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EXPLORATORY MICROBIOLOGICAL STUDY OF THE SIX QU'APPELLE LAKES:

Pasqua, Echo, Mission, Katepwa, Crooked and Round

(July 11-14, 1977)

by

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INTRODUCTION

The Qu'Appelle Lakes are a chain of six narrow lakes extending approximately 135 kilometers along the Qu'Appelle River, northeast of Regina, Saskatchewan (Fig. 1). The first four lakes in the chain, Pasqua, Echo, Mission and Katepwa, cover approximately 40 kilometers of the river. Approximately 55-60 kilometers further downstream, Crooked and Round Lakes plus the interconnecting river cover another 38 kilometers of the downstream river.

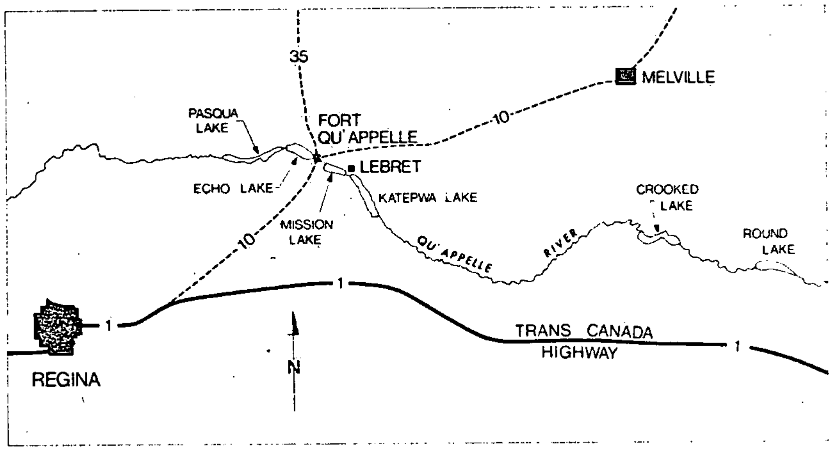
These lakes are highly eutrophic and throughout this short study contained readily visible green algal bloom. It is suspected that the major portion of the nutrients entering this chain of lakes is due to landwash. However sewage effluents discharged by the Regina sewage treatment plant and the lagoon discharges from Fort Qu'Appelle and the town of Labret also affect these waters.

The extent and degree of the effect of sewage effluent on these lakes has never been established and there are little or no data concerning the distribution of health indicator bacteria within these lakes. Therefore an exploratory microbiological study was undertaken to ascertain:

(i) the extent of the effect of present ongoing sewage discharges into the lakes as measured by traditional indicator systems (fecal coliforms, fecal streptococci and *P. aeruginosa*) and also the effect of historical discharges as measured and traced by *Clostridium perfringens* spores;

(ii) whether the lakes can be distinguished from one another by use of microbiological parameters such as heterotroph densities, total microbial biomass and ATP concentrations.

FIGURE 1. RELATION OF QU'APPELLE RIVER AND SIX LAKES TO REGINA, SASKATCHEWAN



KEY MAP

METHODS

Sample Collection

On July 11, 12 and 13 sediment and water samples were collected from the 6 Qu'Appelle lakes at the fifty sampling sites shown in Figure 2. Samples 1-19 were collected on July 11; 20-39 on July 12; and 40-50 on July 13. Surface sediments (1 cm) were collected by means of an Eckman dredge, placed in sterile plastic bags, iced and returned to CCIW for processing. Surface water samples which were collected at the same time, were iced and processed the same day for total bacterial counts (epi-fluorescence technique) and ATP. Sediment depth, colour and consistency were also recorded along with surface water temperature and conductivity (Yellow Springs Instrument Co.).

On July 14 surface water samples were collected from the following lakes and sample sites:

Pasqua......5, 7, 8, 9, 11, 12;

Echo.......13, 16, 18, 19;

Qu'Appelle River...20;

Mission.....21, 22, 24, 25, 27, 28;

Qu'Appelle River...29;

Katepwa.....30, 31, 34, 37;

Crooked.....43;

Round.......48.

