CHEMICAL CONTAMINANTS IN BROAD WHITEFISH FROM THE INUVIALUIT SETTLEMENT REGION AND MERCURY IN ARCTIC CHAR FROM RIVERS NEAR HOLMAN

Report to the Fisheries Joint Management Committee of the Inuvialuit Settlement Region

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Summary

Samples of broad whitefish muscle and liver from five locations in the Inuvialuit Settlement Region, were analysed for heavy metals (mercury, cadmium, lead), organochlorines (PCBs, DDT, toxaphene, etc), and polycyclic aromatic hydrocarbons (PAH). Arctic char muscle samples from four locations in Holman Island were also analysed for mercury. All of the samples had been previously collected between 1987 and 1992. Low concentrations of PCBs (0.8-9 ng g^{-1}) and toxaphene (3-48 ng g^{-1}) were found in whitefish muscle. Significantly higher PCB and toxaphene levels were found in four whitefish from Lake 100 compared to the other four locations. Whitefish from the five areas sampled showed very low levels of total PAHs (1.4-2.5 ng g^{-1} in muscle; 0.7-2.2 ng g^{-1} in liver) although higher levels were also found in samples from Lake 100 than from the other locations. Phenanthrene and naphthalene were the major PAHs present. The mean concentration of heavy metals were largely at background level in muscle (0.016-0.062 μg g^{-1} for mercury; <0.005 μg g^{-1} for lead) and liver (0.083-0.14 μg g^{-1} for mercury; 0.005-0.017 μg g^{-1} for lead). Arctic char from the Holman region had Hg concentrations ranging between 0.028 and 0.076 μg g^{-1}, all well below even the most stringent guideline for human consumption of fish.

Introduction

Late in the 1992/93 fiscal year an agreement was made to analyze samples of broad whitefish from the Inuvialuit Settlement Region for a series of chemical contaminants, namely heavy metals, chlorinated hydrocarbons, and polycyclic aromatic hydrocarbons. There was neither time nor funding to permit special sample collections of fish for these analyses. Consequently, after consultation with Bob Bell from FJMC it was decided to take advantage of extensive collections of whitefish already in the Freshwater Institute as a result of previous field work by Dr. J.D. Reist.

It was recognized that not all contaminant-related questions could be answered by this set of analyses. The most pressing question was whether fish from different areas of the settlement region would display different levels of contamination. It was agreed that the analyses would be concentrated on fish in a size range likely to be consumed by people, and that the organs of greatest interest were liver and muscle. After examining the records of Dr. Reist's collections we selected individuals from 5 locations since they fell within the size range required and covered a broad geographic range including both lake and river habitats. These are listed below:

Sources of broad whitefish	Position		Year collected
Campbell Lake	68° 12' N,	133° 28' W	1992
Travaillant Lake	68° 38' N,	131° 50' W	1992
Lake 100	69° 19' N,	138° 52' W	1988
Mackenzie River at Horseshoe Bend	68° 14' N,	134° 15' W	1992
Kugaluk River	69° 07' N,	130° 55' W	1989

In addition, there was interest in trying to explain the high mercury levels reported in seals from Holman. We also examined a small number of arctic char from rivers in that area to determine whether they might provide a source of mercury to seals consuming them. These were also selected from Dr. Reist's previous field collections:

Source of char	Position		Year collected
Kuuk River	70° 34' N,	112°38' W	1987
Kagloryuak River	70° 18' N,	111° 24' W	1989
Naloagyuk River	70° 13' N,	112° 13 W	1989
Kuujjua River	71° 14' N,	116° 32'W	1992

The locations of all the collections are shown on the map following (Figure 1). Most of the different analyses were performed on muscle samples from the same fish but for livers this was not possible due to the small sample size. Consequently, different individuals had to be used for different analyses. Biological data on the fish used in the analyses are given in Appendix 1A, 1B and 1C.

Three analytical laboratories were involved in the analysis of the samples and interpretation of the data. Rudolf Wagemann was responsible for heavy metals in whitefish, Derek Muir for organochlorines in whitefish and Lyle Lockhart for polycyclic aromatic hydrocarbons in whitefish, as well as mercury in char.

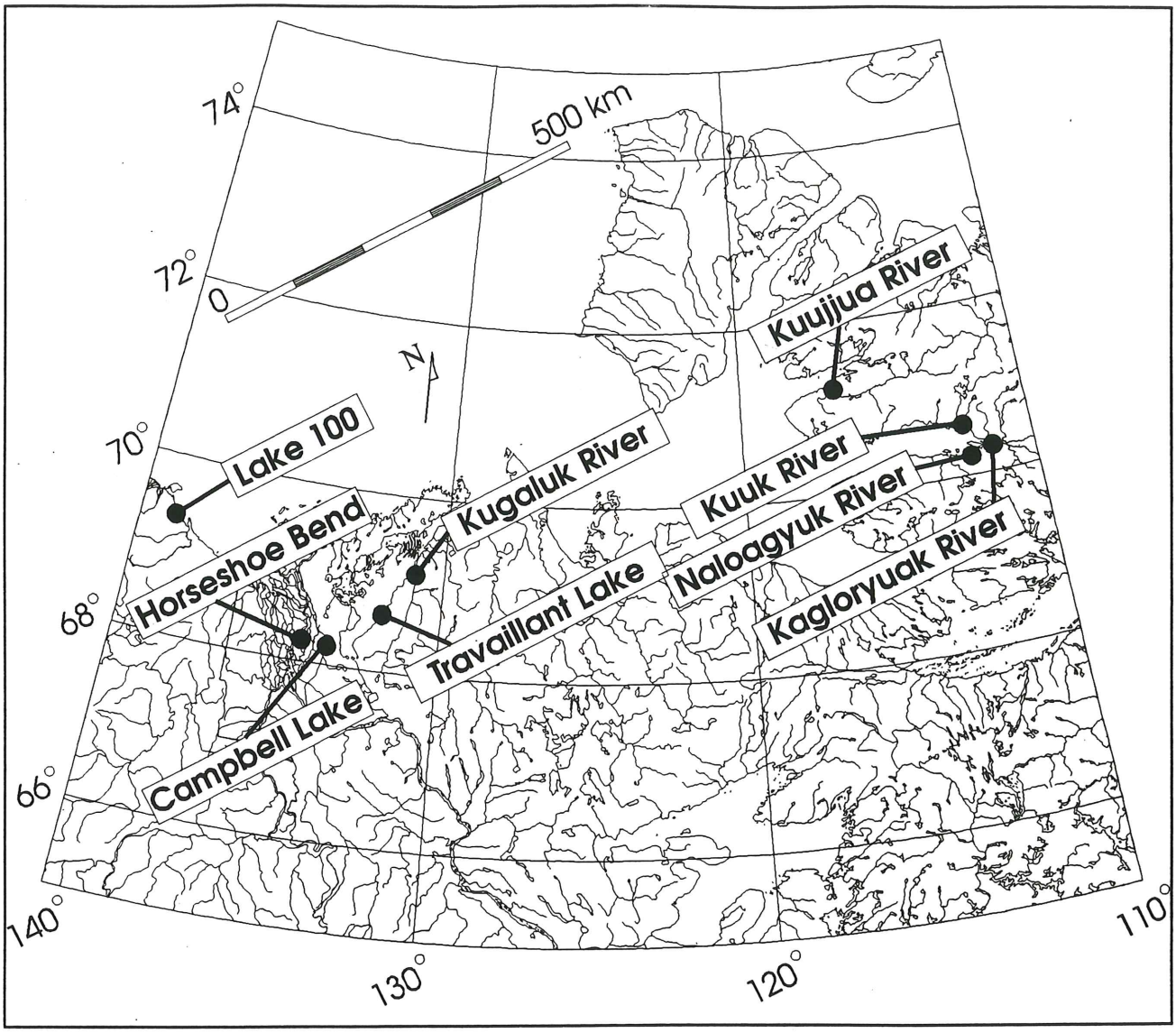

Figure 1. Map of northwestern NWT showing locations of fish collections within the Inuvialuit Settlement Region

Methods

1. Metals

Analytical methods: Samples of Broad whitefish (*Coregonus nasus*), 4 - 12 fish/ per location, from five different locations in the western Canadian Arctic (Figure 1), were analysed for mercury, lead and cadmium. Arctic char from four rivers were analysed by identical procedures. A total of 38 fresh muscles and 38 fresh livers were analysed without first drying them. Methods of analysis were identical to those described by Wagemann (1990), except that Zeeman flameless-AA or flame AA were used. Prior pre-concentration by chelation with DDDC and extraction into n-butyl acetate was required for cadmium and lead. The method is described in detail by Wagemann at al. (1983).
Quality assurance: Accepted quality control protocols (NBA, NRC, reference materials) were used to insure the quality of the data. Blanks were run with each batch to check for contamination of reagents and glassware. The laboratory participates in international interlab comparison programs for trace metals and is currently participating in a Northern Contaminants Quality Assurance inter-lab program.

2. Organochlorines

Analytical methods: Samples of whitefish muscle were analysed for organochlorines (PCB congeners, chlorobenzenes, and other organochlorine (OC) contaminants (toxaphene), dieldrin, hexachlorocyclohexanes, chlordane-related compounds (CHLOR), and the DDT group). Methods of extraction and GC analysis were identical to those described by Muir et al. (1990). In brief: Samples were homogenized by grinding with dry ice. The homogenate (20 g) was Soxhlet extracted with hexane: dichloromethane (1:1). Internal standards of aldrin and octachloronaphthalene OCN) were added at the extraction step. Lipid was removed by automated gel permeation chromatography. Extracts were then chromatographed on a Florisil column to separate PCBs, p,p'-DDE and trans-nonachlor (hexane eluate) from toxaphene, chlordanes and DDT-related compounds. Florisil eluates were then analysed by capillary gas chromatography with electron capture detection using a 60 m x 0.25 mm id DB-5 column with H_2 carrier gas. Confirmation of PCBs was carried out by GC-mass spectrometry using a HP5971MSD while chlorinated bornanes were confirmed by electron-capture negative ion mass spectrometry.
Quality assurance: Recovery of internal standards was checked in each sample and samples with low recoveries (generally $<60\%$) were reextracted. Blank samples were run approximately every 10 samples to check contamination of reagents and glassware. The laboratory routinely participates in the ICES (International Council for Exploration of the Sea) interlab comparison program for PCBs and is currently participating in an NIST (National Institute of Standards, Gaithersburg MD) program to certify additional PCB congeners in the cod liver oil SRM 1588.

