 er dupult so stórt sum í 1999, meðan kadmiummegnið í vaksna kvennharubólkinum í 2001 er meir enn tríggjar ferðir so høgt sum í 1999.

Kyksilvur í bleikju varð mált at vera 0,25 mg/kg í vøddum. Borið saman við kanningar í 2001 av fiski við somu longd úr sama vatni, vóru hesi úrslit júst sum væntað, men hetta kyksilvurmegnið er høgt borið saman við tað, ið vanliga verður funnið í bleikju í øðrum londum.

Kyksilvur varð kannað í botnsigi úr Kaldbaksfirði. Tað er í hesum fjørði, ið ulka er tikin at kanna til AMAP-ætlanina. Sýnini av botnsigi vórðu tikin í eini bendari sýnisleið, ið byrjaði inni í botninum, og síðan varð hildið fram út eftir fjørðinum. Tá ið kyksilvurmegnið í botnsiginum varð gjørt upp fyri innihald av lívrunnum evnum – tað verður gjørt, tí kyksilvur hevur lyndi til at binda seg til tey – gjørdist greitt, at hægsta kyksilvurmegnið fyri hvørja eind av lívrunnum evnum er funnið í tí innastu sýnisstøðini. Harumframt varð staðfest, at tað hægsta tillagaða kyksilvurmegnið varð funnið á 1 til 2 cm dýpi í botnsigskjarnanum.

Kyksilvur, jarn og mangan varð kannað í fýra botnsigskjarnum, ið vórðu tiknir á Sandoyarbanka á landgrunninum. Jarn og mangan í hesi kanning kunnu hava týdning sum ávísar fyri umskapandi tilgongdir, sum kunnu hava broytt útbreiðsluna og á henda hátt profilin á kyksilvuri niðri í kjarnanum. Kyksilvur vísti seg at samsvara frámerkjandi við jarn og mangan í tveimum út av fýra kjarnum, hóast samtíðarsamsvar viðvíkjandi bæði mangan og jarn bert sást í 4. kjarna. Jarn og mangan samsvaraðu frámerkjandi í øllum kjarnum. Hagtølini geva ikke greiðar ábendingar á, um útbreiðslan av kyksilvuri fylgir jarni og/ella mangan ella hvørgum. Tískil kann kanningin ikki siga okkum, um økingin í kyksilvuri í botnsigi, ið er lagst ígjøgnum seinastu øld, er mannaskapt ella hevur verið stýrd av umskapandi tilgongdum.

Í 2004 minkaði PCB-megnið í ulku av Kaldbaksfirði enn meiri, og tað ger sýnini frá 2004 tey lægstu higartil, ið eru skrásett viðvíkjandi PCB. Slík metlág megn vórðu eisini staðfest fyri hini POP-evnini. Allastaðni, tá ið megn, ið umboðar evnasambond funnin í 2000, verða borin saman við tey, ið eru funnin í 2004, í sama slag og í sama fjørði, er staðfest, at tilmunarliga minkingin í megninum er ikki tann sama fyri hvørt evnasamband, men minkar í raðfylgjuni mirex > DDE= trans-nonachlor > Par50 = CB153 > HCB, t.e. at mirexmegnið er minkað mest, og HCB-megnið minst.

Í sýnum av harulivur (n=21) vórðu bara 4 evnasambond funnin í alt, og av teimum bara HCB og oxychlordanir í øllum ella øllum uttan einum sýni. Heildarmiðaltalið av HCB og oxychlordanum var ávikavist 32 µg/kg fiti og 34 µg/kg fiti. Mirex og CB 153 vórðu funnin ávikavist í 2 og 4 sýnum og tá í megni frá 2 til 4 µg/kg fiti.

Teistaegg úr Koltri og Skúvoy vórðu kannað fyri POPs fyri fjórðu ferð. PCB-megnið vísti seg at vera minkað frá 1999 til 2001, men við úrslitunum frá 2004 varð funnið fram til, at minkingin helt ikki á. Mirexmegnið vísti seg at hava somu gongd sum PCB, men DDT, toksafen og chlordanir vísa eina støðugari gongd. HCB-megnið í 2004 var lægri enn í 1999-2001, og tað vísir seg at minka støðugt.

Hóast eitt stórt tal av grindahvali varð kannað fyri PCB seint í 1980-árunum, kunnu úrslitini ikki berast beinleiðis saman við úrslit frá seinnu árunum, tí kanningarhátturin er ikki tann sami. Hesi úrslit – saman við øðrum frá teimum seinastu fáu árunum – benda á, at minkingin í PCB- og DDT-megni í spiki, sum vit sóu hjá vaksnum kallhvalum (men ikki – ella í minni mun – hjá vaksnum kvennhvalum) í árunum 1987 til 1997, helt ikki á. HCB-megnið vísti seg heldur ikki at vera serliga nógv broytt síðan 1997. Grindahvalur hevði ikki verið fyrsta valið til at kanna fyri at staðfesta gongdina í dálkingarnøgd; men sambært kanningarúrslitunum av grindahvali frá hesum seinastu fáu árunum vístu bæði toksafen og chlordanir seg at vera vaksandi.

Í sýnunum frá 2004 av bleikju frá vatninum á Mýrunum samsvaraðu POPs ikki við fiskalongd eins og megnið av POPs sum PCB og DDT gjørdu í sýnum frá 2000 og 2001. Viðvíkjandi megninum av teimum ymisku POPs uttan HCB, sum var eitt sindur lægri í 2004 enn árini frammanundan, var munurin millum sýnini frá 2004 og sýnunum frá árunum frammanundan ikki so stórur.

Botnsig, sum varð tikið á seks støðum í Kaldbaksfirði, varð kannað fyri PCB eins og fyri kyksilvur, eins og greitt er frá frammanundan. Hægsta PCB-megnið var á sama hátt sum kyksilvur funnið í botnsigi innast í botninum nær við munnan á eini á, sum veitti vatnið burtur av fjallalendinum uttanum. Hesi úrslit benda á, at tað er – ella kanska heldur var – ein kelda á staðnum við bæði PCB- og kyksilvurdálking nær við Ka1-økið. Av tí at tað hægsta megnið varð funnið í eini flá niðan fyri tann ovasta flatan á havbotninum, kann ein rokna við, at dálkingarkeldan er minkað tey seinastu árini.

Støðugir isotopar av køvievni og karbon, skrásettir sum d15N og d13C, vórðu kannaðir í bleikju, teistaeggjum, grindahvali og ulku. Størsta upphópingin av d15N og d13C varð funnið í ulku og tann minsta í bleikju, meðan grindahvalur og

teistaegg høvdu virði, sum vóru javnstór og minni enn tey í ulku. Aðrar kanningar hava sett upphópingina av støðugum isotopum í einum djóri í samband við støðu teirra í føðiketuni og hvar tey finna føði sína – á landi ella í sjógvi. At greina út, hvat er fingist burtur úr hesi kanning á henda hátt, vildi sett ulku í hægstu støðu í føðiketuni og bleikju í lægstu. Av teimum kannaðu sløgunum er grindahvalur tann, sum ósvitaliga hevur størsta megn av dálkingarevnum, sum hópast í føðiketuni – sum kyksilvur, PCB og DDT, men eftir d15N at døma vildi hann verið í einum heldur lægri føðiliði enn ulka saman við teistaeggjum. Upphópingin av d15N samsvaraði ikki við megnið av einum umboðandi úrvali av dálkingarevnum uttan í teistaeggjum, har kyksilvur og d15N samsvaraðu.

Orðafrágreiðing:

frámerkjandi adj, adv: significantly
føðiliður m: trophic level
megn n: concentration
samsvar n: correlation
sýnisleið f: transect
tilmunarligur adj: relativ
umskapandi adj: diagenetic
upphóping f: accumulation

Summary and conclusions

Sculpin livers from the Faroe Islands were analysed in the AMAP context in 2004 as in three subsequent years, from 1999 to 2001. The interannual variability in sculpin liver mercury concentration has been quite high, with yearly averages for the 20-25 cm group varying from 0.05 mg/kg in 2001 to 1.4 mg/kg in 2000. The 0.08 mg/kg Hg in 2004 is therefore in the lower end of the range observed hitherto. Also the cadmium concentrations have been somewhat variable from a low 0.20 mg/kg in 1999 and 2001, to 0.38 mg/kg in 2000. The 2004 sculpin liver cadmium concentration is therefore in the mid to low end of this range. The selenium concentration on the other hand, appears to be rather stable in the range 1.3 to 1.6 mg/kg liver for this 20-25 cm size group.

Compared to earlier results of black guillemot egg mercury analyses, the mercury level in the 2004 samples are at the same level as those found in the 1999 samples and somewhat higher than in the years in-between in 2000 and 2001. Comparing the metal concentrations measured in the birds' livers when the birds are grouped according to sex and reproductive status, it is found that the mercury and selenium concentrations are different among these groups. The concentration of mercury appears to be higher in the males than in the females, also in the juvenile males. A correlation analysis involving the 20 individual pairs of metal data indicate that there is a significant negative correlation between Hg and Se in black guillemot liver.

Mercury, cadmium and selenium were analysed in pilot whales sampled in Vestmanna 2001. When calculating a normalised pod mercury average, so as to get an overall picture of the mercury load present in a whale school, it is seen that the mercury concentration in muscle in this particular school was, at 1.68 mg/kg, in the lower end of the range observed since monitoring began in 1997. As has so often been noted, the mercury concentration both in muscle and liver was seen to increase with whale length. Selenium that was not correlated to whale length when muscle concentrations were studied was however, correlated to length when liver selenium concentrations were analysed. This latter observation may be tied to the fact that mercury and selenium concentrations in liver were very highly significantly correlated. Liver selenium and cadmium were also correlated, as were liver cadmium and mercury concentrations. Cadmium in muscle was not significantly correlated to the cadmium concentration either in the liver or in the kidneys, though the cadmium concentrations in liver and kidneys were correlated.

The hare liver mercury concentration in approximated pools of juveniles (n=9), adult females (n=6) and adult males (n=6) were 0.05, 0.13 and 0.06 mg/kg respectively, and those of cadmium were 0.10, 0.37 and 0.25 mg/kg for the same pools. The difference between the 1999 and 2001 hare metal concentrations lie in the adult female pool, which is twice as high in mercury as the adult female pool of 1999, whereas the cadmium concentration in the 2001 adult female pool is more than three times as high as in 1999.

Mercury in Arctic char was found to be 0.25 mg/kg muscle. Compared to analyses in 2001 from the same lake in fish of the same length, these results are very much as expected but this mercury concentration is high compared to what is normally found in Arctic char in other countries.

Mercury was analysed in sediments from Kaldbaksfjørð, which is where sculpin are sampled for the AMAP programme. The sediment samples were taken along a (crooked) transect beginning at the foot of the fjord and continuing outwards. When the mercury concentration in the sediments was corrected for the content of organic matter in these, done because mercury has a tendency to stick to organic

matter, it becomes apparent that the highest concentration of mercury per unit of organic material is in fact found in the innermost sampling station. Also it is seen that the highest corrected mercury concentration is found in the –1 to –2 cm segment of the sediment core.

Mercury as well as iron and manganese were analysed in four sediment cores sampled at Sandoyarbanka on the Faroe Islands shelf. The role of iron and manganese in this investigation is as indicators of diagenetic processes that may have shifted the distribution and thus the profile of mercury down the cores. Mercury was found to be significantly correlated to iron or manganese in two out of four cores, though simultaneous correlation to both manganese and iron was seen only in core 4. Iron and manganese were significantly correlated in all cores. The statistics are thus equivocal as to whether or not the distribution of mercury follows iron and/or manganese. The study is thus inconclusive regarding the question of whether the increase in mercury in sediments deposited during the last century has been driven by man or has been governed by diagenetic processes.

In 2004, the concentration of PCB in sculpin from Kaldbaksfjørð has decreased even further making the 2004 samples the lowest hitherto recorded with respect to PCB. Such record low levels were also detected for the other POPs analysed. Overall, when comparing concentration of representatives of the compounds detected in 2000 to the ones detected in 2004, in the same species in the same fjord, it is noted that the relative decrease in concentration is not the same for every compound, but decreases in the order mirex> DDE= trans-nonachlor> Par50 = CB153> HCB, meaning that the concentration of mirex has decreased the most, and that of HCB the least.

In the hare liver 2001 samples (n=21), only four compounds were detected at all, and then only HCB and oxychlordane in all or all samples except one. The overall averages of HCB and oxychlordane were 32 µg/kg lw and 34 µg/kg lw respectively. Mirex and CB 153 were detected in 2 and 4 samples respectively and then in concentrations from 2 to 4 µg/kg lw.

Black guillemot eggs sampled on the islands Koltur and Skúvoy were analysed for POPs for the fourth time. The concentration of PCB was found to have decreased during 1999 to 2001 but with the 2004 results it is noted that the decrease did not continue. Concentrations of mirex appear to follow the same trend as PCB whereas DDT, toxaphene and chlordanes show a steadier trend. HCB in 2004 were lower than in 1999 – 2001, and appears to be on a steady decreasing trend.

Although a large number of pilot whales were analysed for PCB in the late 1980s, the results are not directly comparable to results from later years because the methods of analyses are not the same. The present results, along with others from the last few years, indicate that the decrease in PCB and DDT in blubber concentrations that were seen among the adult males (but not or to a lesser degree in the adult females) from 1987 to 1997 has not continued. The concentrations of HCB do not appear to have changed much since 1997 either. Pilot whales would not be the primary choice of matrix for detecting trends in pollution level; however, from the analyses results of pilot whales from these last few years both toxaphene and chlordanes appear to be on the rise.

In the 2004 samples of Arctic char from lake Á Mýrunum POPs were not correlated to fish fork length as the concentration of POPS like PCB and DDT had been in the 2000 and 2001 samples. With regard to the actual concentration of the various POPs except for HCB that was somewhat lower in 2004 than earlier years, the 2004 samples were not much different from the earlier ones.

Sediments taken at six stations in Kaldbaksfjørð were analysed for PCB as well as for mercury as already reported above. The highest PCB concentrations were, just as with mercury, found in sediments in the very foot of the fjord near the outlet of a river draining the surrounding mountainous area. These findings indicate that there is or perhaps rather was, a local source of both PCB and mercury pollution near

the Ka1 site, and given that the highest concentrations were found in a segment below the uppermost surface of the seabed, one may assume that the pollution source has diminished in recent years.

Stable isotopes of nitrogen and carbon, reported as d15N and d13C, were analysed in Arctic char, black guillemot eggs, pilot whale and sculpin. The highest accumulation of d15N and d13C was found in sculpin and the lowest in Arctic char, with in-between and similar values in black guillemot eggs and pilot whale. Other studies have linked the degree of accumulation of the stable isotopes in a being to its position in the food web and to the degree of marine or terrestrial character of its foraging area. Interpreting the output of the present study along these lines would put the sculpin at the highest position in the tier and Arctic char at the lowest. Pilot whales, which invariably have the highest concentrations of biomagnifying pollutants like mercury, PCB and DDT among these analysed species, would appear at a somewhat lower trophic level than sculpin along with black guillemot eggs. The accumulation of d15N was not correlated to the concentration of a representative set of pollutants except in black guillemot eggs, were mercury and d15N were correlated.

