# Analyses of Mercury and Organochlorines in Individual Marine Mammals from the Faroe Islands

*Kanningar av kyksilvri og organokloridum í einstøkum havsúgdjórum í Føroyum*

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## Úrtak

Í alt vóru 14 congen av PCB ávíst, eins og seks isomer av DDT, tríggir parlarar av toxaphene, fimm sløg av chlordanum, ß-hexachlorohexane, hexachlorobenzene og mirex. Í alt vóru 100 grindahvalir (*Globicephala melas*), 28 springarar (*Lagenorhyncus acutus*) og 30 láturkópar (*Halichoerus grypus*) kannaðir hvør sær. Eisini er kyksilvursinnihaldið víst í tvøsti av sama tali av djórum, og fyri springarar eru hesar kanningar gjørdar á teimum somu einstaklingunum, sum vóru kannaðir fyri persistent lívrunnin evni. Úrslitini eru víst sum miðalvirði fyri teir ymisku bólkarnar av ungum og vaksnum kall- og kvenndjórum, men eisini í myndum, har dálkingarevnir eru víst sum funktión av kropslongd (hvalir) ella aldur (kópar). Hægstu konsentratiónirnar av persistentum lívrunnum evnum vóru ávíst í vaksnum kalldjórum ella í ungdjórum. Innihaldið av kyksilvri var hægst í fullvaksnum grindahvali. Hægsta innihaldið av CB 153, 6.7 mg/kg fiti, varð funnið í brimlum. Hægsta innihaldið av *p,p'*-DDE, 18.6 mg/kg fiti, varð funnið í vaksnum springarahannum. Trans-nonachlor var tað chlordanið, sum varð funnið í hægstu konsentratiónum, og hægsta innihaldið av trans-nonachlor, 4.8 mg/kg fiti, varð funnið í vaksnum springarahannum.

## Abstract

In all, 14 congeners of PCB are reported as well as six isomers of DDT, three parlars of toxaphene, five representatives of the chlordane group of compounds, ß-hexachlorohexane, hexachlorobenzene, and Mirex. In all, 100 pilot whales (*Globicephala melas*), 28 white-sided dolphins (*Lagenorhyncus acutus*), and 30 grey seals (*Halichoerus grypus)* where analysed individually. The mercury concentration in muscle samples taken from the same number of individuals of these three species is provided also. In the case of the white-sided dolphins, the muscle mercury analyses were done on the same individuals as the persistent organic pollutants (POPs) analyses. The results are given as mean values for groups of juveniles and adult males and females, and are also shown as pollutant concentration vs. individual body length (odontocetes) or age (seal). The highest concentrations of the persistent chlorinated organic pollutants were found in adult males and juveniles. The concentration of mercury was highest in the group of adult male pilot whales. The highest concentration of CB 153, 6.7 mg/kg lipid, was found in the adult male group of grey seals. The highest concentration of *p,p'*-DDE, 18.6 mg/kg lipid, was found in the white-sided dolphin males. Trans-nonachlor was the dominant chlordane compound and the group with the highest trans-nonachlor concentration, equal to 4.8 mg/kg lipid, was the adult males of the white-sided dolphins.

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## Introduction

In 1997, the Faroese governmental agency responsible for food safety – the Food and Environmental Agency – undertook a screening of environmental pollutants in long-finned pilot whales, *Globicephala melas*. The consumption of meat and blubber from these animals may reasonably be considered one of the main sources of mercury and persistent organic pollutants in the human population (Julshamn *et al.*, 1987; Aguilar *et al.*, 1993; Simmonds *et al.*, 1994). The investigation covered 466 individual pilot whales randomly sampled from a total of 913 animals from a total of ten concomitant *grinds* or pilot whale pods (Butterworth, 1996). The samples were, however, analysed as combined samples in three pools from each of the ten *grinds*. The animals were sorted according to sex and sexual maturity. Hence, from one *grind* a pool of adult females, a pool of adult males, and a pool that included the juveniles of both sexes were made. The pooled muscle and blubber samples were then analysed for mercury and organochlorines as PCB, the pesticides Mirex[1] and DDT, and the metabolites, chlordanes, lindane and toxaphene.

The results (Dam and Bloch, 2000) were useful for a general indication of the amount of pesticides and mercury burden that these whales carry. The results revealed that the average concentration of mercury in a long-finned pilot whale pod was 1.9 mg/kg, with some pods near 1 mg/kg and some closer to 3 mg/kg.

The results also confirmed that there is a large, sex-based difference in the concentrations of the persistent organic pollutants, with adult females nearly always having lower concentrations of these pollutants than the adult males. This has been shown to be a consequence of reproduction or, more importantly, lactation, which transfers a significant proportion of the body burden of the fat-soluble persistent organochlorines (OC) to the offspring (Borrell *et al.*, 1995). In instances where the OC concentration in the various pools

***Table 1.*** *The table gives an overview of the samples analysed in the present study*
**Talva 1.** Talvan gevur eitt yvirlit yvir tey sýni, sum vórðu kannað í hesi kanningini.

| Species | Location | Sampling date | Parameter analysed | No. of individuals analysed |
|---|---|---|---|---|
| Grey seal | various locations along the coast | in summer-months of 1993 to 1995 | Hg, PCB, pesticides, Toxaphene | 30 |
| White-sided dolphin | Klaksvík | 21 August 1997 | Hg, PCB, pesticides, toxaphene | 28 |
| Long-finned pilot whale | Sandavágur | 26 August 1997 | PCB, pesticides, toxaphene | 50 |
| Long-finned pilot whale | Tórshavn | 24 September 1997 | PCB, pesticides, toxaphene | 50 |
| Long-finned pilot whale | Tórshavn | 13 November 1997 | Hg | 50 |
| Long-finned pilot whale | Leynar | 2 December 1997 | Hg | 50 |

of adult females did exceed that of the adult males, the reason is more to be sought in the social structure of the pod rather than in the ability to metabolise and excrete OC. This is because studies of pilot whale behaviour indicate that adult males may be regarded as visitors to the pods more than permanent members (Andersen and Sleegismund, 1994; Andersen, 1993). Hence, the foraging area and, therefore, the contaminant exposure history of the adults are not necessarily the same and this is mirrored in the body contaminant burden.

However, from the perspective of whale meat and blubber consumption, it is also useful to know the maximum dose of pollutants that may be encountered via food intake. For this purpose, the results of the pooled samples are not sufficient. It was, thus, decided to analyse individual pilot whales for the pollutants. Favourable circumstances also gave access to samples of another species of whale that is consumed, the white-sided dolphin, and to samples of grey seal. There was much interest in analysing these species, especially given the fact that individual analyses had not been conducted previously on seal samples from the Faroe Islands.

Hence, the present study provides the worst-case scenario from the consumer point of view. The study also indicates, in

***Table 2.*** *The number of individuals in each of the four groups of juveniles and adults, females and males, and the average body lengths and/or ages of these. N = number of individuals, length = body length in cm., size is given in skinn.*

**Talva 2.** Tal av einstaklingum í hvørjum av teimum fýra bólkunum av hvølpum, honum og hannum er víst eins og miðalhvalalongd og/ella aldur. N = tal av einstaklingum, longd = hvalalongd í cm, støddin er víst í skinnum.

| **mean** min. max. | grey seal | | | white-sided dolphin | | pilot whale Sandavágur 26 Aug 1997 | | | pilot whale Tórshavn 24 Sep 1997 | | | pilot whale Tórshavn 13 Nov 1997 | | | pilot whale Leynar 2 Dec 1997 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **age** | **length** | **N** | **length** | **N** | **size** | **length** | **N** | **size** | **length** | **N** | **size** | **length** | **N** | **size** | **length** |
| juv. | | 2 | 137 | | 172 | | 2 | 270 | | 3 | 278 | | 3 | 284 | | 5 | 291 |
| female | N=10 | 1 | 121 | N=7 | 135 | N=7 | 0 | 190 | N =6 | 2 | 220 | N=5 | 2 | 250 | N=7 | 1 | 207 |
| | | 5 | 156 | | 190 | | 4 | 340 | | 5 | 360 | | 6 | 370 | | 7 | 372 |
| ad. | | 15 | 178 | | 222 | | 7 | 430 | | 7 | 428 | | 8 | 426 | | 9 | 404 |
| female | N=11 | 8 | 164 | N=8 | 210 | N=16 | 5 | 375 | N=31 | 2 | 390 | N=21 | 4 | 380 | N =31 | 7 | 375 |
| | | 27 | 190 | | 230 | | 9 | 480 | | 9 | 460 | | 10 | 440 | | 10 | 445 |
| juv. | | 3 | 147 | | 215 | | 4 | 372 | | 7 | 406 | | 8 | 415 | | 7 | 354 |
| male | N=7 | 1 | 129 | N=1 | | N=19 | 1 | 220 | N =9 | 2 | 285 | N =17 | 1 | 220 | N =9 | 3 | 260 |
| | | 5 | 171 | | | | 9 | 480 | | 10 | 490 | | 12 | 490 | | 12 | 440 |
| ad. | | 19 | 216 | | 248 | | 10 | 544 | | 12 | 543 | | 13 | 532 | | 18 | 528 |
| male | N=3 | 13 | 204 | N=12 | 225 | N =8 | 8 | 520 | N =4 | 11 | 510 | N =7 | 12 | 510 | N =3 | 17 | 520 |
| | | 22 | 227 | 12 | 265 | | 11 | 580 | | 13 | 570 | | 15 | 560 | | 18 | 535 |

general, the occurrence of these pollutants in marine mammals that use Faroese waters as a part-time feeding and breeding area, as in the case of the whales, and as a possibly permanent residence area, as in the case of the grey seals. It further provides the confidence limits that must be defined in order to make meaningful comparison between the results of the 1997 screening and the major pilot whale study conducted in 1986-88 (Donovan *et al.*, 1993). In other words, the current study will be a valuable tool for detecting whether the concentration of these pollutants has increased, is constant, or – as has been observed in other areas – has indeed decreased.

***Table 3.*** *The results of the mercury analyses are given as mean values including standard deviation (bold), minimum and maximum values, in mg/kg muscle ww. The results are given both for the whole sample of each species or each school, and for the four subgroups of females and males, adults and juveniles, separately.*
**Talva 3.** Úrslitini av kyksilvurskanningunum eru víst sum miðalvirði og standardfrávik (við feitari skrift), lægst og hægst, í mg/kg av tvøsti.Úrslitini eru víst bæði fyri øll sýni úr eini grind eins og fyri teir fýra undirbólkarnar av hon- og hannhvølum, hvølpum og vaksnum, hvør sær.

| Hg, mg/kg muscle | all | adult females | juv. females | adult males | juv. males |
|---|---|---|---|---|---|
| **Pilot whale Tórshavn** | | | | | |
| **13-11-97** | **2.82** | **3.37** | **1.45** | **3.46** | **2.29** |
| **std. dev** | **1.16** | **1.00** | **1.00** | **1.28** | **0.76** |
| min | 0.68 | 1.73 | 0.68 | 2.07 | 0.86 |
| max | 5.94 | 5.79 | 3.15 | 5.94 | 3.50 |
| **Pilot whale Leynar** | | | | | |
| **2-12-97** | **1.43** | **1.70** | **0.79** | **1.75** | **0.90** |
| **std. dev** | **0.59** | **0.44** | **0.45** | **0.14** | **0.50** |
| min | 0.19 | 0.42 | 0.19 | 1.59 | 0.30 |
| max | 2.99 | 2.99 | 1.31 | 1.86 | 1.43 |
| **W.-sided dolphins** | **0.94** | **1.25** | **0.41** | **1.00** | **1.45** |
| **std. dev** | **0.40** | **0.17** | **0.29** | **0.25** | **na** |
| min | 0.07 | 1.05 | 0.07 | 0.50 | na |
| max | 1.47 | 1.47 | 0.84 | 1.37 | na |
| **Grey seals** | **0.73** | **0.84** | **0.37** | **2.31** | **0.37** |
| **std. dev** | **0.86** | **0.40** | **0.27** | **2.22** | **0.26** |
| min | 0.15 | 0.23 | 0.16 | 0.42 | 0.15 |
| max | 4.76 | 1.51 | 0.92 | 4.76 | 0.90 |

## Methods and materials

*Sorting by age and sex groups*

In order to compare the various pods and species, the results have been presented for groups of individuals of defined size (or age) and sex. The sorting criteria for the various species are given in the separate sections below. The locations and date or time period of sampling as well as the total number of individuals from which samples were taken are given in Table 1. The descriptive parameters of these individuals, seen as subgroups, are given in Table 2.