3. Hydrocarbons:

Samples: Additional samples of whitefish from the same locations were analysed for hydrocarbons because liver samples were too small to be analysed for both metals and PAHs. The biological data for these samples is shown in Appendix 1B. Biological data for the arctic char is given in Appendix 1C.
Analytical methods: Samples of 10 g of muscle or 5 g of liver were chopped finely and added to a 500-mL boiling flask with 150 mL methanol and 7 g potassium hydroxide. This mixture was refluxed for 4 hr and then either centrifuged or passed through a glass wool filter to remove particulate material. The liquid phase was added to a separatory funnel with 50 mL water, and then

this mixture was extracted three times with 50 mL hexane. The combined hexane extracts were evaporated to 1 mL on a rotary evaporator and this was then dried by adding sodium sulfate. The hexane extract was cleaned up by passing it through a column (1 x 15 cm) packed with a slurry of 11 g of silica gel; the column was topped with 1 g 5% deactivated alumina and 1 cm of sodium sulfate. This column was pre-eluted with 30 mL dichloromethane followed by 30 mL of hexane. The sample was added and then eluted first with 25 mL hexane followed with 25 mL dichloromethane:hexane (1:1). The first of these fractions contains the alkanes and the second contains the PAHs. Chromatography and detection of the PAH fractions was by GC/MSD using a bonded phase, 30 m x 0.25 mm, J & W, DB-5 fused silica capillary column. A multiple internal standard method (Fisk *et al*, 1986; McVeety and Hites, 1988), with the MSD in the single ion monitoring (SIM) mode was used for identification and quantitation of the PAH's. The limit for quantitation of any individual PAH was 0.01 ng g^{-1}.

Results and discussion

1. Heavy metals

The metal concentrations in liver and muscle of individual fish are listed in Appendix 2, and the mean metal concentrations for each location are given in Table 1. The concentration results are all expressed on a wet weight basis.

Although the age of fish ranged overall from 5 to 19 years, at individual locations the range was narrower (Table 1). Older fish were obviously larger in size than younger fish, however, the ratio weight/standard length, varied from approximately 2 to 4.5 for different locations. Fish from Horseshoe Bend and Travaillant lake had the highest weight per unit length i. e. weight/length ratio was 4.6 and 4.1, respectively (Figure 2). Very probably, these different ratios (weight/length) reflect different abundances of preferred food items at different locations and therefore may indicate the condition of the fish. Since fish were sampled at the different locations at different times of the year, the different ratios may also be partly a reflection of this temporal variation in sampling time. We examined first if this ratio depended on the age of fish and found that it did not (Figure 2). Since the mean mercury concentration in muscle varied with location we examined whether or not this ratio had a bearing on the mercury level in fish at different locations.

Generally there was no correspondence between the average ratio of weight/length for the different locations (Figure 2) and the average mercury in fish at these locations, indicating that mercury was neither highest in the heaviest fish (standardized to unit length), nor the oldest fish. In fish muscle the mercury concentration was significantly higher in fish from Campbell lake and Horseshoe Bend than in fish from other locations (Figures 3). In liver it was also highest at these two locations (Figure 4) but there was no statistically significant difference (α=0.05) among any of the locations. It must be emphasized that while mercury was higher at some locations than others, the mercury concentration in these fish was still quite low at all locations sampled.

In muscle the mean mercury concentration was well below 0.1 ppm (or $\mu g\ g^{-1}$ wet wt) and in liver $\leq 0.14\ \mu g\ g^{-1}$ at all five locations (Table 1). These concentrations are well below the most stringent Federal Guideline for mercury in fish ($0.2\ \mu g\ g^{-1}$). The metal concentrations reported here are very similar to those roported for broad whitefish from Tuktoyaktuk Harbour (Muir et al., 1987).

When the mean age and the corresponding mean mercury concentration in muscle (Figure 5) and in liver (Figure 6) were plotted for each location the expected relationship of increasing

Table 1. Mean metal concentrations ($\mu g\ g^{-1}$ wet weight) $\pm$ standard deviation (sd), in muscle and liver tissues of broad whitefish (*Coregonus nasus*) from various locations in the Canadian Arctic, the number of fish analyzed (n) and the concentration range at each location.

Location	Age	Muscle			Liver		
	(yrs)	Mercury	Cadmium	Lead	Mercury	Cadmium	Lead
Kugaluk River							
$\bar{x} \pm$ sd	15.3	0.027±0.010	≤0.002	≤0.005	0.083±0.046	0.20±0.11	0.0074±0.0043
n		10	10	10	10	10	10
Range	12-19	0.015-0.044	-	-	0.024-0.16	0.022-0.40	≤0.005-0.015
Horseshoe Bend							
$\bar{x} \pm$ sd	11.8	0.062±0.028	≤0.002	≤0.005	0.10±0.039	0.084±0.062	0.0046±0.0034
n		12	12	12	12	12	12
Range	5-8	0.024-0.12	-	-	0.051-0.17	0.028-0.23	≤0.005-0.013
Travaillant Lake							
$\bar{x} \pm$ sd	15.3	0.023±0.002	≤0.002	≤0.005	0.10±0.080	0.21±0.099	0.0046±0.0033
n		4	4	4	4	4	4
Range	14-16	0.020-0.026	-	-	0.046-0.22	0.15-0.35	≤0.005-0.0074
Campbell Lake							
$\bar{x} \pm$ sd	8.9	0.072±0.022	≤0.002	≤0.005	0.14±0.054	0.15±0.081	0.0078±0.0047
n		8	8	8	10	10	10
Range	6-13	0.043-0.12	-	-	0.070-0.24	0.50-0.28	≤0.005-0.019
Lake 100							
$\bar{x} \pm$ sd	5.6	0.016±0.003	≤0.002	≤0.005	0.10±0.041	0.75±0.19	0.017±0.0094
n		4	4	4	4	4	4
Range	7-12	0.011-0.019	-	-	0.045-0.14	0.65-1.04	0.0079-0.030

concentration with increasing age was not obtained. In fact, some older fish had less mercury than younger ones. The general, positive association between age and mercury concentration appears not extend to these low background concentrations in whitefish.

A linear regression of metal concentration in tissue on age was performed for individual locations where at least 10-12 fish were available (Kugaluk River, Horseshoe Bend, Campbell lake). Some significant correlations between mercury in tissues and age of fish and between cadmium and age were obtained, however, these sample sizes were still too small for the results to have any general validity. A larger sample (60-70 fish per location) with a broad age distribution per sample would be required for regression analysis to reflect better the properties of the population in the lake or river as a whole.

Mean concentrations of lead and cadmium were also very low at all locations in both, liver and muscle (Table 1). In muscle, cadmium and lead were ≤ 0.002 and $\leq 0.005\ \mu g\ g^{-1}$ wet wt, respectively, at all locations. Although concentrations of cadmium were, as expected, somewhat higher in liver than in muscle, $\leq 0.21\ \mu g\ g^{-1}$ wet wt, this was still a very low concentration as was that of lead in liver, $\leq 0.008\ \mu g\ g^{-1}$ wet wt, at all locations except Lake 100. Both cadmium (0.75 $\mu g\ g^{-1}$) and lead (0.017 $\mu g\ g^{-1}$) were somewhat higher at Lake 100 than at other locations, not withstanding the fact that the average age of the sample of fish from this location was younger than from other locations. This may be a consequence of some difference in the preponderant fauna

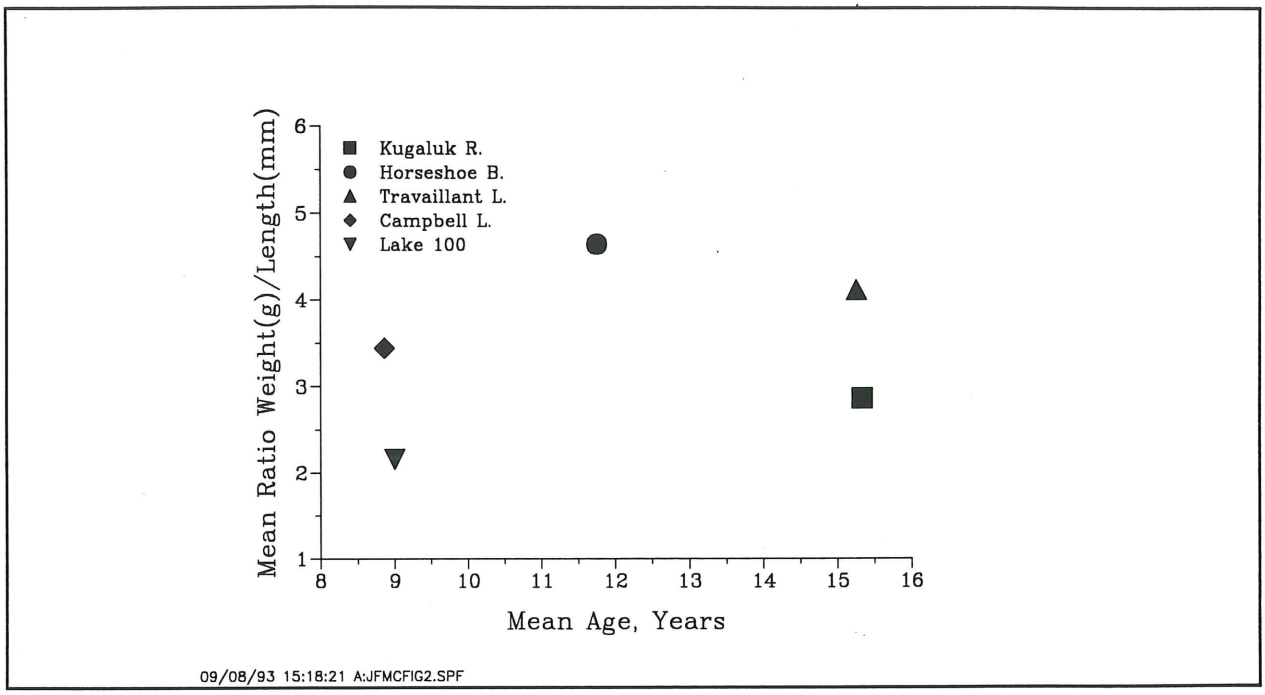

Figure 2. Average ratios weight/standard length of groups of broad whitefish from different locations in the western Canadian Arctic versus average group age.

in Lake 100 and the physical environment. Guidelines similar to those for mercury in fish do not exist for cadmium and lead.

Conclusions (Metals):

Tissues from broad whitefish from five locations in the western Canadian Arctic were analysed for mercury, cadmium and lead. Although there were significant statistical differences in the mercury concentration in muscle of fish from different locations, the concentration of metals in the two tissues analysed were largely at background level and did not indicate any contamination of the fish with mercury, lead or cadmium, anthropogenic or otherwise. Since the mercury concentration in tissues was essentially at background level in all age classes of fish, the commonly found positive correlation between mercury and age of fish was not present in these fish.