1 Introduction

The results in this report are from analyses in 2004-2005 and are part of the AMAP phase III. Faroe Islands has contributed in the two previous phases and the results are reported in Larsen & Dam, 1999, Olsen *et al.*, 2003 and Hoydal *et al.*, 2003.

The metal analysis in phase III include mercury, cadmium and selenium and the POP analysis include PCB and organochlorine pesticides (14 single congeners, chlordanes, ß-HCH), DDT (o,p-isomers and metabolites) and toxaphene (5 individual congeners). In addition four species have been analysed for the stable isotope ratios $^{15}N/^{14}N$ and $^{13}C/^{12}C$.

The species analysed in 2004-2005 are shown below:

Table 1.1 Overview of analysed species 2004-2005

Species	Matrix	Analysis				
		Hg	Cd	Se	POPs	Stable isotopes
Pilot whale	Blubber				+	
	Muscle	+	+	+		+
	Liver	+	+	+		
	Kidney		+			
Short-horn sculpin	Liver	+	+	+	+	+
Black guillemot	Liver	+	+	+		
	Egg	+			+	+
Arctic char	Muscle	+		+	+	+
Mountain hare	Liver	+	+	+	+	
Sheep	Liver	+	+			

As a special task in 2004 sediments from Kaldbaksfjørður were dated and analysed for mercury and PCB in order to locate the source of PCB and metal pollution previously found in biota at the location.

Table 1.2 Special task analyses in 2004

Matrix	Dating	Mercury	PCB7
Marine sediments	+	+	+

In addition marine sediments from Sandoyarbanki, which were dated and analysed for mercury in 2001, have been analysed for iron and manganese.

1.1 Analytical methods

The mercury and cadmium analyses, and Loss on Ignition in sediments, were performed at the Food, Veterinary and Environmental agency on the Faroe Islands (FVEA) and the selenium analyses were performed at Centre de Toxicologie du Quebec (CTQ), except for the sculpin, for which analysis of all three metals were performed at CTQ.

The POP analyses in biota were performed at CTQ whereas the sediments were analysed for PCBs at Alcontrol in Sweden.

The analyses of stable isotope ratios were performed at Stable Isotopes in Nature Laboratory (SINLAB) in Canada.

1.1.1 Metal analysis

At The Food, Veterinary and Environmental Agency cadmium was analysed with atom absorption spectrophotometry using either graphite (Perkin Elmer 1100B) or flame (Perkin Elmer 2380) depending on the content of the examined material. Mercury was analysed with the FIMS 400 (Mercury analysis system) + amalgam system, PERKIN ELMER (AA600).
Quality assurance: Double determinations were performed. A certified reference material and a blank sample were analysed in connection with each series. The certified reference material and the blank were destroyed in the same manner as the samples. A 4-point standard curve was always made. The laboratory participates in regular intercalibration, for example Quasimeme[1]. The laboratory is accredited to the performed analyses: mercury and cadmium.

The loss on ignition analysis was performed by heating the samples to 550ºC over night and subtracting the weight after from the weight before heating.

At CTQ cadmium and selenium were determined by ICP-MS after sample digestion using concentrated nitric acid. Mercury was analysed on the same digest but by cold vapour atomic absorption spectrometry.

The analyses of Mn and Fe in sediments were performed at Alcontrol in Sweden. Only the easy leachable part of the Fe and Mn concentration was analysed. The samples were extracted by solution in 1N HCl for 24h at room temperature (20ºC) as described by Leventhal and Taylor 1990.

1.1.2 Stable isotopes

The samples were analysed for d13C and d15N using a Thermo-Finnigan Delta Plus isotope-ratio mass spectrometer (Bremen, Germany) interfaced with a Carlo Erba NC2500 Elemental Analyzer (Milan, Italy) via the Conflo II or Conflo III, respectively. This is a continuous flow system using helium as a carrier gas. Samples are converted to a gaseous state via combustion.

Four IAEA standards (N1, N2, CH6 and CH7), three elemental standards (Acetanilide, Cyclohexanone, and Nicotinamide) and one internal standard (bovine liver for animal tissue) were used throughout each run to ensure high quality control.

1.1.3 POPs

The POP analyses in biota were performed at CTQ whereas the sediments were analysed for PCBs at Alcontrol in Sweden.

At CTQ all the analysed compounds, except cis-nonachlor and p,p'-DDT, were determined by GC/ECD. Cis-nonachlor and p,p'-DDT were determined by GC/MS. For a more detailed description of the analyses see Pedersen *et al*. (2000). When PCB is given as "Aroclor 1260" it is done to facilitate comparisons, however shaky, to earlier reported PCB analyses results which were in fact quantified using a commercial Aroclor mixture. The "Aroclor 1260" value reported in this report was calculated from individually quantified congeners, using a factor of calibration that was determined on a human tissue matrix.

[1]Quality assurance of information for marine environmental monitoring in Europe

At Alcontrol, PCB7 in sediments was analysed by HRGC/HRMS. Extraction was done by soxhlet in dichloromethane for 18 hours. Thereafter an acid treatment was performed. The PCB content was quantified by HRGC/HRMS using PCB 118 as an internal standard.

2 Sampling

2.1 Short-horn sculpin (Myoxocephalus scorpius)

Shorthorn sculpin were sampled by fish-traps in Kaldbaksbotnur in August – September 2004. The fish traps were set close to land at a depth of approximately 1m and stood until a sufficient number of sculpin had been caught. The catch was collected daily. The sculpin were put in polyethylene bags and frozen at -20ºC prior to dissection.The weight and length of the sculpin were recorded before dissection.

Table 2.1 Composition of sculpin liver samples from 2004.

	Sample mark	ID of sculpin in sample	Length, cm	Weight, g	Gender	Liver content in sample, g
20-25 cm	Ms-1-2004	Ms-0139, Ms-0135	22*	198*	F	7.9
	Ms-0145	Ms-0145	22	220	M	9.5
	Ms-0134	Ms-0134	22.5	234	F	7.3
	Ms-2-2004	Ms-0137, Ms-0136	22.25*	193*	M	8.6
	Ms-6-2004	Ms-0154, Ms-0138	24.15*	245*	F	6.4
	Ms-0155	Ms-0155	23.9	254	F	10.1
25-32 cm	Ms-0146	Ms-0146	25	292	F?	7
	Ms-0152	Ms-0152	26.5	388	F	11.9
	Ms-3-2004	Ms-0133, Ms-0141	26.8*	309*	F	7.3
	Ms-4-2004	Ms-0142, Ms-0143	28*	351*	F	8.2
	Ms-0153	Ms-0153	27	360	F?	9.2
	Ms-5-2004	Ms-0150, Ms-0144	28.4*	389*	F	8,1
	Ms-0151	Ms-0151	28	430	F	11.6
	Ms-0140	Ms-0140	28.3	384	F	13.5
	Ms-0147	Ms-0147	30	480	F?	7.4
	Ms-0149	Ms-0149	30.5	544	F	16.2
	Ms-0148	Ms-0148	31.5	582	F?	22.4
	Ms-7-2004	Ms-0156, Ms-0157	26.6*	292*	F	7.4
	Ms-8-2004	Ms-0158, Ms-0160	25.5*	283*	M/F	5.5
	Ms-0159	Ms-0159	25.9	327	F	6.4

*Mean length or weight in pooled sample

The liver was dissected and stored in polycarbonate jars. For some of the sculpin the liver was too small to make up a sample and in those cases livers from two fishes were pooled to get enough sample tissue. The liver samples were stored in the freezer at -20ºC until shipment to the laboratory for analysis at Centre de Toxicologie du Quebec (CTQ). At CTQ the livers were analysed for Hg, Cd and Se as well as for POPs. Samples of muscle were taken from the right side filet for analysis of stable isotopes at Stable Isotopes in Nature Laboratory (SINLAB) in Canada. The gender was registered, and the gonads as well as the stomach with content and samples of muscle were stored at -20ºC and deposited in the

Environmental Specimens Bank (ESB)[2] for possible use in later studies. The otoliths were sampled but not analysed in this context.

2.2 Black Guillemot (*Cepphus grylle*)

2.2.1 Black Guillemot eggs

Local people at two locations, Koltur and Skúvoy, sampled black guillemot eggs in early June 2004. Only one egg was sampled from each nest and the eggs were stored in the refrigerator until further treatment.

The eggs were weighed and the height and breadth was measured. A hole was made on the top of the egg and the content was poured into a heat-treated glass (400ºC for four hours). The yolk and white was mixed with a fork and the samples were stored at -20ºC until analysis of Hg at the Food, Veterinary and Environmental Agency on the Faroe Islands (FVEA). Samples were also taken for analysis of stable isotopes at SINLAB in Canada.

The eggshell thickness of all the eggs was measured with a micrometer-caliper at three different places as near at the equator as possible. The results of the eggshell thickness are shown in attachment 2.

2.2.2 Black Guillemot liver

The Black guillemots were shot at Sveipur on 2nd May 2002. The weight of each bird was recorded before they were cut from their left side under the wing through the ribs. The gender was registered and the stomach with content was cut out and used in another study (Ólafsdóttir, 2002). The livers were sampled and stored in polycarbonate jars and frozen at -20ºC until analysis. The livers were analysed for Hg and Cd at the FVEA and for Se at CTQ.

Samples of kidney, muscle and feather were stored in polyethylene bags[3] at -20ºC and deposited in the ESB for possible use in later studies.

2.3 Long-finned pilot whale (*Globicephala melas*)

Pilot whale samples are collected in connection with traditional hunting. The sampling takes place after the killing and before the meat distribution. At this time the whales are cut open by an abdominal cut, to facilitate cooling. The samples of blubber and muscle are taken at the sides of these abdominal cuts. Before the sampling the length of the whale and the size in *skinn*[4] are measured and local authorities determine the sex. By using the same identification number this information on the whales, from which samples have been taken, can be obtained later.

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[2] The database of the Environmental specimen bank is searchable from the web at http://www.hfs.fo/index2.htm

[3] The polyethylene bags used for sample storage are invariably of the reg. trademark Millipore type.

[4] Skinn is a special Faroese unit for measuring the size of the whale on an assessment of the mass fit for human consumption.

The samples were collected in Vestmanna on 27th June in 2001. Pieces of blubber, muscle, liver and kidney were sampled in polyethylene bags and stored at -20ºC until shipment for analysis.

The muscle and liver samples were analysed for Hg and Cd at the FVEA on the Faroe Islands and for Se at CTQ in Canada. Samples of muscle were also taken for stable isotope analysis at SINLAB in Canada.

The kidney samples were analysed for Cd at the FVEA on the Faroe Islands.

The blubber samples were analysed for POPs (PCB and organochlorine pesticides, DDT and toxaphene) at CTQ. During the preparation of the blubber samples the outer part of the blubber, which had been in contact with the wrapping, was removed and the blubber samples were transferred to polycarbonate jars and kept frozen until analyses.

2.3.1 Defining groups

According to Desportes *et al.* (1993) and Martin & Rothery (1993) pilot whales can be divided into the following groups as regards their sexual maturity:

Juvenile females: All females < 375 cm
Adult females: All females ≥ 375 cm
Juvenile males: All males < 494 cm
Adult males: All males ≥ 494 cm

The pilot whale school from 27.06.2001 consisted of 95 whales of which 25 were analysed. The sex and age distribution was as follows:

Table 2.2 Composition of entire pilot whale school from 27.06 01 compared to the analysed part.

Age and sex group		*Entire whale school*			*Analysed part of whale school*		
		Length cm	***Skinn*[5]**	**Number**	**Length cm**	***Skinn*[4]**	**Number**
Juveniles	Min	240	2	17 (M=11, F=6)	240	2	6 (M=3, F=3)
	Max	490	13		457	13	
	Mean	**387.5**	**6.6**		**374**	**6.5**	
Adult females	Min	383	6	65	390	7	14
	Max	505	12		500	12	
	Mean	**452**	**9**		**459**	**9.4**	
Adult males	Min	495	12	13	506	12	5
	Max	592	20		583	17	
	Mean	**545**	**15**		**548**	**14.8**	

2.4 Mountain Hare (*Lepus timidus*)

The hares were shot at the locations Signabøhagi and Norðadalur during November and December 2001 using lead shot ammunition. The length and weight of the hare was recorded as well as the length of the foot and the skull. The liver,

[5] *Skinn* is a special Faroese unit for measuring the whale size based on an assessment of the mass fit for human consumption.

intestinal fat and pieces of muscle were sampled. The liver was stored in heat-treated glass jars (400ºC for 4 hours), the intestinal fat in polycarbonate jars and the muscle in polyethylene bags.

The liver was analysed for Hg and Cd at the FVEA and for Se and POPs at CTQ. The samples of muscle and intestinal fat were stored at -20ºC and deposited in the ESB for possible use in later studies.

2.5 Sheep (Ovis aries)

Samples of sheep liver were collected in connection with slaughtering of sheep in October 2001. Arrangement was made with the farmer to take the samples and they were given instructions on the procedure. Samples were taken of the lowest part of the liver lobe of 7 female adult sheep and 13 lambs. The samples were stored in polyethylene bags at -20ºC until analysis.
The samples were analysed for Hg and Cd at the FVEA at the Faroe Islands.

2.6 Arctic char (Salvelinus alpinus)

Permission for fishing in the lake Á Mýrunum was granted by the Chief Veterinary Officer and men from the angling association "Føroya Sílaveiðufelag" caught the Arctic char on 7th July in 2004 by angling. The fish were wrapped in plastic bags and frozen at -20ºC until further treatment. Before and after fishing, the fishing tackle was disinfected with the commercial disinfectant VirkonS.

Length and weight of the fish were recorded. Muscle samples were taken from the right fillet and analysed for Hg at the FVEA and for Se and POPs at CTQ. Muscle samples were also analysed for stable isotopes at SINLAB in Canada.

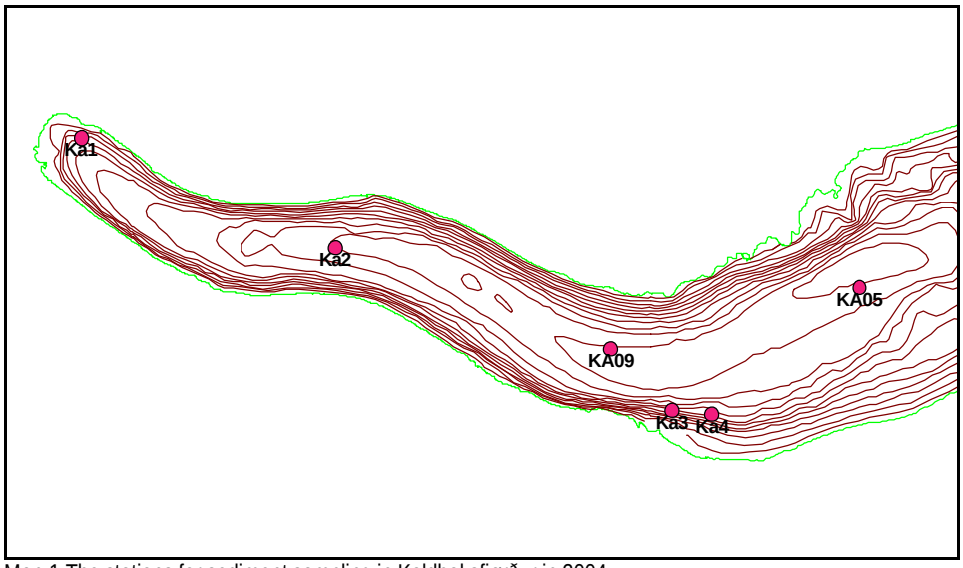
The liver was stored in heat-treated glass jars (400ºC for four hours) in the freezer (-20ºC) and deposited in the ESB for possible use in later studies.

