98-93

NATIONAL HYDROLOGY RESEARCH CENTRE

CENTRE NATIONAL DE RECHERCHE EN HYDROLOGIE

RESEARCH LEADERSHIP IN THE SCIENCE OF WATER

The National Hydrology Research Centre conducts research on issues relevant to the sound management of Canada's aquatic resources. These include the detection and prediction of climatic change, nutrients and toxics in surface and ground waters, environmental impacts on northern systems, and the integrity and health of aquatic ecosystems. In collaboration with national and international partners, NHRC scientists participate in interdisciplinary research programmes designed to address regional, national and international environmental problems.

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LE PLAN VERT DU CANADA

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Metal and persistent organochlorine pollutant (POP) concentrations in four species of predatory fish from Resolution Bay, Great Slave Lake: summer 1996 studies.

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REPORT SUMMARY

This report is based on an investigation of metal and persistent organochlorine pollutant (POP) concentrations in fish harvested from the domestic fish zone for the community of Fort Resolution. In consultation with officers from the Fort Resolution Environmental Working Committee, a study was designed to investigate contaminant concentrations in five pike/jack (muscle, liver, stomach), five walleye/pickerel (muscle, liver), five burbot/loche (muscle, liver), and five inconnu (muscle). In addition, a composite bile and a gall bladder sample from five burbot were analyzed for metals; there was insufficient biomass for POP analyses.

Arsenic, cadmium, copper, mercury, lead, and zinc concentrations generally were low in all tissues. However, mercury concentrations in some large pike and walleye approached or exceeded the 0.2 µg/g consumption guideline recommended by Health and Welfare Canada for frequent consumers of fish. Mercury concentrations were similar to those determined in other Great Slave Lake studies. In those studies, mercury levels were not sufficiently high to warrant human health advisories being released. Copper and zinc, essential minerals to human health, were found in low concentrations in muscle tissue but in higher concentrations in the liver of all fish species and in pike stomach. Mercury tended to occur in higher concentrations in muscle than in liver. Cadmium was detected in liver but not muscle.

Metal concentrations in fish from the Slave River study were compared with metal concentrations in fish from other regions of Great Slave Lake and nearby areas. Concentrations generally were similar with the exception of arsenic which tended to be higher in the summer 1996 study than in many other studies, including one conducted in Resolution Bay in 1992 and 1993. These differences appear to be related to the analytical laboratory conducting the arsenic analyses and not to the fish themselves. The small number (n = 5) of fish examined in this study precluded additional comparisons based on fish size, age, and gender.

Toxaphene and PCB were the predominant POPs present in muscle: mean (average) PCB concentrations ranged from a low of 2.9 ng/g (burbot) to a high of 11.5 ng/g (inconnu) while mean toxaphene concentrations ranged from 2.9 ng/g (burbot) to 31.3 ng/g (inconnu). For the liver, mean toxaphene concentrations were 41.5 ng/g for walleye, 55.7 ng/g for pike, and 348 ng/g for burbot; mean PCB concentrations were 27.8 ng/g for walleye, 35.1 ng/g for pike and 96.4 ng/g for

burbot. Overall, the liver contained substantially higher concentrations of POPs than muscle. In pike, the average POP concentrations in the stomach tended to be similar to concentrations in the liver.

Muscle and liver POP concentrations in fish from Resolution Bay were compared to POP concentrations in whole fish and liver determined during the 1991-1994 Slave River study. In general, PCB concentrations were lower in muscle than in whole fish. Thus, estimates of PCB intake based on whole fish analyses may overestimate PCB consumption. For burbot liver, there was some suggestion that toxaphene (but not PCB) concentrations in fish collected from Great Slave Lake and the Slave River were higher than toxaphene concentrations in burbot collected from Alexie Lake. It is not clear why fish in the Great Slave Lake-Slave River ecosystem would have higher toxaphene but not PCB concentrations than fish from Alexie Lake. It may, in some way, be related to the large volumes of water, sediments, and associated contaminants which are carried downstream with the Slave River from the Peace and Athabasca River watersheds.

Most other POPs were below detection limits in the Slave River study. This negated further comparisons between the Slave River study and study results reported here.

ACKNOWLEDGMENTS

This study was supported by the Northern Contaminant Program of the Department of Indian and Northern Affairs Ottawa. Additional support was provided by the National Water Research Institute, Saskatoon.

This study was initiated by Maurice Boucher and Patrick Simon, Environmental Officers with the Deninu Ku'e First Nation at Fort Resolution. Moreover, this study formed the basis for a larger study investigating the environmental impact of the decommissioned Pine Point Mine on water, sediments, and fish in the Resolution Bay area.

George Low, Fisheries and Oceans, Hay River, facilitated the fish collections and also arranged for their shipment by the Freshwater Fish Marketing Corporation to the Freshwater Institute in Winnipeg. Bob Hunt, Joanne Delaronde, and Bruno Rosenberg performed the metal and persistent organochlorine pollutant analyses.

Carol Casey and Jason Inkster of the National Water Research Institute, Saskatoon, prepared all the figures and tables and also edited the report.

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1.0 INTRODUCTION

The presence of contaminants in Great Slave Lake fish continues to be of concern to many people. People in local communities are concerned because of the importance of fish (and other organisms) in traditional diets. Researchers are concerned because they are aware of the many ways in which contaminants are transported to the lake and then taken up by animals, including fish.

Two types of contaminants are of concern. One type of contaminant is organic in nature - that is it contains carbon and hydrogen, the major components of all organisms. Organic compounds can also contain other elements such as nitrogen, sulfur, oxygen, chlorine, etc. There are more than two million known organic compounds, the vast majority of which are naturally occurring. The types of organic compounds that are of most concern in the Arctic are the man made, persistent organochlorine pollutants (POPs) - compounds such as PCBs, DDT, and toxaphene (Han and Adare 1997). POPs are manufactured compounds, designed for a variety of purposes i.e., PCBs have a wide variety of industrial applications, while DDT and toxaphene were designed as pesticides. While these compounds have a variety of beneficial uses, studies over the decades have shown that there are significant concerns with the release of these POPs into the environment for three basic reasons:

- POPs are not readily broken down into simpler compounds and so they tend to persist in the environment year after year. These compounds are different from a simple organic compound such as sugar which can be broken down in a matter of seconds into simpler compounds.
- The chemical structure of many POPs is such that once they are taken up by an organism (through water and food), they are not readily lost from that organism - hence the term persistent. This occurs because these compounds tend to become associated with other organic compounds such as fat in the body. In a simple way, it is somewhat like iron filings becoming "associated" with a magnet. A fish eating another fish which contains POPs will extract the useful energy from the protein, excrete the unwanted matter (as urine and feces) but will not be as good at getting rid of the POPs. This is in contrast to

"non-persistent" types of organic compounds which organisms can readily get rid of because they do not stay strongly associated with other organic compounds. For example, the simple nitrogen-containing organic compound urea, a breakdown product of protein and the major constituent of urine, is readily lost from the body.

- POPs are of concern because at high concentrations some of these compounds can have harmful effects on organisms. This is nothing unusual because most compounds can be harmful at very high concentrations. Vitamin D, for example, is essential to human health but can be harmful at very high concentrations. Polar bear liver contains high concentrations of Vitamin A and can be "poisonous" if consumed in large quantity (Berkow 1982; Ellis 1971).

Anything which is not an organic compound is called an inorganic compound. There are many types of inorganic compounds. Some inorganic compounds are gases such as carbon dioxide and oxygen. Some inorganic compounds are salts such as table salt (sodium chloride) and baking soda (sodium bicarbonate). Some inorganic compounds are metals such as copper, lead, and zinc. Organisms naturally contain a wide variety of inorganic compounds - oxygen, carbon dioxide, salt, iron, copper, zinc, etc. Although these compounds occur in very low concentrations they have important roles in the normal functioning of the organism (Han and Adare 1997). Some organisms contain more of these inorganic compounds than others. Nuts, beef and pork liver, kidney and dried beans tend to be rich sources of copper while meat, liver, egg, seafood and grains are rich sources of zinc (Tapley et al. 1985). However, at high concentrations, inorganic compounds can have harmful effects. Some other inorganic compounds which are found naturally in low concentrations in organisms have no known useful function, e.g., lead and mercury. At sufficiently high concentrations, these compounds can be harmful.

It is now possible to measure very low concentrations of chemicals in the environment. Some compounds can be detected at 1 part per million (1 ppm or 1 μg/g), 1 part per billion (1 ppb or 1 ng/g) or 1 part per trillion (1 pptr or 1 pg/g). Researchers are developing ways of measuring even lower concentrations of chemicals in the environment. Thus, we know more about where chemical compounds occur in the environment and in what organisms than we did forty years ago when we could not even measure these compounds, but many questions still need to be answered. For example, how do these chemicals affect organisms - for the good, for the not so good, or in no measurable way? Why do some organisms contain higher concentrations of these chemicals than other organisms? Why do some tissues contain higher concentrations of these chemicals than other tissues?

In recent times, there has been a growing concern regarding inorganic compounds such as metals in the environment (Han and Adare 1997). While metals occur naturally in the environment, their concentrations may change as a result of human activities. Combustion of fossil fuels, industrial activities, and incineration of waste can release metals into the atmosphere. These metals can be carried hundreds and thousands of kilometers by the atmosphere to areas such as the Arctic. Some metals may fall onto the land or into the lakes with rainfall and dust fall. Mining activities also can affect metal concentrations. Milling operations concentrate metals, from low concentrations in the rocks to higher concentrations in the processed ore, so they can be used in the manufacturing industry. Water used during the treatment process may become contaminated with high concentrations of metals; some metals may also be released from industrial stacks as dust and vapor e.g., mercury and arsenic.

In the Great Slave Lake region, research has been conducted on the presence of POPs in fish and invertebrates in two regions of the lake - near Fort Resolution and near Lutsel K'e. This research was conducted from 1993 to 1995 with the results reported annually in the Arctic Environmental Strategy Annual reports (Evans 1994, 1996). Fish analyses focused on whitefish muscle, lake trout muscle, and burbot (loche) muscle and liver. Metal analyses were not conducted as part of this study.

Studies conducted by Receveur et al. (1996) have investigated food use by Dene and Metis communities in the Northwest Territories. As part of this study, they determined which foods people were eating. Then, by using data on POP and heavy metal concentrations in traditional foods, they were able to estimate how much (in terms of weight) of that compound people were consuming daily. These estimates were compared to the guidelines established by Health Canada on the tolerable daily intake (TDI) of the various compounds. TDIs can be exceeded when people consume sufficient amounts of a tissue which contains significant amounts of that compound.

Receveur et al. (1996) determined that some people at Lutsel K'e may be exceeding their TDI for chlordane when they consume lake trout muscle, caribou fat, caribou meat, and moose meat. At Fort Resolution, some people who consume caribou bone marrow may exceed their TDI for chlorobenzenes (CBZ). Both chlordane and CBZ are organic compounds which are manufactured during various processes. For metals, some people at Lutsel K'e could exceed their TDI for cadmium when consuming caribou liver, caribou meat, trout flesh, and trout head and for mercury when consuming trout flesh and caribou meat. At Fort Resolution, some people could exceed their TDI for cadmium and lead when consuming moose liver.

Although the studies by Evans (1994, 1996) and Receveur et al. (1996) have answered many questions about contaminants in the Great Slave Lake ecosystem, many questions remain unanswered. Studies by Evans investigated POPs in one or two tissues in only three fish species. Similarly, the Receveur et al. (1996) examined only a few species and tissues for metals. Receveur et al's. (1996) POP data were obtained from the Fort Good Hope and Colville Lake (K'asho Got'ine K'ahbamit'ue) regions, hundreds of kilometers to the north of Great Slave Lake. These sites were located too far away to confidently make comparisons with Resolution Bay data. Therefore it was necessary to sample additional species of fish in Resolution Bay to determine POP concentrations.

In 1996, research studies were conducted in the Fort Resolution area to address knowledge gaps in our understanding of POP and metal concentrations in fish tissues which are important in traditional diets. This research was initiated by the community and was based on fish collections made in Resolution Bay in summer 1996. This report, submitted to Fort Resolution, is based on this study.

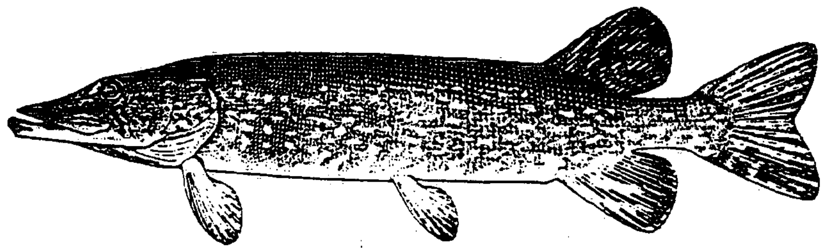
A second study, (Evans et al. 1998), based on issues raised by the community regarding the decommissioned Pine Point mine, was supported by the Department of Indian Affairs (DIAND), Yellowknife. It presented results of summer 1996 investigations into metal concentrations in water and sediments collected from Resolution Bay, offshore of the decommissioned Pine Point mine site, the Slave River, and the Little Buffalo River. It also presented results of studies determining metal (and metallothionein) concentrations in burbot (and a smaller number of inconnu and walleye) from the Slave River and pike (and one walleye) from the Little Buffalo River. These data were then compared with related studies investigating metals in water, sediments, and fish in Great Slave Lake, the Slave River, and reference lake and river studies. Included in these comparisons were the metal data presented in this report. Thus, only highlights of the Pine Point Mine studies and comparisons are reported in this report.

2.0 METHODS

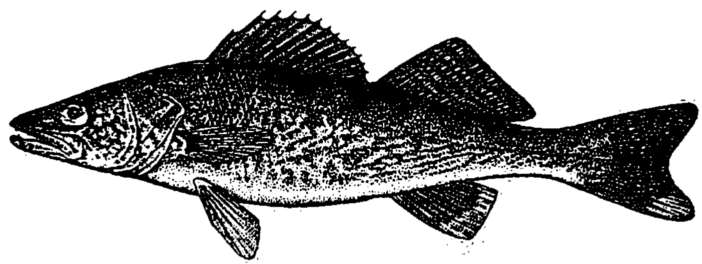
Various discussions were held between the Fort Resolution Environmental Working Committee and M. Evans, NHRI, to decide what species of fish were to be investigated and which fish tissues were to be analyzed. Final decisions were made during a meeting held on August 26, 1996 and are shown in Table 1. POP analyses were to include PCBs (by congener), chlorobenzene, toxaphene, hexachlorocyclohexane, mirex, DDT, DDE, methoxychlor, chlordanes, dieldrin, endrin, and endosulfan. Metal analyses agreed to at the meeting were cadmium (Cd), copper (Cu), mercury (Hg), lead (Pb), and zinc (Zn). Arsenic (As) was subsequently included in the analytical list as the allocated funds allowed.

In the summer of 1996, 10 specimens each of walleye (pickerel, *Stizostedion vitreum*), northern pike (jack, *Esox lucius*), burbot (loche, maria, *Lota lota*) and inconnu (connie, *Stenodus leucichthys*) were collected for POP and metal analyses (Figure 1). Fish were frozen shortly after capture and stored frozen until shipment to the Freshwater Institute. Metal and POP analyses were performed according to methods shown in Appendix A.

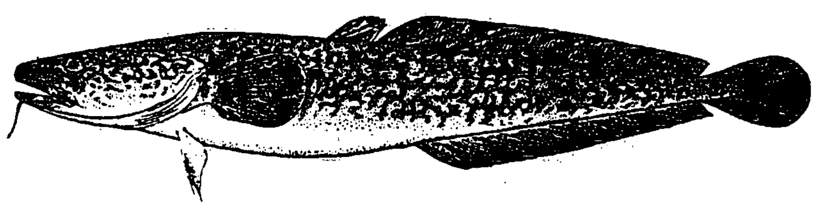
All four species of fish are piscivorous and, as such, would be expected to contain higher levels of POPs and mercury than fish which eat invertebrates or plants. Muscle



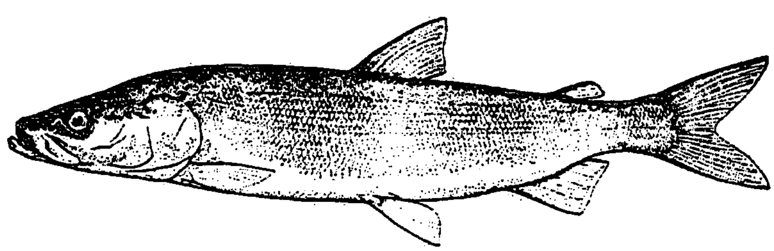
pike = jack = *Esox lucius*



walleye = pickerel = *Stizostedion vitreum*



burbot = loche = maria = *Lota lota*



inconnu = connie = *Stenodus leucichthys*

Figure 1. Drawings of fish investigated in this study, from Scott and Crossman (1973). Also shown are the common and scientific names for each fish.

and liver were selected for study because these tissues are commonly eaten by the community, as is pike stomach. Gall bladder was selected because gall bladder sometimes are used medicinally. For example, some people in Lutsel K'e, use lake trout gall bladder for medicinal purposes. Funds and other considerations limited analysis to a single, five-fish composite, burbot gall bladder sample. Bile also was analyzed. Fish length, weight, and age also were determined.

Complete analyses were conducted on all fish except POP analyses for the liver of three walleye: insufficient material was available for these analyses. Subsequently, an additional three walleye of the 5 remaining from the original collection of 10 specimens were analyzed for the full suite of compounds, i.e., POPs and metals in muscle and liver. Gall bladders were too small for enough tissue and bile to be obtained for POP analyses.

Table 1. Fish species, names, tissues, and number of replicates to be analyzed for metals and POP compounds.

Fish	Scientific name	Scientific	Number of	Tissue
Pike/jack	*Esox lucius*	Esocidae	5	Muscle
		(Pike)	5	Liver
			5	Stomach
Walleye/pickerel	*Stizostedion vitreum*	Percidae	8	Muscle
		(Perch)	5	Liver
Burbot/maria/loche	*Lota lota*	Gadidae	5	Muscle
		(Cod)	5	Liver
			1	Gall bladder *
Inconnu/connie	*Stenodus leucichthys*	Coregoninae**	5	Muscle
TOTAL			41	

* Gall bladder and bile were separated, a composite sample of each prepared from five fish, and then analyzed for metals. There was insufficient biomass for POP analyses.
** Scott and Crossman (1973) designate Coregoninae as a sub-family of the Salmonidae or Salmon family.

3.0 RESULTS

3.1 Fish length, weights, and ages

Pike ranged in standard length from 660 - 765 mm, in weight from 1,713 - 3,364 gm and in age from 9+ to 13+ years of age (Table 2). Walleye ranged from 362 - 480 mm in length, 216 - 770 gm in weight and from 7+ to 10+ years of age. The five burbot analyzed were much more variable in size and age than the five pike and eight walleye analyzed; these burbot ranged from 490 - 730 mm in length, 698 - 2,399 gm in weight, and from 5+ to 18+ in age. Inconnu ranged from 755 - 917 mm in length, 4.59 - 8.11 kg in weight, and from 8+ to 9+ in age. Overall, the five inconnu analyzed spanned a relatively narrow range in size and age.

3.2. Metal analyses

Fish were analyzed for arsenic, cadmium, copper, lead, mercury, and zinc. All values reported are in µg/g wet weight. Lead was below detection limits (0.05 µg/g) for all 42 analyses. It is not discussed further in this section of this report.

3.2.1 Arsenic

Arsenic concentrations in pike muscle (Figure 2; Appendix Table 1) ranged from 0.10 - 0.19 µg/g (or parts per million since 1 gm = 1,000,000 µg). Concentrations averaged 0.15 µg/g. Lowest arsenic concentrations were in walleye muscle, ranging from 0.03 - 0.12 µg/g, and averaging 0.08 µg/g. Arsenic concentrations in burbot muscle ranged from 0.09 - 0.22 µg/g and averaged 0.13 µg/g. Inconnu had the highest and most variable arsenic concentrations with values ranging from 0.09 - 0.50 µg/g and averaging 0.30 µg/g. Health and Welfare Canada has no guideline for arsenic concentrations in fish. Human health assessments are based on a combination of the most current toxicological endpoint and the estimated probable daily intake (H. B. S. Conacher, Health and Welfare Canada, personal communication).

Arsenic in pike liver ranged from 0.08 - 0.20 µg/g and averaged 0.15 µg/g (Figure 3, Appendix Table 2). Thus, arsenic concentrations were similar in both pike muscle and liver. Arsenic concentrations in walleye liver ranged from 0.24 - 0.74 µg/g and averaged

Table 2. Average (mean) ages, lengths and weights of pike, walleye, burbot, and inconnu analyzed from summer 1996 collections, Resolution Bay. The + means that the fish was that year old plus a few months.

Fish Species and Number	Length (mm)	Weight (gm)	Age (yr)
Pike 1	660	1713	12+
Pike 2	732	2223	9+
Pike 3	745	2654	10+
Pike 4	765	3221	13+
Pike 5	760	3364	12+
Average	732.4	2635.0	11.2+
Walleye 1	480	216	9+
Walleye 2	410	710	9+
Walleye 3	445	769	8+
Walleye 4	431	770	8+
Walleye 5	430	700	7+
Walleye 6	396	606	8+
Walleye 7	387	645	10+
Walleye 8	362	484	9+
Average	417.6	612.5	8.5+
Burbot 1	490	698	9+
Burbot 2	500	771	5+
Burbot 3	540	1043	9+
Burbot 4	730	2399	18+
Burbot 5	640	2268	10+
Average	580.0	1435.8	10.2+
Inconnu 1	755	4589	8+
Inconnu 2	800	4901	8+
Inconnu 3	910	8110	8+
Inconnu 4	815	5442	9+
Inconnu 5	917	7526	9+
Average	839.4	6113.6	8.4+

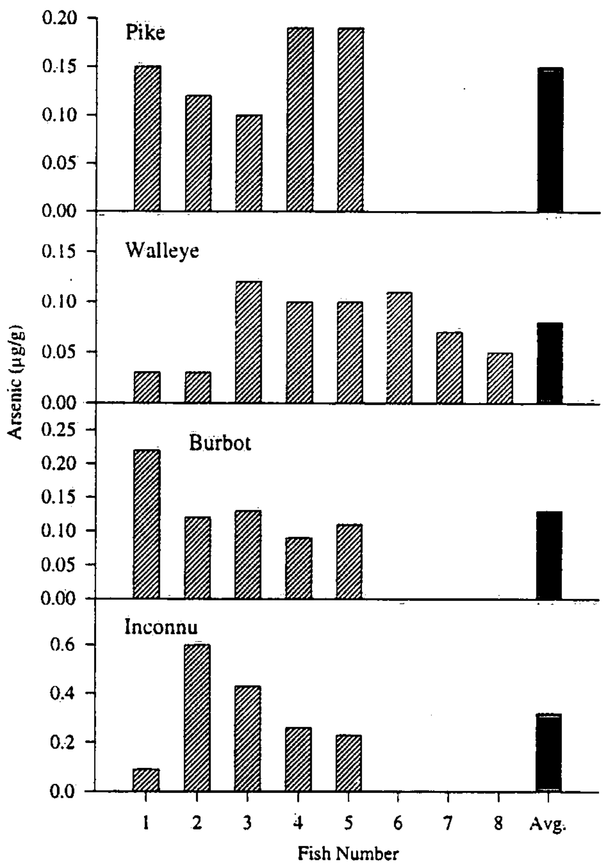


Figure 2. Arsenic concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

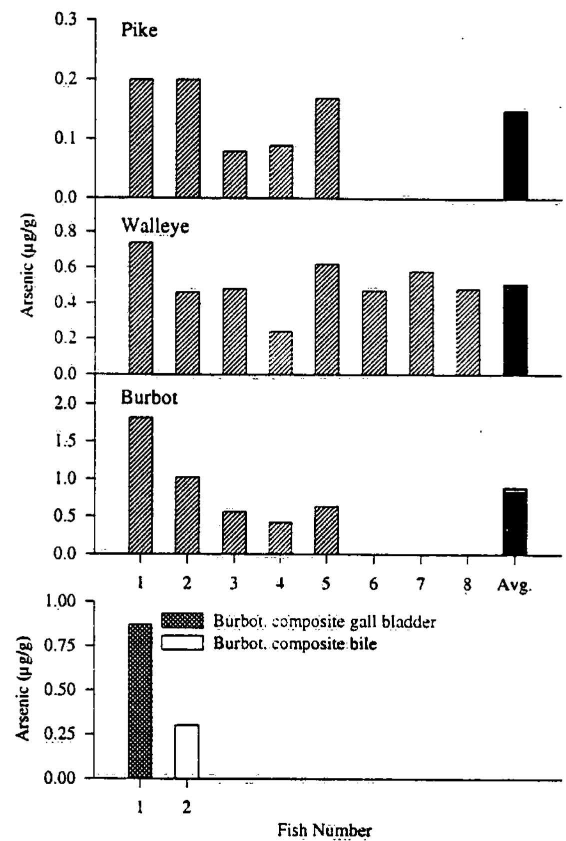


Figure 3. Arsenic concentrations (wet weight) in the liver of three fish species and in composite samples of burbot gall bladder and bile collected from Resolution Bay, summer 1996.

0.51 µg/g, a concentration some 6.4 times greater than in the muscle. In burbot, arsenic concentrations in the liver ranged from 0.42 - 1.82 µg/g and averaged 0.87 µg/g, a value some value some 6.7 times greater than in the muscle. Arsenic concentration in burbot gall bladder (one composite sample) was 0.87 µg/g while the bile itself contained 0.30 µg/g of arsenic.

Arsenic concentrations in pike stomach ranged from 0.33 - 0.50 µg/g and averaged 0.38 µg/g (Figure 4). Concentrations were some 2.5 times higher than in pike liver and muscle.

