THE RELATIONSHIP OF BACTERIAL WATER QUALITY AND HEALTH OF LAKE OKANAGAN SWIMMERS

by

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ABSTRACT

This study was an investigation into the relationship of bacterial water quality and the incidence of illness amongst lake and chlorinated pool swimmers. During the summer of 1972 three groups of swimmers were surveyed:

1. Lake Okanagan swimmers who swam at the Kelowna City Park beach
2. Ogopogo Aquatic Team who swam at the same beach
3. Chlorinated swimmers who swam at an unheated community pool

The swimmers ranged in age from six to sixteen and were surveyed for upper respiratory illness, gastroenteritis, otitis externa, shistosomiasis and conjunctivitis. The lake water, proximal creeks, and chlorinated pool were sampled throughout the swimming season for the fecal contamination indicators; fecal coliforms and fecal streptococci.

Bacterial water quality of the creek varied with the effluent input and quality of the lake water varied with inflow from the creeks and swimming density. The lake fecal

coliform counts generally remained below 200 organisms per 100 milliliters. The lake fecal streptococci counts were slightly higher than the fecal coliforms and more responsive to swimming density. In the chlorinated pool samples fecal coliforms were not present while fecal streptococci counts ranged up to 168 organisms per 100 mls. Contamination at all sites was of both human and animal origin.

Total illness incidence was highest amongst Lake Okanagan swimmers and lowest amongst the Ogopogo Aquatic team swimmers. The most distinctive illness difference observed between lake and chlorinated pool swimmers was the incidence of otitis externa. For Lake Okanagan swimmers the incidence was 17.82 per 1000 person hours water exposure, for the Ogopogo Aquatic Team the incidence was 16.48 and for chlorinated pool swimmers incidence was only 0.67.

It was surmised that the causative organism for the auditory dermatitis was *Pseudomonas aeruginosa* and its presence was verified in the lake water and streams and negated in the chlorinated water.

For lake swimmers the correlations between incidence of illness and lake fecal indicator counts were significantly positive for upper respiratory infections, gastroenteritis and otitis externa. The correlation coefficient exhibited between otitis externa of lake swimmers and the fecal streptococci counts was .866. Throughout statistical analysis fecal streptococci counts displayed stronger positive correlations with illness incidence than the fecal coliform data. For chlorinated pool swimmers the illness patterns did not significantly correlate with fecal streptococci counts.

It was recommended that fecal coliforms alone were an inadequate index of recreational water quality. It was also suggested that *Ps. aeruginosa* warranted further research as a potential water affiliated pathogen and water quality index.

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Chapter 1

INTRODUCTION

Lake Okanagan, located amidst semi-arid mountains and productive valleys, is situated in an attractive and rapidly expanding region of southeastern British Columbia. The lake is one in a chain of several lakes which together with their tributaries form 3,000 square miles of the Okanagan Basin (Figure 1). The attributes of the Okanagan Basin include fertile land, government industrial incentives, Mediterranean summers, ski hills, sport fishing and pleasant beaches. The region is understandably developing relatively quickly.

For years it was assumed that Lake Okanagan and the surrounding Basin would remain an unchanging aesthetic attribute capable of providing for industrial, agricultural, recreational, and tourist needs of the region. If managed with foresight and discretion the lake has renewable potential but presently planning is in a state of flux with one "interest" group battling the priorities of another.

The observations regarding increased polychlorinated biphenyls in fish, weed growth along shorelines, *Anabaena* algae blooms, decreased water transparency and nutrient enrichment from sewage outfalls are not in balance with needs for increased irrigation, housing and highways.

To contend with the problems of future planning in the Okanagan Basin, a two million dollar, four year, federal and provincial study was commenced in 1969. The object of this "Canada British Columbia - Okanagan Basin Agreement Study" was to prepare a framework for the management of water resources. The study endeavoured to produce a plan which included consideration for social, economic and environmental aspects. The controversies resulting from even the preliminary findings are numerous and the arguments will likely abound as to which is the preferable course to follow.

OUTLINE OF INVESTIGATION

Out of this mixed political environmental situation regarding Lake Okanagan, I extracted one area of research. It is an area which received attention in the early 1950's (Stevenson, 1953), has again been requestioned (Krishnaswami, 1971) but as yet has not been sufficiently documented.

The question I examined was whether or not the bacteriological water quality of Lake Okanagan correlated with the illness incidence observed in local swimmers. I undertook research on one Lake Okanagan beach to substantiate the hypothesis that illness patterns of swimmers corresponded with fluctuations in water quality. It was my assumption that the lake environment undermined the health of swimmers and I collected data during the summers of 1972 and 1973 to test this hypothesis.

The project was located in Kelowna (population 47,000 1973) which is the largest of the several cities near Lake Okanagan. The participants were children who swam either at the main city park beach or at the chlorinated community pool. Thought was given to including non-swimmers, however according to Stevenson (1953) and Ames (1969) swimmers demonstrate a greater illness rate than non-swimmers irrespective of location and water contamination. The explanation given for this difference is that water is an abnormal habitat for man and hence affects health regardless of its bacterial quality. Between the two research groups I expected illness incidence among lake swimmers to be greater than the incidence of similar illnesses among chlorinated pool swimmers.

The swimming season, because of temperature changes, lasted a short period beginning with the July 1st weekend and ending with Labour Day, September 3rd. Even by mid-August temperatures dropped sufficiently to lessen participation.

The days were often warm but the cold nights quickly affected temperatures in the chlorinated pool, which was unheated, and the lake.

My investigations did not deal with serious water bourne illnesses such as *Salmonella typhi* or infectious hepatitis, but with the inconvenient nuisance illnesses such as colds and gastroenteritis. For determination of water quality I applied the contamination indicators fecal coliform and fecal streptococci. The concept of coliforms as an indicator of human sewage and hence potential pathogens has been used for almost seventy-five years with occasional reappraisal as to its reliability. Recently fecal coliform rather than the total coliform count has gained favour. Total coliforms included strains ubiquitous to the environment but not necessarily common in fecal material (Geldreich, 1965). Two criticisms against using solely the coliform indicator are firstly it is representative of only enteric pathogens and secondly in some cases enteric infections, such as salmonellosis, have been caused by ingesting water with no or few coliforms (Dutka, 1973).

As a supplement to the fecal coliform analysis I included fecal streptococci counts. Fecal streptococci analysis has been recommended as being "more practical, efficient and accurate than coliform tests for evaluating the sanitary quality of almost all types of water."[1] Fecal streptococci standards are mandatory in parts of the United States, especially for chlorinated pools but are not included in the British Columbia recreational water quality standards (Appendix 1).

RESEARCH OBJECTIVES

This project was the first study on an Okanagan beach combining intensive bacteriological testing and the surveying of illnesses amongst swimmers. The Okanagan Basin Study did not include inquiries into health of the swimming population. Some water sampling was done in which beaches were sampled twice a month (Lynch, 1972), but the actual bathing population was ignored and the conclusion arrived at by the Okanagan Basin Study regarding recreation water quality was "insufficient data." My objective was to delve further into this concern, questioning the influence of recreational water quality on the health of swimmers.

The project was also prompted by information and records from Dr. D. Clarke, Medical Health Officer, South Okanagan Health Unit. During the past fifteen years he had

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[1] C. Bartley, L. Slanetz, "Types and Significance of Fecal Strep," A.J.P.H., Vol. 50, 1960, p. 1552.

sensed an increase in rate of upper respiratory ailments but was lacking data. The total coliform counts which have been taken during these years were within the public health standards but the samples were too intermittent to be used as a baseline for epidemiological judgements.

It was hoped that my study would help clarify the premise that Lake Okanagan water quality has a detrimental effect on the health of swimmers. My investigation involved three questions:

1) do lake swimmers exhibit a higher incidence of illness than chlorinated pool swimmers?

2) is there a correlation between observed illness and bacterial water quality?

3) how and why does the bacterial water quality vary?

Recent assessments were done by the Okanagan Basin Study on physical and chemical features of Lake Okanagan. Investigations were made into seasonal fluctuations of chlorides, phosphates, nitrogen and algae growth. The intention of a bacterial and illness survey was to add to the information available on Lake Okanagan. Questionnaire studies (Okanagan Basin Study Bulletin #5) reported that 91% of tourists considered swimming important, 73% of residents swam annually and 80% of these did so on more than twenty occasions. The lake is obviously an important recreational resource with swimming a prime activity for tourists and residents.

