LIMNOLOGICAL SURVEYS OF SEVEN LAKES NEAR YELLOWKNIFE, NORTHWEST TERRITORIES.

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FISHERIES RESEARCH BOARD OF CANADA
TECHNICAL REPORT NO. 407

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Limnological surveys of seven lakes near Yellowknife, Northwest Territories

M.C. Healey and W.L. Woodall

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In a search for lakes suitable for an experimental fishery, we surveyed seven lakes along the Yellowknife River system in July 1971. In addition we surveyed four lakes with a history of arsenic contamination within the city limits of Yellowknife. The four lakes selected for the experimental fishery will be treated in detail elsewhere. The purpose of this report is to present the information collected on the other seven lakes. These lakes are Frame, Long, Kam and Grace, within the Yellowknife city limits; and Michel, Trout and Dunnet between 30 and 50 kilometers north along the Yellowknife River (Fig. 1). The data presented here are preliminary and often sketchy and must be treated with caution. Nevertheless, in view of the lack of biological information on these lakes, it seemed worthwhile making the data available in manuscript form.

GENERAL SAMPLING METHODS

We visited Frame, Long, Kam and Grace lakes first in June 1971 and a second time in August 1971. Michel, Trout and Dunnet we visited once in July 1971.

Dr. G. Brunskill of the Freshwater Institute is collecting detailed morphometric, hydrographic and chemical data on Frame, Kam and Grace lakes, and will publish these elsewhere. Brief summaries of some of his information and some chemical data he collected on Long Lake will be presented here. We ran transects on Michel, Trout and Dunnet lakes with a Furuno FG 200 MK3 echo sounder to get information on basin shape. We took temperature and oxygen profiles in the deepest part of each lake with a Yellow Springs Instruments, temperature compensated oxygen meter, and measured Secchi depth. We took temperature and oxygen profiles and Secchi depth in Frame, Long, Kam and Grace lakes as well. We took a single surface water sample from Michel, Trout and Dunnet lakes which was later analyzed for conductivity, pH and major ions.

We made outline maps of Michel, Trout and Dunnet lakes from aerial photographs of the area. Maps of the other lakes were copies from outline maps made in the same way by G. Brunskill.

We took four or six total vertical zooplankton hauls with a 25 cm diameter Wisconsin style net of #20 bolting cloth from two or three stations in each lake on each visit. The species of crustacean zooplankton in these samples were identified by Dr. K. Patalas of the Freshwater Institute. We determined the numbers of different plankters by counting the numbers in two or three 1 ml subsamples from a 100 ml total sample volume. We assumed the filtering efficiency of the net to be 25% and converted sample counts to numbers per 10 liters of lake water on this basis.

We took 10 zoobenthos samples from each lake on each visit, five from shallow water (above the thermocline in stratified lakes) and five from deep water (below the thermocline in stratified lakes). We used a 15 cm square tall Ekman dredge to sample the substrate and sieved the sample through a 600 μ mesh screen. We identified benthic organisms to various taxonomic groups, depending on difficulty of identification. To estimate biomass we measured the preserved weight of all samples, then dried half the samples to get a measure of the preserved/dry weight ratio. The dried samples we then ashed to get an estimate of ash content.

We set two or three gill net gangs in each lake during our first visit to sample fish populations. Each gang was 100 yards (91.4 m) long and 2 yards (1.83 m) deep, and composed of five panels of different sized mesh (1½, 2½, 3½, 4½, 5½ inches or 38, 64, 89, 178, 267 mm stretched mesh). We generally set the nets at right angles to shore and in different depths of water (all nets were set on the bottom), to cover as much of the depth range of the lake as possible. We set the nets about 1500 hours each day and lifted them between 1000 and 1100 hours the following morning. We recorded the catch by species and mesh size as the nets were lifted.

For each fish we recorded fork length and wet weight. We took stomach samples from a subsample of at least 10 fish of each species (unless fewer were captured) except suckers (Catostomidae) for diet analysis. We took scales for age determination from at least 25 fish of each species (unless fewer were captured).

Fish found in the stomach samples we identified to species where possible. Benthic organisms were identified to the same taxonomic levels as organisms from the Ekman samples.

RESULTS

Physical and chemical characteristics

Frame Lake (Fig. 2) lies within the present residential area of Yellowknife and is an important recreational area for the town, having a sandy bathing beach and a playground on its shores. The lake has an area of about 84 ha. Its inflow and outflow are mainly seepage. Frame Lake is shallow with a maximum depth of only six and one-half meters (Table 1). Much of the shore is exposed rock although there are some weedy areas in shallow bays. Substrates below about 1 m of water depth are extremely soft and difficult to sample with an Ekman.

Long Lake (Fig. 2) lies beside the Yellowknife airport about 5½ km northwest of town. It has an area of about 157 ha. It is also an important recreational lake and site of the local camp ground. It is similar in general character to Frame Lake, having seepage inflow and outflow, shallow maximum depth and generally rocky shores (Table 1). Bottom sediments are firmer, however.

Table 1. Summary of some physical and chemical data on lakes near Yellowknife.

Lake	Area ha	Max.depth m	Secchi* m	pH	Specific conductance	Major ions mg/l**					
						Ca	Mg	K	Na	HCO_3	SiO_4
Frame	84	6.5	3.1	8.5	332	33.8	15.4	4.9	9.74	134.2	0.22
Long	157	7	5.0	7.4	108	12.8	6.11	2.06	4.52	54.9	0.19
Kam	204	12	1.3	9.3	2000	207.0	21.4	9.87	160.0	103.7	3.25
Grace	62	18	3.8	8.1	138	17.3	5.48	1.92	4.31	54.9	0.78
Michel	345	22	5.3	7.7	100	10.0	4.61	1.99	2.48	48.8	0.17
Trout	320	25	7.5	-	-	10.6	3.51	1.42	2.90	-	0.25
Dunnet	362	10	2.5	8.0	77	9.2	4.56	1.75	3.15	61.0	0.07

* June values given. August values for the first four lakes are 2.5, 4.5, 1.75, 2.1 m.