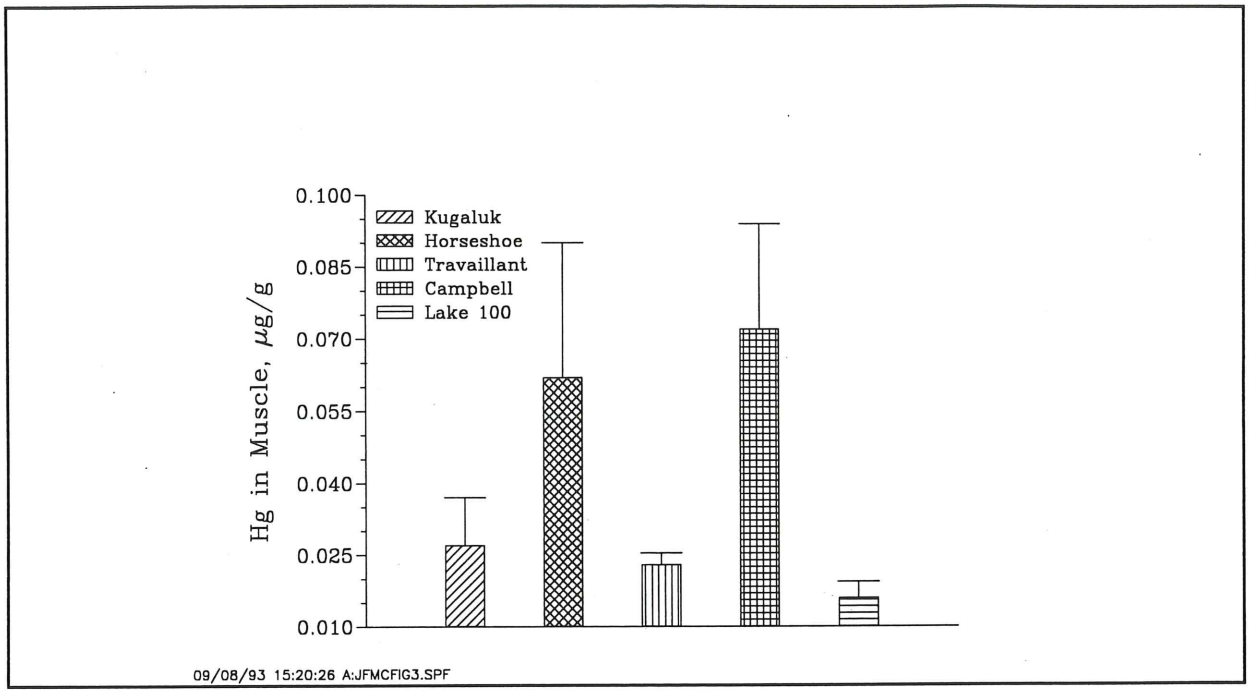

Figure 3. Mean mercury concentrations ($\mu g\ g^{-1}$ wet wt) in **muscle** of broad whitefish from different locations in the western Canadian Arctic.

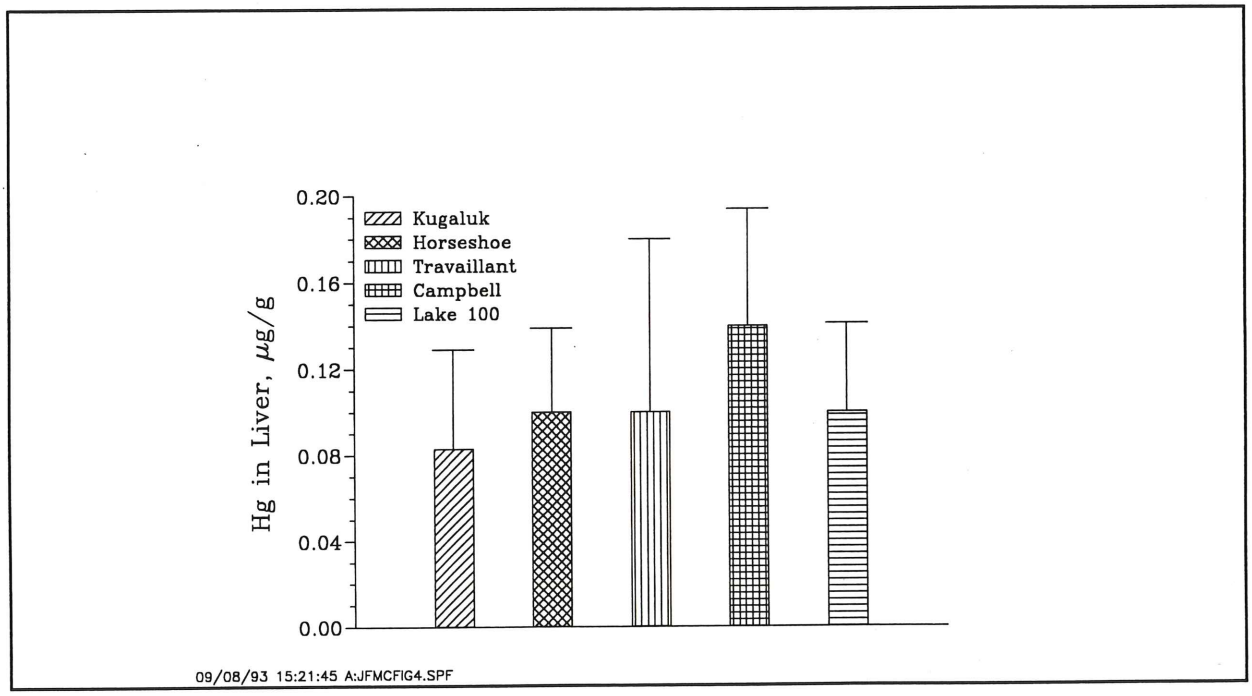

Figure 4. Mean mercury concentrations ($\mu g\ g^{-1}$ wet wt) in **liver** of broad whitefish from different locations in the western Canadian Arctic.

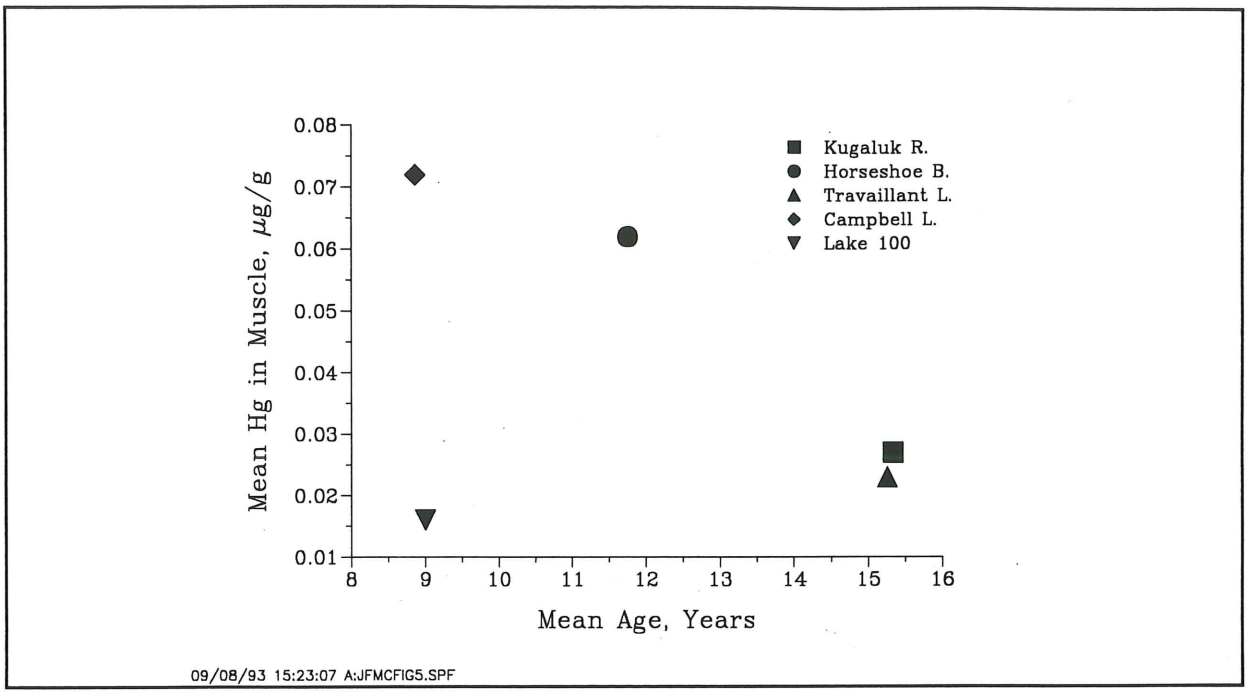

Figure 5. Mean mercury concentrations ($\mu g\ g^{-1}$ wet wt) in broad whitefish **muscle** versus mean age at different locations in the western Canadian Arctic.

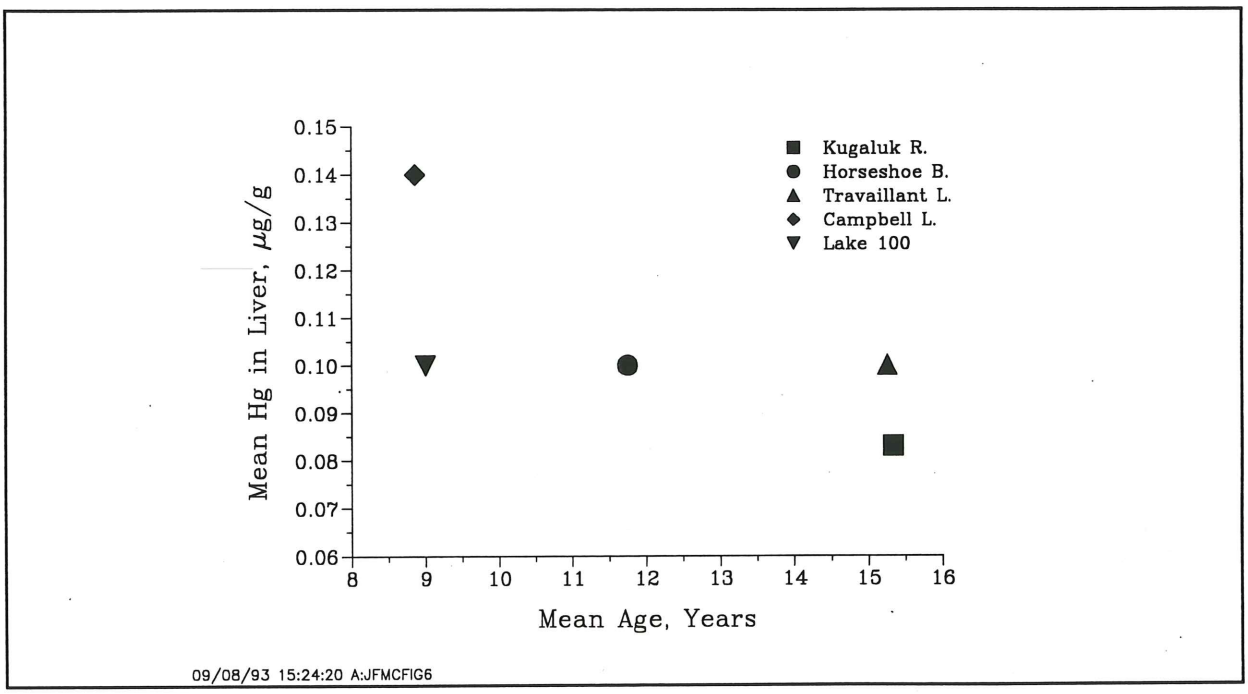

Figure 6. Mean mercury concentrations ($\mu g\ g^{-1}$ wet wt) in broad whitefish **liver** versus mean age at different locations in the western Canadian Arctic.