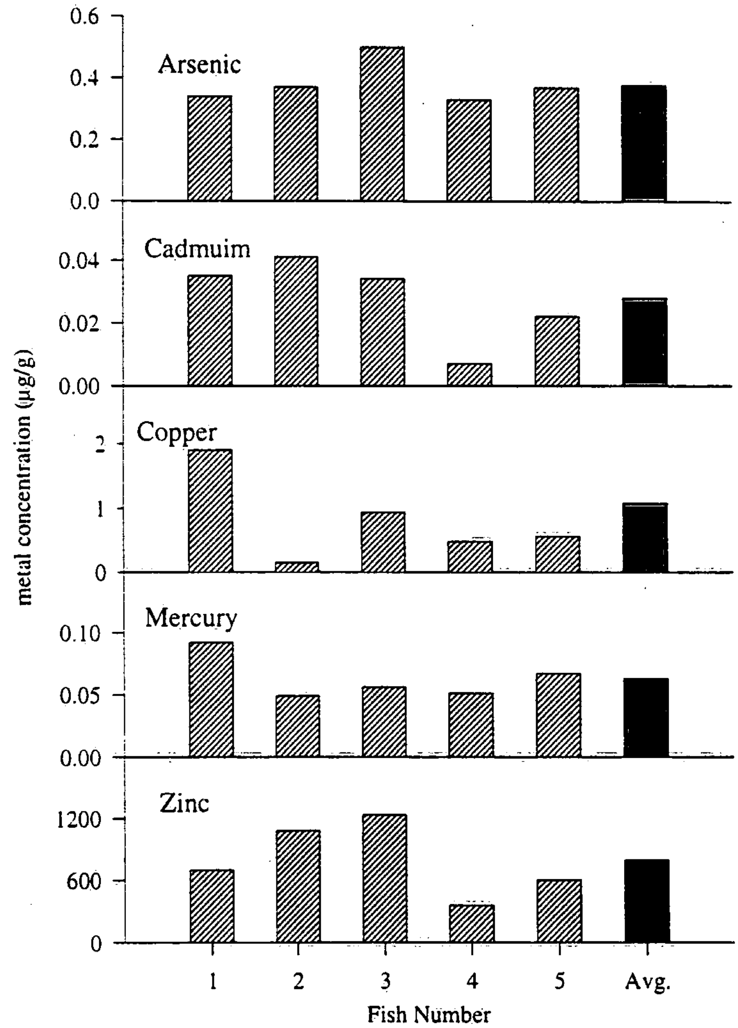


Figure 4. Concentrations (wet weight) of five metals in pike stomach collected from Resolution Bay, summer 1996.

3.2.2 Cadmium

Cadmium concentrations were below detection limits (0.001 µg/g) in the muscle for all eight walleye, five pike, and inconnu and four of the five pike analyzed. For the fifth pike (fish number 4), cadmium concentrations were 0.002 µg/g. Thus, average cadmium concentrations for muscle tissue of all four fish species was <0.001 µg/g. Data are not graphed because 19 of 20 of the analyses were below detection limits.

While cadmium was generally below detection limits in muscle, it was detected in liver, gall bladder, and bile of all species analyzed (Figure 5). Cadmium concentrations in pike liver ranged from 0.06 - 0.16 µg/g and averaged 0.09 µg/g. Cadmium concentrations in walleye liver ranged from 0.13 - 0.41 µg/g and averaged 0.24 µg/g.

Cadmium concentrations in burbot liver ranged from 0.03 - 0.14 μg/g and averaged 0.07 μg/g: gall bladder contained 0.010 μg/g while bile contained 0.003 μg/g of cadmium.

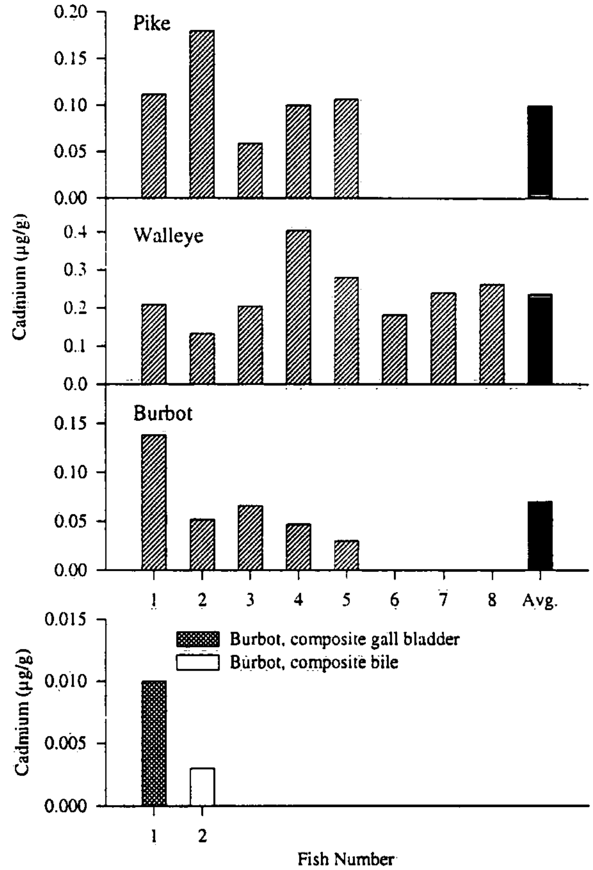


Figure 5. Cadmium concentrations (wet weight) in the liver of three fish species and in composite samples of burbot gall bladder and bile collected from Resolution Bay, summer 1996.

Cadmium concentrations in pike stomach (Figure 4) ranged from 0.01 - 0.04 μg/g and averaged 0.03 μg/g. Cadmium concentrations were higher in pike stomach than pike muscle, but were lower than in pike liver.

Health and Welfare Canada has no guideline for cadmium concentrations in fish. Human health assessments are based on a combination of the most current toxicological endpoint and the estimated probable daily intake (H. B. S. Conacher, Health and Welfare Canada, personal communication).

3.2.3 Copper

Copper concentrations ranged from 0.17 - 0.25 µg/g and averaged 0.21 µg/g in pike muscle (Figure 6). Concentrations were slightly higher in walleye, (mean 0.27 µg/g; range 0.18 - 0.36 µg/g), burbot (mean 0.34 µg/g; range 0.24 - 0.46 µg/g), and inconnu (mean 0.36 µg/g; range 0.34 - 0.37 µg/g) muscle.

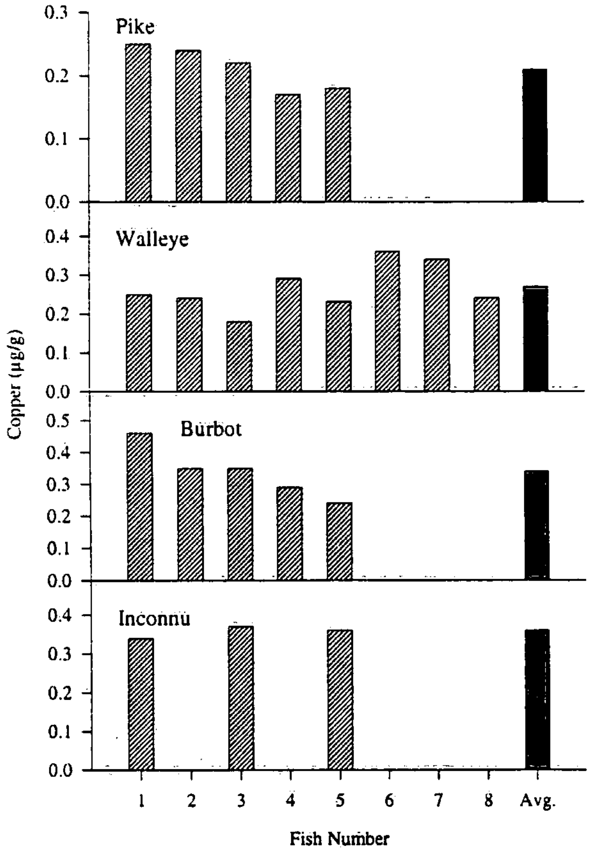


Figure 6. Copper concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

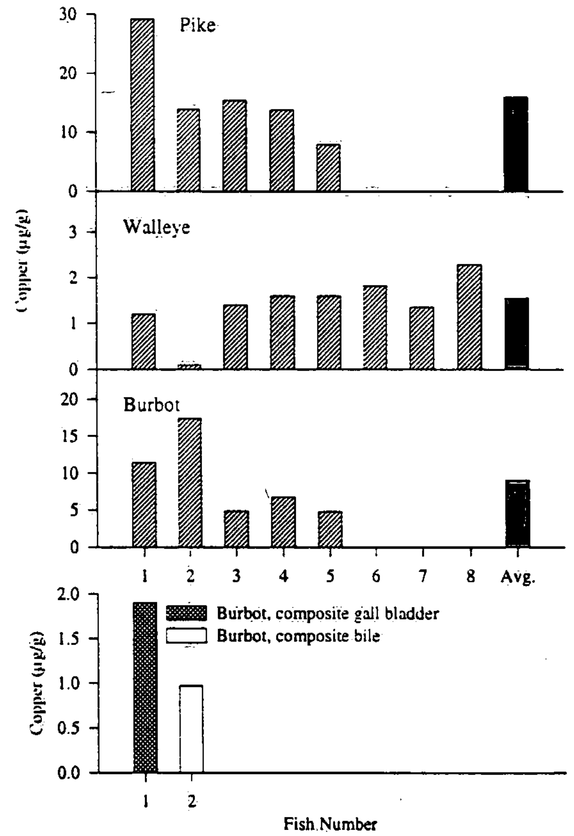


Figure 7. Copper concentrations (wet weight) in the liver of three fish species and in composite samples of burbot gall bladder and bile collected from Resolution Bay, summer 1996.

Copper concentrations were substantially higher in liver than muscle. In pike liver, copper concentrations ranged from 7.9 - 29.2 µg/g and averaged 16.0 µg/g (Figure 7). Copper concentrations were lower in walleye liver ranging from 1.10 - 2.29 µg/g and averaging 1.55 µg/g. Copper concentrations in burbot liver ranged from 4.70 - 17.4 µg/g and averaged 9.0 µg/g: the gall bladder contained 1.90 µ g/g while bile itself contained 0.97 µg/g of copper.

Copper concentrations in pike stomach ranged from 0.48 - 1.90 µg/g and averaged 1.08 µg/g (Figure 4). Thus, copper concentrations were higher in pike stomach than in the muscle but lower than in pike liver.

Health and Welfare Canada has no guideline for copper concentrations in fish. Human health assessments are based on a combination of the most current toxicological endpoint and the estimated probable daily intake (H. B. S. Conacher, Health and Welfare Canada, personal communication).

3.2.4 Mercury

Mercury concentration in pike muscle ranged from 0.19 - 0.32 µg/g and averaged 0.25 µg/g (Figure 8). Mercury concentrations in walleye muscle ranged from 0.12 - 0.32 µg/g and averaged 0.19 µg/g. Mercury concentrations in burbot muscle ranged from 0.04 - 0.16 µg/g and averaged 0.08 µg/g while mercury concentrations in inconnu muscle ranged from 0.08 - 0.13 µg/g and averaged 0.11 µg/g. Highest average mercury concentrations were in pike muscle while the lowest average was for burbot muscle. Mercury levels were below the 0.5 µg/g level established by Health and Welfare Canada for the edible portion of fish (Jensen et al. 1997) for the commercial sale of fish. However, walleye approached and most pike exceeded the 0.2 µg/g guideline recommended who consume large quantities of such fish.

Mercury in pike liver ranged from 0.06 - 0.15 µg/g and averaged 0.10 µg/g (Figure 9). Thus, mercury concentrations were some 2.5 times lower in pike liver than muscle. Mercury concentrations in walleye liver ranged from 0.03 - 0.08 µg/g and averaged 0.06 µg/g, a concentration some 3.2 times lower than in the muscle. Mercury concentrations in burbot liver ranged from 0.02 - 0.04 µg/g and averaged 0.03 µg/g, a value 2.7 times lower than in the muscle. Burbot gall bladder contained 0.03 µg/g while the bile contained 0.005 µg/g of mercury.

Mercury concentrations in pike stomach ranged from 0.05 - 0.09 μg/g and averaged 0.06 μg/g (Figure 4). These concentrations were higher than in liver but lower than in muscle.

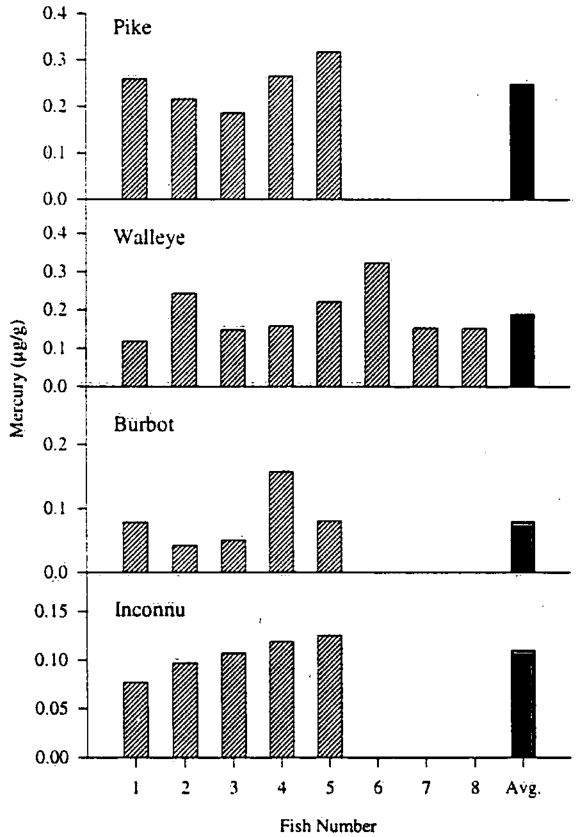


Figure 8. Mercury concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

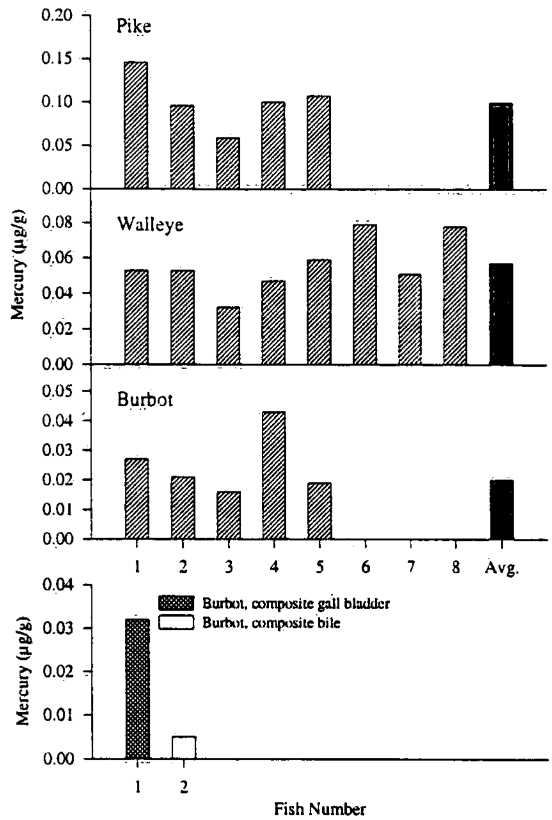


Figure 9. Mercury concentrations (wet weight) in the liver of three fish species and in composite samples of burbot gall bladder and bile collected from Resolution Bay, summer 1996.

3.2.5 Zinc

Zinc concentrations in pike muscle ranged from 3.0 - 4.3 μg/g and averaged 3.7 μg/g (Figure 10). Zinc concentrations in walleye muscle ranged from 2.5 - 3.7 μg/g and averaged 3.1 μg/g. Zinc concentrations in burbot muscle ranged from 2.8 - 3.3 μg/g and averaged 3.0 μg/g while zinc concentrations in inconnu muscle ranged from 2.5 - 2.8 μg/g and averaged 2.7 μg/g. Overall, zinc concentrations were similar in the muscle of all four species analyzed.

Zinc concentrations in pike liver ranged from 25.1 - 45.4 µg/g and averaged 34.2 µg/g (Figure 11). Thus, zinc concentrations were some 9.2 times higher in pike liver than muscle. Zinc concentrations in walleye liver ranged from 12.8 - 24.6 µg/g and averaged 19.5 µg/g, a concentration some 6.3 times higher than in the muscle. Zinc concentrations in burbot liver ranged from 13.8 - 25.4 µg/g and averaged 17.9 µg/g, a value 6.0 higher than in the muscle; gall bladder contained 14.2 µg/g while bile contained 2.2 µg/g of zinc.

Health and Welfare Canada has no guideline for zinc concentrations in fish. Human health assessments are based on a combination of the most current toxicological endpoint and the estimated probable daily intake (H. B. S. Conacher, Health and Welfare Canada, personal communication).

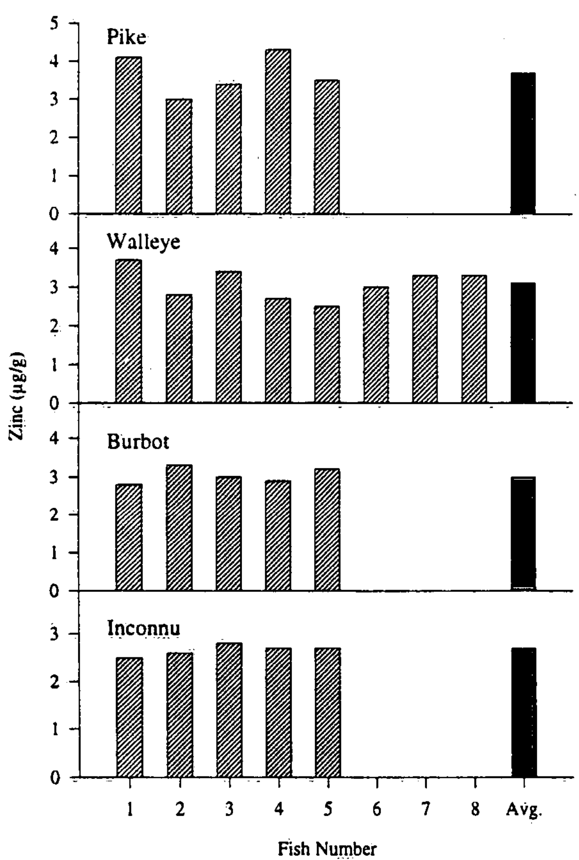


Figure 10. Zinc concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

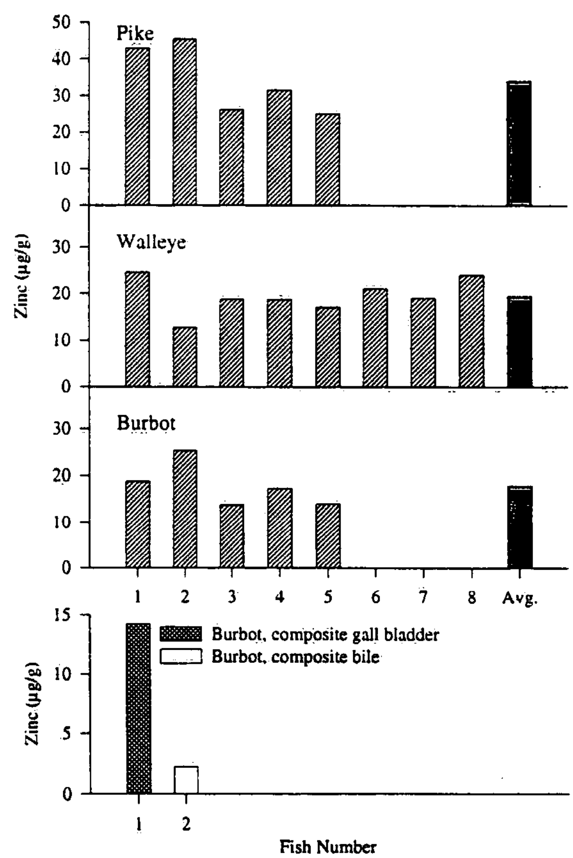


Figure 11. Zinc concentrations (wet weight) in the liver of three fish species and in composite samples of burbot gall bladder and bile collected from Resolution Bay, summer 1996

Zinc concentrations in pike stomach ranged from 361 - 1,237 µg/g and averaged 797 µg/g (Figure 4). Concentrations were 23.3 times higher than in liver and 334 times higher than in muscle.

3.3 Comparison with other related studies

In Evans et al. (1998) extensive comparisons were made of metal concentrations in walleye, pike, inconnu, burbot, whitefish, and suckers collected from Great Slave Lake, reference lakes, and the Little Buffalo and Slave Rivers. The overall purpose of these comparisons was to evaluate whether or not fish living offshore of the decommissioned Pine Point mine site had elevated concentrations of metals when compared to fish collected from the Slave River, Yellowknife-Back Bay, and reference lakes. Highlights of these comparisons are presented below along with abbreviated tables (Tables 3-6) from Evans et al. (1998).

1. Comparisons of metal concentrations between the various studies were confounded by the fact that different laboratories conducted the metal analyses. The Freshwater Institute (FWI) conducted the metal analyses for the 1996 studies in the Resolution Bay area (this report, Evans et al. 1998) and the Yellowknife-Back Bay study (Jackson et al. 1996). A second laboratory, Cantest Ltd., conducted the metal analyses for fish in all other studies done in the 1990s. This includes a Resolution Bay study (Lafontaine 1997), Yellowknife-Back Bay (Jackson et al. 1996), the Slave River with Alexis and Trout Lakes as reference sites (Sanderson et al. 1998), and Trout Lake (Swyripa et al. 1993). Some laboratories had lower detection limits than others. There were major differences in arsenic concentrations across studies which clearly were a function of the laboratory conducting the analyses. Cantest generally reported lower arsenic concentrations than Freshwater Institute. However, arsenic concentrations in some fish caught from the Slave River in some years were similar to concentrations reported by FWI for the same species of fish. Overall, differences in arsenic concentrations between

the two laboratories is believed to be due to some aspect of the laboratory analyses conducted by Cantest.

2. Metal concentrations in the same species of fish generally were comparable across studies (with the above noted exception of arsenic). Cadmium and lead concentrations reported from the Stein and Miller (1972) study must be viewed with some caution because it is uncertain how these fish were analyzed. Overall, there was no evidence that the Pine Point mine had or was continuing to contaminate fish in the Resolution Bay area with heavy metals. A recent Health and Welfare Canada assessment of these data indicated that "consumption of muscle, liver, and kidney of these species from these locations (i.e., Little Buffalo River and Slave River) would not pose a health hazard to the consumer (H. B. S. Conacher, Health and Welfare Canada, personal communication).
3. Mercury concentration in pike and walleye muscle approached or exceeded to 0.2 µg/g guideline established for frequent consumption of fish and 0.5 µg/g for the commercial sale of fish. Health and Welfare Canada has examined metal data from the Lafontaine (1997) and Jackson et al. (1996) studies: no health advisory was required.

Table 3. Mean metal concentrations in burbot, inconnu, pike and walleye muscle from 1996 and earlier studies. Data are expressed as ppm (µg/g) wet weight.

Study	N	As	Cd	Cu	Hg	Pb	Zn
Burbot Muscle							
Resolution Bay, 1996 [1]	5	0.13	<0.001	0.34	0.08	<0.05	3.0
Resolution Bay, 1992-93 [2]	21	<0.02	<0.01	0.28	0.12	<0.01	3.54
Yellowknife-Back Bay, 1992-93 [3]	72	0.23	<0.001	0.34	0.15	<0.03	4.36
Slave River, 1996 [1]	14	0.18	<0.002	0.23	0.13	<0.05	4.01
Slave River, 1990-94 [4]	36	<0.04	<0.01	0.23	0.12	<0.01	4.32
Alexis Lake, 1990-91 [4]	22	<0.08	<0.01	0.22	0.14	<0.01	4.47
Buffalo River, 1971 [5]	1	-	0.23	1.00	-	-	6.50
Inconnu Muscle							
Resolution Bay, 1996 [1]	5	0.32	<0.001	0.21	0.11	<0.05	2.7
Slave River, 1996 [1]	3	0.27	<0.001	0.33	0.11	<0.05	2.45
Paulette Island, 1971 [5]	1	-	0.10	0.50	-	-	13.0
Pike Muscle							
Resolution Bay, 1996 [1]	5	0.15	<0.001	0.21	0.25	<0.05	3.66
Resolution Bay, 1992-93 [2]	20	<0.02	<0.01	0.22	0.22	<0.01	3.75
Yellowknife-Back Bay, 1992-93 [3]	108	<0.20	<0.002	0.33	0.20	<0.03	3.60
Little Buffalo R., 1996 [1]	13	<0.09	<0.001	0.32	0.18	<0.05	4.22
Slave River, 1990-94 [4]	66	<0.04	<0.01	0.24	0.27	<0.01	4.33
Leland Lake, 1990-94 [4]	32	<0.01	<0.01	0.26	0.30	<0.01	7.39
Trout Lake, 1990-91 [6]	2	<0.01	<0.01	0.81	0.10	0.02	5.57
Little Buffalo R., 1971 [5]		-	0.04	0.55	0.30	0.20	6.26
Paulette Island, 1971 [5]		-	0.06	0.82	-	-	6.05
Presqu'ile, 1971 [5]		-	0.00	0.26	0.15	0.17	3.71
Buffalo River, 1971 [5]		-	0.12	0.56	0.09	0.02	5.98
Walleye Muscle							
Resolution Bay, 1996 [1]	5	0.08	<0.001	0.23	0.18	<0.05	3.02
Resolution Bay, 1992-93 [2]	9	<0.01	<0.01	0.24	0.21	<0.01	3.66
Yellowknife-Back Bay, 1992-93 [3]	29	<0.06	0.001	0.29	0.15	<0.03	3.23
Little Buffalo R., 1996 [1]	1	<0.05	<0.001	0.31	0.18	<0.05	4.86
Slave River, 1990-94 [4]	72	<0.05	<0.01	0.29	0.29	<0.02	4.01
Slave R., 1996 [1]	1	0.09	<0.001	0.22	0.19	<0.05	3.06
Leland Lake, 1990-94 [4]	38	<0.02	<0.01	0.28	0.35	<0.03	4.1
Trout Lake, 1990-91 [6]	20	<0.03	<0.01	0.33	0.13	<0.03	4.51
Little Buffalo R., 1971[1]	3-6	-	0.00	0.52	-	0.16	4.92
Paulette Island, 1971 [5]	1	-	0.12	0.70	-	-	3.90
Presqu'ile, 1971 [5]	1	-	-	0.13	-	0.05	1.68
Buffalo River, 1971 [5]	2-14	-	0.12	0.57	0.16	0.14	4.33
Buffalo River, 1971 [5]	1-11	-	0.08	0.83	-	0.10	4.14

[1] Evans et al. (1998) [2] Lafontaine (1997) [3] Jackson et al. (1996)
[4] Sanderson et al. (1997) [5] Stein and Miller (1972) [6] Swyripa et al. (1993)

Table 4. Metal concentrations in pike, walleye burbot and inconnu liver from 1996 and earlier studies. Data are expressed as ppm (μg/g) wet weight.