These samples were iced on collection and returned to CCIW and processed within 30 hours of collection for the following: fecal coliforms, fecal streptococci, *P. aeruginosa*, ATP, total count (epi-fluorescence) and heterotroph counts.

Microbiological Methods

ATP measurements were performed following the modified procedure proposed by Afghan, Ryan and Tobin (1976) with the following modifications: water samples were filtered through an 0.2 micron, 25 mm Nucleopore membrane filter instead of the fibre glass filter, and the centrifugation step was then omitted.

The epi-fluorescence procedure (Dutka, 1975) using 0.2 micron, 25 mm Nucleopore membrane filter combined with the formaldahyde preservative step, was used to estimate the total microbial population and microbial biomass in the water samples.

Clostridium species and Clostridium perfringens densities in sediment were estimated by the MPN technique using Differential Reinforced Clostridial medium (DRCM) with confirmation of C. perfringens by Litmus milk. Diluted sediment samples (10 gram sediment + 90 ml buffer) were heated to 75°C for 15 minutes prior to the preparation of further 10-fold dilutions and inoculation into full tubes of DRCM to which 0.2 ml (single strength broth) and 0.4 ml (double strength broth) of the following solution mixture was added:

Solution #1 - 4 g sodium sulfite in 100 ml distilled H_2O;
Solution #2 - 7 g ferric citrate in 100 ml distilled H_2O;
Solutions #1 and #2 were filter sterilized and mixed in equal portions prior to use.

DRCM tubes were incubated for 48 hrs. at 35°C under anaerobic conditions. Positive tubes were confirmed for C. perfringens by transfer to filled tubes of Litmus milk. Stormy fermentation was taken as positive test for C. perfringens.

Fecal coliform densities in sediment samples were estimated by the MPN technique using A-1 broth (Andrews and Maynard, 1972) with incubation at 44.5^{o}C for 24 hours.

Fecal coliform and fecal streptococcus densities in the water samples were estimated by the MF technique using procedure and media described by Dutka (1975). Pseudomonas aeruginosa densities were estimated by the MF technique using mPA medium B (Dutka and Kwan, 1977). Heterotrophic bacterial densities were estimated by the spread plate technique using Heterotroph agar (Dutka, 1975) with incubation at 20^{o}C for 7 days.

Bacterial biomass estimates (g/litre) were based on total bacterial count estimates outlined by Dutka (1975).

RESULTS AND DISCUSSION

Table 1 presents all the microbiological sediment data collected during the three-day sediment collection programme. In this study, Clostridium spp. and Clostridium perfringens are used to ascertain the effect of various sewage discharges on the six Qu'Appelle lakes. Clostridium perfringens has been suggested as and used as an indicator of fecal wastes since approximately 1900. Because of their (spp. and perfringens) distribution in terrestrial and aquatic environments, their use as indicators are limited to specific instances:

(i) where historical instances of fecal discharges are required;
(ii) where remote sources of pollution are to be detected.