*Pilot whale samples*

Tissue samples of long-finned pilot whale were collected in connection with the *grind* as described elsewhere (Dam and Bloch, 2000). From each *grind*, a sub-sample was picked of ideally 50 individuals, but fewer were also accepted if so determined by the size of the *grind*. The selection of the individuals in the sub-sample was random in the sense that there were no guidelines as to which individual should be included. Samples were normally stored in Minigrip polyethylene bags at <-18°C until sub-samples of a few grams were taken for the analyses. With the blubber samples, care was taken to exclude from the sub-samples

areas that had been in direct contact with the polyethylene bag.

In general, females longer than or equal to 375 cm and males of body length longer than 494 cm were referred to as matures (Bloch *et al.*, 1993; Martin and Rothery, 1993; Desportes *et al.*, 1993).

*White-sided dolphins*

Samples of white-sided dolphins were collected during a drive in Klaksvík on 21 August 1997. The hunt of dolphin is very limited in comparison to that of the pilot whale, but occasionally such schools are taken and the kill is done in the same manner as the pilot whale kill. The sampling, sample storage, and sub-sample preparation were done in the same manner as for the pilot whales. Dolphins become sexually mature at an age where they have attained a whole body length of 190 to 220 cm for the females (which equates to 12 years) and 210 to 240 cm for the males (Bloch and Fuglø, 1999). Individuals that where equal to or longer than the average length at maturity, which is 205 cm and 225 cm for females and males, respectively, were considered to be adults.

***Table 4.*** *PCB in grey seals, as single congeners in µg/kg lw, and as Aroclor 1260 equivalents, in mg/kg lw. The results are shown with mean and standard deviation (bold) and minimum and maximum values for the groups of adult and juvenile, females and males.*

**Talva 4.** PCB í kópi sum einkult kongen í µg/kg av feitti og sum Aroclor 1260 eindir í mg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av opnum og brimlum, hvølpum og vaksnum er víst.

| | Aroclor 1260 (mg/kg lw) | 28 | 52 | 99 | 101 | 105 | 118 | 128 | 138 | 153 | 156 | 170 | 180 | 183 | 187 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **juv. females** | **9** | **5** | **44** | **218** | **78** | **12** | **13** | **41** | **526** | **1142** | **34** | **129** | **209** | **68** | **134** |
| std. dev. | **3** | **1** | **14** | **96** | **16** | **5** | **4** | **9** | **164** | **430** | **8** | **40** | **74** | **22** | **40** |
| N = | 4 | 3 | 25 | 108 | 60 | 6 | 5 | 26 | 272 | 560 | 16 | 54 | 103 | 27 | 59 |
| 10 | 16 | 7 | 66 | 437 | 114 | 22 | 19 | 53 | 908 | 2155 | 46 | 188 | 324 | 110 | 217 |
| **ad. females** | **7** | **nd** | **23** | **108** | **49** | **10** | **10** | **24** | **381** | **885** | **31** | **149** | **288** | **85** | **137** |
| std. dev. | **3** | **na** | **10** | **50** | **16** | **7** | **6** | **13** | **145** | **364** | **10** | **48** | **104** | **27** | **38** |
| N = | 3 | nd | 10 | 38 | 27 | 3 | 3 | 11 | 173 | 315 | 15 | 71 | 120 | 43 | 89 |
| 11 | 11 | 4 | 37 | 183 | 70 | 26 | 20 | 51 | 643 | 1488 | 48 | 219 | 458 | 128 | 217 |
| **juv. males** | **10** | **5** | **65** | **248** | **133** | **17** | **20** | **50** | **688** | **1243** | **44** | **159** | **273** | **86** | **155** |
| std. dev. | **4** | **1** | **21** | **131** | **74** | **5** | **8** | **21** | **278** | **506** | **21** | **86** | **147** | **46** | **71** |
| N = | 6 | 4 | 30 | 107 | 60 | 10 | 11 | 25 | 377 | 759 | 20 | 68 | 118 | 35 | 72 |
| 7 | 17 | 6 | 93 | 458 | 289 | 25 | 35 | 83 | 1117 | 2231 | 79 | 310 | 546 | 170 | 280 |
| **ad. males** | **52** | **4** | **57** | **847** | **119** | **32** | **23** | **151** | **3353** | **6724** | **235** | **980** | **2758** | **950** | **1246** |
| std. dev. | **38** | **0** | **6** | **665** | **32** | **27** | **6** | **99** | **2852** | **4532** | **191** | **760** | **2552** | **928** | **1127** |
| N = | 28 | 4 | 50 | 459 | 96 | 15 | 20 | 60 | 1586 | 3705 | 115 | 502 | 1109 | 317 | 435 |
| 3 | 97 | 5 | 61 | 1614 | 156 | 63 | 31 | 257 | 6643 | 11936 | 455 | 1856 | 5698 | 2015 | 2533 |

*Grey seals*

The seals were shot in various places around the Faroe Islands during the summer months of 1993, 1994 and 1995 in connection with a study of their summer diet (Mikkelsen, 1998). Muscle and blubber samples were taken high on the abdomen near the chest bone. The samples were wrapped in aluminium foil and the parcels were put in plastic bags and stored in a freezer at <-18°C.

The age of some of the seals was determined by means of the lower canine teeth. A growth curve of age vs. body length was constructed from these seals (Hewer, 1963). The age of the remaining seals was then estimated using this growth curve.

The males become sexually mature at the age of four to five years, but generally they do not become sexually active until they reach the age of eight years because of body size dominance and local conditions at the breeding grounds (Mikkelsen, 1998). As a consequence, only males older than eight years of age are included in the group of adult males. All pregnant seals were placed in the adult females group.

*Chemical analyses and sample pre-treatment*

Mercury

The analyses were conducted at the laboratory of the Food and Environmental Agency of the Faroe Islands using borhy-

***Table 5.*** *PCB in white-sided dolphins as single congeners in µg/kg lw and as Aroclor 1260 equivalents in mg/kg lw. The results are shown with mean and standard deviation (bold) and minimum and maximum values for the groups of adult and juvenile, females and males.*

**Talva 5.** PCB í hvítskjórutum springarum sum einkult kongen í µg/kg av feitti og sum Aroclor 1260 eindir í mg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av hon- og hannhvølum, hvølpum og vaksnum er víst.

| | Aroclor 1260 (mg/kg lw) | 28 | 52 | 99 | 101 | 105 | 118 | 128 | 138 | 153 | 156 | 170 | 180 | 183 | 187 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| juv. females | **12** | **32** | **331** | **289** | **359** | **114** | **151** | **170** | **987** | **1408** | **88** | **113** | **324** | **101** | **459** |
| std. dev | **5** | **9** | **86** | **128** | **64** | **40** | **80** | **27** | **385** | **571** | **42** | **44** | **145** | **56** | **213** |
| N = | 6 | 21 | 212 | 113 | 269 | 54 | 91 | 127 | 515 | 708 | 42 | 51 | 149 | 38 | 228 |
| 7 | 19 | 41 | 418 | 440 | 471 | 167 | 302 | 210 | 1450 | 2124 | 150 | 174 | 577 | 192 | 734 |
| ad. females | **3** | **8** | **44** | **41** | **72** | **23** | **37** | **37** | **234** | **368** | **42** | **100** | **235** | **73** | **259** |
| std. dev | **2** | **4** | **21** | **19** | **28** | **9** | **16** | **18** | **121** | **183** | **17** | **49** | **135** | **43** | **134** |
| N = | 1 | 4 | 24 | 23 | 46 | 15 | 19 | 14 | 95 | 149 | 17 | 39 | 76 | 24 | 97 |
| 8 | 6 | 14 | 79 | 79 | 113 | 39 | 73 | 68 | 459 | 675 | 58 | 166 | 444 | 135 | 432 |
| juv. males | **24** | **40** | **556** | **670** | **404** | **125** | **81** | **253** | **1923** | **2693** | **117** | **218** | **577** | **197** | **836** |
| N = 1 | na | na | na | na | na | na | na | na | na | na | na | na | na | na | na |
| ad. males | **45** | **38** | **584** | **1202** | **486** | **180** | **196** | **433** | **3436** | **5131** | **325** | **669** | **1661** | **582** | **1831** |
| std. dev | **15** | **14** | **150** | **409** | **146** | **69** | **100** | **135** | **1085** | **1798** | **128** | **274** | **640** | **236** | **626** |
| N = | 19 | 24 | 363 | 455 | 261 | 58 | 57 | 183 | 1473 | 2133 | 113 | 216 | 612 | 211 | 773 |
| 8 | 70 | 61 | 875 | 1863 | 805 | 289 | 434 | 639 | 4946 | 8602 | 520 | 1012 | 2549 | 948 | 2801 |

***Table 6.*** *PCB in pilot whale blubber is given as single congeners in µg/kg lw and as Aroclor 1260 equivalents in mg/kg lw. The results are shown with mean and standard deviation (bold) and minimum and maximum values for the groups of adult and juvenile, females and males.*

**Talva 6.** PCB í grindahvali sum einkult kongen í µg/kg av feitti og sum Aroclor 1260 eindir í mg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av hon- og hannhvølum, hvølpum og vaksnum er víst.

| Sandavágur | Aroclor 1260 (mg/kg lw) | 28 | 52 | 99 | 101 | 105 | 118 | 128 | 138 | 153 | 156 | 170 | 180 | 183 | 187 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| juv. females | **33** | **58** | **1052** | **1050** | **1452** | **353** | **1125** | **358** | **2777** | **3589** | **228** | **428** | **1020** | **371** | **1077** |
| std. dev | **15** | **22** | **416** | **482** | **572** | **161** | **583** | **167** | **1319** | **1624** | **117** | **263** | **543** | **207** | **522** |
| N = | 10 | 32 | 382 | 315 | 564 | 75 | 208 | 106 | 768 | 1084 | 57 | 95 | 256 | 96 | 302 |
| 7 | 47 | 85 | 1464 | 1517 | 2036 | 526 | 1735 | 563 | 4064 | 5056 | 371 | 836 | 1680 | 636 | 1625 |
| ad. females | **11** | **26** | **260** | **267** | **433** | **111** | **285** | **98** | **907** | **1238** | **85** | **161** | **442** | **148** | **469** |
| std. dev | **7** | **13** | **218** | **243** | **329** | **86** | **235** | **70** | **625** | **807** | **52** | **100** | **239** | **84** | **244** |
| N = | 3 | 9 | 48 | 54 | 103 | 28 | 61 | 36 | 261 | 392 | 32 | 51 | 169 | 58 | 193 |
| 16 | 33 | 52 | 905 | 1038 | 1421 | 339 | 985 | 327 | 2729 | 3527 | 245 | 450 | 1095 | 388 | 1102 |
| juv. males | **27** | **54** | **794** | **769** | **1166** | **320** | **821** | **262** | **2280** | **2987** | **180** | **330** | **892** | **307** | **936** |
| std. dev | **14** | **39** | **431** | **419** | **606** | **200** | **571** | **151** | **1178** | **1501** | **87** | **177** | **446** | **158** | **427** |
| N = | 3 | 7 | 50 | 48 | 99 | 39 | 37 | 36 | 227 | 311 | 45 | 95 | 193 | 67 | 210 |
| 19 | 56 | 188 | 1949 | 1605 | 2746 | 813 | 2295 | 628 | 4726 | 6111 | 343 | 758 | 1763 | 610 | 1712 |
| ad. males | **39** | **47** | **1015** | **1122** | **1518** | **381** | **1313** | **405** | **3276** | **4199** | **288** | **614** | **1411** | **467** | **1345** |
| std. dev | **15** | **15** | **442** | **462** | **658** | **180** | **599** | **157** | **1264** | **1639** | **121** | **261** | **628** | **189** | **527** |
| N = | 18 | 31 | 501 | 514 | 756 | 171 | 549 | 179 | 1452 | 1985 | 120 | 221 | 567 | 205 | 604 |
| 8 | 70 | 76 | 1855 | 1930 | 2872 | 743 | 2561 | 678 | 5839 | 7611 | 495 | 1079 | 2735 | 821 | 2414 |
| Tórshavn 24 Sep 1997 | Aroclor 1260 | 28 | 52 | 99 | 101 | 105 | 118 | 128 | 138 | 153 | 156 | 170 | 180 | 183 | 187 |
| juv. females | **32** | **59** | **966** | **949** | **1370** | **380** | **1059** | **306** | **2652** | **3441** | **206** | **373** | **954** | **303** | **1000** |
| std. dev | **14** | **23** | **502** | **479** | **591** | **216** | **576** | **165** | **1190** | **1567** | **104** | **200** | **463** | **145** | **408** |
| N = | 10 | 30 | 360 | 291 | 498 | 95 | 188 | 91 | 816 | 1121 | 61 | 84 | 267 | 87 | 364 |
| 6 | 51 | 86 | 1721 | 1700 | 2159 | 727 | 1776 | 552 | 4195 | 5558 | 339 | 631 | 1497 | 486 | 1479 |
| ad. females | **11** | **28** | **264** | **244** | **409** | **102** | **264** | **93** | **843** | **1167** | **82** | **164** | **397** | **133** | **432** |
| std. dev | **8** | **25** | **317** | **240** | **386** | **95** | **300** | **81** | **679** | **870** | **50** | **74** | **215** | **74** | **238** |
| N = | 3 | 0 | 55 | 46 | 107 | 25 | 29 | 26 | 217 | 309 | 23 | 59 | 109 | 40 | 153 |
| 31 | 44 | 141 | 1803 | 1265 | 2154 | 508 | 1633 | 469 | 3732 | 4767 | 281 | 367 | 1022 | 368 | 1316 |
| juv. males | **24** | **44** | **711** | **673** | **989** | **285** | **680** | **212** | **1919** | **2654** | **143** | **317** | **713** | **244** | **786** |
| std. dev | **9** | **12** | **263** | **249** | **358** | **82** | **342** | **91** | **783** | **967** | **50** | **121** | **245** | **80** | **266** |
| N = | 8 | 33 | 323 | 241 | 411 | 94 | 218 | 78 | 666 | 823 | 50 | 95 | 293 | 94 | 347 |
| 9 | 37 | 66 | 1271 | 1072 | 1607 | 374 | 1341 | 329 | 3082 | 4163 | 203 | 434 | 1040 | 343 | 1205 |
| ad. males | **31** | **52** | **872** | **923** | **1249** | **278** | **961** | **264** | **2535** | **3396** | **186** | **418** | **1067** | **340** | **1044** |
| std. dev | **9** | **17** | **272** | **291** | **332** | **40** | **444** | **97** | **800** | **1025** | **50** | **84** | **355** | **100** | **306** |
| N = | 19 | 37 | 514 | 576 | 808 | 244 | 413 | 129 | 1541 | 2124 | 121 | 340 | 610 | 223 | 659 |
| 4 | 40 | 75 | 1153 | 1192 | 1520 | 330 | 1488 | 346 | 3322 | 4374 | 227 | 519 | 1408 | 426 | 1320 |