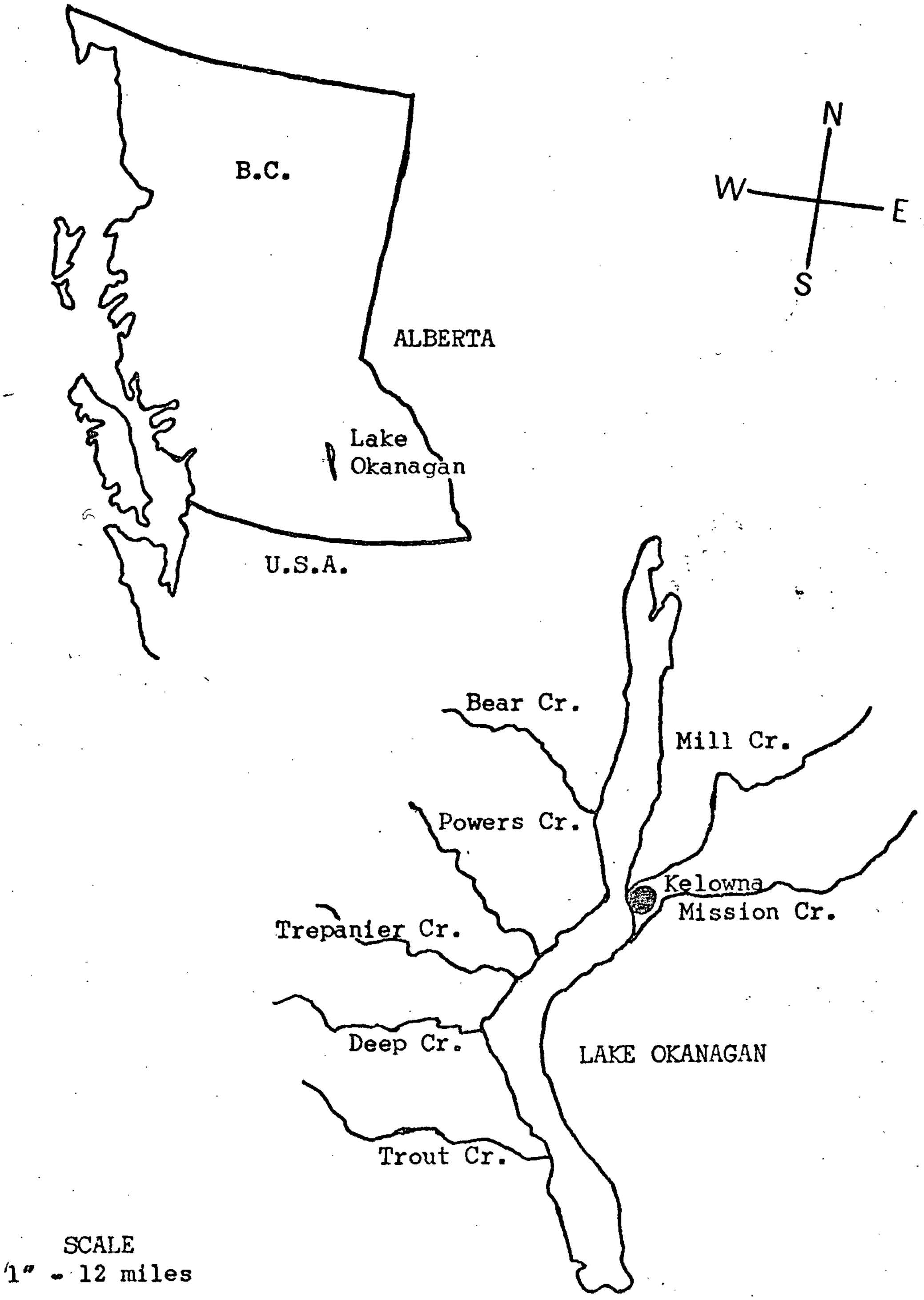

Figure 1A. Location of Lake Okanagan.

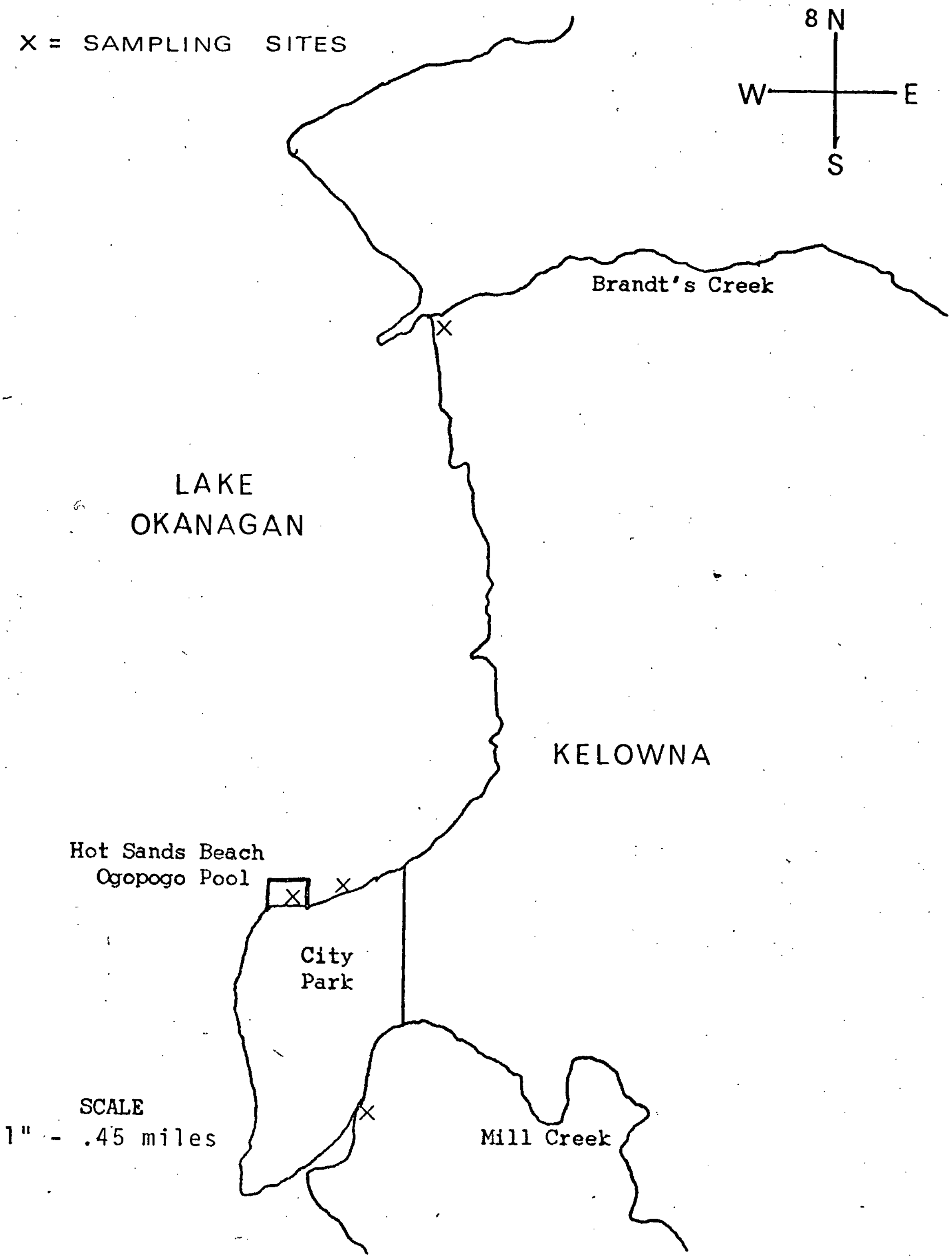

Figure 1B. Water Sampling Sites.

Chapter 2

METHODOLOGY

LOCATION OF INVESTIGATION

There are several public beaches scattered along the shoreline of Kelowna and the most central and popular one is the city park beach commonly called "Hot Sands." The Hot Sands beach includes a semi-enclosed boardwalk area called Ogopogo Pool (Figure 1). Ogopogo is referred to as a pool but in essence it is part of the beach demarcated with a floating walkway.

Form this location I chose two types of swimmers all between the ages of six and sixteen. One group was the Ogopogo Aquatic Swim Team which swam for a minimum of one hour daily during the week in the area designated Ogopogo Pool. Participants in this group remained constant throughout the summer. The other lake group were swimmers from the Hot Sands swimming classes and these children swam one hour three times weekly for a total of two weeks. Participants in this group thus changed every two weeks.

The comparison group for the study swam at the Rutland community pool which at that time was the only chlorinated pool open to the public. As with the "Hot Sands" swimmers classes were held thrice weekly for two weeks. The pool was five miles east of the lake.

I did not individually select the participants. All the children registered for swimming classes in the three locations were included in the illness survey. As a result, group size, age, and sex distribution varied with swimming location. The ratio of male and female participation in the illness survey was as follows:

Location	Total Participants	Male	Female	Ratio
Ogopogo Swim Team	52	26	26	1:1
Hot Sands Swimmers	148	64	84	1:1.32
Rutland Swimmers	248	115	133	1:1.16

Nor did I distinguish participants according to their socio-economic backgrounds. Judging from the distribution of telephone numbers of participants it is my estimation that the Hot Sands and Rutland swimmers represented similar residential cross sections of Kelowna while the Ogopogo Swim Team was comprised of children from the more affluent residential districts.

ILLNESS SURVEY

I collected information on the children's health by interviewing both the children and the parents. Also I gave forms to the swimming instructors[1] and requested them to keep records of specified health problems.

Illnesses and infection surveyed were categorized into: respiratory infections, colds, otitis externa, gastroenteritis, conjunctivitis, shistosomiasis and miscellanea. For purposes of interviewing they were referred to as sore throats, colds, ear aches, stomach flu, eye infections, and skin irritations. These categories were based on research by Stevenson (1953) and previous observations from Lake Okanagan (Clarke, 1959), in which eye, ear, nose, and throat infections and gastroenteritis were the infections associated with swimmers.

Illnesses were categorized with respect to similarity of symptoms rather than similarity of cause. Upper respiratory ailments for example may be caused by several different viruses and some of these same viruses such as the adenoviruses may also cause gastrointestinal symptoms (Sartwell, 1965). Colds, which are caused by rhinoviruses, were in a separate classification for purposes of interviewing and then were amalgamated with upper respiratory infections to simplify analysis.

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[1]Two of the swimming instructors were related to the local medical health officer and may have been slightly biased to over estimate.

Otitis externa or dermatitis of the external auditory canal was specifically included because of its association with swimming (Senturia, 1956; Wright, 1972). Shistosomiasis or swimmer's itch is a known hazard of lake swimming and caused by *shistosome cercariae* (MacKenthum, 1964) which, as a part of their life cycle, are released from snails two or three weeks after the onset of warm weather. Beaches in Kelowna are treated every four years with copper sulfate to eliminate the host snails. Conjunctivitis was included in anticipation of an infection sometimes experienced by chlorinated pool swimmers. No distinction was made between viral, bacterial or chemical conjunctivitis.