2.7 Marine sediments

2.7.1 Sediments from Kaldbak 2004

Sediment cores were sampled at six stations in Kaldbaksfjørður. At two of the stations (KA05 and KA09) samples were taken during a survey with the research vessel "Magnus Heinason" on 30th August 2004 with a HAPS bottom-corer. The samples were frozen immediately and kept frozen until further treatment.

The rest of the samples (Ka1-4) were taken with a smaller HAPS bottom-corer from a small boat. These cores were cut into segments immediately without freezing.



Map 1 The stations for sediment sampling in Kaldbaksfjørður in 2004.

Three replicates were taken at each station. The upper 6 cm of the sediment cores were cut in 1cm segments and each segment was placed in an aluminium tray and left to dry at room temperature. When the segments were dry the three replicates of each segment were mixed and stored in heat-treated glass jars. The segments of 1-3cm for all the cores were analysed for Hg and Loss on Ignition at the FVEA and for PCB at Alcontrol laboratory in Sweden. Unfortunately, two of the samples were destroyed on their way to the laboratory in Sweden, so instead of the 3cm segments of KA05 and KA09, the 4cm segments were analysed for PCB.
The segments (1-6cm) of the KA05 and KA09 cores were dated at Risø National Laboratory, Department of Nuclear Safety Research, based on analyses of ^{210}Pb.

Table 2.1 Overview of sediment samples taken in Kaldbaksfjørður in 2004

Station	Position	Date	Depth
KA05	62º03.347N, 6º49.301W	30.08.2004	55 m
KA09	62º03.193N, 6º50.970W	30.08.2004	52.2 m
Ka1	62º03.862N, 6º54.446W	10.09.2004	18 m
Ka2	62º03.517N, 6º52.779W	10.09.2004	50 m
Ka3	62º03.006N, 6º50.575W	10.09.2004	35 m
Ka4	62º02.990N, 6º50.307W	10.09.2004	38 m

2.7.2 Sediments from Sandoyarbanki 2000

Four cores of sediments taken at Sandoyarbanki in July 2000 at position 61° 51' N, 5° 44' V and depth 330 m, have previously been dated and analysed for mercury (Olsen *et al*., 2003). These sediments were analysed for “easy leachable” Fe and Mn at Alcontrol Laboratories in Sweden.

3 Heavy metal results

3.1 Sculpin

Concentrations of mercury, selenium and cadmium in sculpin livers are given as summary results in Table 3.1. The analyses results were reported on a dry weight basis, and are given as such in the table. The calculation of wet weight based results may be done using the measured dry weight content in the liver samples. The results of the dry weight analyses are however not actually measured values in all these sculpin samples, as some of the samples were too small to allow these analyses. In such instances, the average dry weight of ten similar samples have been assumed as a representative value, and used as an approximation (see Attachment 1). If presented on wet weight basis, the mean concentration of cadmium, mercury and selenium were 0.26 mg/kg Cd, 0.08 mg/kg Hg and 1.3 mg/kg Se in liver from the smaller size sculpin, and 0.90 mg/kg Cd, 0.30 mg/kg Hg and 1.9 mg/kg Se in those from the size group from 25 to 31 cm fork length.

Sculpin livers from the Faroe Islands have also been analysed earlier in the AMAP context (Olsen *et al.*, 2003). In three subsequent years, from 1999 to 2001, sculpin were sampled and analysed for the heavy metals. The interannual variability in sculpin liver mercury concentration has been quite high, with yearly averages for the 20-25 cm group varying from 0.05 mg/kg in 2001 to 1.4 mg/kg in 2000. The 0.08 mg/kg Hg in 2004 is therefore at the lower end of the range observed hitherto. Also the cadmium concentrations have been somewhat variable from a low of 0.20 mg/kg in 1999 and 2001, to 0.38 mg/kg in 2000. The 2004 sculpin liver cadmium concentration is therefore at the mid to low end of this range. The selenium concentration on the other hand, appears to be rather stable in the range 1.3 to 1.6 mg/kg liver for this 20-25 cm size group.

Table 3.1 Cadmium, mercury and selenium in sculpin liver. The metal concentrations are given on a dry weight basis, and summary data are presented for two groups of sculpin, according to the fish fork length.

Length, cm	**n**		**Dry matter*** %	**Cd** mg/kg dw	**Hg**** mg/kg dw	**Se** mg/kg dw
20-25	9	Min.	21	0.15	<0.01	3.3
		Max.	35	2.8	1.2	6.7
		Mean	**26.7**	**1.0**	**0.29**	**4.8**
		Std. dev.	*4.5*	*1.2*	*0.47*	*1.2*
25-31	19	Min.	16	0.15	<0.01	2.7
		Max.	43	15	3.4	15
		Mean	**25.5**	**3.5**	**1.2**	**7.3**
		Std. dev.	*7.5*	*5.1*	*1.1*	*3.8*

* Calculated partly from approximated values (see Attachment 1).
** Analysis results given as “less than detection limit” were treated as being equal to the detection limit in the calculations.

3.2 Black guillemot eggs

The individual mercury data for Black guillemots eggs are given in Table 3.2, with summary results in Table 3.3. The mean mercury concentration in eggs at the two locations was not significantly different, and may be represented by the mean value given in Table 3.3.

Compared to earlier results of egg mercury analyses (Olsen *et al.*, 2003), the mercury level in the 2004 samples are at the same level as those found in the 1999 samples and somewhat higher than in the years in-between in 2000 and 2001, both for the Koltur samples and the Skúvoy samples (Figure 3.1).

Table 3.2 Mercury in Black guillemot eggs

Location:		Koltur		**Location:**		Skúvoy	
ID	**date**	**tissue**	**Hg, mg/kg**	**ID**	**date**	**tissue**	**Hg, mg/kg**
Cg-0247	June 2004	Egg	0.916	Cg-0257	June 2004	Egg	0.274
Cg-0248	June 2004	Egg	0.471	Cg-0258	June 2004	Egg	0.372
Cg-0249	June 2004	Egg	0.181	Cg-0259	June 2004	Egg	0.568
Cg-0250	June 2004	Egg	0.539	Cg-0260	June 2004	Egg	0.916
Cg-0251	June 2004	Egg	0.170	Cg-0261	June 2004	Egg	0.542
Cg-0252	June 2004	Egg	0.365	Cg-0262	June 2004	Egg	0.486
Cg-0253	June 2004	Egg	0.328	Cg-0263	June 2004	Egg	0.664
Cg-0254	June 2004	Egg	0.485				
Cg-0255	June 2004	Egg	0.268				
Cg-0256	June 2004	Egg	0.602				
mean			**0.433**	**mean**			**0.546**
std.dev			*0.224*	*std.dev*			*0.208*
min			0.170	min			0.274
max			0.916	max			0.916

Table 3.3 Summary of mercury in Black guillemot eggs in 2004.

	Hg, mg/kg
N of cases	17
Minimum	0.17
Maximum	0.916
Median	0.485
Mean	**0.479**
Standard Dev	0.219

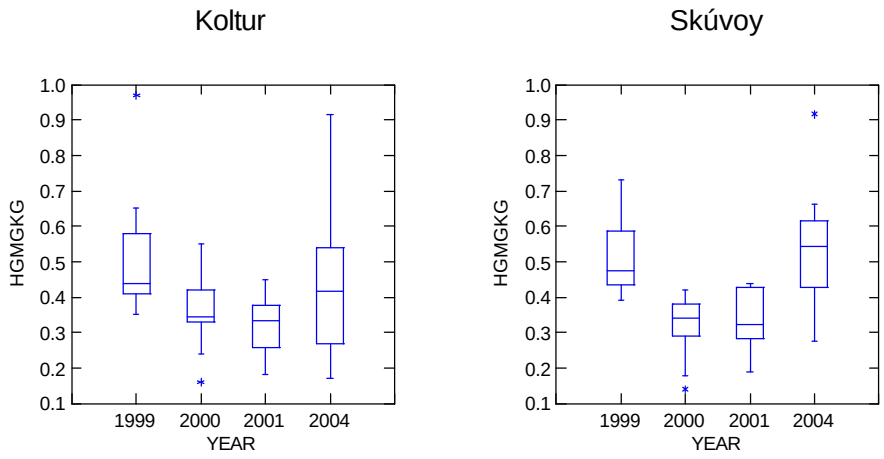


Figure 3.1 Mercury (mg/kg) in Black guillemot eggs from Koltur and Skúvoy.

3.3 Black guillemot liver

The concentration of heavy metals in black guillemot liver was analysed in 8 female and 12 male birds shot for scientific purposes near Sveipur in May 2002. Summary results of mercury, cadmium and selenium are given in Table 3.4 and Figure 3.2. The liver samples were analysed individually and detailed results are given in Attachment 3. Comparing the metal concentrations measured in the birds' livers when the birds are grouped according to sex and reproductive status, Table 3.4, it appears that the mercury and selenium concentrations are different among these groups (Kruskall-Wallis; $p < 0,05$). The concentrations of mercury appear to be higher in the males than in the females, also in the juvenile males. If age was the most decisive parameter one would expect a difference in mercury concentration between the juvenile and the adults at least for one and the same sex.

Table 3.4 Mercury, cadmium and selenium concentration in black guillemot liver 2002 at Sveipur.

Group	Number of birds		Hg, mg/kg	Cd, mg/kg	Se, mg/kg
Adult females	4	Min	0.43	0.56	2.1
		Max	0.58	1.33	2.5
		Mean	**0.48**	**0.95**	**2.3**
		Std.dev	*0.07*	*0.35*	*0.2*
Adult males	7	Min	0.31	0.68	1.5
		Max	1.62	1.77	2.6
		Mean	**0.97**	**0.96**	**2.1**
		Std.dev	*0.45*	*0.38*	*0.3*
Juvenile females	4	Min	0.49	0.65	1.8
		Max	0.74	0.89	2.3
		Mean	**0.63**	**0.79**	**2.1**
		Std.dev	*0.12*	*0.10*	*0.2*
Juvenile males	5	Min	0.80	0.55	1.4
		Max	1.03	1.32	1.8
		Mean	**0.97**	**0.85**	**1.6**
		Std.dev	*0.10*	*0.30*	*0.2*

A glance at Figure 3.2 would indicate that there is a negative correlation between mercury concentration and selenium concentration in the liver samples of the various groups. A Spearman rank correlation ($r_s = -0.428$) analysis involving the 20 individual pairs of metal data indicated that this negative correlation between Hg and Se in black guillemot liver is significant.

Given that there are differences among the groups that may stem from changes in food choice, it is important also to take time of year into consideration when comparing with earlier data, as food choice studies have shown that there is a distinct seasonality in food choice, with fish being the most abundant prey in the late spring to early summer months and decreasing thereafter, making molluscs the winter food type though with a steady intake of crustacea (Dam, 2000). Mercury in black guillemot liver was analysed in black guillemots likewise taken near Sveipur, in sampling events spanning more than one year during the period late 1995 to early 1997 (Dam, 2000; Olsen *et al.*, 2003). Mercury concentrations in adult males (n=12) and adult females (n=6) taken in April 1996 were 0.81 mg/kg and 0.85 mg/kg respectively (Dam, 2000). In the summer of 1996, the liver mercury concentrations in adult males (n=3) and females (n=4) were 1.5 mg/kg[6] and 0.94

[6] The group of adult males contained originally four individuals, but as one of these was an obvious outlier with liver mercury concentration at 3.77 mg/kg; this one was excluded here.

mg/kg (Olsen *et al.*, 2003). It is thus concluded that the level of mercury concentrations measured in birds shot in 2002, is similar to the level recorded for adult males in 1996, but lower than the one measured in adult females.
The groups of adults and juveniles may be rather inhomogeneous with large spans in age in the individuals being assigned to these groups, and thus with an inherent variability in pollutants that do accumulate with age. In the future, better homogeneity will be sought by taking analyses of better-defined age groups, like one consisting only of birds being less than one year.

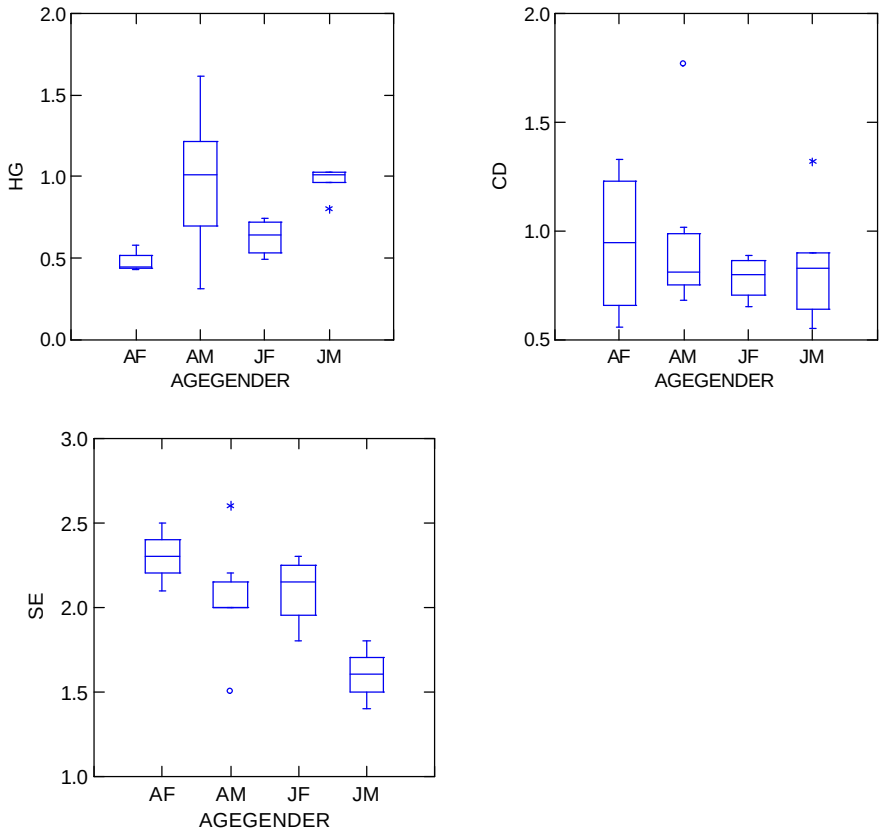


Figure 3.2 Mercury, cadmium and selenium concentrations in black guillemot liver are shown in mg/kg in box plots for groups of birds sampled in 2002. The sorting into groups was done on basis of sexual maturity, as determined from inspection of the gonads upon dissection. The groups are AF: adult females, AM: adult males, juvenile females: JF and juvenile males: JM.