2. Organochlorines

All major classes of organochlorine contaminants (PCBs, chlorobenzenes, OC pesticides) were detectable in whitefish muscle samples at low part per billion (ng g^{-1}) levels from all 5 locations (Figure 7 and Table 1). A total of 130 individual OC compounds were determined (Appendix 3). Toxaphene was the major organochlorine contaminant with mean concentrations ranging from 3.1 ± 1.7 ng g^{-1} at Horseshoe Bend to 48.1 ± 14.5 ng g^{-1} in Lake 100. Higher concentrations of all organochlorines were found in the four whitefish samples from Lake 100. These fish also had the highest lipid levels (averaging 10.8%) of all the fish analysed. Lipid in fish from the other locations ranged from 0.6-6.6%. Mean lipid-based concentrations (wet weight concentration ÷ fraction lipid) of toxaphene in samples from Lake 100, Kugaluk River and Travaillant Lake did not differ significantly (Student's t-test of pairs of means at $p < 0.05$). But lipid based levels of toxaphene at these latter sites were significantly higher ($p < 0.05$) than those in samples from Horseshoe Bend and Travaillant Lake.

Mean concentrations of PCB congeners (ΣPCBs), chlordane-related compounds, chlorobenzenes (ΣCBz), DDT group (ΣDDT) and hexachlorocyclohexanes (ΣHCH) in whitefish muscle from each location were 4 to 10-times lower than levels of toxaphene in the same samples (Figure 7, Table 2). Unlike the results for toxaphene, ΣPCB concentrations were similar in samples from Lake 100 and Kugaluk (Figure 7). On a lipid weight basis, mean concentrations of ΣPCB were similar (i.e. no statistically significant differences, p. < 0.05) in Lake 100, Travaillant, Kugaluk, and Campbell Lakes, while levels from fish at Horseshoe Bend were lower than the other locations. Similar differences between the samples from Horseshoe Bend and the other sampling sites were found for ΣDDT, ΣHCH, and ΣCBz and Σchlordane (Table 2).

The reason for these differences in OC levels are not known. However, differences in levels of bioaccumulating contaminants such as PCBs in lake trout in Ontario lakes have been attributed to food chain length and trophic status (i.e. eutrophic versus oligotrophic) of lakes (Rasmussen et al. 1990). It is possible that the whitefish collected at Horseshoe Bend represent a migrating population which has been exposed to a different dietary source than the fish from the other locations. While lipid content appears to be an important variable in explaining some of the observed differences, age of the fish does not seem to be important because fish from Horseshoe Bend were of similar mean age as those from all other locations except Lake 100.

The variability of OC levels in whitefish muscle of similar aged fish from a relatively small geographic area in the Western Arctic is consistent with results we have obtained for land-locked Arctic char. Char from Amituk Lake on Cornwallis Is., Hazen Lake and Buchanan Lake (Axel Heiberg Is.) show 3 to 4-fold differences in mean concentrations of PCBs and toxaphene even though sources of contamination are atmospheric in all cases and thus expected to be quite similar (Muir and Lockhart 1993).

The levels of PCBs and toxaphene in broad whitefish from the Western Arctic are lower than observed for lake whitefish from Great Slave Lake, Gordon Lake and Fisherman Lake in southwestern NWT when compared on a lipid weight basis (Table 3). This is consistent with trends in OC contaminants previously observed in burbot liver collected from a series of lakes and riverine sites between northwestern Ontario Smith and Fort McPherson (Muir et al. 1990). Concentrations of PCBs (but not toxaphene or more volatile OCs such as HCH) declined significantly with increasing north latitude over the transect.

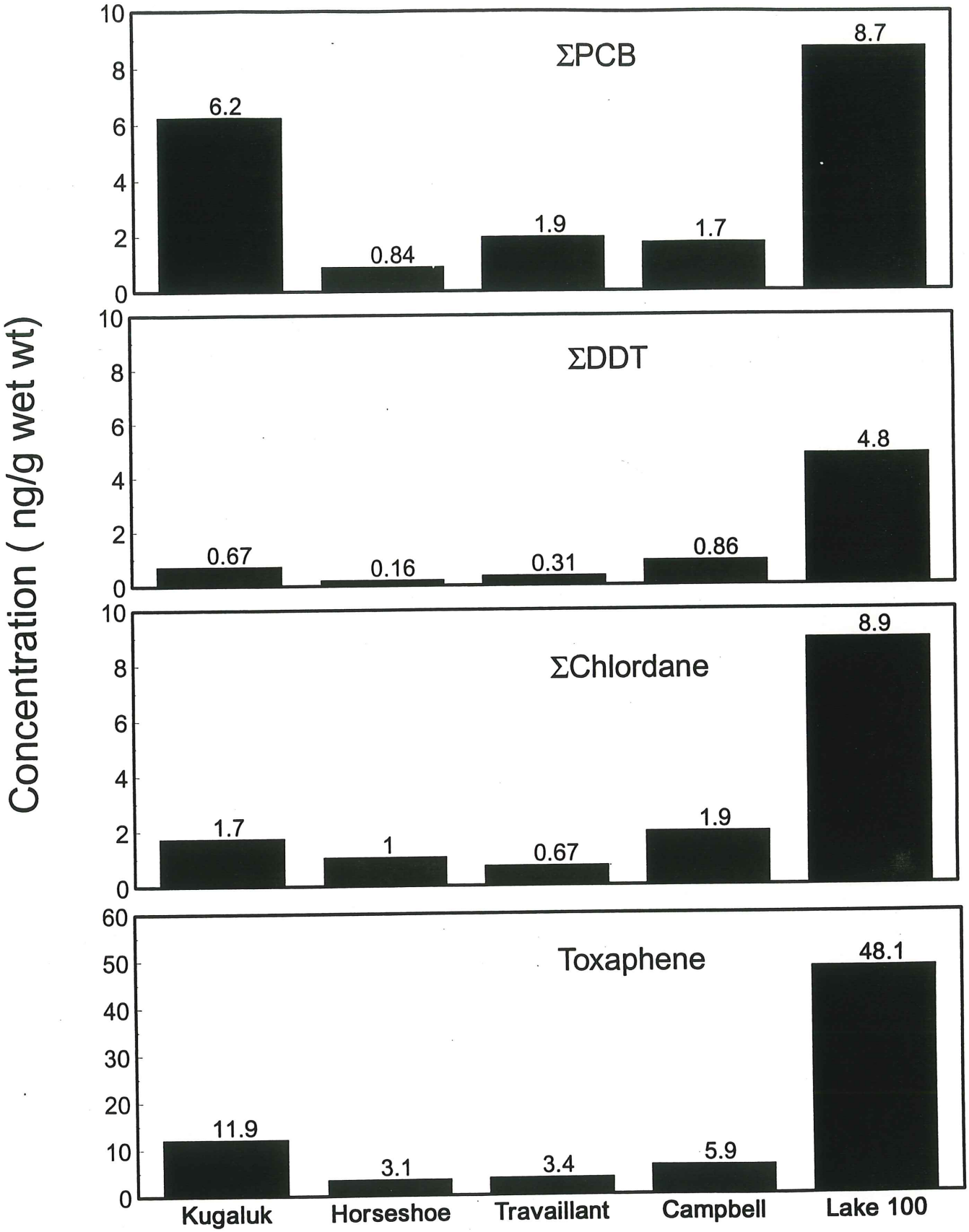

Figure 7. Comparison of major organochlorine contaminants in whitefish muscle from five locations in the Inuvialuit Settlement Region.

Table 2. Mean concentrations (ng g^{-1} wet wt and lipid weight basis) of major organochlorines in whitefish muscle from the Western Canadian Arctic

Lake/River		age (yrs)	sex/N	Lipid %	ΣCBz	ΣHCH	Σchlordane	ΣDDT	ΣPCB	Toxaphene	Dieldrin
Lake 100	Mean wet wt	17.0	4F	10.8	4.05	3.52	8.90	4.76	8.73	48.1	1.05
	SD	1.4		2.4	1.54	2.25	2.47	2.18	5.11	14.5	0.38
	Mean lipid wt				37.2	33.7	84.5	44.9	79.8	458	10.2
	SD				9.5	19.6	25.2	19.0	38.0	138	4.2
Travaillant	Mean wet wt	14.0	4F	2.6	0.57	0.46	0.67	0.31	1.86	3.39	0.08
	SD	2.0		0.5	0.15	0.11	0.11	0.05	0.69	0.66	0.02
	Mean lipid wt				22.1	17.9	26.3	12.3	74.6	134	3.1
	SD				4.2	2.1	2.7	0.9	27.7	23.0	0.8
Kugaluk	Mean wet wt	16.6	4F,5M	3.8	1.40	1.09	1.69	0.67	6.19	11.9	0.13
	SD	3.2		1.6	0.83	0.56	0.68	0.30	3.99	12.1	0.05
	Mean lipid wt				39.0	28.7	48.7	19.4	190	363	3.7
	SD				17.5	6.7	18.7	10.7	134	439	1.0
Campbell	Mean wet wt	9.2	3F,2M	3.5	0.77	1.72	1.86	0.86	1.73	5.86	0.27
	SD	2.2		2.7	0.81	2.38	1.64	1.18	0.92	2.86	0.37
	Mean lipid wt				36.8	72.3	64.3	33.4	107	345	10.7
	SD				29.1	76.6	36.6	30.2	98.4	362	11.2
Horseshoe	Mean wet wt	11.8	3F,5M	3.3	0.30	0.19	1.03	0.16	0.84	3.10	0.10
	SD	3.8		0.9	0.18	0.11	0.65	0.12	0.43	1.69	0.06
	Mean lipid wt				9.0	5.6	34.3	5.4	28.5	109	3.1
	SD				4.7	2.4	28.4	5.0	19.4	105	1.9

Table 3. Comparison of organochlorine levels in **lake or broad whitefish muscle** on a lipid weight basis (ng g^{-1} lipid)[1]

Location/species	Sex	N	ΣDDT	ΣPCB	Toxaphene
Lake Laberge (DF0, 1992)	F	6	13±6	44±52	119±59
	M	4	13±9	38±6	100±30
Fisherman Lake	M+F	4	31±6	672±122	190±43
Great Slave Lake	M&F	4	44±6	119±16	826±73
Gordon Lake	M&F	5	172±170	406±213	918±395
Lake 100	F	4	45±19	80±38	458±138
Travaillant Lake	F	4	12±1	75±28	134±23
Kugaluk R.	M&F	9	27±13	226±175	355±312
Campbell Lake	M&F	5	34±30	107±100	345±363
Horseshoe Bend	M&F	8	5±5	29±19	109±105

[1] Results from Muir and Lockhart (1993) and from the present study.