I was often present at the swimming classes to check ailments with the children. At the completion of each two week swimming session I interviewed parents by telephone. The parents of the Ogopogo participants were interviewed at the end of July and August. Incidence rather than prevalence was surveyed and so a condition was tabulated only once even when a similar infection re-occurred. If, for example, the same participant suffered a succession of ear inflammations the problem was listed as one case not several separate ones.

I interviewed by telephone rather than written questionnaire in order to have an unbiased return rate. I opened the conversation by saying the survey was a South Okanagan Health Unit project on the health of children.

Rather than ask a set order of questions I threaded the questions into conversation and as the comprehension of parents varied, so did my manner. With each interview the following basic information was collected:

age and sex of child
types of illnesses or infections
date of first symptoms
previous incidence of similar problem
services of physician utilized
swimming locations
swimming frequency

Data was accepted from swimmers who swam either only at the Rutland chlorinated pool or in Lake Oganagan. Participants who swam in waters other than the designated pool or lake were excluded from the final data.

BACTERIOLOGICAL SAMPLING

Water samples were taken from Rutland Pool, Ogopogo Pool and the two creeks and were analyzed for fecal coliforms and fecal streptococci. Since Ogopogo pool and the Hot Sands are in juxtaposition, Ogopogo water samples were accepted as representing water quality for both. To ascertain this I ran a preliminary comparative test series for the two swimming areas (Appendix 3). The creeks, Mill and Brandt's

(Figure 2), are located on either side of the Hot Sands and they were each sampled at the mouth for their potential contribution to the beach water quality. Mill Creek is 0.53 miles from Ogopogo Pool and is fed by ground water seepage from surrounding residential and cattle feedlots and from mountain runoff. Its peak flow is during the summer months and 1972 was a particularly heavy runoff year. Brandt's Creek, 0.84 miles from Ogopogo Pool, drains the industrial section of Kelowna and collects effluent from "Calona Wines" and the "Sun Rype Ltd." fruit processing plant. Brandt's Creek has a lower mean discharge and a lesser nitrate concentration than Mill but a higher Biological Oxygen Demand and total coliforma growth (Appendix 2).

During July and August of 1972 the water sampling schedule for each site was as follows:

Location	Frequency	Time
Rutland Pool	Daily	9 a.m.
Ogopogo Pool	Twice or thrice times daily	8 a.m. and/or 12 p.m., 4 p.m.
Mill Creek	Thrice weekly	8:00 a.m.
Brandt's Creek	Thrice weekly	8:30 a.m.

Ogopogo Aquatic Pool
Kelowna, B.C.
July 1972

Mouth of Brandt's
Creek, Kelowna, B.C.
July 1972

Figure 2. Water quality sampling sites.

Water sampling of the lake and creeks continued through September although interviewing of swimmers was completed by the end of August. In the summer of 1973 additional sampling was done to investigate for the presence of *Pseudomonas aeruginosa*. Each location was sampled three times a week in the morning and water was analyzed for fecal coliforms and *Pseudomonas aeruginosa*.

Samples were collected in 6 oz. sterilized bottles from the water surface by facing the bottle mouth against the flow direction. For the chlorinated pool sodium thiosulfate treated bottles were used. Surface sampling is the accepted mode in bathing water quality studies (Carpenter, 1972). Bacteria settle both in the sediment and at the surface but it is the top layer which contacts the nose, mouth, eyes and ears of swimmers. Resuspension of silt may interfere with bacterial concentrations but generally it has been accepted that surface sampling is sufficient (Tennant, 1971). I cultured a series of sediment samples (Appendix 3) for a comparison with surface samples.

Highest daily air temperatures were recorded and the lake and Rutland pool surface water temperatures were measured two to three times a week (Appendix 3). The pH of each sample site was determined weekly with bromthymol blue.

In August 1972 urine samples from six lake swimmers were analyzed for fecal coliforms, fecal streptococci, and

Ps. aeruginosa. The tests were done to substantiate the suspicion that urine was a potential contributing source of these organisms.

LABORATORY ANALYSIS

I completed all bacteriological analysis with Millipore membrane filter apparatus following the techniques and culture medias outlined in "Standard Methods 13th Edition," and the "B.B.L. Manual," and "Biological Analysis of Water and Wastewater."

The plastic "disposable" petri plates were sterilized in ethanol followed by a 24 hour immersion in 1% bleach and rinsing with distilled water. Mayonnaise jars sufficied in lieu of erlynmeyer flasks for autoclaving the media. The media was made very four or five days and stored in a 10°C fridge between use. Grids and filter paper were transferred to plates with flat tipped sterilized tweezers. Broth media were dispensed with 2 ml syringes. All plates were taped prior to incubation.

Fecal coliforms were isolated using M-FC broth in the ampoule form and were incubated in a water bath at 44.5°C for 24 hours. At this elevated temperature only fecal coliforms grow (Kabler, 1961) and colonies are shiny ink blue. KF broth was used for fecal streptococci isolation since it is the media most frequently recommended for accurate results (Kenner, 1961). To give colour differentiation to the streptococci colonies one ml of 1% tetrazolium solution was added to the media (Figure 3). Fecal streptococci colonies were incubated at 37°C in a dry heat incubator and colonies ranged in colour from pale pink to deep red.

To further identify fecal streptococci colonies I transferred with a platinum loop a selection of colonies to brain-heart infusion agar. Plates were incubated at 44.5°C two days and 10°C for five days. Growth at these temperatures distinguished strains according to the schematic outline in Figure 4 (Geldreich, 1969).

Ps. aeruginosa was isolated on pseudosel agar and incubated at 37° and checked after 18-24 hours and 48 hours. Colonies which diffused green pigmentation or fluoresced under UV were quantified as *Ps. aeruginosa* (Dr. Weinstein, pers. comm.).

Results were compiled as the number of organisms per 100 milliliters. For each indicator organism tested two sample plates and one control plate were incubated. The two sample counts were averaged and raised to the nearest integer. For samples which were based on less than 100 mls of water the counts were multiplied by the required multiple to again yield organisms per 100 mls. Samples which produced crowded growth were rejected.

The proximity of sampling sites allowed bacterial plating to be completed within an hour of sampling and hence die-off rate was minimal and accuracy of isolation maximal.[1] The persistence of fecal coliforms and fecal streptococci varies with the species. Most species diminish 50% to 80% after a one to two day lag while others such as *S. faecalis* survive up to two weeks (Geldreich, 1969). Due to these differing survival rates I felt it was important to culture samples immediately.

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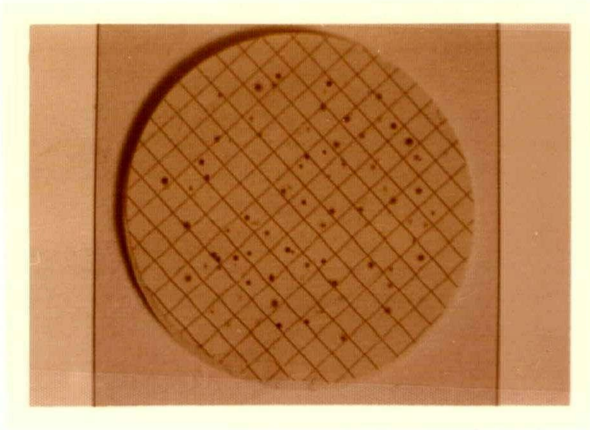
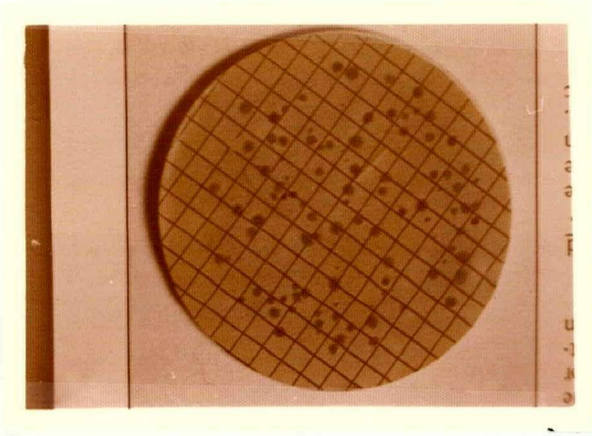
[1]Public Health samples are ordinarily sent to the Provincial Laboratory in Vancouver which means a one to three day lag and it is conceivable that this time lag results in a significant loss of accuracy. It is contended by the S.O.H.U. that provincial lab results are invariably lower than local analysis.



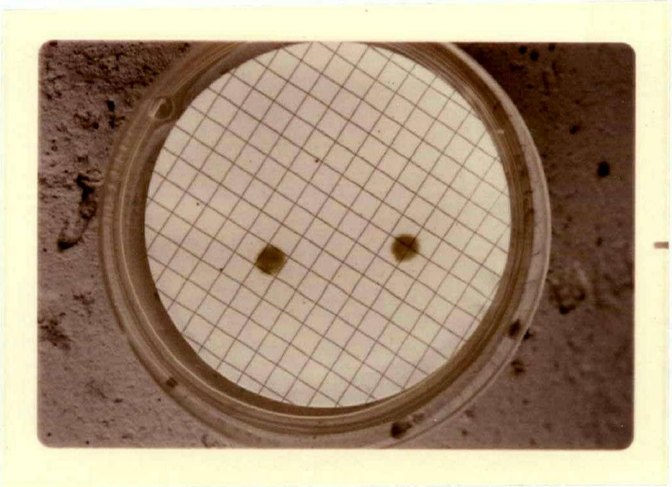
Fecal Streptococci

KF Broth



Fecal Coliforms

M-FC Broth



Ps. aeruginosa

Pseudosel Agar

Figure 3. Laboratory analysis of fecal contamination indicators.