** June values for surface water.

Kam Lake (Fig. 3, Table 1) lies just south of town. It is the largest of the lakes surveyed within the city limits (area 204 ha). It has a maximum depth of 12 m. Its major natural inflows are from Grace Lake to the west and from Pud Lake to the east. In 1972 the city began routing part of its sewage into Kam. Pud Lake is used as a tailings pond by Con mine and arsenic wastes are carried from Pud Lake into Kam.

Grace Lake, located just west of Kam, is the smallest (62 ha) and deepest (18 m) of the lakes in this area (Table 1, Fig. 3). It has considerably less shallow water than the other three, dropping off rapidly to maximum depth with a fairly flat bottom.

Michel Lake (Table 1, Fig. 4), about 50 km northeast of Yellowknife, is comparatively much larger and deeper than the four lakes near the city (area 345 ha, maximum depth 22 m). We found no obvious inflows. The lake flows out at the south end through a meadow and a slough. We estimated the outflow at less than 1 cfs. Relief in the area is low and the shores rise away from the lake gently. In spite of this the bottom of the lake generally slopes down steeply and there was little shallow water and limited areas of emergent vegetation.

Trout Lake (Table 1, Fig. 5), about 39 km northeast of Yellowknife, is the deepest of the seven lakes studied (25 m) and similar in size to Michel (320 ha). We made sufficient echo sounding transects on this lake to draw a rough bathymetric map (Fig. 5). The shores of Trout Lake generally rise steeply away from the lake, especially in the northwest where there are high cliffs. Similarly the bottom slopes steeply down to maximum depth. The lake has one small inlet at the end of the northwest arm and exits through a small creek (< 5 cfs) at the south end.

Dunnet Lake (Table 1, Fig. 6) is the largest of the seven lakes but is generally very shallow. The maximum depth of 10 m occurs in a small bay to the north. The main body of the lake is seldom more than 2 m deep. Surrounding shores are generally low and boggy. The lake receives one small inflow from the east and flows out to the west. We estimated the outflow at less than 5 cfs.

Frame and Long lakes were essentially isothermal throughout the summer. Frame showed a sharp drop in temperature near the bottom in June but this was gone in August. All the other lakes were stratified in their deeper areas (Figs. 7 and 8).

Oxygen profiles generally paralleled temperature profiles (Figs. 7, 8). Oxygen concentrations were low at the bottom in deep areas of Kam, Grace and Dunnet lakes (1.5-3.0% saturation), but were higher in Trout and Michel (26-36% saturation). The oxygen concentration in the surface waters of Kam Lake was very high on June 21 (130%) and this is difficult to explain. A similar profile was obtained by G. Brunskill using the Winkler method of oxygen determination the following day. The lake has abundant phytoplankton and it is possible a bloom could have been occurring at this time.

Frame and Long lakes were generally well oxygenated to the bottom. Frame, however, appears to have a high B.O.D. and became rapidly anoxic during the winter of 1971-72 (G. Brunskill, pers. comm.).

Secchi visibility was not exceptional in any of the lakes and ranged from a low of 1½ m in Kam to 7½ m in Trout (Table 1).

All the lakes lie on Precambrian rock and receive most of their drainage from similar rocks, although there are local outcrops of sedimentary rock. All the lakes showed higher than expected ionic concentrations for Shield lakes (Armstrong and Schindler 1971). Frame and Kam were exceptionally high in salts, Kam having a conductivity of

2000 μmho/cm (Table 1). All the lakes, except Kam, have the expected high carbonate values and relative concentration of cations (Ca > Mg > Na > K). Kam, however, has a much higher sodium concentration than expected (Table 1). pH values were on the alkaline side, especially Kam.

It seems likely that the high ionic concentrations in Frame and its high B.O.D. result from its proximity to the town. The practice of dumping snow scraped from the roads onto Frame Lake has probably contributed to its peculiar chemical characteristics. Kam Lake's high ionic concentration probably stems from the effluent from Pud Lake. Conductivity of the inflow from Pud Lake can be as high as 5000 μmho/cm.

Zooplankton

Twenty-two different species of crustacean zooplankton were recorded in the samples from the seven lakes. Dunnet Lake had the most species (12) while Kam Lake had fewest (4) (Table 2). Frame Lake had the most peculiar species assemblage for the region. The species in Frame Lake are typical of a lake west of the continental divide, in Alaska or northern British Columbia, but extremely uncommon east of the divide. It is difficult to draw any concrete conclusions from the species composition in the other lakes. Kam Lake contained *Daphnia pulex*, a species not found in any of the other lakes, and had no species of *Diaptomus*. This poor assemblage of species may be a result of Kam's peculiar chemistry. The deeper lakes (except for Kam) had more species, but it is difficult to generalize on so few lakes. Grace Lake had no species of *Daphnia* although other *Cladocera* were present.

When the plankton were counted, the various species of *Diaptomus* and *Cyclops* were simply recorded as *Diaptomus* spp. or *Cyclops* spp. All other adult plankters were recorded to species. In addition the numbers of nauplii and rotifers were estimated by counting the numbers in six

Table 2. Species of crustacean zooplankton found in the lakes.

Species	Frame	Long	Kam	Grace	Michel	Trout	Dunnet
Cladocera							
Daphnia retrocurva						+	+
D. longiremis		+			+	+	+
D. pulex			+				
D. middendorffiana	+						
Bosimina longirostris		+		+	+	+	+
Ceriodaphnia lacustris					+	+	
Holopedium gibberum		+		+	+	+	+
Diaphanosoma leuchtenbergianum				+			+
Leptodora kindtii				+	+	+	+
Copepoda							
Limnocalanus macrurus					+	+	+
Senecella calanoides						+	
Epischura lacustris			+	+	+		+
Heterocope septentrionalis	+						
Diaptomus pribilofensis	+						
D. leptopus	+						
D. sicilis				+	+	+	
D. ashlandi		+			+		
D. oregonensis							+
Cyclops bicuspidatus		+		+	+	+	+
C. vernalis	+		+	+	+		+
C. scutifer			+	+			
Ergasilus sp.		+					+

microscope fields on the cell. We took two sets of samples from Frame, Long, Kam and Grace lakes, one in June and the second in August. We averaged the counts from these two sets of samples to give a single estimate for midsummer zooplankton abundance. The results suggest great variation in zooplankton abundance between lakes (Table 3). Kam Lake, in spite of having few species of crustacean zooplankton, had extremely abundant plankton, over 4000 Cyclops and Daphnia per 10 l. In addition rotifers were extremely abundant in Kam, over 70,000 per 10 l. By contrast, Long Lake had only 391 crustacean zooplankters per 10 l, most of which were Bosimina longirostris. No group was consistently abundant in all the lakes in which it occurred. For example, B. longirostris was abundant in Long Lake but scarce elsewhere. Diaptomus spp. were abundant in Frame, Michel, Trout and Dunnet, but scarce in Long and Grace lakes (Table 3).