dride reduction AAS (Perkin Elmer 2380, AOAC (90) 974s264, mod DIN.). The analyses were done on fresh, but previously frozen, material. The sample was dehydrated at 105°C until a stable dry mass was obtained. This procedure facilitates comparison with other studies, and also facilitates the comparison of the results within the present study because the mercury concentration may then be expressed on a dry mass basis. The reason that a dry mass basis is preferred for comparison is that the major part of the mercury is confined to the protein-rich part of the muscle and a sample with a high water (blood) content has markedly lower mercury content per unit of sample. Fifteen percent of the samples were analysed in duplicate for quality control.

Organochlorines

When preparing the blubber samples for analysis, the part of the tissue that had been in contact with the plastic wrapping was cut away, and the material intended for analysis was put into heat-treated glass jars. The analyses for organochlorines were done on blubber tissue, at Le Centre de Toxicologie du Québec, CTQ, Canada. Aliquots of tissue where homogenised in the presence of methylene chloride, anhydrous sodium sulphate and an internal standard, PCB # 198.

Determination of lipid content: An aliquot of the methylene chloride extract

**Table 7.** *The results for pesticides in grey seal blubber, in µg/kg lipid. The results are shown with mean (bold) minimum and maximum values for the groups of adult and juvenile, females and males.*
**Talva 7.** Skaðakyktaeitur í kópi er víst í µg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av opnum og brimlum, hvølpum og vaksnum er víst.

| # Ref. | p,p'-DDD | p,p'-DDT | pp'-DDE | Sum Chlordanes | ß-HCH | alpha-chlordane | gamma-chlordane | cis-nonachlor | Hexachlorobenzene | Mirex | Oxychlordane | Transnonachlor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **juv. females** | **nd** | **180** | **951** | **533** | **nd** | **nd** | **5** | **25** | **26** | **23** | **276** | **227** |
| std. dev. | **na** | **45** | **273** | **107** | **nd** | **3** | **1** | **8** | **32** | **10** | **76** | **60** |
| N = | nd | 117 | 717 | 358 | nd | nd | 4 | 12 | 6 | 8 | 148 | 120 |
| 10 | nd | 262 | 1609 | 687 | 5 | 8 | 7 | 40 | 90 | 42 | 356 | 319 |
| **ad. females** | **nd** | **159** | **544** | **348** | **nd** | **5** | **3** | **25** | **29** | **50** | **155** | **160** |
| std. dev. | **na** | **72** | **229** | **142** | **na** | **5** | **2** | **8** | **34** | **10** | **71** | **69** |
| N = | nd | 67 | 153 | 160 | nd | nd | nd | 15 | 2 | 34 | 46 | 92 |
| 11 | nd | 280 | 871 | 602 | nd | 13 | 6 | 35 | 115 | 66 | 291 | 314 |
| **juv. males** | **nd** | **290** | **1383** | **674** | **nd** | **5** | **5** | **37** | **23** | **30** | **350** | **277** |
| std. dev. | **na** | **68** | **394** | **249** | **na** | **6** | **1** | **9** | **22** | **22** | **195** | **67** |
| N = | nd | 196 | 1024 | 384 | nd | nd | 4 | 23 | 6 | 9 | 150 | 195 |
| 7 | nd | 385 | 1912 | 1049 | 7 | 13 | 6 | 53 | 72 | 72 | 694 | 390 |
| **ad. males** | **60** | **771** | **3033** | **1284** | **nd** | **10** | **3** | **71** | **14** | **358** | **652** | **548** |
| std. dev. | **19** | **506** | **1293** | **505** | **na** | **17** | **3** | **30** | **9** | **324** | **280** | **244** |
| N = | 43 | 380 | 2264 | 839 | nd | nd | nd | 41 | 6 | 126 | 488 | 300 |
| 3 | 81 | 1343 | 4525 | 1833 | 6 | 30 | 6 | 101 | 24 | 729 | 976 | 787 |

was transferred by a pipette into a tared aluminium cup and was desiccated in a ventilated oven at 30°C. The sample for OC analysis was defatted using gel permeation chromatography (GPC) and reduced by evaporation. The clean up was done by column chromatography on deactivated Florisil (0.5%). PCBs, toxaphene, and organochlorinated pesticides were eluted with hexane/methylene chloride (75:25). The eluent was reduced on a "Speed-Vac" evaporator and further with the aid of a jet of nitrogen at 40°C. PCBs and organochlorinated pesticides were analysed on a HP-5890 gas chromatograph equipped with dual capillary columns split-splitless injector and dual $^{63}$Ni electron capture detectors. For each batch of samples, two standards and one method blank and one reference control (cod liver oil) were used. The normal quality control protocol includes duplicate analyses on 10% of the samples.

Peaks were identified by their relative retention times (RRT) obtained on the two columns, using a computer program developed at CTQ. The identification window was 0.001. The precision for PCB congeners was 5 to 21%, for organochlorinated pesticides 6 to 16%, and for Aroclor 1260 6.4%.

The method for converting congener data to Aroclor 1260 is empirical. It is based on results obtained from the analyses of human blood plasmas. After quantifica-

***Table 8.*** *The results for pesticides in white-sided dolphins blubber, in µg/kg lipid. The results are shown with mean values for the groups of adult and juvenile, females and males.*
**Talva 8.** Skaðakyktaeitur í hvítskjórutum springarum er víst í µg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av hon- og hannhvølum, hvølpum og vaksnum er víst.

| # Ref. | Sum Chlordanes | ß-HCH | Mirex | Hexachlorobenzene | alpha-chlordane | gamma-chlordane | cis-nonachlor | Oxychlordane | Trans-nonachlor |
|---|---|---|---|---|---|---|---|---|---|
| juv. females | **2968** | **52** | **86** | **498** | **455** | **91** | **738** | **234** | **1450** |
| std. dev | **1350** | **15** | **37** | **82** | **113** | **33** | **318** | **104** | **792** |
| N = | 1782 | 32 | 38 | 387 | 339 | 53 | 452 | 135 | 742 |
| 7 | 4868 | 68 | 140 | 633 | 625 | 145 | 1246 | 378 | 2474 |
| ad. females | **583** | **13** | **98** | **69** | **93** | **25** | **133** | **27** | **304** |
| std. dev | **289** | **4** | **37** | **53** | **38** | **8** | **66** | **17** | **174** |
| N = | 273 | 8 | 56 | 23 | 46 | 16 | 64 | 13 | 135 |
| 8 | 1170 | 18 | 159 | 171 | 138 | 37 | 267 | 53 | 687 |
| juv. males | **6194** | **129** | **121** | **481** | **572** | **147** | **1372** | **543** | **3560** |
| N = | na | na | na | na | na | na | na | na | na |
| 1 | na | na | na | na | na | na | na | na | na |
| ad. males | **8067** | **99** | **366** | **540** | **698** | **170** | **1810** | **619** | **4771** |
| std. dev | **2366** | **32** | **127** | **120** | **179** | **47** | **607** | **181** | **1464** |
| N = | 3603 | 69 | 158 | 393 | 371 | 90 | 779 | 321 | 2042 |
| 12 | 12020 | 158 | 571 | 803 | 1055 | 236 | 3284 | 1011 | 7138 |

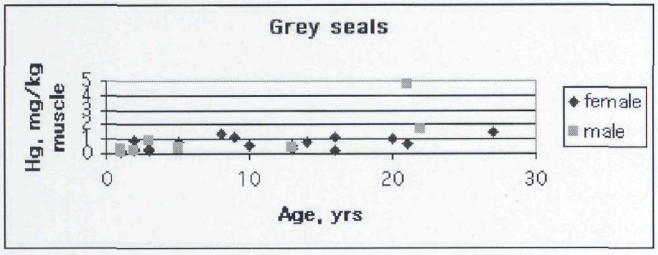



*Fig. 1. The concentration of mercury in grey seal muscle is shown as a function of age.*
**Mynd 1.** Innihaldið av kyksilvri í kópavøddum er víst sum funktión av aldri.

tion of "Aroclor 1260" using an Aroclor 1260 standard, a correlation test to other, simultaneously quantified, single congeners gave the best fit using the sum of congeners 138 and 153 (Weber, CTQ, personal comm.). In Figs. 4 and 5 the magnitude of the various congeners in the congener profile is calculated as the fraction of the concentration of the congener in question divided by the concentration of the congener CB 153. The congener CB 153 is chosen as a reference because this is the dominating congener appearing in the highest concentrations. The reason for comparing the congener profile between the species is to see whether there are indications of explicit difference between them that could stem from, for example, different capabilities to metabolise the compounds.

***Table 9.*** *The results for DDT in white-sided dolphin blubber, in µg/kg lipid. The results are shown with mean and standard deviation values (bold) and minimum and maximum values for the groups of adult and juvenile, females and males.*
**Talva 9.** DDT í hvítskjórutum springarum er víst í µg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av hon- og hannhvølum, hvølpum og vaksnum er víst.

| # Ref. | % Lipids | Sum DDT | o,p'-DDE | p,p'-DDE | o,p'-DDD | p,p'-DDD | o,p'-DDT | p,p'-DDT |
|---|---|---|---|---|---|---|---|---|
| juv. females | **90** | **7077** | **168** | **3510** | **259** | **1212** | **805** | **1123** |
| std. dev | **3** | **3930** | **74** | **2291** | **110** | **539** | **451** | **518** |
| N = | 87 | 3522 | 91 | 1410 | 155 | 727 | 384 | 604 |
| 7 | 97 | 13413 | 306 | 6835 | 475 | 2137 | 1624 | 2036 |
| ad. females | **91** | **1200** | **27** | **578** | **40** | **194** | **158** | **203** |
| std. dev | **3** | **660** | **14** | **365** | **22** | **90** | **92** | **124** |
| N = | 86 | 621 | 13 | 271 | 16 | 105 | 79 | 33 |
| 8 | 97 | 2618 | 47 | 1367 | 70 | 345 | 356 | 435 |
| juv. males | **94** | **17976** | **344** | **11019** | **494** | **2245** | **2117** | **1757** |
| N = | na | na | na | na | na | na | na | na |
| 1 | na | na | na | na | na | na | na | na |
| ad. males | **90** | **26921** | **351** | **18578** | **469** | **2317** | **2918** | **2288** |
| std. dev | **3** | **10730** | **138** | **8015** | **205** | **916** | **1342** | **826** |
| N = | 85 | 9600 | 181 | 6208 | 234 | 1006 | 943 | 1003 |
| 12 | 97 | 46264 | 667 | 34477 | 956 | 4587 | 5737 | 4252 |

***Table 10.*** *Pesticides in pilot whale blubber. The results are given in µg/kg lipid. The results are shown with mean and standard deviation (bold) and minimum and maximum values for the groups of adult and juvenile, females and males.*