Conclusions (organochlorines)

Levels of PCBs, toxaphene and other OC contaminants in whitefish muscle from the Mackenzie delta region of the Western Canadian Arctic were generally lower than found in lake whitefish from lakes in southwestern NWT and well below all Health and Welfare guideline limits for fish consumption. Significantly lower levels of most OCs were found between samples from Horseshoe Bend on the Mackenzie River and those from nearby lakes and smaller rivers (Kugaluk) which may reflect dietary differences between fish stocks. Lipid content is an important covariable in explaining intersite differences. Further surveys should be carried out in order to more fully characterize and understand the reasons for these differences.

3. Hydrocarbons in whitefish and mercury in arctic char

Hydrocarbons: This part of the report describes a number of polycyclic aromatic hydrocarbons (PAHs) including most of those established by the United States Environmental Protection Agency as "priority pollutants". The PAHs which would be identified with confidence under the conditions used includes those listed below.

Full name	Abbreviation used
naphthalene	Nap
2-methylnaphthalene	2-Me-Nap
acenaphthylene	Acy
acenaphthene	Ace
fluorene	Flu
dibenzothiophene	Dbt
phenanthrene	Phe
anthracene	Ant
fluoranthene	Fln
pyrene	Pyr
retene	Ret
benzo(a)anthracene	BaA
chrysene	Chr
benzo(b)fluoranthene and benzo(k)fluoranthene	BbkF
benzo(e)pyrene	BeP
benzo(a)pyrene	BaP
perylene	Per
indeno(1,2,3-cd)pyrene	Idp
dibenzo(ah)anthracene	DbA
benzo(ghi)perylene	Bpe

Most of the analyses for individual hydrocarbons were below limits of detection. A table giving all the hydrocarbon analyses in all of the samples is appended. Phenanthrene, naphthalene, flouranthene and pyrene were detected most consistently, and mean levels of these are listed in Table 4 for each site and organ. The totals for all PAHs identified are also given for each group, and it is clear that the four listed accounted for most of the total in all cases.

The initial point of the sample selection was to enable comparisons to be made among the different locations. However, with so many samples falling below detection limits, very little can be done to compare the areas except to say that they are all low. There are two exceptions to this; phenanthrene was identified in all the samples and naphthalene was found in all the muscle samples. The means for phenanthrene are shown in figure 1 for liver and muscle. Statistical comparisons of the means using PROC GLM of SAS failed to indicate differences among the locations at the 5 % probability level. With naphthalene in muscle (Figure 2), however, there were significant statistical differences among the five locations. They segregated into two groups; Lake 100 and Kugaluk River comprised one group and Horseshoe Bend, Campbell Lake and Travaillant the other.

Comparing muscle and liver from the same source, muscle consistently exceeded liver in naphthalene both in terms of the amounts present and also in terms of the frequency of levels exceeding detection limits. Fluoranthene and pyrene were more frequently encountered in muscle than in liver in all but Campbell Lake. Phenanthrene was encountered in all the fish but there was no clear pattern to distinguish between muscle and liver.

There have been very limited previous studies of PAHs in northern coregonid fish. Wong et al, (1976) reported molecular masses corresponding to several PAHs in least cisco and arctic cisco from Atkinson Point, but they found that the aluminum foil used to store the fish was contaminated with PAHs, and so the samples may have been compromised. Muir et al. (1986) reported four PAHs in two inconnu from Tuktoyaktuk, as determined by high-pressure liquid chromatography. Naphthalene was under 1 ng g^{-1} and anthracene was under 0.1 ng g^{-1} in both fish. Phenanthrene levels were 1.1 and 1.3 ng g^{-1} and fluoranthene was 0.3 and 0.2 ng g^{-1} in the two samples respectively. Envirotest Laboratories (1984) analyzed two whitefish from Tuktoyaktuk and identified naphthalene at 5 ng g^{-1} and a sum of dimethyl- and trimethyl naphthalenes at 35 ng g^{-1}. Anthracene was found at 5 ng g^{-1} while phenanthrene and methyl phenanthrene combined totaled 4 ng g^{-1}. These values are relatively high in comparison with the present values, and may reflect the history of hydrocarbon usage locally in Tuktoyaktuk harbour.

The Mackenzie River is known to be a source of hydrocarbons (Erickson and Fowler, 1987; Lockhart et al., 1989; Carey et al., 1990). Lockhart et al. (1989) analyzed liver and muscle of burbot from the Mackenzie River at several points and found naphthalene in about one third of samples and phenanthrene in about one quarter of samples. Fluorene, anthracene and chrysene/benzo(a)anthracene were found almost as frequently. Naphthalene levels were sometimes quite high, up to 137 ng g^{-1} while the high for phenanthrene was about 6 ng g^{-1}. This study included an experiment in which whitefish from Arctic Red River were analyzed for very low-boiling hydrocarbons several weeks after collection and then analyzed again several months later. Hydrocarbon levels were lower in the second analysis, indicating losses of these volatile materials during the frozen storage period. Some fish from the current collection had been in storage for several years, and so some of the hydrocarbon levels may have been higher initially than at the time of analysis.

Lawrence and Weber (1984) reported PAH levels in several species of Lake Ontario fish in the range of 2.1-7.9 ng g^{-1}, but the suite of PAHs analyzed in those fish was slightly different from that used here. Neither naphthalene nor phenanthrene was included in the Ontario study, and so the results in terms of total PAHs are not readily compared. Some individual PAHs can be compared, since several of the same individual compounds were determined in both studies. On this basis, the northern whitefish were less contaminated than any Lake Ontario species. For example, pyrene levels ranged from 1.1 to 2.3 ng g^{-1} in the Lake Ontario fish, but the maximum level for this compound in the northern whitefish was only 0.51 ngg^{-1} (Appendix). Similarly fluoranthene levels in Lake Ontario fish were from 0.6 to 1.4 ng g^{-1}, while its maximum here was 0.44 ng g^{-1}.

Table 4. Mean concentrations (ng g^{-1} wet weight) of naphthalene, phenanthrene, fluoranthene, pyrene and total PAHs identified in liver and muscle of broad whitefish from the Inuvialuit Settlement Region. (Totals include all the PAHs from the appendix.) Values in parentheses show the number above detection limits/the number analyzed. Means were calculated taking below detection as zero.)

Source of fish	Organ	Nap	Phe	Fln	Pyr	Total
Travaillant Lake	Liver	nd (0/4)	0.73 4/4)	nd (0/4)	nd (0/4)	0.73
Travaillant Lake	Muscle	0.83 (4/4)	0.46 (4/4)	0.02 (3/4)	0.04 (4/4)	1.35
Campbell Lake	Liver	0.25 (1/9)	0.86 (9/9)	0.11 (5/9)	0.16 (6/9)	1.46
Campbell Lake	Muscle	0.96 (5/5)	0.47 (5/5)	0.02 (1/5)	0.02 (1/5)	1.65
Lake 100	Liver	1.38 (1/4)	0.58 (4/4)	0.01 (1/4)	0.05 (1/4)	2.16
Lake 100	Muscle	2.02 (4/4)	0.76 (4/4)	0.13 (4/4)	0.09 (4/4)	3.36
Kugaluk River	Liver	0.83 (5/10)	0.71 (10/10)	0.03 (1/10)	0.02 (1/10)	1.59
Kugaluk River	Muscle	1.83 (9/9)	0.55 (9/9)	0.03 (7/9)	0.03 (8/9)	2.49
Horseshoe Bend	Liver	nd (0/10)	0.80 (10/10)	0.07 (4/10)	0.08 (4/10)	0.95
Horseshoe Bend	Muscle	1.04 (10/10)	0.76 (10/10)	0.04 (8/10)	0.04 (8/10)	1.88

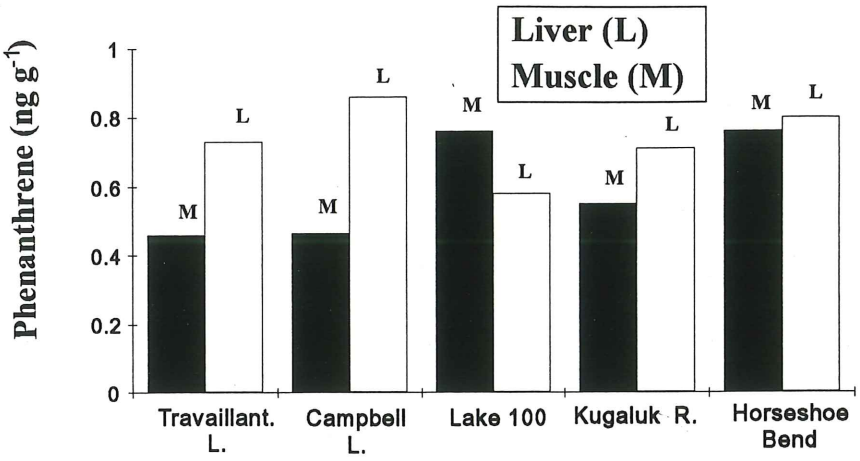

Figure 8. Phenanthrene (ng g^{-1}) in liver and muscle of broad whitefish from the five collections.

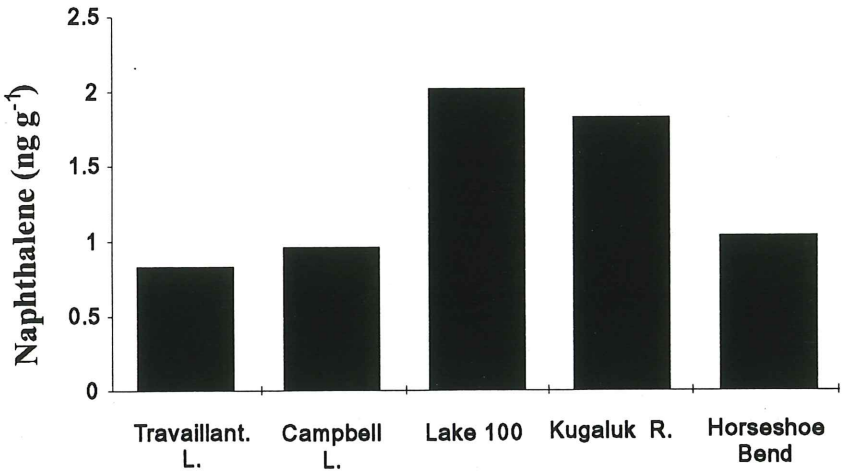

Figure 9. Naphthalene in muscle of broad whitefish from the five collection areas.

