beak

Study of Toxic Substances in the Great Lakes

Analysis of Heavy Metals

a report for Environment Canada

Government of Canada / Gouvernement du Canada

MEMORANDUM **NOTE DE SERVICE**

M.J.Strachan/NWRI/4222/emk

SECURITY-CLASSIFICATION-DE SÉCURITÉ

OUR FILE—N/RÉFÉRENCE
1135-E5-1

YOUR FILE—V/RÉFÉRENCE

DATE
20 August 1979

TO / A
Dr. R. Bisson
Contaminants Control Branch
Environmental Impact Control Directorate
Environmental Protection Service

FROM / DE
Head, Toxic Substances Section
National Water Research Institute
Environmental Management Service

SUBJECT / OBJET Environmental Contaminants Contract Fund:
Project 929-EMS-CCIW-77-302: Toxic Substances in the Great Lakes

The report on the above project, sited in Lake Superior, was received earlier and nine copies transmitted to yourself, c/o Contaminants Control Branch. This memo constitutes the report of the Scientific Authority. It is, in fact, a distillation of comments by Mr. M. Whittle, who provided very necessary liaison and assistance from Great Lakes Biolimnology Laboratory, and myself.

The samples were all collected by ourselves (sediments, suspended material and water) and Ontario Ministry of Natural Resources (fish). The latter were processed at the Canada Centre for Inland Waters using the accepted procedures of the Surveillance Programme of the International Joint Commission Water Quality Board. Sample material not employed in these analyses will be stored in a tissue bank and will be very useful in extending the time frame back (to 1979) for those regions of Lake Superior which were sampled. Only the sediments and fishes were provided for metal analyses because the amount of material in the case of suspended material and water was not high; all four types were submitted for organic analyses. The balance of this report is broken into organics and metals because this is the presentation of the contractors which was brought about, in turn, by the tendering process and the uncertainty, initially, of whether there would be enough funds for both parts.

Organic Analyses:

Beak has basically used the methods of IWD/WQB with some modifications. In principle, they should be adequate and their recovery tests would seem to bear this out. Their results from the water samples are investigative (resin adsorption was included as an experimental item) and must be viewed with caution as the methods are untried. They are, however, quite interesting. The three blanks indicate considerable background interference but above this, the following statistically significant results (in ppt) were observed:

Thunder Bay: dieldrin (0.8); PCP (4.5); lindane (1.8)
Marathon: - lindane (2.3)
Michipicoten: dieldrin (0.2); PCP (1.7); Lindane (1.8); endrin (0.5)

In general, for the other substances and locations, high blanks and variability does not allow quantitation of any of the substances. The dominance of DDE (over other DDT forms) in this medium is to be expected; PCB seem to be present but at levels of less than 1 ppt.

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In the analysis of the suspended material, which was obtained with the same frequency and location as the water samples, it is not possible to make comments about statistical significance because it is not possible to have an appropriate blank. Hence the comments below pertain only to means which were significantly different from zero and from each other. Levels are in ppm.

DDE: Again the most dominant DDT form (as expected), although DDD is appearing; DDE is highest in Michipicoten (0.2), followed by Thunder Bay (0.05), then Marathon (0.03).

PCBs: Michipicoten (0.3) which is surprising for the location; other locations were comparable but not statistically different from zero.

α-*endosulfan:* This environmentally unstable compound was found in all three areas with Michipicoten highest (3.6); the β-isomer was also observed but at levels which were not significant.

There were other substances noted but when evaluated statistically, the area means were not significantly different from zero. This does not mean that the substances were not present, only that there was great variability in the values. PCP and HCB in particular should be noted - they were found in substantial quantities in all areas.

A. *Sediments:*

PCBs are generally low in all areas except at stations 14, 15, 16 and 19 (very close to the inner harbour at Marathon where the chloralkali plant effluent used to discharge) and reflects flows out of Penninsula Harbor. Station 14 is also replicated as sample 34A and 34AR which tend to confirm the results;

DDT residues are present at all stations, mainly as DDE. Fresh DDT apparently is entering the environment in a similar manner to the PCBs at Marathon and also at Michipicoten; except for the questionable extreme value at station 7, station 10 (near the harbor) is the highest level in Thunder Bay;

HCB appears at decidedly elevated levels near the city of Thunder Bay itself; it also is found exiting from a source in Penninsular Harbor at even higher levels than in Thunder Bay and partially confirmed; it does not appear particularly at Michipicoten;

PCP is observed at a number of locations in Thunder Bay. There is a known source of this material in the city itself but no known reason can be offered for the particularly high values found near Pie Island and Sibley Penninsula. Levels in the Bay are generally higher than elsewhere. At Marathon, levels are low, except in Ashburton Bay, for which no explanation is offered. Michipicoten is notable that its levels are "elevated" although not so much as in Thunder Bay;

Methoxychlor is found in Michipicoten Bay to the north of the Montreal River.

All other contaminants showed much lower levels and no notable patterns.

B. *Fishes:* One objective of the study, although not required of the contractor, was to examine for constancy of the concentration ratio of contaminants in whole fish versus fillets in an attempt to integrate this study with others done elsewhere. This is currently being done. Initially, whitefish from Marathon show a whole fish:fillet ratio of 2:6 (26 pts, s.d. 1.2). This must be done with other species/contaminants/areas; obviously the permutations are large, as is the data base. It must also be examined as a function of sex and lipid content.

With respect to a qualitative evaluation for Priority List organic substances (excluding pesticides);

PCBs are present in all samples but especially at Marathon and in whitefish, a bottom feeder, in particular. These concentrations range from the sub ppm to tens of ppm with a few more extreme. These are definitely in the range of concern (2 ppm for food). *PCPs* are not currently reported but will be forthcoming from Beak. Their holdback depends on it - they estimate end of September. *Mirex* seems to be largely missing from Marathon except for a few Lake Trout; in Thunder Bay and Michipicoten, it is present in disturbing quantities, especially in the trout species. *HCB* appears in all three species in all three areas; it seems highest near Marathon, probably related to the chloralkali plant which was there and with which *HCB* formation has been associated.

Some special notations: The labels WTF for samples 26-30 on p. 47 should be LKT; the legend for symbols appears on p. 27, after the data quality tables, etc.; it may not be clear that Table I refers to a 50 litre sample - hence the figures given are 50 x concentration (in ppt); it may also not be clear that the samples in Table 2 were derived from 6092 ± 50 litres. (It is desirable to have the data presented in ng/g for comparison with sediments; it is also desirable to have it as ng/ℓ to compare with "dissolved") and also that the wet weight is in fact dry weight (105°C).

Metals Analyses

Several general comments can be noted. First, Beak's interlaboratory results with Hg in fish are excellent as is their comparison with reference material. This despite the extensive heating (220°C) of samples does much to ease the concern felt in that regard. Their replications for mercury are also reasonable although there did appear to be some "wild" replicate pairs (C_V = 0.61). For arsenic and cadmium, the analytical accuracy is reasonable and the precision acceptable for arsenic in fish generally and for cadmium in fillets. Arsenic precision is poor in sediments and cadmium is poor in sediments as well as in whole fish. This may reflect the fact that the analyzed values are near to the quantitation limits. Lead, on the other hand, is both inaccurate (ca. 4 x real value) and only fair on the precision. In this case it should be noted that the requested quantitation limits, based upon existing IWD procedures, was well above the values found.

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One aspect that requires commendation - their investigation of sample storage effects with mercury. Over a three-month period, there appears to be an increase in whole fish values, while in fillets the picture is inconsistent. On the average, however, the changes are not much greater than the replication and it would appear that the values reported in the study should be considered comparable.

On the blind replicates which were submitted, the contractor did not do so well. Mercury is acceptable for fish and sediments; arsenic is acceptable for fish and poor for sediments; replication for lead in fish is poor as it is apparently for sediments; cadmium is poor in both fish and sediments. The explanations above as to measuring at the quantitation limits are appropriate for the latter two metals. These two metals, however, also gave a non-random increase in reported levels between the "original" and the "blind". Since the blinds are scattered albeit among the fillets, this is difficult to rationalize on the basis of methodology change.

I would like to see, and will seek, additional comments on the methodology, particularly the absolute detection limits of their methods and further details on their procedures employed. For the purpose of this report, however, the following are offered:

Sediments

	Thunder Bay		Marathon		Michipicoten Bay	
	Mean	Cv	*Mean*	Cv	*Mean*	Cv
Hg	0.38	0.73	1.82	1.03	0.08	0.36
As	5.3	0.58	3.6	0.67	insufficient data	
Cd	1.54	0.28	1.25	0.42	2.45	0.63
Pb	38.1	0.42	32.5	0.42	44.6	0.41

There is no inherent reason why all sediments should have the same values at each location - the Cv merely indicates the variability of the concentration in the area. Marathon is considerably higher in mercury than the other areas; Michipicoten regretably, seems to have relatively elevated levels of Cd and Pb.

The fish data again is voluminous and will be examined in detail. Mercury in Marathon samples is higher in lake trout than whitefish. (Lean) Lake trout from Thunder Bay, however, seem to be comparable and a disturbing number are over the 0.5 g/g guideline. There also does not seem to be any distribution favouring the fillets. Lead levels are not significant per the preceding comments but seem to be higher in Thunder Bay and Michipicoten than at Marathon. There appears to be some accumulation in the fillet tissue. Cadmium has almost identical occurrence to lead in this study and similar comments apply. Arsenic does not have any regional or tissue accumulation. All of these aspects, in the next six months, will receive closer scrutiny and evaluation.

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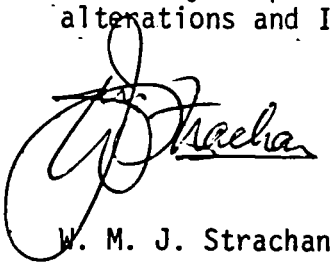
It should be noted that the correction factors indicated on p. 19 do not apply (and were not) to the sediment samples. This was an error on the part of the contractor in preparing his report. Please note this in all copies.

I would also, personally, like to thank all of those persons who assisted in this study. Aside from CCIW personnel, you and Dr. Hyslop at D.S.S. were very cooperative with various requests that I made for contract alterations and I am grateful.