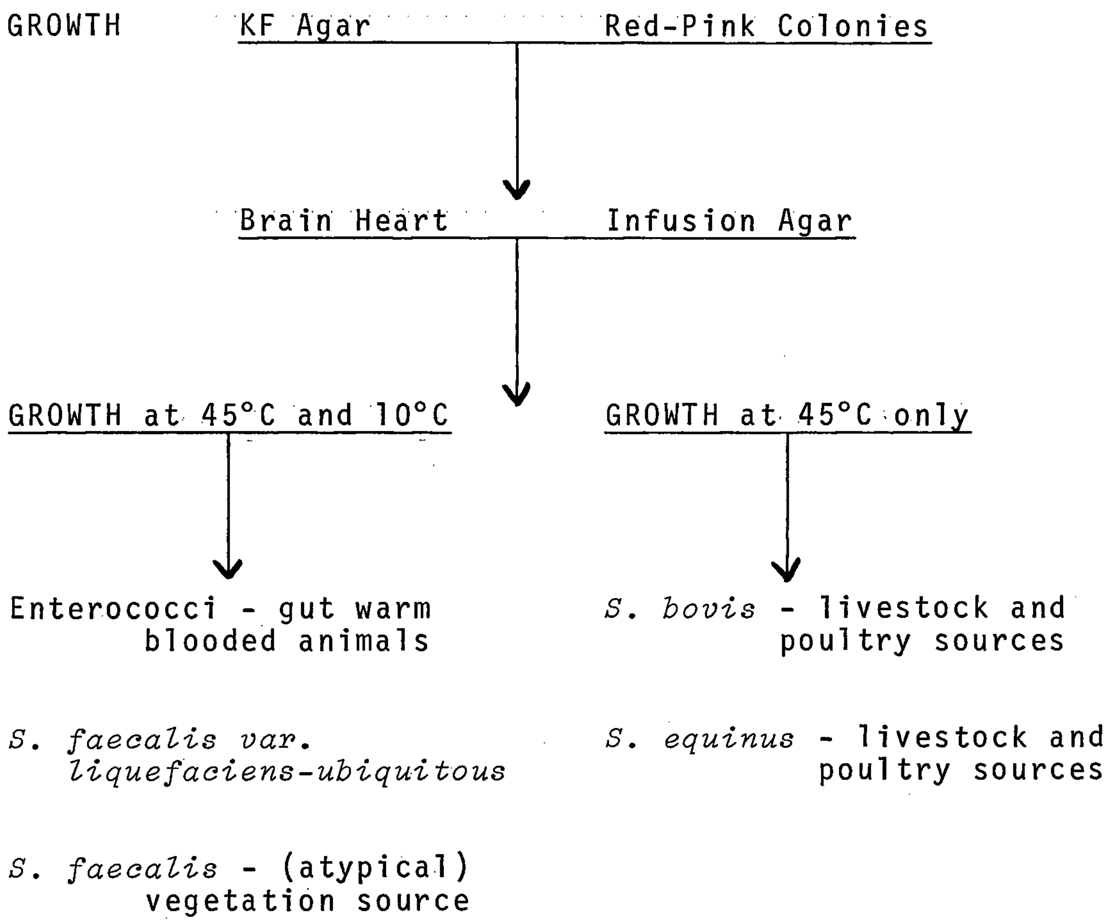


Figure 4. Fecal streptococci: schematic outline of preliminary identification.

Chapter 3

WATER QUALITY RESULTS

BACTERIAL WATER QUALITY

The details of the fecal indicator counts from each water sample are presented in Tables I to V and depicted in Figures 5 to 8.

At the chlorinated pool fecal coliforms were undetected while fecal streptococci were frequently isolated and ranged as high as 168 organisms/100 mls. Streptococci are slightly more chlorine resistant than coliforms and it is not uncommon for fecal streptococci to be present in chlorinated pools (Mallman, 1962).

The counts yielded in the chlorinated pool samples were dependent on the density of swimmers at the time of sampling (Mallman, 1962). The surface waters have pockets of contamination which vary with the distribution of swimmers and these pockets are destroyed by dissemination and chlorine. Additional sampling of the pool would have provided a more descriptive representation of the changing fecal streptococci levels. I collected all the Rutland samples five to ten minutes after children entered the water and it would have been interesting to test levels later in the day when crowding was heavier.

The lake water samples usually produced fecal coliforms and fecal streptococci counts which fluctuated in unison (Figure 5). However there were distinct differences between the daily vicissitudes of the two indicators. Fecal coliforms were more stable over time and sometimes remained zero for several days. The fecal streptococci counts tended to be higher and increased throughout the day. The 8 a.m. samples were taken before even the avid tourists were swimming but by noon, when the beaches were crowded, fecal streptococci counts had increased (Table II). Fecal coliforms did not display this daily trend nor did they reach the high levels of the streptococci. There were six occasions when fecal streptococci were over 200/100 mls but only once was fecal coliforms this dense.

In Mill Creek the fecal streptococci organisms usually predominated over fecal coliforms (Figure 6) while in Brandt's Creek the fecal coliforms counts were far higher than fecal streptococci (Figure 7). In Brandt's Creek there was one atypical week in which both fecal index organisms were destroyed by the chemicals released during "Sun Rype" processing. During July, the fecal streptococci counts in

Table I

Fecal Coliform Counts, July, August, September 1972

Date	Rutland Pool (Chlorinated)	Ogopogo Pool 8 a.m.	Ogopogo Pool 12 p.m.	Ogopogo Pool 4 p.m.	Brandt's Creek	Mill Creek
July						
11	0	8	0		38	584
12	0	4	4		2,000	720
13	0	20	40			
14		68	75	-	5,000	1,820
17	0	0	4			330
18		0	0		10	0
19		0	0		25,000	440
20	0	0	0		8	0
21		2	9		20,000	330
24	0	2	-	8	340	560
25	0	2	0	-	14,000	270
26	0	72	36	10	18,000	710
27	0	16	8	46	28,000	560
28	0	4	5	251	7,800	480
31	0	2	0	0	2,000	370
Aug.						
1	0	2	2	40	80,000	316
2		10	8	-		
3	0	22	4	4	140,000	452
4	0	80	60	80		
7	0	20	4	6	27,500	380
8	0	0	4	4		
9	0	8	2	10	17,500	604
10	0	4	6	12		
11	0	14	40	136	80,000	268
14	0	4	0	6	6,600	580
15	0	12	76	0		

CONTINUED

Table I (Continued)

Date	Rutland Pool (Chlorinated)	Ogopogo Pool 8 a.m.	Ogopog Pool 12 p.m.	Ogopogo Pool 4 p.m.	Brandt's Creek	Mill Creek
Aug.						
16	0	0	22	6	0*	664
17	0	6	0	-		
18	0	0	2	0	0	280
21		0	2	16	0	196
22	0	0	6	0		
23	0	100	0	0	2,000	84
24	0	0		0	4,800	-
25	0	2		108	1,700	676
28	0	18		18	0	240
30		10		2		700
31	0	0		0	1,400	500
Sept.						
5		36	0		5,200	228
8		0	0		2,980	240
12		2	0		6,300	60
15		2	0		3,200	400
19		2	0		1,000	0
22		0	6		1,314	50
24						
26		4	4		390	50
29		0	0		46,000	218

*Zero readings due to NaoH from fruit processing.

Table II

Fecal Streptococci Counts, July, August, September 1972

Date	Rutland Pool (Chlorinated)	Ogopogo Pool 8 a.m.	Ogopogo Pool 12 p.m.	Ogopogo Pool 4 p.m.	Brandt's Creek	Mill Creek
<u>July</u>						
11	0	5	0		10	144
12	0	22	52		340	1,000
13	3	10	15			
14		39	38		40	48
17	0	7	15		44	102
18		2	10		4	
19		4	2		92	474
20	0	1	1		2	68
21		2	113		312	700
24	3	32	88	350	560	1,600
25	1	28	75		2,500	-
26	14	18	80	775	2,600	3,000
27	16	9	113	134	3,000	3,200
28	0	75	28	226	950	2,800
31	4	6	96	226	290	1,500
<u>Aug.</u>						
1	82	0	63	26	2,500	466
2		27	22			
3	15	110	9	92	4,500	492
4	8	6	113	103		
7	2	21	290	198	4,500	228
8	0	8	48	22		
9	3	102	89	330	2,000	604
10	1	18	87	85		
11	168	12	27	87	4,000	204
14	1	206	34	32	232	224
15	2	9	7	0		

CONTINUED

Table II (Continued)

Date	Rutland Pool (Chlorinated)	Ogopogo Pool 8 a.m.	Ogopogo Pool 12 p.m.	Ogopogo Pool 4. a.m.	Brandt's Creek	Mill Creek
Aug.						
16	0	6	49	2	8	0
17	0	0	1			
18	30	35	22	0	8	0
21		12	0	41	88	900
22	10	12	1	7		
24	1	1		56		
25	41	37		84	3,000	8
28	2	8		58	1,750	41
30	0	0		57	12,000	400
31	0	1		0	14,000	390
Sept.						
5		17	0		880	626
8		31	1		1,460	1,400
12		1	1			
15		0	0		1,200	60
19		0	6		1,000	0
22		0	0		8,000	38
24						
26		0	0		-	0
29		4	0		60,000	0