**Talva 10.** Skaðakyktaeitur í grindahvali er víst í µg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av opnum og brimlum, hvølpum og vaksnum er víst.

| Sandavágur | Sum Chlor danes | ß-HCH | Hexa-chloro-benzene | Mirex | alpha-chlor dane | gamma-chlor dane | cis-nona chlor | Oxy chlor dane | Trans nona chlor |
|---|---|---|---|---|---|---|---|---|---|
| juv. females | **5962** | **51** | **888** | **172** | **613** | **92** | **1640** | **609** | **3008** |
| std. dev. | **2524** | **17** | **422** | **86** | **232** | **46** | **834** | **262** | **1299** |
| N = | 2187 | 29 | 406 | 65 | 342 | 51 | 485 | 261 | 1048 |
| 7 | 9545 | 74 | 1695 | 311 | 1081 | 188 | 2983 | 1088 | 4342 |
| ad. females | **1778** | **15** | **220** | **119** | **216** | **32** | **449** | **167** | **914** |
| std. dev. | **1288** | **7** | **128** | **34** | **125** | **16** | **369** | **121** | **670** |
| N = | 458 | 5 | 70 | 76 | 70 | 11 | 109 | 26 | 230 |
| 16 | 5567 | 32 | 427 | 187 | 539 | 68 | 1535 | 489 | 2939 |
| juv. males | **4746** | **37** | **605** | **161** | **478** | **74** | **1342** | **470** | **2381** |
| std. dev. | **2495** | **16** | **375** | **64** | **236** | **48** | **782** | **249** | **1236** |
| N = | 437 | 16 | 55 | 66 | 74 | 13 | 100 | 35 | 215 |
| 19 | 10952 | 83 | 1726 | 266 | 1019 | 198 | 3281 | 1152 | 5321 |
| ad. males | **5056** | **36** | **529** | **224** | **442** | **49** | **1303** | **474** | **2788** |
| std. dev. | **1633** | **7** | **184** | **108** | **123** | **12** | **563** | **137** | **837** |
| N = | 2743 | 28 | 317 | 112 | 295 | 31 | 638 | 298 | 1424 |
| 8 | 7888 | 47 | 871 | 457 | 641 | 65 | 2318 | 634 | 4232 |
| Tórshavn 24-09-97 | **Sum Chlor danes** | **ß-HCH** | **Hexa-chloro-benzene** | **Mirex** | **alpha-chlor dane** | **gamma-chlor dane** | **cis-nona chlor** | **Oxy chlor dane** | **Trans nona chlor** |
| juv. females | **5836** | **47** | **858** | **176** | **573** | **101** | **1357** | **595** | **3210** |
| std. dev | **2725** | **16** | **329** | **65** | **196** | **44** | **575** | **307** | **1639** |
| N = | 2525 | 32 | 459 | 63 | 376 | 66 | 606 | 267 | 1203 |
| 6 | 10253 | 76 | 1258 | 242 | 868 | 180 | 2266 | 1108 | 5831 |
| ad. females | **1767** | **17** | **302** | **109** | **229** | **43** | **373** | **172** | **950** |
| std. dev | **1705** | **14** | **416** | **33** | **224** | **43** | **373** | **200** | **886** |
| N = | 558 | 7 | 58 | 51 | 71 | 10 | 123 | 24 | 293 |
| 31 | 9829 | 82 | 2447 | 198 | 1307 | 255 | 2148 | 1128 | 4992 |
| juv. males | **4187** | **33** | **558** | **156** | **454** | **76** | **851** | **442** | **2363** |
| std. dev | **1603** | **8** | **232** | **49** | **165** | **31** | **414** | **154** | **955** |
| N = | 1714 | 21 | 326 | 71 | 244 | 39 | 373 | 181 | 877 |
| 9 | 6648 | 47 | 1098 | 228 | 773 | 125 | 1624 | 707 | 4078 |
| ad. males | **4372** | **31** | **502** | **177** | **438** | **65** | **817** | **477** | **2576** |
| std. dev | **1382** | **5** | **154** | **62** | **98** | **24** | **426** | **152** | **801** |
| N = | 2736 | 25 | 352 | 97 | 349 | 40 | 353 | 345 | 1619 |
| 4 | 5770 | 37 | 661 | 231 | 535 | 96 | 1382 | 636 | 3242 |

***Table 11.*** *DDT and metabolites in pilot whale blubber. The results are given in µg/kg lipid. The results are shown with mean and standard deviation (bold) and minimum and maximum values for the groups of adult and juvenile, females and males.*

**Talva 11.** DDT í grindahvali er víst í µg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av hon- og hannhvølum, hvølpum og vaksnum er víst.

| Sandavágur | % Lipids | Sum DDT | o,p'-DDE | p,p'-DDE | o,p'-DDD | p,p'-DDD | o,p'-DDT | p,p'-DDT |
|---|---|---|---|---|---|---|---|---|
| juv. females | **90** | **19603** | **366** | **10828** | **559** | **2397** | **2414** | **3039** |
| std. dev. | **2** | **8886** | **136** | **5889** | **211** | **1186** | **1071** | **1004** |
| N = | 87 | 5818 | 126 | 3047 | 197 | 665 | 653 | 1130 |
| 7 | 92 | 28022 | 478 | 17331 | 768 | 4150 | 3417 | 4356 |
| ad. females | **92** | **5243** | **101** | **2570** | **150** | **610** | **690** | **1121** |
| std. dev. | **4** | **5331** | **106** | **2944** | **154** | **459** | **767** | **955** |
| N = | 83 | 1116 | 18 | 584 | 30 | 137 | 137 | 207 |
| 16 | 95 | 23038 | 459 | 12737 | 665 | 1944 | 3285 | 3948 |
| juv. males | **89** | **14545** | **272** | **7898** | **428** | **1788** | **1857** | **2303** |
| std. dev. | **6** | **8278** | **136** | **5131** | **216** | **1033** | **1032** | **1110** |
| N = | 78 | 1114 | 21 | 434 | 32 | 138 | 139 | 350 |
| 19 | 97 | 32001 | 585 | 20899 | 923 | 4504 | 3763 | 4531 |
| ad. males | **93** | **24257** | **275** | **15839** | **438** | **2069** | **2468** | **3167** |
| std. dev. | **3** | **11987** | **66** | **8701** | **150** | **831** | **1010** | **1375** |
| N = | 86 | 8367 | 154 | 4452 | 218 | 970 | 1009 | 1564 |
| 8 | 96 | 47909 | 378 | 33630 | 680 | 3493 | 4352 | 5376 |
| Tórshavn 24-09-97 | % Lipids | Sum DDT | o,p'-DDE | p,p'-DDE | o,p'-DDD | p,p'-DDD | o,p'-DDT | p,p'-DDT |
| juv. females | **91** | **19449** | **480** | **11111** | **651** | **1466** | **2485** | **3257** |
| std. dev | **6** | **10837** | **314** | **6680** | **397** | **663** | **1558** | **1521** |
| N = | 81 | 5858 | 179 | 2274 | 285 | 734 | 877 | 1509 |
| 6 | 96 | 37118 | 1038 | 21000 | 1350 | 2591 | 5280 | 5859 |
| ad. females | **93** | **4864** | **96** | **2569** | **134** | **460** | **601** | **1004** |
| std. dev | **4** | **4980** | **104** | **2765** | **142** | **557** | **557** | **978** |
| N = | 82 | 1265 | 18 | 521 | 33 | 128 | 156 | 344 |
| 31 | 98 | 27912 | 578 | 14506 | 812 | 3248 | 3063 | 5705 |
| juv. males | **91** | **12329** | **251** | **7330** | **348** | **911** | **1456** | **2033** |
| std. dev | **5** | **5313** | **108** | **3214** | **134** | **444** | **667** | **1015** |
| N = | 81 | 3946 | 100 | 1865 | 161 | 348 | 550 | 846 |
| 9 | 97 | 19797 | 402 | 12780 | 538 | 1678 | 2380 | 3980 |
| ad. males | **96** | **17840** | **284** | **12030** | **376** | **1027** | **1781** | **2344** |
| std. dev | **2** | **7384** | **127** | **4881** | **143** | **515** | **848** | **1228** |
| N = | 94 | 7520 | 114 | 5189 | 169 | 360 | 708 | 980 |
| 4 | 98 | 23881 | 416 | 16254 | 499 | 1615 | 2781 | 3929 |

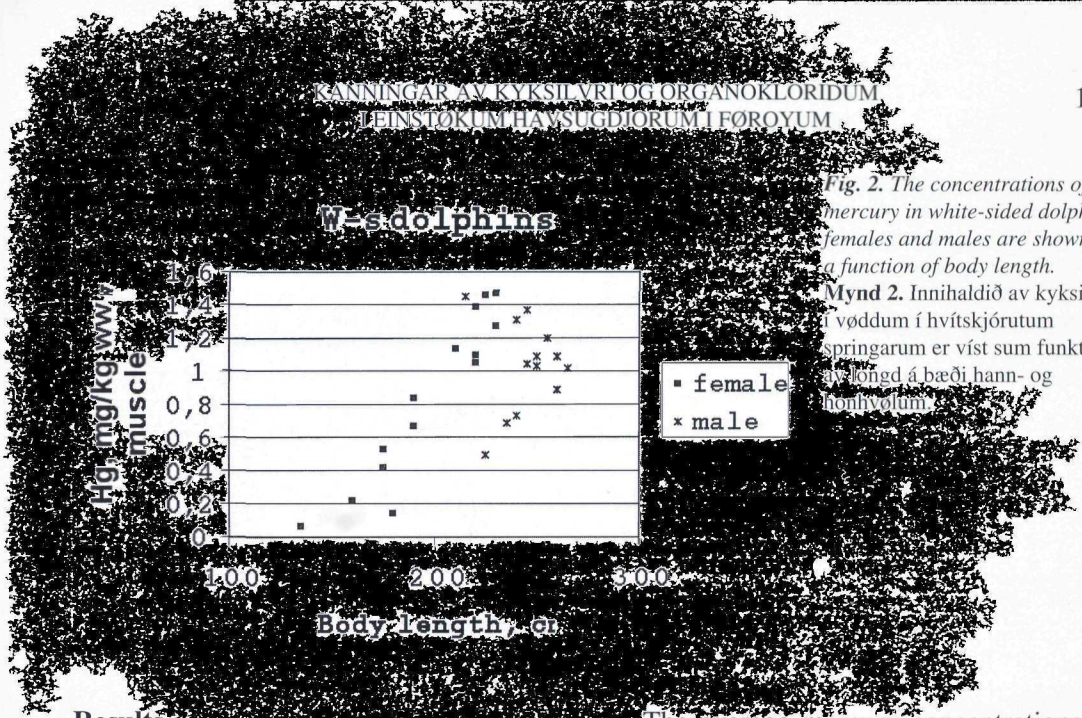



*Fig. 2. The concentrations of mercury in white-sided dolphin females and males are shown as a function of body length.*
**Mynd 2.** Innihaldið av kyksilvri í vøddum í hvítskjórutum springarum er víst sum funktión av longd á bæði hann- og honhvølum.

**Results**

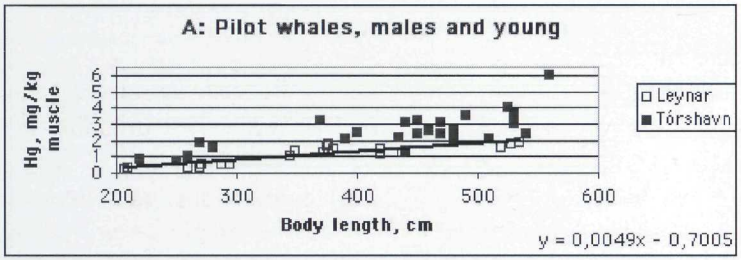
Mercury

The individual mercury concentrations in the grey seals are shown in Fig. 1. It is noteworthy that all seals, except a 21-year-old male, had mercury concentrations lower than 2 mg/kg. The old male had an entirely different level at almost 5 mg mercury per kg of muscle.