Study	N	As	Cd	Cu	Hg	Pb	Zn
Pike Liver							
Resolution Bay, 1996 [1]	5	0.15	0.10	16.04	0.10	<0.05	34.2
Yellowknife-Back Bay, 1992-93 [3]	108	0.25	0.07	4.06	0.07	<0.05	30.0
Little Buffalo R., 1996 [1]	13	<0.05	0.09	10.77	0.10	<0.05	46.9
Little Buffalo R., 1971 [5]	14-32	-	0.08	7.80	-	0.14	31.0
Paulette Island, 1971 [5]	1	-	0.20	5.80	-	-	29.0
Presqu'ile, 1971 [5]	1-14	-	0.20	4.32	-	0.53	35.7
Buffalo River, 1971 [5]	4-8	-	0.08	3.84	-	0.13	22.9
Walleye Liver							
Resolution Bay, 1996 [1]	5	0.51	0.25	1.38	0.05	<0.05	18.4
Yellowknife-Back Bay, 1992-93 [3]	30	0.40	0.21	1.85	0.07	<0.05	18.5
Slave R., 1996 [1]	1	0.23	0.22	1.21	0.06	<0.05	19.2
Little Buffalo R., 1996 [1]	1	0.13	0.16	1.52	0.06	<0.05	16.6
Little Buffalo R., 1971 [5]	3		0.13	2.60	-	-	19.3
Paulette Island, 1971 [5]			-	-	-	-	16.1
Presqu'ile, 1971 [5]	1		-	0.77	-	-	-
Buffalo River, 1971 [5]	7-20		0.37	1.21	-	0.21	14.7
Burbot Liver							
Resolution Bay, 1996 [1]	5	0.89	0.07	9.00	0.03	<0.05	17.9
Resolution Bay, 1992-93 [2]	10	<0.03	<0.03	6.00	0.03	<0.03	16.0
Yellowknife-Back Bay, 1992-93 [3]	72	1.07	0.20	7.33	0.05	<0.05	15.2
Slave River, 1996 [1]	14	0.75	0.15	12.25	0.06	<0.05	23.8
Slave River, 1990-94 [4]	36	0.41	<0.09	7.40	0.02	<0.13	15.4
Alexis Lake, 1991-94 [4]	22	<0.01	<0.03	4.65	0.03	<0.03	12.5
Little Buffalo R., 1971 [5]	1	-	0.20	16.00	-	-	29.0
Inconnu Liver							
Resolution Bay, 1996 [1]	5	-	-	-	-	-	-
Slave River, 1996 [1]	3	<0.05	0.05	26.76	0.17	<0.05	34.5
Paulette Island, 1971 [5]	3	-	0.10	29.60	-	-	33.0
Buffalo River, 1971 [5]	3-10	-	0.01	21.3	-	0.08	26.6

[1] Evans et al. (1998) [2] Lafontaine (1997) [3] Jackson et al. (1996)
[4] Sanderson et al. (1997) [5] Stein and Miller (1972)

3.4 Persistent organochlorine pollutants (POPs): non-pesticide compounds

POPs can be divided into two types of compounds - pesticides and non-pesticides. Some non-pesticides are used by industry for various purposes. Prominent among these are PCBs and chlorobenzenes (CBZs). POPs tend to be lipophilic and thus occur in higher concentrations in lipid-rich tissues such as the liver and in the muscle of fatty fish such as inconnu.

3.4.1 PCBs

PCBs or *p*olychlorinated *b*iphenyls were first introduced into commercial use in the late 1930s (Sittig 1985). They are mixture of compounds prepared by the chlorination of biphenyl (Figure 12). Biphenyl, in turn, is a compound consisting of two benzene (phenyl) rings connected by a single carbon-to-carbon bond. The name "polychlorinated" comes from the fact that PCBs contain at least one and generally several chlorine atoms attached along the biphenyl backbone. Theoretically, there are 209 possible compounds which can be formed during this process. However, only about 100 to 150 compounds (or congeners) have been detected in commercial PCBs and in the environment (Hoffman et al. 1995). For example, there are three monochloro-PCB compounds (with one chlorine atom), 12 dichloro-PCB congeners (with two chlorine atoms), 42 tetrachloro-PCB congeners (with four chlorines), 46 pentachloro-PCB compounds (with five chlorines), 42 hexachloro-PCB compounds (with six chlorines), but only 1 decachloro-PCB compounds (with ten chlorines) which are theoretically possible to be formed during the chlorination of biphenyl process. Some PCB commercial mixtures have also been shown to contain other classes of chlorinated derivatives such as chlorinated naphthalenes and chlorinated dibenzofurans (Sittig 1985).

In 1974 approximately 18 million kg of PCBs were manufactured in the U.S.; 65-70% were used in capacitors, 29-34% in transformers, and 1% for miscellaneous use (Simmons 1984). Worldwide production between 1930 and 1976 has been estimated at 1.3 billion pounds or 0.6 billion kg (Hoffman et al. 1995). It was not until the early 1970s that evidence began to emerge that, in high concentrations, exposure to PCBs

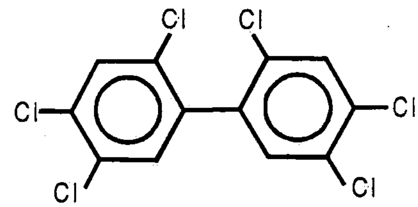


Figure 12. Structural formula of hexachlorobiphenyl, PCB 153.

could be harmful to man and the environment. It was not easy to demonstrate this before the early 1970s because there was no reliable way of measuring PCBs in the environment. PCB concentrations can be low in the environment i.e., one part per million (1 μg/g), and within this concentration may consist of more than 100 possible compounds. It took researchers a long time to develop gas chromatographic techniques to measure and identify these compounds. And, even before they could put the sample into the gas chromatograph, they had to develop methods of sample treatment to separate the compounds they wanted to measure from other compounds. As part of this, they had to remove other compounds that would interfere with or mask the detection of those compounds of interest. Even today, researchers continue to develop better and better methods for detecting lower and lower concentrations of more and more compounds that people are concerned about. Researchers can now detect some compounds at parts per trillion (one part in a million millions or 1 picogram/g or 1 pg/g).

During the early 1970s, researchers began to notice that organisms, including people, who consumed large amounts of PCBs, could become unhealthy. Research during the late 1960s and early 1970s showed that PCB biomagnified in food webs where it potentially could harm organisms. Thus, its manufacture and use was banned in many countries, including Canada, during the 1970s (Han and Adare 1997). However, recent studies have suggested that it may not be the PCBs causing health problems but polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzodioxins (PCDDs) associated with PBCs. For example, in the 1968 Yusho incident (Japan), people became very ill when eating rice oil contaminated with PCB fluids (Hoffman et al. 1995). Researchers first blamed PCBs but many people now think that it was PCDFs, occurring in trace amounts in the PCBs, that actually made people sick. Similarly, Gilbertson (1988) has argued that trace amounts of PCDFs in PCB fluids and PCDFs and PCDDs released by incinerators may have affected some of the diseases attributed to PCBs and DDT in Great Lakes birds, mammals, and fish.

PCB concentrations were relatively low in muscle (Figure 13; Appendix Table 3) averaging 5.3 ng/g in pike, 4.6 ng/g in walleye, and 2.9 ng/g in burbot. Highest concentrations were in inconnu muscle (11.5 ng/g), the fish which has the most lipid-rich muscle of the four species tested.

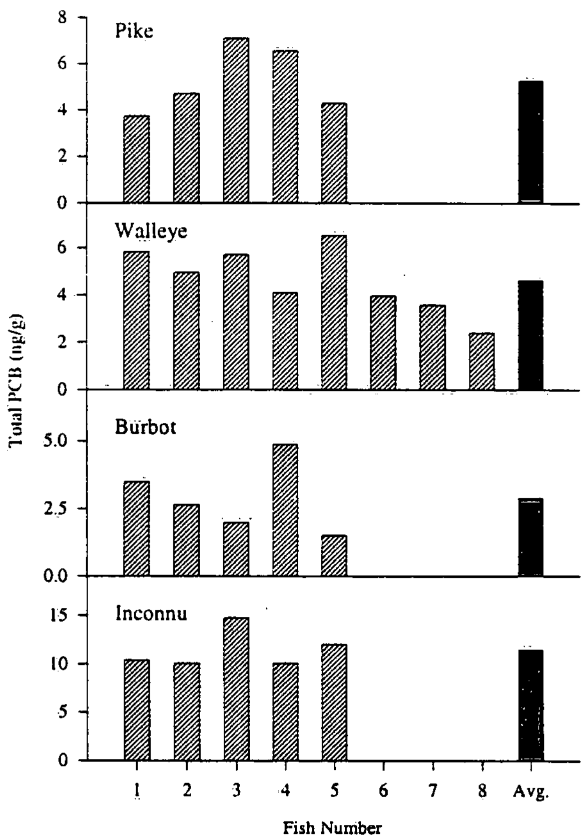


Figure 13. Total PCB concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

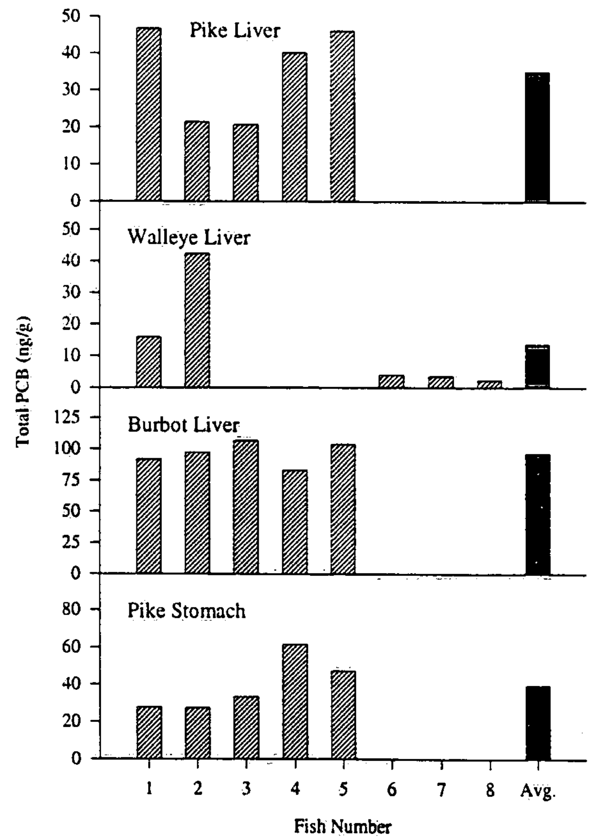


Figure 14. Total PCB concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996

PCB concentrations were substantially higher in liver (Figure 14), a lipid-rich organ. Concentrations averaged 35.1 ng/g in pike, 27.8 ng/g in walleye, and 96.4 ng/g in burbot. Pike stomach had similar mean PCB concentrations (39.4 ng/g) as pike liver.

In general, PCBs in both muscle and liver were dominated by penta- (5 chlorines) and hexa- (6 chlorines) PCB congeners (Appendix Table 4). Lower chlorinated PCBs are more readily metabolized and thus are less persistent in tissues than the more highly-chlorinated penta- and hexa-PCBs.

3.4.2 Chlorobenzenes

Chlorobenzenes (CBZs) are produced by the chlorination of benzene and may contain from one to six chlorine atoms (Figure 15). They are simpler compounds than PCBs. CBZs may be formed inadvertently in various chloride-carbon electrode processes such as those used in the manufacture of chlorine (Strachan and Edwards 1984). Certain dielectric fluids contain CBZs in addition to PCBs (Hoffman et al. 1995). CBZs have a wide variety of uses as outlined below.

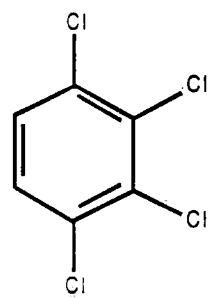


Figure 15. Structural formula of tetrachlorobenzene.

Monochlorobenzene is used in the manufacture of phenol, aniline, and pesticides. It also is a solvent for paints and a heat transfer medium (Sittig 1985; Budavari 1989).

Dichlorobenzenes contain two chlorine atoms and can have one of three different isomers (structural forms) (Sittig 1985). These compounds are used in the synthesis of dyestuffs, herbicides, and degreasers, and as air deodorants.

Trichlorobenzenes have three chlorine atoms. The primary compound used by manufacturers in any quantity is 1,2,4-trichlorobenzene (Sittig 1985) which is used as a dye carrier, a herbicides intermediate, a heat transfer medium, a dielectric fluid in transformers, a degreaser, a lubricant, and as a potential termite pesticide.

No information could be found on tetrachlorobenzenes. Pentachlorobenzenes, containing five chlorines, are used primarily as a flame retardant and as precursors to the fungicide pentachloronitrobenzene. Some compounds such as lindane (hexachlorocyclohexane) degrade into pentachlorobenzene.

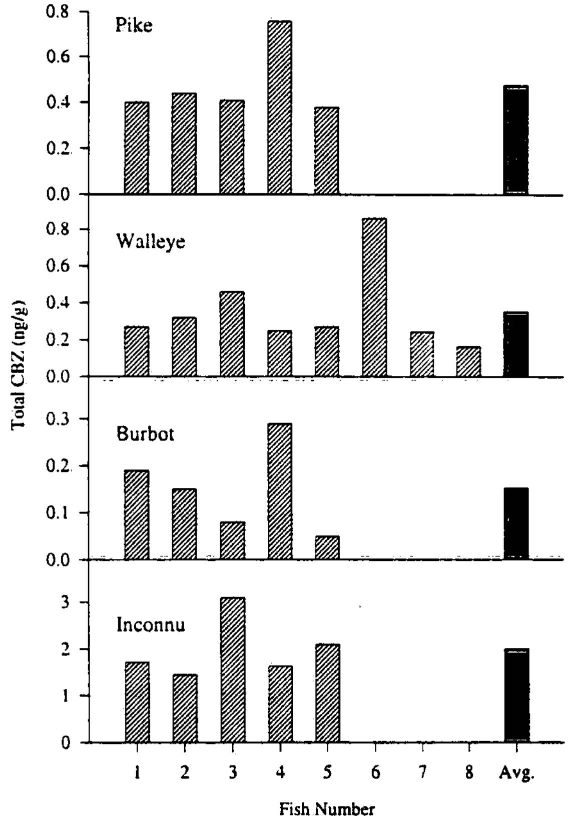


Figure 16. Total CBZ concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

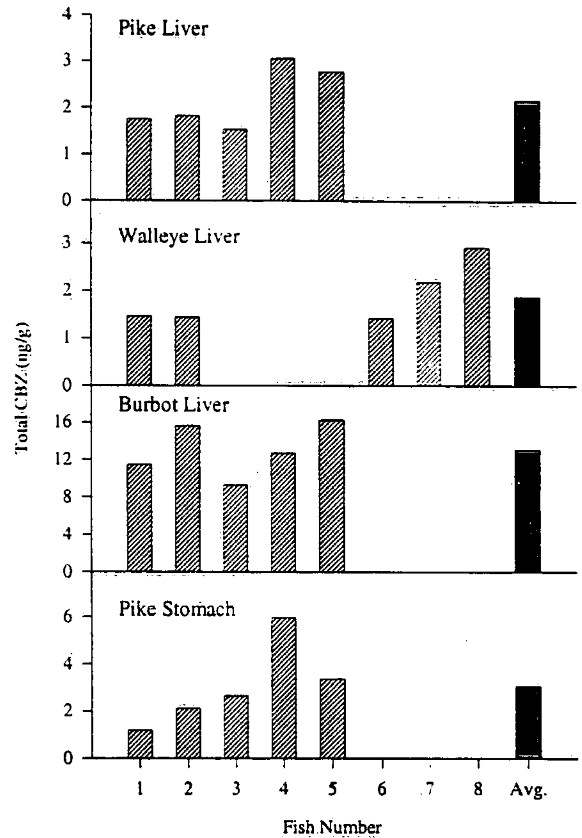


Figure 17. Total CBZ concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996

Hexachlorobenzene (HCBZ) has six chlorine atoms. HCBZ is used as a starting material for the production of the wood preservative pentachlorophenol (Sittig 1985). It is one of the main substances in the tarry residue which remains from the production of chlorinated hydrocarbons and also has been used a pesticide (Strachan and Edwards 1984). HCBZ is widespread in the environment and has been found in soil, wildlife, fish, and food (Sittig 1985). HCBZ readily evaporates from the soil and thus can be transported world-wide through air currents. It bioaccumulates and biomagnifies in the environment and at high concentrations can be toxic.

Total chlorobenzene concentration averaged 0.48 ng/g in pike muscle, 0.36 ng/g in walleye muscle, 0.15 ng/g in burbot muscle, and 2.0 ng/g in inconnu muscle (Figure 16; Appendix Table 5). Concentrations were substantially higher in the liver, averaging 2.20 ng/g in pike, 1.88 ng/g in walleye, and 13.06 ng/g in burbot (Figure 17). Pike stomach had an average CBZ concentration of 3.05 ng/g.

CBZs were dominated by penta- and hexa-CBZs (Appendix Table 5). Tetra-CBZs tended to be more prevalent in muscle than in liver. The analytical method was not set up to detect the lower chlorinated CBZs. These lower chlorinated CBZs, like the lower chlorinated PCBs, probably were readily excreted from tissues.

3.4.3 Octachlorostyrene

Octachlorostyrene or pentachloro(trichloroethenyl) benzene (Figure 18) apparently is not produced for any specific industrial application, i.e., it probably is produced as a byproduct during the synthesis of other compounds. Very little has been published about octachlorostyrene.

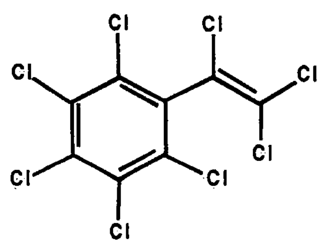


Figure 18. Structural formula of octachlorostyrene.

Octachlorostyrene concentrations averaged 0.09 ng/g in pike muscle, 0.04 ng/g in walleye and burbot muscle and 0.25 ng/g in inconnu muscle (Figure 19; Appendix Table 5). Concentrations were approximately ten times higher in liver averaging 0.82 ng/g in pike, 0.58 ng/g in walleye, and 2.79 ng/g in burbot (Figure 20). Pike stomach had an average concentration of 1.01 ng/g.

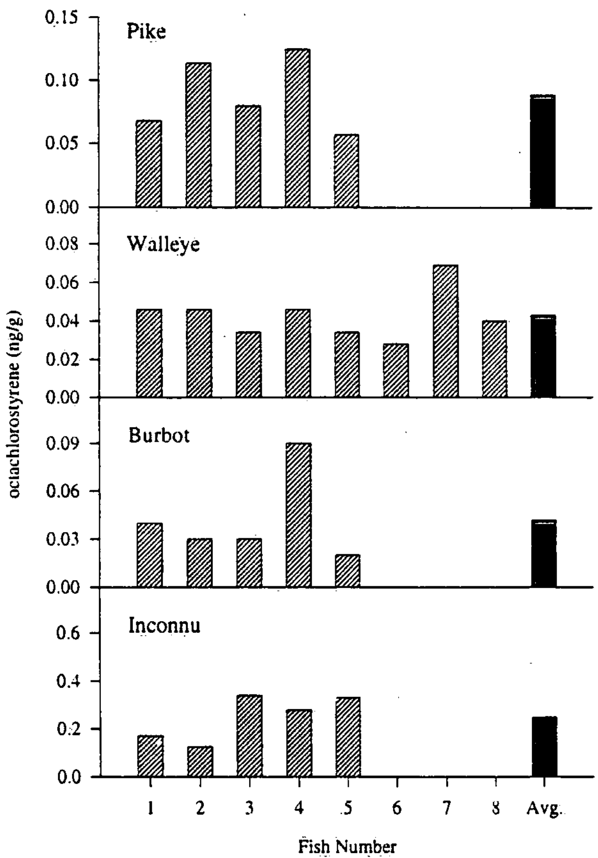


Figure 19. Octachlorostyrene concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

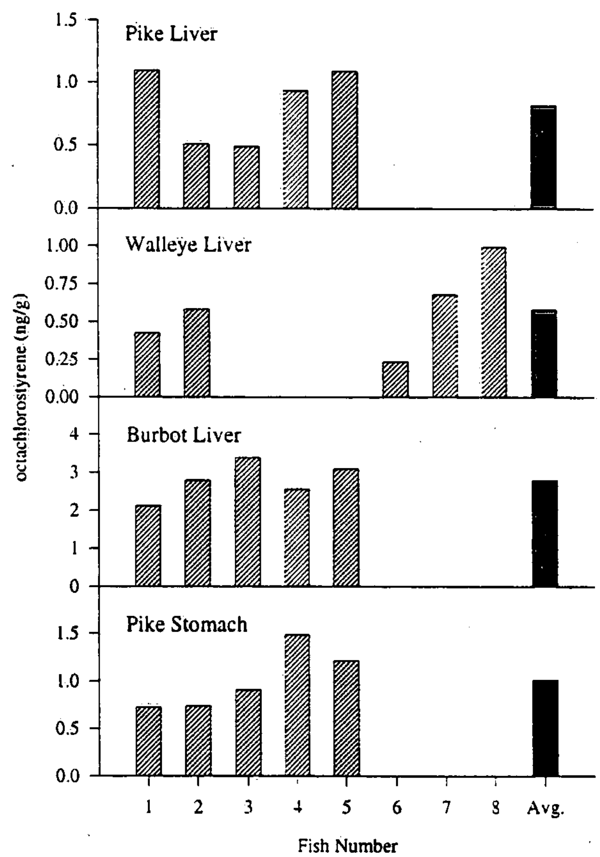


Figure 20. Octachlorostyrene concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996

3.5 Persistent organochlorine pollutants: pesticide compounds

There are a wide variety of POP pesticides which can be divided into groups based on their chemical structure. These include DDT and its analogues, toxaphene and related chemicals, hexachlorocyclohexane, dieldrin and other cyclodienes, and mirex (Hoffman et al. 1995).

3.5.1 Toxaphene

Toxaphene, like DDT, is a broad-spectrum pesticide (Figure 21). Toxaphene has been used as a fish poison to rid lakes of undesirable fish species (Rice and Evans 1984). When DDT usage was banned in the early 1970s, toxaphene replaced it as the major agricultural pesticide. It was the most heavily used pesticide in the U.S. in 1982 (Hoffman et al. 1995).

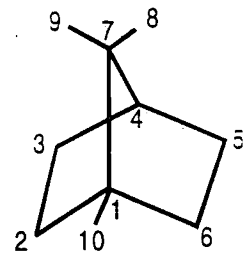


Figure 21. Structural formula of toxaphene (numbers denote possible Cl positions).

Toxaphene consists of a mixture of more than 177 polychlorinated diterpenes although 26 components account for 40% of the product: polychloroboranes and polychlorotricyclenes generally predominate (Hainzl et al. 1994; Zhu et al. 1994; Worthing 1987; Budavari 1989). Toxaphene also is known as chlorinated borane, camphechlor, polychlorocamphenes, and Strobane® (Rice and Evans 1984). It is a major organochlorine pesticide contaminant in fish and marine mammals in North America and Europe waters due to its extensive use, long term persistence and strong biomagnification properties (Stern et al. 1992). Toxaphene has been shown to have harmful effects on birds in high doses (Hoffman et al. 1995). Lakes where toxaphene has been used to kill fish may remain toxic to fish for several years after the initial application. Toxaphene, when used as a pesticide, has had adverse effects on birds and on fish, primarily at high exposure concentrations (Rice and Evans 1984; Hoffman et al. 1995). Toxaphene usage was banned in the U.S. in 1982 although existing stocks could continue to be used

(Hoffman et al. 1995). Toxaphene was never licensed for agricultural use in Canada (Han and Adare 1997), however, it continues to be used in developing countries.

Toxaphene concentrations in muscle (Figure 22; Appendix Table 6) averaged 23.2 ng/g in pike, 15.5 ng/g in walleye and 31.3 ng/g in inconnu; mean toxaphene concentration was only 2.9 ng/g in burbot muscle. Concentrations were substantially higher in liver (Figure 23) averaging 55.7 ng/g in pike, 41.5 ng/g in walleye, and 348.0 in burbot. Toxaphene concentrations were higher in pike stomach (106.6 ng/g) than liver.

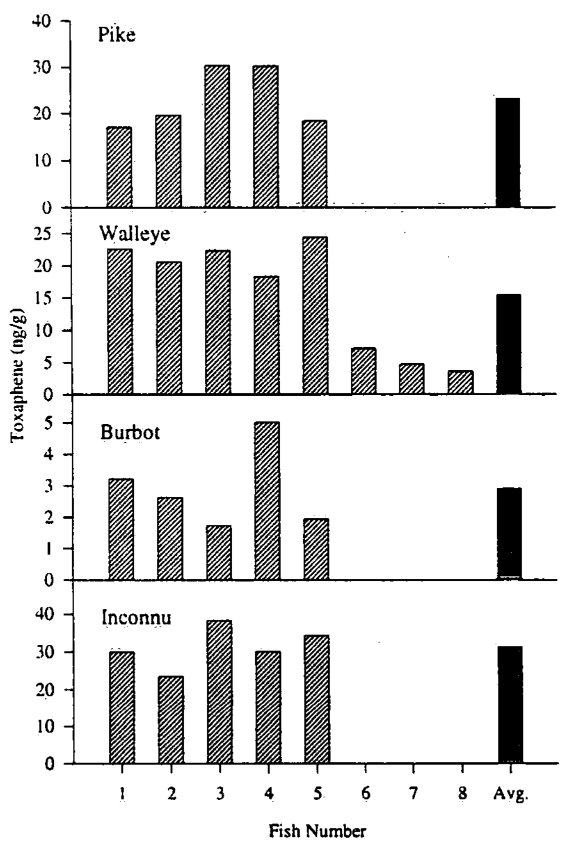


Figure 22. Toxaphene concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

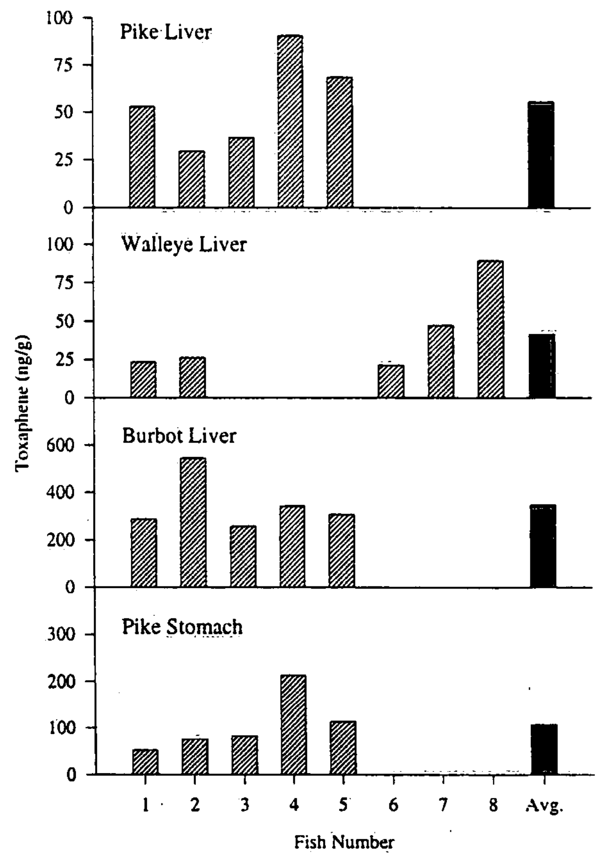


Figure 23. Toxaphene concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996

3.5.2 HCH

HCH or hexachlorocyclohexane, also known as benzene hexachloride (BHC), is a pesticide (Figure 24). Lindane (γ-HCH or gamma-HCH) is the active isomer among eight well-described stereoisomers (Budavari 1989). Gamma-HCH is used in mixtures with various fungicides, primarily as seed treatments (Worthing 1987).