The separate sets of plankton samples taken in Frame, Long, Kam and Grace lakes in June and August did not indicate any marked change in zooplankton abundance over the summer.

Benthos

As with plankton, counts from benthos samples taken in June and August from Frame, Long, Kam and Grace lakes were averaged to give a single estimate for midsummer. The lakes showed considerable variability in the amount and type of organisms found in the Ekman samples (Table 4). Presumably if we had identified all the organisms to species the differences would have been even more striking. In general the benthic fauna was dominated by molluscs, chironomid larvae and amphipods. Among the molluscs, sphaerids generally dominated except in Kam where lymnaeids and valvatids were more numerous. Lymnaeidae were absent from the Ekman samples except in Frame and Kam. Pontoporeia affinis was the only amphipod in the samples, although Hyalella azteca and Gammarus lacustris were common in other lakes in the region. G. lacustris also occurred in the stomachs

Table 3. Midsummer zooplankton abundance in the lakes. Nos. per 10 l. Very rare species omitted.

Species	Frame	Long	Kam	Grace	Michel	Trout	Dunnet
Limnocalanus macrurus					13.2	39.2	
Epischura lacustris				4.8	2.9		116
Heterocope septentrionalis	112						
Diaptomus spp.	488	3.5		6.8	276	216	132
Cyclops spp.	1112	2.6	3796	540	100	120	300
Daphnia retrocurva						29.6	
D. longiremis		0.8			324	1.6	424
D. pulex			540				
Diaphanosoma leuchtenbergianum				30			8
Holopedium gibberum				0.8	0.8		
Leptodera kindtii				1.2			4.8
Bosimina longirostris		284		0.4	44	24	84
Nauplii	7850	1176	1716	136	1228	420	992
Rotifers	--	5340	71196	6628	1980	1656	8344

Table 4. Benthos numbers per square meter above and below the thermocline in the lakes.

Taxonomic group	Frame	Long	Kam		Grace		Michel		Trout		Dunnet	
	Shallow	Shallow	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Annelida												
Oligochaeta	0	65	0	0	340	0	0	0	56	344	8	0
Mollusca												
Lymnaeidae	253	0	16	0	0	0	0	0	0	0	0	0
Valvatidae	136	269	60	0	80	0	200	0	320	0	88	0
Sphaeridae	1198	1051	8	4	1852	0	1528	8	768	16	168	0
Nematomorpha	0	0	0	0	8	0	0	0	0	0	8	8
Crustacea												
Amphipoda												
Pontoporeia affinis	0	105	4	0	1632	0	2696	16	592	1624	0	0
Mysidacea												
Mysis relicta	0	0	0	0	0	0	0	8	0	16	0	0
Diptera												
Chironomidae												
Chironominae	2226	151	16	0	224	84	48	72	56	168	88	24
Tanytarsinae	4	182	0	0	464	0	200	32	344	40	40	0
Orthodadiinae	0	20	0	0	16	0	0	8	0	0	0	0
Tanypodinae	151	71	104	8	256	4	72	16	776	32	0	0
Ceratopagonidae	0	0	0	0	28	0	0	0	0	0	0	0
Ephemeroptera	98	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	0	0	0	0	12	0	8	0	0	0	0	0
Odonata												
Zygoptera	34	0	0	0	0	0	0	0	0	0	0	0
Hemiptera												
Corixidae	6	0	36	0	0	0	0	0	0	0	0	0
Hydracarina	0	11	32	8	0	0	0	0	0	0	0	0
Totals	4106	1925	276	20	4912	88	4752	160	2912	2240	400	32

of whitefish (Coregonus clupeaformis) captured in Trout and Grace lakes, so it must have been present. Among the Chironomidae, Chironominae and Tanytarsinae were most common while Orthocladiinae were uncommon.

Frame, Grace and Michel had about equal numbers of total benthos in shallow water (4000-5000 organisms/m^2). In Frame, chironomids and sphaerids dominated while in the other two, sphaerids and Pontoporeia dominated. Shallow water benthos was less abundant in Long and Trout lakes (2000-3000/m^2), dominated by sphaerids in Long Lake and by sphaerids, chironomids and Pontoporeia in Trout. Dunnet and Kam lakes had very sparse shallow water benthos. Deep water benthos was sparse in all the deeper lakes except Trout Lake where it was as abundant as the shallow water benthos (Table 4).

The four lakes near Yellowknife, which were sampled twice, showed a marked increase in abundance of benthos between June and August. Numbers doubled in Long and Kam lakes, increased by four times in Grace and almost five times in Frame Lake (Table 5).

Estimates of biomass of benthos did not exactly parallel estimates of abundance. Frame Lake had the greatest abundance of benthos and also the greatest biomass. Long Lake, however, was fifth in abundance but third in biomass. Other differences of a similar order were apparent (Table 6). These differences reflect the differences in benthic composition and also the differences in size among animals from different lakes (Fig. 9). Benthic animals were not uniformly small or large from a particular lake. For example, Grace Lake had small chironomid larvae but relatively large Pontoporeia. Without more thorough identification to the species level it is not possible to say whether the size differences reflect different conditions for growth in the lakes or simply differences in species composition.

Table 5. Comparison of abundance of benthos between sampling dates in four lakes (organisms/m^2).