***Table 12.*** *The ratio of p,p'-DDT to p,p'-DDE are shown for the four age-sex groups of the species analysed.*
**Talva 12.** Lutfallið millum *p,p´*-DDT og *p,p´*-DDE er víst fyri teir fýra undirbólkarnar av honum, hannum, ungum og vaksnum í teimum trimum sløgunum, sum vórðu kannað.

| DDT/DDE | grey seal | w.-sided dolphin | pilot whale Sanda-vágur | pilot whale Tórshavn 24-09-97 |
|---|---|---|---|---|
| juv. females | 0.2 | 0.3 | 0.3 | 0.3 |
| ad. females | 0.3 | 0.4 | 0.4 | 0.4 |
| juv. males | 0.2 | 0.2 | 0.3 | 0.3 |
| ad. males | 0.3 | 0.1 | 0.2 | 0.2 |

The average mercury concentrations in the pilot whales taken in Tórshavn on 13 November 1997 and in the Leynar pod were 2.82 and 1.43 mg/kg, respectively (Table 3). When comparing overall concentrations of mercury among the groups of young and adults of both sexes, it is apparent that the overall highest concentration is found in the adult males, but is almost as high in adult females. The concentration in juveniles is lower than in the adults. When plotting the mercury concentrations vs. pilot whale body length, a tendency towards increasing concentrations with body length emerges (Fig. 3). This tendency is apparent as well for young females and males and also for adult males. For the group of adult female pilot whales (Fig. 3B) in the Tórshavn pod, there are large variations in mercury concentration, but there still appears to be an increase as body length increases. In the Leynar pod, on the other hand, the increase with body length in adult females is much less pronounced and the actual high-



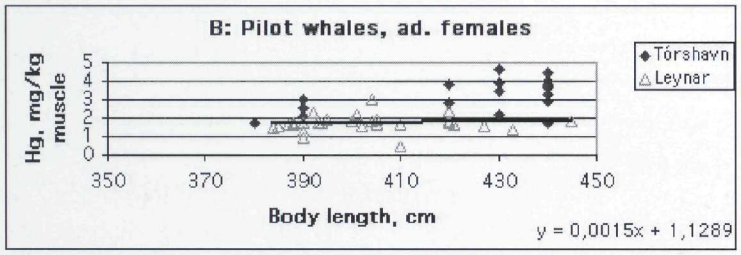




*Fig. 3. The concentration of mercury in pilot whale muscle is shown as a function of body length. Results for the juveniles of both sexes and the adult males are shown in part A. Those for the adult females are shown separately in part B.*

**Mynd 3.** Innihaldið av kyksilvri í grindahvalavøddum er víst sum funktión av hvalalongd. Úrslitini fyri hvølpar av báðum kynjum og fyri hannhvalir eru víst á mynd 3 A. Tey fyri vaksnar honhvalir eru víst fyri seg á mynd 3 .

***Table 13.** The results for toxaphene parlars in grey seal and white-sided dolphin blubber, in µg/kg lipid. The results are shown with mean and standard deviation (bold) and minimum and maximum values for the groups of adult and juvenile, females and males.*

**Talva 13.** Úrslitini av toxaphenparlarum í kópi og hvítskjórutum springarum eru víst í µg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av honum og hannum, hvølpum og vaksnum djórum, er víst.

| Grey seal | Parlar no. 26 ( T2 ) | Parlar no. 50 ( T12 ) | Parlar no. 62 ( T20 ) | % Lipids | w-s. dolphins | Parlar no. 26 ( T2 ) | Parlar no. 50 ( T12 ) | Parlar no. 62 ( T20 ) |
|---|---|---|---|---|---|---|---|---|
| juv. females | **16** | **20** | **nd** | **91** | juv. females | **1289** | **1872** | **846** |
| std. dev | **4** | **6** | **na** | **3** | std. dev | **728** | **786** | **201** |
| N = | 9 | 9 | nd | 85 | N = | 505 | 924 | 616 |
| 11 | 21 | 31 | nd | 97 | 7 | 2216 | 2924 | 1122 |
| ad. females | **17** | **22** | **nd** | **89** | ad. females | **134** | **229** | **126** |
| std. dev | **8** | **11** | **na** | **4** | std. dev | **57** | **101** | **46** |
| N = | 7 | 8 | nd | 84 | N = | 78 | 124 | 83 |
| 13 | 31 | 40 | nd | 98 | 8 | 215 | 380 | 204 |
| juv. males | **28** | **33** | **nd** | **87** | juv. males | **2217** | **2366** | **743** |
| std. dev | **11** | **12** | **na** | **5** | std. dev | **na** | **na** | **na** |
| N = | 13 | 17 | na | 81 | N = | na | na | na |
| 7 | 43 | 45 | na | 94 | 1 | na | na | na |
| ad. males | **25** | **39** | **15** | **87** | ad. males | **3251** | **3618** | **882** |
| std. dev | **9** | **20** | **na** | **7** | std. dev | **1493** | **1599** | **358** |
| N = | 15 | 18 | nd | 80 | N = | 107 | 292 | 156 |
| 3 | 31 | 56 | 15 | 94 | 12 | 6327 | 6517 | 1390 |

est concentration of mercury in the Leynar pod, 2.99 mg/kg muscle, occurs in a female of 404 cm body length.

The assumption, however, that length is proportional to age is a simplification that does not take into account the fact that growth is highly dependent on factors like availability of food in the main growth periods, and thus means that the longest individual need not be the oldest. Especially among females, the body length vs. age curve is very flat at ages 15 years and older (Bloch *et al.*, 1993) and a female of very modest body length may in fact be among the oldest. A more precise method of determining the age is by reading the whale teeth (Lockyer, 1993), but this was not done in the present study.

Plotting mercury concentrations in both male and female white-sided dolphins together (Fig. 2) reveals a peak at the upper border of attainable female body length. As in the Leynar pod of pilot whales, the maximum concentration of mercury that was measured in the group of white-sided dolphins was found in a female and was equal to 3.47 mg/kg muscle. The highest mercury concentration measured was 5.94 mg/kg muscle and this was found in the largest male (560 cm body length) in the Tórshavn pod of pilot whales. Earlier results (Simmonds *et al.*, 1994; HS, unpub-

***Table 14.*** *The results for toxaphene parlars in pilot whale blubber in the two pods are given in µg/kg lipid. The results are shown with mean and standard deviation values (bold) and minimum and maximum values for adult and juvenile, females and males.*

**Talva 14.** Úrslitini av toxaphenparlarum í grindahvali eru víst í µg/kg av feitti. Úrslitini eru víst sum miðalvirði við standardfrávikum (við feitari skrift), eins og lægsta og hægsta virði fyri teir fýra undirbólkarnar av hon- og hannhvølum, hvølpum og vaksnum djórum, er víst.

| Sandavágur 26 Aug 1997 | Parlar no. 26 ( T2 ) | Parlar no. 50 ( T12 ) | Parlar no. 62 ( T20 ) | Tórshavn 24 Sep. 1997 | Parlar no. 26 ( T2 ) | Parlar no. 50 ( T12 ) | Parlar no. 62 ( T20 ) |
|---|---|---|---|---|---|---|---|
| juv. females | **2981** | **3852** | **856** | juv. females | **2489** | **3937** | **742** |
| std. dev | **1453** | **1747** | **367** | std. dev | **1682** | **2342** | **354** |
| N = | 1283 | 1812 | 341 | N = | 734 | 1462 | 279 |
| 7 | 5354 | 6250 | 1381 | 6 | 4932 | 7305 | 1184 |
| ad. females | **637** | **1096** | **287** | ad. females | **537** | **935** | **259** |
| std. dev | **506** | **795** | **132** | std. dev | **613** | **916** | **212** |
| N = | 105 | 242 | 121 | N = | 96 | 196 | 71 |
| 16 | 1877 | 3323 | 567 | 31 | 3442 | 5158 | 1248 |
| juv. males | **1699** | **2661** | **552** | juv. males | **1592** | **2459** | **479** |
| std. dev | **901** | **1517** | **292** | std. dev | **700** | **1015** | **217** |
| N = | 109 | 243 | 101 | N = | 662 | 1098 | 315 |
| 19 | 4200 | 7323 | 1446 | 9 | 3070 | 4376 | 967 |
| ad. males | **2060** | **2774** | **562** | ad. males | **1628** | **2422** | **447** |
| std. dev | **605** | **880** | **187** | std. dev | **566** | **772** | **133** |
| N = | 981 | 1837 | 339 | N = | 797 | 1450 | 274 |
| 8 | 3049 | 4259 | 818 | 4 | 2067 | 3254 | 570 |

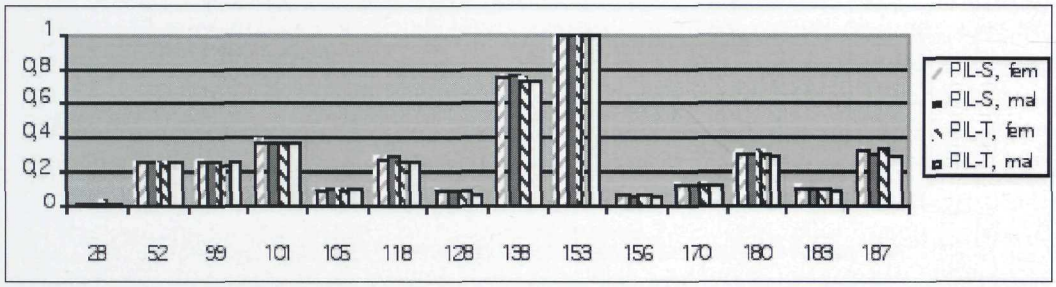



*Fig. 4. The mean concentrations of the PCB congeners relative to that of CB 153 are shown. The results for the two pods of pilot whales are shown, separated into sub-groups of females and males.*
**Mynd 4.** Miðalinnihaldið av PCB-kongenunum er víst í mun til innihaldið av CB 153. Úrslitini fyri teir báðar grindahvalabólkarnar eru víst, býtt í undirbólkar av hon- og hannhvølum.

*Table 15. Precision of the PCB 7 results, which were calculated as the sum of the individually quantified congeners CBs 28, 52, 101, 18, 138, 153 and 180.*
**Talva 15.** Neyvleikin í PCB 7-úrslitunum eru víst. PCB 7-úrslitini vórðu roknað út sum samløgan av teimum einstøku kongenunum CB 28, 52, 101, 118, 138, 153 og 180.

| # Ref. | PCB 7 µg/kg lipid, mean | std. dev | std. dev% |
|---|---|---|---|
| 56F | 1559 | 86 | 5% |
| 58M | 13131 | 105 | 1% |
| S8M | 5722 | 178 | 3% |
| S14F | 14240 | 370 | 3% |
| S21M | 9178 | 240 | 3% |
| S37M | 22343 | 1679 | 8% |
| S66F | 10696 | 3 | 0% |
| T27F | 4841 | 357 | 7% |
| T49F | 3236 | 0 | 0% |
| T104F | 3215 | 14 | 0% |
| T115F | 2975 | 166 | 6% |
| T126F | 7997 | 6 | 0% |
| H14F | 1770 | 123 | 7% |
| H53F | 2490 | 110 | 4% |
| H68F | 1766 | 197 | 11% |
| **All (n = 15)** | | | 4% |

lished) yielded reason to believe that the maximum concentration in individual pilot whales would be approximately three times the average. Thus, with an average close to 2 mg/kg muscle, the reported nearly 6 mg of mercury per kg of muscle was indeed expected.

## Organochlorines – PCB

The results of the PCB analyses are summarised in Tables 4 through 6. Comparing the two pods of pilot whales, the one school of white-sided dolphins, and the grey seals, the group with the highest PCB concentration is the white-sided dolphin males (Fig. 6), but with only marginal differences to that found in the pilot whale males. The group with the over-all lowest concentration is the grey seal females, but the white-sided dolphin females are nearly as low. The difference between adult dolphin females and males is very large compared to the difference between the adult groups of pilot whales. The difference between the dolphin adult groups is a factor of almost 13 in CB 153 concentration. The adult male seal group, on average, contain about


*Fig. 5. The relative concentrations of the PCB congeners relative to that of CB 153 are shown for the three species analysed.*
**Mynd 5.** Tað lutfalsliga innihaldið av PCB-kongenunum í mun til CB 153 eru víst fyri tey trý sløgini, sum vórðu kannað.

*Table 16. Precision of Sum Chlordane results, which were calculated as the sum of individually quantified chlordanes α-chlordane, γ-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane.*
**Talva 16.** Neyvleikin í sum-klordanúrslitunum eru víst. Sum-klordanúrslitini vórðu roknað út sum samløgan av teimum einstøku klordanunum.

| # Ref. | Sum Chlordane µg/kg lipid mean | std. dev | std. dev% |
|---|---|---|---|
| 56F | 656 | 40 | 6% |
| 58M | 7367 | 1020 | 14% |
| S8M | 2730 | 19 | 1% |
| S14F | 6774 | 55 | 1% |
| S21M | 5375 | 350 | 7% |
| S37M | 7698 | 269 | 3% |
| S66F | 5325 | 342 | 6% |
| T27F | 2530 | 51 | 2% |
| T49F | 2536 | 46 | 2% |
| T104F | 2202 | 32 | 1% |
| T115F | 1295 | 48 | 4% |
| T126F | 4586 | 44 | 1% |
| H14F | 457 | 19 | 4% |
| H53F | 668 | 65 | 10% |
| H68F | 609 | 3 | 1% |
| **All (n = 15)** | | | 4% |

a factor 7 higher CB 153 concentration than the adult female, whereas among pilot whales the difference is approximately 3 (3.5 and 2.8 in the Sandavágur and Tórshavn 24 September 1997 pods, respectively, Table 6).