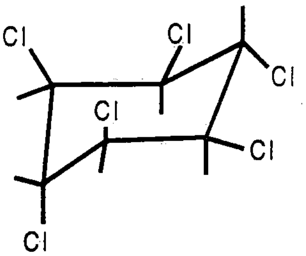


Figure 24. Structural formula of γ-hexachlorocyclohexane.

Several isomers of HCH impart unpleasant flavors to food, crops and poultry products; hence its use in the U.S for these applications was voluntarily canceled by the principal manufacturer in 1978 (Hoffman et al. 1995). After ingestion, lindane is rapidly metabolized to water-soluble chlorobenzenes and chlorophenols which are readily excreted. Lindane also is rapidly degraded in the environment after field application. Thus, it is not as persistent in the environment and does not biomagnify as strongly as pesticides such as DDT and toxaphene and compounds such as PCBs. However, at high concentrations, lindane can have adverse effects on birds. Consequently, while lindane is still widely used as a pesticide, it is not used to control insects in poultry-rearing facilities or where humans live.

Total HCH concentrations averaged 0.46 ng/g in pike muscle (Figure 25; Appendix Table 6), 0.21 ng/g in walleye muscle, 0.12 ng/g in burbot muscle, and 0.72 ng/g in inconnu muscle. In liver (Figure 26), concentrations averaged 0.97 ng/g in pike, 1.07 ng/g in walleye, and 7.07 ng/g in burbot. Pike stomach had average an HCH 1.28 ng/g.

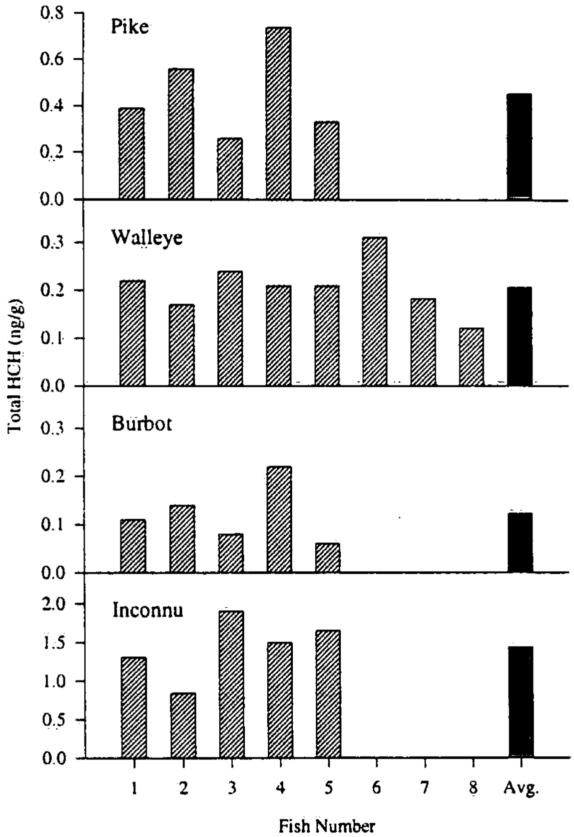


Figure 25. Total HCH concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

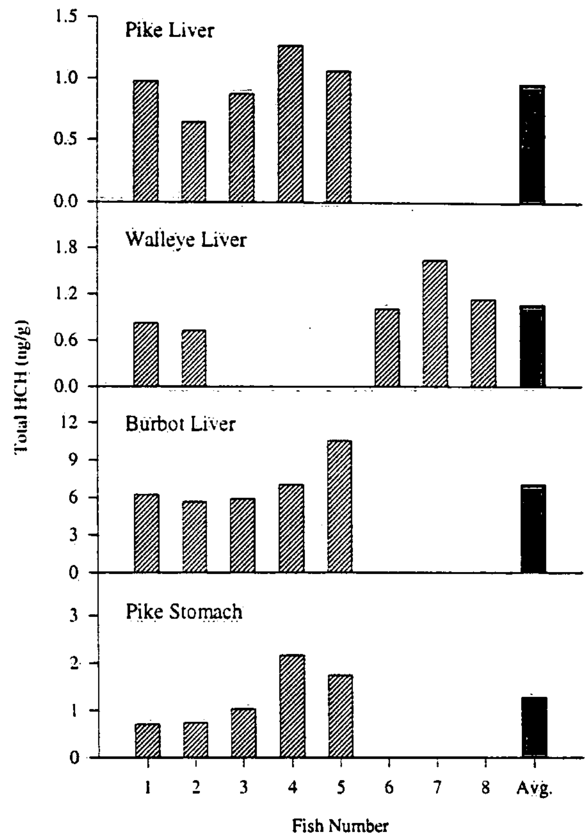


Figure 26. Total HCH concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996

3.5.3 Mirex

Mirex (Figure 27) is a pesticide but can also be used as a fire retardant for plastics, rubber, paint, paper, and electrical goods (Budavari 1989). In the southeastern United States, mirex was used as a replacement for dieldrin and heptachlor in attempts to control the imported fire ant. Mirex degrades in the environment to Kepone® (chlordecone) and related compounds, including photomirex. Mirex is only partially metabolized, is slowly eliminated, and bioaccumulates in lipid-rich tissues (Hoffman et al. 1995). In the Great Lakes region, mirex was accidentally released in the environment in relatively high concentrations from a production plant in the Niagara River and from an industrial accident at a plant on the Oswego River (Strachan and Edwards 1984). While mirex has been implicated in causing severe damage to fish and wildlife, the evidence supporting this has not been strong. Adverse effects in experimentally exposed birds have only been observed at very high concentrations. All uses of mirex in the U. S. were banned in 1978.

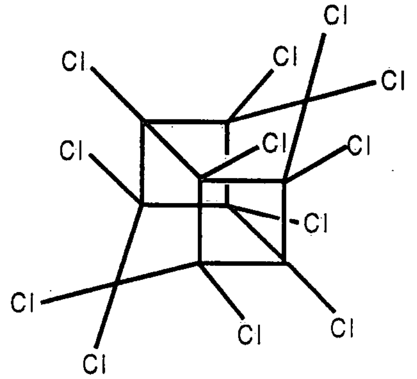


Figure 27. Structural formula of mirex.

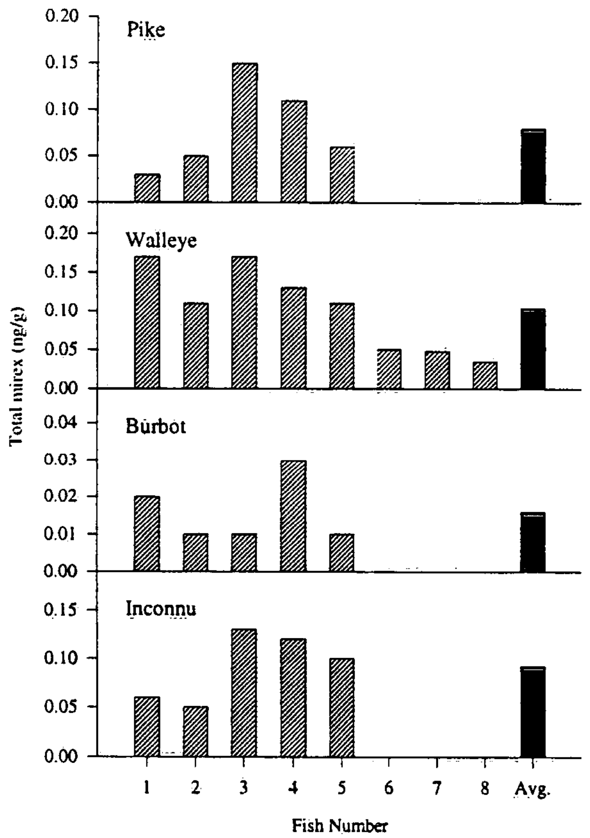


Figure 28. Total mirex concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

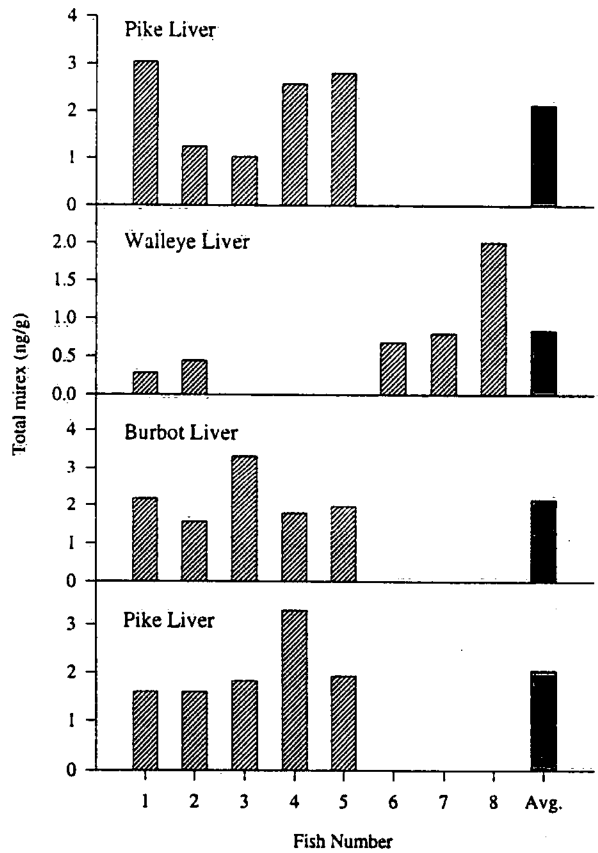


Figure 29. Total mirex concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996.

Mirex concentrations averaged 0.08 ng/g in pike muscle (Figure 28; Appendix Table 6), 0.10 ng/g in walleye muscle, 0.016 ng/g in burbot muscle, and 0.09 ng/g in inconnu muscle. Mirex concentrations were substantially higher in liver averaging 1.00 ng/g in pike (Figure 27), 0.63 ng/g in walleye, and 2.16 ng/g in burbot liver. Mirex concentrations averaged 1.06 ng/g in pike stomach. Photomirex was detected only in pike liver (1.13 ng/g), pike stomach (0.98 ng/g), and walleye liver (0.02 ng/g).

3.5.4 DDT and its analogues

3.5.4.1 DDT

DDT is a relatively-inexpensive, broad spectrum pesticide (Sittig 1985). It is produced by the condensation of chlorobenzene with trichloroacetaldehyde producing p,p'-DDT (*d*ichloro*d*iphenyl*t*richloroethane) as the main product (Figure 30). The technical product also contains o,p-DDT, although this compound generally accounts for less than 30% of the mixture (Worthing 1987). DDT was first described in 1874 but its value as an pesticide was not discovered until 1939 by P. Mueller working in Switzerland (Meister 1997). DDT began to be produced extensively in the United States in the mid 1940s for military use as a pesticide. It rapidly became a popular pesticide because

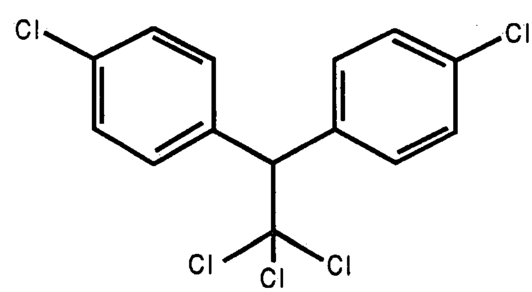


Figure 30. Structural formula of DDT.

of its very high toxicity to insects and because of its low toxicity to birds and mammals. In later years, several problems were identified with DDT including the fact that it was persistent in the environment, was strongly biomagnified, and was rapidly dispersed by air currents to remote regions of the world, including the arctic (Hoffman et al. 1995; Metcalf 1973). Many insect pests also were able to develop resistance to DDT. Its use was banned by the U. S. EPA in 1972 (Sittig 1985) although it continues to be used in other regions of the world. Its methoxy analog, methoxychlor, (Figure 31) is now used in areas where DDT usage has been banned.

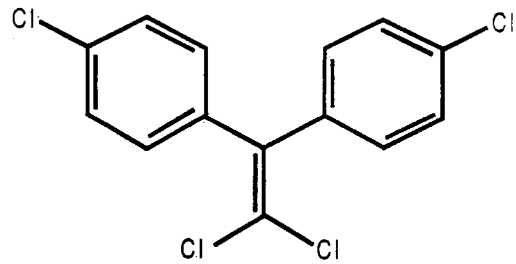


Figure 31. Structural formula of DDE.

DDT is degraded in the environment to DDE under oxygenated conditions and to DDD (Figure 32) under reducing conditions (Strachan and Edwards 1984). DDD, more properly known as TDE, also was manufactured for use as an pesticide (Hoffman et al. 1995). DDT and its metabolites have been dispersed throughout the world and are now found in air, water, and biota from the Arctic to the Antarctic.

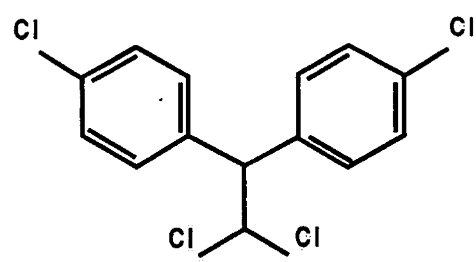


Figure 32. Structural formula of DDD.

Total DDT concentrations (Figure 33; Appendix Table 7) averaged 2.7 ng/g in pike muscle, 1.7 ng/g in walleye muscle, 0.8 ng/g in burbot muscle, and 4.4 ng/g in inconnu muscle. Concentrations were substantially higher in liver (Figure 34) averaging 8.1 ng/g in pike, 5.3 ng/g in walleye, and 27.7 ng/g in burbot. Total DDT concentrations were slightly higher in pike stomach (mean 12.9 ng/g) than in the liver.

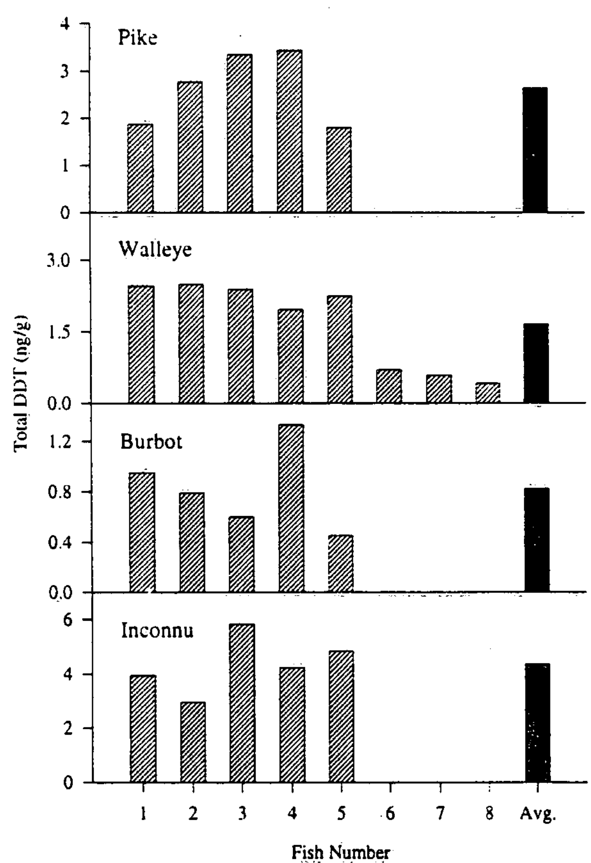


Figure 33. Total DDT concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996.

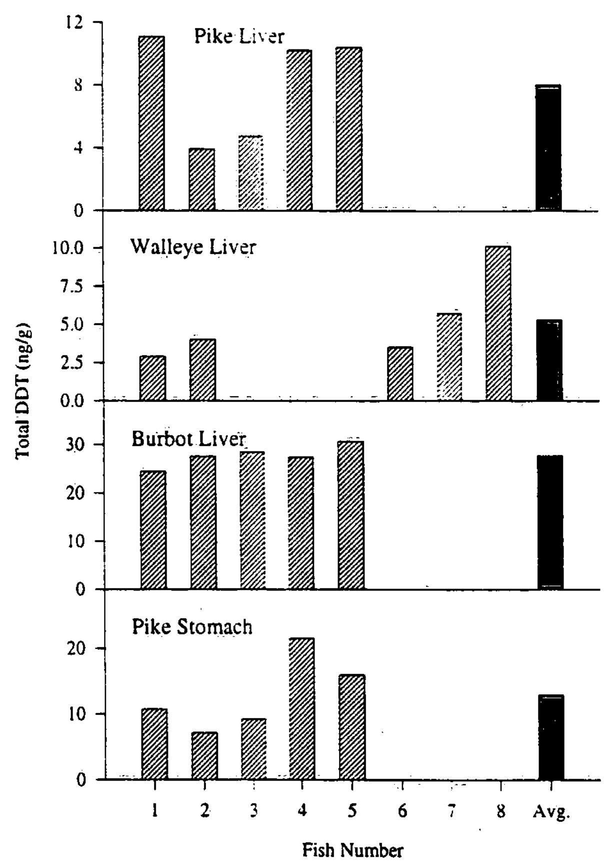


Figure 34. Total DDT concentrations (wet weight) in the liver of three fish species and pike stomach tissue collected from Resolution Bay, summer 1996.

3.5.4.2 Methoxychlor

Methoxychlor is a DDT analogue (Figure 35). It has largely replaced DDT in the control of Dutch Elm disease in American elms (Hoffman et al. 1995). It is rapidly broken down in the environment. Consequently it tends not to be detected in the tissues of birds in areas where it has been sprayed.

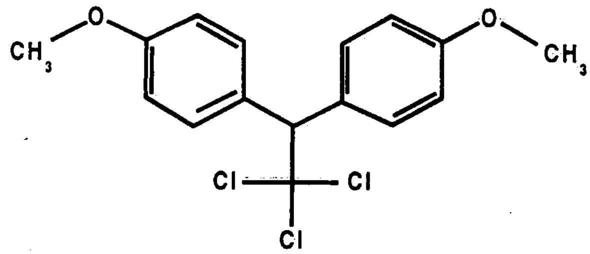


Figure 35. Structural formula of methoxychlor.

Methoxychlor was not detected in pike, burbot and inconnu muscle, but averaged 0.22 ng/g in walleye muscle (Figure 36; Appendix Table 7). Concentrations in the liver (Figure 37) averaged 0.20 ng/g in walleye and 0.31 ng/g in burbot. Methoxychlor was not detected in pike liver but averaged 0.11 ng/g in pike stomach

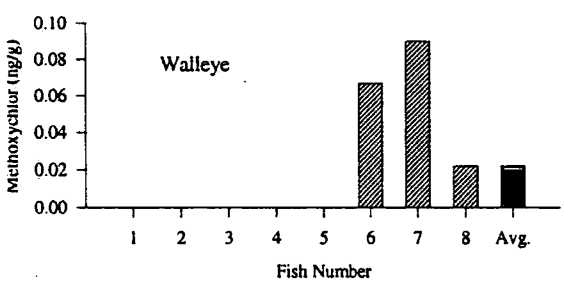


Figure 36. Methoxychlor concentrations (wet weight) in the muscle of walleye collected from Resolution Bay, summer 1996

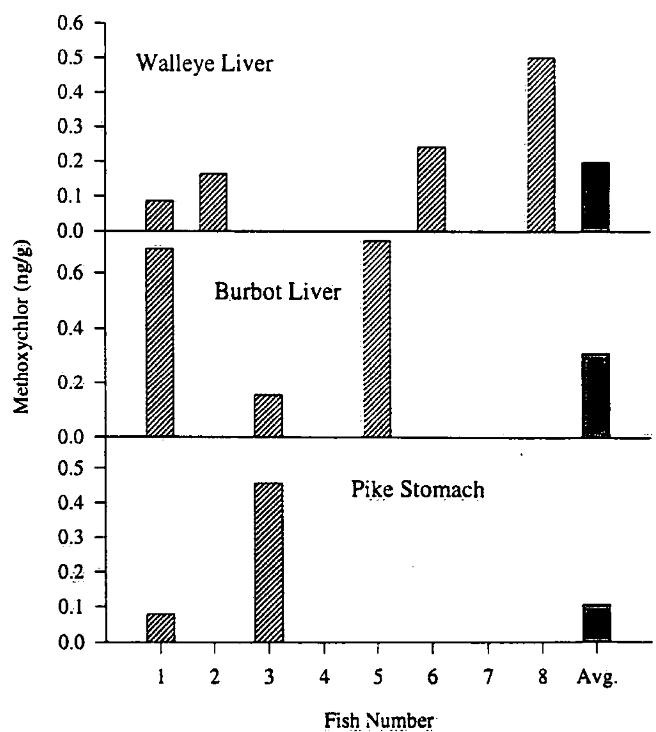


Figure 37. Methoxychlor concentrations (wet weight) in the liver of two fish species and in pike stomach tissue collected from Resolution Bay, summer 1996.

3.5.5 Cyclodiene insecticides

3.5.5.1 Total Chlordane

Total chlordane includes oxychlordane, trans-chlordane and cis-chlordane, trans-nonachlor and cis-nonachlor as well as heptachlor, heptachlor epoxide, and other related compounds (Appendix Tables 8). Chlordane is an insecticide (octachlorohexahydro-methanoidene) containing eight chlorine atoms (Figure 38). Nonachlor is a similar compound containing nine chlorine atoms (Figure 39). Both chlordane and nonachlor can occur in the cis and trans stereoisomers. Heptachlor (Figure 40) was isolated from chlordane and its insecticide properties were first reported in 1951 (Tomlin 1997). In animals, heptachlor is metabolized to heptachlor epoxide (Figure 41) which can be found in the muscle, feces, and urine, and to 1-exo-hydroxchlordene epoxide which is found in the urine (Tomlin 1997). Plants also metabolize heptachlor to heptachlor epoxide. In soil and water, heptachlor is degraded to 1-hydroxychlordene which is degraded to 1-hydroxy-2,3-epoxychlordene. Heptachlor has a half life of 9-10 months in soil when used at agricultural rates. The commercial chlordane product is a mixture containing 60-75% of the pure compound and 25-40% of related compounds (Budavari 1989; Dearth and Hites 1991).

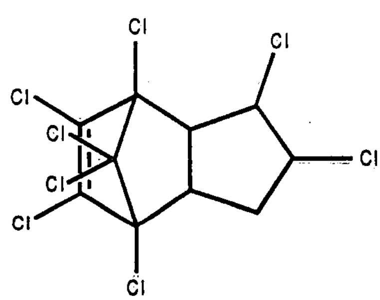


Figure 38. Structural formula of chlordane.

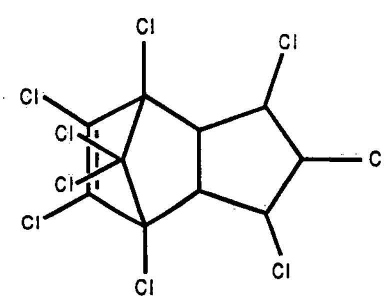


Figure 39. Structural formula of nonachlor.

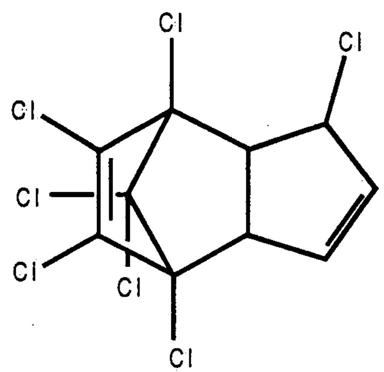


Figure 40. Structural formula of heptachlor.

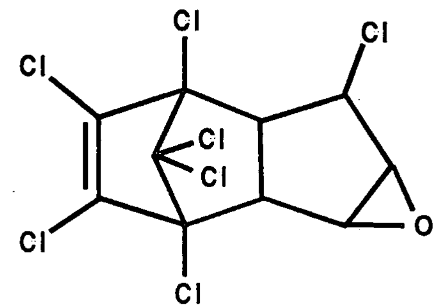


Figure 41. Structural formula of heptachlor epoxide

Chlordane has been used to control ants, cutworms, grasshoppers, termites, and other pests (Worthing 1987). It also has been used to control human and animal pests, as a wood preservative, a protective treatment of underground cables, and to reduce earthworm populations in lawns. In the mid 1970s, the U. S. EPA canceled registrations of this compound except for use in termite control (subsurface application) and for dipping the roots or tops of non-food plants (Budavari 1989).

Heptachlor has been used to control ants, termites, soil insects and household pests. Heptachlor is highly toxic to aquatic life, is persistent, and bioconcentrates in food webs; it exhibits carcinogenic activity in mice (Sittig 1985; Hoffman et al. 1995). In 1975, the U. S. EPA canceled the registrations for the use of insecticides containing heptachlor except for use in subsurface ground insertion for termite control and for the dipping of roots and tops of non-plant foods (Budavari 1989). It also is used in the U. S. to control fire ants in certain underground utility cable applications (Meister 1997).

Chlordane and its metabolites, including oxychlordane, are widespread and persistent in the environment: they tend to bioaccumulate in fatty tissues. Several studies have documented mortalities in birds as a result of high chlordane concentrations (Hoffman et al. 1995).