3.4 Pilot whale

Pilot whales sampled in 2001 were analysed for heavy metals and selenium in muscle (n=25) and liver (n=20), and for cadmium in kidney (n=20). The results of heavy metals in the various tissues are shown below in subsections on muscle, liver and kidney data. Individual data are given in Attachment 4.

3.4.1 Muscle

Table 3.5 shows the results of the heavy metals and selenium analyses in pilot whale muscle. The individual data have been combined into groups according to sex and length, but age, which is an important parameter for accumulating compounds like mercury, can only be approximated by whale length up to a certain limit, Figure 3.4. The correlation between muscle mercury and whale length is significant nonetheless (Spearman rank, r_s =0.418, $p<0.05$). The correlation between cadmium in muscle and whale length is however, not that strong

(Spearman rank, r_s =0.370, p<0.10). Selenium in muscle is not correlated to whale length though there is an overall trend towards decreasing concentrations with length.
The heavy metal concentration in muscle is at the same level as was found in previous analyses of pilot whale schools from 1999 and 2000 (Olsen *et al*., 2003), and with a normalised pool Hg average (Dam and Bloch, 2000) at 1.68 mg/kg, this pool may be considered as being at the lower end of the range observed in pilot whales since regular monitoring began in 1997. The mercury concentration was highest in adult males and the cadmium concentration was highest in adult females (Figure 3.3).

Table 3.5 Heavy metals in pilot whale muscle from 27.06.01 (mg/kg ww)

Age and sex group	Number		Dry weight %	Hg	Cd	Se
Juveniles	6	Min	25	0.34	0.04	0.46
		Max	29	1.98	0.13	0.70
		Mean	**27.3**	**1.40**	**0.09**	**0.61**
		Std.dev.	*1.6*	*0.63*	*0.03*	*0.10*
Adult females	14	Min	26	1.33	0.07	0.50
		Max	32	2.75	0.61	0.96
		Mean	**27.7**	**1.82**	**0.30**	**0.64**
		Std.dev.	*1.8*	*0.43*	*0.16*	*0.13*
Adult males	5	Min	26	1.7	0.08	0.36
		Max	29	2.14	0.20	0.72
		Mean	**27.4**	**1.98**	**0.13**	**0.51**
		Std.dev.	*1.1*	*0.17*	*0.05*	*0.14*

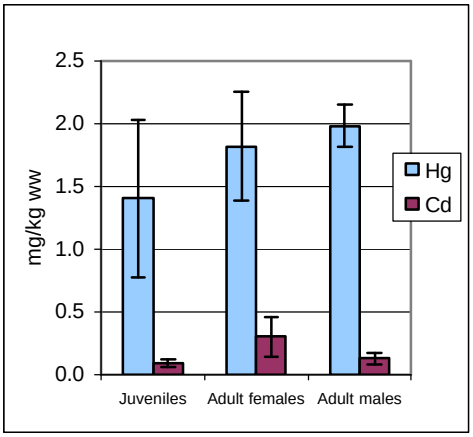


Figure 3.3 Mercury and cadmium in pilot whale muscle from 27.06.01.

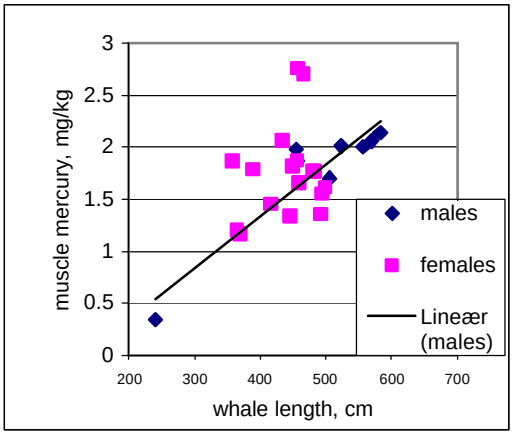


Figure 3.4 Mercury in pilot whale muscle plotted vs. whale length.

3.4.2 Liver

The results of the heavy metal and selenium analyses in liver are shown in Table 3.6. Due to the limited number of individuals, the data have been pooled into two groups, one for females and one for males.

The concentration of Hg in liver showed great variation, with a distinct tendency to increase with increasing whale length (Figure 3.5). Although there was a certain positive correlation between the concentration of Hg in muscle and liver this was not found to be significant (Spearman rank, p(two-tail)>0.05).

The concentration of mercury in muscle is plotted against the liver mercury concentration in Figure 3.6.

Table 3.6 Heavy metals in pilot whale liver from 27.06.01 (mg/kg ww.)

Age and sex group	Number		Dry weight %	Hg	Cd	Se
Males	5	Min	27	24.4	16.1	11
		Max	29	99.7	45.3	46
		Mean	**28.6**	**60.22**	**28.26**	**24**
		Std.dev.	*0.9*	*34.87*	*11.81*	*17*
Females	15	Min	27	11.5	20.1	8
		Max	32	179	76.6	77
		Mean	**29.1**	**75.54**	**45.3**	**39**
		Std.dev.	*1.3*	*48.66*	*17.14*	*22*

Selenium was not correlated to whale length when muscle concentrations were studied, but were however, correlated to length when liver selenium concentrations were analysed (Spearman rank, r_s =0.499, p<0.05). This observation may be tied to the fact that mercury and selenium concentrations in liver were very highly significantly correlated (Spearman rank, r_s=0.935, p<0.01). Liver selenium and cadmium was also correlated, as was liver cadmium and mercury (Spearman rank, p<0.05), though not as strongly as selenium and mercury.

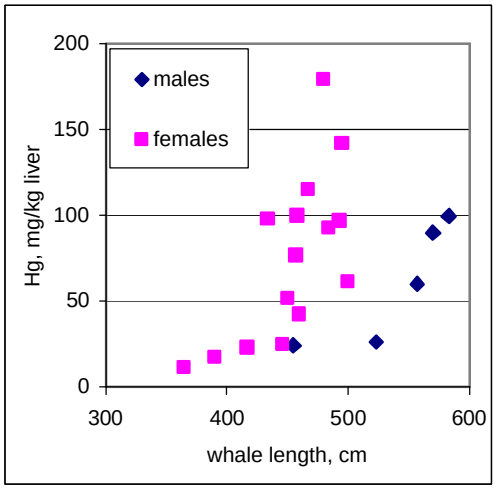


Figure 3.5 Mercury in pilot whale liver plotted vs. whale length.

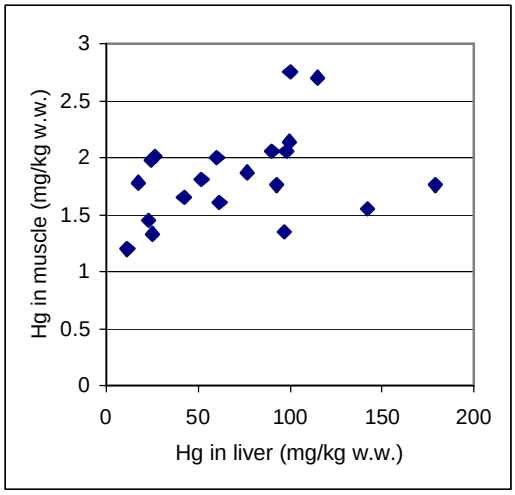


Figure 3.6 Mercury in muscle versus mercury in liver in pilot whale.

3.4.3 Kidney

The kidneys from 20 of the individuals were analysed for cadmium and the results are shown in Table 3.7.

Table 3.7 Cadmium in pilot whale kidney from 27.06.01 (mg/kg ww.).

Age and sex group	Number		Cd
Males	5	Min	42.9
		Max	96.4
		Mean	**74.6**
		Std.dev.	*21.48*
Females	15	Min	50.7
		Max	159
		Mean	**101.1**
		Std.dev.	*31.69*

The cadmium concentrations in pilot whale kidney are lower than in samples from 1999 and 2000 (Olsen *et al*., 2003), where mean values of 110-146 mg/kg and 155-160 mg/kg were found for males and females respectively.

Cadmium in liver and kidney were significantly correlated (Spearman rank, p(two-tail)=0.000), whereas cadmium in muscle was not significantly correlated to either liver or kidney (Figure 3.7 and Figure 3.8).

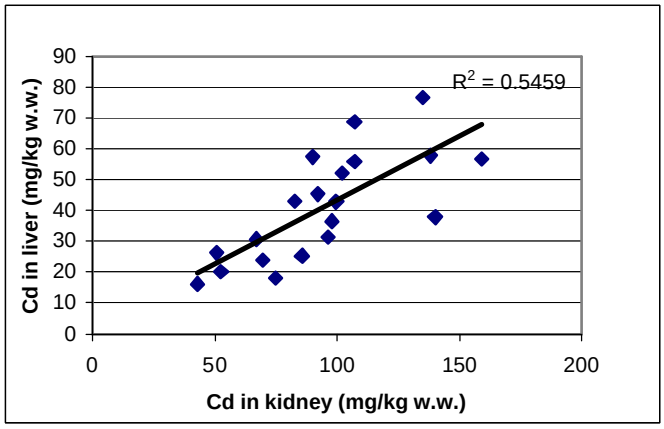


Figure 3.7 Concentration of cadmium in liver versus concentration in kidney of pilot whale from 27.06.01.

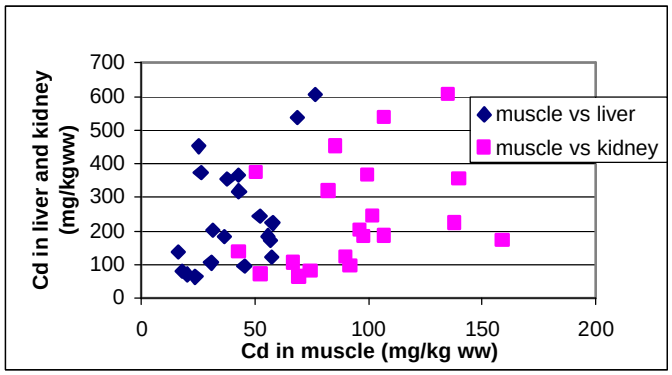


Figure 3.8 Concentration of cadmium in muscle versus concentration in liver and kidney in pilot whale from 27.06.01.

3.5 Mountain hare

The length and weight of the hares are shown in Figure 3.9.

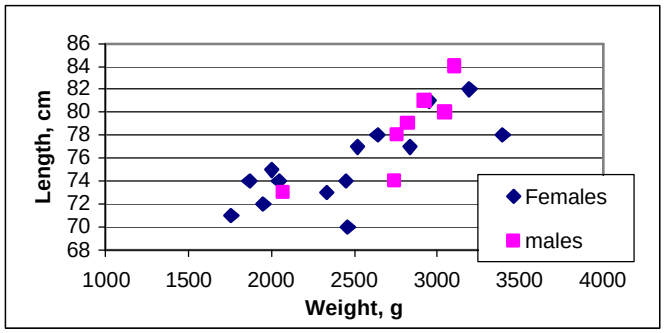


Figure 3.9 Length versus weight of hare from 2001

Table 3.8 and Figure 3.10 and Figure 3.11 show the heavy metal content in hare liver. The levels in 2001 seem to be somewhat higher than in 1999 when the Hg

concentrations were 0.04 mg/kg ww in males and 0.06 mg/kg ww in females, and the Cd concentrations were 0.15 and 0.09 mg/kg ww in males and females respectively (Olsen *et al*., 2003). However, the hare samples from 1999 were divided into juveniles and adults and some of the samples were analysed as pooled samples, and this makes them difficult to compare to the 2001 samples. As an approximation though, a sorting of the 2001 hares was subsequently done according to body weight, as the 1999 material indicated that most juvenile hares weigh less than 2.5 kg. When such a sorting was done on the 2001 material, we got a pool of 9 hares of less than 2.5 kg weight, and two pools each with 6 individuals of either females or males, all above 2.5 kg. The liver mercury concentration in these pools were 0.05, 0.13 and 0.06 mg/kg for these approximated pools of juveniles, adult females and adult males respectively, and those of cadmium are 0.10, 0.37 and 0.25 mg/kg for the same pools.

By treating the data in this manner it becomes obvious that the difference between the 1999 and 2001 hare metal concentrations lie in the adult female pool, which is twice as high in mercury as the adult female pool of 1999, whereas the cadmium concentration in the 2001 adult female pool is more than three times as high as in 1999. Given that the mercury and cadmium concentration increase with weight (Figure 3.10, Figure 3.11), a possible reason for this difference may lie in the fact that the adult females in the 2001 samples generally are larger (heavier and longer) than the 1999 adult females, whereas the juvenile and adult male pools of these two years are more comparable with regard to mean weight and length.

Table 3.8 Mercury and cadmium in hare liver

Gender	n		Hg, mg/kg	Cd, mg/kg	Se, mg/kg
Females	14	Min	0.013	0.030	0.32
		Max	0.286	0.624	1.22
		Mean	**0.089**	**0.219**	**0.62**
		Std.dev.	*0.082*	*0.214*	*0.24*
Males	7	Min	0.029	0.043	0.55
		Max	0.099	0.370	0.90
		Mean	**0.056**	**0.221**	**0.74**
		Std.dev.	*0.022*	*0.124*	*0.12*

As can be seen in Figure 3.10 and Figure 3.11 the mercury concentration in the hares from Norðadalur seems to be higher than in the hares from Signabø, whereas the cadmium concentration seems to be at the same level at both locations. The difference in the mercury concentration was however not found to be significant (t-test, p=0.24).

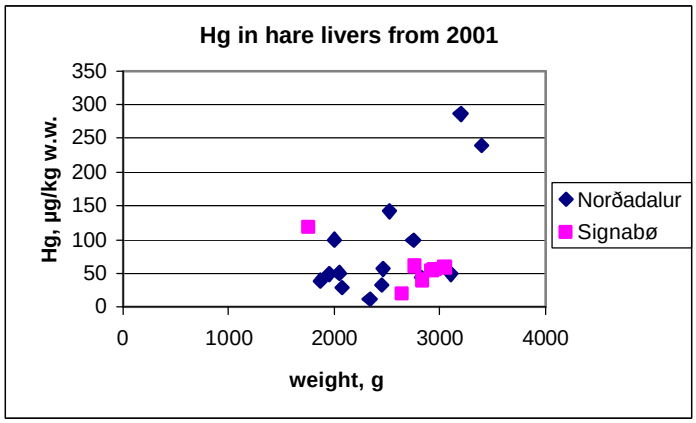


Figure 3.10 Mercury in hare liver versus weight of the hare

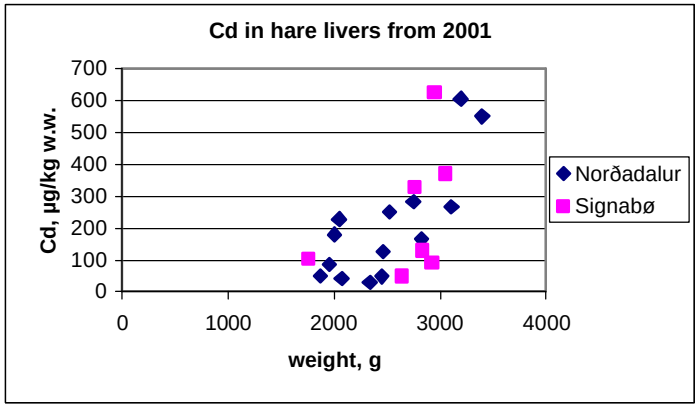


Figure 3.11 Cadmium in hare liver versus weight of the hare

3.6 Sheep

The results of the metal analyses in sheep liver are shown in Table 3.9. The cadmium results show that the adult females have higher values than the juveniles, whereas little difference is seen in the mercury results. The results are comparable to previous analyses of cadmium and mercury in sheep liver from the same location in 1997 and 1999 (Larsen and Dam, 1999; Olsen *et al.*, 2003).