The explanation for the differences among the species studied may be sought in the age differences within the groups. This is best exemplified by comparing the juvenile group of seals to the juvenile group of pilot whales wherein the former is comprised of almost entirely one- to three-year-old individuals, and the latter includes males of an age equivalent of 10 to 15 years (up to 480 cm) (Bloch *et al.*, 1993). With the present material from white-sided dolphin, it is reasonable to assume that the reason for the high difference between males and females stems from the overall presence of older males, as indicated in the figures where Mirex is plotted as function of body length (Fig. 8). Influences from other sources, however, are possible as cofac-

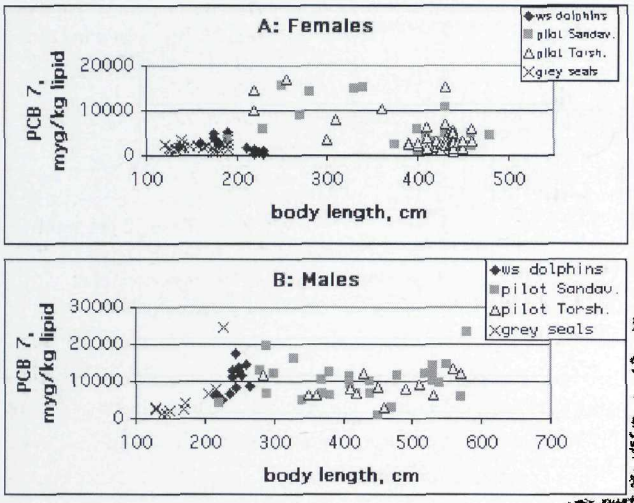



*Fig. 6. The concentrations of PCB 7 in grey seals, white-sided dolphins and pilot whales are plotted as a function of whole body length. Note that the scale for PCB for females (A) is different than that for males (B).*
**Mynd 6.** Innihaldið av PCB 7 [illegible] láturkópum, hvítskjörutum springarum og grindahvølum eru víst sum funktión av kropslongd. Gerið greitt eftir, at stigini eru ikki eins á myndum A og B.

*Table 17. Precision of Sum DDT results, which were calculated as the sum of the individually quantified p,p'-DDT, p,p'-DDE, p,p'-DDD, and the o,p'-substituted isomers.*
**Talva 17.** Neyvleikin í sum-DDT-úrslitunum eru víst. Sum-DDT varð roknað út sum samløgan av *p,p'-DDT, p,p'-DDE, p,p'-DDD* og teimum *o,p'*-substitueraðu isomerunum.

| # Ref. | Sum DDT µg/kg lipid, mean | std. dev | std. dev% |
|---|---|---|---|
| 56F | 1288 | 21 | 2% |
| 58M | 22501 | 738 | 3% |
| S8M | 8254 | 161 | 2% |
| S14F | 25217 | 1187 | 5% |
| S21M | 13153 | 325 | 2% |
| S37M | 45687 | 3143 | 7% |
| S66F | 22689 | 494 | 2% |
| T27F | 6488 | 245 | 4% |
| T49F | 6146 | 42 | 1% |
| T104F | 4655 | 88 | 2% |
| T115F | 3576 | 47 | 1% |
| T126F | 13389 | 184 | 1% |
| H14F | 766 | 16 | 2% |
| H53F | 1328 | 76 | 6% |
| H68F | 995 | 47 | 5% |
| **All (n= 15)** | | | 3% |

tors. Such species-specific differences could stem from differences in the duration of the nursing period. Grey seals, for example, nurse their offspring for a few weeks whereas the toothed whale species nurse their young for a year or more (Bloch and Fuglø, 1999).

The two pods of pilot whale that were analysed are similar with respect to the concentration of PCB. Also the relative contribution of the various congeners, often termed the congener profile (Fig. 4), are similar in these two pods. Therefore, to simplify the comparison of the congener profile between the species, only one of the pilot whale pods was included (Fig. 5). The absolute concentrations are not suitable indicators of species-specific differences because the absolute concentrations are highly influenced by dietary intake of the compounds, which, of course, varies for the various food groups and from area to area.

Earlier studies of species-specific differences in other marine mammal species re-

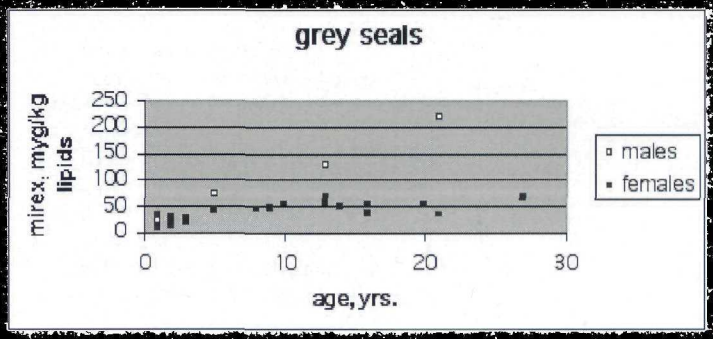



*Fig. 7. The concentration of Mirex in grey seal blubber is plotted as a function of age. The 22-year-old male with the highest Mirex concentration, 729 µg/kg lipid, is excluded in this figure.*
**Mynd 7.** Innihaldið av Mirex í fituvevnaði er víst sum funktión av aldri á kópi. Tann 22 ára gamli brimhvin, sum hevði hægsta innihald av Mirex, 729 µg/kg av feitti, er ikki víst á myndini.

*Table 18. The precision of the toxaphene analyses, calculated as the sum of the sum of the parlars that were quantifiable (Parlar 26, 50 and 62).*
**Talva 18.** Neyvleikin í toksafenúrslitunum eru víst. Toksafenúrslitini vórðu roknað út sum samløgan av teimum einstøku parlarunum, sum kunnu teljast (parlarar 26, 50 og 62).

| Location | Sample ID | Sum Parlars µg/kg lipid mean | std. dev | std. dev, % |
|---|---|---|---|---|
| Sandavágur | | | | |
| 26 August 1997 | Pilot whale 8 | 4630 | 358 | 8% |
| | Pilot whale 14 | 13025 | 837 | 6% |
| | Pilot whale 21 | 4989 | 147 | 3% |
| | Pilot whale 37 | 6981 | 308 | 4% |
| | Pilot whale 66 | 5496 | 293 | 5% |
| Tórshavn | | | | |
| 24 September | Pilot whale 27 | 2428 | 92 | 4% |
| 1997 | Pilot whale 49 | 2222 | 45 | 2% |
| | Pilot whale 104 | 1927 | 87 | 5% |
| | Pilot whale 115 | 1616 | 40 | 2% |
| | Pilot whale 126 | 6435 | 133 | 2% |
| Klaksvík | | | | |
| 21 August | W.-s. dolphin 56 | 544 | 15 | 3% |
| 1997 | W.-s. dolphin 58 | 9133 | 361 | 4% |
| Faroe Islands | | | | |
| 1993 - 1995 | Grey seal 14 | 55 | 3 | 5% |
| | Grey seal 53 | 39 | 1 | 3% |
| | Grey seal 68 | 41 | 1 | 3% |
| **All (n = 15)** | | | | 4% |

vealed that seals were more able to metabolise PCB than toothed whales (Boon *et al.*, 1992; 1996; 1997). Such differences were clearly seen in the relative concentration of CB 118, but also other congeners like CB 52, 101, and 187 are found in relatively lower concentrations in seals than in whales. The two whale species have similar relative concentrations of the higher chlorinated congeners (those to the right of CB 138, whereas the lower chlorinated congeners appear to be more easily degraded in the smaller dolphins than in the pilot whales. Especially among the white-sided dolphin males the relative concentrations of the CBs 28 and 52 and the pentachlorinated CBs are markedly lowered. These congeners are normally not as prone to bioaccumulation (*i.e.* the increment in concentration that follows with age) as the heavier ones like CB 153 and CB 138. In light of the probable higher mean age of the white-sided dolphin males in this material, as mentioned above, increased age could explain the relatively lower concentrations of the lower chlorinated congeners in the males because the "enrichment" time for the more persistent congeners is longer.

In Fig. 6, the concentration of PCB is

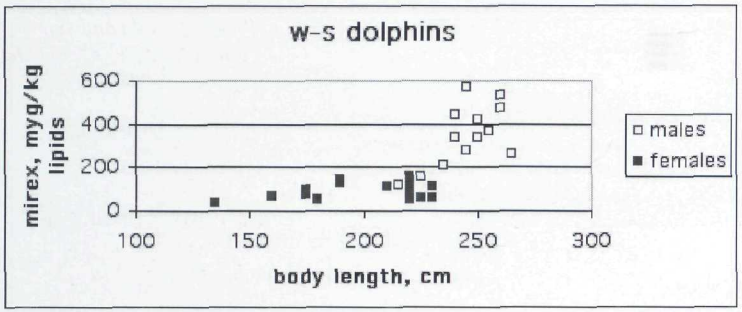


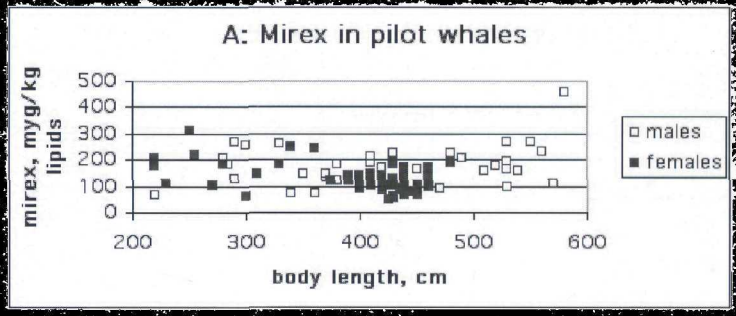

*Fig. 8. Mirex in white-sided dolphin blubber is shown in µg/kg lipid.*
**Mynd 8.** Mirex í hvítskjórutum springaraspiki er víst í eindini µg/kg av feitti.

shown as a function of individual body lengths for the three species analysed. The PCB in Fig. 6 is given as PCB 7, which is the sum of the concentrations of the individual CBs numbered 28, 52, 101, 118, 138, 153 and 180. Because the scale of Fig. 6 is dictated by the larger body size of the pilot whales, this figure may reasonably be described as "the pilot whale perspective". The overall different tracks of the PCB vs. body lengths curves for the females (Fig. 6A) as compared to that of the males (Fig. 6B) are, however, clear even in the distorted perspective. A review of the plotted data in Fig. 6A reveals that a peak in PCB concentration in the females occurs at an intermediate body length, whereas for the grey seal and white-sided dolphin males there

***Table 19.*** *The highest and lowest concentrations encountered in the present study, comprising in all 261 marine mammals of which 200 are pilot whales from four separate pods.*
**Talva 19.** Hægsta og lægsta innihald, sum varð ávíst í hesi kanning, sum fevnir um til samans 261 havsúgdjór, teirra millum eru 200 grindahvalir úr fýra ymiskum grindum.

| Parameter | **max- min** µg/kg lipid* | **Highest concentrations** individual | **Lowest concentration** individual |
|---|---|---|---|
| Mercury | 5,940-70 | Pilot whale, Tórshavn, 13-11-97, male (560 cm) | W-s dolphin, Klaksvík, 21-08-97, female 37F, (smallest one) |
| PCB 7 | 24,518-436 | Grey seal, 08-08-94, male H38M | W-s dolphin, Klaksvík, 21-08-97, female 41F |
| Sum DDT (incl. *o,p'*-isomers) | 47,909-220 | Pilot whale, Sandavágur 26-08-97, male S37M | Grey seal, 18-08-95, female H64F |
| Toxaphene (Sum Parlars) | 14,234-15 | W-s dolphin, Klaksvík, 21-08-97, male 14M | Grey seal, 18-08-95, female H65F |
| Sum Chlordanes | 12,020-160 | W-s dolphin, Klaksvík, 21-08-97, male 38M | Grey seal, 18-08-95, female H64F |
| Mirex | 729-8.4 | Grey seal, 08-08-94, male H38M | Grey seal, 18-07-95, female H51F |

* Mercury is given as µg/kg muscle.