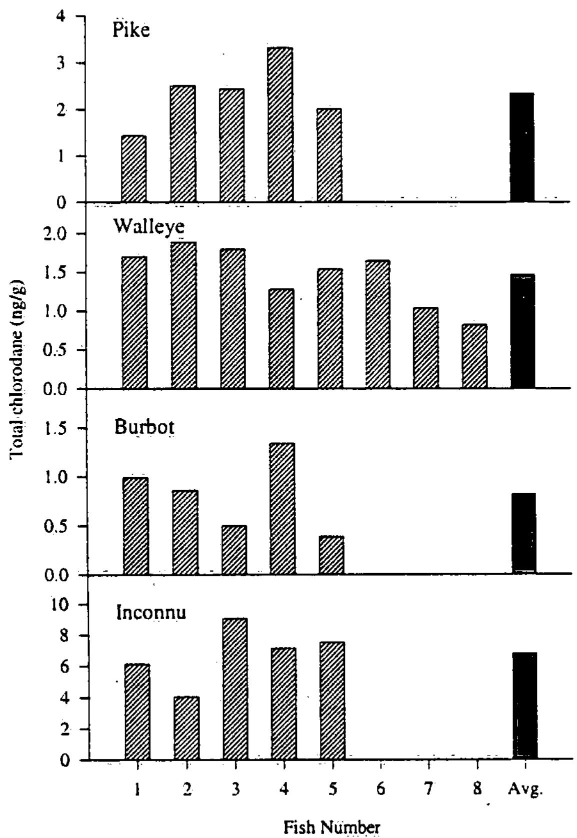


Figure 42. Total chlordane concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996

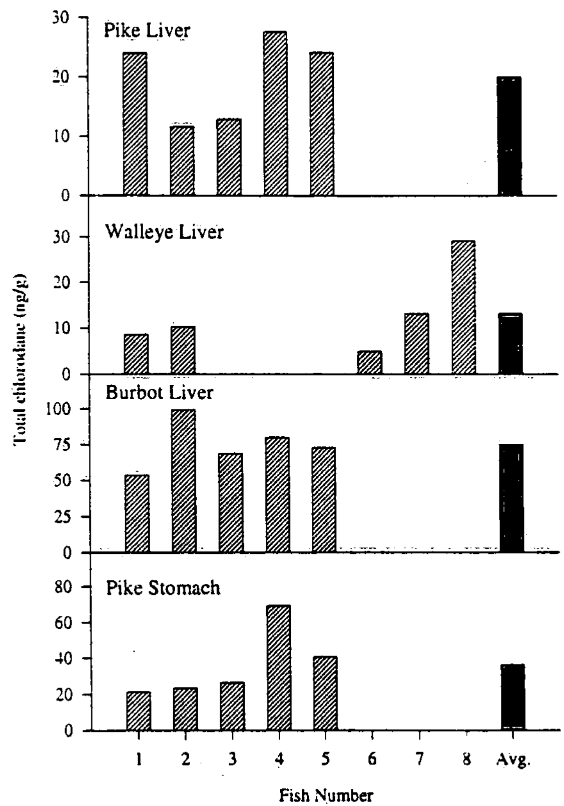


Figure 43. Total chlordane concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996.

Total chlordane concentrations in muscle averaged 2.25 in pike, 1.42 ng/g in walleye, 0.77 ng/g in burbot, and 6.54 ng/g in inconnu muscle (Figure 42). Concentrations in liver averaged 19.2 ng/g in pike, 12.6 ng/g in walleye, and 71.9 ng/g in burbot (Figure 43). Total chlordane concentrations averaged 39.3 ng/g in pike stomach. Trans-nonachlor and cis-nonachlor tended to be the most abundant compounds followed by oxychlordane. Cis-chlordane was more prevalent than trans-chlordane.

Heptachlor concentrations in fish muscle (Figure 44; Appendix Table 8) averaged 0.011 ng/g in pike and 0.017 ng/g in walleye: heptachlor was not detected in burbot and inconnu muscle. Heptachlor epoxide (Figure 49) occurred in an average concentration of 0.121 ng/g in pike muscle, 0.078 ng/g in walleye muscle, 0.044 ng/g in burbot muscle, and 0.463 ng/g in inconnu muscle.

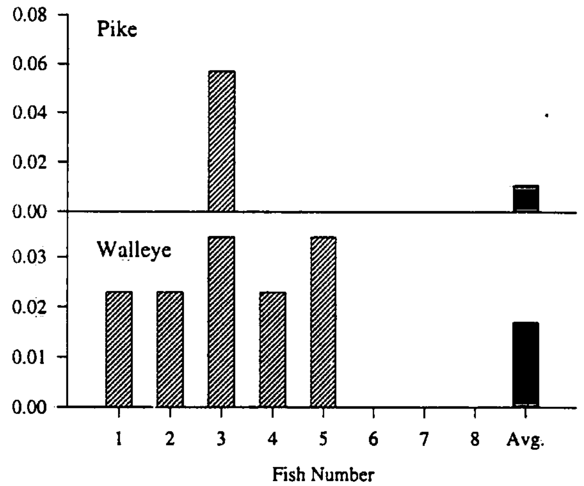


Figure 44. Heptachlor concentrations (wet weight) in the muscle of two fish species collected from Resolution Bay, summer 1996.

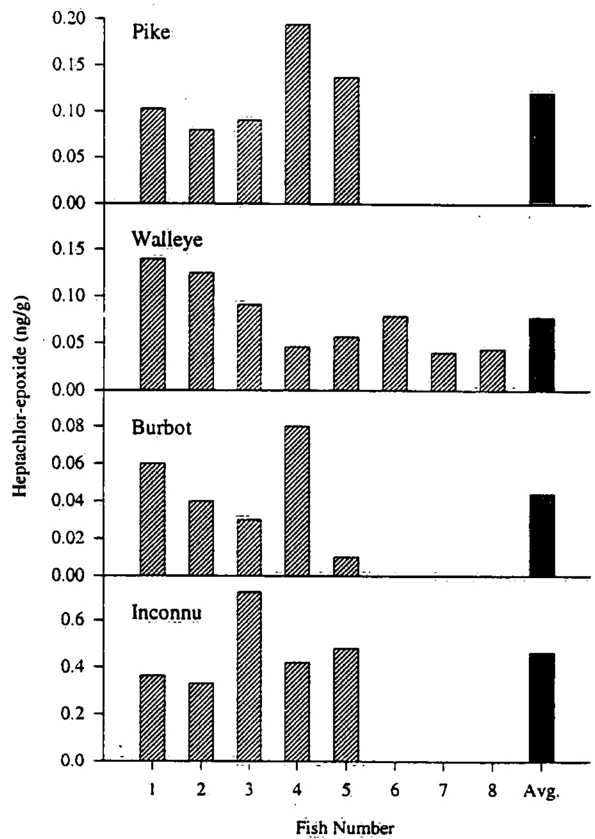
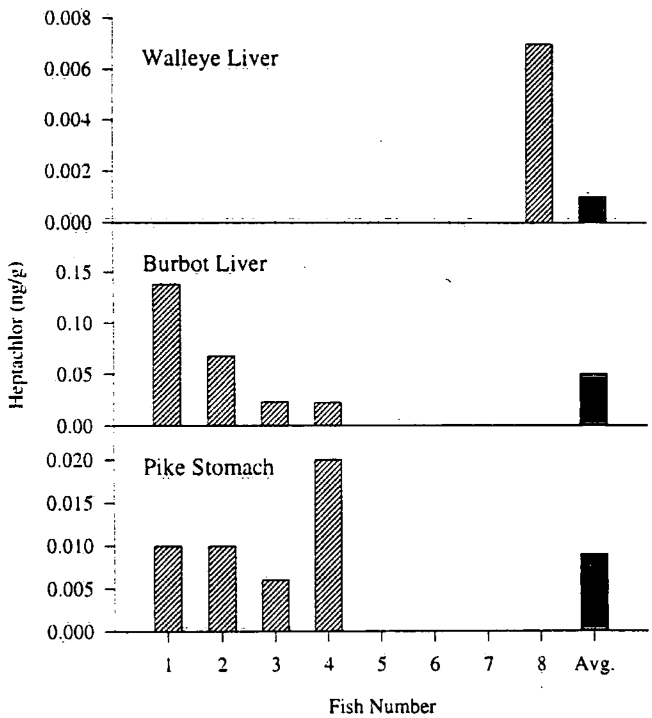


Figure 45. Heptachlor epoxide concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996

Heptachlor was not detected in pike liver but was detected in one of the five walleye liver analyzed (average concentration 0.001 ng/g) (Figure 46). It occurred in an average concentration of 0.050 ng/g in burbot liver. Hepatchlor epoxide occurred in an average concentration of 0.838 ng/g in pike, 1.042 ng/g in walleye liver, and 5.127 ng/g in burbot liver (Figure 47). In pike stomach, heptachlor was detected at an average concentration of 0.009 ng/g and heptachlor epoxide at an average concentration of 3.528 ng/g.



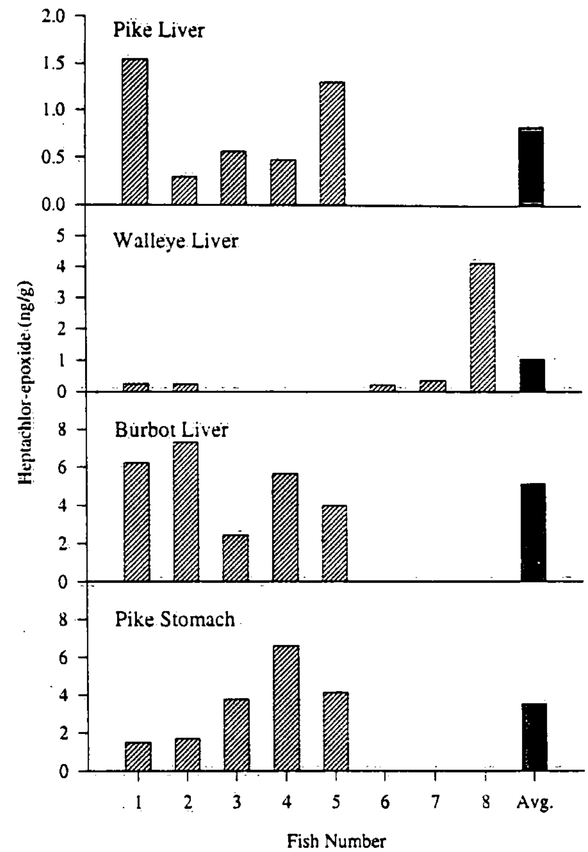


Figure 46. Heptachlor concentrations (wet weight) in the liver of two fish species and in pike stomach collected from Resolution Bay, summer 1996.

Figure 47. Heptachlor epoxide concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996.

3.5.5.2 Dieldrin

Dieldrin is a cyclodiene insecticide (Figure 48). Its primary use was in the control of corn pests although it also has been used as a timber preservative and in termite proofing (Sitting 1985; Worthing 1987). Dieldrin is a highly persistent and biomagnifies in the environment. At high concentrations, dieldrin has been implicated in adversely affecting birds and, in one study, bats (Hoffman et al. 1995). However, some of the noted adverse impacts on birds could have been associated with other POP contaminants in the environment, e.g., aldrin, heptachlor, and DDT and its metabolites. Aldrin, also a insecticide, rapidly breaks down into dieldrin (Figure 49). Dieldrin and aldrin usage was canceled in the U.S. in 1974 except for limited usages. Several others countries also banned these compounds in the 1970s.

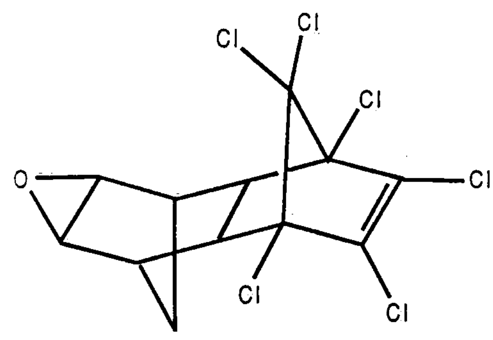


Figure 48. Structural formula of dieldrin.

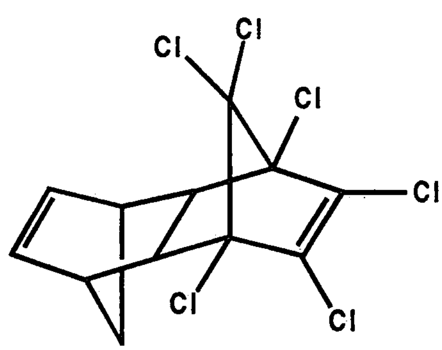


Figure 49. Structural formula of aldrin.

Dieldrin concentrations in muscle averaged 0.16 ng/g in pike (Figure 50; Appendix Table 9), 0.11 ng/g in walleye, 0.07 ng/g in burbot, and 0.87 ng/g in inconnu muscle. Concentrations were higher in the liver (Figure 51) averaging 1.43 ng/g in pike, 1.97 ng/g in walleye, and 7.63 ng/g in burbot. Pike stomach had an average dieldrin concentration of 7.79 ng/g.

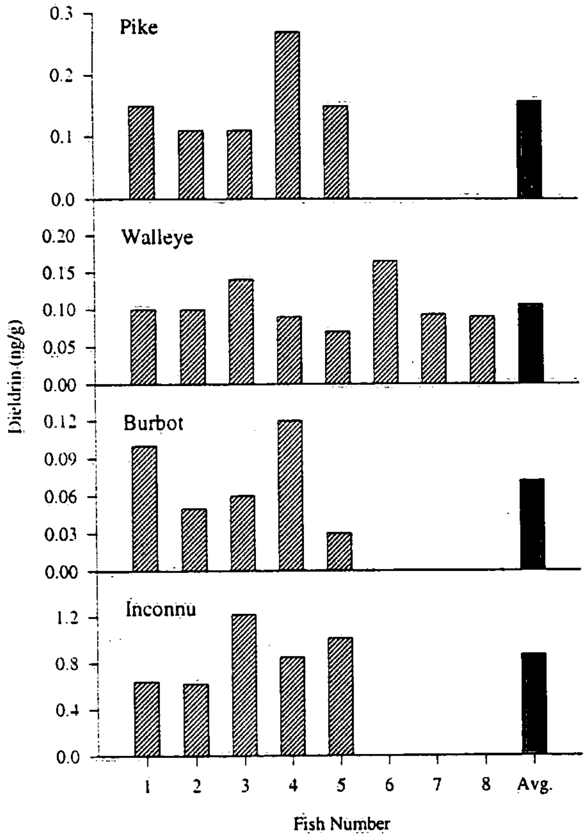


Figure 50. Dieldrin concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996

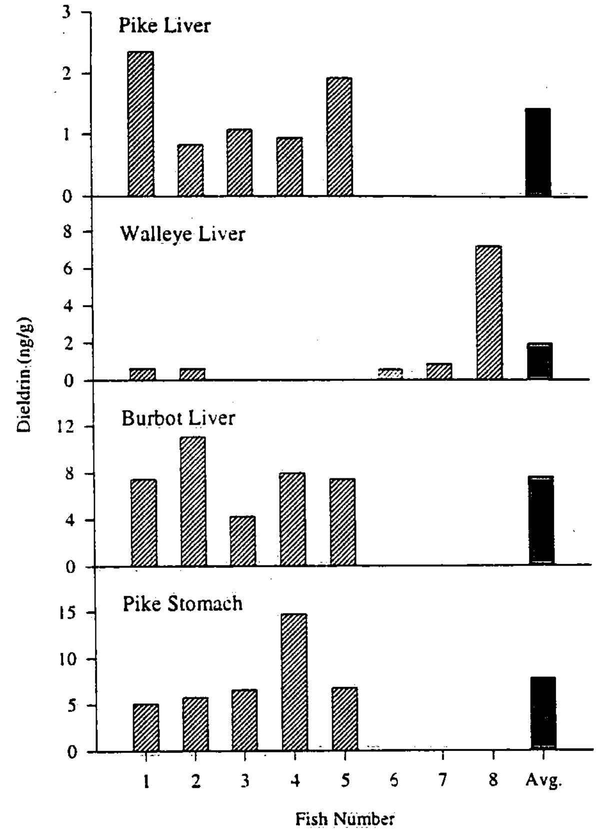


Figure 51. Dieldrin concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996.

3.5.5.3 Endrin

Endrin, like dieldrin, is a cyclodiene compound (Figure 52). It is an acutely toxic insecticide and is no-longer manufactured and used in the U. S. (Budavari 1989; Hoffman et al. 1995). In 1976, the U. S. EPA issued a notice against its registration based on its carcinogenic and tetragenetic properties and because of reductions in endangered and nontarget species (Sittig 1985).

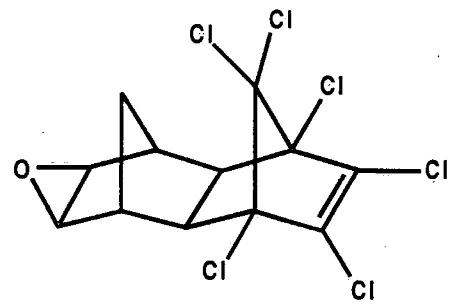


Figure 52. Structural formula of endrin.

Endrin was not detected in pike, burbot and inconnu muscle. It only was detected in the muscle of three of eight walleye analyzed (Figure 53; Appendix Table 9). Concentrations averaged 0.009 ng/g. Substantially higher concentrations were detected in pike liver (0.197 ng/g) (Figure 54), walleye liver (0.269 ng/g), and burbot liver (0.202 ng/g). Endrin also was detected in pike stomach (0.043 ng/g).

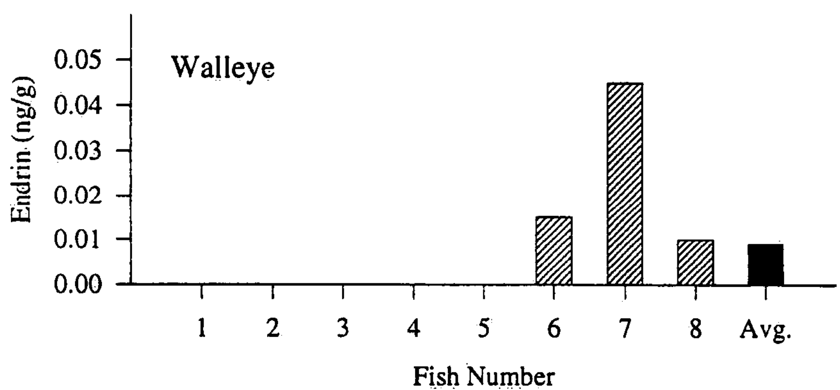


Figure 53. Endrin concentrations (wet weight) in the muscle of walleye collected from Resolution Bay, summer 1996.

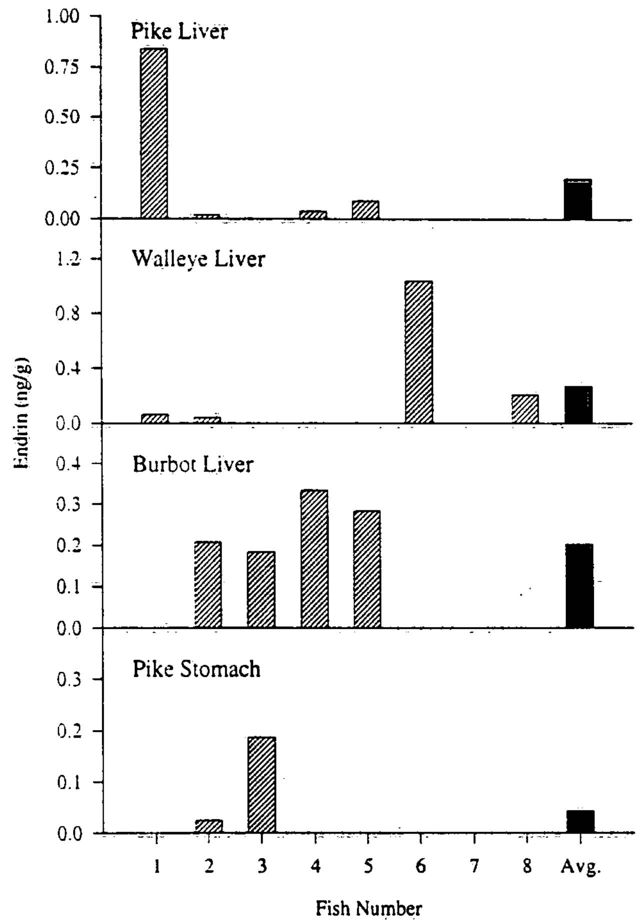


Figure 54. Endrin concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996.

3.5.5.4 Endosulfan

Endosulfan (Figure 55) consists of an alpha and beta stereoisomer. It is used to control insects and mites on a wide variety of crops including fruits, vines, vegetables, ornamentals, tobacco, sugar cane, cereals, maize, mushrooms, in forestry and greenhouse crops.

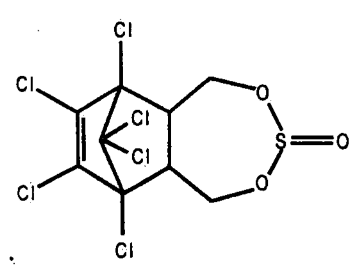


Figure 55. Structural formula of endosulfan

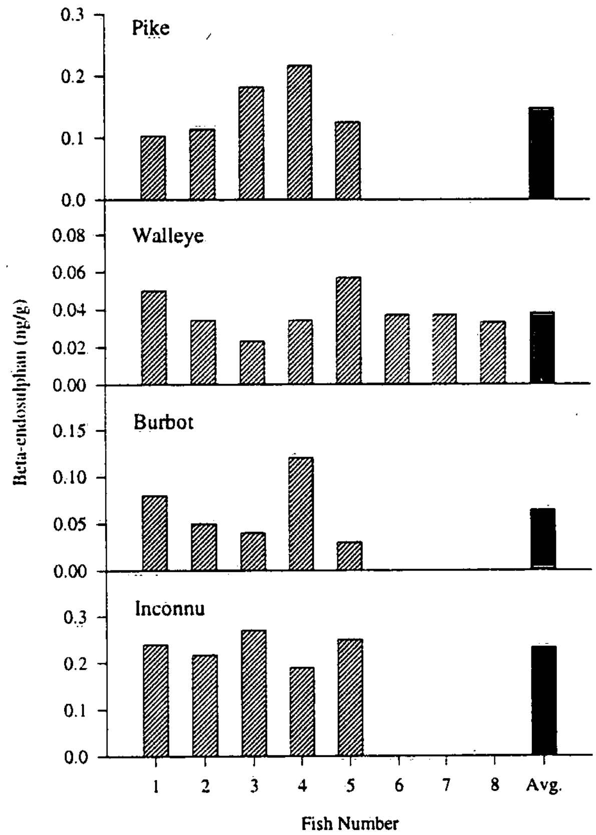


Figure 56. Endosulfan concentrations (wet weight) in the muscle of four fish species collected from Resolution Bay, summer 1996

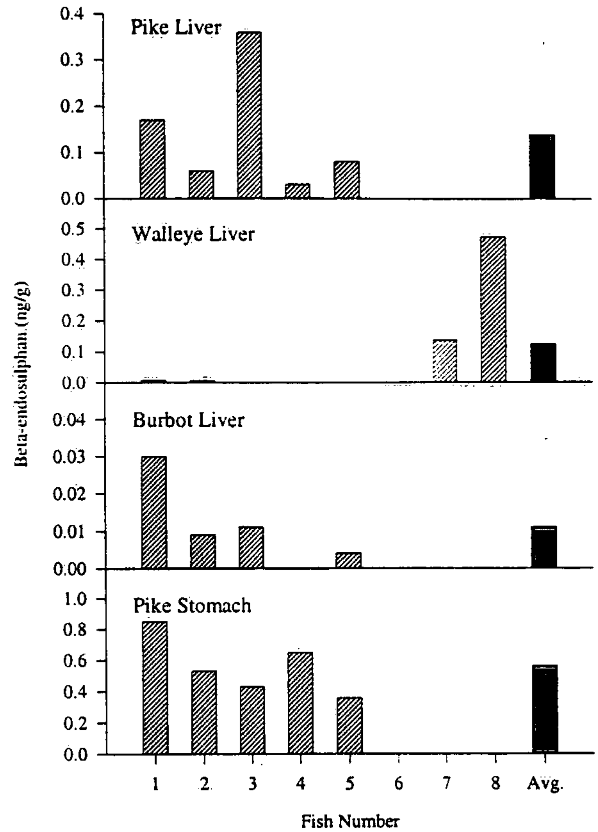


Figure 57. Endosulfan concentrations (wet weight) in the liver of three fish species and in pike stomach tissue collected from Resolution Bay, summer 1996.

Endosulfan concentrations averaged 0.148 ng/g in pike muscle (Figure 56; Appendix Table 9), 0.038 ng/ in walleye muscle, 0.064 ng/g in burbot muscle, and 0.233 ng/g in inconnu muscle. Concentrations were somewhat higher in liver (Figure 57) averaging 0.140 ng/g in pike, 0.124 ng/g in walleye, and 0.011 ng/g in burbot. Pike stomach had an average endosulfan concentration of 0.564 ng/g.

3.6 Comparisons with other related studies

Although a relatively small number (n = 5-8 for each species) of fish were analyzed for POPs in this study, results can be compared with other, related studies including those conducted under the Northern Contaminants Program (NCP). The largest data sets are for the recently released Slave River study (Sanderson et al. 1998). During this study, which was conducted over 1990-1994, fish were collected from the Slave River itself and from one or two (depending on the fish species) reference lakes. The Slave River study differs from the work reported here in two major aspects:

1. For most species, whole fish rather than muscle were analyzed for POPs in the Slave River study. The notable exception was burbot where the liver also was examined for POPs.
2. Detection limits employed for the Slave River study were substantially higher than in this study. As a consequence, most POPs were below detection limits with the notable exception of toxaphene, PCB, and p,p-DDE which generally (but not always) were above detection limits.

Contaminant concentrations are compared for fish collected during the summer 1996 Resolution Bay study, the Slave River study and other studies. Statistical analyses, comparing fish on the basis of age, length, and gender, are not included in these comparisons given the small sample size of fish analyzed in the 1996 Resolution Bay study.

3.6.1 Pike

Entire pike were analyzed in Slave River study (Sanderson 1998), including pike from Leland Lake, a reference lake (Table 5). Toxaphene and PCB were the predominant POPs followed by p,p-DDE in both studies. As previously noted, with the exception of these three compounds, all others POPs analyzed were at or below detection limits in the Slave River study. POPs concentrations appeared similar in fish from the Slave River and from Leland Lake, suggesting that contaminant levels were not elevated in fish inhabiting the Slave River. While mean PCB and p,p-DDE concentrations were slightly higher in Slave River than Leland Lake pike, the sample size is probably too small to merit statistical analyses.

Whole pike analyzed from the Slave River and from Leland Lake had substantially higher PCB and p,p-DDE concentrations and somewhat higher toxaphene concentrations than pike muscle from Resolution Bay (Table 5). Differences in contaminant concentration between the Slave River study and our study are believed to be due to the difference in contaminant concentration in the entire fish versus the muscle alone. This in turn suggests that total daily intake estimates (TDI), based on whole body analyses, overestimate POPs intake when only muscle is consumed.

Other researchers investigating POPs in pike have focused on muscle. For example, three pike (muscle) were examined from Waskesiu Lake (Prince Albert National Park, Saskatchewan) as part of a pilot study (Evans unpublished data). Muscle had a mean lipid concentration of 5.2%, a mean PCB concentration of 3.45 ng/g, a mean toxaphene concentration of 16.1 ng/g, and a mean DDT concentration of 3.63 ng/g. These concentrations are similar to those observed in pike muscle from Resolution Bay.