Taxonomic group	Frame June	Frame Aug	Long June	Long Aug	Kam June	Kam Aug	Grace June	Grace Aug
Annelida								
Oligochaeta	0	0	9	120	0	0	13	404
Mollusca								
Lymnaeidae	124	382	0	0	6	17	0	0
Valvatidae	22	249	156	382	56	28	36	49
Sphaeridae	857	1538	822	1280	6	17	671	1595
Nematomorpha	0	0	0	0	0	0	0	15
Crustacea								
Amphipoda								
Pontoporeia affinis	0	0	0	209	0	0	67	1516
Diptera								
Chironomidae								
Chironominae	368	4085	49	253	0	22	93	272
Tanytarsinae	9	0	356	9	0	0	58	513
Orthodadinae	0	0	35	4	0	0	0	20
Tanypodinae	107	195	44	98	89	67	124	183
Ceratopagonidae	0	0	0	0	0	0	0	25
Ephemeroptera	0	195	0	0	0	0	0	0
Trichoptera	0	0	0	0	0	0	0	15
Odonata								
Zygoptera	0	67	0	0	0	0	0	0
Hemiptera								
Corixidae	0	13	0	0	0	50	0	0
Hydracarina	0	0	4	18	28	39	0	0
Totals	1487	6724	1475	2373	185	240	1062	4607

Table 6. Biomass (g dry wt/m^2) of benthos in the lakes.

Lake	Date	Biomass	% ash
Frame	June 71	1.35	30
	Aug 71	7.21	12
Long	June 71	0.85	67
	Aug 71	2.57	63
Kam	June 71	0.68	62
	Aug 71	0.13	36
Grace	June 71	0.68	36
	Aug 71	3.10	54
Michel	July 71	1.27	46
Trout	July 71	1.34	27
Dunnet	July 71	0.36	-

Ash content of the total benthos was generally very high, partly a result of the abundance of molluscs (Table 6).

Fish populations

No fish were captured in Frame Lake. Some fish were captured in all the other lakes. In addition, species not captured in the gill nets were noted in the guts of pike (Esox lucius) and lake trout (Salvelinus namaycush). The species list produced by this method is by no means a complete list (Table 7). Whitefish, cisco (Coregonus artedii) and pike occurred in all the lakes, and probably sticklebacks (Pungitius pungitius) as well. Trout occurred only in the deeper lakes but were replaced by pickerel (Stizostedion vitreum) in Grace Lake. The deeper lakes appeared to have more species than the shallower, although with an incomplete species list it is difficult to be sure. One surprise was the occurrence of grayling (Thymallus arcticus) in Kam Lake.

Table 7. Species of fish captured in gill nets (+) or noted in guts of fish captured (0).

	Lake					
Species	Long	Kam	Grace	Michel	Trout	Dunnet
Salvelinus namaycush	-	-	-	+	+	-
Coregonus clupeaformis	+	+	+	+	+	+
C. artedii	0	+	+	0	0	0
Esox lucius	+	+	+	+	+	+
Thymallus arcticus	-	+	-	-	-	-
Lota lota	-	-	+	+	-	-
Stizostedion vitreum	-	-	+	-	-	-
Catostomus commersoni	-	-	-	+	+	+
Pungitius pungitius	0	-	0	0	0	0
Cottus spp.	0	-	-	-	0	-

Catch per unit effort in numbers of fish was not as variable as we expected from such different lakes. Catches were low in Kam and high in Grace but similar in the other lakes (Table 8). The amount each species contributed to the catch, however, differed considerably among the lakes. Pike, for example, ranged from 5-26% of the catch and whitefish from 44-74% (Table 8). Because of differing catchabilities, the proportions of species in the catches are unlikely to reflect their true abundance in the lake. Comparisons for one species between lakes are probably reasonable, however. Considered in this way the results suggest that pike were most abundant in Long and Michel lakes and least abundant in Trout and Kam lakes, while whitefish were most abundant in Grace and

Table 8. Catch of fish per 100 yd net in the lakes and percent composition.

Lake	Species																Total
	Salvelinus namaycush		Coregonus clupeaformis		Coregonus artedii		Esox lucius		Thymallus arcticus		Lota lota		Stizostedion vitreum		Catostomus commersoni		
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	
Long	0	0	18.3	74	0	0	6.3	26	0	0	0	0	0	0	0	0	24.6
Kam	0	0	7.1	53	1.3	10	2	15	3	22	0	0	0	0	0	0	13.4
Grace	0	0	33.7	54	22.7	37	3.3	5	0	0	1.7	3	0.7	1	0	0	62.1
Michel	5	16	14	44	0	0	5	16	0	0	0.5	2	0	0	7	22	31.5
Trout	5	18	20.3	73	0	0	2	7	0	0	0	0	0	0	0.7	2	28
Dunnet	0	0	16	70	0	0	6	26	0	0	0	0	0	0	1	4	23

Table 9. Mean length and weight (cm and g) of fish caught in standard gill net gangs in lakes.

Lake	Species															
	Salvelinus namaycush		Coregonus clupeaformis		Coregonus artedii		Esox lucius		Thymallus arcticus		Lota lota		Stizostedion vitreum		Catostomus commersoni	
	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
Long	-	-	32	530	-	-	60	2297	-	-	-	-	-	-	-	-
Kam	-	-	33	831	32	677	34	300	32	533	-	-	-	-	-	-
Grace	-	-	43	1294	22	169	55	1348	-	-	53	1063	53	1861	-	-
Michel	53	1844	39	789	-	-	51	1104	-	-	65	1850	-	-	45	1495
Trout	52	2062	42	1025	-	-	60	1646	-	-	-	-	-	-	50	2200
Dunnet	-	-	37	748	-	-	51	1162	-	-	-	-	-	-	46	1650

Trout lakes, and scarce in Kam (Table 8).

Average size of fish in the catches varied considerably (Table 9). Whitefish varied from 32 cm fork length and 530 grams in Long Lake to 43 cm and 1294 grams in Grace. Pike varied from 34 cm and 300 grams in Kam to 62 cm and 2297 grams in Long.

Pike and whitefish were the only species captured in sufficient numbers in all the lakes to permit a comparison of length/weight relationships. The slopes of the regression of log weight on log length were statistically more variable among whitefish than among pike (Table 10).

Table 10. Slopes of log length - log weight regressions for pike and whitefish from the lakes.

	Pike			Whitefish		
Lake	N	Slope "b"	SD_b	N	Slope "b"	SD_b
Long	19	3.045	0.0789	63	3.34	0.0484
Kam	6	2.950	0.1061	20	3.26	0.0615
Grace	10	3.070	0.0985	60	3.23	0.1206
Michel	10	2.920	0.2100	27	3.45	0.0903
Trout	6	3.060	0.1281	61	3.49	0.0645
Dunnet	12	2.420	0.4590	30	3.16	0.0564

The small sample sizes for pike, however, probably prevented the detection of any differences. The slopes for both pike and whitefish were low in Dunnet, while whitefish from Michel and Trout had rather steep slopes. Coefficients of condition (weight X 100/length^b where b is the slope of the log length-log weight regression) further emphasized the differences between the lakes, whitefish from Kam having the highest coefficient (0.93) followed by Dunnet (0.83), Grace (0.68) and Long (0.50). The condition of whitefish in Michel and Trout lakes was quite low (0.26 and 0.22 respectively). The condition of pike was best in Long Lake (1.06) and lower but about the same in the other lakes (ranging from 0.76-0.87).

Only whitefish and pike were captured in sufficient numbers to provide some indication of growth. Growth of whitefish in nearby Great Slave Lake may be compared with the growth in these small lakes. In general, young fish from the small lakes were larger than those from Great Slave. Asymptotic sizes appeared to be similar, or smaller than in Slave, except for Grace and Kam lakes. Fish from Kam Lake in particular appear to grow very fast and to a larger size (Fig. 10). In addition, the fish captured in Kam were very young; most were 3-4 years old as opposed to 7-8 years old or older in the other lakes (Table 11). By comparison, whitefish from Long Lake grew very slowly and had a small maximum size.

Table 11. Median age and range of ages of whitefish caught in the lakes.

Lake	Median age	Range of ages
Long	6	2 - 10
Kam	3	1 - 11
Grace	9	4 - 15
Michel	8	2 - 14
Trout	10	3 - 14
Dunnet	7	2 - 10

Whitefish appeared to have a clear asymptotic size (Fig. 10). An asymptotic size for pike was not at all clear, however (Fig. 11). The pike from Dunnet Lake may have an asymptotic size but the results from

Dunnet are peculiar in that the pike captured ranged from 5-10 years old and were all of a similar size.

Median age and range of ages captured are shown for other species in Table 12. Ages for trout are suspect due to problems of aging this species from scales. Not much can be made of these data because of the small sample sizes. However, it is worth noting that the grayling in Kam Lake were all young (2-3 years) and sexually mature. Also the ciscos in Grace Lake, although relatively large, were quite young as well.

Table 12. Median ages and range of ages for species other than whitefish in the lakes.

Lake	Species	Median age	Range of ages
Long	pike	8	3 - 10
Kam	cisco	10	7 - 11
	pike	4	3 - 5
	grayling	3	2 - 3
Grace	cisco	3	2 - 6
	pike	8	7 - 10
Michel	pike	6	2 - 13
	trout	4	4 - 5
Trout	pike	8	5 - 10
	trout	5	3 - 6
Dunnet	pike	7	5 - 10

Food habits of whitefish differed considerably among the lakes (Table 13). Chironomid larvae figured predominantly in their diet in all the lakes except Long Lake. Other important foodstuffs, however, differed from lake to lake. Molluscs and Trichoptera were important in Long Lake; corixids and <u>Daphnia</u> in Kam; Sphaerids in Grace; <u>Gammarus</u> in Trout; and fish and Trichoptera in Dunnet. The selection of dominant

Table 13. Occurrence of various foods in whitefish guts. Dominant food organisms marked ++.

Food item	Lake: Dunnet	Long	Grace	Kam	Trout
Chironomid larvae	++	+	++	++	++
pupae	+	+	+	+	+
Trichoptera	++	++	+	+	+
Corixidae	-	+	-	++	-
Ephemeroptera	-	-	+	-	-
Gammarus lacustris	-	-	+	-	++
Daphnia	-	-	-	++	-
Chydoridae	-	+	-	-	-
Conchostraca	-	-	+	-	-
Sphaeridae	+	++	++	-	+
Valvatidae	+	++	+	-	+
Lymnaeidae	-	-	-	+	-
Hydrocarina	+	+	-	-	-
Hirudinia	-	+	-	-	-
Nematomorpha	-	+	-	-	+
Pisces	++	-	+	-	+

foodstuffs in the diet is difficult because of the wide range of things eaten by whitefish. Such results confirm the conclusion of Hart (1931) that whitefish will eat whatever is available.

The occurrence of items in the diet was not directly related to their occurrence in the benthos as indicated by Ekman samples. For example, caddis larvae were generally more prominent in the diet than in the benthic samples. Pontoporeia were common in Trout and Grace lakes but did not occur in the stomachs sampled, while Gammarus which was not present in the Ekman samples formed an important dietary item in Trout Lake.

The diets of other species were less variable. Pike and trout ate almost exclusively fish (cisco, sticklebacks, cottids mainly) although pike from Kam Lake had eaten corixids. Grayling from Kam had fed mainly on corixids but also on chironomids. Ciscos from Kam had fed mainly on Daphnia pulex but also on chironomid and chaoborus larvae. Cisco from Grace had fed mainly on small copepods but also on chironomid larvae.

DISCUSSION

The general biological characteristics of Frame Lake are not typical of Shield lakes and probably result from a combination of circumstances associated with its proximity to Yellowknife and the influence of the city upon it. The peculiar species composition of the plankton is probably an accident of geologic history. The shallowness of the lake, together with its slow flushing rate and the inevitable input of materials from the city have probably resulted in an increased productivity and accumulation of organic material. This in turn has resulted in deoxygenation during the winter stagnation period. The deoxygenation during the winter probably asphyxiated any fish which may originally have inhabited the lake. This lack of predators together with abundant organic matter for food may account for the abundance and high biomass of benthic organisms.

Long Lake is superficially similar to Frame Lake but is farther from town and, therefore, less influenced by the town. It seems likely that Frame Lake was originally more similar to Long Lake, and that, as the city grows, Long Lake could become like Frame is today. Presently, however, the biological characteristics of the lake seem appropriate to its morphometry and chemistry. Benthic animals are reasonably abundant, as one might expect in a small shallow lake. Plankton is rather sparse and made up of small forms. This may be a result of an abundance of planktivorous fishes such as cisco and sticklebacks. Although gill net catches did not indicate an abundance of cisco, this may be due to net selection, as the abundant and healthy pike were feeding mainly on cisco and stickleback. The lake is physically well suited to pike with lots of shallow weed beds for spawning and apparently sufficient food. The whitefish, although reasonably abundant, grew poorly. Feeding conditions for whitefish may be poor as they were subsisting mainly on molluscs.