OGOPOGO POOL, FECAL COLIFORM VS. FECAL STREPTOCOCCI

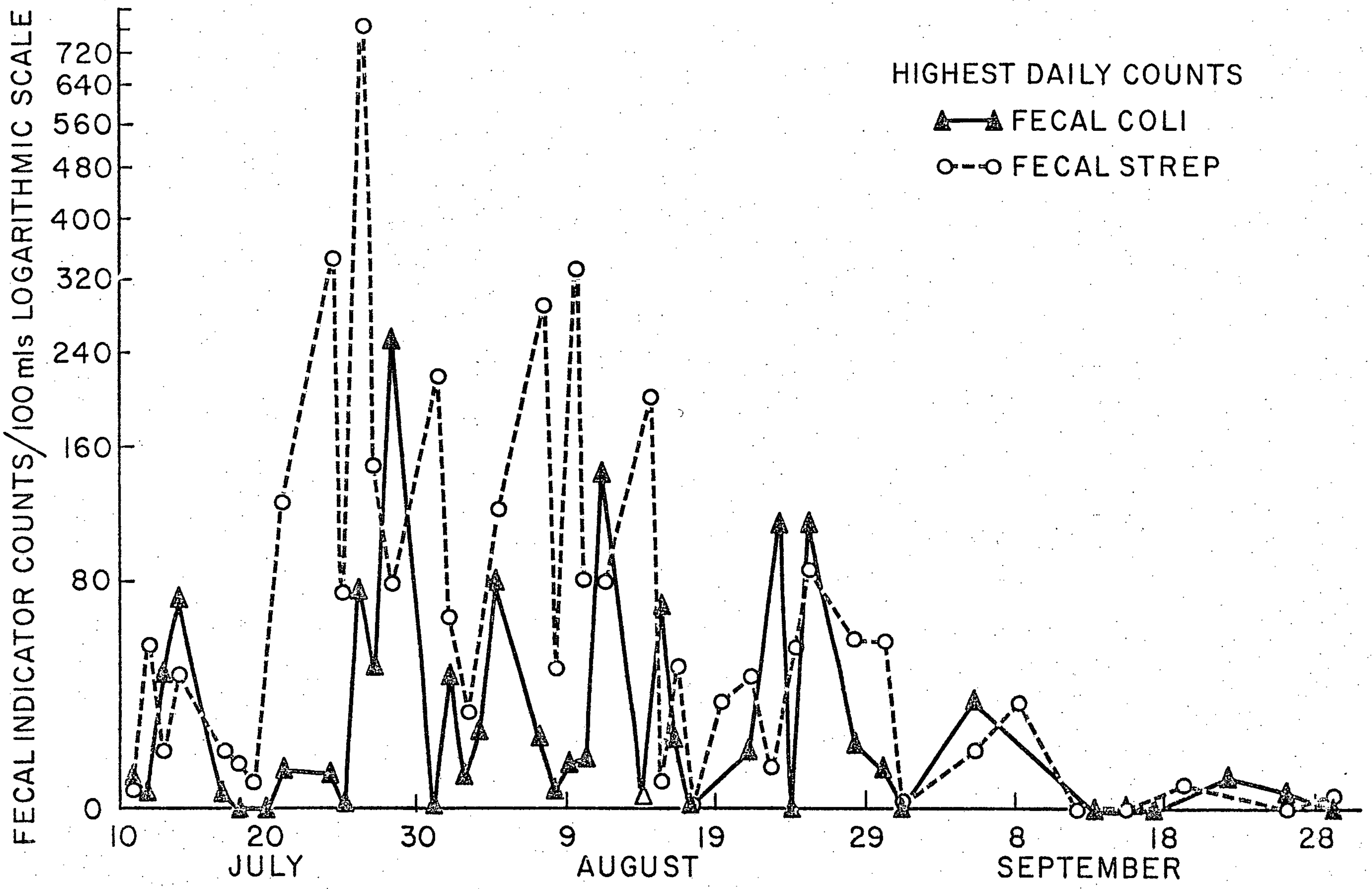


FIGURE 5

MILL CREEK, FECAL COLIFORM VS. FECAL STREPTOCOCCI

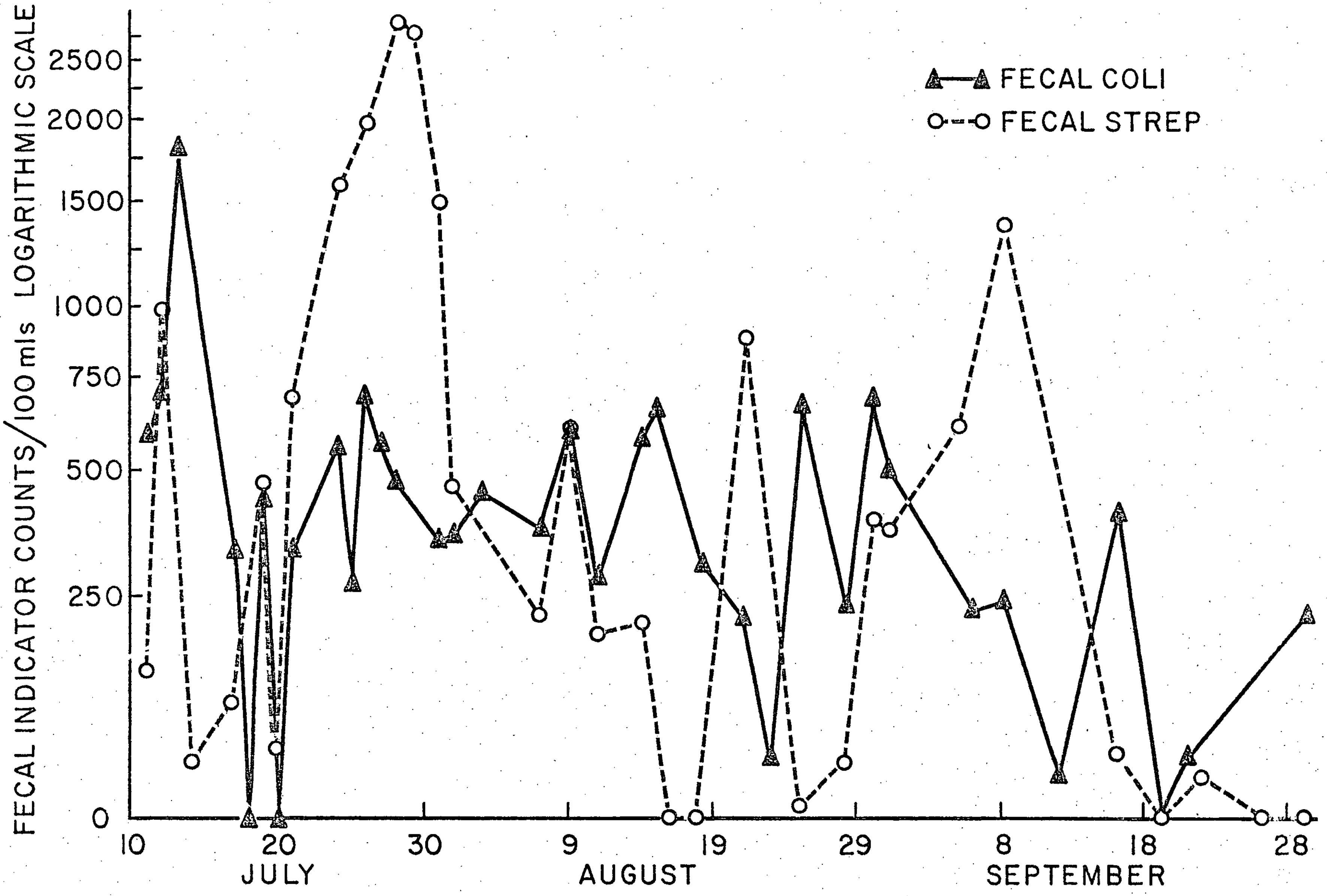


FIGURE 6

BRANDT'S CREEK, FECAL COLIFORM VS. FECAL STREPTOCOCCI

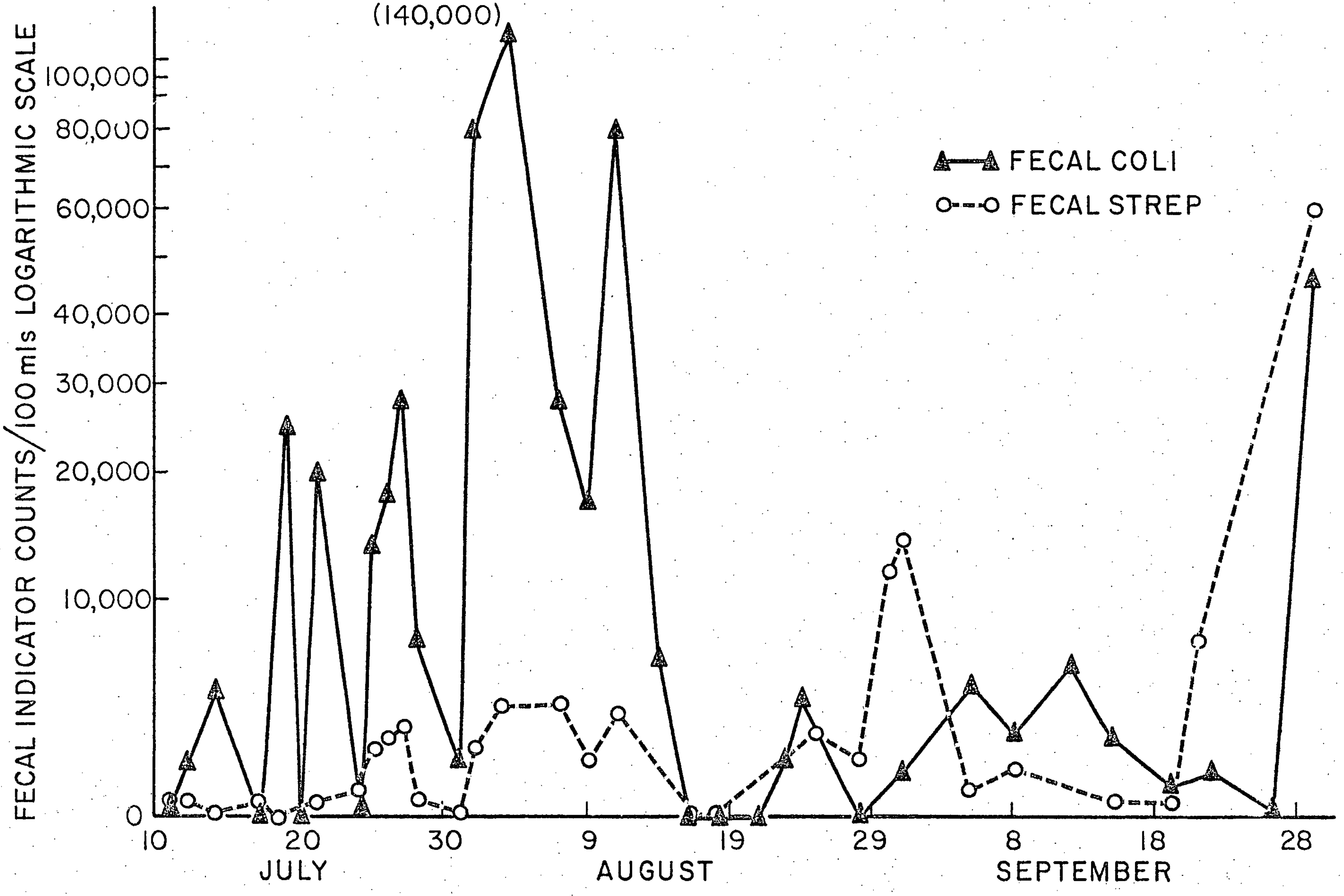


FIGURE 7

Mill Creek were slightly higher than counts in Brandt's whereas during August, the fecal streptococci counts in Brandt's were noticeably higher than counts in Mill Creek.

After September 15th 1972 counts dropped for both indicators at all locations except Brandt's Creek. Brandt's dropped temporarily and then peaked again towards the end of September.

Morphology and Identification of Fecal Streptococci

Fecal streptococci colonies were easily distinguished by colour and I have summarizeddin the next table typical colours and colony sizes observed. I did not quantify colonies in reference to colour since there is not yet sufficient information to match morphology on KF broth with streptococcal species. Each location had its own anomalies. In Mill Creek a large purple colony appeared several times during the summer and at Rutland the streptococci colonies suspiciously resembled the colonies later isolated from urine. Although this colour differentiation is not of immediate value for this study, it may, in future, become a guideline for determining source of contamination.

The results from the preliminary fecal streptococci differentiation on brain heart infusion agar are listed in Table IV. Again this was a qualitative sampling of colonies

Table III

Fecal Streptococci Morphology

COLONY MORPHOLOGY ON KF AGAR Range in size of colonies: 0.1 mm - 1.0 mm Coloured colonies examined under microscope: were gram + ve some diploid only most in chains most colonies were shiny and moist COLOURS OBSERVED: Rutland Pool: Small bright pink colonies. Ogopogo Pool: Wide variety of colours. Brandt's Creek: Variety of pink colours. Mill Creek: Samples were often predominated by medium pale pink colonies. The only sample site containing purple colonies. Any colonies appearing as opaque white were counted as overgrowth.

and not a measurement of the actual ratios of livestock and human contamination. Strains of human origin were isolated from each sample site. This was substantiated by growth at both 10°C and 45°C. According to the results at 10°C each site was also shown to harbour the livestock strains *S. bovis* and *S. equinus*. The livestock strains are particularly short

Table IV

Fecal Streptococci: Preliminary Identification of Human and Livestock Strains

a. <u>Growth of Fecal Streptococci on Brain Infusion Agar - 10° and 45°</u>

These colonies were either Enterococci, atypical *S. faecalis* or *S. faecalis var liquefaciens*.

Colony Source	Size	Colour on KF Broth
Rutland Pool	small	pale pink
Ogopogo Pool	large	dark red
"	large	orange
"	medium	pink
"	medium	orange
"	medium	purple
"	large	pale pink
"	medium	dark red
"	large	pink
"	large	orange
"	medium	pale
"	large	pale yellow-orange
"	small	red
Brandt's Creek	medium	dark red
Mill Creek	medium	dark red
"	medium	dark pink
"	large	pale pink
"	large	pink

b. <u>Growth of Fecal Streptococci on Brain Infusion Agar - 10°C</u>

These colonies were either *S. bovis* or *S. equinus* of livestock origin.

Rutland Pool	medium	pale yellow-orange
"	medium	pink
Ogopogo Pool	large	pink
"	small	orange
"	small	bright orange
"	large	pink
"	medium	pink
"	large	pale pink.
"	medium	orange
"	medium	pale yellow-orange
"	small	red
"	medium	dark red
"	large	orange
Brandt's Creek	large	pale pink
"	small	dark pink
"	medium	yellow-orange
Mill Creek	medium	pink

.1 mm small
.5 mm medium
1.0 mm large

short-lived and therefore in order to have been isolated the contamination must have been fairly recent. The lake water samples displayed the most varied colour representives of both human and livestock strains.