Total DDT concentrations were slightly higher in Waskesiu Lake pike muscle (mean = 3.63 ng/g) than Resolution Bay muscle (mean = 2.66 ng/g). These differences probably are not statistically significant given the small sample size. Nevertheless, because there is some evidence of localized use of DDT in the Park, these differences, if real, may have explanation in the form of a local contaminant source (Evans unpublished data).

Jensen et al. (1997) reported than two pike (muscle) from northern Quebec had a mean lipid content of 0.6%, PCB concentrations of <15 ng/g, and HCH, chlordane, and DDT concentrations of <5 ng/g. Thus, pike from Resolution Bay had POP concentrations (muscle) which was similar to concentrations observed in the pike inhabiting the relatively pristine waters of Waskesiu Lake, Prince Albert National Park, and northern Quebec.

In contrast, five pike analyzed from Lac Laberge, had mean a mean concentration of 90 ng/g PCB in their muscle and concentrations of 247 ng/g DDT, 14 ng/g chlordane and 48 ng/g toxaphene (Jensen et at 1997). Substantially lower concentrations of these POPs were observed in nearby reference lakes: <0.1-1.1 ng/g PCB, <0.1-2.5 ng/g DDT, <0.1-0.5 ng/g chlordane, and <0.1-1.2 ng/g toxaphene.

Table 5. Comparison of mean POP concentration (ng/g wet weight) in pike from Resolution Bay, the Slave River and Leland Lake.

	Resolution Bay		Slave River.	Leland Lake	Waskesiu Lake
	Muscle [1]	Liver [1]	Whole fish [2]	Whole fish [2]	Muscle [3]
Years sampled	1996	1996	1993, 1994	1993, 1994	1995
Sample size	5	5	10	4	3
% lipid	2.20	5.63	2.31	1.71	5.15
Hexachlorobenzene	0.20	1.76	<2	<2	0.23
Pentachlorobenzene	0.14	0.16	<2	-	0.08
Octachlorostyrene	0.09	0.82	<2	<2	0.06
PCBs	5.29	35.1	32.6	27.4	3.45
Toxaphene	23.2	55.7	<31*	<31*	16.11
alpha-HCH	0.34	0.61	<2	<2	0.47
beta- HCH	0.03	0.06	<2	<2	0.04
gamma-HCH	0.09	0.25	<2	<2	0.13
delta-HCH	-	-	<2	<2	-
Mirex	0.08	1.00	<2	<2	0.12
Photomirex	-	1.13	<2	<2	0.00
p,p'-DDE	0.81	5.21	<6*	<4*	1.38
o,p'-DDE	0.43	-	-	-	0.35
p,p'-DDD	0.24	0.83	<2	<2	0.49
o,p'-DDD	0.32	0.33	-	-	0.43
o,p'-DDT	0.39	0.56	<2	<2	0.36
p,p'-DDT	0.47	1.16	<2	<2	0.62
Methoxychlor	-	-	<2	<2	0.00
cis-Chlordane	0.31	2.09	<2	<2	0.20
trans-Chlordane	0.06	0.19	<2	<2	0.04
Heptachlor	<0.01	-	<2	<2	0.01
Heptachlor epoxide	0.12	0.84	<2	<2	0.13
Dieldrin	0.16	1.43	<2	<2	0.22
Endrin	-	-	<2	<2	0.00
beta-Endosulfan	0.15	0.14	<2	<2	0.15

[1] this report
[2] Sanderson et al. 1998
[3] Evans unpublished data
< value was below detection limit
* average value based on one or more values below detection limit

POP concentrations were higher in pike liver than pike muscle in the Resolution Bay summer 1996 collections (Table 5). PCB, hexachlorobenzene, octachlorostyrene, mirex, photomirex, cis-chlordane, heptachlor epoxide, and dieldrin occurred in particularly greater concentrations in liver than in muscle.

3.6.2 Walleye

Only whole walleye were analyzed in Sanderson's Slave River study (1998) including those from Leland Lake (Table 6). Most compounds were close to or below detection limits with toxaphene, PCB, and p,p-DDE primary POP contaminants detected. PCB, toxaphene, and p,p-DDE concentrations appeared similar in whole walleye collected from the Slave River and Leland Lake collections. While mean PCB and toxaphene concentrations were slightly higher in Slave River than Leland Lake pike, further analyses would be required of the data to assess whether these differences were statistically significant.

PCB, toxaphene, and pp-DDE concentrations were substantially lower in the muscle of the walleye analyzed from the summer 1996 Resolution Bay study than the whole body determinations of walleye collected from the Slave River and Leland Lake. Again, this may suggest that total daily intake estimates (TDI), based on whole body analyses, overestimates POPs intake when only muscle is consumed.

Walleye from Hay River have a reported mean (3 fish) concentrations of 0.4 ng/g toxaphene, 1.4 ng/g PCB, 0.61 ng/g DDT, 0.65 ng/g chlordane, and 0.16 ng/g HCH in their muscle (Muir and Lockhart 1996). Thus, toxaphene concentrations in walleye muscle from Hay River was substantially lower than concentrations in walleye collected from Resolution Bay; other contaminants occurred in somewhat lower concentrations in walleye from Hay River than Resolution Bay.

Table 6. Comparison of mean POP concentrations (ng/g wet weight) in walleye from Resolution Bay, the Slave River, Leland Lake and Waskesiu Lake.

	Resolution Bay		Slave River	Leland Lake	Waskesiu Lake
	Muscle [1]	Liver [1]	Whole fish [2]	Whole fish [2]	Muscle [3]
Years sampled	1996	1996	1990-1994	1990-1994	1995
Sample size	5	5	50	31	3
% lipid	3.5	7.2	6.5	4.6	5.7
Hexachlorobenzene	0.20	1.60	2	<2	0.35
Pentachlorobenzene	<0.09	0.14	<2	-	0.07
Octachlorostyrene	0.04	0.58	<2	<2	0.02
PCBs	4.64	27.84	57	43	9.27
Toxaphene	15.46	41.53	<37*	<29*	33.72
alpha-HCH	0.14	0.68	3	<2	0.37
beta- HCH	<0.01	0.10	<2	<2	<0.01
gamma-HCH	0.06	0.28	<2	<2	0.17
delta-HCH	-	-	<2	<2	-
Mirex	0.10	0.63	<2	<2	0.18
Photomirex	-	0.22	<2	<2	-
p,p'-DDE	0.33	3.11	5	5	1.19
o,p'-DDE	<0.22	-	-	-	0.59
p,p'-DDD	0.33	0.47	<2	<2	0.17
o,p'-DDD	0.17	0.33	-	-	0.51
o,p'-DDT	0.34	0.76	<2	<2	0.26
p,p'-DDT	0.27	0.58	<2	<3	0.84
Methoxychlor	<0.02	0.20	<2	<2	0.02
cis-Chlordane	0.27	1.88	<3	<2	0.30
trans-Chlordane	0.04	0.29	<2	<2	0.05
Hepatchlor	<0.02	<0.001	<2	<2	0.01
Heptachlor epoxide	0.08	1.04	<2	<2	0.24
Dieldrin	0.11	1.97	2	<3	0.39
Endrin	<0.01	0.27	<3	<3	0.02
beta-Endosulfan	0.04	0.12	<2	<2	0.08

[1] this report
[2] Sanderson et al. 1998
[3] Evans unpublished data
< value was below detection limit
* average value based on one or more values below detection limit

Three walleye from Waskesiu Lake examined for POP concentrations (Evans, unpublished data) had concentrations similar to those observed in the five fish from Resolution Bay, i.e., PCB concentrations in muscle averaged 9.27 ng/g, toxaphene 33.71 ng/g, DDT 4.77 ng/g, and chlordane 1.13 ng/g. Total DDT concentrations were slightly higher in Waskesiu Lake walleye muscle than Resolution Bay muscle (mean = 1.66 ng/g). Again, these differences probably are not statistically significant given the small sample size for both the Waskesiu Lake and Resolution Bay collections. Nevertheless, because there is some evidence of localized use of DDT in the Park, differences in the slightly higher concentrations of DDT in Waskesiu Lake than Resolution Bay fish may be real. A larger sample size from both locations is required to test this hypothesis.

Hexachlorobenzene, octachlorostyrene, PCB, p,p-DDE, cis-chlordane, heptachlor epoxide, dieldrin, and endrin concentrations were substantially higher in walleye liver than muscle from fish from Resolution Bay. A similar phenomenon was observed for pike from Resolution Bay.

3.6.3 Burbot

POP concentrations in burbot were determined for liver tissue in the Slave River study (Sanderson 1998). PCB and toxaphene were the predominant POPs followed by p,p-DDE (Table 7). Concentrations tended to be higher in burbot liver collected from the Slave River than from Alexie Lake. Additional analyses would be required to assess whether these apparent differences were statistically significant.

Toxaphene concentrations in burbot liver from Resolution Bay were slightly lower than concentrations observed in the Slave River but higher than in Alexie Lake (Table 7). Earlier, Evans (1995) reported that mean toxaphene concentrations were 244 ng/g and 762 ng/g respectively for burbot liver from Resolution Bay and the East Arm of Great Slave Lake. Muir and Lockhart (1996) reported that burbot liver from Alexie Lake had an average toxaphene concentration of 40.5 ng/g while Trout Lake concentrations averaged 93.2 ng/g. Overall, there is some evidence that toxaphene concentrations are higher in burbot liver from the Slave River-Great Slave Lake ecosystem than for fish collected in Trout and Alexie lakes, reference lakes in the Mackenzie River Basin.

Table 7. Comparison of mean POP concentration (ng/g wet weight) in burbot from Resolution Bay, the Slave River, Alexie Lake and Waskesiu Lake.

	Resolution Bay [1]		Slave River [2]	Alexie Lake [2]	Waskesiu Lake [3]
	Muscle	Liver	Liver	Liver	Muscle
Years sampled	1996	1996	1990-1994	1990-11994	1995
Sample size	5	5	50	27	3
% lipid	0.98	43.3	29.9	24.1	32.7
Hexachlorobenzene	0.10	11.2	26	8	0.24
Pentachlorobenzene	0.03	0.92	-	-	0.05
Octachlorostyrene	0.04	2.79	9	<2	0.02
PCBs	2.91	96.43	237	114	3.10
Toxaphene	2.91	348.0	464	53	3.27
alpha-HCH	0.10	4.65	9	9	0.08
beta-HCH	-	0.26	<2	<2	-
gamma-HCH	0.02	2.16	2	2	0.07
delta-HCH	-	-	<2	<2	-
Mirex	0.02	2.16	9	<3	0.02
Photomirex	-	-	18	<2	0.02
p,p'-DDE	0.18	16.14	49	24	0.18
o,p'-DDE	0.13	-	-	-	0.03
p,p'-DDD	0.10	2.14	7	2	0.06
o,p'-DDD	0.12	<0.01	-	-	0.02
o,p'-DDT	0.02	2.55	8	<2	0.08
p,p'-DDT	0.19	6.82	<11*	<3	0.18
Methoxychlor	-	0.31	<2	<2	0.02
cis-Chlordane	0.10	5.38	6	4	0.10
trans-Chlordane	0.06	0.46	<2	<2	0.02
Heptachlor	-	0.05	<2	<2	0.02
Heptachlor epoxide	0.04	5.13	<5	<7	0.07
Dieldrin	0.07	7.63	12	4	0.14
Endrin	-	<0.20	<2	<2	0.02
beta-Endosulfan	0.06	0.01	<2	<2	0.02

1 this report
2 Sanderson et al. 1998
3 Evans unpublished data
< value was below detection limit
* average value based on one or more values below detection limit

In contrast, PCB concentrations in burbot liver collected in Resolution Bay were lower than in fish collected from the Slave River and similar to values observed in Alexie Lake fish (Table 7). Earlier, Evans (1995) reported that burbot liver from the Resolution Bay area had a mean PCB concentration of 74.5 ng/g versus 138 ng/g in burbot liver from the East Arm of Great Slave Lake. Muir and Lockhart (1996) reported that burbot liver from Alexie Lake had an average PCB concentration of 26.9 ng/g while from Trout Lake concentrations averaged 51.6 ng/g. Overall, these limited data may suggest that PCB concentrations are higher in burbot liver from the Slave River-Great Slave Lake ecosystem than for fish collected in Trout and Alexie lakes. The reasons for these observations are not known.

PCB and toxaphene concentrations in burbot liver from Great Slave Lake were lower than burbot liver from Lac Laberge (1,267 ng/g and 2,301 ng/g respectively) and Atlin Lake (136 ng/g and 1,533 ng/g respectively) in the Yukon Territory (Jensen et al. 1997). The reasons for the elevated PCB and toxaphene concentrations in burbot from these two Yukon lakes is not fully understood but may involve a combination of trophic biomagnification (Kidd et al. 1995) and localized influences. PCB and toxaphene concentrations were not elevated in Fox Lake, also in the Yukon (Jensen et al. 1997).

Toxaphene concentrations were substantially lower in burbot muscle than in the liver of fish collected from Resolution Bay in summer 1996 (Table 7). Overall, PCB, toxaphene, and total DDT concentrations were similar to concentrations observed in fish from Waskesiu Lake, Prince Albert National Park. Of the four species examined in the Resolution Bay study, burbot had the lowest POP concentrations in muscle.

3.6.4 Inconnu

Relatively few studies have investigated organic contaminant concentrations in inconnu. Although inconnu were not investigated in the Slave River study (Sanderson et al. 1998), POP concentrations were determined in whole lake whitefish (Table 8). Whitefish and inconnu belong to the taxonomic subfamily Coregonidae and so comparisons of POP concentrations in the two species is of some interest. But these comparisons are confounded for several reasons. First, the Resolution Bay study analyzed inconnu muscle while whole whitefish were analyzed in the Slave

Table 8. Comparison of mean POP concentrations (ng/g wet weight) in inconnu and whitefish from Resolution Bay, Slave River and Waskesiu Lake.

	Resolution Bay		Slave River	Waskesiu Lake
	Inconnu Muscle[1]	Whitefish Muscle[1]	Whitefish Whole Fish[2]	Whitefish 3[3]
Years sampled	1996	1995	1993-1994	1995
Sample size	5	3	10	3
% lipid	20.5	18.8	6.2	3.9
Hexachlorobenzene	1.43	0.46	<2	0.10
Pentachlorobenzene	0.30	0.09	2	0.06
Octachlorostyrene	0.25	0.03	<2	0.02
PCBs	11.47	5.84	36	3.13
Toxaphene	31.27	17.53	<34*	7.23
alpha-HCH	0.09	0.48	<2	0.13
beta- HCH	-	-	<2	0.00
gamma-HCH	0.32	0.02	<2	0.10
delta-HCH	-	-	<2	0.00
Mirex	0.09	0.03	<2	0.07
Photomirex	-	-	<2	0.00
p,p'-DDE	1.11	1.27	3	1.22
o,p'-DDE	0.45	0.12	-	0.08
p,p'-DDD	0.42	0.20	<2	0.40
o,p'-DDD	0.46	0.31	-	0.10
o,p'-DDT	0.56	0.40	<2	0.25
p,p'-DDT	1.36	0.52	<2	0.11
Methoxychlor	-	-	<2	-
cis-Chlordane	1.88	.024	<2	0.03
trans-Chlordane	0.35	0.05	<2	0.05
Heptachlor	-	0.01	<2	0.01
Heptachlor epoxide	0.46	0.13	3	0.06
Endrin	-	-	2	0.02
Dieldrin	0.87	0.45	2	0.10
beta-Endosulfan	0.23	0.12	<2	0.09

1 this report
2 Sanderson et al. 1998
3 Evans unpublished data
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River study. Second, comparisons are confounded by differences in feeding behavior between the two species, i.e., whitefish feed primarily upon bottom invertebrates while inconnu are predatory fish (Scott and Crossman 1973). Inconnu, therefore, would be expected to contain higher concentrations of POPs which biomagnify in the food web than whitefish. Finally, most POPs were below detection limits in the Slave River study. With these limitations in mind, it can be stated that PCB and toxaphene were the predominant POPs in Resolution Bay inconnu muscle and Slave River whole whitefish. Furthermore, there were similar concentrations of toxaphene but slightly lower PCB concentrations in inconnu muscle from Resolution Bay than whole whitefish from the Slave River.

Whitefish also have been collected from Resolution Bay as part of larger POP investigations in Great Slave Lake. Evans (1995) reported that PCB concentrations (in muscle) averaged 4.2 ng/g and toxaphene 23.5 ng/g for whitefish collected in 1993 from Resolution Bay and 5.6 ng/g PCB and 33.1 ng/g toxaphene for fish collected from the East Arm. An additional three fish were collected from Resolution Bay in 1995; these fish had mean PCB concentrations of 5.8 ng/g and toxaphene concentrations of 17.5 ng/g (Table 8).

Overall, whitefish muscle tended to contain lower concentrations of POPs than inconnu muscle. Since the lipid content of whitefish and inconnu muscle were similar, the higher levels of POPs in inconnu muscle over whitefish muscle may be associated with the predatory feeding habits of inconnu versus the benthic feeding habits of whitefish. PCB concentrations in whitefish muscle from Resolution Bay were lower than concentrations in whole fish from the Slave River (Table 8). This again suggests that consumption guidelines based on whole fish POP determinations may overestimate contaminant intake when only the muscle is consumed.

POPs concentrations were determined in three whitefish from Waskesiu Lake (Table 8). PCB and total DDT concentrations tended to be lower while toxaphene concentrations were higher in Waskesiu Lake than in Resolution Bay. These differences are unlikely to be statistically significant, given the very small sample size in both studies. Muir and Lockhart (1994) reported mean PCB concentrations of 4.4 ng/g for whitefish from Colville Lake and 7.94 ng/g for fish from Gordon Lake: toxaphene concentrations were 11.0 ng/g and 13.9 ng/g, respectively. PCB and toxaphene concentrations averaged 6.9 ng/g and <11.7 ng/g for Watson Lake in the Yukon but 61 ng/g and 33.8 ng/g in Lake Laberge (Jensen et al. 1997).

4.0 CONCLUDING REMARKS

Data presented here complement other recent studies of inorganic and organic contaminants in Great Slave Lake, the Slave River, and reference lakes (Swyripa et al. 1993; Jackson et al. 1996; Lafontaine 1997; Sanderson et al. 1998; Evans et al. 1998). This study was initiated in part to address concerns related to the potential contamination of fish in the Resolution Bay area with metals by the decommissioned Pine Point mine. It also was designed to obtain more information on the concentrations of POPs in fish commonly harvested from Resolution Bay.

As discussed in Evans et al. (1998), there was no evidence that the decommissioned Pine Point mine had or is significantly contaminating fish from the Resolution Bay area with heavy metals. We conclude from that study and this study that metal concentrations in fish are at levels observed in fish collected in other regions of the Great Slave Lake ecosystem including Yellowknife-Back Bay, the Slave River, and reference lakes. Mercury concentrations in the muscle of some large pike and burbot in the Evans et al. (1998) study and pike and walleye in this study approached the 0.2 µg/g established by Health and Welfare Canada for frequent fish consumption. The reasons why mercury concentrations were at these levels was not determined in this study but appear to be due to a widely-occurring phenomenon occurring in the lakes in the Mackenzie River Basin (Jensen et al. 1997).

POP concentrations in fish sampled during this study were comparable to concentrations observed in fish collected during the more extensive Slave River study. Toxaphene and PCBs were the predominant POP compounds. Concentrations were low in all fish tissues with the exception of burbot liver. There was some evidence that burbot from the Slave River and Great Slave Lake have higher concentrations of toxaphene (and possibly PCBs) than fish collected from reference lakes. The reasons for these apparent differences remain unknown. Presumably, they are associated with some aspect of the Slave River drainage system, including the fact that it drains an extensive area in the Peace and Athabasca River watersheds. Future study, involving the use of stable isotopes to infer trophic feeding (as in Kidd et al. 1995) would help elucidate some aspects of this issue. Future studies also should contain sufficient replication to allow for statistical comparisons between study sites. Ideally, should the Slave River study continue at some point in the future, analytical methods should include lower detection limits for the POPs commonly encountered in the Resolution Bay summer 1996 study. Because many fish and extracts from the Slave River study are archived (M. Whittle, personal communication, Fisheries and Oceans, Burlington), it also would be possible to reanalyze some of the fish analyzed in the original study.

Finally, most POPs occurred in higher in whole fish analyses (walleye, pike, whitefish) than in muscle tissue analyses. This suggests that TDI estimated on whole fish determinations may overestimate PCB intake if muscle is the primary tissue consumed.

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APPENDIX A

Analytical methods for determining metal concentrations in fish tissue (J. Delaronde).

All of the methods detailed here have the following commonalties. The acids used for the analyses were concentrated and of trace metal analysis grade. The water was both distilled and deionized. Throughout the entire procedure set commercial standards of atomic absorption, reagent blanks and standard materials were used. 25 x 200 ml Pyrex test tubes were used for sample digestion. Before their use in sample digestion the test tubes were washed with nitric acid (10%) and rinsed with deionized and distilled water. Digestion was carried out in a programmable aluminum block test tube heater.

Mercury (Hot block digestion - cold vapor atomic absorption method) (Hendzel and Jamieson 1976)

A small (0.2 g) amount of wet tissue was digested with 5 ml of a 4:1 mixture of sulfuric: nitric acids for 12 hours at 180° C. After cooling the solution was then diluted with water to 25 ml. A reducing agent of stannous chloride was added to the solution which liberated the mercury in its elemental form. This mercury was captured and carried by a flow of air for atomic absorption detection by a LDC model 3200 Mercury Monitor.

Arsenic (Borohydride reduction method) (Vijan and Wood 1974)

A solution consisting of 4 ml nitric acid, 0.5 ml sulfuric acid and 1 ml perchloric acid was used to digest a small (0.8 g muscle, 0.4 g liver) amount of wet tissue. The tissue was digested for 5 hours at 130° C and then 2 hours at 200° C. 15 ml water and 7.5 ml hydrochloric acid were added to the solution and it was warmed to 90° C for 1 hour then cooled and diluted to 25 ml with water. A solution of 2% sodium bromide and 10% potassium iodide were automatically added to the digested material which produced arsine gas. The gas was carried by a nitrogen stream to an 800° C electric quartz tube furnace placed inside the burner cavity of a Varian SpectrAA-20 atomic absorption spectrophotometer. Selenium hydride was released with the addition of the 2% sodium borohydride solution and detected as previously described.

Copper and Zinc

A solution consisting of 4 ml nitric acid, 0.5 ml sulfuric acid and 1 ml perchloric acid was used to digest a small (5.0 g muscle, 2.0 g liver/kidney) amount of wet tissue. The tissue was digested for 5 hours at 130° C and then 2 hours at 200° C. The cooled sample was diluted to 25 ml with water and then analyzed by air-acetylene flame atomic absorption (Varian SpectrAA-20) with deuterium background correction.

Cadmium Nickel and Lead

Tissue samples were digested in the same manner as copper and zinc except the sulfuric acid constituent was reduced to 0.2 ml. A Hitachi model Z8200 Zeeman background corrected graphite furnace atomic absorption spectrophotometry unit was then used to analyze the samples.

Blanks

A series of reagent blanks were treated and analyzed along side each group of samples. The following formula was used to calculate the results for the blanks:

Blank (µg/g) = [Blank (µg/L) x 0.025 L] / (method sample weight) g

Analytical methods for determining POC concentrations in fish tissue.

Chemical analysis:

Fish were frozen whole upon collection and later partially thawed to remove liver or dorsal muscle tissue. Weights and lengths of the fish were measured, and the otoliths were removed for aging purposes.

Liver:

Samples were partially thawed and 2 g combined with anhydrous Na_2SO_4 (heated at 600 °C for 16 hours prior to use). The mixture was then extracted twice with hexane in a small (50 ml) ball mill, centrifuging and decanting the hexane between extractions. Surrogate recovery standards of PCB 30 and octachloronaphthalene (OCN) were added prior to extraction. Extractable lipids were determined gravimetrically on a fraction (1/10) of the extract. A portion of the extract equivalent to approximately 100 mg lipid was separated into three fractions of increasing polarity on Florisil (8 g; 1.2 % v/w water deactivated). The first fraction was eluted with hexane and contained PCBs, DDE, *trans*-nonachlor, and mirex; the second fraction was eluted with hexane:DCM (85:15) and contained HCHs, most chlorinated bornanes (toxaphene) and chlordanes. Some chlorobornanes, most notably T2 (Parlar no. 26), were partially eluted with hexane. The third fraction, containing dieldrin and heptachlor epoxide, was eluted with a 1:1 mixture of hexane:DCM. Each fraction, after addition of aldrin as a volume corrector, was analyzed for OCs by capillary gas chromatogaraphy (GC) with ^{63}Ni electron capture detection (ECD) by means of an automated Varian 3400 GC (Varian Instruments, Palo Alto, CA). Samples were injected on a 60m x 0.25 mm i.d. DB-5 column (film thickness = 0.25 um). H_2 was used as the carrier gas (1 mL/min) and N_2 as the make-up gas (40 mL/min). A total of 103 PCB congeners (including co-eluting congeners) and 40 OC pesticides were quantified by using external standard mixtures (Ultra Scientific, North Kingstown, RI).

Muscle:

Samples were ground with dry ice and after CO_2 sublimation, 10 to 25 g was Soxhlet extracted using a 1:1 mixture of hexane and dichloromethane (DCM). All lipids were removed from the muscle samples using gel permeation chromatography (GPC) on SX-3 Biobeads with DCM;Hexane (1:1) as the eluant. Surrogate recovery standards of PCB 30 and octachloronaphthalene (OCN) were added prior to extraction. As described above, the chlorinated hydrocarbons were then fractionated into three fractions on Florisil and analyzed using capillary gas chromatogaraphy (GC).

Recoveries of the surrogates, PCB-30 and OCN were for both liver and muscle tissues were uniformly greater than 80% and no corrections were made for recoveries. Other quality assurance measures included the analysis of standard reference materials (NIST cod liver oil 1588) and duplicated analysis of every 12^{th} sample.

Appendix Table 1. Metal concentrations in pike, walleye, burbot, and inconnu muscle ($\mu g/g$ wet weight) collected from Resolution Bay, summer 1996.
Data are shown for individual fish and as the average (Mean) concentration for the species.
Data shown with a "<" sign were below the detection limits for that analysis.