Kam Lake appears to be dominated by the inflow of toxic wastes from Pud Lake and, of course, will be influenced by the inflow of sewage from the city as well. It is tempting to ascribe the biological conditions in Kam to the effects of the Pud Lake inflow and this may be true. But it is not possible to establish any cause-effect relationship from the present data. It may be that few planktonic species can survive in Kam, but those that can are extremely abundant. Benthos is extremely poor, especially in deeper waters. Nevertheless, the whitefish in the lake were able to exploit the abundant Daphnia and showed a startling growth rate. Their good growth may, however, have been partly a result of their low population density. The young age of the whitefish is difficult to explain. Possibly Kam suffers occasional fish kills and the lake is recolonized by fry washed down from nearby Grace Lake. The grayling may not have been resident but may have migrated into Kam from Great Slave Lake.

The situation in Grace Lake is the most difficult to explain. We can see no immediate reason why such a small lake of such average character should have such a diverse and abundant fish fauna. Some features may be explained as interactions among the fish and their food. For example, the absence of Daphnia sp. may be a result of an abundance of planktivorous fishes. However, such speculations seem idle, as the abundance and size composition of both plankton and benthos is similar to Trout and Michel lakes, which have about half the standing crop of fish.

Michel Lake was the only lake sampled which had any abundance of suckers (Catostomus commersoni), although they occurred in Trout and Dunnet as well. This is another mystery as it is not at all clear why conditions should favor suckers in Michel and not in Trout or Dunnet. The trout from Michel, although reasonably abundant, were generally thin and undernourished.

Trout Lake had the third most abundant fish fauna after Grace and Michel lakes. It was the most "scenic" of the lakes with high cliffs and clear water. It is at first sight an ideal lake for lake trout and the healthiest and largest trout were captured there.

The shallowness of Dunnet Lake is probably partly responsible for its relatively poor fish fauna. When a meter of ice forms on the lake its total volume would be reduced considerably. The small area of deep water probably precluded the development of a trout population. Nevertheless, whitefish were reasonably abundant, though of smaller than average size. In Dunnet small fish formed a significant part of the whitefish diet. It seems unlikely that this was due to an abundance of small fish as the pike in the lake were neither exceptionally large nor exceptionally fat. It seems more likely due to the sparse benthos, which was of similar abundance to Kam Lake. In Kam, the whitefish turned to Daphnia as an alternate food source. Although another cladoceran, D. longiremis, was almost as abundant in Dunnet as D. pulex was in Kam, it is of much smaller size and presumably was a less satisfactory alternate food source than small fish.

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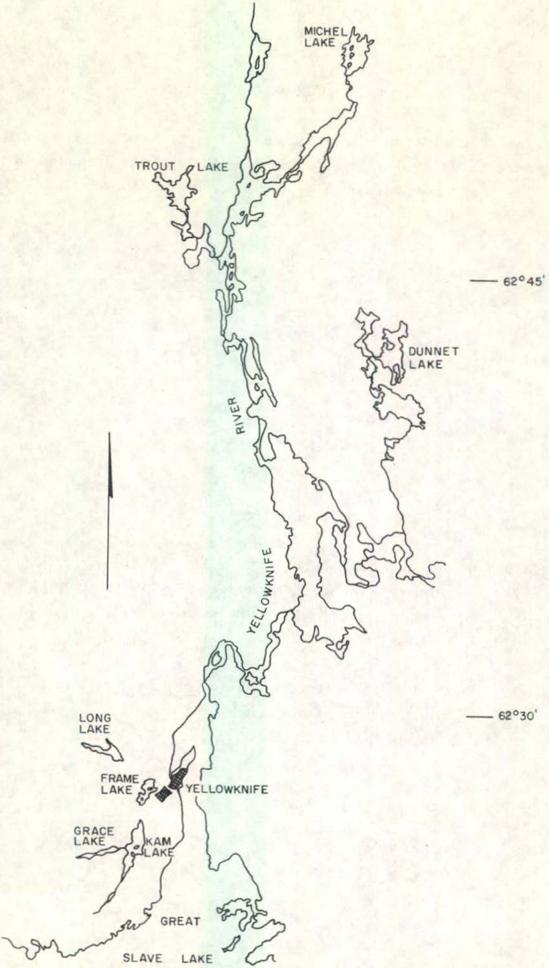

Fig. 1. Map showing the locations of the seven lakes.

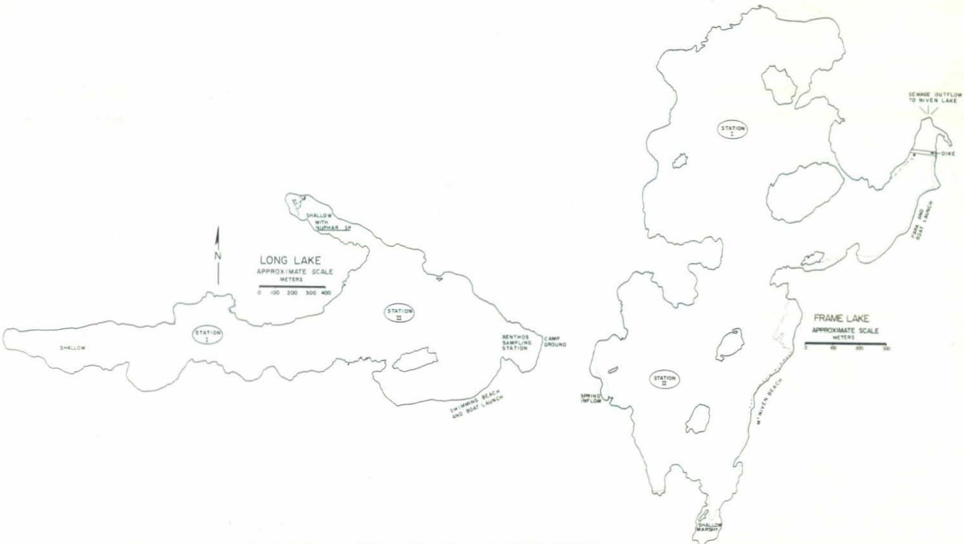

Fig. 2. Outline maps of Frame and Long lakes showing sampling locations.