On balance, the broad whitefish from the five areas sampled showed very low levels of polycyclic aromatic hydrocarbons. A few PAHs, however, were present in some or all of the samples. There was no clear pattern to suggest major differences among the different collection areas. Perhaps the most curious observation is that fish from Lake 100 had the highest muscle levels of naphthalene and phenanthrene. The presence of these materials cannot be compared with a standard established to protect humans from exposure since, to the knowledge of the authors, no such standard has been established for fish.

Mercury in arctic char: In addition to the whitefish analyzed for hydrocarbons, 24 arctic char were analyzed for muscle mercury. These analyses were done as a result of interest in explaining the mercury reported in seals from Holman.

The concentrations of mercury in muscle of arctic char from four rivers are given in Table 5 and the biological descriptions of these char are given in Appendix 4. The usual criterion for the human consumption of fish is 0.5 $\mu g\ g^{-1}$ with the lower level of 0.2 $\mu g\ g^{-1}$ recommended for people who consume a lot of fish. The levels in these char were all well below either of these concentrations. Statistically the Kagloryuak river fish had somewhat higher levels of mercury than the other groups. Comparring the ages of the fish, the Kagloryuak fish were the youngest. Smith and Armstrong (1975) analyzed muscle tissue of twelve char from near Holman and reported a mean mercury level of 0.049 $\pm$ 0.017 $\mu g\ g^{-1}$. If the present analyses are pooled into a single sample, the mean is 0.051 $\pm$ 0.014 $\mu g\ g^{-1}$, virtually the same value as that from the samples taken in 1972 and within the range of values reported here for whitefish (Table 1). Desai-Greenaway and Price (1976) reviewed data available at that time and listed char from the Mackenzie Delta at 0.07 $\mu g\ g^{-1}$. Wheatley and Wheatley (1981) obtained a mean of 0.03 $\mu g\ g^{-1}$ in forty-one char sampled from near Sugluk, Quebec, in 1979.

Conclusions (hydrocarbons)

Low levels of polycyclic aromatic hydrocarbons were identified in muscle and liver of broad whitefish collected from the Inuvialuit settlement region over the period from 1988 to 1992. Those most regularly detected were phenanthrene and naphthalene, with the former being identified in every fish. These compounds were relatively uniformly distributed over the five sites. This was somewhat unexpected since the Mackenzie River is well established as a source of hydrocarbons. Consequently it was anticipated that the fish from Horseshoe Bend might show higher concentrations than the other fish. However, it turned out to be the fish from Lake 100 that in fact showed concentrations higher than expected. These compounds are both quite volatile and would be expected to move widely with air masses, and so the most probable source is aerial transport from temperate areas where fossil fuels are used in larger volumes. However, there is also a possibility that the levels of these compounds change under conditions of storage. The levels are low in comparison with Great Lakes fish, although the species analyzed were different. It is not known whether these levels would constitute an issue for human consumers of the fish since there are no standards established for these compounds.

Mercury levels in the arctic char from four rivers within the Settlement Region are given in the Table 5. These range between 0.028 and 0.076 $\mu g\ g^{-1}$, all well below even the most stringent guideline for human consumption of fish. There appear to be minor but statistically meaningful differences in the mercury levels among the groups.

Table 5. Mercury levels in arctic char muscle ($\mu g\ g^{-1}$ wet weight)

Sample number	Location	Year caught	Mercury ($\mu g\ g^{-1}$)
25199	KUUK R.	1987	0.029
25200	KUUK R.	1987	0.073
25201	KUUK R.	1987	0.041
25202	KUUK R.	1987	0.069
25205	KUUK R.	1987	0.052
25206	KUUK R.	1987	0.039
26181	KAGLORYUAK	1989	0.043
26182	KAGLORYUAK	1989	0.064
26189	KAGLORYUAK	1989	0.064
26190	KAGLORYUAK	1989	0.061
26191	KAGLORYUAK	1989	0.076
26192	KAGLORYUAK	1989	0.061
26198	NALOAGYUK	1989	0.040
26199	NALOAGYUK	1989	0.031
26201	NALOAGYUK	1989	0.041
26202	NALOAGYUK	1989	0.028
26205	NALOAGYUK	1989	0.049
26206	NALOAGYUK	1989	0.048
36322	KUUJJUA R.	1988	0.045
36323	KUUJJUA R.	1988	0.059
36324	KUUJJUA R.	1988	0.071
36325	KUUJJUA R	1988	0.047
36326	KUUJJUA R.	1988	0.060
36327	KUUJJUA R.	1988	0.044

Summary and Recommendations

Metals

1. Although mercury levels in fish from the western Arctic were low, they did vary significantly with geographic location. It would therefore be desirable to analyze broad whitefish and char for mercury from more numerous locations covering a broader geographic distribution to see if there may be a geographic trend or pattern of mercury in fish that reflects local geologic conditions or patterns of long range transport and deposition from Eurasia.
2. Tissues of belugas and ringed seals from the Mackenzie Delta and Sachs Harbour that were analysed in the past for total mercury showed relatively high concentrations of total mercury (Wagemann et al 1990; Smith and Armstrong, 1975). Information on methyl mercury in belugas is totally lacking. It would be desirable to determine the fraction of methyl mercury in freshly collected tissues of belugas and ringed seals from the western Arctic. Such tissue collections are apparently already in progress (verbal communication by Brian Ferguson).

Organochlorines and hydrocarbons

1. It would be desirable to analyze some freshly collected broad whitefish from one of the locations to see whether the time in frozen storage has had an effect on the levels of PAHs detected. Some of these could be examined as soon as possible after collection, and some could be frozen for subsequent analyses at intervals.
2. It would be desirable to analyze bile from freshly collected broad whitefish, particularly those from Horseshoe Bend, to see whether the low tissue levels of PAHs reflect high metabolism and elimination.
3. The relatively high levels of PAHs and organochlorines in the Lake 100 fish prompts further investigation. Is a bathymetric map available for this lake? It may be possible to core this lake and find out what the historical inputs of both organochlorines, PAHs, and mercury have been. They may explain the levels found. Whitefish from additional lakes/rivers in the region, and/or more fish from the lakes/rivers already sampled, should be analysed to examine the extent of variation.
4. In addition to analysing more char for mercury, the same samples should also be analysed for PCBs and other organochlorines because of the importance of these fish as a source of food in the region.
5. Additional marine samples (fish and invertebrates) should be examined as potential sources of mercury and organochlorines to the marine mammals.

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Appendix 1A: Biological Data on Broad Whitefish analysed for metals (Reist, 1993)

ID	Year	Location	Weight (g)	Standard Length (mm)	Fork Length (mm)	Sex	Maturity	Gonad weight (g)	Age (yrs)
35670	1992	Campbell L.	1486	416	452	M	7	144	12
35675	1992	Campbell L.	1264	418	454	M	6	1	12
35674	1992	Campbell L.	1511	420	458	M	6	1	6
35662	1992	Campbell L.	1824	448	490	M	7	140	10
35677	1992	Campbell L.	1937	446	490	M	6	26	13
35669	1992	Campbell L.	1080	372	406	F	1	45	5
35661	1992	Campbell L.	1335	404	438	F	1	79	7
35666	1992	Campbell L.	1397	405	445	F	1	86	7
35245	1992	Horseshoe	1511	395	432	M	7	226	8
35236	1992	Horseshoe	1438	400	435	M	7	205	5
35232	1992	Horseshoe	1769	405	446	M	7	302	8
35224	1992	Horseshoe	2503	467	512	M	7	252	18
35221	1992	Horseshoe	1651	402	445	F	2	1916	14
35246	1992	Horseshoe	2048	458	502	F	2	2119	15
35247	1992	Horseshoe	2166	463	502	F	2	2781	11
35244	1992	Horseshoe	2700	468	510	F	2	3838	12
35231	1992	Horseshoe	2345	468	512	F	2	3104	12
35237	1992	Horseshoe	2242	470	512	F	2	4108	13
35222	1992	Horseshoe	2039	474	517	F	5	296	14
35235	1992	Horseshoe	2600	477	521	F	2	4063	11
33485	1989	Kugaluk R.	1220	420	455	M	7	238	17
33492	1989	Kugaluk R.	1202	420	456	M	7	202	19
33489	1989	Kugaluk R.	1150	420	456	M	7	152	16
33500	1989	Kugaluk R.	1269	414	456	M	7	234	16
33495	1989	Kugaluk R.	1234	424	458	M	7	233	14
33511	1989	Kugaluk R.	970	393	425	F	2	741	-
33502	1989	Kugaluk R.	1066	397	428	F	2	1453	12
33513	1989	Kugaluk R.	1414	410	441	F	2	1718	16
33494	1989	Kugaluk R.	1143	412	444	F	2	1322	14
33483	1989	Kugaluk R.	1131	411	449	F	2	1235	14

26969	1988	Lake 100	666	342	371	M	6	1	7
26970	1988	Lake 100	959	376	412	F	5	92	12
26971	1988	Lake 100	663	334	363	F	1	24	8
26972	1988	Lake 100	736	342	376	F	1	23	9
36231	1992	Travaillant L.	1911	444	485	M	8	166	16
36246	1992	Travaillant L.	1845	441	483	M	8	109	14
36238	1992	Travaillant L.	1765	446	486	F	3	1977	15
36247	1992	Travaillant L.	1779	447	483	F	3	2200	14

Legend for Appendix 1A.

ID= Collection Site and Fish Number (Our Reference #)
Year= Year of Collection
Weight= Round Weight (g)
Maturity= Sexual Maturity Code: Females: 1=immature, 2=mature, 3=ripe, 4=spent, 5=resting, 0=cannot be sexed; Males: 6=testes long and thin, 7=current year spawner, 8=testes full size, 9=spawning complete, 10=testes tubular.
Age= Age of fish (years), fin ray.