PSEUDOMONAS AERUGINOSA AS A WATER QUALITY INDEX

During my exploration of health and swimmers I interviewed two doctors for their thoughts and observations. The ear, nose and throat specialist (Dr. P. Found, pers. comm.) mentioned that he had in previous years sent in swabs from patients complaining of otitis externa but since *Ps. aeruginosa* was always identified he now no longer bothered to verify the cause. He said he was not certain if the Pseudomonas was associated with the lake water and so I decided to pursue this aspect. Samples mailed to the Provincial Laboratory during August 1972 confirmed the presence of the potential pathogen at Brandt's Mill, Ogopogo and Hot Sands, but not in the Rutland pool.

In the summer of 1973 I obtained the quantiative results listed in Table V. Mill Creek was positive for *Ps. aeruginosa* on 63% of the days sampled, Brandt's and Ogopogo on 30% of the days. In an environmental study of the Gatineau Lakes (Tannant, 1971), where fecal coliforms and fecal streptococci counts were comparative to those measured in

Lake Okanagan, *Ps. aeruginosa* was confirmed in only 8% to 10% of samples from lakes and tributaries. In comparison therefore I feel that the Kelowna beach warrants further investigation into the quantitative[1] presence of *Ps. aeruginosa* and its potential role as pathogen and indicator organism.

The pseudomonas data did not relate to the fecal coliforms fluctuations observed during the same summer. *Ps. aeruginosa* is present in 10% of healthy human fecas (Reitler, 1957; Sutter, 1961) and I had expected the organism to correspond with coliform counts. *Ps. aeruginosa* is capable of metabolizing over 100 organic compounds and hence would be able to survive well in the creeks but again its presence was not verified as consistently as I had expected.

Not all strains of *Ps. aeruginosa* are pathogenic and even apparently identical strains may or may not be pathogenic (Dr. J. Campbell, pers. comm.). It is established as a pathogenic organism in skin necrosis, mixed intestinal infections and otitis externa.

Without further study I cannot interrelate *Ps. aeruginosa* with any other variables. The results confirm and establish the presence of this organism in Mill Creek, Brandt's Creek and Ogopogo pool.

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[1]The quantiative accuracy of pseudosel media in combination with membrane filter technique is unsettled (Dr. S. Weinstein, pers. comm.). I found that when pseudomonas did grow it was obvious (Figure 3) since each colony was enveloped in a diffusion of green pigment.

Table V

Ps. aeruginosa and Fecal Coliform Counts, July and August 1973

a. *Pseudomonas aeruginosa* counts

Date	Mill Creek	Ogopogo Pool	Brandt's Creek
June 11	0	0	0
20	0	0	0
22	0	0	0
27	0	0	0
July 3	0	0	0
4	0	46	0
6	T.M.T.C.	0	0
9	0	0	0
11	13	0	0
13	1	2	0
17	6	0	0
18	6	2	0
20	0	3	0
23	0	0	0
25	6	0	0
27	1	3	0
30	16	7	0
Aug. 1	6	2	0
3	1	0	0
6	10	0	4
8	17	0	12
10	4	1	6
13	1	0	4
15	9	39	12
17	4	2	2
20	1	0	16
22	3	1	0
24	T.M.T.C.	0	-

b. Fecal coliform counts

Date	Mill Creek	Ogopogo Pool	Brandt's Creek
June 11	56	0	448
20	144	0	520
22	>172	0	50-
27	436	0	100
July 3	320	138	280
4	400	0	320
6	650	96	T.M.T.C.
9	50	2	73,000
11	200	154	56,000
13	270	-	240,000
17	300	0	>100,000
18	230	0	129,000
20	-	6	600,000
23	210	5	130,000
25	490	0	150,000
27	100	0	2,600,000
30	130	32	-
Aug. 1	152	12	580,000
3	332	98	22,500,000
6	160	2	80,000
8	1,100	100	>35,000
10	640	34	21,000
13	560	12	>1,000
15	650	12	>1,000
17	475	66	>3,200
20	210	4	400
22	410	8	>1,300
24	1,250	4	14,600

ADDITIONAL VARIABLES MEASURED

Temperature

Water temperature fluctuations clearly responded to air temperature changes (Table XVII). The Rutland pool temperatures were similar to those of Ogopogo pool and dependent on air temperatures. I did not measure swimming density but it was visibly obvious that hotter weather induced more children to swim more frequently.

Urine and Fecal Indicators

Toilet facilities were far enough from the beach to make urinating in the water easier. Urine in the bladder is sterile but on passing through the urinary tract it contacts with fecal coliform and fecal streptococci. Normal body flora is predominated by Gram positive staphylococci and streptococci (Carpenter, 1972) and therefore in urine fecal streptococci tend to outnumber fecal coliforms.

I coaxed a few unwilling children to donate urine samples and the results obtained are listed below. The female urine in these samples produced the higher counts.

Water pH

Chemical effluents, temperature changes, swimming load and season Biological Oxygen Demand increases were a few

Table VI

Fecal Indicator Counts in Urine Samples from Lake Swimmers

Sex	Fecal Coliforms	Fecal Streptococci	*Ps. aeruginosa*
M	0	TMTC* (> 200,000)	0
M	40	TMTC	0
M	4,000	45,000	0
F	80	TMTC	0
F	6,000	TMTC	0
F	TMTC (> 200,000)	TMTC	0

*TMTC = Too Many to Count

of the variables which influenced pH changes (Appendix 3). The pH values fluctuated from 6.8 to 9 at Brandt's Creek, 7.5 to 8.6 for Mill and 7.2 to 8.4 for Ogopogo. At Rutland the pH readings were on occasion below the required standards. of British Columbia. Since colourimetry rather than a pH meter was used I question the accuracy of these results.

During the summer, alkalinity increases in the lake are related to increased primary productivity, and CO_2 and bicarbonate depletion. During this period the average lake pH rises from 8.0 to 8.2. This subtle change was not measurable at the Ogopogo pool because shallow water combined with swimming density interfered with typical pH readings of the lake water.

Chapter 4

ILLNESS RESULTS

INADEQUACIES OF INTERVIEWING

To uncover illness patterns, which were often associated with subjective symptoms, was, at times, a confusing task. Children complained about imaginary problems, hoping for attention, mothers could not recall which child had been sick and what one parent considered serious another one overlooked. There were occasions when parents suppressed information already given by their children. In one case a young boy reported an obvious shistosomiasis rash but when the mother was contacted several days later she insisted her son was fine and denied the possibility of a skin irritation.

When being interviewed certain parents immediately sensed the issue of a "pollution study" and volunteered their own interpretations. Some parents stated that they refused to allow their children to swim in the lake because of "pollution" or previous summers of ear infections. One parent announced that the lake must be improving because "the children weren't as sick this summer." Mothers of the higher income Ogopogo swimmer's were more sensitive to the questions I asked, more distraught over unwell children but less opinionated than residents from other areas.

The psychological awareness of an illness was subjective as was my interpretation of what was said so the incidences recorded were undeniably biased. I attempted to be consistent when interpreting data. For instance, if there were conflicting remarks between a parent and child I then believed whichever person claimed an illness had occurred. The major advantage of the conversation approach was that eventually 100% of children and parents were contacted.

GENERAL ILLNESS PROBLEMS

Health problems enumerated during the swimming season were compiled with reference to illnesses observed per group (TableeVII) and then for ease of visual and statistical comparisons converted into percentages (Table VIII). Unfortunately, sample size varied both between and within the three groups surveyed. Statistical transformations, however, were not deemed necessary for a generalized comparison of illness patterns.

I have collated illnesses according to the weeks surveyed rather than individual days. Water samples were not taken during weekends and so I could not statistically match illnesses with two of every seven days. Also when talking with children or parents they were often vague as to whether the onset of an illness was one day or the next. I attempted to reduce the degrees of freedom and lost statistical power.

I omitted the variables age and sex from illustrations since I did not consider these variables meaningful for the elementary analysis desired. I also amalgamated the two categories "upper respiratory ailments" and "colds" into one. Although the respiratory illnesses represented several etiological agents and was more ambiguous than the "cold" category, combining the two categories was convenient and did not affect statistical relevance.

With regard to total illnesses experienced during the summer of 1972, the highest percentage was from the Ogopogo aquatic team (88.5%) followed by Hot Sands swimmers (51.4%). The total illness rates of the lake swimmers included shistosomiasis and otitis externa, neither of which was prevalent amongst chlorinated pool participants. This difference accounted in part for the lower total illnesses observed with chlorinated pool swimmers.

For comparative interest a 1959 Okanagan Lake illness survey based on identical categories and similar types of swimmers reported relatively lower total illness percentages (Clarke, 1959):

1956-59 Percentage of Illness Amongst Lake Okanagan Swimmers

Site	1956	1957	1958	1959
Ogopogo Aquatic Pool	31%	40%	72.4%	50.9%
Hot Sands Beach	13%	21%	25%	20%

At all three swimming sites upper respiratory infections represented a significant problem and for Rutland and Hot Sands swimmers colds were a main complaint. The one obvious sex related difference I observed in the raw data was with colds. The incidence of colds was more frequent among girls. Since the sex ratio at Rutland and the Hot Sands was in the favour of females this may explain the high percentages quoted for upper respiratory problems.

Studies from other fresh water regions have measured "eye, ear, nose and throat" ailments as representing 60% to 70% of total illnesses (Stevenson, 1953; Dutka, 1973). Illness results from the present study yield an ever greater proportion of such ailments:

"Eye, Ear, Nose and Throat" Infections of Swimmers

Location	Eye, Ear, Nose and Throat Infections	% of Total Infections
Rutland Pool	43	87.8%
Hot Sands Beach	55	72.4%
Ogopogo Pool	43	93.6%

This does not categorically imply that the Okanagan has a significantly higher eye, ear, nose and throat infection rate because it may also indicate a lesser problem with other illnesses such as gastroenteritis.

INCIDENCE OF SPECIFIC ILLNESSES

Swimmer's itch or shistosomiasis was observed on the legs of younger lake swimmers and occasionally on instructors who taught standing in the water. Two cases were reported by Ogopogo swimmers but they may have acquired the rash wading through the shallower waters to reach the pool. Some individuals, owing perhaps to skin pH, are more sensitive than others to the cercariae embedding. One mother interviewed had four children who swam together but only one acquired the rash. The highest incidence was reported during the second week in July, two weeks after the beginning of warm weather.

Four cases of conjunctivitis were reported by pool swimmers but not until August. Red and sore or itchy eyes have in past been a condition observed in lake swimmers although there were no instances of irritated eyes during 1972. It has been suggested (Dr. D. Clarke, pers. comm.) that either algae or chemical effluents were responsible for previous lake associated eye redness.

Gastroenteritis was reported by each group of swimmers but again not until August for Rutland swimmers. The last week in July four Rutland swimmers had gastroenteritis but because they had been swimming elsewhere the data was excluded. From Ogopogo swimmers three cases of gastroenteritis were reported, all during the fourth week in July, while from Hot Sands swimmers gastroenteritis was reported in July and August.

Into the miscellaneous category, I put everything from pneumonia to low grade fevers. In early August several lake swimmers mentioned they had stomach aches combined with difficulty breathing. It seemed too non-specific to include with miscellanea but in future perhaps more attention should be taken with this category.

The outstanding difference between lake and chlorinated pool swimmers was the incidence of external ear infections.

From 200 lake swimmers a total of 47 otitis externa cases were noted while at the chlorinated pool only one instance was reported out of 248 swimmers. Amongst the Ogopogo swimmers, otitis externa was prevalent during the entire swimming season but incidence peaked to 30.8% in July and then dropped to zero after the first week in August. With Hot Sands participants the incidence of external ear infections was more evenly distributed throughout the summer, with a peak of 12.8% (Table VII). The highest incidence for both groups of lake swimmers was the final week in July.

External ear infections have been a swimming associated annoyance for many years and it is my impression that the problem has increased within the past decade. The figures from a survey of the Ogopogo aquatic team in the late fifties (Alcock, 1960) were lower than the 1972 results. In this earlier study information was not given as to the age range of the group, swimming frequency or other variables and the comparison with present rates may be unjustified.

Cases of Otitis Externa: Ogopogo Aquatic Swim Team

	1957	1958	1959	1960	1972
Number in group	40	58	55	74	52
% ear infections	20.0%	39.7%	18.2%	31.0%	57.7%

There were also several other brief surveys done on Lake Skaha in 1970-1971 in which the incidence of otitis externa did not fall below 15% for any given group (South Okanagan Health Unit, 1971).

The ear infections varied in severity and after the initial one most children suffered a series of ear aches. Each person interviewed stated that he did not experience problems during other seasons although several said they had suffered ear infections in previous summers. Some children used isopropanol drops on occasion and three Ogopogo swimmers wore ear plugs. Such prophylactic measures were likely successful and may have lessened the incidence potential.

With Hot Sands swimmers there was an age differential associated with otitis externa. The younger children were not as frequently afflicted and this was probably attributable to swimming ability and hence exposure of ears to water. Amongst 6 to 8 year olds the incidence was 14.8% and amongst 12-14 it was 43%. Although the participation age distribution for Ogopogo swimmers was similar these children did not exhibit the same otitis externa age distinction. Even the youngest were accomplished swimmers and in competitive swimming undoubtedly were well exposed to water regardless of age.