W. M. J. Strachan, Ph.D.

cc: M. Whittle, Great Lakes Biolimnology Laboratory

APPENDIX 1

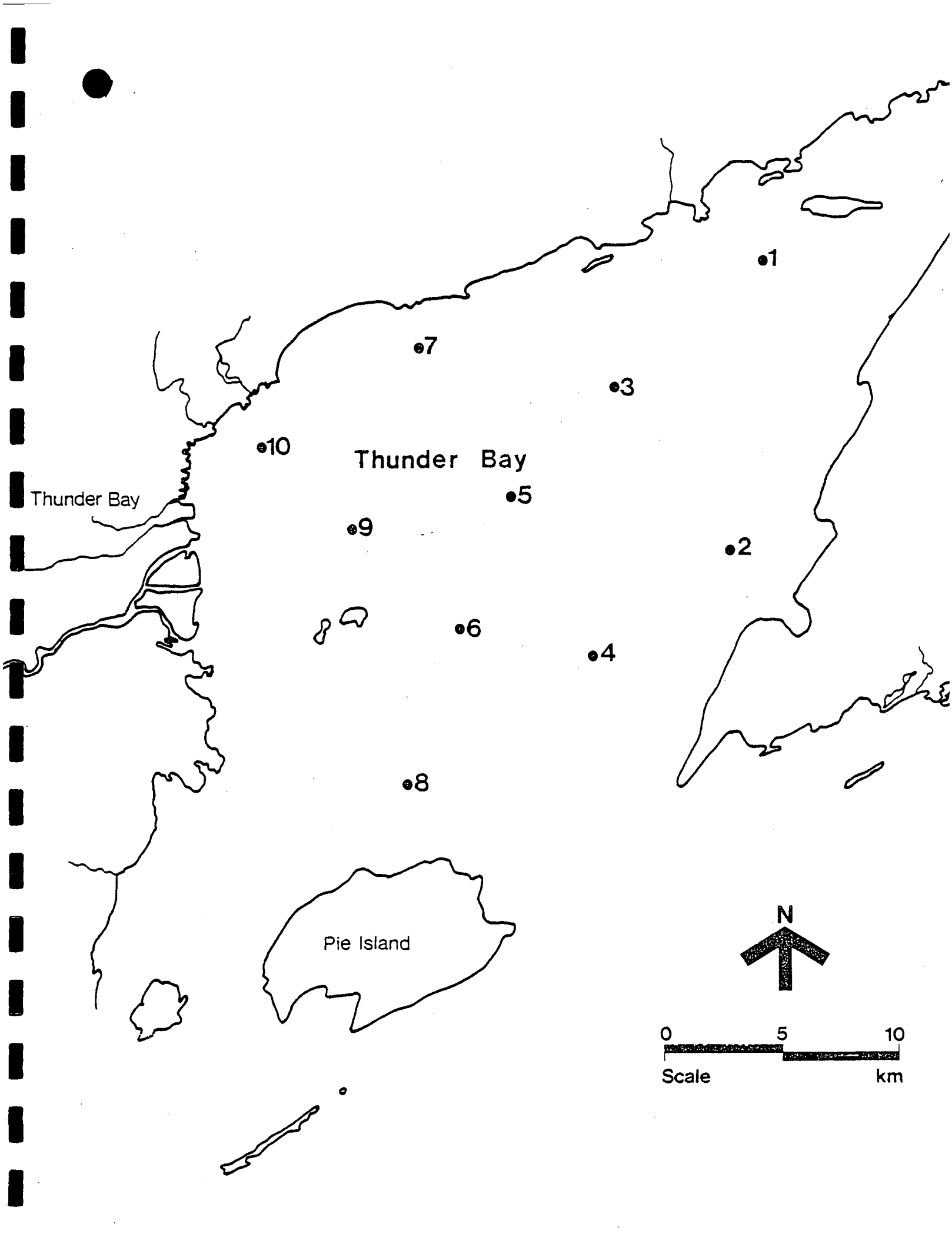
STATION LOCATIONS AND MAPS

N.B. Study of analysis of trace organics filed under TD 427 07 S78 1979

LAKE SUPERIOR - 1978/79
TOXIC SUBSTANCES CRUISE

Station Number	Latitude N.	Longitude W.	Station Designation
1	48° 30' 00"	88° 54' 00"	S
2	48° 23' 30"	88° 54' 30"	S
3	48° 27' 00"	88° 58' 00"	S & W
4	48° 21' 00"	88° 59' 00"	S & W
5	48° 24' 30"	89° 02' 00"	S
6	48° 21' 30"	89° 04' 00"	S
7	48° 28' 00"	89° 05' 00"	S
8	48° 18' 00"	89° 05' 30"	S
9	48° 24' 00"	89° 08' 00"	S & W
10	48° 26' 00"	89° 10' 00"	S
11	48° 39' 30"	86° 22' 30"	S
12	48° 40' 30"	86° 23' 00"	S
13	48° 41' 30"	86° 24' 00"	S & W
14	48° 43' 30"	86° 24' 30"	S & W
15	48° 42' 00"	86° 25' 00"	S
16	48° 43' 00"	86° 25' 30"	S
17	48° 43' 30"	86° 26' 30"	S & W
18	48° 44' 00"	86° 27' 00"	S
19	48° 45' 00"	86° 27' 30"	S
20	48° 45' 00"	86° 30' 00"	S
21	47° 55' 30"	84° 51' 00"	S & W
22	47° 57' 00"	84° 52' 30"	S & W
23	47° 55' 00"	84° 54' 00"	S & W
24	47° 53' 00"	84° 56' 30"	S
25	47° 55' 00"	84° 58' 00"	S
26	47° 51' 00"	84° 59' 00"	S
27	47° 49' 00"	85° 02' 00"	S
28	47° 55' 00"	85° 02' 00"	S
29	47° 55' 00"	85° 06' 00"	S
30	47° 55' 00"	85° 10' 00"	S

S - Sediment
S & W - Sediment & Water


1
7
3
10
Thunder Bay
Thunder Bay
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Pie Island
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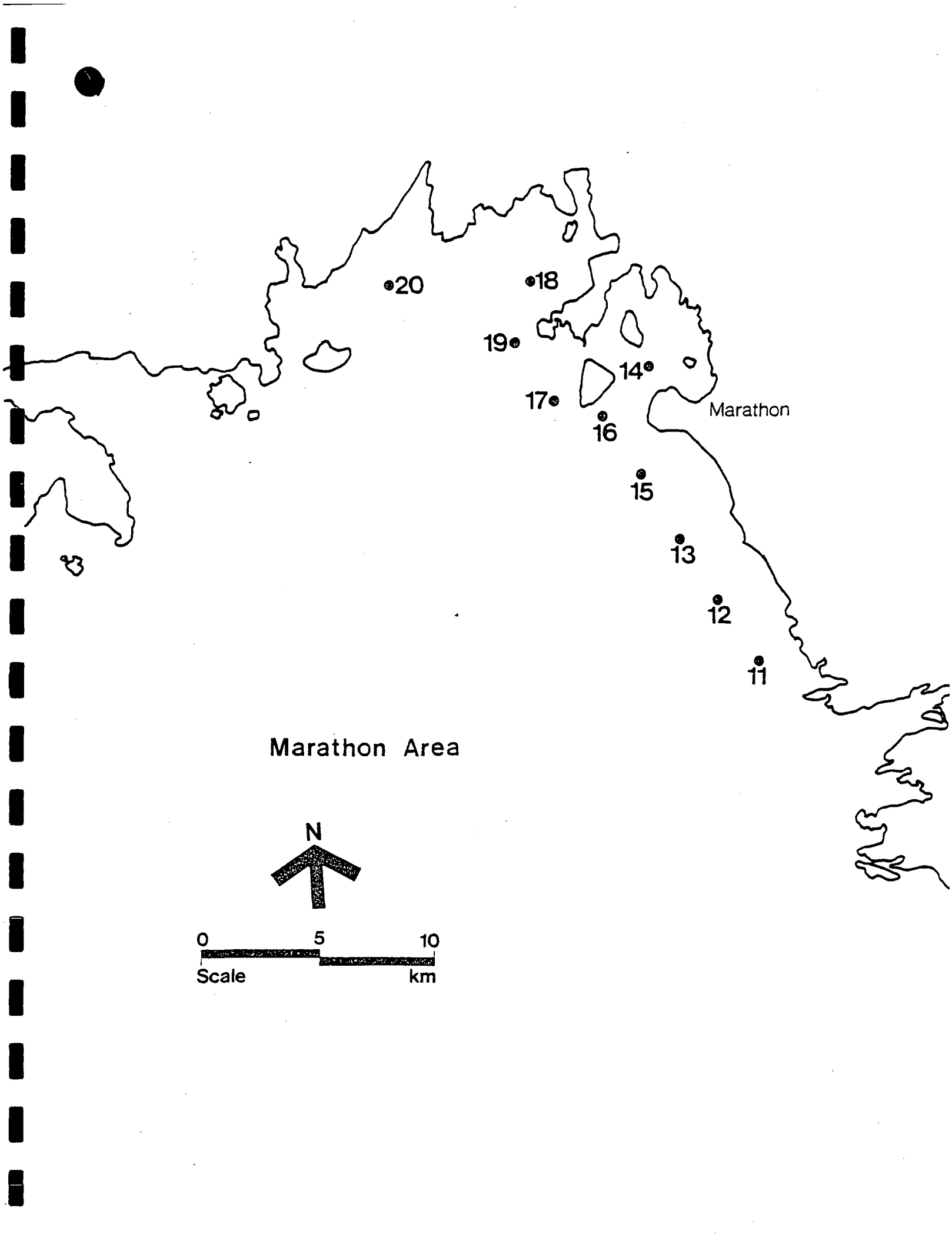
Scale
km


20
18
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14
17
Marathon
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13
12
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Marathon Area
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5
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Scale
km

APPENDIX 1

Beak Consultants Limited

Montreal
Toronto
Saskatoon
Calgary
Vancouver

6870 Goreway Drive
Mississauga/Ontario/Canada
L4V 1L9
Telephone (416) 671-2600
Telex 06-983527

STUDY OF TOXIC SUBSTANCES IN THE GREAT LAKES: SAMPLE ANALYSES FOR METALS

A Report for

DEPARTMENT OF FISHERIES AND ENVIRONMENT
PROCESS RESEARCH DIVISION
CANADA CENTRE FOR INLAND WATERS
BURLINGTON, ONTARIO

JULY 1979

A MEMBER OF THE SANDWELL GROUP

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1.0 INTRODUCTION

During the summer of 1978, Beak Consultants Limited was awarded a contract by Supply and Services Canada as a result of a successful response to a Request for Proposal titled "Study of Toxic Substances in the Great Lakes - Sample Analyses for Metals".

The Department of Fisheries and Environment conducted a survey in Lake Superior during the period 8 to 23 June 1978, sampling in Thunder Bay, Marathon and Michipicoten areas. Ten sampling stations were chosen in each area and included the collection of water, sediment, and fish samples from lightly polluted and unpolluted areas. The Scientific Authority was responsible for the collection and preparation of all samples and these were then supplied to BEAK for analysis of lipids, moisture, arsenic, cadmium, lead, and mercury.

This report describes the analytical procedures, documents the findings, and discusses the results with respect to parameters investigated.