Table 3.9 Metals in sheep liver from 2001 (mg/kg ww.)

	n		Hg, mg/kg	Cd, mg/kg
Adult females	7	Min	<0.010*	0.053
		Max	0.049	0.320
		Mean	**0.017**	**0.173**
		Std.dev.	*0.015*	*0.100*
Juveniles	13	Min	<0.010*	0.022
		Max	0.026	0.174
		Mean	**0.014**	**0.062**
		Std.dev.	*0.006*	*0.048*

*Detection limit for Hg was 0,010 mg/kg. In statistical analysis values below detection limit were replaced by half the value of the detection limit.

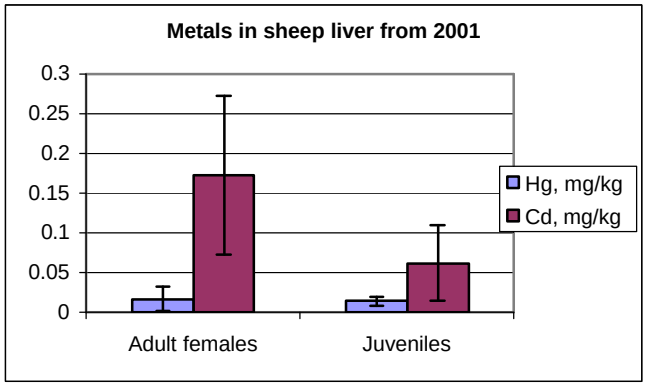


Figure 3.12 Metals in sheep liver from 2001

3.7 Arctic char

The results of the heavy metal results of Arctic char are shown in Table 3.10, and the mean values of mercury and selenium for different size groups of 34-36 cm, 36-37cm and 37 –39 cm fork length (n= 6; 7 and 7) respectively, are shown in Figure 3.13. Overall, the mean mercury in the Arctic char muscle is 0.25 mg/kg and the mean selenium concentration is 1.45 mg/kg. Compared to analyses in 2001 from the same lake, with pool mercury concentrations in the range of 0.21 to 0.26 mg/kg in fish of the same length, these results are very much as expected. They are however, at the high end of mercury concentrations normally encountered in landlocked Arctic char when compared to the findings in Iceland, Norway, Lavrentia in far eastern Russia and several lakes in Canada (AMAP 2002). There are however lakes in Greenland and high Arctic Canada with overall higher mercury concentrations in this fish species, which are, as well as these char from á Mýranar, above the Canadian subsistence food guideline of 0.2 mg/kg (AMAP 2002). As in 2001 selenium is also present in higher concentrations compared to other countries, with a molar surplus of a factor of approx. 15 when seen in relation to mercury.

Table 3.10 Mercury and selenium concentration in Arctic char muscle

Size group	ID	Gender	Length, cm	Weight, g	Condition index	Dry matter %	Hg, mg/kg	Se, mg/kg
34-36 cm	Sa-0108	M	34.3	470	1.16	26	0.185	1.7
	Sa-0103	M	35	480	1.12	23	0.284	1.5
	Sa-0107	M	35	568	1.32	25	0.204	1.6
	Sa-0110	M	35	530	1.24	24	0.243	1.6
	Sa-0115	M	35.2	504	1.16	21	0.262	1.3
	Sa-0117	F	36	510	1.09	26	0.252	1.3
36-37 cm	Sa-0104	M	36.3	480	1.00	20	0.270	1.4
	Sa-0114	F	36.3	536	1.12	24	0.198	1.3
	Sa-0116	M	36.5	556	1.14	23	0.303	1.5
	Sa-0118	F	36.8	538	1.08	25	0.288	1.4
	Sa-0099	M	37	614	1.21	25	0.177	1.7
	Sa-0101	M	37	594	1.17	22	0.267	1.5
	Sa-0109	M	37	400	0.79	19	0.356	1.3
37-39 cm	Sa-0105	M	37.2	568	1.10	22	0.219	1.3
	Sa-0113	M	37.3	512	0.99	21	0.229	1.4
	Sa-0102	M	37.5	524	0.99	21	0.213	1.4
	Sa-0106	M	37.8	604	1.12	21	0.235	1.4
	Sa-0111	M	38	484	0.88	17	0.297	1.3
	Sa-0112	M	38.5	402	0.70	19	0.351	1.4
	Sa-0100	M	38.8	514	0.88	20	0.180	1.6
		Min	34.3	400	0.70	17	0.177	1.3
		Max	38.8	614	1.32	26	0.356	1.7
		Mean	**36.6**	**519.4**	**1.06**	**22.2**	**0.251**	**1.45**
		Std.dev.	*1.25*	*57.92*	*0.15*	*2.5*	*0.05*	*0.14*

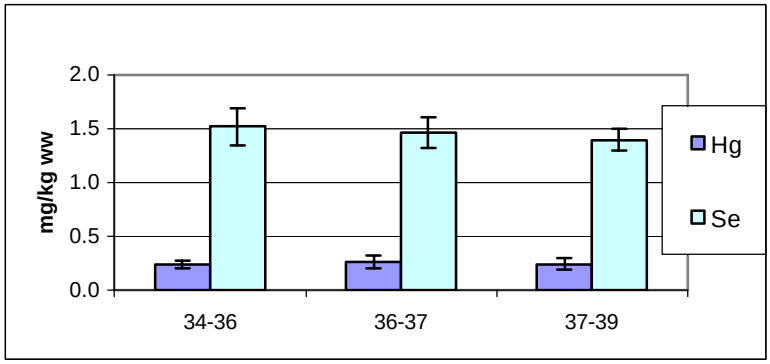


Figure 3.13 Mercury and selenium in Arctic char muscle for different size groups.

3.8 Marine sediments from Kaldbak

Sculpin from Kaldbak are being analysed for metals and POPs in the AMAP context. Earlier results have shown relative high and variable mercury, cadmium and PCB values indicating some local source of metals and PCB in the area. In order to try to locate the source, sediments from Kaldbaksfjørður have been analysed. The possible sources in the area are an oil-fuelled power plant, a military station located on the mountain surrounding Kaldbaksfjørður with a river running from the general areas of the military station into the foot of the Kaldbaksfjørður bay, and a fish processing plant which may be seen as a possible source of biogenic organic material but not a likely source of POPs and heavy metals. Samplings of sediments were done at stations shown in Map 2 with Ka1 innermost in the fjord bay and K05 outermost. Stations Ka3 and Ka4 are off and down current to the power plant where there also is a quay that is only occasionally used by larger fishing vessels and coast guard vessels**.** The quayside has however been used as a handy dump for domestic odd-sized waste like bicycles and prams according to divers.

The KA05 and KA09 sampling sites represent the deeper areas of the fjord. The dating analysis of the KA09 core showed an accumulation rate of 0.95 mm/year (raw data are given in Attachment 8). The dating procedure of the KA05 core showed that there had been some mixing in the sediment layers, making the laboratory unable to date them. Table 3.11 shows the age of the sediment segments at increasing depth of KA09.

Table 3.11 Age of the KA09 sediment based on analyses of ^{210}Pb

KA09	
Sedimentation rate:	0.95 mm/y
Depth mm	Age years
-10	-10.5
-20	-21.1
-30	-31.6
-40	-42.1
-50	-52.6

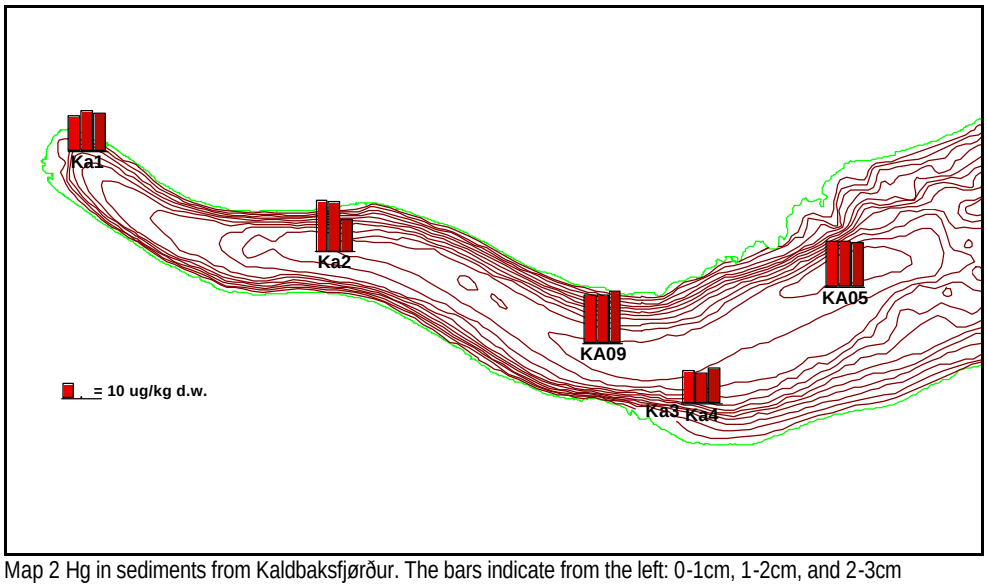
The results of the Hg analysis and organic matter analysis (Loss on Ignition) are shown in Table 3.12. The Hg results are also illustrated in Map 2.

Table 3.12 Mercury and Loss on Ignition in sediments from Kaldbaksfjørður.

	Depth	**Ka1**	**Ka2**	**KA09**	**Ka3**	**Ka4**	**KA05**
Hg	0-1 cm	23.6	34.8	32.9	<17	22.1	31.2
ug/kg dw.	1-2 cm	27	33.9	32.4	<17	20.6	31.3
	2-3 cm	25.5	21.9	35.2	<17	24	30.5
Loss on Ignition	0-1 cm	52.9	117.1	115.8	54.2	73.2	114.6
g/kg dw.	1-2 cm	52.8	110.8	112.9	54	73.7	110.2
	2-3 cm	54.7	108.8	111.7	56.2	80.7	107.8
Hg/LOI	0-1 cm	0.45	0.30	0.28	<0.31	0.30	0.27
ug/g org mat.	1-2 cm	0.51	0.31	0.29	<0.31	0.28	0.28
	2-3 cm	0.47	0.20	0.32	<0.31	0.30	0.28

The stations with the highest depth (Ka2, KA09, and KA05; depth>50m) seem to have the highest load of mercury and highest content of organic matter, shown by the loss on ignition. This is most likely due to sediment cumulation at the deepest parts of the fjord. The high loss on ignition also means that mercury has a tendency to end up there due to its affinity for organic material, and therefore, a mercury term corrected for the organic content has been calculated (last rows of Table 3.12).

Looking at these corrected mercury concentrations, it becomes apparent that the highest concentration of mercury per unit of organic material is in fact present in the innermost sampling stations and decreasing out in the fjord. Also, it is seen that the highest corrected mercury concentration is found in the surface –1 to -2 cm segment.



Map 2 Hg in sediments from Kaldbaksfjørður. The bars indicate from the left: 0-1cm, 1-2cm, and 2-3cm segments.

3.9 Marine sediments from Sandoyarbanki

Metals in sediments can be redistributed due to diagenesis, which can be explained as chemical and physical changes of the sediments originating from changes in oxygen concentrations in the near-bottom water column. Chemical changes are mostly driven by redox reactions. Manganese, Mn, and iron, Fe, are metals that are known to redistribute due to diagenesis. The formation of manganese- and iron oxides can make the metals diffuse upwards and accumulate at the interface between reduced and oxidized sediment resulting in profiles, which do not show the actual metal sedimentation history. Since manganese and iron are not expected to increase with anthropogenic pollution, the concentration of these metals can give a picture of the amount and behaviour of naturally occurring metals in sediments and be compared to the profiles of other metals, which may have been added by anthropogenic pollution.

Marine sediments from Sandoyarbanki, sampled in 2000 were analysed for Mn and Fe. The samples have previously been dated and analysed for Hg (Olsen *et al.*, 2003). The results of the Fe and Mn analyses for each of the dated segments are shown in Table 3.13 In Attachment 9 the analyses data are given along with some calculated values.

In Figure 3.14 the concentration of mercury, iron and manganese as well as the ratio of mercury to iron and manganese are shown vs. sediment core segment age. The correlation between the three metals was analysed by non-parametric correlation analyses (Table 3.14). Overall, manganese and iron are strongly correlated in the samples from the four cores, also when seen separately. Given however, that the four cores are apparently different in terms of both the absolute metal concentration and how these changes with depth (or with age as given in Figure 3.14) it seems more appropriate to analyse the metal concentration correlations for the four cores separately.

When the four cores are treated separately mercury is significantly correlated to iron or manganese in two out of four cores, though simultaneously correlation to

both the “diagenetic” metals is only seen in core 4. The statistics thus indicate that mercury may or may not follow iron or manganese, and thus that the increase in mercury in the sediments segments deposited during last century could or could not be natural and not necessarily a consequence of increased antropogenic input.

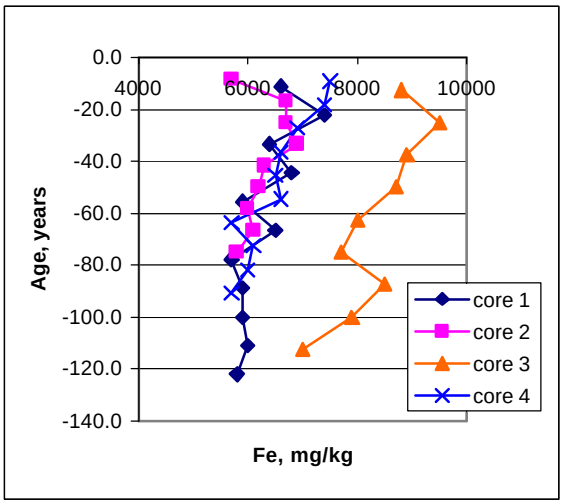
A visual inspection of the graphs in Figure 3.14, also those depicting the ratio between mercury and iron or manganese, do not strengthen the assumption of a common source and influx of these metals. The correlation found between Mn and Fe on the other hand, is plausible also upon a visual inspection of the graphs. Though, this correlation does not necessarily indicate that the cores in general have been subjected to diagenetic shifts in Fe and Mn concentrations in the timespan shown, it may just as well be interpreted as an indication that the source of Mn and Fe deposited in this period has been the same. In core 4, however, we notice that the correlation between Hg and Fe and Mn is closer than in the other cores, and in this case, diagenesis is more easily accepted as the pattern maker.

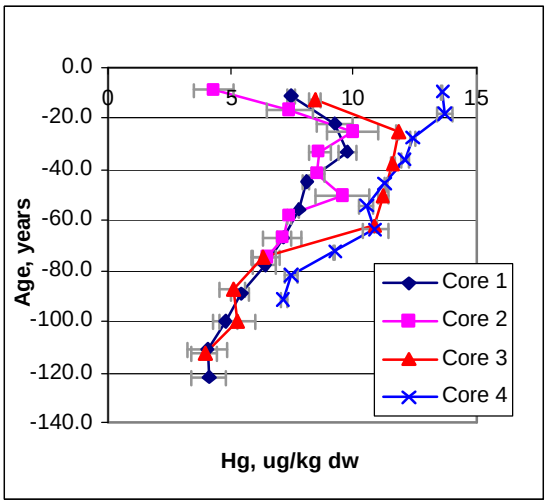
Table 3.13 Fe and Mn in sediments from Sandoyarbanki in 2000.

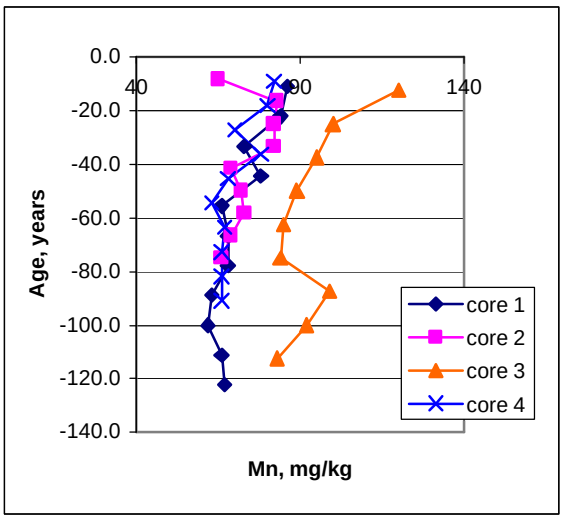
	Core 1			**Core 2**			**Core 3**			**Core 4**		
Sed. rate	0.9 mm/y			1.2 mm/y			0.8 mm/y			1.1 mm/y		
Depth in mm	**Age,** years	**Fe,** mg/kg	**Mn,** mg/kg	**Age,** years	**Fe,** mg/kg	**Mn,** mg/kg	**Age,** years	**Fe,** mg/kg	**Mn,** mg/kg	**Age,** years	**Fe,** mg/kg	**Mn,** mg/kg
-10	-11.1	6600	86	-8.3	5700	65	-12.5	8800	120	-9.1	7500	82
-20	-22.2	7400	84	-16.7	6700	83	-25.0	9500	100	-18.2	7400	80
-30	-33.3	6400	73	-25.0	6700	82	-37.5	8900	95	-27.3	6900	70
-40	-44.4	6800	78	-33.3	6900	82	-50.0	8700	89	-36.4	6600	78
-50	-55.6	5900	66	-41.7	6300	69	-62.5	8000	85	-45.5	6500	68
-60	-66.7	6500	68	-50.0	6200	72	-75.0	7700	84	-54.5	6600	63
-70	-77.8	5700	68	-58.3	6000	73	-87.5	8500	99	-63.6	5700	67
-80	-88.9	5900	63	-66.7	6100	69	-100.0	7900	92	-72.7	6100	66
-90	-100.0	5900	62	-75.0	5800	66	-112.5	7000	83	-81.8	6000	66
-100	-111.1	6000	66							-90.9	5700	66
-110	-122.2	5800	67									

Table 3.14 Spearman rank correlation coefficients for the metal concentrations of the four cores analysed separately and combined. Significant or highly significant correlation (two-tailed, $p<0.05$ or <0.01) is marked by* or ** respectively.

rs	Core 1	Core 2	Core 3	Core 4	Core 1-4
n	11	9	9	10	39
Hg vs Mn	0.676*	0.630	0.400	0.890**	0.292
Hg vs Fe	0.615	0.728	0.817*	0.854**	0.424**
Mn vs Fe	0.687*	0.831*	0.817*	0.691*	0.871**







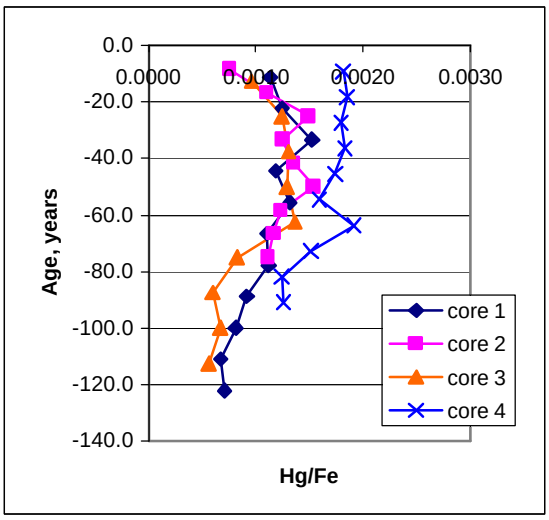
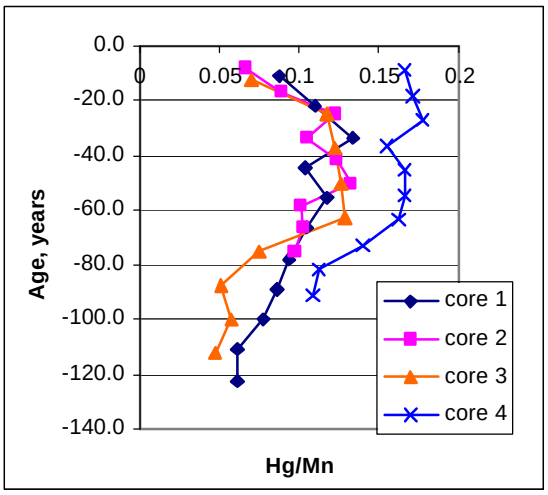


Figure 3.14 Marine sediments from Sandoyarbanki.



4 POP results

4.1 Sculpin

POPs like PCB and the pesticides DDT and the DDT derivates, toxaphene and chlordanes were analysed in sculpin liver. The individual analyses results are given in Attachment 1. POPs have previously been analysed in sculpin from Kaldbaksfjørð in 1999, 2000 and 2001 (Hoydal *et al.*, 2003). As with mercury, the concentration of PCB in sculpin liver recorded this far have been variable, with concentration of CB 153 for the size group 20-25 cm varying from 740 µg/kg lw in 1999 to 1760 µg/kg lw in 2000 and down again to 620 µg/kg lw in 2001. In 2004, the concentration has decreased even further to 186µg/kg lw (Table 4.1) making the 2004 samples the lowest hitherto recorded with respect to PCB. DDT was overall not detected, but the metabolite p,p´-DDE was, with a mean of 131 µg/kg lw in the 20-25 cm size group, compared to concentrations in the range 250 to 2340 µg/kg lw in 1999 to 2001, again making the 2004 samples record low. Toxaphene as Parlar 50 was found at a mean value of 10 µg/kg lw in the 2004 samples, compared to means in the range of 18 - 129 µg/kg lw in earlier analyses. Also mirex, trans-nonachlor and HCB has been recorded in the 2004 in concentrations which are less than has been recorded in the earlier years, where overall highest concentrations were recorded in 2000. Overall, when comparing concentration of representatives of the compounds detected in 2000 to the ones detected in 2004, in the same species in the same fjord, it is noted that the relative decrease in concentration is not the same for every compound, but decreases in the order mirex> DDE= trans-nonachlor> Par50 = CB153> HCB, meaning that the concentration of mirex has decreased the most, and that of HCB the least.

Table 4.1 PCB in sculpin liver (µg/kg of lipids).

Year	Length	n		Lipids %	Aroclor 1260	CB 153	PCB 7*
2004	20-25 cm	7	Min	4.1	717	87.7	192
			Max	19.5	2640	303.9	704
			Mean	**13.0**	**1500**	**185.7**	**413**
			Std.dev.	*6.3*	*639*	*73.7*	*177*
	25-30 cm	13	Min	1.4	1275	154.2	337
			Max	26.7	8591	977.5	2194
			Mean	**9.6**	**3814**	**450.6**	**1082**
			Std.dev.	*8.7*	*2268*	*255.7*	*642*

*When results were reported as not detected, half of the detection limit was used in the calculation of PCB7.

Table 4.2 Toxaphene and p,p'-DDE in sculpin liver (µg/kg of lipids).

Year	Length	n		Toxaphene			p,p'-DDE
				Parlar no. 26 (T2)*	**Parlar no. 50** (T12)	**Parlar no. 62** (T20)*	
2004	20-25 cm	7	Min	0.4	8.3	0.3	59.5
			Max	6.1	12.5	3.5	306.9
			Mean	**3.4**	**10.0**	**1.8**	**130.8**
			Std.dev.	*2.0*	*1.6*	*1.2*	*82.3*
	25-30 cm	13	Min	0.2	0.8	0.2	86.2
			Max	12.0	19.4	10.2	579.3
			Mean	**3.6**	**7.6**	**3.3**	**264.2**
			Std.dev.	*3.3*	*7.0*	*3.7*	*145.5*

*Some individual analyses results were lower than the detection limit. When analytical data reported as "not detected" were used in calculations of the mean, half of the detection limit was used.

Table 4.3 Organochlorine pesticides in sculpin liver (µg/kg of lipids).

Year	Length	n		ß-HCH*	alpha-chlordane*	gamma-chlordane	cis-nonachlor	hexa-chloro-benzene	mirex	oxychlordane	trans nonachlor
2004	20-25 cm	7	Min	0.5	0.4	ND	8.7	7.1	1.1	13.2	10.2
			Max	3.1	1.1	ND	19.1	12.2	5.3	21.2	22.6
			Mean	**1.1**	**0.7**	ND	**13.4**	**8.8**	**2.3**	**16.5**	**14.9**
			Std.dev.	*0.9*	*0.3*	ND	*3.6*	*1.7*	*1.6*	*3.0*	*4.3*
	25-30 cm	13	Min	0.4	0.1	ND	3.4	6.5	1.6	15.6	10.9
			Max	10.2	3.4	ND	52.3	32.1	21.0	51.6	55.0
			Mean	**3.1**	**1.2**	ND	**22.0**	**12.7**	**7.5**	**26.1**	**19.9**
			Std.dev.	*3.7*	*1.2*	ND	*11.7*	*8.4*	*6.9*	*9.5*	*12.0*

* Some individual analyses results were lower than the detection limit. When analytical data reported as "not detected" were used in calculations of the mean, half of the detection limit was used.

4.2 Black guillemot eggs

Black guillemot eggs sampled on the islands Koltur and Skúvoy were analysed for POPs as in 1999, 2000 and 2001 (Hoydal *et al.*, 2003). The concentration of PCB as CB 153 was found to decrease in the three consecutive years, from approx. 1050 µg/kg lw in 1999 to 470 µg/kg lw in 2001. With the 2004 analyses results of CB 153 at approx. 850 µg/kg lw (mean of the two sampling locations, Table 4.4) it is noted that the decrease occurring at the turn of the millennium did not continue. Concentrations of mirex (Table 4.6) appear to follow the same trend in going from 57 µg/kg lw to 39 µg/kg to lw 30 µg/kg lw in the period 1999 to 2001, and upwards again in 2004. For DDE, Parlar 50 and trans-nonachlor a steadier trend is indicated though with a possible high in 2001, and with overall means for 2004 being the lowest hitherto (Table 4.5). HCB in 2004 was lower than in 1999 – 2001, and appears to be on a steadily decreasing trend (linear regression analyses; coeff.=-11.6; p= 0.003).

Table 4.4 PCB in black guillemot eggs (µg/kg of lipids).

Year	Location	n		Aroclor 1260 mg/kg of lipids	PCB 7*	CB 153
2004	Koltur	10	Min	2654	738	405
			Max	12705	3370	1777
			Mean	**6135**	**1672**	**896**
			Std.dev.	*2890*	*763.2*	*398.4*
	Skúvoy	7	Min	3698	1005	524
			Max	8460	2262	1178
			Mean	**5678**	**1518**	**799**
			Std.dev.	*1850*	*485.3*	*243.1*

* When results were reported as not detected, half of the detection limit was used in the calculation of PCB7.

Table 4.5 Toxaphene and p,p'-DDE in black guillemot eggs (µg/kg of lipids).

Year	Location	n		% Lipids	Parlar no. 26 (T2)*	Parlar no. 50 (T12)	Parlar no. 62 (T20)*	p,p'-DDE
2004	Koltur	10	Min	4.7	0.2	36.9	0.5	215.7
			Max	9.6	35.3	207.0	32.8	899.0
			Mean	**7.6**	**18.4**	**77.9**	**13.5**	**439.2**
			Std.dev.	*1.27*	*10.2*	*48.7*	*9.4*	*201.4*
	Skúvoy	7	Min	4.6	0.2	0.2	8.2	200.9
			Max	10.5	25.1	97.1	21.2	391.9
			Mean	**7.3**	**14.5**	**56.0**	**15.2**	**281.6**
			Std.dev.	*2.05*	*7.8*	*32.2*	*4.9*	*73.6*

* Some individual analyses results were lower than the detection limit. When analytical data reported as "not detected" were used in calculations of the mean, half of the detection limit was used.

Table 4.6 Organochlorine pesticides in black guillemot eggs (µg/kg of lipids).

Year	Location	n		ß-HCH	alpha-chlordane*	cis-nonachlor	hexa-chloro-benzene	mirex	oxychlordane	trans nonachlor
2004	Koltur	10	Min	11.3	0.17	14.1	87.0	21.3	21.2	8.4
			Max	28.7	0.63	70.5	154.7	62.4	80.5	20.3
			Mean	**17.0**	**0.45**	**31.6**	**123.7**	**35.4**	**40.7**	**12.8**
			Std.dev.	*5.0*	*0.14*	*17.5*	*21.2*	*11.8*	*18.0*	*5.1*
	Skúvoy	7	Min	14.3	0.10	18.6	92.7	26.4	22.3	7.4
			Max	19.1	0.63	35.3	126.2	66.9	50.5	15.2
			Mean	**16.7**	**0.42**	**27.2**	**112.5**	**39.9**	**33.4**	**11.1**
			Std.dev.	*1.89*	*0.20*	*7.76*	*11.9*	*13.2*	*9.64*	*2.72*

* Some individual analyses results were lower than the detection limit. When analytical data reported as "not detected" were used in calculations of the mean, half of the detection limit was used.

4.3 Pilot whale

Monitoring of POPs in pilot whales is done more due to its importance as a vector of POPs to the Faroese human population and concern for the whales' living in such a high pollution regime, than due to its usefulness in detecting trends in environmental pollution. The concentration of POPs varies between schools according to factors like food preference, area of foraging, age and sex and, for females, very likely the number of calves she has given birth to and suckled.

POPs have been analysed in pilot whales since the late 1980s. At that time, a quantification of PCB using mixtures of congeners in commercial formulas like Aroclor 1254 or Aroclor 1260 or a mixture of both was common practise. When more regular monitoring of pilot whales began in the mid 1990s, a method of quantifying PCB using discrete congeners had become standard, and thus comparison to older data was not straightforward. An additional hindrance to detecting time trends in POPs concentration in pilot whales in general is the application of sample pooling strategies occasionally used, thus rendering rigorous data analyses difficult. In 2001, samples were taken of pilot whales in the drive kill in Vestmanna in June. In Table 4.7 to Table 4.10 a summary of the results of POPs analyses in blubber in 25 individual whales are given. Details of the results are given in Attachment 4.

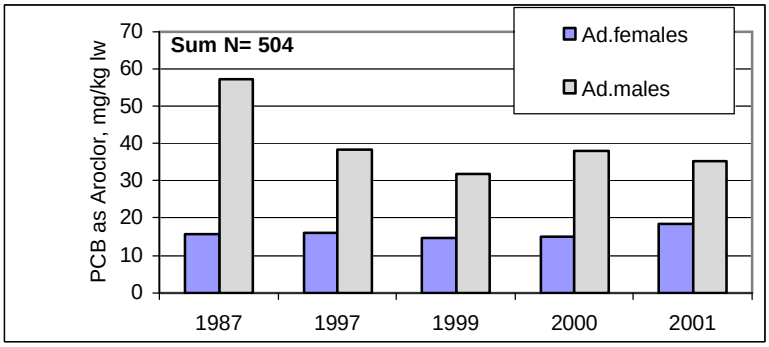


Figure 4.1 PCB as Aroclor in pilot whale blubber samples from the Faroe Islands (data adapted from Hoydal and Dam, 2004).

In Figure 4.1 PCB concentration in groups of adult female and male samples from 1987 to 2001 are given as Aroclor 1254:1260 (1:1) or 1260 equivalents. Inspection of PCB results in Table 4.7 reveals that a presentation of PCB as PCB 7 would be equivalent to 6 and 11 mg/kg lw in the adult females and males respectively in the 2001 samples, meaning that PCB when expressed as Aroclor units appears in figures approx. three times the PCB 7 concentration. Interpretation of the relative magnitude of the bars in Figure 4.1 must be done taking into consideration the

various uncertainties that are hard to quantify. It seems justified though, to interpret it as depicting a decrease in PCB blubber concentration among the adult males, although this decrease is not seen among the adult females.

Table 4.7 PCB in pilot whale blubber from 27.06.01(µg/kg of lipids).

Age and sex group	**Number of whales**		**Length cm**	***Skinn*[7]**	**Lipids %**	**Aroclor 1260** mg/kg of lipids	**PCB 7** µg/kg of lipids	**CB 153** µg/kg of lipids
Juveniles	6	Min	240	2	49.7	21122	7537	2345
		Max	457	13	95.4	87998	28592	10735
		Mean	**374**	**6.5**	**82.0**	**47631**	**15195**	**5396**
		Std. dev.	*79.7*	*3.9*	*18.1*	*28083*	*8661*	*3415*
Adult females	14	Min	390	7	27.1	6498	2107	684
		Max	500	12	96.6	33211	11185	3592
		Mean	**459**	**9.4**	**77.0**	**18422**	**6122**	**2034**
		Std. dev.	*31.2*	*1.3*	*26.5*	*8614*	*2768*	*934*
Adult males	5	Min	506	12	61.1	19573	6340	2168
		Max	583	17	93.3	53393	16927	5933
		Mean	**548**	**14.8**	**85.8**	**35176**	**11222**	**3928**
		Std. dev.	*32.3*	*2.3*	*13.9*	*14501*	*4647*	*1604*

Table 4.8 Toxaphene in pilot whale blubber from 27.06.01 (µg/kg of lipids).

Age and sex group		**Parlar no. 26** (T2)	**Parlar no. 32** *	**Parlar no. 50** (T12)	**Parlar no. 62** (T20)	**Parlar no. 69**
Juveniles	Min	1784	0.4	2517	335	ND
	Max	4543	12.6	6156	1244	ND
	Mean	**2704**	**2.9**	**4103**	**724**	**ND**
	Std.dev.	1261	*4.8*	1532	311	ND
Adult females	Min	292	0.4	611	198	ND
	Max	2464	10.4	4033	613	ND
	Mean	**1218**	**3.9**	**2131**	**404**	**ND**
	Std.dev.	598	*3.6*	914	108	ND
Adult males	Min	1163	0.4	2077	364	ND
	Max	2471	10.1	3520	513	ND
	Mean	**1848**	**3.6**	**2831**	**450**	**ND**
	Std.dev.	628	*4.5*	665	53.9	ND

* Some individual analyses results were lower than the detection limit. When analytical data reported as "not detected" were used in calculations of the mean, half of the detection limit was used.

Toxaphene, as Parlar 50, was analysed in samples from several pilot whale schools in 1997 and found to be 2.3 mg/kg lw in juveniles (n=173), 2.2 mg/kg lw in adult males (n=52) and 1.1 mg/kg lw in adult females (n=193; Dam and Bloch, 2000). In 1999, 2000 and 2001 toxaphene has been analysed in pilot whales as well (Hoydal *et al.*, 2003) and when the analyses results of these earlier years are compared to the 2001 data (Table 4.8) a tendency of increasing toxaphene concentration is seen in the three groups of juveniles, adult females and males.

[7] *Skinn* is a special Faroese unit for measuring the whale size based on an assessment of the mass fit for human consumption.

DDT was analysed in a large number of pilot whales sampled in 1986-88 and again in 1997. The concentration of total DDT[8] in adult females in 1987 (n=113) was 9.2 mg/kg lw, and 50.9 mg/kg lw in adult male (n=11) (Borrell and Aguilar, 1993). In 1997, the total DDT concentration was 6.3 mg/kg lw in adult females (n=193) and 17.7 mg/kg lw in the adult males (n=54), whereof the major part (approx. 65 %) was p,p´-DDE (Dam and Bloch 2000). In 2000 the proportion of total DDT made up by the very persistent metabolite p,p´-DDE was on average 70%, and using this as an approximation for the 2001 data as well, we may estimate a total DDT concentration in adult females and males to be 7.5 mg/kg lw and 16.5 mg/kg lw respectively. It appears thus, that the decrease in DDT that was seen when going from 1987 to 1997, especially in the juveniles (not shown) and adult males, has not continued.

In 1997, the mean concentrations of HCB in juveniles, adult females and adult males were 480 µg/kg lw, 220 µg/kg lw and 360 µg/kg lw respectively (Dam and Bloch, 2000). In 1999 and 2000 the average HCB concentration in the four schools analysed (Hoydal *et al.*, 2003) had been in the range of 226 to 340 µg/kg lw in adult females and 370 to 450 µg/kg lw in adult males and hence the concentrations found in the 2001 samples, 380 and 447 µg/kg lw in adult female and males respectively, do not appear to have changed much.

Trans-nonachlor is the chlordane compound occurring in highest concentration in pilot whales. In 1997, the average concentration of trans-nonachlor in juveniles was 2.2 mg/kg lw, in adult females and males it was 0.9 and 2.0 mg/kg lw (Dam and Bloch, 2000). As with the other POPs, trans-nonachlor has been analysed in four schools in 1999 (n=67) and 2000 (n=74) (Hoydal *et al.*, 2003), and with the present 2001 results a picture emerges of increasing rather than decreasing chlordane concentrations in pilot whales. The apparent increases may not be statistically significant, but they may still warrant a close watch on the POPs in pilot whales also in the future, being as it is, an important part of the Faroese subsistence diet.

Table 4.9 p,p'-DDE in pilot whale blubber from 27.06.01 (µg/kg of lipids).

Age and sex group		**p,p'-DDE**	**p,p'-DDT**
Juveniles	Min	6074	1362
	Max	38974	3002
	Mean	**16381**	**1864**
	Std.dev.	*12685*	*692*
Adult females	Min	1371	384
	Max	10489	1553
	Mean	**5281**	**964**
	Std.dev.	*2502*	*364*
Adult males	Min	5413	939
	Max	20417	1996
	Mean	**11566**	**1468**
	Std.dev.	*6092*	*493*

[8] total DDT = p,p´-DDT + p,p´-DDE + p,p´-DDD + o,p´-DDT.

Table 4.10 Organochlorine pesticides in pilot whale blubber from 27.06.01 (µg/kg of lipids).

Age and sex group		ß-HCH	alpha-chlordane	gamma-chlordane	cis-nonachlor	hexa-chloro-benzene	mirex	oxychlordane	trans nonachlor
Juveniles	Min	24.1	270	7.5	640	357	47	391	2316
	Max	58.5	658	36.8	1643	1131	176	1001	7072
	Mean	**40.4**	**464**	**16.0**	**1036**	**645**	**120**	**606**	**4098**
	Std.dev.	*13.4*	*147*	*10.7*	*442*	*285*	*44.7*	*293*	*2110*
Adult females	Min	12.4	88	6.2	133	83	55	57	469
	Max	38.5	512	18.4	896	555	164	433	3391
	Mean	**23.4**	**248**	**11.9**	**470**	**380**	**94**	**266**	**1844**
	Std.dev.	*7.71*	*105*	*2.9*	*209*	*132*	*30.6*	*114*	*893*
Adult males	Min	20.1	187	9.3	451	341	68	264	1756
	Max	38.1	411	14.2	1043	607	174	547	4070
	Mean	**28.1**	**314**	**12.5**	**713**	**447**	**123**	**419**	**2908**
	Std.dev.	*8.52*	*96.1*	*2.0*	*253*	*111*	*48.1*	*144*	*1050*

4.4 Mountain hare

In going from the marine species to the terrestrial non-avian species, like hare and Arctic char, the pathway by which contaminants may enter is reduced to one of solely air and depositional transport. This restricted input along with other factors is manifested in the very low if at all detectable concentrations of POPs in hare liver (Table 4.11). Of the in all 28 analysed compounds (Attachment 7; 14 congeners of PCB, 5 of toxaphene, 5 chlordanes etc.), only four were detected in one or more individual hares; HCB was detected in all samples, oxychlordane in all but one, and CB 153 and mirex were detected in 2 and 4 respectively of the 21 samples of hare livers. HCB and oxychlordane are present in similar mean concentration of 32 and 34 µg/kg lw respectively, while CB 153 and mirex was present in concentrations from 2 to 4 µg/kg lw in the individuals where it could be detected.

POPs in hare liver samples from 1997 (n=3) and 1999 (n=13) were reported by Hoydal *et al.*, 2003. In these older samples HCB was recorded at 11 to 123 µg/kg lw, with the highest concentrations in the juvenile hares (mean 46 µg/kg lw) and on average 26 µg/kg lw in the adult hares in 1999. The concentration of oxychlordane in the 1999 samples were very similar to the HCB concentration in the same samples and was found to be 26 µg/kg lw in the adults and 40 µg/kg lw in the juveniles. In the 2001 samples, the sorting into juveniles and adults was not done, and thus the overall averages of 32 µg/kg lw and 34 µg/kg lw of HCB and oxychlordane should be compared with caution to the 1999 data. If a rough sorting of the individuals is done into groups weighing more or less than 2,5 kg, where the lower body mass group would represent the juveniles, then an average of 25 µg/kg lw and 40 µg/kg lw of HCB are calculated for the two groups of less and more than 2,5 kg respectively (that is the opposite of what was seen in 1999).

Table 4.11 POPs in hare liver from 2001 (µg/kg of lipids).

Age and sex group	n		Lipids %	Aroclor 1260 mg/kg of lipids	CB 153	pp'-DDE	hexa-chloro benzene	oxy chlor dane
Females	14	Min	1.6	ND	ND	ND	10.9	1.4
		Max	2.6	ND	ND	ND	205.0	50.3
		Mean	**2.1**	ND	ND	ND	**37.8**	**25.9**
		Std. dev.	*0.3*	ND	ND	ND	*49.1*	*12.5*
Males	7	Min	1.4	ND	ND	ND	12.6	30.8
		Max	2.7	ND	ND	ND	42.3	49.1
		Mean	**1.9**	ND	ND	ND	**25.9**	**41.0**
		Std. dev.	*0.4*	ND	ND	ND	*9.1*	*6.7*

4.5 Arctic char

POPs in 2004 Arctic char samples are given as summary data in Table 4.12 and Table 4.13, and in detail in Attachment 5.
In the 2004 samples POPs were not correlated to fish fork length as the concentration of PCB (as CB 153), DDT (as p,p´-DDE), chlordane (as trans-nonachlor) and toxaphene (as Parlar 50) had been in the 2000 samples were the total range of fish length was only marginally wider (+4%) than in 2004 (Hoydal *et al.*, 2003).

In 2001, Arctic char were analysed in pools of individuals with comparable length, and also for these samples a clear correlation between POPs concentration and pool mean length was seen. HCB appears to be different in that it was not correlated to fish length in the three years from which analyses results are available at present. It was however, the parameter closest to being significantly correlated to length in the 2004 samples, and these may thus be regarded as somewhat different from the earlier samples also in this respect. With regards to the actual concentration of the various POPs except for HCB, the 2004 samples were not much different from the earlier ones(Figure 4.2).

Table 4.12 PCB in Arctic char muscle (µg/kg of lipids). Note that the Sum of the seven PCB normally denoted PCB 7 were not calculated due to the abundance of results reported as less than the limit of detection.

Length	n		Lipids %	Aroclor 1260 µg /kg of lipids	CB 153 µg/kg of lipids
34-36 cm	6	Min	0.7	156	17.5
		Max	1.9	464	56.7
		Mean	**1.3**	**283**	**33.1**
		Std. dev.	*0.51*	*143.2*	*18.1*
36-37 cm	7	Min	0.3	127	15.4
		Max	2.7	1135	143.1
		Mean	**1.1**	**444**	**53.8**
		Std. dev.	*0.94*	*356.8*	*45.3*
37-39 cm	7	Min	0.2	318	36.7
		Max	1.1	859	102.3
		Mean	**0.6**	**533**	**64.2**
		Std. dev.	*0.33*	*203.7*	*25.4*

Table 4.13 Organochlorine pesticides and toxaphene in Arctic char muscle (µg/kg of lipids).