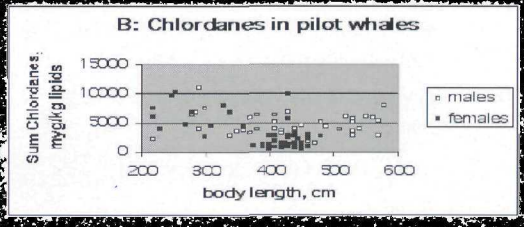




*Fig. 9. Mirex (in A) and Sum Chlordanes (in B) in pilot whale blubber from the two pods Tórshavn 24 September 1997 and Sandavágur 26 August 1997 are shown in µg/kg lipid.*
**Mynd 9.** Mirex (í A) og Sum-klordan (í B) úr grindahvala-spiki í teimum báðum grind-unum 24. september 1997 í Tórshavn og 26. august 1997 í Sandavági er vist í eindini µg/kg av feiti.

seems to be a tendency towards a steadily increasing PCB concentration with age. The picture is a bit more complex for pilot whales, however, which seem to go through a minimum, in-body PCB concentration in the pre-adult/early-adult stage. The general large gap in PCB loads between the females and the males of the species is partly masked by the different scales used.

The individual with the highest burden of PCB 7 was also the one with the highest concentration of CB 153 with 11,936 µg/kg lipid (Tables 4 and 19). Conversely, the individual with the lowest burden of PCB 7 also had the lowest concentration of CB 153. What this means is that CB 153 makes up a major part of the total body burden of PCB. Among the pilot whales, the maximum concentration of PCB was found in a male No. 37 from Sandavágur, 26 August 1997, with a concentration of PCB 7 of 23,530 µg/kg lipid and CB 153 of 7,611 µg/kg lipid. The minimum concentration of PCB among the pilot whales is found in a female whale, No. 36 from Tórshavn 24 September 1997, which also had the lowest concentration of CB 153 equal to 309 µg/kg lipid. The male with the highest concentration had a body length of 580 cm. This animal was of more than average size, but not exceptional considering that the longest male in the whole group of 466 individuals covered in the screening (Dam and Bloch, 2000) was 650 cm. This same individual was also the carrier of the highest concentrations of Sum DDT and Mirex. The fe-

***Table 20.** Precision of the mercury analyses is shown as average relative standard deviation.*
**Talva 20.** Neyvleikin í kyksilvurskanningunum eru víst sum standardfrávik í miðallutfalli.

| | Average relative standard deviation | No. of doublet analyses |
|---|---|---|
| pilot whales, Leynar | 4.2% | 11 |
| pilot whales, Tórshavn | 4.0% | 12 |
| grey seals | 5.4% | 9 |
| white-sided dolphins | 5.3% | 6 |

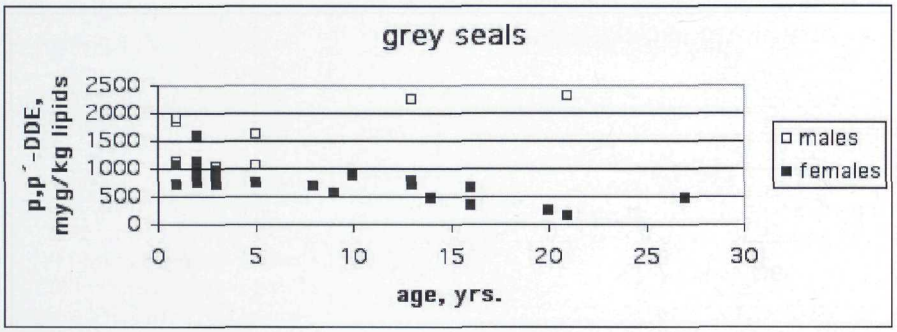



*Fig. 10. The concentration of p,p'-DDE in grey seal blubber is plotted as a function of age. The 22-year-old male with the highest p,p'-DDE concentration, 4,525 µg/kg lipid, is excluded in the figure.*
**Mynd 10.** Innihaldið av *p,p'*-DDE í láturkópaspiki er víst sum funktión av aldri. Tann 22 ára gamli brimilin við tí hægsta *p,p'*-innihaldinum, tað sama sum 4525 µg/kg av feitti, er ikki við á myndini.

male with the lowest body burden was measured at 440 cm body length. The average adult female body length in the material of 466 individuals was 430 cm.

*Pesticides*

The pesticides analysed were chlordanes, ß-HCH, Mirex, HCB (hexachlorobenzene), DDT, and toxaphene. The chlordanes are a class of cyclopentadiene compounds of which the compounds cis (α)- and trans (γ) –chlordane and cis- and trans-nonachlor were present in the original commercial pesticide product, whereas oxychlordane is the semi-degraded metabolite of these (USEPA, 1998). ß-HCH is present as an impurity in the technical hexachlorobenzene formulation, where the gamma isomer (lindane) is the actual active ingredient (Waxman, 1998). The organochlorine compound Mirex has been used mainly on the North American continent. In the US, it has been used as a pesticide and in smaller amounts in Canada as a flame retardant (AMAP, 1998). Toxaphene is a mixture of chlorinated bornanes and was the world's

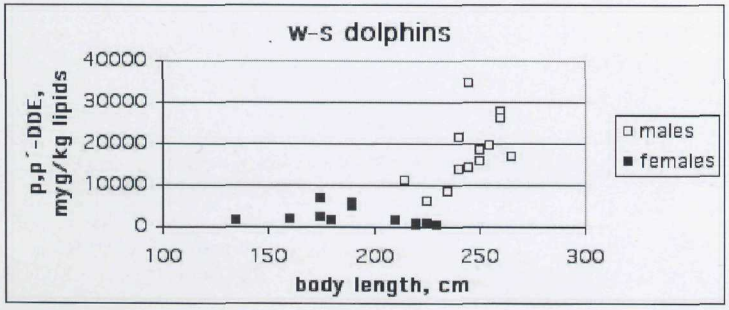



*Fig. 11. The concentration of p,p'-DDE, in µg/kg lipid, in white-sided dolphin blubber is plotted as a function of body length for males and females.*
**Mynd 11.** Innihaldið av *p,p'*-DDE í hvítskjórutum springaraspiki er víst sum funktión av kropslong á hann- og honhvølum.

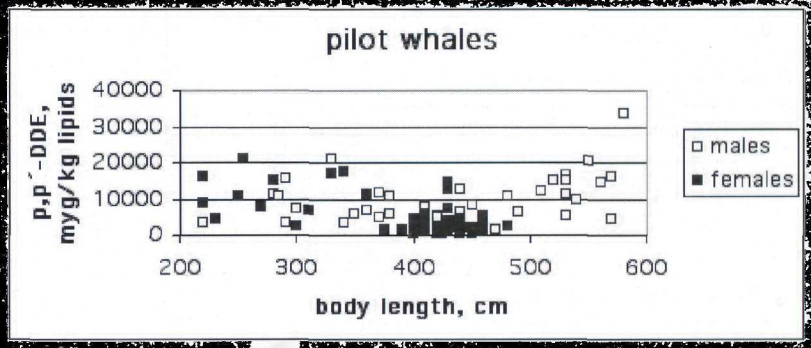



*Fig. 12. The concentration of p,p´-DDE, in µg/kg lipid, in pilot whale blubber is plotted as a function of body length for all the males and females of the two pods Tórshavn 24 September 1997 and Sandavágur 26 August 1997.*

Mynd 12. Innihaldið av *p,p´*-DDE, í µg/kg av feiti, í grindahvalaspiki er víst sum funktión av longdini á hann- og hoyndyrunum í teimum báðum grindunum 24. september 1997 í Tórshavn og 26. august 1997 í Sandavági.

most heavily used pesticide in the period 1972 to 1984 (Saleh, 1991). Other compounds have been widely used in the post-war period until the 1970s (DDT and the chlordanes), and some are still used in restricted applications (HCB, lindane, and DDT) (Waxman, 1998).

The analysis results for grey seal are given in Table 7. The most striking feature is the difference in Mirex concentration in adult males in comparison to that in groups of juveniles and adult females. The adult male concentration of DDT and the chlordanes are two to four times as high in the adult males as in the juveniles of both sexes. The Mirex concentration, however, is more than ten times higher in the adult males than in the juveniles. A closer inspection of the data shows that one particular male, a 22 year old, pulled the average upwards very markedly with a concentration of 729 µg/kg lipid (not shown in Fig. 7). The individual with the next highest concentration was also an adult male 21

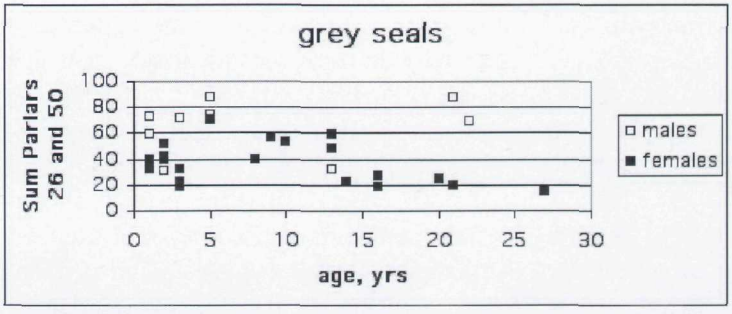



***Fig. 13.*** *The sum of toxaphene parlars no. 26 and 50 (nos. 32, 62, and 69 where not detected) in grey seal blubber, expressed as µg/kg lipid, is plotted vs. age.*
**Mynd 13.** Samløgan av toksafenparlarunum nr. 26 og 50 (nr. 32, 62 og 69 vórðu ikki ávíst) í láturkópaspiki, í µg/kg av feitti, er víst sum funktión av aldri.

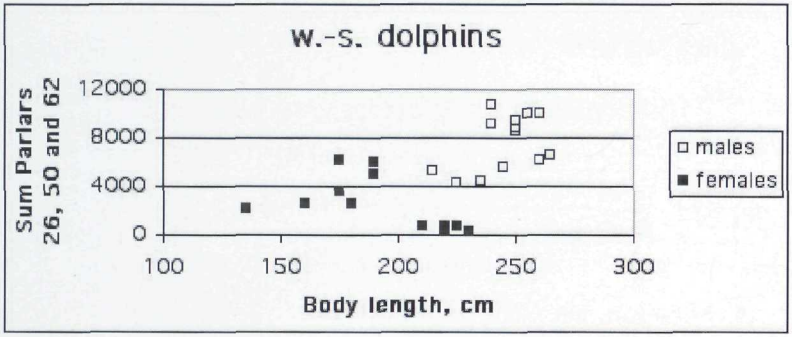



*Fig. 14. The sum of toxaphene parlars no. 26, 50, and 62 (nos. 32 and 69 where not detected) in white-sided dolphins, expressed as µg/kg lipid, is plotted vs. body length in cm.*
**Mynd 14.** Samløgan av toksafenparlarunum nr. 26, 50 og 62 (nr. 32 og 69 vórðu ikki ávíst) í hvítskjórutum springaraspiki, í µg/kg av feitti, er víst sum funktión av hvalalongd í cm.

years of age, whose blubber Mirex concentration was 218 µg/kg lipid and this is the same individual that contained markedly elevated mercury concentrations in comparison to the other grey seals, including the above mentioned 22-year-old.

The results of the analyses on white-sided dolphin blubber samples are given in Table 8 and a plot of Mirex concentration versus body length is shown in Fig. 8. The results for the pilot whales are given in Table 10 and Fig. 9. Comparing the concentration of Mirex in the juvenile females of the three species shows that the concentration increases in this order: grey seals < white-sided dolphins < pilot whales in a ratio of approximately 1 : 4 : 8.

The active pesticide isomer, *p,p'*-DDT, upon biodegradation, is metabolised to *p,p'*-DDE and via a different metabolic route to *p,p'*-DDD (WHO, 1979). The ortho,para isomer, *o,p'*-DDT, is a by-product in the synthesis of the potent pesticide. Only a small fraction is present in the original formulation compared to the para,para isomer. However, upon biotransformation and biodegradation in the food chain, after the pesticide generally has entered the environment, the relationship between the concentrations of these isomers is altered considerably. Because *p,p'*-DDE is also persistent and lipid soluble, as is *p,p'*-DDT, it has been suggested that the ratio between the concentration of the parent compound and the metabolite could be used as an indication of the time elapsed since the parent compound was originally released into the environment. However, because the rate of degradation is both species-dependent and dose-dependent as well as varying between the individuals according to sex and age (Table 12), this comparison can only be used in a qualitative manner (WHO, 1979).