2.0 DESCRIPTION OF FIELD PROGRAM

2.1 Sample Type

Duplicate Shipek grab samples of surface sediments and sediment core samples were obtained. Complete details of surface sediments, including pH, Eh, depth, and sediment description are given below:

Station	Depth	Temperature	Eh	pH	Description of Surface
Thunder Bay					
1	40	4.9/4.9	+280/+290	7.8/8.1	Soft, brown silt
2	40	5.0	+290	7.5	Dark brown mud
3	38	4.9/4.8	+270/+300	8.1/8.2	Dark brown, silty mud
4	69	4.5	+100/+63	6.9/6.9	Soft, brown silt
5	58	4.8/4.8	+310/+250	6.9/7.2	Brown silty mud
6	55	5.0/5.0	+240/+300	6.7/6.5	Green brown silt
7	41	4.5/4.5	-160/-35	6.7/7.2	Brown silty mud
8	23.7	6.2/6.2	+145/+170	8.3/8.3	Sand and gravel
9	30	6.1/6.2	+20/0	7.6/7.5	Brown silt
10	21	6.1/6.1	-130/-130	7.1/7.1	Grey clay
Marathon					
11	84.0	4.6	-100	7.8	Dark grey clay
12	73.0	4.4	-80	7.6	Sandy, light brown
13	69.5	5.0/5.0	+170/+220	7.9/8.0	Fine clay, brown
14	40.0	4.8/4.9	+200/+200	7.3/7.4	Silty sand
15	80.0	4.0/4.0	-120/-170	7.4/8.0	
16	76.0	4.0/4.0	-220/-210	7.3/7.4	Sandy silt
17	27.0	5.0/5.0	-110/-100	8.3/8.2	Dark grey gravel
18	40.0	4.5/4.6	+120/+120	8.4/8.3	Grey layered clay
19	91.0	4.1/4.2	-100/-100	7.8/7.9	Slimy, dark grey
20	120.0	4.5/4.5	-180/-175	7.6/7.6	Dark grey slime

(continued)

Station	Depth	Temperature	Eh	pH	Description of Surface
Michipicoten					
21	56	4.0	-20	6.9	Dark grey
22	56	4.3/4.1	-110/-120	7.8/7.6	Dark brown
23	93	3.7/3.7	-110/-105	6.8/6.8	Grey brown silt
24	129	3.0	+135	6.2	Dark silt
25	109	4.0	+225	7.3	Dark brown silt
26	172	3.0/3.6	-20/-50	7.2/7.0	Green grey silt
27	180	3.2/3.2	+260/+220	6.5/6.5	Green grey silt
28	79	3.6/3.6	+235/+240	7.4/7.3	Light brown silt
29	95	3.5/3.7	+250/+265	7.5/7.4	Sand and dark brown
30	80	3.7/3.7	+260/+270	7.1/7.1	Light brown and sand

Each half of the duplicate grab sample was divided into three subsamples with one subsample being stored frozen in either a glass jar, a plastic vial, or a plastic bag.

One set of glass vials, for organochlorine analysis, listed below, including replicates from Stations 9, 14, and 21, and one set of plastic vials for heavy metal analysis, including the replicates from Stations 9, 14, and 21, were sent to BEAK for analysis of Pb, As, Cd, and Hg.

Cores were stored in the dark at 4°C and subsequently extruded. Segments from 0 to 1 cm, 1 to 2 cm, 8 to 9 cm, 9 to 10 cm, 20 to 21 cm, and 40 to 41 cm, were taken and stored at 4°C for future study.

2.2 Location of Stations

The location of stations and maps are presented in Appendix 1.

3.0 DESCRIPTION OF ANALYTICAL PROGRAM

3.1 Sample Type

A total of 33 sediment samples and 259 fish samples were submitted for trace metal analysis. In addition, moisture was to be determined in all sediments and lipids in fish tissue.

Sediments were supplied frozen in polystyrene containers. It was determined prior to defrosting that most of the containers had cracked and a few were split. Steps were taken to minimize contamination and loss of water by transferring the sediment to plastic bags.

About 50 grams of minced, blended fish tissue including separate whole fish and fillet samples was supplied in 4 oz. clean glass jars. Many samples were found to be of non-uniform consistency, showing stringy and lumpy characteristics. Some samples contained pieces of bone and skin. Discolouration was observed in a number of fish tissues which may be attributed to air oxidation in the jars.

3.2 Analytical Procedures

3.2.1 Fish

Prior to weighing, each tissue sample was thoroughly mixed to ensure that any separated oil and water were uniformly distributed to provide as homogeneous a matrix as possible. Lumpy flesh, skin and bone were excluded.

Mercury:- A sample (0.2 g) was weighed out and heated with 5.0 mL H_2SO_4 :HNO_3 (3:1) overnight at 90°C. Samples were heated to fuming (220°C) and then cooled. Six percent (1.5 mL) $KMnO_4$ was added and the samples were left for two hours. Thirty percent H_2O_2 was then added dropwise to remove about 95 percent of the brown precipitates. The sample was then made up to 50 mL and mercury was determined by cold vapour technique.

Arsenic, Cadmium, Lead:- A 5 to 6 g portion was weighed out and digested on a sand bath at a final temperature of 210°C with 10 mL HNO_3, 4 mL $HClO_4$ and 2 mL 50 percent H_2SO_4 until dense white fumes were evident and the remaining solution was clear and light green yellow. If samples were oily, more acid was added to prevent charring. The sample

was made up to 25 mL and cadmium and lead were determined by flame atomic absorption. A portion of the sample was used to analyze for arsenic by flameless hydride generation technique.

Lipids:- About 10 g of wet tissue were mixed intimately with an appropriate weight of sodium sulphate. The mixture was extracted for 8 to 9 hours with hexane in a soxhlet apparatus. After evaporation of the solvent, the residue was weighed and reported as lipid content.

3.2.2 Sediments

Sediments were analyzed as received without sieving.

Mercury:- About 1.5 g wet sediment were weighed out (another portion was weighed out simultaneously for moisture determination) and digested for 1 hour at 90°C with 5.0 mL H_2SO_4:HNO_3 (3:1). Concentrated HCl (2 mL) was then carefully added to the sample. After frothing had subsided, the sample was heated at 90°C until brown fumes ceased evolving. After cooling, 6 mL 6 percent $KMnO_4$ and 1 mL 5 percent $K_2S_2O_8$ was added to the sample, which was then left overnight. Hydroxylamine sulphate (0.25 mL, 5 percent) was added to remove the brown precipitation. The sample was then made up to 50 mL and mercury was determined by cold vapour technique.

Arsenic:- Dry sediment (1.0 g) was weighed out and digested with 10 mL concentrated HCl at 100°C for 1 hour. Then 1 mL $K_2S_2O_8$ (5%) was added and digestion was continued (water losses were replaced) for another 2 hours. The sample was then made up to 50 mL and arsenic was determined by the flameless hydride generation technique.

Cadmium, Lead:- Were determined by flame atomic absorption after 1.0 g dry sediment was digested at 90°C with 10 mL aqua regia (HCL:HNO_3; 3:1) for 2 hours. The sample was made up to 50 mL and allowed to settle overnight. Cadmium and lead were determined on the supernatant.

Moisture:- A portion of the sediment was dried overnight at 105°C and loss of water content reported as % moisture.

3.3 Analytical Quality Assurance

3.3.1 Interlaboratory Cross-Checks

BEAK participates in a number of cross-check programs with outside agencies for mercury analysis. One such program is with Environment Canada, Fisheries and Marine Service, Winnipeg. The most recent results for fish flesh are reported below as µg/g mercury.

	Sample Number (April 1978)			
	76	77	78	79
Fisheries & Marine Lab.	1.04±0.06	0.56±0.03	0.47±0.03	0.33±0.04
BEAK Lab.	1.08±0.05	0.65±0.04	0.57±0.03	0.41±0.01
Correction Factor	0.963	0.862	0.825	0.805

	Sample Number (August 1978)			
	80	81	82	83
Fisheries & Marine Lab.	0.83±0.04	0.55±0.04	0.41±0.04	0.26±0.04
BEAK Lab.	0.88±0.03	0.59±0.01	0.45±0.03	0.28±0.01
Correction Factor	0.943	0.932	0.911	0.929

	Sample Number (January 1979)			
	84	85	86	87
Fisheries & Marine Lab.	0.17±0.04	1.26±0.11	0.56±0.06	0.43±0.04
BEAK Lab.	0.13±0.03	1.00±0.06	0.46±0.03	0.36±0.05
Correction Factor	1.307	1.259	1.218	1.195

The January 1979 set was analyzed at the same time as fish tissues for this project. It appears that a small bias may have been introduced. The average correction factor determined is 1.24.

Only limited data are available for sediments. We have not received written reports for two sediment cross-checks including the one with C.C.I.W. One previous interlaboratory evaluation with 5 laboratories proved inconclusive, although our values were mean in a set of scattered values. An extensive comparison between two laboratories (1) showed that copper and lead values were consistent, but zinc and cadmium inconsistent. Our values were used in the data interpretation.

3.3.2 Standard Reference Materials

The following reference biological materials were analyzed during this project and used to normalize the raw data generated:

1. Bovine Liver 1577. National Bureau of Standard U.S.
2. Albacor Tuna Research Material 50. National Bureau of Standard U.S.
3. Oyster Homogenate MA-M-1. International Atomic Energy Agency.
4. Fish Homogenate MA-A-2. International Atomic Energy Agency.

		µg/g		
	Arsenic	Cadmium	Lead	Mercury
Bovine Liver 1577		0.27±0.04	0.34±0.08	
BEAK		0.32±0.02	1.32±0.07	
Correction Factor		0.84	0.26	
Albacore Tuna 50	3.3±0.4	-	0.46	0.95±0.1
BEAK	3.6±0.1	(0.01±0.01)	1.63±0.14	0.96±0.08
Correction Factor	0.91	-	0.28	None
Oyster MA-M-1	12.3±0.3	2.3±0.1	1.3±0.2	
BEAK	14.0±0.7	2.1±0.1	4.5±0.05	
Correction Factor	0.89	1.10	0.29	
Fish MA-A-2 (Provisional)		0.16±0.04	0.7	0.48±0.02
BEAK		0.20±0.05	1.4±0.1	0.50±0.08
Correction Factor		0.80	-	None

The coefficients of variation (C_v) determined from the above study are: arsenic (0.027, 0.050), cadmium (0.063, 0.048, 0.25), lead (0.053, 0.086, 0.11, 0.071), and mercury (0.010, 0.16). C_v values vary with type of reference material analyzed and increase with approach to the detection limit. At least three separate determinations were made for each material.

The differences observed in BEAK and reference results are reflected in the correction factors provided. Average corrections were applied to analytical data as discussed later.

3.3.3 Internal Replicate Analyses

Many of the fish samples were analyzed in replicate in order to provide an internal check on analytical variability including sample effects. Results with * after them in the following tables are somewhat suspect.