TABLE 1. 1977 QU'APPELLE LAKE STUDY. SEDIMENT SAMPLES

Lake	Station No.	Date	Clostridium Species/10gm	Clostridium Perfringens/10gm	Fecal Coliform /10gm	Depth in Metres	Sediment Description
Pasqua	1	July 11	>2400	350	11	1	black reduced soft mud
Pasqua	2	July 11	>2400	>2400	34	1	black reduced soft mud
Pasqua	3	July 11	350	240	2	1.5	1-2mm green brown surface, black reduced very soft
Pasqua	4	July 11	>2400	>2400	9	1	black reduced soft mud
Pasqua	5	July 11	>2400	240	<2	1	1mm green brown surface, black reduced sub-surface, firm
Pasqua	6	July 11	>2400	240	<2	1.5	black reduced very soft, fine green brown surface layer
Pasqua	7	July 11	>2400	240	1600	3	black reduced very soft, fine green brown surface layer
Pasqua	8	July 11	>2400	>2400	<2	10	black reduced very soft, fine green brown surface layer
Pasqua	9	July 11	>2400	>2400	2	10	black reduced very soft, fine green brown surface layer
Pasqua	10	July 11	>2400	>2400	2	10	black reduced very soft, fine green brown surface layer
Pasqua	11	July 11	>2400	>2400	<2	10	black reduced very soft, fine green brown surface layer
Pasqua	12	July 11	920	540	350	1	black reduced very soft, fine green brown surface layer
Echo	13	July 11	920	240	130	1	sandy, shells, 1-2mm green brown layer, black reduced below

Lake	Station No.	Date	Clostridium		Fecal Coliform /10gm	Depth in Metres	Sediment Description
			Species/10gm	Perfringens/10gm			
Echo	14	July 11	>2400	>2400	<2	14	very anoxic, H_2S, black ooze, no definite surface
Echo	15	July 11	1600	350	<2	15	H_2S, greyish film on fluid surface of black ooze
Echo	16	July 11	>2400	>2400	<2	15.5	H_2S, black ooze, all reduced
Echo	17	July 11	>2400	1600	<2	15.5	H_2S, black ooze, all reduced
Echo	18	July 11	>2400	>2400	<2	16	H_2S, black ooze, all reduced
Echo	19	July 11	540	240	46	.5	sandy, 1cm brown green layer on top, reduced below
Qu'Appelle River	20	July 12	>2400	1600	>2400	1	sandy, 1cm brown layer on top
Mission	21	July 12	1600	920	33	1	sand
Mission	22	July 12	>2400	1600	<2	12	no surface structure, green algal mass over black ooze
Mission	23	July 12	>2400	1600	<2	14.2	no surface structure, green algal mass over black ooze
Mission	24	July 12	1600	920	<2	14.2	no surface structure, green algal mass over black ooze
Mission	25	July 12	>2400	>2400	4	14.2	no surface structure, green algal mass over black ooze
Mission	26	July 12	920	540	17	14.2	thin layer green algae over soft indefinite black ooze
Mission	27	July 12	920	540	17	6.2	sandy, 1cm brown green layer over black sand

Lake	Station No.	Date	Clostridium Species/10gm	Clostridium Perfringens/10gm	Fecal Coliform /10gm	Depth in Metres	Sediment Description
Mission	28	July 12	1600	170	40	1	sandy, shells, reed bed with some black mud
Qu'Appelle River	29	July 12	>2400	540	170	1	sandy, .5cm light brown surface with black mud below
Katepwa	30	July 12	>2400	920	170	1	hard sand, no obvious layers
Katepwa	31	July 12	>2400	920	<2	19	soft black mud with watery surface
Katepwa	32	July 12	>2400	>2400	<2	19.2	grey green thin surface over black soft ooze
Katepwa	33	July 12	>2400	>2400	<2	19	very soft indefinite black ooze, H_2S
Katepwa	34	July 12	>2400	1600	<2	20	very soft indefinite black ooze, H_2S
Katepwa	35	July 12	>2400	>2400	<2	19.1	very soft indefinite black ooze, H_2S
Katepwa	36	July 12	>2400	1600	2	19.1	very soft indefinite black ooze, H_2S
Katepwa	37	July 12	>2400	1600	<2	19.5	very soft indefinite black ooze, H_2S
Katepwa	38	July 12	>2400	>2400	2	19.5	grey surface, streaked black ooze
Katepwa	39	July 12	>2400	49	<2	1	hard sand with fine, soft overlay