Appendix 1B. Biological data on broad whitefish analyzed for hydrocarbons (Reist, 1993)

Numbe	Year	Location	Weight	Standard Length	Fork Length	Sex	Maturity	Gonad weight	Age
35651	1992	Campbell L.	2065	447	487	M	6	14	
35654	1992	Campbell L.	1718	441	477	M	6	11	
35655	1992	Campbell L.	1407	419	461	M	6	8	
35658	1992	Campbell L.	1620	437	474	M	6	8	
35671	1992	Campbell L.	1715	435	474	F	1	8.2	11
35672	1992	Campbell L.	1440	424	458	F	1	6	6
35673	1992	Campbell L.	1689	420	465	M	6	0.9	10
35676	1992	Campbell L.	1506	422	457	F	1	10.4	8
35679	1992	Campbell L.	1498	451	492	F	1	8.8	11
35223	1992	Horseshoe	1610	421	460	M	7	23.5	11
35226	1992	Horseshoe	1676	423	463	M	7	27.5	6
35227	1992	Horseshoe	1956	438	480	F	2	285.8	14
35228	1992	Horseshoe	1503	423	465	M	7	21.6	16
35230	1992	Horseshoe	2023	429	468	F	2	293.6	13
35238	1992	Horseshoe	1847	447	488	M	7	21.8	10
35240	1992	Horseshoe	1677	416	463	F	2	251.6	12
35241	1992	Horseshoe	1543	428	475	F	2	251.6	19
35242	1992	Horseshoe	1732	433	472	M	7	27.8	9
35243	1992	Horseshoe	1986	448	495	M	7	24.6	14
33475	1989	Kugaluk R.	1185	425	462	F	2	111.1	15
33478	1989	Kugaluk R.	1130	430	467	M	7	18.2	21
33480	1989	Kugaluk R.	1259	425	466	F	2	158.3	20
33482	1989	Kugaluk R.	998	427	464	M	7	19.4	14
33484	1989	Kugaluk R.	1180	427	461	F	2	115.7	15
33487	1989	Kugaluk R.	1170	425	458	F	2	102.2	17
33488	1989	Kugaluk R.	1393	423	463	M	7	18.9	10
33496	1989	Kugaluk R.	1186	425	462	M	7	22.3	18
33499	1989	Kugaluk R.	1377	436	471	F	2	154.2	17
33510	1989	Kugaluk R.	1298	425	461	M	7	22.9	16
26965	1988	Lake 100	1230	406	444	F	5	39.4	16
26966	1988	Lake 100	1814	450	486	F	5	47.6	17
26967	1988	Lake 100	1407	424	461	F	5	28.1	19
26968	1988	Lake 100	1289	419	456	F	5	13.3	16

36249	1992	Travaillant L.	1576	443	483	M	8	8.7	13
36258	1992	Travaillant L.	1839	439	485	M	8	14.4	17
36270	1992	Travaillant L.	1906	454	487	M	3	94.7	13
36275	1992	Travaillant L.	1779	447	486	M	4	80.8	13

Appendix 1C. Biological data on arctic char analyzed for muscle mercury (Reist 1993)

Number	Year	Location	Weight	Standard Length	Fork Length	Sex	Maturity	Gonad weight	Age
25199	1987	Kuuk R	1024	413	451	M	6	0	11
25200	1987	Kuuk R	2397	572	627	F	1	17.3	14
25201	1987	Kuuk R	2824	575	630	M	6	2.6	14
25202	1987	Kuuk R	3717	656	710	F	1	23.1	17
25205	1987	Kuuk R	3641	626	678	F	1	18.6	
25206	1987	Kuuk R	4033	647	706	F	1	18.4	16
26181	1989	Kagloryuak R.	1914	506	550	M	6	2.5	11
26182	1989	Kagloryuak R.	356	300	324	M	6	0.1	9
26189	1989	Kagloryuak R.	73	170	186	F	1	0.1	6
26190	1989	Kagloryuak R.	255	264		M	6	0.1	8
26191	1989	Kagloryuak R.	320	284	309	F	1	0.1	9
26192	1989	Kagloryuak R.	259	258		M	6	0.1	6
26798	1989	Naloagyuk R	1116	425	465	F	1	0.5	8
26199	1989	Naloagyuk R	717	378		M	6	0.3	8
26201	1989	Naloagyuk R	1583	455	495	F	1	7.1	11
26202	1989	Naloagyuk R	1594	471	515	F	1	9.4	11
26205	1989	Naloagyuk R	1736	489	532	F	1	8.6	15
26205	1989	Naloagyuk R	1124	454	499	M	6	0.6	13
36322	1992	Kuujjua R.	2637	529	570	F	5	15.4	10
36323	1992	Kuujjua R.	3744	608	655	M	10	2.9	
36324	1992	Kuujjua R.	3027	610	665	F	5	36.7	
36325	1992	Kuujjua R.	2628	552	596	F	5	17.2	11
36326	1992	Kuujjua R.	3165	561	604	F	5	21	11
36327	1992	Kuujjua R.	1866	485	527	F	1	6.5	8

Appendix 2: Metal concentrations ($\mu g\ g^{-1}$ wet weight) in muscle and liver tissues of broad whitefish (*Coregonus nasus*) from various locations in the Canadian Arctic.

Location	Muscle			Liver		
	Mercury	Cadmium	Lead	Mercury	Cadmium	Lead
Kugaluk River						
33483	0.015	≤0.002	≤0.005	0.030	0.13	≤0.005
33485	0.031	≤0.002	0.006	0.077	0.17	≤0.005
33489	0.017	≤0.002	≤0.005	0.078	0.25	0.012
33492	0.029	≤0.002	≤0.005	0.084	0.27	0.007
33494	0.044	≤0.002	≤0.005	0.045	0.022	≤0.005
33495	0.030	≤0.002	≤0.005	0.067	0.12	0.015
33500	0.015	≤0.002	≤0.005	0.12	0.21	0.010
33502	0.016	≤0.002	≤0.005	0.024	0.10	0.006
33511	0.038	0.003	≤0.005	0.16	0.29	0.011
33513	0.030	≤0.002	≤0.005	0.15	0.40	≤0.005
Horseshoe Bend						
35221	0.047	≤0.002	≤0.005	0.074	0.040	≤0.005
35222	0.068	≤0.002	≤0.005	0.098	0.18	0.013
35224	0.024	≤0.002	≤0.005	0.051	0.23	0.007
35231	0.078	≤0.002	≤0.005	0.14	0.073	≤0.005
35232	0.068	≤0.002	≤0.005	0.14	0.068	≤0.005
35235	0.047	≤0.002	≤0.005	0.060	0.028	≤0.005
35236	0.042	≤0.002	≤0.005	0.10	0.034	≤0.005
35237	0.12	≤0.002	≤0.005	0.17	0.057	0.007
35244	0.094	≤0.002	≤0.005	0.073	0.051	≤0.005
35245	0.048	≤0.002	≤0.005	0.12	0.10	0.006
35246	0.079	≤0.002	≤0.005	0.13	0.11	≤0.005
35247	0.027	≤0.002	≤0.005	0.060	0.038	≤0.005

Appendix 2, Continued

Location	Muscle			Liver		
	Mercury	Cadmium	Lead	Mercury	Cadmium	Lead
Travaillant Lake						
36231	0.022	≤0.002	≤0.005	0.22	0.35	≤0.005
36238	0.020	≤0.002	≤0.005	0.052	0.15	0.006
36246	0.023	≤0.002	≤0.005	0.086	0.17	0.007
36247	0.026	≤0.002	≤0.005	0.046	0.15	≤0.005
Campbell Lake						
35653	-	-	-	0.24	0.10	≤0.005
35659	-	-	-	0.091	0.075	≤0.005
35661	0.043	≤0.002	≤0.005	0.11	0.25	0.019
35662	0.070	≤0.002	≤0.005	0.22	0.050	0.011
35666	0.075	≤0.002	≤0.005	0.11	0.20	0.009
35669	0.084	≤0.002	≤0.005	0.13	0.074	≤0.005
35670	0.065	≤0.002	≤0.005	0.12	0.21	0.008
35674	0.12	≤0.002	≤0.005	0.13	0.098	0.007
35675	0.066	0.004	0.007	0.15	0.28	≤0.005
35677	0.057	≤0.002	≤0.005	0.070	0.18	0.007
Lake 100						
26969	0.011	0.003	≤0.005	0.045	0.66	≤0.005
26970	0.016	≤0.002	≤0.005	0.12	0.65	0.014
26971	0.019	≤0.002	≤0.005	0.14	1.04	0.016
26972	0.018	≤0.002	≤0.005	0.11	0.66	0.008

Appendix 3. List of PCBs and other organochlorine compounds determined in whitefish samples by DFO Winnipeg.

PCBs	# Cl	PCBs	# Cl	PCBs	# Cl	Other OCs	Group
3[1]	1	56/60	4/4	178/129	7/6	1245-Cl_4benzene	CBz
4/10[1]	2	91	5	175	7	1234-Cl_4benzene	CBz
7[1]	2	84/89	5	187	7	Cl_5-benzene	CBz
6[1]	2	101	5	183	7	Cl_6-benzene	CBz
8/5	2	99	5	128	6	α-HCH	HCH
19	3	83	5	185	7	β-HCH	HCH
18	3	97	5	174	7	γ-HCH	HCH
17	3	87	5	177	7	Chlordane "C"	Chlordane
24/27	3	85	5	171	7	heptachlor	Chlordane
16/32	3	136	6	156	6	Cl_8-sytrene	
26	3	110	5	201/157	8/6	Chlordane-C1B	Chlordane
25	3	82	5	172/197	7/8	Chlordane-C2	Chlordane
31	3	151	6	180	7	Chlordane-C3	Chlordane
28	3	144/135	6	193	8	Chlordane-C5	Chlordane
33	3	149	6	191	8	Nonachlor-III	Chlordane
22	3	118	5	200	9	oxychlordane	Chlordane
45	4	134	6	170	8	t-chlordane	Chlordane
46	4	114	5	190	8	c-chlordane	Chlordane
52	4	131	6	198	8	t-nonachlor	Chlordane
49	4	146	6	199	8	c-nonachlor	Chlordane
47	4	153	6	196/203	8/8	hept. epoxide	Chlordane
48	4	132	6	189	8	dieldrin	
44	4	105	5	208	9	endrin	
42	4	141	6	195	8	p,p'-DDE	DDT
41/71	4	130	6	207	9	p,p'-DDD	DDT
64	4	141	6	194	8	p,p'-DDT	DDT
40	4	130/176	6/7	205	8	o,p'-DDE	DDT
74	4	179	7	206	9	o,p'-DDD	DDT
70/76	4	137	6	209	10	o,p'-DDT	DDT
66	4	138	6			mirex	
95	5	158	7	Other OCs		photomirex	
				toxaphene[2]		Cl_5-anisole	
				α-endosulfan[1]		methoxychlor[1]	

[1]These compounds were not detected in fish tissues [2] 19 chlorobornane peaks were monitored.

Appendix 4. Polycyclic aromatic hydrocarbons (napthalene to pyrene) and dibenzothiophene (ng g^{-1} wet weight) identified in liver (L following sample number) and muscle (M following sample number) of broad whitefish from the Inuvialuit Settlement Region. Detection limit = 0.01 ng g^{-1}; nd = <0.01 0.01 ng g^{-1}.