Results of Replicate Analyses (µg/g)

Whole Fish

	Arsenic			Cadmium			Lead		
LS 3 AM	0.28	0.32		0.21	0.17		0.25	0.25	
LS 12 AM	0.44*	0.30		<0.01*	0.11		0.06*	0.03	
LS 15 AM	0.61*	0.26		<0.01*	0.14		0.06*	0.17	
LS 20 AM	0.85*	0.77		<0.01*	0.16		0.14*	0.22	
LS 22 AM	0.41*	0.41	0.46	0.09*	0.14	<0.01	0.08*	0.17	0.14
LS 30 AM	0.18*	0.28		<0.01*	0.11		<0.03*	0.17	
LS 34 AM	0.37	0.23	0.36	0.11	0.11	0.16	0.11	0.11	
LS 50 AM	0.18	0.14		0.07*	0.16		0.14*	0.20	
LS 62 AM	0.17	0.17		<0.01*	0.13		0.06*	0.14	
LS 63 AM	0.19	0.19		0.10	0.15		0.08	0.14	
LS 64 AM	0.19	0.23		0.11	0.02		<0.03	0.11	
LS 74 AM	0.40	0.28		0.22	0.17		0.11	0.08	
LS 75 AM	0.28	0.33		<0.01	0.12		<0.03	0.17	
LS 78 AM	0.31	0.29		<0.01	0.16		<0.03	0.17	
LS 88 AM	0.58	0.23		0.18	0.19		0.31	0.28	
LS 91 AM	0.56	0.30		0.17	0.19		0.20	0.17	
LS 113 AM	0.41	0.51		0.19	0.11		0.20	0.14	

Fillet

	Arsenic		Cadmium		Lead	
LS 6 BM	0.21	0.43	0.15	0.19	0.08	0.11
LS 18 BM	0.29	0.29	0.13	0.13	0.08	0.08
LS 28 BM	0.43	0.32	0.13	0.12	0.20	0.17
LS 36 BM	0.23	0.23	0.11	0.11	0.06	0.06
LS 46 BM	0.16	0.22	0.16	0.19	0.08	0.20
LS 56 BM	0.22	0.14	0.10	0.11	0.08	0.08
LS 73 BM	0.20	0.35	0.15	<0.01	0.06	<0.03
LS 74 BM	0.50*	0.23*	0.11*	0.12*	0.08*	0.06*
LS 74 BM	0.16	0.20	0.15	0.16	0.06	<0.03
LS 75 BM	0.35*	0.30	0.07*	0.07	<0.03*	0.08
LS 81 BM	0.19	0.18*	0.07	0.10*	0.06	0.03*
LS 90 BM	0.14	0.14	0.11	0.10	0.06	0.03
LS 100 BM	0.10	0.21	0.11	0.13	0.06	0.08
LS 115 BM	0.58*	0.20	0.15*	0.11	0.06*	0.03
LS 118 BM	0.43	0.30	0.10	0.10	0.06	0.06
LS 123 BM	0.35	0.37	0.08	<0.01	0.03	<0.03
LS 130 BM	0.37	0.72	0.11	0.03	0.06	<0.03

Results of Replicate Analyses (µg/g)

Mercury

	Whole Fish		Fillet	
LS 1 AM	0.192	0.179	0.040	0.167
LS 2 AM	1.352	0.751	0.715	1.893
LS 6 AM	0.223	0.182	0.798	0.723
LS 14 AM	0.209	0.197	0.040	0.106
LS 26 AM	0.112	0.117	0.278	0.263
LS 33 AM	1.006	0.743	1.427	0.963

Whole Fish			Fillet			
LS 34 AM	0.439	0.500	LS 38 BM	0.146	0.222	
LS 48 AM	0.070	0.066	LS 42 BM	1.028	0.985	
LS 57 AM	0.030	0.036	LS 45 BM	0.498	0.528	
LS 69 AM	0.027	0.025	LS 48 BM	0.160	0.154	
LS 73 AM	1.505	2.138	LS 52 BM	0.096	0.103	
LS 74 AM	1.522	1.714	LS 58 BM	0.089	0.091	
LS 78 AM	0.328	0.384	LS 67 BM	0.122	0.119	
LS 84 AM	0.087	0.137	LS 73 BM	2.50	2.33	
LS 90 AM	0.231	0.233	LS 82 BM	0.555	0.564	
LS 100 AM	0.451	0.369	LS 90 BM	0.208	0.251	
LS 108 AM	0.169	0.229	LS 99 BM	0.246	0.164	0.320
LS 118 AM	0.790	0.840	LS 114 BM	1.371	0.890	
LS 124 AM	0.783	0.800	LS 119 BM	0.945	1.046	
LS 125 AM	0.801	0.821	LS 121 BM	0.878	0.947	
LS 131 AM	0.173	0.270	LS 129 BM	1.094	0.831	
			LS 20 BM	0.705	0.930	
			LS 104 BM	0.312	0.352	

Sediments were all carried through a duplicate analysis. The results are reported in Table 11 in the following section.

Comparison of replicate data is made by means of their coefficients of variation ($\sigma/\bar{x}$). The following table gives the average C_v, the range of C_v values observed and the selected range after removing outliers.

Some comments can be made regarding trends for paired fish data. Variation increases with approach to the detection limits for different parameters and the increase is similar to that observed for the reference materials. Generally, the C_v for metal values is higher in the fish samples tested than in the reference standards and may be due to the physical characteristics of the tissues.

A comparison of whole fish and fillet data suggests that precision is about the same for the metals except for cadmium and lead where the C_v was significantly higher for the whole fish. In other work (1) it has been shown that variability between samples is in part a function of sample integrity and type of fish species analyzed.

Coefficients of Variations (Cv) for Replicate Analyses

	Arsenic	Cadmium	Mercury	Lead
FISH TISSUE				
Fillet				
Average Cv	0.18 (17)	0.18 (17)	0.14 (23)	0.22 (17)
Range	0.0 - 0.49 (17)	0.0 - 0.88 (17)	0.008 - 0.61 (23)	0.0 - 0.46 (17)
Range Selected	0.0 - 0.28 (12)	0.0 - 0.12 (12)	0.008 - 0.26 (20)	0.0 - 0.33 (15)
Whole Fish				
Average Cv	0.16 (17)	0.51 (17)	0.091 (21)	0.31 (17)
Range	0.0 - 0.43 (17)	0.03 - 0.88 (17)	0.004 - 0.29 (21)	0.0 - 0.70 (17)
Range Selected	0.0 - 0.22 (14)	0.03 - 0.69 (10)	0.004 - 0.10 (15)	0.0 - 0.48 (14)
SEDIMENTS				
Average Cv	0.30 (26)	0.29 (32)	0.034 (33)	0.13 (22)
Range	0.022 - 0.837 (26)	0.0 - 0.860 (32)	0.0 - 0.171 (33)	0.003 - 0.343 (22)
Range Selected	0.022 - 0.354 (21)	0.0 - 0.471 (25)	0.0 - 0.049 (27)	0.003 - 0.196 (19)

3.3.4 Effect of Sample Handling on Mercury Recovery

Analyses were carried out to determine if sample handling and storage of fish tissues over the period of this project would affect mercury results. The following table presents the dates and results of this investigations.

Sample	Date Analyzed	Mercury (ppm)	Date Analyzed	Mercury (ppm)	Average	Cv
LS 1AM	11 Jan.	0.192, 0.179	5 April	0.235	0.210	0.12
LS 14AM	11 Jan.	0.209, 0.197	5 April	0.254	0.229	0.11
LS 26AM	11 Jan.	0.112, 0.117	5 April	0.146	0.131	0.12
LS 48AM	12 Jan.	0.070, 0.066	5 April	0.116	0.092	0.26
LS 90AM	13 Jan.	0.231, 0.233	5 April	0.223	0.228	0.020
	Average	0.160		0.194		0.13
LS 10BM	15 Jan.	0.798, 0.723	5 April	1.165	0.963	0.21
LS 25BM	17 Jan.	0.278, 0.263	5 April	0.276	0.274	0.009
LS 58BM	18 Jan.	0.089, 0.091	5 April	0.068	0.079	0.14
LS 67BM	18 Jan.	0.122, 0.119	5 April	0.086	0.103	0.17
LS 82BM	18 Jan.	0.555, 0.564	5 April	0.583	0.572	0.02
	Average	0.361		0.436		0.11

There appears to be an increase in average mercury concentration most likely due to dehydration resulting from freezer burn and sample handling. C_V values are similar and, because the original analyses were carried out over a short span of time, this effect may be assumed to be negligible.

3.3.5 Blind Replicate Analyses

Replicate samples of whole fish were distributed in the fillet group of tissues to provide an external check on analytical variability and bias of results. The values for the original fish and replicates are presented below.

Sample LSAM	Mercury (µg/g)			Arsenic (µg/g)			% Lipids
	Original	Blind	Cv	Original	Blind	Cv	
1	0.192 0.179	0.064	0.49	0.56	0.39	0.18	17.4, 14.4
2	1.352 0.751	0.705	0.20	0.18	0.20	0.05	18.7, 16.4
3	0.355	0.341	0.02	0.28 0.32	0.37	0.10	22.2, 22.8
4	0.279	0.296	0.03	0.33	0.41	0.11	18.6, 18.5
5	0.250	0.249	0.00	0.50	0.43	0.14	20.2, 20.6
6	0.223 0.182	0.225	0.05	0.40	0.54	0.15	18.8, 17.3
7	0.154	0.132	0.08	0.43	0.27	0.23	18.2, 18.9
8	0.228	0.300	0.14	0.59	0.28	0.36	19.2, 19.7
9	0.139	0.203	0.12	0.33	0.36	0.04	20.5, 20.1
10	0.701	1.050	0.20	0.16	0.22	0.16	9.1, 8.2
11	0.322	0.381	0.08	0.62	0.38	0.24	25.3, 25.4
12	0.247	0.333	0.15	0.30	0.21	0.18	23.3, 24.0
13	0.233	0.249	0.03	0.53	0.22	0.41	21.1, 13.2
14	0.209	0.230	0.05	0.54	0.36	0.20	24.9, 25.0

Sample LSAM	Mercury (µg/g) Original	Blind	Cv	Arsenic (µg/g) Original	Blind	Cv	% Lipids
15	0.289	0.274	0.03	0.26	0.18	0.18	20.8, 20.9
16	0.201	0.214	0.03	0.33	0.32	0.02	23.9, 24.2
17	0.217	0.205	0.03	0.54	0.37	0.19	24.6, 22.9
18	0.166	0.164	0.01	0.42	0.32	0.14	18.9, 21.4
19	0.175	0.114	0.17	0.55	0.34	0.24	17.0, 16.4
20	0.323	0.318	0.01	0.77	0.39	0.33	30.8, 29.1
21	0.382	0.312 0.352	0.07	0.64	0.20	0.52	24.3, 23.6
22	0.162	0.159	0.01	0.46 0.41	0.21	0.35	21.6, 22.7
23	0.240	0.193	0.11	0.41	0.41	0.00	21.8, 22.1
24	0.139	0.139	0.00	0.58	0.48	0.09	18.5, 18.5
		Average Cv	0.09		Average Cv	0.19	