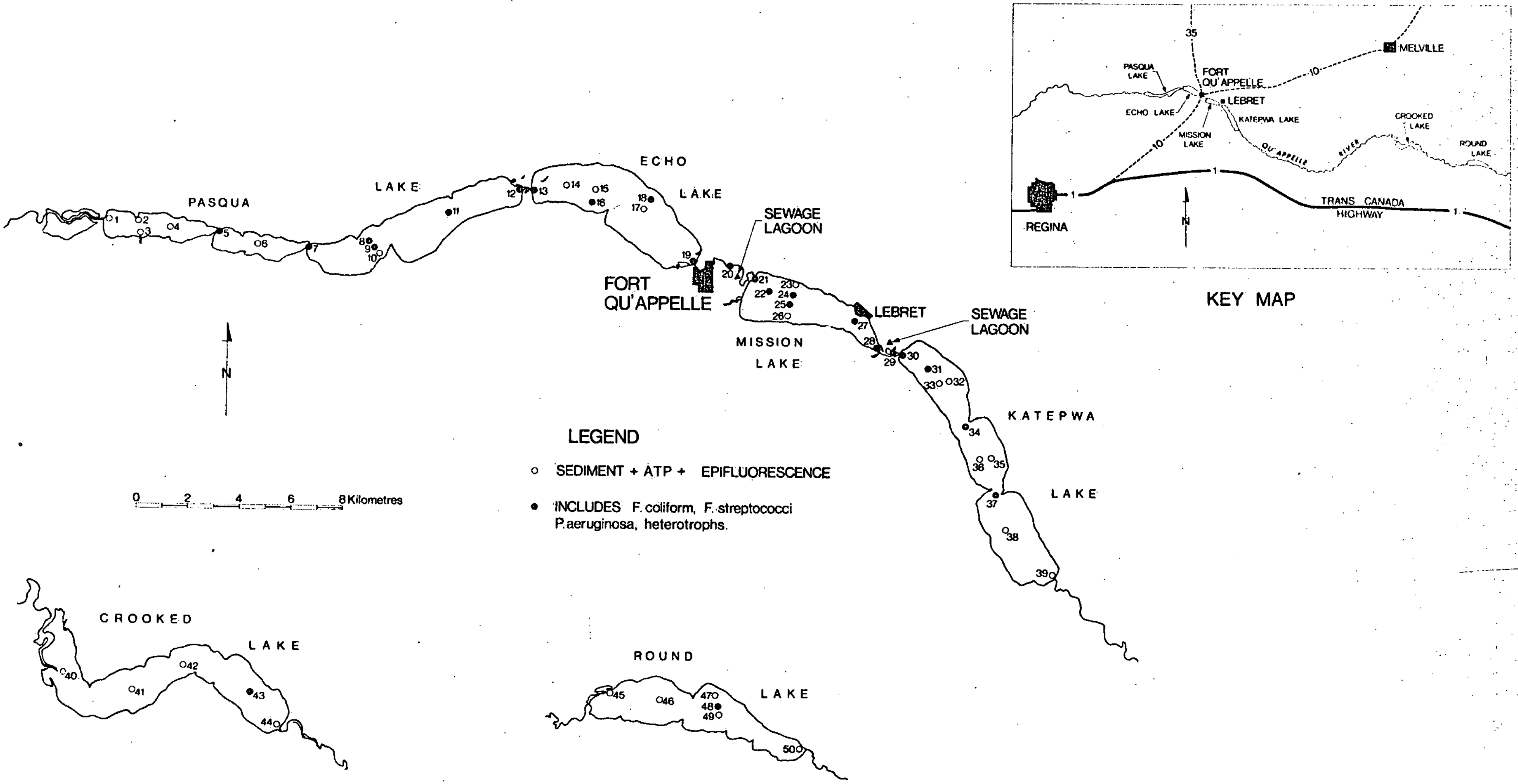
Lake	Station No.	Date	Clostridium		Fécal Coliform /10gm	Depth in Metres	Sediment Description
			Species/10gm	Perfringens/10gm			
Crooked	40	July 13	>2400	1600	540	2.7	grey black mud with green overlay, clay consistency of mud
Crooked	41	July 13	>2400	920	2	10.5	green algae on surface of grey green mud
Crooked	42	July 13	>2400	540	<2	16	grey black ooze
Crooked	43	July 13	>2400	350	<2	11	grey black ooze
Crooked	44	July 13	>2400	17	5	1	hard sand
Round	45	July 13	>2400	540	33	1.6	1-3cm green algae over grey brown soft mud
Round	46	July 13	>2400	540	<2	11.2	soft green brown ooze over grey brown mud
Round	47	July 13	>2400	540	2	11.2	soft green brown ooze over grey brown mud
Round	48	July 13	>2400	350	2	11.1	green brown mud
Round	49	July 13	>2400	540	<2	12	green brown soft mud
Round	50	July 13	>2400	240	240	1	sandy with area of black ooze