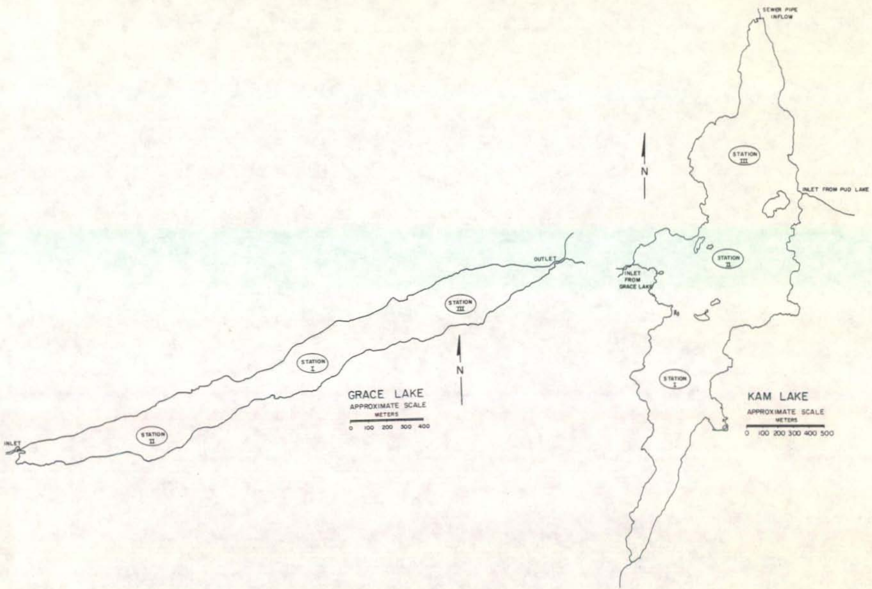

Fig. 3. Outline maps of Kam and Grace lakes showing sampling locations.

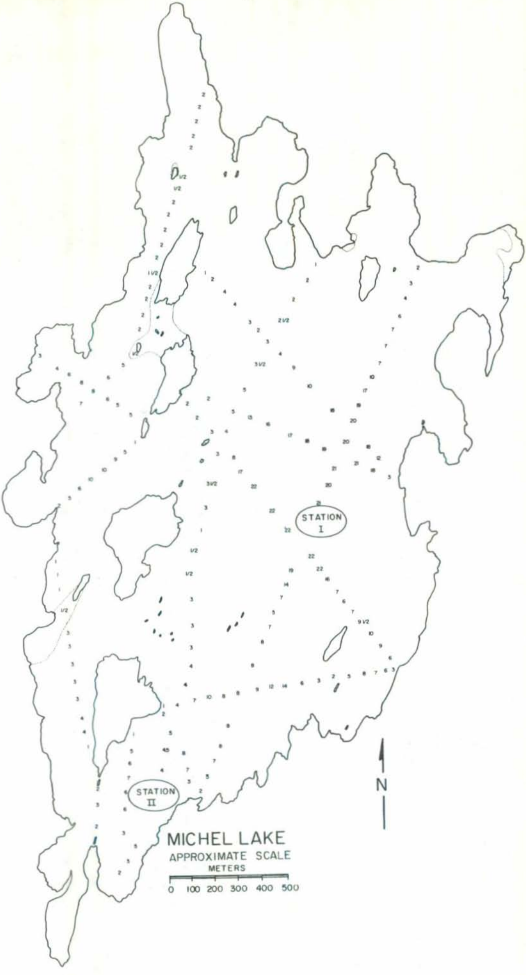

Fig. 4. Outline map of Michel Lake with soundings and sampling locations.

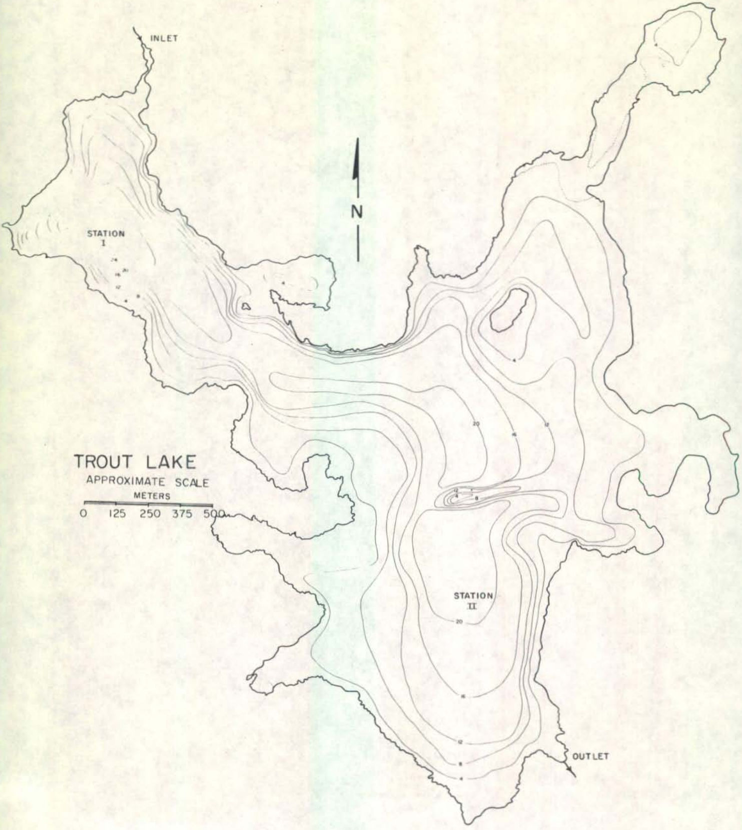

Fig. 5. Outline map of Trout Lake with contours and sampling locations.