Sample LSAM	Lead (µg/g)			Cadmium (µg/g)		
	Original	Blind	Cv	Original	Blind	Cv
1	0.06	0.20	0.54	0.02	0.18	0.80
2	0.11	0.17	0.18	0.03	0.14	0.65
3	0.25 0.25	0.20	0.11	0.21 0.17	0.13	0.19
4	0.08	0.17	0.36	0.03	0.11	0.57
5	0.06	0.20	0.51	0.01	0.13	0.85
6	0.03	0.34	0.84	0.01	0.18	0.89
7	0.03	0.22	0.76	0.01	0.17	0.89
8	0.08	0.20	0.14	0.01	0.11	0.83
9	0.03	0.11	0.57	<0.01	0.07	0.75
10	0.06	0.25	0.61	0.03	0.22	0.76
11	0.03	0.11	0.57	0.02	0.18	0.80
12	0.03	0.11	0.57	0.11	0.11	0.00
13	0.20	0.08	0.43	0.11	0.02	0.69
14	0.03	0.20	0.74	<0.01	0.22	0.91
15	0.17	0.20	0.08	0.14	0.21	0.20
16	0.06	0.25	0.61	0.03	0.26	0.79
17	0.03	0.22	0.76	0.01	0.22	0.91
18	0.06	0.17	0.45	0.01	0.10	0.82
19	0.06	0.08	0.14	0.02	0.13	0.73

Sample LSAM	Lead (µg/g) Original	Blind	Cv	Cadmium (µg/g) Original	Blind	Cv
20	0.22	0.22	0.00	0.16	0.17	0.03
21	0.03	0.06	0.33	<0.01	<0.01	0.00
22	0.17 0.14	0.20	0.13	0.14 <0.01	0.10	0.14
23	0.06	0.22	0.57	<0.01	0.18	0.89
24	0.17	0.20	0.08	<0.01	0.20	0.90
		Average Cv	0.43		Average Cv	0.59

The blind fish combinations were whole fish mixed in with fillet samples as follows:

LSAM	LSBM	LSAM	LSBM	LSAM	LSBM	LSAM	LSBM	LSAM	LSBM
1	19	6	53	11	71	16	110	21	104
2	20	7	57	12	72	17	111	22	105
3	26	8	68	13	84	18	88	23	106
4	27	9	69	14	108	19	95	24	107
5	28	10	70	15	109	20	103		

Good precision is observed for lipids, mercury, and arsenic. The C_V for blind replicates matches the internal replicates (mercury 0.09/0.09 and arsenic 0.19/0.16).

Poor precision is observed for lead and cadmium which corresponds to the large variability found in the internal replicates (lead 0.43/0.31 and cadmium 0.59/0.51). The somewhat higher coefficient for blind replicates is probably due to the performance of these analyses over a longer period of time. A substantial portion of the internal pairs were analyzed during the same time. The above C_V ratios (arsenic 1.19; lead 1.39; cadmium 1.16) suggest a potential bioas of 15 to 40 percent over the period of analysis.

The discrepancy in precision among metals may be ascribed to high reagent blanks. For mercury and arsenic, the blanks were less than 10 percent of the average reported values. For lead, the blank was five times, and for cadmium three times the average reported value. Because the fish tissues proved difficult to digest and samples required varied additions of nitric acid (especially during onset of charring or frothing), identical reagent blanks were not possible for each sample. It was not practical to use the same large quantities of acids for all digestions. These problems were not observed with the SRM's (6) which required known fixed volumes of reagents.

Because lead and cadmium are subject to flame absorption, light scattering and matrix interference, background correction is preferable in atomic absorption analysis. However, background correction causes a higher noise level resulting in poor sensitivity. When values are near the detection limit, decreasing sensitivity must be avoided. Adjusting data with SRM's is satisfactory provided all samples have the same matrix composition. A standard matrix is difficult to obtain with samples that consume varying amounts of perchloric and nitric acid.

Replicate samples of sediments were provided and results compared here.

Sample		Arsenic µg/g	Cadmium µg/g	Lead µg/g	Mercury µg/g	% Moisture
9A	Original	2.7	0.9	16.4	0.097	42.6
		3.2	0.8	13.4	0.089	
	Blind	0.7	1.0	15.5	0.192	46.6
		0.9	1.1	12.6	0.177	
14A	Original	0.8	0.9	15.0	6.01	40.2
		0.5	1.1	12.4	6.13	
	Blind	1.0	1.5	23.1	4.03	35.6
		3.9	1.2	20.2	4.40	
21A	Original	1.8	0.9	15.5	0.050	51.1
		3.0	0.7	15.0	0.051	
	Blind	5.1	1.3	47.1	0.047	44.4
		4.6	1.4	-	0.044	

The replicate pairs appeared to be somewhat physically different in terms of colour and texture and were combined as follows:

9A - 32A
14A - 33A
21A - 31A

Difficulty was experienced in replicating results. Original analysis showed very good precision on internal paired data but poor agreement with blind samples. Re-analysis of selected samples produced incompatible data. A complete analysis was again carried out and the best values reported for all samples.

The reason for such an observed range of values has not been satisfactorily explained. It appears that the original digestion was taken to near dryness. Aqua regia digestion is a weak acid leaching and increasing the length of time may cause solubilization of lead and cadmium not available under standard conditions. This may also apply to the hydrochloric-persulphate digestion for arsenic. Variation in analysis could also be associated with the heterogeneous nature of some of the sediments and the fact that they were not sieved prior to analysis.

If the original analysis were also correct, then there may be a geological component in the sediment which could yield metals under more rigorous decomposition conditions, but which may prove to have little environmental significance in terms of bioaccumulation.

4.0 ANALYSIS DATA

The following tables document the findings of this study. All results are reported as µg/g or ppm wet weight for fish and dry weight for sediments. The definitions and correction factors are given below.

Definition:

WTF	-	Whitefish
LKT	-	Lake trout
F. LKT	-	Fat lake trout
L. LKT	-	Lean lake trout
S. LKT	-	Sis lake trout
LSAM	-	Lake Superior whole fish metals
LSBM	-	Lake Superior fillet metals

Correction Factors:

The tabulated data has been corrected and normalized with respect to standard reference materials. The correction factors used on the original raw data are:

Mercury	-	None
Lead	-	0.28
Cadmium	-	0.82
Arsenic	-	0.90

Table 1

Collection Area: Marathon Ypres Pt.

Sample (LSAM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
1	WTF	56.8	2226.9	F	0.192	0.06	0.02	0.56	17.4
					0.179				
2	WTF	58.0	2124.2	F	1.352	0.11	0.03	0.18	18.7
					0.751				
3	WTF	56.0	1823.2	M	0.355	0.25	0.21	0.28	22.2
						0.25	0.17	0.32	
4	WTF	57.2	1777.1	M	0.279	0.08	0.03	0.33	18.6
5	WTF	52.2	1692.5	F	0.250	0.06	0.01	0.50	20.2
6	WTF	48.8	1156.5	M	0.223	0.03	0.01	0.40	18.8
					0.182				
7	WTF	49.2	1335.9	F	0.154	0.03	0.01	0.43	18.2
8	WTF	46.0	1189.3	F	0.228	0.08	0.01	0.59	19.2
9	WTF	44.5	988.5	M	0.139	0.03	<0.01	0.33	20.5
10	WTF	46.4	1116.9	M	0.701	0.06	0.03	0.16	9.1
11	WTF	55.9	1965.2	F	0.322	0.03	0.02	0.62	25.3
12	WTF	51.3	1568.1	F	0.247	0.06	<0.01	0.44	23.3
						0.03	0.11	0.30	
13	WTF	51.0	1452.0	F	0.233	0.08	0.02	0.53	21.1
14	WTF	50.1	1433.0	M	0.209	0.03	<0.01	0.54	24.9
					0.197				
15	WTF	52.5	1321.0	M	0.289	0.06	<0.01	0.61	20.8
						0.17	0.14	0.26	
16	WTF	50.2	1313.5	M	0.201	0.06	0.03	0.33	23.9
17	WTF	48.2	1243.0	M	0.217	0.03	0.01	0.54	24.6
18	WTF	48.3	1155.2	M	0.166	0.06	0.01	0.42	18.9
19	WTF	48.0	990.5	F	0.175	0.06	0.02	0.55	17.0
20	WTF	43.3	882.0	F	0.323	0.14	<0.01	0.85	30.8
						0.22	0.16	0.77	

Table 1 (continued)

Collection Area: Marathon Ypres Pt.

Sample (LSAM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm Hg	Pb	Cd	As	% Lipids
21	WTF	56.0	1774.0	F	0.382	0.03	<0.01	0.64	24.3
22	WTF	49.5	1448.0	F	0.162	0.08	0.09	0.36	21.6
						0.17	0.14	0.41	
						0.14	<0.01	0.41	
23	WTF	46.3	1393.0	F	0.240	0.06	<0.01	0.41	21.8
24	WTF	51.4	1377.0	F	0.139	0.17	<0.01	0.58	18.5
25	WTF	51.4	1414.0	F	0.149	0.06	0.01	0.74	19.8
26	LKT	30.3	266.1	Imm	0.112	0.06	0.01	0.24	7.7
					0.117				
27	LKT	27.9	138.5	Imm	0.111	0.06	0.02	0.14	3.2
28	LKT	31.9	326.0	M	0.240	0.14	0.02	0.20	14.4
29	LKT	50.3	1138.1	M	0.161	<0.03	<0.01	0.24	17.9
30	LKT	50.7	1514.1	F	0.975	<0.03	<0.01	0.18	42.6
						0.17	0.11	0.28	
31	LKT	75.0	4499.0	F	0.453	<0.03	<0.01	0.24	19.1
32	LKT	49.8	1854.0	F	0.384	0.03	0.02	0.23	21.7
33	LKT	54.6	2144.0	M	1.006	<0.03	<0.01	0.39	37.0
					0.743				
34	LKT	71.7	5359.0	F	0.439	0.11	0.11	0.37	44.6
					0.500	0.11	0.11	0.23	
							0.16	0.36	
35	LKT	71.7	4769.0	M	0.437	<0.03	<0.01	0.39	24.6
36	LKT	70.4	4609.0	M	0.399	0.06	<0.01	0.38	19.1
						0.06	0.01	0.17	