It may be argued that the *Clostridium spp.* (sulfite reducers) will always be present in soil and in natural waters; however, in contrast to the anaerobic sporeformers, coliforms are also present and may multiply there. What is of greater importance is that the sulfite reducers may be enumerated with far greater precision and accuracy than coliforms, and the results have been found to obey the Poisson law of distribution, which makes tests of significance between results rather easy. Because of the latter, it is possible to distinguish with certainty between a background pollution and a pollution of fecal origin.

From Table 1 it can be seen that *Clostridium spp.* (anaerobic sulfite reducers) which include natural forms, animal and human forms, are fairly evenly distributed throughout the six lake chain. However, the more restrictive *C. perfringens* population estimates indicate, with the exception of station 40 in Crooked Lake (Fig. 2), that the last two lakes in the chain, Crooked and Round, are minimally affected by fecal pollution with densities of less than 920 per 10 g sediment. Lower *C. perfringens* counts were also noted in areas with hard sandy bottoms, areas subjected to the scouring action of currents thus inhibiting the build-up of sediment.

Fecal coliform densities in the majority of sediment samples were very low, an indication of little ongoing fresh pollution. Most of the sampling points which had elevated sediment fecal coliform densities (7, 20, 29, 30) were near obvious potential sources of fecal input. Station 7, with the second highest concentrations of fecal coliforms (1600 per 10 g), is situated at a narrowing point within

FIGURE 2. DETAILED MAP OF QU'APPELLE LAKES SHOWING SAMPLING STATIONS AND SAMPLES COLLECTED



Pasqua Lake which has a fairly heavy shoreline population. Since the C. perfringens population at sampling point 7 was relatively low, it is suspected that the shoreline residences are contributing a low level of local pollution which may be multiplying or settling out in the sampled area. Sampling point 20 in the Qu'Appelle River near Ft. Qu'Appelle had the highest density of fecal coliforms (>2400 per 10 g) and also had high C. perfringens (1,600 per 10 g) levels. These data are strongly indicative of continuing fecal pollution of the area, possibly from the Ft. Qu'Appelle sewage lagoon. Similarly at the two Lebret stations 29 and 30, which are in the Qu'Appelle River, there appears to be a local low-grade fecal pollution effect with the local lagoon being the suspected source.

The elevated fecal coliform densities found at stations 40 (Crooked Lake) and 50 (Round Lake) were unexpected and may be indicative of animal pollution or some local unsuspected potential problem area.

Generally it would appear that long-term historical discharges of fecal material into the six Qu'Appelle lakes have affected all portions of these lakes, based on C. perfringens distribution patterns. However, fecal coliform density patterns indicate that the lakes are being subjected to fresh fecal pollution in a few limited areas only.

Table 2 presents all water column data while Table 3 presents the mean data of the trophic indicators. From Tables 2 and 3 it can be seen that microbial populations and microbial biomass are similar throughout the six lakes, although there are local wide fluctuations within most lakes; e.g., Stations 3 and 4 in Pasque produced similar

TABLE 2. SURFACE WATER DATA FROM SIX QU'APPELLE LAKES.