Number/ organ	Source	Nap	2-Me -Nap	Acy	Ace	Flu	Dbt	Phe	Ant	Fln	Pyr
36249L	TRAV L.	nd	nd	nd	nd	nd	nd	0.88	nd	nd	nd
36258L	TRAV L.	nd	nd	nd	nd	nd	nd	1.02	nd	nd	nd
36270L	TRAV L.	nd	nd	nd	nd	nd	nd	0.45	nd	nd	nd
36275L	TRAV L.	nd	nd	nd	nd	nd	nd	0.57	nd	nd	nd
36249M	TRAV L.	0.50	nd	nd	nd	nd	nd	0.42	nd	0.05	0.02
36258M	TRAV L.	1.16	nd	nd	nd	nd	nd	0.58	nd	0.02	0.04
36270M	TRAV L.	0.80	nd	nd	nd	nd	nd	0.46	nd	nd	0.02
36275M	TRAV L.	0.84	nd	nd	nd	nd	nd	0.39	nd	0.02	0.07
35651L	CAMPBELL	nd	nd	nd	nd	nd	nd	1.32	nd	0.44	0.51
35654L	CAMPBELL	nd	nd	nd	nd	nd	nd	1.63	nd	nd	0.33
35655L	CAMPBELL	nd	nd	nd	nd	nd	nd	0.94	nd	nd	nd
35658L	CAMPBELL	nd	nd	nd	nd	nd	nd	0.70	nd	nd	nd
35671L	CAMPBELL	nd	nd	nd	nd	nd	nd	0.63	nd	0.11	0.11
35672L	CAMPBELL	nd	nd	nd	nd	nd	nd	0.76	nd	0.12	0.13
35673L	CAMPBELL	nd	nd	nd	nd	nd	nd	0.43	nd	nd	nd
35676L	CAMPBELL	2.28	nd	nd	nd	nd	nd	0.68	nd	0.24	0.23
35679L	CAMPBELL	nd	nd	nd	nd	nd	nd	0.66	nd	0.06	0.09
35671M	CAMPBELL	0.68	nd	nd	nd	nd	nd	0.41	nd	nd	nd
35672M	CAMPBELL	1.50	nd	nd	nd	nd	nd	0.48	nd	nd	nd
35673M	CAMPBELL	1.15	nd	nd	nd	nd	nd	0.61	nd	nd	nd
35676M	CAMPBELL	0.41	nd	0.93	nd	nd	nd	0.35	nd	nd	nd
35679M	CAMPBELL	1.05	nd	nd	nd	nd	nd	0.49	nd	0.09	0.11
26965L	LAKE 101	nd	nd	nd	nd	nd	nd	0.50	nd	nd	nd
26966L	LAKE 101	5.52	0.57	nd	nd	nd	nd	0.52	nd	0.05	0.19
26967L	LAKE 101	nd	nd	nd	nd	nd	nd	0.78	nd	nd	nd
26968L	LAKE 101	nd	nd	nd	nd	nd	nd	0.53	nd	nd	nd
26965M	LAKE 101	2.35	0.31	nd	nd	0.48	nd	1.10	nd	0.28	0.18
26966M	LAKE 101	1.49	nd	nd	nd	nd	nd	0.45	nd	0.02	0.05
26967M	LAKE 101	1.54	0.10	nd	nd	0.32	nd	0.70	nd	0.11	0.05
26968M	LAKE 101	2.69	nd	nd	nd	0.28	nd	0.79	nd	0.11	0.08
33475L	KUGALUK	nd	nd	nd	nd	nd	nd	0.84	nd	nd	nd
33478L	KUGALUK	0.94	nd	nd	nd	nd	nd	0.55	nd	nd	nd
33480L	KUGALUK	0.44	nd	nd	nd	nd	nd	0.89	nd	nd	nd
33482L	KUGALUK	2.06	nd	nd	nd	nd	nd	0.62	nd	nd	nd
33484L	KUGALUK	2.27	nd	nd	nd	nd	nd	0.90	nd	nd	nd
33487L	KUGALUK	nd	nd	nd	nd	nd	nd	0.84	nd	nd	nd
33488L	KUGALUK	nd	nd	nd	nd	nd	nd	0.52	nd	nd	nd

Appendix 4 continued. Polycyclic aromatic hydrocarbons (napthalene to pyrene) and dibenzothiophene (ng g^{-1} wet weight) identified in liver (L following sample number) and muscle (M following sample number) of broad whitefish from the Inuvialuit Settlement Region. Detection limit = 0.01 ng g^{-1}; nd = <0.01 0.01 ng g^{-1}.

Number/ organ	Source	Nap	2-Me -Nap	Acy	Ace	Flu	Dbt	Phe	Ant	Fln	Pyr
33496L	KUGALUK	nd	nd	nd	nd	nd	nd	0.45	nd	nd	nd
33499L	KUGALUK	2.60	nd	nd	nd	nd	nd	1.02	nd	0.26	0.20
33510L	KUGALUK	nd	nd	nd	nd	nd	nd	0.71	nd	nd	nd
33475M	KUGALUK	2.14	0.12	nd	nd	nd	nd	0.62	nd	0.02	0.05
33478M	KUGALUK	1.42	nd	nd	nd	nd	nd	0.52	nd	0.08	0.04
33480M	KUGALUK	1.16	nd	nd	nd	nd	nd	0.55	nd	0.02	0.04
33484M	KUGALUK	3.96	nd	nd	nd	nd	nd	0.45	nd	0.03	0.07
33487M	KUGALUK	1.28	0.07	nd	nd	nd	nd	0.62	nd	0.02	0.01
33488M	KUGALUK	1.62	nd	nd	nd	0.13	nd	0.72	nd	0.06	0.05
33496M	KUGALUK	1.48	nd	nd	nd	nd	nd	0.42	nd	nd	nd
33499M	KUGALUK	1.96	0.06	nd	nd	nd	nd	0.65	nd	0.03	0.04
33510M	KUGALUK	1.48	nd	nd	nd	nd	nd	0.45	nd	nd	0.03
35223L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.72	nd	0.24	0.37
35242L	HORSESHOE	nd	nd	nd	nd	0.11	nd	0.74	nd	0.30	0.31
35226L	HORSESHOE	nd	nd	nd	nd	nd	nd	1.21	nd	0.10	0.12
35227L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.80	nd	nd	nd
35228L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.71	nd	nd	nd
35230L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.66	nd	nd	nd
35238L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.89	nd	0.14	0.10
35240L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.80	nd	nd	nd
35241L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.78	nd	nd	nd
35243L	HORSESHOE	nd	nd	nd	nd	nd	nd	0.70	nd	nd	nd
35223M	HORSESHOE	0.90	nd	nd	nd	nd	nd	0.73	nd	nd	nd
35226M	HORSESHOE	1.05	nd	nd	nd	nd	nd	0.44	nd	nd	nd
35227M	HORSESHOE	0.87	nd	nd	nd	0.28	nd	1.43	nd	0.03	0.08
35228M	HORSESHOE	0.95	nd	nd	nd	nd	nd	0.59	nd	0.04	0.04
35230M	HORSESHOE	0.89	nd	nd	nd	nd	nd	0.83	nd	0.03	0.05
35238M	HORSESHOE	1.52	nd	nd	nd	nd	nd	1.15	nd	0.10	0.09
35240M	HORSESHOE	1.30	nd	nd	nd	nd	nd	0.78	nd	0.09	0.05
35241M	HORSESHOE	0.97	nd	nd	nd	nd	nd	0.36	nd	0.01	0.03
35242M	HORSESHOE	0.95	nd	nd	nd	nd	nd	0.73	nd	0.02	0.03
35243M	HORSESHOE	0.99	nd	nd	nd	nd	nd	0.41	nd	0.06	0.02

Appendix 4 continued. Polycyclic aromatic hydrocarbons (retene to benzo(ghi)perylene) (ng g^{-1} wet weight) identified in liver (L following sample number) and muscle (M following sample number) of broad whitefish from the Inuvialuit Settlement Region. Detection limit = 0.01 ng g^{-1}; nd = <0.01 0.01 ng g^{-1}.

Number/ organ	Source	Ret	BaA	Chr	BbkF	BeP	BaP	Per	Idp	Dba	Bpe
36249L	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
36258L	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
36270L	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
36275L	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
36249M	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
36258M	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
36270M	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
36275M	TRAV L.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35651L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35654L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35655L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35658L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35672L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35673L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35676L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35679L	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35671M	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35672M	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35673M	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35676M	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35679M	CAMPBELL	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
26965L	LAKE 100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
26966L	LAKE 100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
26967L	LAKE 100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
26968L	LAKE 100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
26965M	LAKE 100	2.32	nd	nd	nd	nd	nd	nd	nd	nd	nd
26966M	LAKE 100	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
26967M	LAKE 100	2.74	nd	nd	nd	nd	nd	nd	nd	nd	nd
26968M	LAKE 100	0.92	nd	nd	nd	nd	nd	nd	nd	nd	nd
33475L	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33478L	KUGALUK		nd	nd	nd	nd	nd	nd	nd	nd	nd
33480L	KUGALUK	nd	nd	nd		nd	nd	nd	nd	nd	nd
33482L	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33484L	KUGALUK	nd	nd	nd	nd	nd	nd	2.39	nd	nd	nd
33487L	KUGALUK	nd	nd	nd	nd	nd	nd	0.97	nd	nd	nd
33488L	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Appendix 4 continued. Polycyclic aromatic hydrocarbons (retene to benzo(ghi)perylene) (ng g^{-1} wet weight) idendified in liver (L following sample number) and muscle (M following sample number) of broad whitefish from the Inuvialuit Settlement Region. Detection limit = 0.01 ng g^{-1}; nd = <0.01 0.01 ng g^{-1}.

Number/ organ	Source	Ret	BaA	Chr	BbkF	BeP	BaP	Per	Idp	Dba	Bpe
33496L	KUGALUK	nd	nd	nd	nd	nd	nd	0.73	nd	nd	nd
33499L	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33510L	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33475M	KUGALUK	0.44	nd	nd	nd	nd	nd	nd	nd	nd	nd
33478M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33480M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33484M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33487M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33488M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33496M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33499M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
33510M	KUGALUK	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35223L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35242L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35226L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35228L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35230L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35238L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35240L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35241L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35243L	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35223M	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35226M	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35227M	HORSESHOE	0.10	nd	nd	nd	nd	nd	nd	nd	nd	nd
35228M	HORSESHOE	0.02	nd	nd	nd	nd	nd	nd	nd	nd	nd
35230M	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35238M	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35240M	HORSESHOE	0.19	nd	nd	nd	nd	nd	nd	nd	nd	nd
35241M	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35242M	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
35243M	HORSESHOE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd