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THE EFFECT OF THE ABANDONED VENUS MINES TAILINGS POND ON THE AQUATIC ENVIRONMENT OF WINDY ARM, TAGISH LAKE, YUKON TERRITORY

78-13

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ABSTRACT

Biological and water chemistry data were collected from Windy Arm, Tagish Lake, and only water chemistry data were collected from the abandoned Venus Mine tailings pond. Reduced water quality and altered biological communities reflected a detrimental effect of the effluent on the lake in the immediate vicinity of the effluent outflows. Differences in the water quality data were found between under-the-ice sampling and the ice-free period, and in the distribution of metals in the sediments. The analyses for zinc and lead in the sediments showed that the zinc was more widely distributed than lead in sediments and that both elements had elevated levels. Existed at elevated levels in the area of the outfall. Mercury was fairly evenly distributed in the sediments throughout the lake. The analyses of fish tissue for lead, zinc, copper, arsenic, and mercury showed that levels were within the expected levels for such an environment and levels were below those suggested by Health and Welfare Canada as safe for human consumption.

RÉSUMÉ

On a recueilli des données biologiques et chimiques sur les eaux de Windy Arm, au lac Tagish, ainsi que des données chimiques sur l'eau de l'étang de stériles de la mine abandonnée Venus. La réduction de la qualité de l'eau et l'altération des communautés biologiques indiquaient l'effet délétère qu'a exercé l'effluent sur le lac dans les environs immédiats de la décharge. La qualité de l'eau et la distribution des métaux dans les sédiments variaient suivant qu'il s'agissait d'échantillons prélevés sous la glace ou en période libre de celle-ci. Les analyses ont montré que le zinc se retrouvait plus largement distribué que le plomb; de forts taux de ces deux métaux se retrouvaient néanmoins à proximité de la décharge. Le mercure se trouvait quant à lui à peu près également distribué dans tous les sédiments du lac. Les analyses de plomb, zinc, cuivre, arsenic et mercure effectuées sur le poisson ont révélé des taux normaux de ces métaux, compte tenu de l'environnement; ils se situaient en deçà des limites prescrites pour la consommation humaine par Santé et Bien-être social Canada.

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CONCLUSIONS

Windy Arm is typical of large, mountain lakes in the southern Yukon in relation to water chemistry, bottom fauna, and fish species.

The abandoned mill site and tailings pond had an effect on the lake in the immediate area of the overflow. The effects in the area of the outfall were seen in the reduced diversity of the bottom fauna community and the higher concentrations of zinc and lead in the sediments as compared to similar areas of the lake.

The levels of lead, zinc, copper, mercury, and arsenic in fish tissue were well below the levels set in the Food and Drug Act Regulations (wet weight): Lead <10 ppm; arsenic <5 ppm; zinc <100 ppm; copper <100 ppm; and mercury <0.05 ppm.

1 INTRODUCTION

1.1 Venus Mines Ltd.

Routine water sampling on Windy Arm, Tagish Lake, in 1974 by Department of Indian and Northern Affairs (DINA) revealed elevated arsenic levels in the lake. During the winter of 1974-1975, the Environmental Protection Service, in conjunction with DINA, initiated a program to sample the water, fish, macro-invertebrates and sediments of Windy Arm.

The object of this study was to ascertain whether the abandoned mill and, in particular, the tailings pond were having any adverse effects on the water, fish, macro-invertebrates and sediments of Windy Arm.

The Venus Mine property is located on the west side of Windy Arm, 16 kilometers southeast of the community of Carcross and 6.5 kilometers south of the abandoned tramline and settlement of Conrad. The property lies adjacent to the access road connecting Carcross and the British Columbia border.

Work was first started in this area during the second decade of this century. More recent activity began in the mid-sixties and culminated in the construction of a 300 TPD (272 metric ton) capacity mill which went into production in September, 1970. Operational problems forced the mill to close and in June, 1971, the company entered receivership.

There were two types of concentrate produced, silver-zinc-cadmium and lead-silver-gold. The zinc concentrate contained 1 oz gold and 30 oz silver per ton (31.25 grams gold, 937.5 grams silver per metric ton) as well as 2.5% cadmium. The lead concentrate held 7 oz of gold and 270 oz of silver per ton (218.8 grams gold and 8437.6 grams silver per metric ton) including 0.05% cadmium (Craig and Laporte, 1972). The host rocks were andesite breccian while the veins consisted of crystalline quartz and carbonate with pyrite and arsenopyrite present (Craig and Laporte, 1972).

1.2 Study Area

During the sampling program in September, there was no visible discharge from the tailings pond into Windy Arm; however, there was a culvert which discharges water into the lake, located 6 metres below the tailings pond (vertical measure) and approximately 70 metres away. The discharge on September 4, 1975, was about 18 litres per minute (calculation).

Seven stations were established (six for water, biological and sediments sampling; one station for water only) (Figures 1 and 2). Sampling was concentrated in the vicinity of the Venus mill site and all stations were on Windy Arm. They can be described as follows:

Station 1: at the north end of Windy Arm, approximately 10.5 kilometres north of Venus mill site between Bove Island and the west shore (water depth at station, 3 metres);

Station 2: where Big Thing Creek enters Windy Arm near Conrad (water depth at station, 8 metres);

Station 3: near the west shore of the lake out from the abandoned tailings pond (water depth at station, (11 metres);

Station 4: approximately 1.6 kilometres south of Venus mill site near the west shore of the lake (water depth at station, 10 metres);

Station 5: in the middle of the lake opposite the Venus mine tailings pond (water depth at station, 30 metres);

Station 6: near the east shore opposite the Venus mill site (water depth at station, 19 metres);

Station 7: from the culvert mentioned above, the culvert mouth was approximately 15 cm above the water surface.

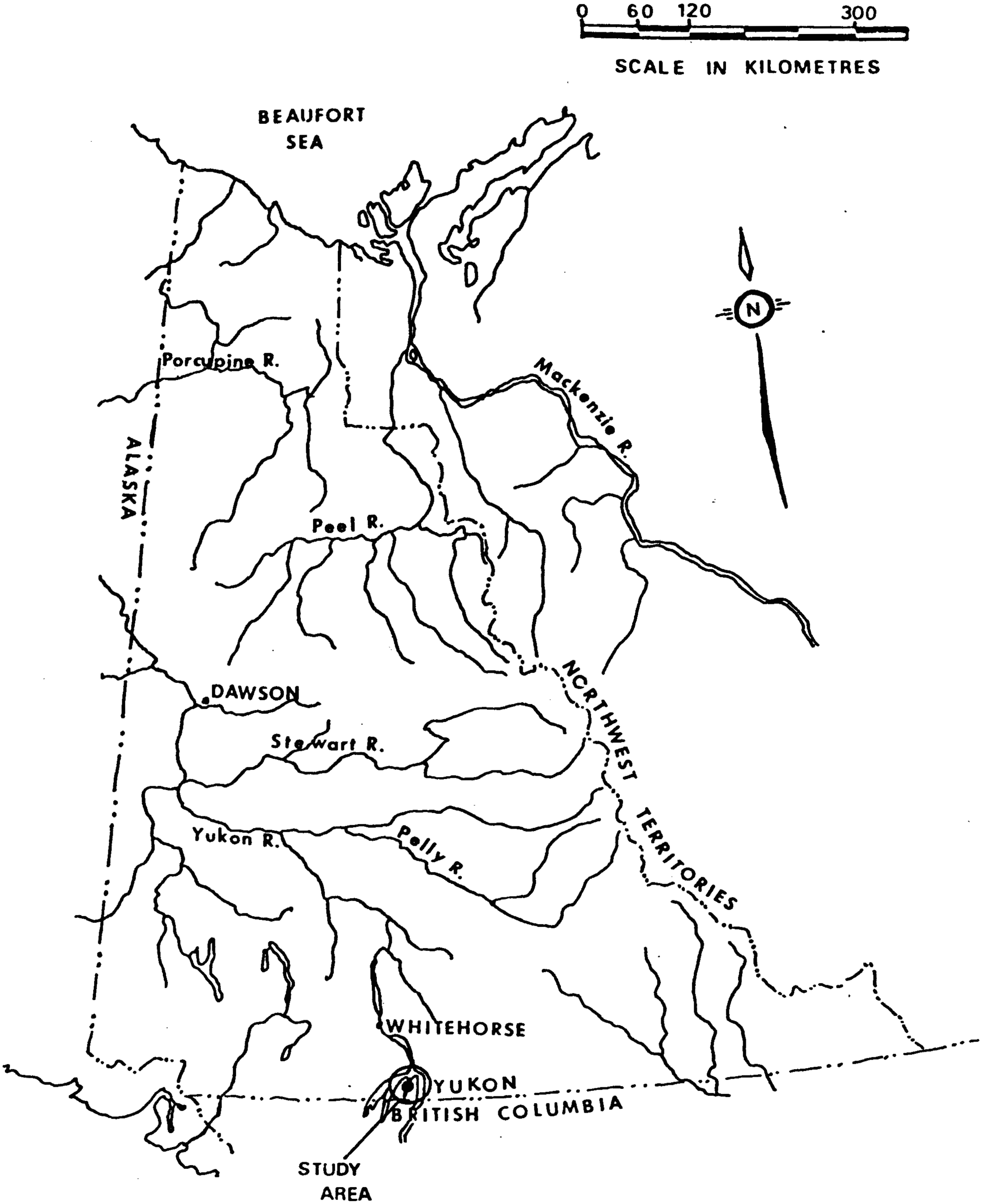

FIGURE 1: MAP OF THE YUKON TERRITORY SHOWING THE STUDY AREA.

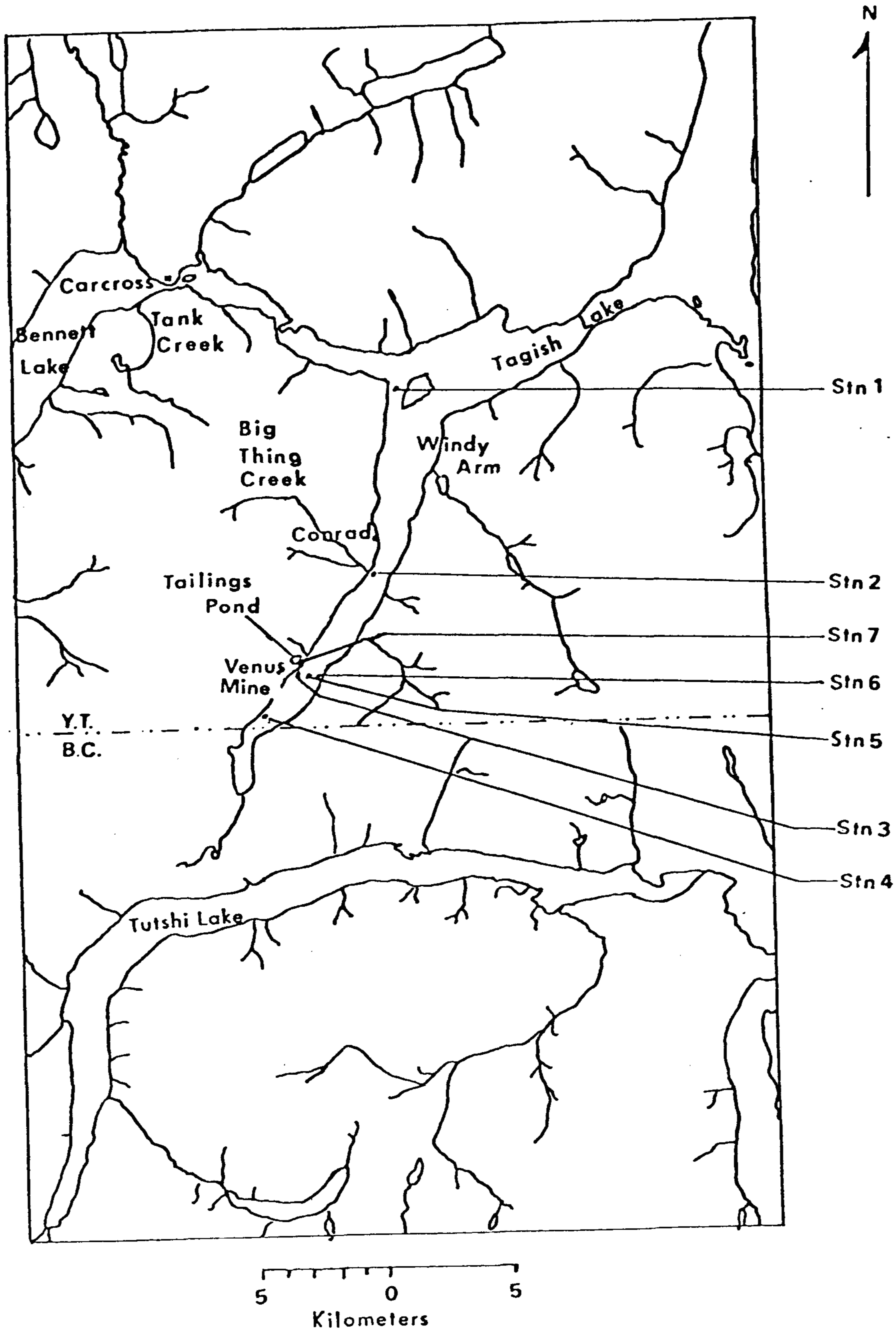

FIGURE 2: MAP OF THE STUDY AREA SHOWING THE SAMPLING STATIONS AND THE LOCATION OF THE ABANDONED TAILINGS POND.

2 METHODS

2.1 Water Chemistry

All the water chemistry samples were collected by DINA. Surface water samples were collected at all stations during the last week in April, 1973 (through the ice cover), June 11, 1975, and September 4, 1975, the latter coinciding with the biological sampling program. Station 7 was sampled one additional time, August 22, 1975. The samples were analysed by the Water Quality Branch, Inland Waters Directorate, Department of Fisheries and the Environment, North Vancouver, B.C. The parameters measured were: pH, turbidity, colour, specific conductance, total dissolved solids, filterable and non-filterable residue, alkalinity, hardness, sulphate, total organic and inorganic carbon, total cyanide, and extractable iron, manganese, copper, zinc, lead, mercury, arsenic, silver, molybdenum, nickel, barium, cadmium, and selenium. The temperature was measured in the field at the time of collection.

2.2 Sediments

Sediments were collected using an Ekman 15 cm x 15 cm x 23 cm deep dredge from which a 450 g sub-sample was randomly taken. In 1975, the samples were analysed for zinc and lead; mercury was added in 1976.

2.3 Bottom Fauna

Stations 1 through 6 were sampled for macro-invertebrates using a 15 cm x 15 cm x 23 cm deep Ekman dredge. Three samples were taken at each station and preserved in 75% methanol. The samples were sorted to family in Whitehorse, with the final identification and counting of organisms conducted by Dr. Charles Low of Envirocon Ltd., Vancouver, B.C. Samples were collected on September 4, 1975, and August 4, 1976.

Species diversity and evenness indices were calculated for the organisms collected using the following formulae:

Species diversity (H')		$\Sigma\ P_i \log P_i$
where:	P	n /N
	n	the number of individuals in the ith species
	N	the total number of individuals sampled
Evenness (J)		$\frac{\Sigma\ P_i \log P_i}{\log s}$
where:	s	the total number of species/samples
	Jmax	1

These formulae are described by Pielou (1966, 1967).

2.4 Fish

Gill nets were set on July 3, 1975, at Stations 3 and 4 and were collected 24 hours later. At each station, 92 metres of net were set. This length of net was composed of one 46-metre panel of 10 cm mesh and one 46-metre panel of 4 cm mesh. Both were floating nets, anchored on the bottom. The average water depths at Stations 3 and 4 were 12 metres and 23 metres, respectively. A similar net set was made at Station 3 on August 4, 1976.

All fish collected in 1975 were measured for length and weight and sexed. In 1976, no weights were taken. A scale sample was taken for age determination. The age was estimated by counting scale annuli using a Microcon 1600 scale reader. A tissue sample was taken from each fish from the muscle directly posterior to the dorsal fin and on the right side of the body. Each sample was approximately 16 cubic centimetres in volume. The samples were frozen and sent to the Pacific Environment Institute, West Vancouver, B.C., where they were analysed for lead, zinc, and arsenic content. In fish that had not deteriorated while in the net, the livers were frozen and analysed for lead, zinc, and arsenic. In 1976, copper and mercury analyses were also done on the liver and muscle samples and arsenic was deleted.

3 RESULTS

3.1 Water Chemistry

Water chemistry data collected during the survey is summarized in Tables 1 and 2. The data showed Windy Arm had characteristics typical of an oligotrophic lake. It was noted that values for specific conductance, total alkalinity, total hardness, and total inorganic carbon were lower when measured under ice cover than during the ice-free period. Conversely values for turbidity, iron, mercury, lead, and zinc were higher when measured under the ice. During the period late April and early May, when under-ice samples were collected at the lake stations, there was an overflow from the abandoned tailings pond (Station 7) entering the lake. All parameters except total alkalinity, total hardness, sulphate, total inorganic carbon, and arsenic measured in the overflow at this time were higher than when measured during the ice-free period.

Mercury analysis results from Stations 1 and 5 collected on September 4, 1975, were significantly higher than mercury levels encountered on any other date during this survey.

Two samples from the overflow (June 11, 1975, and August 22, 1975) had levels of arsenic ranging from two to three orders of magnitude higher than those encountered in Windy Arm.

3.2 Sediments

The sediment analysis data for zinc, lead, arsenic, and mercury are presented in Table 3. In 1975, the water at Station 5 was too deep for the equipment used and therefore was not sampled. Station 3 in Windy Arm, directly off the overflow, exhibited the highest lead and zinc values of the 5 stations sampled in 1975, while both Stations 3 and 4 showed high values in 1976.

3.3 Bottom Fauna

In 1975, there were 369 individual organisms collected representing 14 species and 9 families and sub-families. The predominant organisms represented the Family Tendipedidae and, in particular, the sub-families Hydrobaeninae and Pelopiinae. In 1976, there were 255 organisms representing 31 species and 8 families and sub-families and again the predominant organisms were Tendipedidae.

The results of the benthic sampling are summarized in Tables 4, 5, and 6. In 1975, 3 samples were collected at Station 6; however, 2 samples (A and C) were devoid of invertebrates and Station 5 proved too deep for the equipment. In 1976, the samples from Station 6 had a good representation of fauna but even though Station 5 was sampled, few invertebrates were found.

3.4 Fish

The species of fish recorded in Tagish Lake system are: Lake Trout, *Salvelinus namaycush*; Grayling, *Thymallus arcticus*; Least Cisco, *Coregonus sardinella*; Humpback Whitefish, *Coregonus clupeformis*; Round Whitefish, *Prosopium cylindraceum*; Burbot, *Lota lota*; Longnose sucker, *Catostomus catostomus*; and Northern Pike, *Esox lucius* (R. Kendall, 1976, Fisheries Management Service Biologist, personal communication).

Lake Trout, Humpback Whitefish, and Round Whitefish were the only fish captured in the gill net sets. Analyses of the fish samples for lead, zinc, arsenic, copper, and mercury as well as the length, weight, sex, and age of fish are summarized in Tables 7 and 8.

The zinc values were 3 orders of magnitude greater than mercury, 2 orders of magnitude greater than those of lead and arsenic, and 1 order of magnitude greater than copper in most samples. There was no appreciable difference in the analyses results between samples taken in 1975 and 1976.

TABLE 1 SUMMARY OF THE DINA WATER CHEMISTRY DATA COLLECTED DURING THE SURVEY (EXCLUDING THE METAL DATA) ALL UNITS IN mg/l (ppm)

Station	Sample Date	Temp. at Sampling (°C)	pH	Turbidity (Turb. Units)	Colour (Rel. Units)	Sp. Conductance umhos/cm	Total Dissolved Solids	Residue H.F. (105°C)	Residue F. (105°C)	Total Alkalinity $CaCo_3$	Total Hardness $CaCo_3$	Sulfate (SO_4) Dissolved	Total Organic Carbon	Total Inorganic Carbon	Cyanide (HCN) (Total)
1.	01/05/75	1.0	7.2	1.5	<5.0	26.0	11.0	7.0	-	9.8	10.5	1.9	2.5	2.3	-
	11/06/75	6.0	7.9	0.33	<5.0	78.1	-	-	46.0	32.0	36.0	6.9	7.8	1.7	<0.001
	04/09/75	10.0	7.8	0.24	<5.0	81.0	-	-	-	32.4	37.6	7.6	1.9	7.7	<0.005
2.	29/04/75	1.0	7.2	2.10	<5.0	39.0	15.0	9.0	-	15.4	16.3	2.6	6.6	2.0	-
	11/06/75	5.0	7.9	0.20	<5.0	82.2	-	-	48.0	33.3	33.0	7.5	0.6	8.7	<0.001
	04/19/75	10.0	7.7	0.25	<5.0	79.7	-	-	-	32.8	36.9	7.6	2.1	6.9	<0.005
3.	24/04/75	1.0	7.2	3.4	<5.0	38.2	4.0	2.0	-	14.5	16.5	2.9	2.8	3.3	-
	11/05/75	5.0	8.0	0.15	<5.0	83.6	-	-	60.0	33.6	39.4	7.9	0.7	8.8	<0.001
	04/09/75	10.6	7.7	0.32	<5.0	78.3	-	-	-	33.1	35.7	7.9	5.0	7.2	<0.005
4.	30/04/75	1.0	6.4	13.0	<5.0	19.0	12.0	27.0	-	6.0	5.8	1.5	17.0	0.4	-
	11/06/75	5.0	8.0	0.27	<5.0	87.4	-	-	58.0	35.2	40.0	8.3	0.3	8.9	<0.001
	04/09/75	10.0	7.7	0.27	<5.0	81.5	-	-	-	32.4	38.1	7.6	2.7	6.7	<0.005
5.	24/04/75	1.0	7.5	3.4	<5.0	72.6	7.0	4.0	-	31.8	34.3	6.0	3.6	6.9	-
	11/06/75	5.0	7.9	0.18	<5.0	82.5	-	-	70.0	33.5	39.0	8.2	1.0	8.2	<0.001
	04/09/75	10.0	7.8	0.98	<5.0	80.7	-	-	-	32.5	37.3	7.6	2.1	6.9	<0.005
6.	24/04/75	1.0	7.0	10.0	<5.0	51.1	20.0	10.0	-	20.3	21.9	4.2	5.8	4.2	-
	11/06/75	5.0	8.0	0.22	<5.0	83.6	-	-	60.0	33.5	39.0	7.8	0.1	8.6	<0.001
	04/09/75	10.0	7.8	0.31	<5.0	90.6	-	-	-	32.6	37.1	7.5	1.9	6.9	<0.005
7.	24/04/75	1.0	8.0	>1000.0	<5.0	633.0	7730.0	3970.0	-	151.0	306.0	22.0	2.6	22.5	-
	11/06/75	12.0	8.5	7.8	<5.0	509.0	-	46.0	338.0	146.2	270.0	168.0	<1.0	25.6	0.94
	22/08/75	11.0	8.4	22.0	<5.0	462.0	-	48.3	302.0	144.0	243.0	107.5	-	-	<0.005
	04/09/75	8.9	8.2	9.5	<5.0	466.0	-	16.1	294.0	144.0	252.0	112.0	3.5	31.9	<0.005

TABLE 2 SUMMARY OF THE WATER CHEMISTRY DATA FOR METALS COLLECTED BY DINA DURING THE SURVEY ALL UNITS IN mg/l (ppm)

Station	Sample Date	Arsenic (As)	Barium (Ba)	Cadmium (Cd)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)(ug/l)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Zinc (Zn)
1.	01/05/75	0.0009	-	-	0.003	0.08	0.008	<0.01	0.17	0.0006	0.002		<0.005	0.027
	11/06/75	0.0018	0.06	<0.0002	<0.001	0.014	<0.001	<0.01	<0.05	0.0019	<0.001		<0.005	0.075
	04/09/75	0.023	0.06	<0.0002	<0.001	0.007	<0.001	<0.01	5.2	0.003	<0.001	0.0006	<0.005	<0.001
2.	29/04/75	0.001	-	-	0.005	0.19	0.016	0.02	0.10	0.0004	0.003		<0.005	0.009
	11/06/75	0.0033	0.06	0.0004	<0.001	0.004	<0.001	<0.01	<0.05	0.002	<0.001		<0.005	0.004
	04/09/75	0.0034	0.06	<0.0002	<0.001	0.011	<0.001	<0.01	<0.05	0.002	<0.001	<0.0001	<0.005	<0.001
3.	24/04/75	0.0200	-	-	0.009	1.1	0.50	<0.01	0.18	0.0021	0.012		<0.005	0.016
	11/06/75	0.0040	0.06	<0.0002	<0.001	0.011	0.005	<0.01	<0.05	0.0021	<0.001		<0.005	0.005
	04/09/75	0.0011	0.06	<0.0002	<0.001	0.029	<0.001	<0.01	0.08	0.003	<0.001	0.0001	<0.005	<0.001
4.	30/04/75	0.0019	-	-	0.014	0.21	0.21	0.01	0.40	<0.0002	0.002		<0.005	0.031
	11/06/75	0.0039	0.06	<0.0002	<0.001	0.046	<0.001	<0.01	<0.05	0.0018	<0.001		<0.005	0.007
	04/09/75	0.0029	0.07	<0.0002	<0.001	0.010	<0.001	<0.01	<0.05	0.004	<0.001	0.0001	<0.005	<0.001
5.	24/04/75	0.0041	-	-	0.025	1.4	0.06	0.01	0.17	0.0028	0.013		<0.005	0.024
	11/06/75	0.0036	0.05	<0.0002	<0.001	0.018	<0.001	<0.01	<0.05	0.0019	<0.001		<0.005	0.002
	04/09/75	0.0024	0.07	<0.0002	<0.001	0.021	<0.001	<0.01	1.2	0.004	<0.001	0.0001	0.006	<0.001
6.	24/04/75	0.005	-	-	0.009	2.5	0.13	0.03	0.16	0.0031	0.016		<0.005	0.046
	11/06/75	0.0039	0.11	<0.0002	<0.001	0.007	<0.001	<0.01	<0.05	0.0018	<0.001		<0.005	0.003
	04/09/75	0.0023	0.07	<0.0002	<0.001	0.007	<0.001	<0.01	<0.05	0.004	<0.001	0.001	<0.005	<0.001
7.	24/04/75	0.5000	-	-	0.19	35.0	7.2	2.3	-	0.0053	0.032	-	0.008	5.4
	11/06/75	1.30	0.19	0.014	-	1.1	0.350	0.14	<0.05	0.0035	<0.001	-	<0.005	0.230
	22/03/75	2.20	0.24	0.023	0.006	0.64	0.290	0.07	<0.05	0.003	<0.001	-	<0.005	0.150
	04/09/75	0.410	0.17	0.007	0.004	0.58	0.120	0.07	<0.05	0.005	<0.001	0.0006	<0.005	0.120

TABLE 3 SUMMARY OF THE ANALYSIS OF SEDIMENTS FOR LEAD, ZINC, AND MERCURY

	Zinc (ppm)		Lead (ppm)		Mercury (ppm)	
Station	1975	1976	1975	1976	1975	1976
1	150	170	24	48	-	0.026
2	100	130	20	46	-	0.033
3	192	820	210	1200	-	0.054
4	150	270	31	1500	-	0.150
5	-	220	-	170	-	0.047
6	13	160	23	68	-	0.122

TABLE 4 SPECIES LIST FOR THE INVERTEBRATE SPECIES COLLECTED FROM WINDY ARM IN 1975 AND 1976

Phylum: Annelida
Class: Oligochaeta
Oligochaeta sp

Phylum: Arthropoda
Class: Arachnida
Order: Acarina
Super family: Hydracarinae
mite sp

Class: Crustacea
Sub Class: Ostracoda
Ostracoda sp

Order: Cladocera
Sub order: Calyptomera
Tribe: Anomopoda
Family: Chydoridae
Eurycerus amellatus

Class: Insecta
Order: Diptera
Family: Empididae
Hemerodromia sp

Family: Deuterophebiidae
Chelifera sp

Family: Tendipedidae
Sub familyl: Hydrobaeninae
Brillia sp
Corynoneura sp
Spaniotoma sp
Psectrocladius sp
Circotopus sp
Trissocladius sp
Heterotrissocladius sp
Tendipedini sp pupa
Sub familyl: Pelopiinae
Pentaneura sp
Pelopiinae sp pupa
Procladius sp
Tribe: Pentancurini

Sub family: Tendipedinae
Eukiefferiella sp
Smittia sp
Constempellina sp
Cryptochironomus sp
Stichtochironomus sp
Tribe: Chironomini
Tribe: Cabpsectrini (Tanytarsini)
Tribe: Rheotanytarsini

Sub family: Diamesinae
Diamesa sp
Pseudodiamesa sp

Family: Empididae
Hemerodromia sp

Phylum: Mollusca
Class: Gastropoda
Order: Pulmonata
Family: Lymnaeidae
Lymnae sp

Order: Ctenobrachiata
Familyl: Valvatidae
Valvata sp

Class: Pelecypoda
Family: Sphaeridae
Psisdium sp

TABLE 5 DISTRIBUTION OF INVERTEBRATES COLLECTED FROM WINDY ARM IN 1975 BY SPECIES AND STATION AND THE DIVERSITY AND EVENNESS INDICES

	Station 1			Station 2			Station 3			Station 4			Station 5	Station 6		
Species Sample	A	B	C	A	B	C	A	B	C	A	B	C		A	B	C
Oligochaeta sp	1	1	10	12	8	5	-	-	-	7	4	1		-	-	-
mite sp	-	-	-	-	-	-	-	-	1	-	-	-		-	-	-
Ostracoda sp	-	-	-	-	-	1	-	-	-	-	-	-		-	-	-
Eurycerus amellatus	-	-	-	2	-	1	-	-	-	-	-	-		-	-	-
Hemerodromia sp	-	-	2	-	-	-	1	1	-	-	-	-	No	-	-	-
Pentaneura sp	8	17	10	20	17	10	-	2	1	10	7	8		-	1	-
Pelopiinae sp	-	-	-	-	-	-	-	-	-	-	-	-	Samples	-	1	-
Brillia sp	-	-	-	-	-	1	-	-	-	-	-	-		-	2	-
Corynoneura sp	-	-	-	-	-	1	-	-	-	-	4	-		-	-	-
Spaniotoma sp	3	3	11	50	45	24	1	3	2	2	1	2		-	4	-
Tendipedini sp	-	-	-	-	2	4	-	-	-	-	1	-		-	-	-
Lymnae sp	-	-	-	-	-	-	-	-	-	-	-	1		-	-	-
Valvata sp	1	5	-	-	1	-	-	-	-	-	-	1		-	-	-
Pisidium sp	3	1	4	5	5	2	-	-	-	1	-	3		-	-	-
Diversity Index (H')	0.5737	0.4741	0.6368	0.5109	0.5250	0.6971	0.3010	0.4393	0.4515	0.4752	0.5993	0.6268		-	0.6197	-
Evenness Index (J)	0.8208	0.6783	0.9111	0.7309	0.6747	0.7165	1.0000	0.9208	0.9463	0.7893	0.8574	0.8055		-	0.8866	-

TABLE 6 DISTRIBUTION OF INVERTEBRATES COLLECTED FROM WINDY ARM IN 1976 BY SPECIES AND STATION AND THE DIVERSITY AND EVENNESS INDICES

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
Species Sample	A	B	A	B	A	B	A	B	A	B	A	B
Chironominae	2	1	-	-	-	-	-	-	-	-	-	-
Psectrocladius sp	7	17	-	1	-	1	-	-	-	1	1	3
Diamesinae	2	2	-	-	-	-	-	-	-	-	-	-
Constempellina sp	4	8	-	-	-	-	-	5	-	-	-	-
Stichtochironomus sp	3	2	-	-	-	-	-	-	-	-	-	-
Tanytarsini	1	5	-	-	-	-	-	-	-	-	-	-
Procladius sp	1	7	8	-	-	-	2	-	-	-	3	4
Pentaneurini	1	-	-	-	-	-	-	-	-	-	-	-
Smittia sp	2	18	-	3	-	-	13	-	-	-	15	-
Orthocladiinae	1	2	-	-	16	4	-	8	-	-	1	-
Tanypadinae	1	9	-	1	1	-	-	1	-	-	-	-
Chelifera	1	-	-	-	-	-	-	-	-	-	-	-
Heteratrissocladius sp	-	-	1	3	-	-	-	-	-	-	-	-
Brillia sp	-	3	1	-	-	-	-	-	-	-	1	5
Trissocladius sp	-	1	-	-	-	-	-	-	-	-	-	-
Rheotanytarsini	-	1	-	-	-	-	-	-	-	-	-	-
Eukiefferiella sp	-	-	7	-	-	-	-	-	-	-	-	-
Cryptochironomus sp	-	-	2	-	-	-	-	-	-	-	1	-
Pseudodiamese sp	-	-	1	-	-	-	-	-	-	-	1	-
Empididae	-	-	-	1	-	-	-	-	-	-	-	-
Chironamini	-	-	-	1	-	-	-	-	-	-	-	-
Pentaneura sp	-	-	-	1	-	1	-	-	-	-	5	-
Cricotopus sp	-	-	-	-	1	-	-	-	-	-	1	-
Hemerodromia sp	-	-	-	-	-	1	-	-	-	-	-	-
Diamesa sp	-	-	-	-	-	1	-	-	-	-	-	-
Chironomidae	-	1	-	-	-	2	1	2	-	-	-	2
Tubirifexs	1	3	1	1	-	1	-	-	-	-	1	-
Peloscolex sp	-	-	1	-	-	-	-	-	-	-	-	-
Gyraules sp	-	-	-	-	-	-	1	1	-	1	-	-
Pisidium sp	-	-	-	-	-	-	1	1	1	-	1	1
Corynoneur sp	-	-	-	-	-	-	-	-	-	-	1	-
Diversity Index (H')	1.0030	1.0023	0.5066	0.7950	0.1849	0.7678	0.4172	0.6369	-	-	0.7996	0.6470
Evenness Index (J)	0.9004	0.8324	0.5610	0.9407	0.3875	0.9086	0.5969	0.8184	-	-	0.7410	0.9256

TABLE 7 SUMMARY OF DATA COLLECTED FROM THE FISH NETTED IN WINDY ARM IN 1975

								Analysis (ug/g)					
				Age	Length	Weight	Sample	Zn		Pb		As	
Station	Set	Sex	Fish*	(yrs)	(cm)	(g)	Type	Dry	Wet	Dry	Wet	Dry	Wet
4	1	F	1	19+	84	6810	Liver	120	44.0	1.0	0.4	0.8	0.2
	1		1				Flesh	12	3.7	1.0	0.3	0.8	0.2
	1	F	2	11+	60	2043	Liver	200	54.0	1.4	0.4	1.3	0.4
	1		2				Flesh	30	8.4	1.0	0.3	0.8	0.2
	1	F	3	8+	46	1135	Flesh	32	8.6	1.0	0.3	0.8	0.2
3	2	M	1	18+	85	5902	Liver	100	32.0	1.0	0.3	0.8	0.2
	2		1				Flesh	12	1.9	1.0	0.3	0.8	0.2
	2	M	2	8+	47	1135	Liver	130	36.0	1.2	0.3	0.9	0.2
	2		2				Flesh	18	4.7	1.0	0.3	0.8	0.2
	2	F	3	5+	31	227	Flesh	19	4.5	1.0	0.3	0.8	0.2
	2	M	4	8+	37	454	Flesh	19	4.8	1.0	0.3	0.8	0.2
	2	F	5	10+	43	1021	Liver	130	55.0	1.0	0.3	0.8	0.2
	2		5				Flesh	27	8.4	1.3	0.4	0.8	0.2
	2	F	6	7+	33	454	Flesh	25	6.7	1.0	0.3	0.8	0.2
	2		6				Liver	140	30.0	2.4	0.5	0.8	0.2

* All fish tested were Lake Trout (_Salvelinus namaycush_)

TABLE 8 SUMMARY OF DATA COLLECTED FROM THE FISH NETTED IN WINDY ARM IN 1976

Species	Sex	Age	Fork Length (cm)	Sample	Analysis (ug/g) Cu Dry	Cu Wet	Zn Dry	Zn Wet	Pb Dry	Pb Wet	Hg Dry	Hg Wet
Trout	M	4+	23.4	Liver	43.0	11.0	109	49	1	0.2	-	-
				Muscle	3.0	0.6	47	10	1	0.2	0.34	0.07
	M	8	45.7	Muscle	2.0	0.4	24	5	1	0.2	0.29	0.05
	F	9+	59.6	Liver	5.0	1.0	100	26	1	0.2	0.40	0.10
				Muscle	1.0	0.2	14	3	1	0.2	0.39	0.09
	M	8	46.9	Liver	91.0	23.0	230	58	1	0.2	0.83	0.15
				Muscle	1.0	0.3	26	6	1	0.2	0.49	0.11
	F	8	49.5	Liver	51.0	13.0	190	47	1	0.2	0.88	0.22
				Muscle	1.0	0.3	16	4	1	0.2	0.02	0.22
	F	8+	45.0	Liver	12.0	3.0	110	28	1	0.2	0.40	0.10
				Muscle	1.0	0.2	15	3	1	0.2	0.48	0.11
Humpback Whitefish	F	6+	45.0	Liver	56.0	14.0	150	38	1	0.2	0.87	0.22
				Muscle	2.0	0.4	38	8	1	0.2	0.40	0.09
	F	7	45.0	Liver	38.0	9.0	140	34	1	0.2	0.75	0.19
				Muscle	1.0	0.2	34	8	1	0.2	0.89	0.20
	F	8	48.5	Liver	19.0	5.0	110	28	1	0.2	0.93	0.21
				Muscle	1.0	0.3	35	8	1	0.2	0.67	0.15
	M	7	42.5	Liver	76.0	19.0	170	43	1	0.2	0.74	0.19
				Muscle	2.0	0.4	24	5	1	0.2	0.59	0.13
	F	9	41.9	Liver	27.0	7.0	120	31	1	0.2	0.40	0.10
				Muscle	1.0	0.3	36	8	1	0.2	0.20	0.04
	M	9	45.0	Liver	100.0	26.0	170	42	1	0.2	0.55	0.11
				Muscle	2.0	0.4	32	7	1	0.2	0.28	0.06
	M	9	50.8	Liver	42.0	12.0	160	41	1	0.2	0.38	0.10
				Muscle	2.0	0.4	49	11	1	0.2	0.13	0.05
	F	9	45.7	Liver	49.0	2.0	150	37	1	0.2	0.82	0.21
				Muscle	1.0	0.3	28	6	1	0.2	0.30	0.07
	F	8	46.9	Liver	94.0	23.0	160	41	1	0.2	0.96	0.24
				Muscle	2.0	0.3	41	9	1	0.2	0.37	0.08
	F	8	48.2	Muscle	2.0	0.4	43	9	1	0.2	0.23	0.06
Round Whitefish	M	4+	30.4	Muscle	2.0	-	33	7	1	0.2	0.22	0.05
	M	-	29.2	Liver	2.0	0.5	28	7	1	0.2	0.73	0.18
	M	5	31.7	Liver	2.0	1.0	100	23	1	0.2	0.41	0.10
				Muscle	0.4	0.3	30	7	1	0.2	0.75	-
	M	5	30.4	Muscle	2.0	0.4	34	8	1	0.2	0.29	0.07
	M	6	35.5	Liver	9.0	2.0	100	25	1	0.2	1.07	0.27
				Muscle	-	-	24	5	1	0.2	0.13	-
	M	-	32.3	Liver	8.0	2.0	120	29	1	0.2	0.41	0.10
				Muscle	1.0	0.3	29	6	1	0.2	0.40	0.09
	M	4+	34.3	Liver	10.0	3.0	120	30	1	0.2	0.86	0.22
				Muscle	2.0	0.5	29	6	1	0.2	0.28	0.07
	M	4	29.8	Liver	11.0	3.0	120	30	1	0.2	0.38	0.10
				Muscle	1.0	0.3	26	6	1	0.2	-	-
	F	5+	34.9	Liver	9.0	2.0	110	29	1	0.2	0.38	0.10
				Muscle	2.0	0.4	42	10	3	0.7	0.41	0.09
	M	6	36.8	Liver	4.0	1.0	59	15	3	0.7	-	-

4 DISCUSSION

4.1 Water Chemistry

The differences noted between under-ice and ice-free sampling seem to be related to melt water. This statement applies in general to all the lake stations (1 through 6). Even though the lake was ice covered during our spring sampling, April 24, 1975, to May 1, 1975, the snow cover on the ice had melted and a good percentage of the snow pack had melted. The water chemistry data from this date showed consistently low values for total alkalinity, total hardness, specific conductance, and total inorganic carbon. Kerekes (1974) recorded similar decreases in specific conductance and total alkalinity and related this phenomena to melt water.

Total inorganic carbon is related to the total alkalinity and carbon dioxide concentration (Yeasted and Shane, 1976); therefore, the reduction in total inorganic carbon during the period of ice cover could be related to the reduced total alkalinity and the absence of the air-water interface.

Melt water was also responsible in the instances where higher levels for turbidity and extractable iron, mercury, lead, and zinc when measured under the ice in spring, as compared to the ice-free period. These elevated levels are related to melt water in two ways: (1) melt water entering the lake from the land would be carrying a higher sediment load and, (2) the overflow from the abandoned tailings pond was one order of magnitude higher for turbidity and non-filterable residue and values for copper, iron, lead, manganese, and zinc were 20 to 30 times greater than at any other sampling date. Item (2) above illustrates the prime point of concern based on the data collected, which is the transport of materials from the abandoned tailings impoundment into the lake under spring runoff conditions.

4.2 Sediments

The results of the analysis for zinc in the sediment indicated that zinc was distributed fairly evenly throughout the sampled areas of Windy Arm with the exception of Station 3. The higher values at Station 3 indicated the continuing influence of the overflow and the slightly lower level at Station 2 was most likely related to the mixing of lake sediments with those of the creek which enters the lake near Station 2. The low value for zinc at Station 6 in 1975 was probably related to the rock nature of the substrate sampled as compared to 1976.

The high level of lead in the sediments at Station 3 in 1975 and Station 3, 4, and 5 in 1976 indicated that little transport of lead away from the immediate vicinity of the overflow had occurred. The apparent differential transfer of lead and zinc away from the overflow can be related to the higher density of lead sulfide as compared to zinc sulfide.

The levels of mercury in sediments found in Windy Arm were within or below the levels reported by Allan et al (1974) for lakes in mineralized areas of the Canadian Shield. These levels were as follows: Sudbury, 100-200 ppb; Chiboagamau Lake, 100 ppb; Red Lake 10-120 ppb.

4.3 Bottom Fauna

The low number of organisms collected during the survey was indicative of the low productivity and oligotrophic nature of the lake. However, the species composition is similar to that reported by Kussat (1973) for stations with soft substrates in Aishihik Lake, Yukon Territory. At all of the stations from Windy Arm where benthic data was collected, soft substrates were found. While there was no vegetation, sand, or gravel encountered, several attempts had to be made at Station 6 where either bedrock or large boulders interferred with the sampling equipment. In Aishihik Lake, Tendipedidae larva and oligochaetes were present at most stations with soft substrate and the molluscs were primarily represented by pelecypods. With the exception of Station 3, this was also the situation in Windy Arm, indicating that the bottom fauna was typical of large, mountain lakes in the southern Yukon.

The lower number of species and individuals present at Station 3 would suggest that the overflow was having a continuing effect on the bottom fauna in this area. This effect may be related to the continuous addition of potentially toxic substances from the abandoned tailings impoundment, or the high levels of lead and zinc in the sediments.

A comparison of the species list and diversity indices for Stations 2 and 4 in 1975, and 2, 4, and 6 in 1976, showed these stations had similar bottom communities and are most likely representative of the benthic population of Windy Arm. The lower species diversity indices of Station 3 also pointed to the detrimental effect of the abandoned tailings pond on this area of the lake. Due to the low number of organisms collected, the species evenness indices for all stations are of little statistical value.

4.4 Fish

The average zinc levels encountered in the liver (42 ppm) of the lake trout sampled in Windy Arm were higher than the zinc levels reported by Peterson et al (1970) for the livers of rainbow trout (average 30 ppm) from lakes in northern British Columbia. On the other hand, the average lead values for lake trout livers (average 0.4 ppm) were lower than the levels reported from northern B.C. lakes (average 0.7). The high zinc and low lead values for the Windy Arm fish could be related to the overall high levels of zinc in the sediments and lower levels of lead.

The average mercury level (wet weight) found in the lake trout muscle from Windy Arm was 0.13 ppm, lake whitefish was 0.09 ppm, and round whitefish was 0.07 ppm. As compared with other areas, Northcote et al (1975) reported an average level of 0.09 ppm in the muscle of rainbow trout muscle from the Fraser River and, Fimreite et al (1971)reported an average level of 5.78 ppm in lake trout muscle and 0.38 ppm in rainbow trout muscle from Pinchi Lake, B.C. The levels from Windy Arm are lower than the above but within the background levels of 0.02 to 0.10 ppm suggested in EPA (1973).

There appeared to be a positive correlation between the length and mercury content of muscle and liver; however, the data was too limited to determine whether the relationship was statistically significant.

There was no apparent relationship between size, age, sex, or maturity and lead, zinc, or copper concentrations in the muscle or liver for any of the species. It is interesting to note, however, that the older fish (18+ and 19+) had the lowest levels of both zinc and lead in the 1975 muscle samples. Only two of the lake trout sampled in 1975 had arsenic levels over the detection limit which would indicate that arsenic uptake by lake trout in Windy Arm did not present a problem at the time of the study.

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