Lake/River	Station No.	Date	F. coliform /100 ml	F. streptococci /100 ml	Pseudomonas aeruginosa /100 ml	Heterotrophs	Total Count /ml	Bacterial Biomass g/m^3	ATP femtograms $x10^8$ /litre	Temperature ^oC	Conductivity µ mho/cm
PASQUA	1	July 11					$4.23x10^7$	42.3	18.0		
	2	July 11					$3.80x10^7$	38.0	3.1		
	3	July 11					$1.41x10^7$	14.1	10.0		
	4	July 11					$1.43x10^7$	14.3	.475		
	5	July 11					$3.92x10^7$	39.2	4.78		
		July 14	<9	<9	<1	$2.9x10^4$	$6.13x10^7$	61.3	10.7	20.5	1020
	6	July 11					$5.18x10^7$	51.8	8.88		
	7	July 11					$3.13x10^7$	31.3	7.76		
		July 14	<9	<9	2	$6.9x10^4$	$3.59x10^7$	35.9	9.9	19.9	1420
	8	July 11					$3.50x10^7$	35.0			
		July 14	<9	<9	<1	$6.1x10^4$	$4.59x10^7$	45.9	5.03	19.7	1720
	9	July 11					$4.49x10^7$	44.9	5.0		
		July 14	<9	<9	<1	$6.0x10^4$	$4.67x10^7$	46.7	9.9	19.5	1720
	10	July 11					$5.19x10^7$	51.9			
	11	July 11					$3.27x10^7$	32.7	1.54		
		July 14	<9	<9	<1	$3.6x10^4$	$6.24x10^7$	62.4	2.2	19.7	1720
	12	July 11					$3.10x10^7$	31.0	3.69		
		July 14	<9	54	<1	$6.1x10^4$	$4.31x10^7$	43.1	2.73	20.7	1660

Lake/River	Station No.	Date	F. coliform /100 ml	F. streptococci /100 ml	Pseudomonas aeruginosa /100 ml	Heterotrophs	Total Count /ml	Bacterial Biomass g/m^3	ATP femtograms $x10^8$ /litre	Temperature ^oC	Conductivity µ mho/cm
ECHO	13	July 11					$2.98x10^7$	29.8	1.89		
		July 14	18	350	<1	$8.4x10^4$	$3.15x10^7$	31.5	5.91	20.4	1630
	14	July 11					$6.44x10^7$	64.4	5.9		
	15	July 11					$3.90x10^7$	39.0	1.36		
	16	July 11					$4.13x10^7$	41.3	2.56		
		July 14	<9	<9	<1	$1.0x10^4$	$1.58x10^7$	15.8	4.28	19.5	1400
	17	July 11					$1.96x10^7$	19.6	1.6		
	18	July 11					$2.33x10^7$	23.3	1.85		
		July 14	<9	<9	<1	$5.6x10^3$	$3.71x10^7$	37.1	21.5	19.7	1430
	19	July 11					$2.05x10^7$	20.5	1.98		
		July 14	45	81	4	$4.1x10^4$	$2.70x10^7$	27.0	10.3	20.3	1380
QU'APPELLE RIVER	20	July 12					$4.64x10^7$	46.4	17.1	20.0	1370
		July 14	36	99	2	$3.4x10^4$	$2.59x10^7$	25.9	20.8		