Species	Replicate	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
Pike	1	0.15	<0.001	0.25	<0.05	0.259	4.1
	2	0.12	<0.001	0.24	<0.05	0.216	3.0
	3	0.10	<0.001	0.22	<0.05	0.186	3.4
	4	0.19	0.002	0.17	<0.05	0.265	4.3
	5	0.19	<0.001	0.18	<0.05	0.318	3.5
	Mean	0.15	<0.001	0.21	<0.05	0.249	3.7
	Std Dev.	0.04		0.04		0.050	0.5
	Std. Err.	0.02		0.02		0.023	0.2
Walleye	1	0.03	<0.001	0.25	<0.05	0.118	3.7
	2	0.03	<0.001	0.24	<0.05	0.243	2.8
	3	0.12	<0.001	0.18	<0.05	0.147	3.4
	4	0.10	<0.001	0.29	<0.05	0.158	2.7
	5	0.10	<0.001	0.23	<0.05	0.222	2.5
	6	0.11	<0.001	0.36	<0.05	0.323	3.0
	7	0.07	<0.001	0.34	<0.05	0.152	3.3
	8	0.05	0.001	0.24	<0.05	0.151	3.3
	Mean	0.08	<0.001	0.27	<0.05	0.189	3.1
	Std Dev.	0.04		0.06		0.068	0.4
	Std. Err.	0.01		0.02		0.024	0.1
Burbot	1	0.22	<0.001	0.46	<0.05	0.079	2.8
	2	0.12	<0.001	0.35	<0.05	0.043	3.3
	3	0.13	<0.001	0.35	<0.05	0.051	3.0
	4	0.09	<0.001	0.29	<0.05	0.158	2.9
	5	0.11	<0.001	0.24	<0.05	0.081	3.2
	Mean	0.13	<0.001	0.34	<0.05	0.082	3.0
	Std Dev.	0.05		0.08		0.045	0.2
	Std. Err.	0.02		0.04		0.020	0.1
Inconnu	1	0.09	<0.001	0.34	<0.05	0.077	2.5
	2	0.50	<0.001	n/s	<0.05	0.097	2.6
	3	0.43	<0.001	0.37	<0.05	0.107	2.8
	4	0.26	<0.001	n/s	<0.05	0.119	2.7
	5	0.23	<0.001	0.36	<0.05	0.125	2.7
	Mean	0.30	<0.001	0.36	<0.05	0.105	2.7
	Std Dev.	0.16		0.02		0.019	0.1
	Std. Err.	0.07		0.01		0.009	0.1

Appendix Table 2. Metal concentrations in pike, walleye, and burbot liver (µg/g wet weight) collected from Resolution Bay, summer 1996. Also shown are metal concentrations in pike stomach and burbot gall bladder and bile. Data are shown for individual fish and as the average (Mean) concentration for the species. Gall bladder and bile determinations were made by combining the gall bladders (and bile) from the five fish for one composite sample. Data shown with a "<" sign were below the detection limits for that analysis.

Species and Tissue	Replicate	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
Pike liver	1	0.20	0.112	29.20	<0.05	0.146	42.9
	2	0.20	0.160	13.90	<0.05	0.096	45.4
	3	0.08	0.059	15.40	<0.05	0.059	26.2
	4	0.09	0.072	13.80	<0.05	0.100	31.5
	5	0.17	0.055	7.90	<0.05	0.107	25.1
	Mean	0.15	0.092	16.04	<0.05	0.102	34.2
	Std. Dev.	0.06	0.044	7.90		0.031	9.4
	Std. Error	0.03	0.020	3.53		0.014	4.2
Walleye liver	1	0.74	0.209	1.20	<0.05	0.053	24.6
	2	0.46	0.132	1.10	<0.05	0.053	12.8
	3	0.48	0.205	1.40	<0.05	0.032	18.8
	4	0.24	0.405	1.60	<0.05	0.047	18.7
	5	0.62	0.260	1.60	<0.05	0.059	17.0
	6	0.47	0.181	1.82	<0.05	0.079	21.0
	7	0.58	0.240	1.35	<0.05	0.051	19.0
	8	0.48	0.262	2.29	<0.05	0.078	24.0
	Mean	0.51	0.237	1.55	<0.05	0.057	19.5
	Std. Dev.	0.15	0.080	0.38		0.016	3.8
	Std. Error	0.05	0.028	0.13		0.006	1.34
Burbot liver	1	1.82	0.138	11.40	<0.05	0.027	18.8
	2	1.02	0.052	17.40	<0.05	0.021	25.4
	3	0.56	0.066	4.80	<0.05	0.016	13.8
	4	0.42	0.047	6.70	<0.05	0.043	17.3
	5	0.53	0.030	4.70	<0.05	0.019	14.0
	Mean	0.87	0.067	9.00	<0.05	0.025	17.9
	Std. Dev.	0.58	0.042	5.43		0.011	4.7
	Std. Error	0.26	0.019	2.43		0.005	2.1
Burbot gall bladder	1	0.87	0.010	1.90	<0.05	0.032	14.2
Burbot bile	1	0.30	0.003	0.97	<0.05	0.005	2.2
Pike stomach	1	0.34	0.035	1.90	<0.05	0.092	699.4
	2	0.37	0.041	1.50	<0.05	0.049	1083.0
	3	0.50	0.034	0.94	<0.05	0.056	1236.5
	4	0.33	0.007	0.48	<0.05	0.051	360.8
	5	0.37	0.022	0.56	<0.05	0.067	604.8
	Mean	0.38	0.028	1.08	<0.05	0.063	796.9
	Std. Dev.	0.07	0.014	0.61		0.018	357.7
	Std. Error	0.03	0.006	0.27		0.008	160.0

Appendix Table 3. PCB congener concentrations (ng/g wet weight) by number of chlorines, total PCBs and % lipids for fish sampled at Resolution Bay, summer 1996.

Sample	Replicate	MON/DI	TRI	TETRA	PENTA	HEXA	HEPTA	OCTA	NONA	DECA	TOTAL PCBs	% Lipid
Pike muscle	1	0.02	0.41	0.59	0.96	1.22	0.44	0.08	0.00	0.00	3.73	1.13
	2	0.02	0.67	0.70	1.24	1.43	0.56	0.09	0.00	0.00	4.71	2.26
	3	0.06	0.84	1.14	1.48	2.19	1.14	0.25	0.00	0.00	7.11	2.58
	4	0.06	0.67	1.12	1.65	2.31	0.66	0.10	0.00	0.00	6.57	2.54
	5	0.02	0.55	0.67	0.93	1.53	0.51	0.09	0.00	0.00	4.31	2.51
	Mean	0.04	0.63	0.84	1.25	1.74	0.66	0.12	0.00	0.00	5.28	2.20
	Std. dev.	0.02	0.16	0.26	0.32	0.49	0.28	0.07	0.00	0.00	1.47	0.61
Pike liver	1	0.36	3.83	4.44	9.42	18.58	8.35	1.72	0.17	0.00	46.87	5.36
	2	0.43	3.03	1.75	4.64	8.38	2.92	0.37	0.00	0.00	21.52	2.86
	3	0.22	2.71	1.63	4.10	8.15	3.34	0.39	0.00	0.22	20.77	4.36
	4	0.41	2.79	5.03	8.55	15.29	6.51	1.40	0.25	0.00	40.24	6.82
	5	0.26	4.02	5.30	9.15	18.24	7.75	1.32	0.10	0.00	46.14	8.73
	Mean	0.34	3.28	3.63	7.17	13.73	5.77	1.04	0.11	0.04	35.11	5.63
	Std. dev.	0.09	0.61	1.80	2.58	5.15	2.51	0.62	0.11	0.10	13.00	2.26
Pike stomach	1	0.11	0.68	3.33	5.39	11.49	5.44	0.95	0.11	0.02	27.50	5.74
	2	0.24	0.80	3.24	5.95	9.51	6.29	1.09	0.11	0.03	27.28	6.18
	3	0.12	0.79	4.00	6.86	13.06	7.14	1.15	0.13	0.01	33.27	10.08
	4	0.23	1.68	8.52	12.73	23.05	12.81	2.29	0.28	0.07	61.65	16.29
	5	0.16	0.81	6.33	9.54	19.29	9.63	1.58	0.12	0.00	47.46	17.51
	Mean	0.17	0.95	5.08	8.09	15.28	8.26	1.41	0.15	0.03	39.43	11.16
	Std. dev.	0.06	0.41	2.29	3.04	5.68	2.99	0.54	0.07	0.03	14.89	5.52
Walleye muscle	1	0.06	0.86	0.83	1.50	1.60	0.78	0.22	0.00	0.00	5.84	3.31
	2	0.05	0.69	0.87	1.07	1.47	0.67	0.15	0.00	0.00	4.96	2.63
	3	0.05	0.59	0.95	1.31	2.04	0.67	0.11	0.00	0.00	5.72	5.72
	4	0.03	0.59	0.63	0.86	1.35	0.56	0.09	0.00	0.00	4.10	2.88
	5	0.09	0.86	1.11	1.57	1.77	0.95	0.19	0.00	0.00	6.54	2.65
	6	0.19	0.61	0.47	0.91	1.33	0.43	0.05	0.00	0.00	3.98	nd
	7	0.35	0.49	0.31	0.58	1.22	0.52	0.10	0.00	0.00	3.58	nd
	8	0.11	0.24	0.21	0.59	0.85	0.37	0.05	0.00	0.00	2.41	nd
	Mean	0.12	0.62	0.67	1.05	1.45	0.62	0.12	0.00	0.00	4.64	3.44
	Std. dev.	0.11	0.20	0.32	0.39	0.36	0.19	0.06	0.00	0.00	1.37	1.30
Walleye liver	1	0.43	0.10	2.62	4.34	5.91	2.27	0.20	0.08	0.00	15.95	8.32
	2	0.70	0.16	2.96	12.14	19.36	6.19	0.94	0.04	0.00	42.49	6.14
	6	1.93	0.46	1.23	4.97	5.95	2.68	0.95	0.00	0.00	18.16	nd
	7	1.59	1.21	2.19	6.64	9.70	4.16	0.51	0.03	0.00	26.04	nd
	8	0.13	0.87	4.40	7.54	14.35	7.85	1.27	0.14	0.01	36.56	nd
	Mean	0.96	0.56	2.68	7.12	11.05	4.63	0.77	0.06	0.00	27.84	7.23
	Std. dev.	0.77	0.48	1.16	3.08	5.79	2.37	0.42	0.05	0.01	11.50	1.54
Burbot muscle	1	0.06	0.33	0.63	0.99	1.08	0.37	0.04	0.00	0.00	3.50	1.07
	2	0.04	0.27	0.43	0.73	0.84	0.31	0.03	0.00	0.00	2.65	0.97
	3	0.03	0.22	0.34	0.56	0.59	0.24	0.01	0.00	0.00	1.99	0.92
	4	0.08	0.41	0.98	1.41	1.42	0.48	0.09	0.00	0.00	4.87	1.20
	5	0.02	0.15	0.25	0.43	0.45	0.18	0.03	0.00	0.00	1.51	0.75
	Mean	0.05	0.28	0.53	0.82	0.88	0.32	0.04	0.00	0.00	2.91	0.98
	Std. dev.	0.02	0.10	0.29	0.39	0.39	0.12	0.03	0.00	0.00	1.33	0.17
Burbot liver	1	1.43	2.33	13.80	20.21	36.47	14.54	2.11	0.76	0.00	91.65	39.64
	2	0.70	2.62	17.58	22.58	36.78	14.99	1.24	0.53	0.00	97.03	43.18
	3	0.63	1.22	13.78	22.50	44.70	18.97	2.92	1.89	0.06	106.67	45.55
	4	0.55	2.13	11.40	18.33	32.85	15.44	1.51	0.79	0.00	83.01	31.36
	5	0.67	2.75	14.88	24.23	40.90	17.70	1.74	0.93	0.00	103.80	56.68
	Mean	0.79	2.21	14.29	21.57	38.34	16.33	1.91	0.98	0.01	96.43	43.28
	Std. dev.	0.36	0.60	2.24	2.31	4.56	1.91	0.65	0.53	0.03	9.52	9.22
Inconnu muscle	1	0.18	1.05	1.39	2.90	3.91	0.85	0.12	0.00	0.00	10.39	15.23
	2	0.15	1.03	1.50	2.47	3.59	1.08	0.25	0.00	0.00	10.08	14.06
	3	0.35	1.40	2.06	4.18	4.98	1.47	0.31	0.00	0.00	14.75	29.49
	4	0.21	0.76	1.14	3.02	3.65	1.06	0.23	0.00	0.00	10.07	21.59
	5	0.30	0.98	1.41	3.58	4.14	1.36	0.28	0.00	0.00	12.05	21.95
	Mean	0.24	1.04	1.50	3.23	4.05	1.16	0.24	0.00	0.00	11.47	20.46
	Std. dev.	0.09	0.23	0.34	0.66	0.56	0.25	0.07	0.00	0.00	2.01	6.19

Appendix Table 4. Average PCB congener composition in fish tissue (ng/g wet weight) from Resolution Bay, summer 1996.

		Pike			Walleye		Burbot		Inconnu
CONGENERS		Muscle	Stomach	Liver	Muscle	Liver	Muscle	Liver	Muscle
MON/DI	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4/10	0.000	0.097	0.000	0.033	0.282	0.000	0.399	0.000
	7	0.000	0.014	0.195	0.014	0.377	0.000	0.292	0.000
	6	0.000	0.009	0.000	0.018	0.132	0.046	0.103	0.000
	8/5	0.036	0.052	0.142	0.051	0.166	0.000	0.000	0.237
	SUM	0.036	0.172	0.337	0.116	0.958	0.046	0.795	0.237
TRI	16/32	0.016	0.000	0.000	0.017	0.000	0.000	0.000	0.000
	17	0.000	0.006	0.000	0.029	0.000	0.000	0.156	0.000
	18	0.034	0.106	0.000	0.014	0.024	0.016	0.218	0.040
	19	0.002	0.117	0.000	0.010	0.019	0.000	0.120	0.000
	22	0.043	0.030	0.000	0.023	0.042	0.024	0.026	0.173
	24/27	0.018	0.001	0.000	0.008	0.000	0.022	0.003	0.026
	25	0.014	0.000	0.000	0.016	0.000	0.016	0.265	0.039
	26	0.005	0.000	0.000	0.008	0.000	0.000	0.013	0.000
	28	0.125	0.300	3.276	0.229	0.340	0.058	0.552	0.237
	31	0.251	0.283	0.000	0.228	0.057	0.112	0.858	0.390
	33	0.121	0.109	0.000	0.033	0.078	0.028	0.000	0.139
	SUM	0.629	0.953	3.276	0.616	0.560	0.276	2.211	1.043
TETRA	40	0.011	0.090	0.013	0.017	0.032	0.000	0.255	0.000
	41/71	0.032	0.000	0.000	0.016	0.000	0.026	0.000	0.084
	42	0.007	0.233	0.075	0.033	0.129	0.000	1.247	0.000
	44	0.036	0.726	0.523	0.048	0.475	0.024	2.317	0.063
	45	0.050	0.595	0.418	0.027	0.254	0.000	0.634	0.000
	46	0.005	0.059	0.028	0.027	0.090	0.000	0.147	0.000
	47	0.002	0.137	0.150	0.021	0.141	0.000	0.647	0.000
	48	0.027	0.003	0.000	0.029	0.051	0.018	0.000	0.000
	49	0.171	0.327	0.442	0.131	0.226	0.126	1.054	0.334
	52	0.246	0.652	0.375	0.173	0.326	0.084	2.224	0.307
	56/60	0.062	1.441	0.969	0.024	0.455	0.042	3.293	0.150
	64	0.025	0.152	0.088	0.016	0.081	0.036	0.471	0.080
	66	0.052	0.000	0.000	0.043	0.000	0.046	0.000	0.127
	70/76	0.052	0.411	0.315	0.036	0.263	0.080	1.290	0.143
	74	0.064	0.258	0.236	0.030	0.158	0.044	0.712	0.167
	SUM	0.842	5.084	3.632	0.671	2.679	0.526	14.290	1.454

Appendix Table 4 (cont.). Average PCB congener composition in fish tissue (ng/g wet weight) from Resolution Bay, summer 1996.

		Pike			Walleye		Burbot		Inconnu
CONGENERS		Muscle	Stomach	Liver	Muscle	Liver	Muscle	Liver	Muscle
PENTA	82	0.000	0.000	0.000	0.001	0.041	0.000	0.000	0.000
	84/89	0.030	0.061	0.000	0.018	0.073	0.054	0.172	0.129
	83	0.007	0.000	0.000	0.016	0.000	0.000	0.000	0.000
	95	0.157	0.717	0.653	0.174	0.941	0.106	1.861	0.302
	85	0.128	0.000	0.131	0.063	0.000	0.050	0.000	0.151
	87	0.057	0.420	0.402	0.058	0.475	0.066	1.336	0.284
	91	0.043	0.739	0.589	0.033	0.162	0.036	0.067	0.082
	97	0.100	0.026	0.056	0.054	0.161	0.090	0.418	0.294
	99	0.078	0.879	0.775	0.079	0.482	0.030	2.743	0.183
	101	0.203	1.910	1.548	0.164	1.181	0.066	5.800	0.299
	105	0.036	0.519	0.430	0.039	0.578	0.028	1.686	0.107
	110	0.148	0.958	0.951	0.127	1.196	0.106	2.623	0.433
	114	0.052	0.214	0.158	0.024	0.095	0.000	0.503	0.082
	118	0.214	1.651	1.480	0.202	1.738	0.174	4.361	0.886
	SUM	1.253	8.093	7.172	1.049	7.124	0.806	21.569	3.232
HEXA	128	0.027	1.577	1.454	0.063	0.888	0.022	3.292	0.093
	137	0.027	0.311	0.807	0.084	0.058	0.024	0.209	0.062
	131	0.016	0.260	0.032	0.040	0.201	0.000	0.527	0.000
	132	0.036	0.629	0.506	0.055	0.556	0.028	1.954	0.189
	134	0.041	0.161	0.015	0.019	0.048	0.000	0.000	0.125
	136	0.048	0.012	0.060	0.027	0.316	0.000	0.055	0.028
	138	0.319	4.185	3.803	0.277	3.079	0.212	10.181	1.176
	141	0.043	0.548	0.481	0.046	0.505	0.032	1.269	0.085
	151	0.228	0.788	0.660	0.118	0.564	0.092	2.138	0.258
	144/135	0.105	0.470	0.297	0.063	0.317	0.044	0.446	0.130
	146	0.039	0.472	0.403	0.085	0.412	0.032	1.676	0.172
	149	0.349	1.203	1.215	0.152	1.401	0.172	3.659	0.354
	153	0.424	4.043	3.445	0.386	2.270	0.200	11.208	1.302
	158	0.032	0.621	0.551	0.036	0.438	0.020	1.724	0.079
	SUM	1.734	15.280	13.729	1.452	11.054	0.878	38.339	4.054

Appendix Table 4 (cont.). Average PCB congener composition in fish tissue (ng/g wet weight) from Resolution Bay, summer 1996.

CONGENERS		Pike				Walleye		Burbot		Inconnu
		Muscle	Stomach	Liver		Muscle	Liver	Muscle	Liver	Muscle
HEPTA	130/176	0.021	0.879	0.383		0.035	0.445	0.000	3.087	0.000
	156	0.014	0.473	0.398		0.033	0.241	0.000	1.032	0.000
	170	0.036	0.464	0.388		0.034	0.264	0.026	1.108	0.096
	171	0.000	0.327	0.309		0.000	0.153	0.000	0.379	0.000
	172/197	0.027	0.532	0.167		0.023	0.265	0.010	0.000	0.067
	174	0.027	0.279	0.196		0.038	0.393	0.012	0.286	0.071
	175	0.014	0.189	0.063		0.017	0.095	0.000	0.454	0.000
	177	0.025	0.402	0.255		0.029	0.106	0.014	0.000	0.044
	178/129	0.034	0.388	0.323		0.038	0.281	0.014	0.826	0.055
	179	0.018	0.129	0.102		0.032	0.093	0.000	0.225	0.000
	180	0.153	1.332	1.130		0.119	0.612	0.070	3.128	0.309
	183	0.105	1.007	0.750		0.056	0.497	0.040	2.559	0.130
	185	0.025	0.179	0.124		0.018	0.098	0.000	0.406	0.000
	187	0.103	1.125	0.787		0.106	0.862	0.108	1.753	0.275
	189	0.000	0.036	0.021		0.000	0.007	0.000	0.000	0.000
	190	0.016	0.151	0.128		0.001	0.067	0.000	0.348	0.000
	191	0.014	0.036	0.034		0.014	0.022	0.000	0.135	0.000
	193	0.032	0.335	0.216		0.024	0.128	0.022	0.600	0.117
	SUM	0.664	8.263	5.774	#	0.618	4.631	0.316	16.327	1.164
OCTA	194	0.016	0.234	0.175		0.011	0.066	0.012	0.015	0.023
	195	0.011	0.117	0.068		0.011	0.020	0.000	0.109	0.038
	196/203	0.039	0.448	0.382		0.038	0.188	0.018	0.975	0.088
	198	0.007	0.074	0.049		0.009	0.040	0.000	0.168	0.000
	199	0.019	0.236	0.207		0.021	0.172	0.010	0.501	0.056
	200	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000
	201/157	0.032	0.270	0.129		0.031	0.269	0.000	0.137	0.032
	205	0.000	0.031	0.027		0.000	0.018	0.000	0.000	0.000
	SUM	0.124	1.410	1.037		0.120	0.774	0.040	1.906	0.238
NONA	206	0.000	0.073	0.054		0.000	0.018	0.000	0.162	0.000
	207	0.000	0.045	0.034		0.000	0.018	0.000	0.512	0.000
	208	0.000	0.032	0.018		0.000	0.022	0.000	0.307	0.000
	SUM	0.000	0.150	0.106		0.000	0.058	0.000	0.981	0.000
DECA	209	0.000	0.026	0.045		0.000	0.003	0.000	0.013	0.000
	TOTAL PCB'S	5.28	39.43	35.11	#	4.64	27.84	2.89	96.43	11.42

Appendix Table 5. Chlorobenzene and ocytachlorostyrene concentrations (ng/g) from fish sampled at Resolution Bay, summer 1996.

Sample	Replicate	Chlorobenzenes					
		1245TCB	1234TCB	P5CBZ	HCBZ	Total	Octachlorostyrene
Pike muscle	1	0.068	0.057	0.091	0.182	0.399	0.068
	2	0.080	0.068	0.103	0.194	0.445	0.114
	3	0.046	0.068	0.080	0.217	0.410	0.080
	4	0.125	0.103	0.251	0.285	0.764	0.125
	5	0.046	0.034	0.160	0.137	0.376	0.057
	Mean	0.073	0.066	0.137	0.203	0.479	0.089
	Std. dev.	0.033	0.025	0.071	0.054	0.161	0.030
Pike liver	1	0.000	0.155	0.091	1.508	1.754	1.095
	2	0.000	0.427	0.156	1.241	1.823	0.508
	3	0.000	0.245	0.188	1.110	1.544	0.490
	4	0.000	0.291	0.164	2.611	3.066	0.936
	5	0.000	0.286	0.197	2.304	2.787	1.093
	Mean	0.000	0.281	0.159	1.755	2.195	0.824
	Std. dev.	0.000	0.098	0.042	0.666	0.683	0.304
Pike stomach	1	0.000	0.109	0.068	1.005	1.182	0.720
	2	0.072	0.091	0.112	1.842	2.116	0.735
	3	0.072	0.123	0.161	2.293	2.650	0.905
	4	0.134	0.136	0.311	5.382	5.964	1.486
	5	0.072	0.150	0.232	2.903	3.357	1.211
	Mean	0.070	0.122	0.177	2.685	3.054	1.012
	Std. dev.	0.047	0.023	0.097	1.659	1.810	0.331
Walleye muscle	1	0.023	0.023	0.034	0.194	0.274	0.046
	2	0.023	0.046	0.046	0.205	0.319	0.046
	3	0.034	0.057	0.103	0.262	0.456	0.034
	4	0.023	0.057	0.046	0.125	0.251	0.046
	5	0.034	0.034	0.034	0.171	0.274	0.034
	6	0.000	0.169	0.432	0.259	0.860	0.028
	7	0.000	0.030	0.021	0.193	0.244	0.069
	8	0.000	0.011	0.000	0.153	0.164	0.040
	Mean	0.017	0.053	0.089	0.195	0.355	0.043
	Std. dev.	0.015	0.050	0.142	0.048	0.220	0.012
Walleye liver	1	0.000	0.181	0.099	1.186	1.465	0.425
	2	0.000	0.132	0.139	1.165	1.436	0.582
	6	0.000	0.166	0.191	1.063	1.419	0.235
	7	0.000	0.038	0.095	2.048	2.182	0.679
	8	0.079	0.135	0.177	2.520	2.912	0.995
	Mean	0.016	0.130	0.140	1.596	1.883	0.583
	Std. dev.	0.035	0.055	0.044	0.651	0.659	0.285
Burbot muscle	1	0.030	0.000	0.030	0.130	0.190	0.040
	2	0.020	0.000	0.030	0.100	0.150	0.030
	3	0.010	0.000	0.020	0.050	0.080	0.030
	4	0.050	0.000	0.060	0.180	0.290	0.090
	5	0.010	0.000	0.010	0.030	0.050	0.020
	Mean	0.024	0.000	0.030	0.098	0.152	0.042
	Std. dev.	0.017	0.000	0.019	0.061	0.095	0.028
Burbot liver	1	0.309	1.082	0.845	9.208	11.444	2.126
	2	0.000	0.000	0.962	14.649	15.611	2.789
	3	0.000	0.925	0.651	7.733	9.308	3.385
	4	0.000	1.046	0.926	10.744	12.716	2.562
	5	0.000	1.446	1.207	13.584	16.237	3.089
	Mean	0.062	0.900	0.918	11.183	13.063	2.790
	Std. dev.	0.138	0.539	0.201	2.906	2.890	0.484
Inconnu muscle	1	0.171	0.137	0.331	1.083	1.721	0.171
	2	0.148	0.137	0.262	0.901	1.448	0.125
	3	0.260	0.050	0.380	2.410	3.100	0.340
	4	0.180	0.030	0.250	1.170	1.630	0.280
	5	0.190	0.040	0.290	1.580	2.100	0.330
	Mean	0.190	0.079	0.303	1.429	2.000	0.249
	Std. dev.	0.042	0.053	0.053	0.602	0.659	0.096

Appendix Table 6. Toxaphene, hexachlorocyclohexane, mirex and photo-mirex concentrations (ng/g wet weight) in fish sampled at Resolution Bay, summer 1996.