Length	n		pp' - DDE *	Toxaphene Parlar no. 50 (T12)*	alpha-chlordane*	cis-nonachlor*	hexachlorobenzene*	oxychlordane*	trans-nonachlor*
34-36 cm	6	Min	36.1	1.6	5.0	1.6	26.0	2.8	7.3
		Max	87.3	18.8	10.3	7.3	29.2	5.2	18.3
		Mean	**56.8**	**9.3**	**7.1**	**3.9**	**27.5**	**3.6**	**11.4**
		Std. dev.	*23.4*	*7.58*	*1.97*	*2.14*	*1.21*	*0.82*	*4.49*
36-37 cm	7	Min	21.3	0.9	4.1	2.8	23.5	2.8	6.6
		Max	108.0	23.5	10.3	7.0	46.8	7.0	16.8
		Mean	**65.2**	**8.7**	**6.8**	**4.6**	**35.7**	**4.6**	**10.2**
		Std. dev.	*33.9*	*8.21*	*1.84*	*1.61*	*9.28*	*1.59*	*4.03*
37-39 cm	7	Min	8.6	4.4	2.9	ND	12.8	ND	6.9
		Max	112.9	15.9	12.8	ND	52.0	ND	12.9
		Mean	**67.8**	**10.7**	**7.2**	ND	**33.4**	ND	**10.6**
		Std. dev.	*34.4*	*4.04*	*3.32*	ND	*13.6*	ND	*2.18*

* Some individual analyses results were lower than the detection limit. When analytical data reported as "not detected" were used in calculations of the mean, half of the detection limit was used.

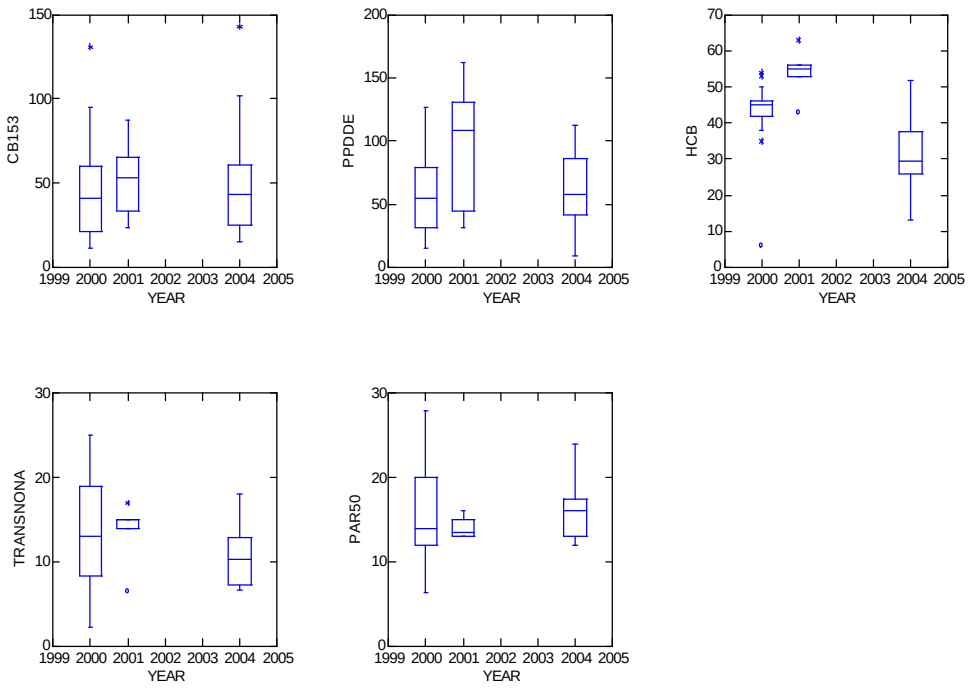


Figure 4.2 Box plots of concentration of POPs in µg/kg lw in muscle in Arctic char from á Mýranar (data from the present work and adapted from Olsen *et al.*, 2001). Note that the box plot combines results for pooled samples (2000 n=25; 2001 n=40 in 5 pools; 2004 n=20)

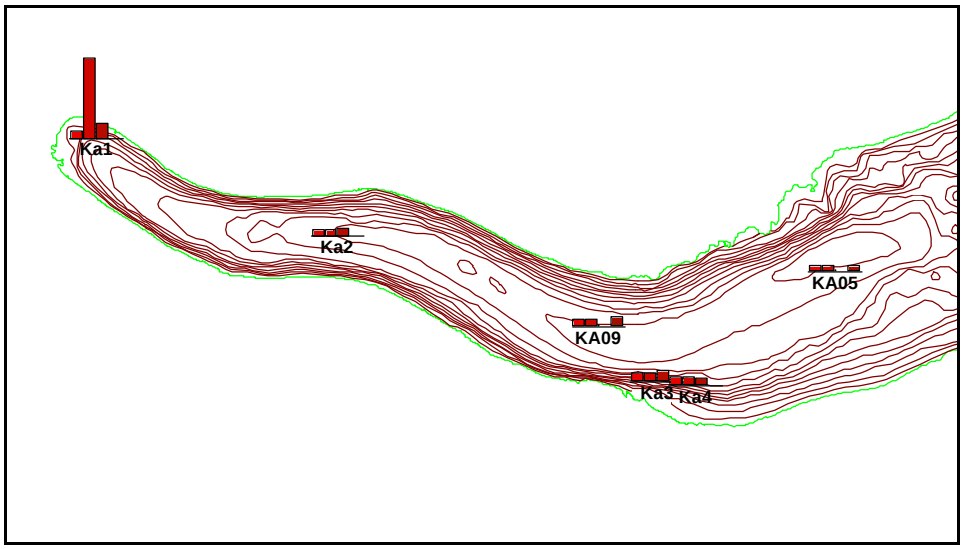
4.6 Marine sediments from Kaldbak

Sediment samples from Kaldbaksfjørð were analysed for PCB and loss on ignition. The analyses results for the individual congeners of PCB are given in Attachment 8 whereas summary data are given in Table 4.14 and shown in Map 3. In Map 3, the PCB concentration has been correlated to the organic matter content (as Loss on Ignition) of the sediments. The rationale for presenting PCB in this way, is because PCB strongly associates with organic matter and therefore sediments with high organic content will appear to have been exposed to elevated PCB concentrations compared to sediments with lower organic content. In the present case though (Table 4.14) it is easy to see both from the dry weight based results as well as the organic content based results that sediments at the Ka1 site have very high PCB concentrations at the 2cm depth compared to the other sites and depths. This indicates a local source of PCB pollution near the Ka1 site, and one that has diminished in recent years from a more polluting state. Near the Ka1 site, a river is feeding into the foot of the fjord. This river drains a watershed of the surrounding mountains where a military station is located. To point out the source with any degree of certainty would require however, that further analyses be made of sediments near the Ka1 site.

Table 4.14 Concentrations of PCB7 and loss on ignition for the various segments at the 6 sediment-sampling stations in Kaldbaksfjørð in 2004 are given.

	Depth	**KA05**	**KA09**	**Ka1**	**Ka2**	**Ka3**	**Ka4**
PCB7 ng/kg dw	0-1 cm	580	650	350	600	350	530
	1-2 cm	540	710	3500	560	360	530
	2-3 cm	*	*	680	770	490	510
	3-4 cm	560	860	-	-	-	-
Loss on Ignition g/kg dw.	0-1 cm	114.6	115.8	52.9	117.1	54.2	73.2
	1-2 cm	110.2	112.9	52.8	110.8	54.0	73.7
	2-3 cm	107.8	111.7	54.7	108.8	56.2	80.7
	3-4 cm	104	104	-	-	-	-

*The 3cm layers for KA05 and KA09 were destroyed on their way to the laboratory and thus the 4cm layers were analysed instead.



Map 3 PCB7/Loss on Ignition in sediments from Kaldbaksfjørður. The bars indicate from the left: 1cm, 2cm, 3cm and 4cm segments.

5 Stable isotopes

The ratios of heavier to lighter isotopes of nitrogen and carbon can be used to examine the trophic relationship in food webs. The heavier isotopes are enriched in animal tissue compared to the diet (Sagerup *et al*., 2002), with the enrichment factors between tissue and diet being about 1‰ for the ^{13}C isotope and 3‰ for the ^{15}N isotope (Sagerup *et al*., 2002; Fry, 1988).
Tissue of pilot whale muscle, shorthorn sculpin muscle, Arctic char muscle and black guillemot eggs were analysed for the fraction of stable isotopes of nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$) at SINLAB in Canada.

5.1.1 Results

The level of lipids in the samples was very variable. This affects the C:N values as ^{13}C is discriminated against during lipid synthesis, leading to higher C:N values and lower d13C when the lipid content is high. To avoid this the d13C was normalized (d') using an estimated lipid content (L) according to the formula from McConnaughy & McRoy, 1979.

$$L = 93/[1+(0.246C/N-0.775)^{-1}]$$

$$d' = d+D[-0.207+3.90/(1+287/L)]$$

where L is % lipid, C/N is the carbon to nitrogen ratio in muscle and D is the depletion of 12C (‰) relative to protein and assigned 6‰ (Sagerup *et al*., 2002; McConnaughy & McRoy, 1979).
The normalized d13C' values versus d15N is shown in Figure 5.1.

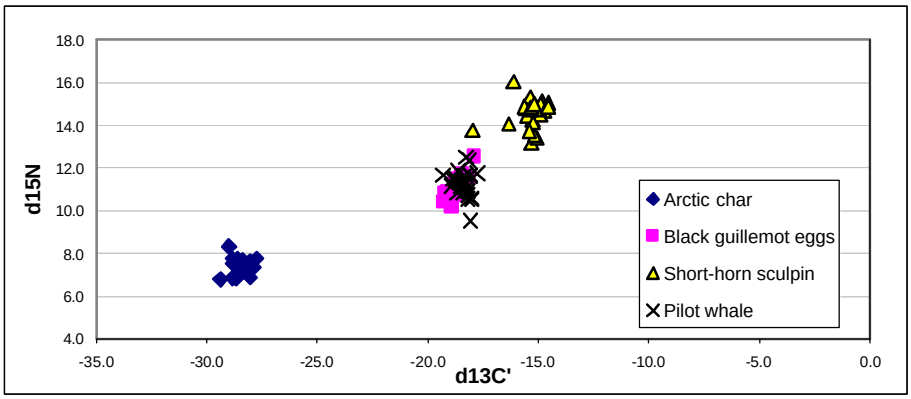


Figure 5.1 d13C' (normalised) versus d15N in arctic char muscle, black guillemot eggs, sculpin muscle and pilot whale muscle.

5.1.2 Discussion

The enrichment of d15N and d13C is shown to increase going from Arctic char to sculpin with intermediate and similar values for pilot whale and eggs from black guillemot (Figure 5.1). The increase in d15N is very highly correlated to that of d13C' when all data sets from the four species are considered simultaneously. When the increments in d15N vs. d13C' is considered for each species separately, a very highly significant correlation is found in the black guillemot eggs data (Spearman rank correlation, two-tailed, $p<0.01$), but no correlation is seen in the datasets from the other species. When searching for correlation between d15N and the concentration of biomagnifying pollutants like mercury and representatives of the POP groups (CB 153, p,p´-DDT, HCB, trans-nonachlor and Par50), no

correlation was observed except in black guillemot eggs, where d15N was significantly correlated to mercury (Spearman rank, two-tailed, $p<0.05$). When all samples from all species were combined in the analyses, no correlation between the pollutant representatives and d15N was observed. This lack of correlation is easily realised by a visual comparison of the position of these four species in the Figure 5.1, with sculpin at the high end and Arctic char at the low, to the summary pollutants data in Figure 5.2. In this figure, representatives of lipid-normalised POPs are shown for the four species in box plots, and it is obvious that the concentration of mercury and these POPs is highest in pilot whales.

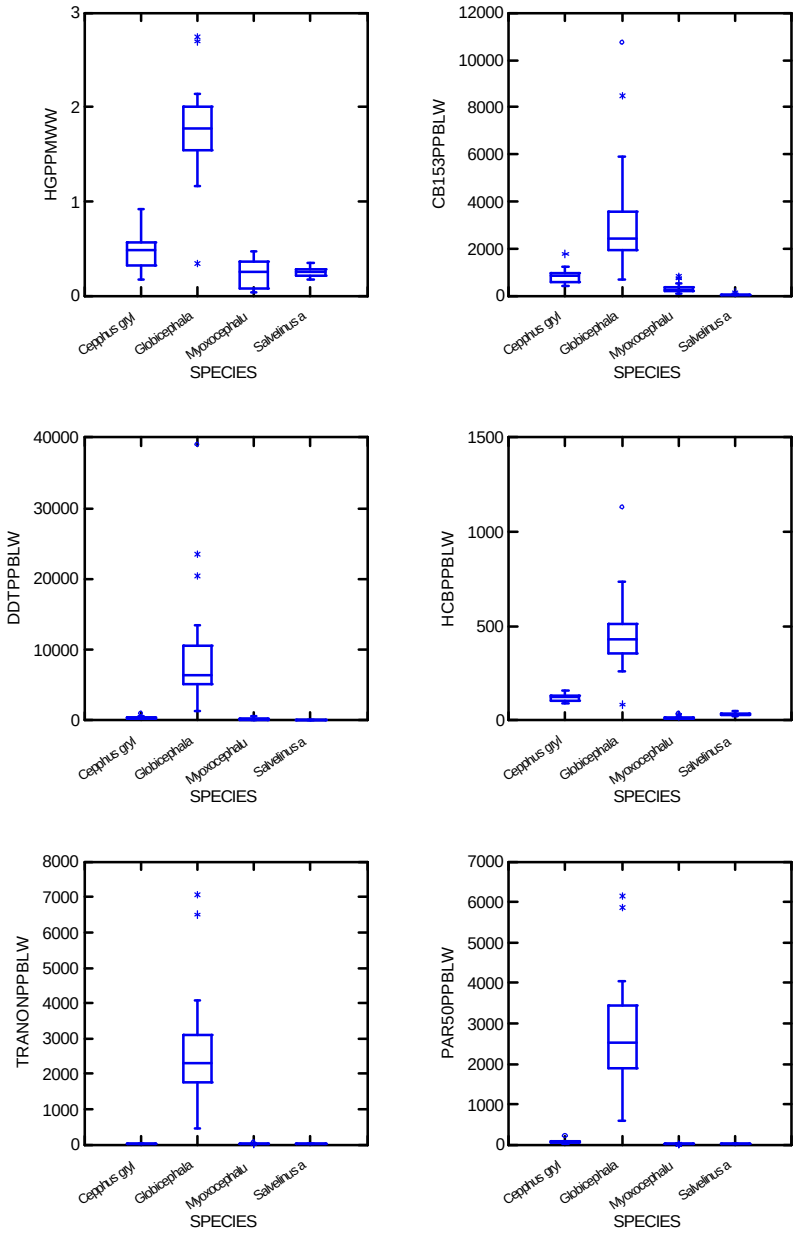


Figure 5.2 Box plots of pollutants in the four species which were analysed for stable isotopes; Cepphus gryl =black guillemot eggs, Globicephala= pilot whale muscle (Hg) or blubber (POPs), Myoxocephalu=sculpin liver, Salvelinus a=Arctic char muscle. The concentration of mercury is given as mg/kg ww, whereas the POPs representatives, CB 153, p,p´-DDT, HCB, trans-nonachlor and Par50 have been lipid normalised, and are given as µg/kg lw.

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Attachments