Lake/River	Station No.	Date	F. coliform /100 ml	F. streptococci /100 ml	Pseudomonas aeruginosa /100 ml	Heterotrophs	Total Count /ml	Bacterial Biomass g/m^3	ATP femtograms x10^8 /litre	Temperature °C	Conductivity µ mho/cm
MISSION LAKE	21	July 12					2.98×10^7	29.8	2.53	19.8	1350
		July 14	27	36	<1	2.2×10^4	2.35×10^7	23.5	9.0		
	22	July 12					4.55×10^7	45.5	4.14	19.5	1270
		July 14	9	9	<1	6.1×10^3	3.65×10^7	36.5	2.53		
	23	July 12					4.10×10^7	41.0	3.96	19.5	1280
	24	July 12					2.45×10^7	24.5	2.13	19.4	1270
		July 14	9	9	<1	2.5×10^3	3.42×10^7	34.2	2.77		
	25	July 12					4.47×10^7	44.7	2.04	19.3	1270
		July 14	<9	<9	<1	1.4×10^4	2.11×10^7	21.1	2.48		
	26	July 12					8.28×10^7	82.8	2.64	19.2	1270
	27	July 12					9.21×10^7	92.1	3.96	19.2	1270
		July 14	<9	<9	<1	5.6×10^3	1.81×10^7	18.1	7.30		
	28	July 12					3.68×10^7	36.8	1.96	19.6	1250
		July 14	<9	<9	2	1.4×10^4	2.32×10^7	23.2	4.10		
QU'APPELLE RIVER	29	July 12					4.29×10^7	42.9	3.98	19.8	1270
		July 14	20	27	6	1.8×10^4	1.55×10^7	15.5	8.62		

Lake/River	Station No.	Date	F. coliform /100 ml	F. streptococci /100 ml	Pseudomonas aeruginosa /100 ml	Heterotrophs	Total Count /ml	Bacterial Biomass g/m^3	ATP femtograms x10^8 /litre	Temperature ^oC	Conductivity µ mho/cm
KATEPWA LAKE	30	July 12					2.54×10^7	25.4	5.45	19.8	1270
		July 14	36	18	1	2.4×10^4	1.89×10^7	18.9	6.71		
	31	July 12					3.17×10^7	31.7	3.80	20.0	1220
		July 14	<9	<9	<1	4.0×10^2	3.54×10^7	35.4	2.04		
	32	July 12					4.36×10^7	43.6	1.64	20.0	1210
	33	July 12					4.12×10^7	41.2	1.65	20.0	1210
	34	July 12					3.95×10^7	39.5	4.50	19.8	1220
		July 14	<9	<9	<1	3.0×10^2	2.85×10^7	28.5	3.52		
	35	July 12					3.88×10^7	38.8	2.57	19.8	1230
	36	July 12					3.82×10^7	38.2	3.21	19.8	1220
	37	July 12					15.06×10^7	150.6	3.12	19.5	1220
		July 14	<9	<9	<1	9.0×10^2			4.23		
	38	July 12					3.05×10^7	30.5	3.85	19.7	1220
	39	July 12					4.27×10^7	42.7	4.0	19.1	1230

Lake/River	Station No.	Date	F. coliform /100 ml	F. streptococci /100 ml	Pseudomonas aeruginosa /100 ml	Heterotrophs	Total Count /ml	Bacterial Biomass g/m^3	ATP femtograms x10^8 /litre	Temperature ^{o}C	Conductivity μ mho/cm
CROOKED LAKE	40	July 13					$4.17x10^7$	41.7	6.16	19.0	1500
	41	July 13					$2.52x10^7$	25.2	4.45	19.1	1320
	42	July 13					$6.14x10^7$	61.4	13.7	19.0	1320
	43	July 13					$3.65x10^7$	36.5	3.87	19.2	1250
		July 14	<9	<9	<1	$6.8x10^3$	$4.93x10^7$	49.3	4.56		
	44	July 13					$3.90x10^7$	39.0	2.40	19.2	1250
ROUND LAKE	45	July 13					$8.75x10^7$	87.5	9.4	18.2	1390
	46	July 13					$4.24x10^7$	42.4	4.49	18.8	1360
	47	July 13					$3.14x10^7$	31.4	1.77	19.0	1350
	48	July 13					$3.05x10^7$	30.5	2.55	19.2	1370
		July 14	<9	<9	<1	$3.8x10^4$	$4.44x10^7$	44.4	4.01		
	49	July 13					$2.68x10^7$	26.8	3.09	19.2	1370
	50	July 13					$1.80x10^7$	18.0	2.10	19.2	1340

TABLE 3. MEAN BIOMASS DATA, QU'APPELLE LAKES.