Table 2

Collection Area: S. Pie Island

Sample (LSAM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
48	WTF	49.6	1198.5	M	0.070	0.06	0.01	0.18	17.6
					0.066				
49	WTF	51.0	1364.0	M	0.079	0.06	<0.01	0.18	20.9
50	WTF	49.7	1048.0	M	0.071	0.14	0.07	0.18	15.1
						0.20	0.16	0.14	
51	WTF	53.6	1802.9	F	0.040	0.14	<0.01	0.14	14.6
52	WTF	51.2	1594.5	F	0.042	0.17	<0.01	0.10	18.0
53	WTF	43.0	918.5	F	0.074	0.11	0.01	0.28	18.3
54	WTF	48.3	1043.0	M	0.041	0.06	<0.01	0.18	14.7
55	WTF	47.1	1152.1	M	0.049	0.11	0.07	0.11	14.4
56	WTF	49.4	1289.4	F	0.073	<0.03	0.02	0.18	20.7
57	WTF	45.0	764.0	M	0.030	0.06	0.02	0.22	13.2
					0.036				
58	WTF	54.6	1811.0	F	0.042	0.06	<0.01	0.13	17.1
59	WTF	49.5	1424.9	F	0.018	0.11	0.01	0.17	13.6
60	WTF	48.8	1082.9	M	0.053	0.06	<0.01	0.14	14.2
61	WTF	49.5	1445.8	F	0.055	0.08	0.25	0.17	18.0
62	WTF	49.5	1312.5	F	0.053	0.06	<0.01	0.17	16.2
						0.14	0.13	0.17	
63	WTF	47.7	1095.2	F	0.032	0.08	0.10	0.19	15.5
						0.14	0.15	0.19	
64	WTF	50.0	1239.0	M	0.069	<0.03	0.11	0.19	18.3
						0.11	0.02	0.23	
65	WTF	51.2	1274.2	F	0.022	<0.03	<0.01	0.21	14.6
66	WTF	51.2	1369.8	F	0.035	0.11	0.10	0.23	17.0
67	WTF	45.3	928.0	M	0.040	0.06	0.02	0.23	14.7

Table 3

Collection Area: S.E. of Pie Island

Sample (LSAM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
68	F. LKT	39.5	568.1	F	0.045	<0.03	0.02	0.16	12.2
69	F. LKT	33.3	280.5	F	0.027 0.025	0.03	0.01	0.16	6.2
70	F. LKT	35.0	362.0	M	0.115	0.17	0.13	0.19	11.7
71	F. LKT	37.3	492.5	F	0.225	0.03	0.02	0.21	9.1
72	F. LKT	33.6	329.9	M	0.044	0.03	0.01	0.15	11.5
73	F. LKT	73.1	5707.5	F	1.505 2.138	<0.03	<0.01	0.22	35.8
74	F. LKT	77.4	6766.7	F	1.522 1.714	0.11 0.08	0.22 0.17	0.40 0.28	38.6
75	F. LKT	78.3	7693.6	F	0.789	<0.03 0.17	<0.01 0.12	0.28 0.33	48.9
76	F. LKT	70.6	4170.9	M	0.478	<0.03	<0.01	0.29	27.9
77	F. LKT	72.8	6346.4	F	0.458	<0.03	<0.01	0.23	30.7
78	F. LKT	60.9	2567.1	F	0.328 0.384	<0.03 0.17	<0.01 0.16	0.31 0.29	25.6
79	F. LKT	64.5	3060.7	F	0.256	<0.03	<0.01	0.20	19.5
80	F. LKT	54.0	1484.7	F	0.228	0.03	<0.01	0.23	9.6
81	F. LKT	54.4	2187.2	F	0.332	0.06	<0.01	0.20	20.6
82	F. LKT	66.7	4202.8	F	0.292	0.03	<0.01	0.17	29.4
83	F. LKT	70.0	4855.0	F	0.576	0.08	0.01	0.18	28.1

Table 3 (continued)

Collection Area: S.E. of Pie Island

Sample (LSAM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
84	F. LKT	35.1	381.0	M	0.087	0.28	0.17	0.23	9.9
					0.137				
85	F. LKT	43.8	1017.5	F	0.113	0.25	0.14	0.19	11.7
86	F. LKT	52.6	1463.3	M	0.143	0.28	0.13	0.19	18.4
87	F. LKT	49.5	1346.9	F	0.143	0.25	0.18	0.23	20.1
88	L. LKT	42.6	796.8	F	0.671	0.31	0.18	0.58	15.0
					0.741	0.31	0.19	0.23	
89	L. LKT	54.5	1544.9	F	0.133	0.28	0.19	0.32	14.4
90	L. LKT	53.6	1518.2	F	0.231	0.14	0.09	0.32	20.8
					0.233				
91	L. LKT	71.5	3927.4	M	0.355	0.20	0.17	0.56	24.1
						0.17	0.19	0.30	
92	L. LKT	50.8	1387.2	F	0.253	0.14	0.15	0.23	19.9
93	L. LKT	67.2	2907.9	M	0.391	0.17	0.11	0.42	24.4

Table 4

Collection Area: S. of Pie Island

Sample (LSAM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
94	L. LKT	64.8	2853.9	F	0.314	0.17	0.13	0.24	22.4
95	L. LKT	42.8	750.8	M	0.245	0.20	0.13	0.35	14.1
96	L. LKT	58.9	1944.1	F	0.377	0.08	0.06	0.23	17.3
97	L. LKT	68.0	6334.3	M	0.789	0.17	0.17	0.25	24.5
98	L. LKT	50.9	1271.5	F	0.227	0.20	0.19	0.22	10.9
99	L. LKT	54.6	1714.9	F	0.314	0.14	0.14	0.24	15.6
100	L. LKT	66.6	3337.0	F	0.451	0.11	0.03	0.32	23.7
					0.369				
101	L. LKT	66.9	3335.0	F	0.703	0.20	0.16	0.22	27.0
102	L. LKT	53.4	1633.0	F	0.307	0.08	0.14	0.22	16.0
103	L. LKT	47.3	940.5	Imm	0.220	0.17	0.17	0.19	13.7
104	L. LKT	47.5	997.5	Imm	0.336	0.17	0.19	0.21	14.5
105	L. LKT	45.5	986.0	Imm	0.204	0.14	0.11	0.21	16.3
106	L. LKT	44.5	892.0	Imm	0.196	0.17	0.15	0.18	12.0
107	L. LKT	46.5	1119.0	M	0.194	0.25	0.21	0.22	7.2
108	S. LKT	44.3	806.9	F	0.169	0.17	0.18	0.44	14.6
					0.229				
					0.160				
109	S. LKT	42.0	754.2	F	0.204	0.17	0.22	0.47	20.6
110	S. LKT	45.5	1033.0	F	0.281	0.22	0.21	0.22	20.1
111	S. LKT	43.2	934.6	F	0.224	0.17	0.18	0.23	12.0
112	S. LKT	57.5	1801.1	F	0.171	0.17	0.16	0.32	17.0

Table 5

Collection Area: Michipicoten

Sample (LSAM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
113	F. LKT	55.8	2486.0	F	0.563	0.20	0.19	0.36	51.1
						0.14	0.11	0.45	
114	F. LKT	58.4	2601.7	F	0.616	0.22	0.14	0.29	37.2
115	F. LKT	71.3	4942.0	F	0.704	0.14	0.19	0.48	51.6
116	F. LKT	66.0	4793.0	F	0.795	0.11	0.19	0.54	49.7
117	F. LKT	57.9	2611.8	F	0.513	0.11	0.18	0.46	19.9
118	F. LKT	71.5	5240.0	F	0.790	0.14	0.18	0.65	47.8
					0.840				
119	F. LKT	68.0	4831.5	F	0.728	0.03	0.14	0.61	54.8
120	F. LKT	58.6	2907.5	M	0.695	0.20	0.27	0.36	30.2
121	F. LKT	70.2	4341.5	F	0.757	0.08	0.14	0.27	49.2
122	F. LKT	66.3	4217.0	F	0.766	0.14	0.16	0.48	48.5
123	F. LKT	68.2	4771.5	F	0.801	0.08	0.11	0.48	58.5
124	F. LKT	69.5	4635.5	F	0.783	0.03	0.15	0.63	54.1
					0.800				
125	F. LKT	67.1	4422.5	F	0.801	0.14	0.23	0.32	67.2
					0.821				
126	F. LKT	66.3	4446.0	F	0.814	0.17	0.20	0.64	49.4
127	F. LKT	64.2	4134.5	F	0.645	0.14	0.19	0.52	50.0
128	F. LKT	67.3	4172.0	F	0.690	0.20	0.21	0.34	50.7
129	F. LKT	58.9	3087.2	F	0.619	0.20	0.21	0.23	41.7
130	F. LKT	70.5	3999.0	F	0.593	0.25	0.21	0.37	43.1
131	F. LKT	63.1	3392.3	F	0.173	0.22	0.25	0.39	28.7
					0.270				
132	F. LKT	62.8	3920.5	F	0.501	0.20	0.20	0.31	43.6
133	F. LKT	61.8	3463.5	F	0.509	0.20	0.21	0.27	41.2
134	F. LKT	63.0	3592.0	F	0.900	0.22	0.18	0.45	39.9
135	F. LKT	64.9	3703.0	F	0.711	0.28	0.21	0.48	51.5

Table 6

Collection Area: Marathon Ypres Pt.

Sample (LSBM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
1	WTF	56.8	2226.9	F	0.040	0.08	0.14	0.46	5.4
					0.167				
2	WTF	58.0	2124.2	F	0.715	0.06	0.16	0.28	9.3
					1.893				
3	WTF	56.0	1823.3	M	0.252	0.11	0.16	0.43	10.0
4	WTF	57.2	1777.1	M	0.213	0.08	0.11	0.51	10.8
5	WTF	52.2	1692.5	F	0.024	0.11	0.14	0.30	7.6
6	WTF	48.8	1156.5	M	0.011	0.08	0.15	0.21	8.5
						0.11	0.19	0.43	
7	WTF	49.2	1335.9	F	0.081	0.11	0.15	0.27	7.9
8	WTF	46.0	1189.3	F	0.112	0.08	0.14	0.24	7.6
9	WTF	44.5	988.5	M	0.145	0.08	0.16	0.36	7.7
10	WTF	46.4	1116.9	M	0.798	0.03	0.03	0.19	3.1
					0.723				
11	WTF	55.9	1965.2	F	0.197	0.08	0.14	0.27	13.7
12	WTF	51.3	1568.1	F	0.303	0.08	0.16	0.26	10.7
13	WTF	51.0	1452.0	F	0.263	0.08	0.13	0.23	5.8
14	WTF	50.1	1433.0	M	0.249	0.06	0.04	0.36	11.7
15	WTF	52.5	1321.0	M	0.265	0.06	0.12	0.29	11.5
16	WTF	50.2	1313.5	M	0.040	0.08	0.12	0.23	9.8
					0.106				
					0.297				
17	WTF	48.2	1243.0	M	0.213	0.08	0.14	0.32	8.5
18	WTF	48.3	1155.2	M	0.169	0.08	0.13	0.29	8.7
						0.08	0.13	0.29	
19	WTF	48.0	990.5	F	0.064	0.20	0.18	0.39	14.4
20	WTF	43.3	882.0	F	0.705	0.17	0.14	0.20	16.4
					0.930				
21	WTF	56.0	1774.0	F	0.154	0.08	0.11	0.23	11.2
22	WTF	49.5	1448.0	F	0.141	0.08	0.11	0.27	10.9

Table 6 (continued)

Collection Area: Marathon Ypres Pt.

Sample (LSBM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm Hg	Pb	Cd	As	% Lipids
23	WTF	46.3	1393.0	F	0.228	0.06	0.11	0.20	10.9
24	WTF	51.4	1377.0	F	0.038	0.11	0.13	0.35	6.0
25	WTF	51.4	1414.0	F	0.278	0.08	0.09	0.30	6.2
					0.263				
26	LKT	30.3	266.1	Imm	0.341	0.20	0.13	0.37	22.8
27	LKT	27.9	138.5	Imm	0.296	0.17	0.11	0.41	18.5
28	LKT	31.9	326.0	M	0.249	0.20	0.13	0.43	20.6
						0.17	0.12	0.32	
29	LKT	50.3	1138.1	M	0.264	0.14	0.11	0.27	8.7
30	LKT	50.7	1514.1	F	1.427	0.06	0.07	0.22	27.1
					0.963				
31	LKT	75.0	4499.0	F	0.971	0.17	0.13	0.21	10.5
32	LKT	49.8	1854.0	F	0.646	0.03	0.04	0.19	10.6
33	LKT	54.6	2144.0	M	0.852	0.03	0.11	0.32	32.9
34	LKT	71.7	5359.0	F	0.750	<0.03	<0.01	0.61	43.2
35	F. LKT	71.7	4769.0	M	0.733	0.06	0.09	0.23	16.3
36	F. LKT	70.4	4609.0	M	0.552	0.06	0.11	0.23	9.1
						0.06	0.11	0.23	
37	WTF	51.4	1414.0	F	0.183	0.14	0.15	0.28	20.1
38	LKT	50.3	1138.1	M	0.146	0.17	0.20	0.20	17.1
					0.222				
39	LKT	50.7	1514.1	F	0.889	0.14	0.15	0.24	25.0
40	LKT	75.0	4499.0	F	0.517	0.20	0.18	0.16	18.3
41	LKT	49.8	1854.0	M	0.425	0.17	0.16	0.20	20.3
42	LKT	54.6	2144.0	M	1.028	0.14	0.16	0.21	31.7
					0.985				

Table 6 (continued)

Collection Area: Marathon Ypres Pt.

Sample	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
43	LKT	71.7	5359.0	F	0.515	0.20	0.16	0.27	46.7
44	LKT	71.7	4769.0	M	0.479	0.17	0.16	0.23	23.8
45	LKT	70.4	4609.0	M	0.498 0.528	0.14	0.18	0.23	18.8
46	WTF	49.6	1198.5	M	0.570	0.08 0.20	0.16 0.19	0.16 0.22	16.7
47	WTF	51.0	1364.0	M	0.108	0.25	0.23	0.20	19.9

Table 7

Collection Area: S. Pie Island

Sample (LSBM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
48	WTF	49.6	1198.5	M	0.160	0.14	0.16	0.16	3.0
					0.154				
49	WTF	51.0	1364.0	M	0.147	0.11	0.14	0.12	5.5
50	WTF	49.7	1048.0	M	0.204	0.11	0.13	0.13	4.8
51	WTF	53.6	1802.9	F	0.098	0.11	0.12	0.12	6.9
52	WTF	51.2	1594.5	F	0.096	0.11	0.13	0.09	8.5
					0.103				
53	WTF	43.0	918.5	F	0.225	0.34	0.18	0.54	17.3
54	WTF	48.3	1043.0	M	0.095	0.11	0.10	0.13	6.3
55	WTF	47.1	1152.1	M	0.100	0.08	0.10	0.14	4.7
56	WTF	49.4	1289.4	F	0.196	0.08	0.10	0.22	4.6
						0.08	0.11	0.14	
57	WTF	45.0	764.0	M	0.132	0.22	0.17	0.27	18.9
58	WTF	54.6	1811.0	F	0.089	0.11	0.14	0.12	6.2
					0.091				
59	WTF	49.5	1424.9	F	0.052	0.14	0.14	0.08	4.9
60	WTF	48.8	1082.9	M	0.142	0.11	0.11	0.14	4.6
61	WTF	49.5	1445.8	F	0.180	0.11	0.13	0.13	6.9
62	WTF	49.5	1312.5	F	0.132	0.11	0.13	0.16	6.8
63	WTF	47.7	1095.2	F	0.167	0.11	0.13	0.21	4.1
64	WTF	50.0	1239.0	M	0.122	0.14	0.20	0.12	4.5
65	WTF	51.2	1274.2	F	0.084	0.11	0.14	0.12	3.2
66	WTF	51.2	1369.8	F	0.104	0.11	0.11	0.17	5.6
67	WTF	45.3	928.0	M	0.122	0.11	0.11	0.12	2.6
					0.119				

Table 7 (continued)

Collection Area: S. Pie Island

Sample	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
68	F. LKT	39.5	568.1	F	0.300	0.20	0.11	0.28	19.7
69	F. LKT	33.3	280.5	F	0.203	0.11	0.07	0.36	20.1
70	F. LKT	35.0	362.0	M	1.050	0.25	0.22	0.22	8.2
71	F. LKT	37.3	492.5	F	0.381	0.11	0.18	0.38	25.4
72	F. LKT	33.6	329.9	M	0.333	0.11	0.11	0.21	24.0
73	F. LKT	73.1	5707.5	F	2.50	0.06	0.15	0.20	23.9
					2.33	0.03	<0.01	0.35	
74	F. LKT	77.4	6766.7	F	2.80	0.08	0.11	0.50	26.9
						0.06	0.12	0.23	
						0.06	0.15	0.16	
						<0.03	0.16	0.20	
75	F. LKT	78.3	7693.6	F	1.126	<0.03	0.07	0.35	47.0
						0.08	0.07	0.30	
76	F. LKT	70.6	4170.9	M	0.727	<0.03	0.18	0.18	17.5
77	F. LKT	72.8	6346.4	F	0.762	<0.03	0.15	0.24	17.5
78	F. LKT	60.9	2567.1	F	0.628	0.03	0.13	0.20	13.6
79	F. LKT	64.5	3060.7	F	0.462	0.06	0.18	0.21	10.0
80	F. LKT	54.0	1484.7	F	0.320	0.03	0.16	0.21	8.7

Table 8

Collection Area: S.E. of Pie Island

Sample (LSBM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
81	F. LKT	54.4	2187.2	F	0.580	0.06	0.07	0.19	9.0
						0.03	0.10	0.18	
82	F. LKT	66.7	4202.8	F	0.555	0.03	0.08	0.15	12.6
					0.564				
83	F. LKT	70.0	4855.0	F	0.640	0.06	0.07	0.17	16.5
84	LKT	35.1	381.0	M	0.249	0.20	0.11	0.22	13.2
85	F. LKT	43.8	1017.5	F	0.216	0.08	0.11	0.17	5.0
86	F. LKT	52.6	1463.5	M	0.322	0.06	0.11	0.11	8.8
87	F. LKT	49.5	1346.9	F	0.293	0.06	0.11	0.15	7.4
88	L. LKT	42.6	796.8	F	0.164	0.17	0.10	0.32	21.4

Table 9

Collection Area: S. of Pie Island

Sample (LSBM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm Hg	Pb	Cd	As	% Lipids
89	L. LKT	54.5	1544.9	F	0.306	0.03	0.13	0.18	9.3
90	L. LKT	53.6	1518.2	F	0.208	0.06	0.11	0.14	10.3
					0.251	0.03	0.10	0.14	
91	L. LKT	71.5	3927.4	M	0.612	0.03	0.05	0.17	11.9
92	L. LKT	50.8	1387.2	F	0.355	0.06	0.13	0.12	7.9
93	L. LKT	67.2	2907.9	M	0.512	0.06	0.11	0.17	14.0
94	L. LKT	64.8	2853.9	F	0.354	0.06	0.11	0.11	9.7
95	L. LKT	42.8	750.8	M	0.114	0.08	0.13	0.34	16.4
96	L. LKT	58.9	1944.1	F	0.409	0.11	0.14	0.13	7.9
97	L. LKT	68.0	6334.3	M	1.217	0.11	0.14	0.20	11.7
98	L. LKT	50.9	1271.5	F	0.300	0.08	0.18	0.14	3.2
99	L. LKT	54.6	1714.9	F	0.246	0.08	0.17	0.13	4.3
					0.164				
					0.320				
100	L. LKT	66.6	3337.0	F	0.640	0.06	0.11	0.10	11.2
						0.08	0.13	0.21	
101	L. LKT	66.9	3335.0	F	1.138	0.08	0.16	0.29	14.0
102	L. LKT	53.4	1633.0	F	0.429	0.06	0.12	0.05	5.9
103	L. LKT	47.3	940.5	Imm	0.318	0.22	0.17	0.39	29.1
104	L. LKT	47.5	997.5	Imm	0.312	0.06	<0.01	0.20	23.6
					0.352				
105	L. LKT	45.5	986.0	Imm	0.159	0.20	0.10	0.21	22.7
106	L. LKT	44.5	892.0	Imm	0.193	0.22	0.18	0.41	22.1
107	L. LKT	46.5	1119.0	M	0.139	0.20	0.20	0.48	18.5
108	LKT	44.3	806.9	F	0.230	0.20	0.22	0.36	25.0
109	LKT	42.0	754.2	F	0.274	0.20	0.21	0.18	20.9
110	LKT	45.5	1033.0	F	0.214	0.25	0.26	0.32	24.2
111	LKT	43.2	934.6	F	0.205	0.22	0.22	0.37	22.9
112	F. LKT	57.5	1801.1	F	0.186	0.25	0.21	0.18	10.7

Table 10

Collection Area: Michipicoten

Sample (LSBM)	Species	Length (cm)	Weight (gms)	Sex	Metals ppm Hg	Pb	Cd	As	% Lipids
113	F. LKT	55.8	2486.0	F	0.920	0.03	0.11	0.51	39.7
114	F. LKT	58.4	2601.7	F	1.371	0.11	0.17	0.21	20.8
					0.890				
					0.818				
115	F. LKT	71.3	4942.0	F	1.093	0.06	0.15	0.58	37.2
						0.03	0.11	0.20	
116	F. LKT	66.0	4793.0	F	1.083	0.06	0.14	0.18	43.9
117	F. LKT	57.9	2611.8	F	1.438	0.08	0.14	0.16	25.8
118	F. LKT	71.5	5240.0	F	0.826	0.06	0.10	0.43	39.0
						0.06	0.12	0.30	
119	F. LKT	68.0	4831.5	F	0.945	<0.03	<0.01	0.45	48.2
					1.046				
120	F. LKT	58.6	2907.5	F	1.041	0.08	0.13	0.24	17.8
121	F. LKT	70.2	4341.5	F	0.878	<0.03	<0.03	0.33	48.8
					0.947				
122	F. LKT	66.3	4217.0	F	1.136	0.06	0.11	0.28	43.0
123	F. LKT	68.2	4771.5	F	1.091	0.03	0.08	0.35	42.9
						<0.03	<0.01	0.37	
124	F. LKT	69.5	4635.5	F	1.234	0.03	0.14	0.42	47.1
						<0.03	0.07	0.48	
125	F. LKT	67.1	4422.5	F	1.152	0.06	0.13	0.23	39.3
126	F. LKT	66.3	4446.0	F	1.322	<0.03	<0.01	0.51	45.3
127	F. LKT	64.2	4134.5	F	0.981	0.08	0.16	0.43	45.9
128	F. LKT	67.3	4172.0	F	0.945	<0.03	<0.01	0.37	45.2
129	F. LKT	58.9	3087.2	F	1.094	0.03	0.09	0.40	28.7
					0.831				
130	F. LKT	70.5	3999.0	F	1.103	0.06	0.11	0.37	39.9
						<0.03	0.03	0.72	

Table 10 (continued)

Collection Area: Michipicoten

Sample	Species	Length (cm)	Weight (gms)	Sex	Metals ppm				% Lipids
					Hg	Pb	Cd	As	
131	F. LKT	63.1	3392.3	F	0.467	0.11	0.19	0.20	10.9
132	F. LKT	62.8	3920.5	F	0.818	0.11	0.21	0.19	33.2
133	F. LKT	61.8	3463.5	F	0.684	<0.03	0.07	0.47	34.4
134	F. LKT	63.0	3592.0	F	0.990	<0.03	0.07	0.29	34.6
135	F. LKT	64.9	3703.0	F	0.946	<0.03	0.11	0.23	42.9

Table 11: Sediment data (µg/g)

Sample	Arsenic		Cadmium		Lead		Mercury		% Moisture
1A	1.9	2.2	1.1	1.5	19.5	30.8	0.068	0.075	51.7
2A	2.7	9.9	1.7	2.7	27.0	34.6	0.213	0.234	66.1
3A	4.2	6.4	1.3	2.6	-	55.8	0.368	0.346	74.2
4A	9.7	17.9	2.0	-	50.0	-	0.716	0.682	87.5
5A	8.1	7.7	2.3	6.3	65.9	62.0	0.682	0.652	78.2
6A	10.0	15.7	1.0	4.1	-	61.9	0.856	0.816	80.2
7A	6.9	3.7	1.5	2.0	39.9	40.8	0.430	0.476	74.9
8A	3.0	2.9	2.2	1.8	57.1	34.8	0.069	0.069	42.2
9A	2.7	3.2	0.9	0.8	16.4	13.4	0.097	0.089	42.6
10A	3.8	3.5	1.5	1.1	43.3	34.8	0.306	0.275	42.9
11A	1.1	0.7	1.4	1.5	-	23.0	0.143	0.140	38.7
12A	2.6	2.7	1.4	1.6	-	22.5	0.281	0.240	39.5
13A	2.1	1.8	1.4	1.1	-	26.3	1.264	1.245	44.4
14A	0.8	0.5	0.9	1.1	15.0	12.4	6.01	6.13	40.2
15A	3.2	2.0	0.9	1.3	34.0	32.0	1.76	2.03	51.1
16A	3.0	0.9	1.0	1.1	15.6	20.0	3.33	3.17	40.3
17A	4.3	3.1	0.9	1.9	14.2	23.2	0.037	0.037	32.9
18A	3.3	3.2	1.0	1.5	22.3	23.2	0.046	0.043	39.6
19A	7.0	2.6	1.4	2.1	-	54.3	2.42	2.78	67.9
20A	8.1	5.5	2.6	2.6	-	68.3	2.60	2.75	74.2
21A	1.8	3.0	0.9	0.7	15.5	15.0	0.050	0.051	51.1
22A	42.0	34.2	3.5	1.6	38.8	39.1	0.093	0.090	59.7
23A		15.6	5.9	2.0	61.8	55.5	0.115	0.112	69.2
24A		4.9	4.1	1.1	-	32.8	0.076	0.078	69.3
25A		5.8	2.0	0.6	-	13.3	-	0.090	67.4
26A		5.2	1.8	1.6	37.4	49.4	0.115	0.120	82.4
27A		6.2	0.9	1.4	43.5	41.4	0.084	0.083	78.3
28A		11.0	1.3	1.5	50.4	53.5	0.076	0.072	62.1
29A		4.3	1.5	0.8	23.7	20.6	0.038	0.037	45.0
30A	11.0	4.4	1.3	0.9	24.3	30.0	0.029	0.041	52.1
31A	5.1	4.6	1.3	1.4	-	47.1	0.047	0.044	44.4
32A	0.7	0.9	1.0	1.1	15.5	12.6	0.192	0.177	46.6
33A	1.0	3.9	1.5	1.2	23.1	20.2	4.03	4.40	35.6

5.0 DISCUSSION OF RESULTS

5.1 Fish

The concentration of arsenic, cadmium and lead is relatively low and mercury levels are consistently higher only at Michipicoten Island.

Generally, the data suggest that considerable variability exists between species and areas surveyed. Previous work (1)(5) has found no consistent relationship between fish weight and metal concentration in relatively clean waters. No systematic differences either between metals or species were noted, however, as in this study, regional and inter-species differences in fish muscle were common.

Mercury values appear to be higher in fillet homogenates and this has been observed elsewhere (1). There is a strong correlation between fish weight and mercury concentration. There are some differences between whole and fillet samples.

Whole fish data show less precision than fillet data especially for cadmium and lead. Analysis (1) of skeletal material showed a great deal of variation between specimens. There are some differences between whole and fillet samples.

Whitefish show less difference than trout. Mercury, cadmium and lead yield higher values in the fillet for Marathon Ypres Point and south of Pie Island. Arsenic, cadmium and lead show increased concentrations in whole fish homogenates from southeast of Pie Island and Michipicoten.

5.2 Sediments

The sediments appear to be lightly to moderately contaminated relative to pristine unaffected substrates occasionally found in the Great Lakes (3)(4). The nature of the contamination may not be of man-induced origin depending to some extent on the geochemistry of a particular area.

The sediment results (Table 11) exhibit a great deal of location variability. Such variability is not unexpected considering the natural physical effects which must be present at various sites. The substrates are composed of varying amounts of fine sand, silt, clay and organic debris.

Those areas which show relatively higher metal concentrations are discussed below:

Thunder Bay

Increased metal values were found at stations in the middle of the bay east of the city of Thunder Bay and north of Pie Island. These are probably due to sediment deposition patterns in the area. Higher lead levels were detected at Station 10 offshore from the city and at Stations 3, 5, and 6.

Marathon Area

Mercury levels were much higher along the shore west and south of Marathon. Stations 19 and 20 appeared to consistently show increased trace metal contamination for all parameters.

Michipicoten Bay

Most stations exhibited higher levels of all metals. Arsenic appears widespread, as well as lead and cadmium, particularly along the southwest shore of the bay. Mercury does not appear to be a problem in this region and is lower than in other areas.

6.0 LITERATURE CITED

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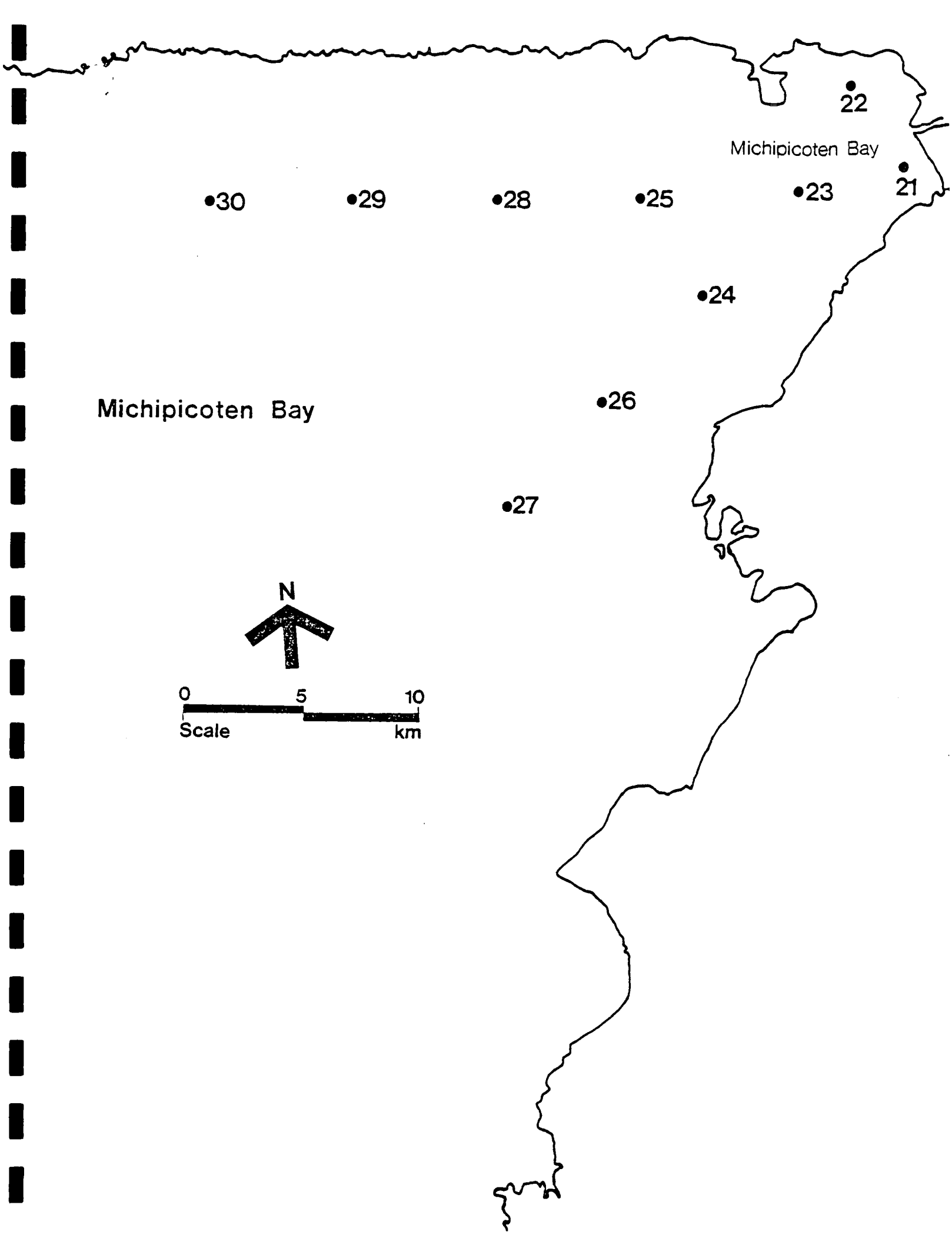
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