Sample	Replicate	Toxaphene			Hexachlorocyclohexane					Mirex	Photo Mirex
		TOXSRF 1	TOXSRF 2	Total	a-HCH	b-HCH	g-HCH	d-HCH	Total		
Pike muscle	1	1.778	15.322	17.100	0.331	0.023	0.034	0.000	0.388	0.034	0.000
	2	2.440	17.203	19.642	0.445	0.011	0.103	0.000	0.559	0.046	0.000
	3	6.487	23.986	30.472	0.171	0.000	0.091	0.000	0.262	0.148	0.000
	4	5.837	24.453	30.290	0.513	0.068	0.160	0.000	0.741	0.114	0.000
	5	2.793	15.640	18.433	0.239	0.023	0.068	0.000	0.331	0.057	0.000
	Mean	3.867	19.321	23.187	0.340	0.025	0.091	0.000	0.456	0.080	0.000
	Std. dev.	2.139	4.531	6.628	0.141	0.026	0.046	0.000	0.193	0.049	0.000
Pike liver	1	18.688	34.170	52.858	0.649	0.113	0.216	0.000	0.978	1.504	1.536
	2	11.091	18.362	29.452	0.352	0.103	0.189	0.000	0.644	0.499	0.746
	3	11.553	24.986	36.539	0.518	0.158	0.203	0.000	0.880	0.484	0.544
	4	29.504	61.319	90.823	0.786	0.092	0.397	0.000	1.274	1.235	1.335
	5	27.726	40.855	68.580	0.751	0.058	0.257	0.000	1.067	1.299	1.497
	Mean	19.712	35.938	55.651	0.611	0.105	0.253	0.000	0.969	1.004	1.132
	Std. dev.	8.690	16.586	24.818	0.178	0.036	0.085	0.000	0.233	0.479	0.456
Pike stomach	1	29.160	22.518	51.678	0.434	0.020	0.190	0.065	0.710	0.723	0.869
	2	37.809	36.532	74.340	0.437	0.041	0.263	0.000	0.741	0.880	0.711
	3	38.702	42.628	81.330	0.703	0.018	0.308	0.000	1.029	0.837	0.988
	4	104.979	108.007	212.986	1.286	0.064	0.815	0.000	2.165	1.666	1.633
	5	50.085	62.603	112.688	0.979	0.345	0.417	0.000	1.741	1.212	0.711
	Mean	52.147	54.457	106.604	0.768	0.098	0.399	0.013	1.277	1.064	0.982
	Std. dev.	30.456	33.224	63.346	0.367	0.140	0.247	0.029	0.647	0.383	0.382
Walleye muscle	1	4.685	17.875	22.561	0.148	0.000	0.068	0.000	0.217	0.171	0.000
	2	5.711	14.877	20.588	0.125	0.000	0.046	0.000	0.171	0.114	0.000
	3	6.452	15.949	22.401	0.182	0.000	0.057	0.000	0.239	0.171	0.000
	4	4.503	13.737	18.240	0.148	0.000	0.057	0.000	0.205	0.125	0.000
	5	5.187	19.255	24.442	0.137	0.000	0.068	0.000	0.205	0.114	0.000
	6	3.633	3.570	7.204	0.211	0.012	0.087	0.000	0.311	0.050	0.000
	7	2.363	2.305	4.668	0.114	0.021	0.047	0.000	0.183	0.048	0.000
	8	1.821	1.728	3.549	0.070	0.016	0.035	0.000	0.121	0.035	0.000
	Mean	4.295	11.162	15.456	0.142	0.006	0.058	0.000	0.207	0.103	0.000
	Std. dev.	1.601	7.358	8.782	0.043	0.009	0.016	0.000	0.055	0.054	0.000
Walleye liver	1	10.489	12.891	23.380	0.528	0.073	0.222	0.000	0.823	0.284	0.000
	2	14.798	11.443	26.241	0.472	0.067	0.189	0.000	0.728	0.443	0.000
	6	8.946	12.356	21.302	0.608	0.163	0.234	0.000	1.006	0.681	0.000
	7	21.315	26.028	47.343	1.035	0.185	0.424	0.000	1.644	0.797	0.000
	8	42.530	46.844	89.373	0.773	0.019	0.339	0.000	1.131	0.919	1.085
	Mean	19.616	21.912	41.528	0.683	0.102	0.282	0.000	1.066	0.625	0.217
	Std. dev.	13.677	15.172	28.702	0.227	0.070	0.097	0.000	0.359	0.259	0.485
Burbot muscle	1	1.210	2.010	3.220	0.100	0.000	0.010	0.000	0.110	0.020	0.000
	2	0.980	1.650	2.630	0.120	0.000	0.020	0.000	0.140	0.010	0.000
	3	0.510	1.220	1.730	0.070	0.000	0.010	0.000	0.080	0.010	0.000
	4	2.450	2.560	5.010	0.160	0.000	0.060	0.000	0.220	0.030	0.000
	5	0.890	1.050	1.940	0.050	0.000	0.010	0.000	0.060	0.010	0.000
	Mean	1.208	1.698	2.906	0.100	0.000	0.022	0.000	0.122	0.016	0.000
	Std. dev.	0.739	0.611	1.315	0.043	0.000	0.022	0.000	0.063	0.009	0.000
Burbot liver	1	135.516	152.646	288.161	3.965	0.243	2.017	0.000	6.224	2.175	0.000
	2	240.794	303.715	544.510	3.462	0.235	1.953	0.000	5.650	1.566	0.000
	3	109.480	148.705	258.185	3.697	0.238	1.957	0.000	5.893	3.315	0.000
	4	165.913	176.561	342.474	4.586	0.255	2.198	0.000	7.039	1.781	0.000
	5	155.453	151.043	306.496	7.529	0.346	2.673	0.000	10.547	1.965	0.000
	Mean	161.431	186.534	347.965	4.648	0.263	2.159	0.000	7.071	2.161	0.000
	Std. dev.	49.307	66.464	114.036	1.664	0.047	0.304	0.000	2.013	0.683	0.000
Inconnu muscle	1	5.012	25.010	30.022	0.034	0.000	0.251	0.000	1.311	0.057	0.000
	2	3.557	19.996	23.552	0.103	0.000	0.217	0.000	0.844	0.046	0.000
	3	8.790	29.540	38.330	0.091	0.000	0.450	0.000	0.541	0.130	0.000
	4	5.990	24.110	30.100	0.160	0.000	0.310	0.000	0.470	0.120	0.000
	5	6.720	27.610	34.330	0.068	0.000	0.380	0.000	0.448	0.100	0.000
	Mean	6.014	25.253	31.267	0.091	0.000	0.321	0.000	0.723	0.091	0.000
	Std. dev.	1.952	3.638	5.516	0.046	0.000	0.095	0.000	0.365	0.038	0.000

Appendix Table 7. DDT and methoxychlor concentrations (ng/g wet weight) in fish sampled at Resolution Bay, summer 1996.

Sample	Replicate	DDTs op-DDE	pp-DDE	op-DDD	pp-DDD	op-DDT	pp-DDT	Total	Methoxychlor
Pike muscle	1	0.228	0.593	0.239	0.137	0.388	0.285	1.870	0.000
	2	0.331	1.083	0.319	0.171	0.376	0.490	2.770	0.000
	3	0.547	0.889	0.422	0.513	0.456	0.524	3.352	0.000
	4	0.638	1.049	0.353	0.205	0.502	0.695	3.443	0.000
	5	0.399	0.410	0.251	0.148	0.239	0.353	1.801	0.000
	Mean	0.429	0.805	0.317	0.235	0.392	0.470	2.647	0.000
	Std. dev.	0.165	0.293	0.075	0.158	0.100	0.160	0.785	0.000
Pike liver	1	0.000	7.697	0.555	1.221	0.579	1.051	11.102	0.000
	2	0.000	2.582	0.214	0.469	0.336	0.334	3.936	0.000
	3	0.000	2.679	0.216	0.446	0.433	0.987	4.762	0.000
	4	0.000	5.859	0.371	1.030	0.753	2.209	10.222	0.000
	5	0.000	7.240	0.287	0.980	0.707	1.204	10.417	0.000
	Mean	0.000	5.211	0.329	0.829	0.562	1.157	8.088	0.000
	Std. dev.	0.000	2.451	0.142	0.351	0.177	0.676	3.441	0.000
Pike stomach	1	0.000	7.973	0.426	0.477	0.584	1.251	10.711	0.079
	2	0.000	5.544	0.323	0.473	0.711	0.087	7.138	0.000
	3	0.000	6.795	0.175	0.466	0.717	1.069	9.222	0.457
	4	0.000	14.541	0.455	1.484	1.820	3.187	21.488	0.000
	5	0.000	11.354	0.349	1.067	1.083	2.073	15.927	0.000
	Mean	0.000	9.241	0.346	0.794	0.983	1.533	12.897	0.107
	Std. dev.	0.000	3.668	0.110	0.464	0.503	1.164	5.797	0.199
Walleye muscle	1	0.296	0.422	0.251	0.559	0.445	0.490	2.462	0.000
	2	0.331	0.399	0.262	0.610	0.513	0.376	2.491	0.000
	3	0.376	0.353	0.239	0.467	0.616	0.342	2.394	0.000
	4	0.353	0.296	0.251	0.353	0.399	0.308	1.961	0.000
	5	0.410	0.422	0.296	0.399	0.285	0.433	2.246	0.000
	6	0.000	0.355	0.034	0.083	0.143	0.087	0.701	0.067
	7	0.000	0.232	0.030	0.061	0.195	0.066	0.585	0.090
	5	0.000	0.168	0.015	0.092	0.096	0.050	0.420	0.022
	Mean	0.221	0.331	0.172	0.328	0.336	0.269	1.658	0.036
	Std. dev.	0.186	0.092	0.122	0.222	0.186	0.176	0.920	0.041
Walleye liver	1	0.000	1.667	0.128	0.393	0.404	0.305	2.897	0.087
	2	0.000	2.603	0.129	0.469	0.405	0.424	4.029	0.164
	6	0.000	1.066	0.629	0.362	0.949	0.491	3.497	0.242
	7	0.000	2.756	0.584	0.636	1.266	0.482	5.724	0.000
	8	0.000	7.467	0.193	0.512	0.788	1.175	10.134	0.502
	Mean	0.000	3.112	0.333	0.474	0.762	0.575	5.256	0.199
	Std. dev.	0.000	2.531	0.252	0.108	0.369	0.343	2.923	0.192
Burbot muscle	1	0.160	0.210	0.140	0.100	0.130	0.210	0.950	0.000
	2	0.120	0.170	0.100	0.120	0.100	0.180	0.790	0.000
	3	0.090	0.140	0.080	0.060	0.090	0.140	0.600	0.000
	4	0.220	0.290	0.210	0.160	0.160	0.290	1.330	0.000
	5	0.080	0.110	0.050	0.040	0.060	0.110	0.450	0.000
	Mean	0.134	0.184	0.116	0.096	0.108	0.186	0.824	0.000
	Std. dev.	0.057	0.070	0.062	0.048	0.038	0.069	0.340	0.000
Burbot liver	1	0.000	15.046	0.033	1.911	0.989	6.504	24.483	0.686
	2	0.000	15.950	0.000	2.267	1.322	8.019	27.559	0.000
	3	0.000	16.422	0.000	2.161	2.935	6.865	28.383	0.154
	4	0.000	15.755	0.000	1.965	3.389	6.192	27.301	0.000
	5	0.000	17.549	0.000	2.395	4.121	6.531	30.596	0.716
	Mean	0.000	16.144	0.007	2.140	2.551	6.822	27.664	0.311
	Std. dev.	0.000	0.928	0.015	0.203	1.347	0.710	2.201	0.362
Inconnu muscle	1	0.445	0.866	0.445	0.456	0.376	1.357	3.944	0.000
	2	0.319	0.764	0.308	0.296	0.342	0.923	2.953	0.000
	3	0.560	1.560	0.610	0.490	0.910	1.690	5.820	0.000
	4	0.410	1.120	0.450	0.400	0.520	1.320	4.220	0.000
	5	0.490	1.230	0.510	0.450	0.640	1.510	4.830	0.000
	Mean	0.445	1.108	0.464	0.418	0.558	1.360	4.353	0.000
	Std. dev.	0.090	0.315	0.110	0.075	0.230	0.284	1.064	0.000

Appendix Table 8. Chlordane concentrations (ng/gwet weight) in fish sampled at Resolution Bay, summer 1996.

Sample	replicate	"C"	C1A	C1B/U6	C2/U-5	C3	C5	U1	U3
Pike muscle	1	0.000	0.000	0.000	0.023	0.000	0.034	0.000	0.000
	2	0.000	0.000	0.000	0.034	0.000	0.046	0.000	0.000
	3	0.000	0.000	0.000	0.114	0.000	0.125	0.000	0.000
	4	0.000	0.000	0.000	0.114	0.000	0.091	0.000	0.000
	5	0.000	0.000	0.000	0.034	0.000	0.057	0.000	0.000
	Mean	0.000	0.000	0.000	0.064	0.000	0.071	0.000	0.000
	Std. dev.	0.000	0.000	0.000	0.046	0.000	0.037	0.000	0.000
Pike liver	1	0.000	0.000	0.013	0.013	0.125	0.542	0.091	0.000
	2	0.045	0.000	0.000	0.015	0.297	0.323	0.110	0.000
	3	0.029	0.000	0.000	0.030	0.239	0.379	0.064	0.000
	4	0.119	0.000	0.020	0.033	0.219	0.852	0.277	0.000
	5	0.086	0.000	0.000	0.021	0.141	0.610	0.182	0.000
	Mean	0.056	0.000	0.007	0.022	0.204	0.541	0.145	0.000
	Std. dev.	0.047	0.000	0.009	0.009	0.071	0.209	0.086	0.000
Pike stomach	1	0.049	0.000	0.000	0.010	0.155	0.323	0.085	0.000
	2	0.073	0.000	0.000	0.021	0.155	0.465	0.090	0.000
	3	0.082	0.000	0.009	0.019	0.135	0.565	0.115	0.000
	4	0.273	0.000	0.026	0.059	0.329	1.310	0.448	0.000
	5	0.162	0.000	0.007	0.032	0.205	0.826	0.000	0.000
	Mean	0.128	0.000	0.008	0.028	0.196	0.697	0.148	0.000
	Std. dev.	0.091	0.000	0.011	0.019	0.079	0.389	0.173	0.000
Walleye muscle	1	0.000	0.000	0.000	0.023	0.000	0.046	0.000	0.000
	2	0.000	0.000	0.000	0.057	0.000	0.068	0.000	0.000
	3	0.000	0.000	0.000	0.125	0.000	0.114	0.000	0.000
	4	0.000	0.000	0.000	0.046	0.000	0.046	0.000	0.000
	5	0.000	0.000	0.000	0.057	0.000	0.034	0.000	0.000
	6	0.018	0.022	0.000	0.000	0.000	0.000	0.059	0.027
	7	0.000	0.010	0.000	0.009	0.000	0.000	0.000	0.000
	8	0.006	0.007	0.000	0.000	0.000	0.000	0.000	0.000
	Mean	0.003	0.005	0.000	0.040	0.000	0.038	0.007	0.003
	Std. dev.	0.006	0.008	0.000	0.042	0.000	0.040	0.021	0.010
Walleye liver	1	0.016	0.000	0.026	0.017	0.090	0.256	0.028	0.000
	2	0.000	0.000	0.021	0.014	0.083	0.261	0.025	0.000
	6	0.104	0.056	0.000	0.127	0.021	0.000	0.064	0.021
	7	0.139	0.146	0.000	0.171	0.028	0.000	0.251	0.028
	8	0.090	0.000	0.010	0.021	0.149	0.620	0.126	0.000
	Mean	0.070	0.041	0.011	0.070	0.074	0.227	0.099	0.010
	Std. dev.	0.060	0.064	0.012	0.074	0.052	0.255	0.094	0.014
Burbot muscle	1	0.000	0.000	0.000	0.020	0.000	0.010	0.000	0.000
	2	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000
	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.000	0.000	0.000	0.030	0.000	0.020	0.000	0.000
	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Mean	0.000	0.000	0.000	0.012	0.000	0.006	0.000	0.000
	Std. dev.	0.000	0.000	0.000	0.013	0.000	0.009	0.000	0.000
Burbot liver	1	0.411	0.000	0.077	0.125	0.966	1.872	0.736	0.000
	2	0.591	0.000	0.049	0.000	0.747	2.981	1.015	0.000
	3	0.230	0.000	0.000	0.101	0.433	2.097	0.273	0.000
	4	0.358	0.000	0.000	0.161	1.188	2.669	0.655	0.000
	5	0.319	0.000	0.000	0.194	0.613	2.779	0.498	0.000
	Mean	0.382	0.000	0.025	0.116	0.789	2.480	0.635	0.000
	Std. dev.	0.134	0.000	0.036	0.074	0.296	0.473	0.276	0.000
Inconnu muscle	1	0.000	0.000	0.000	0.114	0.000	0.137	0.000	0.000
	2	0.000	0.000	0.000	0.103	0.000	0.080	0.000	0.000
	3	0.000	0.000	0.000	0.150	0.000	0.170	0.000	0.000
	4	0.000	0.000	0.000	0.090	0.000	0.090	0.000	0.000
	5	0.000	0.000	0.000	0.120	0.000	0.130	0.000	0.000
	Mean	0.000	0.000	0.000	0.115	0.000	0.121	0.000	0.000
	Std. dev.	0.000	0.000	0.000	0.023	0.000	0.037	0.000	0.000

Appendix Table 8 (cont.). Chlordane concentrations (ng/g wet weight) in fish sampled at Resolution Bay, summer 1996.

Sample	replicate	oxy-chlordane	trans-chlordane	cis-chlordane	trans-nonachlor	cis-nonachlor	heptachlor	heptachlor-epoxide	Total chlordane
Pike muscle	1	0.217	0.023	0.171	0.524	0.274	0.000	0.103	1.368
	2	0.388	0.034	0.399	0.946	0.467	0.000	0.080	2.394
	3	0.239	0.171	0.479	0.661	0.422	0.057	0.091	2.360
	4	0.513	0.057	0.319	1.072	0.832	0.000	0.194	3.192
	5	0.388	0.023	0.160	0.638	0.513	0.000	0.137	1.949
	Mean	0.349	0.062	0.306	0.768	0.502	0.011	0.121	2.253
	Std. dev.	0.122	0.063	0.140	0.230	0.206	0.025	0.046	0.669
Pike liver	1	4.073	0.148	2.302	7.623	6.444	0.000	1.544	22.916
	2	1.758	0.237	1.514	4.018	2.475	0.000	0.300	11.092
	3	2.058	0.176	1.621	3.988	3.260	0.000	0.563	12.408
	4	6.349	0.216	2.808	8.189	7.073	0.000	0.478	26.633
	5	4.832	0.181	2.223	7.349	6.098	0.000	1.308	23.031
	Mean	3.814	0.192	2.094	6.233	5.070	0.000	0.838	19.216
	Std. dev.	1.926	0.035	0.531	2.058	2.060	0.000	0.551	6.993
Pike stomach	1	3.801	0.092	1.347	6.878	6.472	0.010	1.486	20.707
	2	3.358	0.221	2.937	7.902	5.708	0.010	1.692	22.632
	3	3.125	0.200	2.594	8.610	6.408	0.006	3.761	25.628
	4	16.068	0.338	4.672	19.513	18.288	0.020	6.582	67.926
	5	8.427	0.257	2.804	11.736	10.938	0.000	4.116	39.510
	Mean	6.956	0.222	2.871	10.928	9.563	0.009	3.528	35.281
	Std. dev.	5.540	0.090	1.189	5.130	5.301	0.007	2.078	19.680
Walleye muscle	1	0.137	0.068	0.342	0.547	0.331	0.023	0.140	1.656
	2	0.148	0.046	0.296	0.650	0.433	0.023	0.125	1.847
	3	0.160	0.068	0.353	0.513	0.308	0.034	0.091	1.767
	4	0.137	0.034	0.228	0.410	0.262	0.023	0.046	1.231
	5	0.182	0.057	0.285	0.399	0.399	0.034	0.057	1.505
	6	0.174	0.022	0.294	0.697	0.227	0.000	0.079	1.619
	7	0.079	0.038	0.200	0.456	0.134	0.000	0.040	0.966
	8	0.079	0.014	0.156	0.364	0.107	0.000	0.044	0.778
	Mean	0.137	0.044	0.269	0.505	0.275	0.017	0.078	1.421
	Std. dev.	0.039	0.020	0.069	0.121	0.117	0.015	0.039	0.389
Walleye liver	1	0.815	0.357	1.601	2.816	1.817	0.000	0.260	8.100
	2	1.127	0.270	1.525	3.855	2.296	0.000	0.245	9.721
	6	0.574	0.226	0.836	1.994	0.474	0.000	0.214	4.712
	7	0.838	0.370	2.594	5.581	1.912	0.000	0.357	12.417
	8	3.434	0.220	2.850	9.462	7.041	0.007	4.133	28.163
	Mean	1.358	0.289	1.881	4.742	2.708	0.001	1.042	12.623
	Std. dev.	1.177	0.072	0.829	2.959	2.518	0.003	1.729	9.124
Burbot muscle	1	0.190	0.080	0.120	0.320	0.150	0.000	0.060	0.950
	2	0.170	0.060	0.100	0.290	0.160	0.000	0.040	0.830
	3	0.100	0.040	0.060	0.140	0.100	0.000	0.030	0.470
	4	0.220	0.110	0.160	0.420	0.210	0.000	0.080	1.250
	5	0.090	0.030	0.050	0.110	0.080	0.000	0.010	0.370
	Mean	0.154	0.064	0.098	0.256	0.140	0.000	0.044	0.774
	Std. dev.	0.057	0.032	0.045	0.129	0.051	0.000	0.027	0.359
Burbot liver	1	2.056	0.433	3.734	15.439	19.167	0.138	6.233	51.387
	2	24.810	0.522	7.024	27.800	23.465	0.068	7.316	96.389
	3	13.491	0.341	4.712	21.403	19.498	0.023	2.433	65.034
	4	16.475	0.481	5.948	23.545	20.165	0.022	5.664	77.331
	5	16.437	0.497	5.464	19.985	18.806	0.000	3.987	69.578
	Mean	14.654	0.455	5.376	21.634	20.220	0.050	5.127	71.944
	Std. dev.	8.212	0.072	1.244	4.550	1.882	0.055	1.927	16.602
Inconnu muscle	1	0.513	0.331	1.562	1.642	1.322	0.000	0.365	5.985
	2	0.342	0.182	0.969	1.208	0.730	0.000	0.331	3.944
	3	1.120	0.480	2.530	1.890	1.670	0.000	0.720	8.730
	4	1.000	0.410	2.280	1.320	1.250	0.000	0.420	6.860
	5	0.890	0.350	2.080	1.680	1.450	0.000	0.480	7.180
	Mean	0.773	0.351	1.884	1.548	1.284	0.000	0.463	6.540
	Std. dev.	0.331	0.111	0.623	0.279	0.349	0.000	0.154	1.757

AppendixTable 9. Cyclodiene insecticide concentrations (ng/g wet weight) in fish sampled at Resolution Bay, summer 1996.

Sample	Replicate	Total Chlordane	Heptachlor	Dieldrin	Endrin	Endosulfan
Pike muscle	1	1.368	0.000	0.148	0.000	0.103
	2	2.394	0.000	0.114	0.000	0.114
	3	2.360	0.057	0.114	0.000	0.182
	4	3.192	0.000	0.274	0.000	0.217
	5	1.949	0.000	0.148	0.000	0.125
	Mean	2.253	0.011	0.160	0.000	0.148
	Std. dev.	0.669	0.025	0.066	0.000	0.049
Pike liver	1	22.916	0.000	2.350	0.839	0.170
	2	11.092	0.000	0.830	0.019	0.060
	3	12.408	0.000	1.080	0.000	0.360
	4	26.633	0.000	0.940	0.037	0.030
	5	23.031	0.000	1.930	0.088	0.080
	Mean	19.216	0.000	1.426	0.197	0.140
	Std. dev.	6.993	0.000	0.674	0.361	0.134
Pike stomach	1	20.707	0.010	5.060	0.000	0.850
	2	22.632	0.010	5.790	0.025	0.530
	3	25.628	0.006	6.580	0.187	0.430
	4	67.926	0.020	14.740	0.000	0.650
	5	39.510	0.000	6.760	0.000	0.360
	Mean	35.281	0.009	7.786	0.043	0.564
	Std. dev.	19.680	0.007	3.946	0.082	0.194
Walleye muscle	1	1.656	0.023	0.100	0.000	0.050
	2	1.847	0.023	0.103	0.000	0.034
	3	1.767	0.034	0.137	0.000	0.023
	4	1.231	0.023	0.091	0.000	0.034
	5	1.505	0.034	0.068	0.000	0.057
	6	1.619	0.000	0.165	0.015	0.037
	7	0.966	0.000	0.093	0.045	0.037
	8	0.778	0.000	0.090	0.010	0.033
	Mean	1.421	0.017	0.106	0.009	0.038
	Std. dev.	0.389	0.015	0.031	0.016	0.011
Walleye liver	1	8.100	0.000	0.629	0.063	0.007
	2	9.721	0.000	0.600	0.040	0.006
	6	4.712	0.000	0.550	1.037	0.000
	7	12.417	0.000	0.852	0.000	0.135
	8	28.163	0.007	7.231	0.206	0.473
	Mean	12.623	0.001	1.972	0.269	0.124
	Std. dev.	9.124	0.003	2.942	0.436	0.203
Burbot muscle	1	0.950	0.000	0.100	0.000	0.080
	2	0.830	0.000	0.050	0.000	0.050
	3	0.470	0.000	0.060	0.000	0.040
	4	1.250	0.000	0.120	0.000	0.120
	5	0.370	0.000	0.030	0.000	0.030
	Mean	0.774	0.000	0.072	0.000	0.064
	Std. dev.	0.359	0.000	0.037	0.000	0.036
Burbot liver	1	51.387	0.138	7.473	0.000	0.030
	2	96.389	0.068	11.059	0.208	0.009
	3	65.034	0.023	4.257	0.183	0.011
	4	77.331	0.022	7.943	0.334	0.000
	5	69.578	0.000	7.423	0.283	0.004
	Mean	71.944	0.050	7.631	0.202	0.011
	Std. dev.	16.602	0.055	2.414	0.128	0.012
Inconnu muscle	1	5.985	0.000	0.638	0.000	0.239
	2	3.944	0.000	0.616	0.000	0.217
	3	8.730	0.000	1.220	0.000	0.270
	4	6.860	0.000	0.850	0.000	0.190
	5	7.180	0.000	1.010	0.000	0.250
	Mean	6.540	0.000	0.867	0.000	0.233
	Std. dev.	1.757	0.000	0.255	0.000	0.031

CHEF DE FILE DE LA RECHERCHE EN HYDROLOGIE

Le Centre national de recherche en hydrologie effectue des travaux de recherche sur des questions ayant trait à la saine gestion des ressources aquatiques du Canada: détection et prévision des changements climatiques, éléments nutritifs et organismes toxiques présents dans les eaux superficielles et souterraines, répercussions sur les systèmes écologiques du Nord et intégrité des écosystèmes aquatiques. Les scientifiques du Centre, en collaboration avec des partenaires canadiens et étrangers, participent à des programmes de recherche pluridisciplinaire visant à résoudre des problèmes écologiques régionaux, nationaux et mondiaux.

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