Lake/ River	No. of Samples	Total Bacteria $\times 10^7$	Microbial Biomass g/m^3	ATP femtograms $\times 10^8$ per litre	Conductivity μ mho/cm
PASQUA	18	4.01	40.1	6.48	1540
ECHO	11	3.17	31.75	5.375	1460
MISSION	14	3.95	39.5	3.68	1280
KATEPWA	14	4.34	43.4	3.60	1230
CROOKED	6	4.21	42.1	5.85	1330
ROUND	7	4.01	40.1	3.91	1360

and lowest microbial biomass of all stations samples, while total biomass as measured by ATP content varied from 10.0×10^8 femtograms per litre (Station 3) to 0.475×10^8 femtograms per litre (Station 4) an indication of a great algal biomass difference between these stations.

Total biological biomass (ATP) tends to decrease the further downstream the lake. This pattern is broken by Crooked and Round Lake data due to the low number of stations sampled and the influence of a single high station. In Crooked Lake, Station 42 waters contained 13.7×10^8 femtograms ATP per litre; in Round Lake, Station 45 waters contained 9.4×10^8 femtograms per litre. Station 45 was also found to have the second highest bacterial biomass of the 50 stations sampled in the six lake chain. This station was also found to have high clostridium and fecal coliform levels in its sediment.

The surface waters of these Qu'Appelle lakes were found to contain very low levels of the traditional health hazard organisms, fecal coliforms, fecal streptococci and P. aeruginosa, an indication of a very low level of direct fecal contamination of these waters. At those stations where slightly elevated fecal coliform and fecal streptococci populations were found, invariably the fecal streptococci populations were greater, an indication that the main source of these organisms was land drainage.

Surface water temperatures were very consistent in the six lakes during the sampling period. Conductivity patterns were similar to ATP patterns in that Pasqua and Echo were the highest, the middle two lakes were the lowest and the last two lakes, Crooked and Round had slightly higher conductivity rates than Mission and Katepwa.

CONCLUSIONS

(i) Based on sediment clostridium populations, the first four lakes in the Qu'Appelle Lake chain, Pasqua, Echo, Mission and Katepwa have been equally affected by historical sewage pollution, while the last two lakes, Crooked and Round have been affected to a lesser degree.

(ii) Sediment fecal coliform populations were very low at most stations, an indication that little fresh fecal pollution is taking place.

(iii) Surface water fecal coliform, fecal streptococcus and *P. aeruginosa* data tend to support the sediment fecal coliform data. Furthermore the pollution that is occurring would appear to be mainly due to surface runoff.

(iv) At Stations 7, 20, 29 and 30, increased sediment fecal coliform densities were found, as well as elevated surface water health hazard bacterial counts. Each of these stations was in an area where local conditions (sewage, lagoon or heavy shoreline populations) were conducive to water pollution.

(v) The six Qu'Appelle lakes appear to support similar microbial populations at the nutrient levels present within these lakes; this suggests that temperature may be more important than nutrient levels in determining the final microbial biomass.

(vi) ATP levels provide a potential means of classifying these lakes, based on total productivity, with Pasqua being the most productive and Katepwa the least (in the first four lakes of the chain).

(vii) Interpretation of Crooked and Round Lake data is difficult in that fewer samples were collected from each lake and single high values tend to skew the mean data.

(viii) Station 45 is an enigma. Surface waters and sediment data indicate fecal pollution and high productivity and yet the lake area provides no obvious indication of the source of these organisms.

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