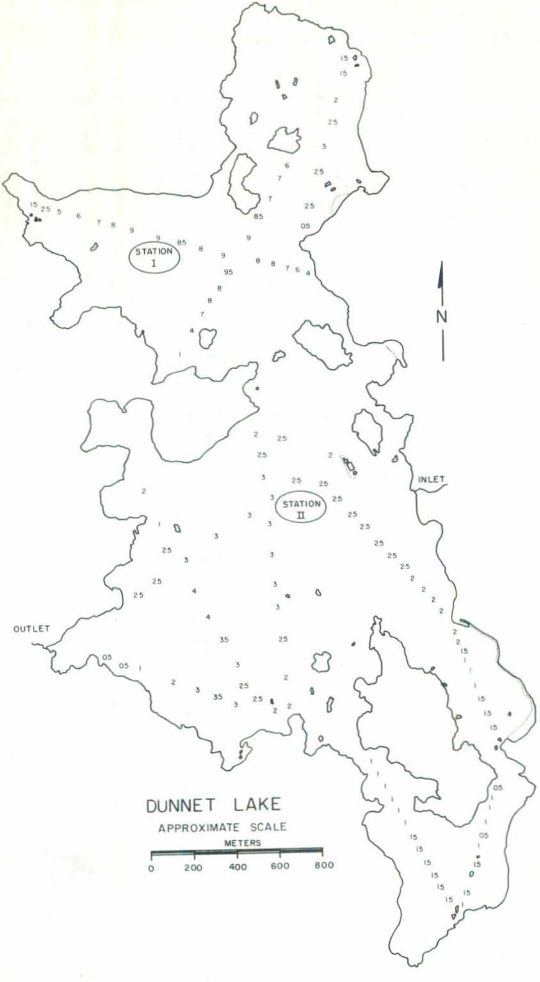

Fig. 6. Outline map of Dunnet Lake with soundings and sampling locations.

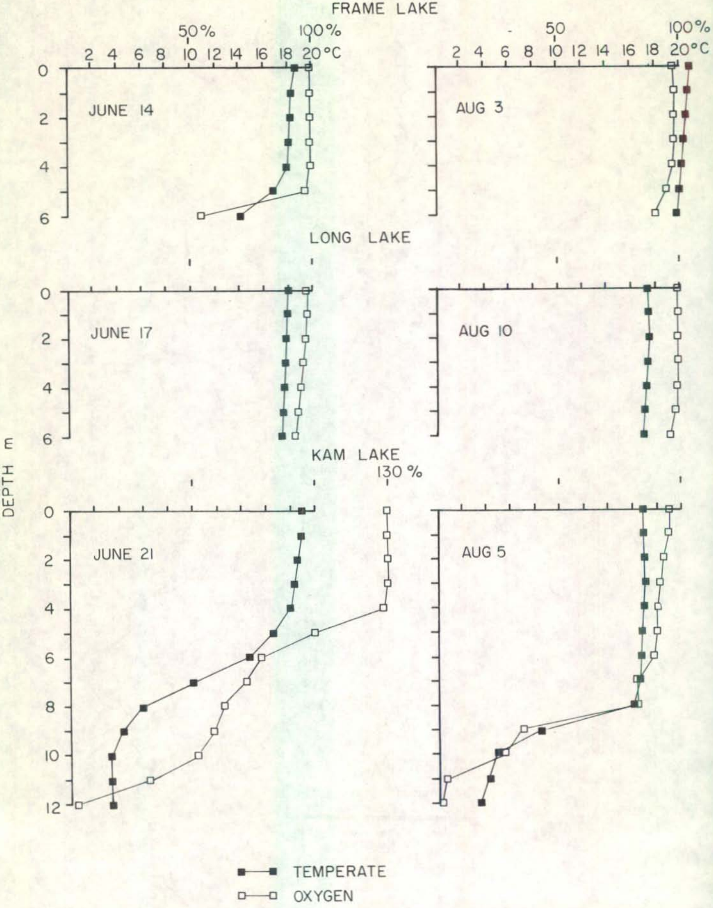

Fig. 7. Temperature and oxygen profiles for Frame, Long and Kam lakes.

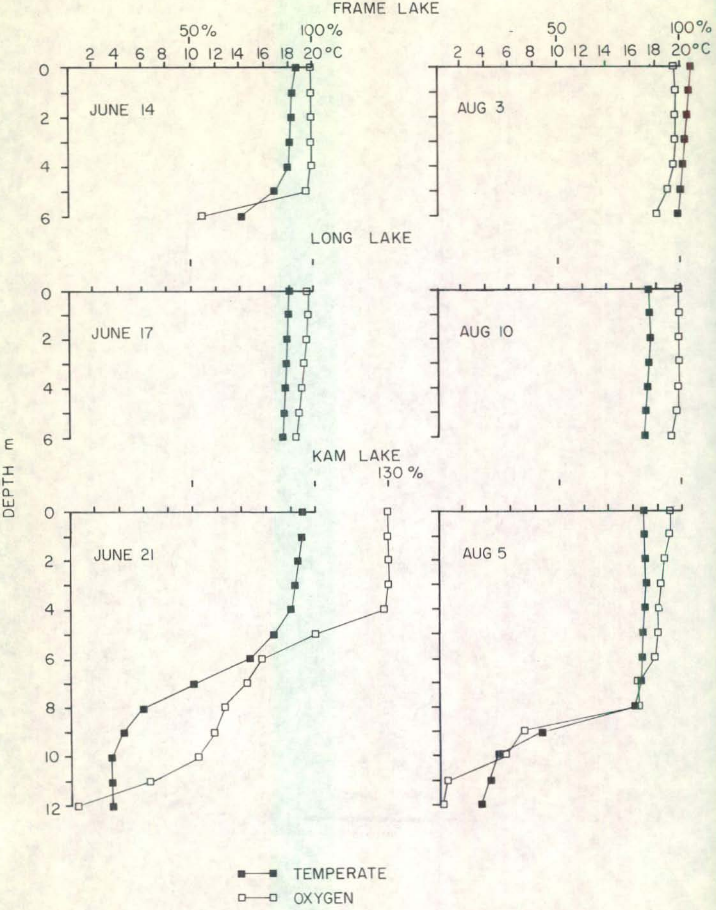

Fig. 7. Temperature and oxygen profiles for Frame, Long and Kam lakes.