Of the DDT group, only *p,p'*-DDT and *p,p'*-DDE (Fig. 10) were present in detectable amounts in the grey seal blubber, although in the adult males small concentrations of *p,p'*-DDD, mean 60±19 µg/kg

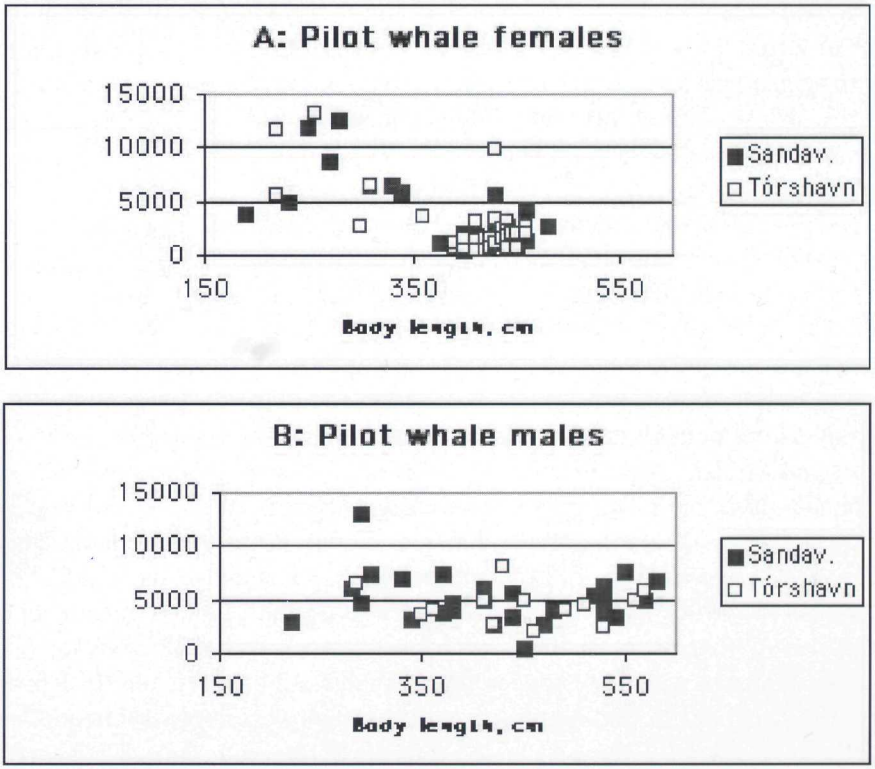



*Fig. 15. The sum of toxaphene parlars no. 26, 50, and 62 (nos. 32 and 69 where not detected) in the Tórshavn 24 September 1997 and the Sandavágur 26 August 1997 pods of pilot whales, expressed as µg/kg lipid, are plotted vs. body length in cm. In A: Females, and in B: Males.*

**Mynd 15.** Samløgan av toksafenparlarunum nr. 26, 50 og 62 (nr. 32 og 69 vórðu ikki ávíst) í grindahvalaspiki í teimum báðum grindunum 24. september 1997 í Tórshavn og 26. august 1997 í Sandavági er víst sum funktión av hvalalongd í cm. Eindin er µg/kg av feitti. Í A: honhvalir og í B: hannhvalir.

lw (lipid weight), were also found (Table 7). The ortho,para isomers were not detectable at approximately 2 µg/kg lw or were found in concentrations very close to this detection limit.

The concentrations of the DDTs in white-sided dolphins are given in Table 9 and those in the pilot whales in Table 10. The larger part of the Sum DDT[2] concentration consists of *p,p'*-DDE, and this is to be expected based on the above-mentioned reasons. The concentrations vs. body length are given for white-sided dolphins and pilot whales in Fig. 11 and Fig. 12, respectively. What is really remarkable is the comparatively high concentration of *o,p'*-DDT, which is present in a small percentage only in the original technical pesticide formulation (WHO, 1979). In pilot whales and white-sided dolphins, the concentration of *o,p'*- DDT is approximately equal to that of *p,p'*-DDT. In absolute values, the

concentration of Sum DDT is similar for the adult male groups of the two whale species. In both whale species *o,p'*-DDE were found in the lowest concentration of the six DDT isomers analysed.

Of the toxaphene compounds, the parlars 26, 32, 50, 62, and 69 were analysed, but of these parlars 32 and 69 were not detected in any sample. The parlars 26 (T2) and 50 (T12), the former an octa- and the latter a nonachlorbornane, are both present in technical toxaphene in small percentages (less than 1%), but known to be persistent in marine biota (Buser and Müller, 1993; Vetter *et al.*, 1993). In a study of biotransformation in harbour seals, it was found that the chlorinated bornanes 32 and 62 were fully metabolised (Boon *et al.*, 1996).

The concentration of toxaphene in the groups of grey seals is shown with those for white-sided dolphins in Table 13 and plotted vs. age (Fig. 13). As with the grey seals, there were no measurable concentrations of Parlars 32 and 69 in the white-sided dolphins. Parlar 62, which was only found in one adult male grey seal (the 21 year old), is abundant in the white-sided dolphins and this correlates well with the metabolism observed to occur in white-beaked dolphins (Boon *et al.*, 1996). What is most remarkable about the toxaphene results is perhaps that the mean value for Sum toxaphene for the adult females is merely a factor of one-tenth that of the mean for all the white-sided dolphins (Fig. 14).

The results of the toxaphene analyses in pilot whales are shown in Table 14 and Fig. 15. The two highest toxaphene concentrations in both pods, equal to 13 and 12 mg/kg lipid, were found in juvenile females, but Fig. 15 shows that also among the males, the juveniles carry relatively high concentrations.

## Discussion

The results of this study reveal that essentially the concentration of the organochlorines analysed was always lowest in the adult females of a species. The one exception was that of the grey seals: the adult female group had higher concentrations than the juvenile females of some of the POPs like Mirex, hexachlorobenzene, and α-chlordane. An explanation for this may be that the juvenile female seals on average are very young, only two years, whereas the average age of the juvenile female pilot whales is probably around four years.

The Tórshavn 24 September 1997 juvenile pilot whales were in general larger than those of the Sandavágur pod. The average body length of the young females and males of the former pod was 277 cm and 406 cm, respectively. The females and males of the latter pod were 270 and 372 cm, respectively. The mean body length of the 54 juvenile females and 104 males analysed in the full screening was 297 cm and 387 cm, respectively (Dam and Bloch, 2000).

The present study confirms the results from an earlier study of pilot whales and grey seals (Larsen and Dam, 1999) in which the concentration of CB 153 was found to be higher in adult male seals than in adult pilot whale males. The concentration in the adult females and young were, however, lower in the seals than in the

whales. The most immediate explanation for this phenomenon would be that the adult seal males migrate to more polluted areas during their lifetime (perhaps early "adulthood"). This would also be consistent with the present knowledge of the grey seals in the Faroe Islands.

There are, however, additional possible reasons for these differences. For example, sample characteristics, such as group mean age and the general "representativity" of the sample, may be a reason, as well as those unique differences that are inherent in the specific species. In addition, factors, which may be termed combined species and general socio-ecological differences, which lead to variability in frequency of reproduction, etc. will influence the intake and elimination of pollutants. Possible differences in diets and foraging areas among females and males of the same species will also contribute to these differences.

It appears that a combination of factors contribute to very high concentrations of persistent organic pollutants in a few adult male seals. Individual variations are more moderate among the pilot whales, however, and it is plausible that pilot whales, which live in pods, as a species represent a more homogeneous group. This is also suggested by the similarities in the persistent organic pollutant concentrations in the two pods studied. Review of the pollutants vs. body length curves (Figs. 2, 8, 11, 14) for the white-sided dolphins reveals a shortage of juvenile males in this sample, and perhaps also an under-representation of adult females. Given these uncertainties, it seems premature to try to set the present findings into a model. However, comparison of the pollutants vs. body length curves for the white-sided dolphins against the curves plotted for the pilot whales indicates that the mature males of the former species are accumulating the lipid soluble pollutants at a much higher rate than the pilot whale males.

**Correlations**

Review of the "highest concentration" column in Table 19 reveals that the compounds analysed may be sorted into levels. The highest level of concentration is the DDT group, which thus accounts for the highest mass of the analysed pollutants in the blubber tissue. The DDT group is followed by PCB, toxaphene, and then the chlordanes. There is a significant drop to the mercury level and subsequently to the lowest level comprised of HCB, Mirex, and ß-HCH.

The Sum DDT in the adult male groups are in the range 4,000 to 27,000 µg/kg lipid with grey seals at the lower level and the white-sided dolphins at the upper level, with small margins only with the pilot whales, which have average concentrations of 18,000 and 24,000 µg/kg lipid in the Tórshavn 13 November 1997 and the Sandavágur pods, respectively. The PCB 7 for the adult male groups ranged from 10,000 µg/kg lipid in the pilot whales of the Tórshavn 13 November 1997 pod to 11,500 µg/kg lipid in the white-sided dolphins to 13,000 µg/kg lipid in the Sandavágur pods of pilot whales and the grey seals. ß-HCH was detected in three grey seal individuals, but only at 5, 6, and 7 µg/kg lipid in a three-

year-old female and two males, a one-year-old and a thirteen-year-old, respectively. In the white-sided dolphin adult males, the concentration of ß-HCH was about 100 µg/kg lipid, which is approximately triple the concentration in the adult male pilot whales.

In the white-sided dolphin female group, there was a clear correlation (Pearson correlation coefficient ≥0.90) between the organochlorines occurring at the highest concentration level, represented by *p,p'*-DDE, CB 153, trans-nonachlor, and Parlar 50. Such correlation, however, was absent in the male group. In the pilot whale female group, there was a clear correlation between Parlar 50 and CB 153, but not to other compounds, except the other toxaphene constituents Parlar 26 and Parlar 62. Neither was there any clear correlation between CB 153 and *p,p'*-DDE nor CB 153 and trans-nonachlor. There was, however, correlation between *p,p'*-DDE and trans-nonachlor. In the female seals, the picture was opposite with no strong correlation between toxaphene and PCB, but correlation between CB 153 and *p,p'*-DDE. In the male seal group, there was also a strong correlation between CB 153 and trans-nonachlor.

From these observations, it is obvious that there are no straightforward correlations between the relative concentrations of the various POPs among the various species. Correlation analyses failed to indicate any pattern in pollutant concentrations other than clear-cut correlations between isomers, metabolites, and congeners of compounds. For pilot whales, for instance, the most persistent CB congener, CB 153, was highly correlated to CB 138 with a Pearson correlation coefficient equal to 0.997. The other congeners also correlated to each other, except the lower chlorinated CB 28, which was not or more weakly correlated to the other congeners with correlation coefficients in the range 0.21 to 0.68 for the pilot whale males and 0.51 to 0.82 for the pilot whale females.

The compounds in the DDT group correlated to each other with the highest correlation between the ortho,para substituted compounds (> 0.94 in the pilot whales) and more modestly between the para,para compounds (in the range 0.82 to 0.89 for the pilot whales). In the white-sided dolphins, the highest correlation was between the *o,p'*-DDE and the two DDD isomers, *o,p'*-DDD and *p,p'*-DDD, with correlation coefficients of 0.996 and 0.993 in the females and somewhat weaker 0.968 and 0.971 in the males. The correlation between especially *p,p'*-DDE and *p,p'*-DDT and *p,p'*-DDD was much weaker in the male dolphins than in the female dolphins with coefficients of correlation of 0.643 and 0.678, respectively, in the males and 0.970 and 0.954, respectively, in the females.

For the male dolphins, the correlation between Mirex and *p,p'*-DDE was clear (0.930), but not for the females (0.206). The same was also true for the seals; for the females there was no particular correlation between Mirex and *p,p'*-DDE, but with the male seals there was high correlation between Mirex and *p,p'*-DDE (0.947) and also very markedly with *p,p'*-DDT (0.992). In pilot whales, the highest Pearson corre-

lation coefficient (0.84) for Mirex was found in relation to *p,p'*-DDE, and, when performing the correlation analyses of Mirex concentration vs. the DDT group for the males and the females separately, it appeared that the correlation was weaker in the males than in the females. The correlation between the Mirex and the DDT compound groups is thus different in the two whale species, as well as between the whales and the seals.

The very same white-sided dolphin individuals that were analysed for organochlorines, were also analysed for mercury, and, thus, correlation analyses were performed on females and males separately. The analyses revealed negative correlations between mercury and the organochlorines for the females and no positive correlations for the males.

*Quality Assurance – Quality Control*

The general quality control protocol of the laboratories includes duplicate analyses on 10% (POPs) or 15% (Hg) of the samples. The precision of the mercury analyses is given as a relative standard deviation between doublet analyses of the samples (Table 20). A summary of the precision report for the PCB analyses is given in Table 15. Tables 16 and 17 summarise the results of the precision analyses, exemplified with the Sum Chlordane and Sum DDT, as a percent standard deviation. For toxaphene analyses, the overall mean standard deviation of the 14 duplicate analyses was 4%. The individual results are provided in Table 18.

[1] Mirex (empirical formula $C_{10}Cl_{12}$) is also known as a hexachloropentadiene dimer.

[2] Sum DDT = *p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, *o,p'*-DDT, *o,p'*-DDE and *o,p'*-DDD.

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