Table VII

Cases of Illness Amongst Chlorinated Pool and Lake Swimmers, 1972

Location	Date	Group Size	Upper Respiratory Infection	Colds	Otitis Externa	Gastroenteritis	Shistosomiasis (Swimmer's Itch)	Conjunctivitis	Misc.	Totals
Rutland Pool	July 1st Wk	58	1	2	-	-	-	-		3
	2nd	58	2	8	-	-	-	-		10
	3rd	60	2	1	-	-	-	-		3
	4th	60	-	2	-	-	-	-		2
	Aug. 1st Wk	80	1	1	1	3	-	1	4	11
	2nd	80	4	7	-	1	-	1		13
	3rd	50	3	3	-	1	-	-		7
	4th	50	-	1	-	1	-	2		4
TOTAL		248	13	25	1	6	-	4	4	53
Hot Sands	July 1st Wk	62	1	1	-	-	1	-		3
	2nd	62	2	5	2	3	6	-		18
	3rd	63	2	7	4	-	1	-		14
	4th	63	2	13	8	4	-	-		27
	Aug. 1st Wk	23	-	2	1	2	2	-		5
	2nd	23	-	3	2	2	-	-		9
	3rd	16	-	-	-	-	-	-		
	4th	6	-	-	-	-	-	-		
TOTAL		148	7	31	17	11	10	-		76
Ogopogo Aquatic Pool	July 1st Wk	52	-	-	1	-	-	-		1
	2nd	52	1	-	4	-	2	-		5
	3rd	52	1	3	8	-	-	-	2	12
	4th	52	2	1	16	3	-	-	2	22
	Aug. 1st Wk	52	3	-	1	-	-	-		4
	2nd	52	2	-	-	-	-	-		2
	3rd	52	-	-	-	-	-	-		
TOTAL		52	9	4	30	3	2	-	4	46

Table VIII

Percentages of Illness Amongst Chlorinated Pool and Lake Swimmers, 1972

Location	Date	Group Size	Upper Respiratory (inc. colds)	Otitis Externa	Gastroenteritis	Shistosomiasis Swimmer's Itch	Conjunctivitis	Misc.	Total Per Cent Illness
Rutland Pool	July 1st Wk	58	5.17%	-	-				5.16%
	2nd	58	17.30	-	-				17.3
	3rd	60	5.0	-	-				5.0
	4th	60	3.33	-	-				3.33
	Aug. 1st Wk	80	2.5	1.25%	3.75%		1.25%	5.0%	13.8
	2nd	80	13.75	-	1.25		1.25		16.3
	3rd	50	12.0	-	2.0				14.0
	4th	50	2.0	-	2.0		4.0		8.0
TOTAL		248	15.32%	1.25%	2.42%		1.61%	5.0%	21.37%
Hot Sands	July 1st Wk	62	3.23	-	-	1.63%			4.85%
	2nd	62	11.29	3.22%	4.85%	9.7			29.09
	3rd	63	14.29	6.35	-	1.59			22.3
	4th	63	23.80	12.7	6.35				42.8
	Aug. 1st Wk	23	8.69	4.35	8.7				21.7
	2nd	23	13.04	8.70	8.7	8.7			39.2
	3rd	16	-	-	-				
	4th	6	-	-	-				
TOTAL		148	25.67%	11.50%	7.43%	6.75%			51.35%
Ogopogo Aquatic Pool	July 1st Wk	52	-	1.93%					1.92%
	2nd	52	1.92	7.7		3.85			9.6
	3rd	52	7.69	15.4			3.85		23.1
	4th	52	5.77	30.8	5.77%		3.85		42.3
	Aug. 1st Wk	52	5.77	1.93					7.7
	2nd	52	3.85						3.85
	3rd	52	-						
TOTAL		52	25.00%	57.70%	5.77%	3.85%	7.69%		88.46%

Chapter 5

INTERPRETATION OF WATER QUALITY DATA

Fecal streptococci is beginning to become more popular in North America as an indicator organism to be measured in conjunction with fecal coliforms for the determination of recreational water quality. I purposefully used the word popular since the functional role of indicator organisms and the somewhat arbitary health standards for recreational water receives constant criticism (Ames, 1969; Dutka, 1973; Kevin, 1968; Krishnaswami, 1971). In my scanning of the literature I abstracted one author who presented epidemiological evidence correlating illness rates of swimmers with bacterial water quality and the level noted in his research (Stevenson, 1953) was 2,300 total coliforms. Whether it is salt, fresh or chlorinated water the arguments abound as to what is a "potential health hazard." It is claimed that 200 fecal coliform and 100 fecal streptococci (Tennant, 1971) are the demarcation points but these conclusions are not founded on sufficient empirical evidence. A comment by Mallman (1962) sums the criticisms for chlorinated pool standards.

> *Swimming pool bacteriological standards are really standards of attainability and are not based on epidemiological evidence.*[1]

Recent Canadian studies on recreational water quality, which include parts of the Okanagan Basin Study and the Environment Canada report on the Gatineau Lakes, accepted as their initial premise the health standards summarized in Appendix 1. By testing assorted public beaches and finding them within total and fecal coliform limits both studies interpreted these results as conclusive evidence of acceptable water quality. It was not questioned further as to whether water quality could still have a negative impact on health.

Bacterial results from the Kelowna beach were within the British Columbia water standards but I wish to go beyond this preset limit and interpret the "potential health hazard" to swimmers from association with this one particular beach. Although the fecal indicator counts were within the health standards this does not deny the possibility that the observed water quality had a deleterious effect on health. My data lacks the depth and variability upon which to estimate

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[1]Mallman, "Cocci Test for Determining Mouth and Nose Pollution of Swimming Pool Water," AJPH, Vol. 47, p. 2001.

precise points or "magic number" at which water quality does or does not affect health. It does however have enough substance to describe certain relationships which exist between the streams, the lake and the swimmers.

FECAL CONTAMINATION OF THE CREEKS

Fecal coliform and fecal streptococci are both incubated in the feces of warm blooded animals, however, the relative ratios of the organisms vary with the types of animal. Human feces contains roughly four times more fecal coliform than streptococci while domestic and wild animal feces grow greater numbers of fecal streptococci (Geldreich, 1969). This is a useful distinction for tracing sources of recent contamination. The basic relative ratios rule to be used with discretion is:

- if the fecal coliform to fecal streptococci ratio is greater than 4.0 contamination is of human origin
- if the ratio is less than 0.7 contamination is from animal origin (Geldreich, 1969).

Due to discrepancies of die off rates this rule applies only to fresh fecal contamination.

From the creek water quality data it was apparent that fecal streptococci predominated in Mill Creek and fecal coliform in Brandt's. The ratios at Mill were commonly less than 0.7 and in Brandt's usually greater than 4.0 (Table IX). Since Mill Creek received more agricultural drainage and Brandt's the industrial effluents, the ratios comply with expectations. Ogopogo water quality from the morning samples was a mixture of ratios and will be discussed separately.

Table IX

Ratios of Fecal Indicator Counts
Fecal Coliform: Fecal Streptococci

Date	Ogopogo Pool 8 a.m. Samples	Brandt's Creek	Mill Creek
July 26	4.0	6.92	0.355
27	1.78	9.45	0.176
28	0.053	2.20	0.178
31	0.33	6.90	0.247
August 2	2.0	32.0	0.676
3	0.2	31.2	0.92
4	13.3	--	--

BACTERIAL STATISTICAL ANALYSIS

Did bacterial counts in Mill Creek fluctuate concomitantly with those in Ogopogo Pool? Were fecal streptococci counts in Ogopogo significantly higher than fecal coliform and did the creeks contribute to these counts? To further interpret such question I made use of paired "t" tests and product moment correlation coefficients. The "t" tests were used to check whether the time and location differences were significant. The correlation coefficients were used to determine how closely aligned the index organisms of the lake were with those of the creek and to relate temperature and fecal indicators. Since sample sizes varied, the significance of the correlation coefficients was further tested with the "t" test.

The statistical analysis for bacterial water quality is summarized in Table X.

FECAL CONTAMINATION OF THE KELOWNA BEACH

Prior to interpreting the water quality of the lake swimming area I wish to emphasize two sampling comparisons which were done. The first was the comparison of Ogopogo Pool with the Hot Sands Beach and the second was the comparison of the surface with sediment samples (Table X). The "t" test accepted the null hypothesis for the first comparison and therefore all bacterial measurements taken can be related to Ogopogo Pool and Hot Sands swimmers. In the second comparison the null hypothesis was accepted for fecal streptococci but rejected for fecal coliforms. This results implies that stirring of the sediments by wind or swimmers may have affected surface fecal coliform counts. Depth related variations have also been observed in other studies but they were considered of "minor" importance (Tennant, 1971).

When the Ogopogo 8 a.m. fecal coliform counts were compared statistically with the noon and 4 p.m. fecal coliform results the difference was insignificant (Table X). When the daily fecal coliform counts were compared with the daily fecal streptococci levels the differences were significant at 8 a.m., 12 p.m. and 4 p.m. As was initially apparent in the results, fecal streptococci counts were fractionally higher than fecal coliform. An additional significant difference was detected between 8 a.m. fecal streptococci counts and the 12 p.m. and 4 p.m. fecal streptococci counts. The morning fecal streptococci counts were statistically lower than the noon or afternoon counts. There was not, however, a significant difference between the 12 p.m. and 4 p.m. counts.

The count differences observed, both between the two index organisms and during the daily fecal streptococci increases, likely relates to the presence and density of swimmers. Natural skin flora and urine, as mentioned previously, are predominated by Gram positive streptococci (Carpenter, 1972). When daily swimming desntiy increased so did the amount of direct contact between water and skin. Fecal streptococci counts correspondingly increased with the desntiy of bathers and then dropped again each night as the water dispersed. As one of the mothers I spoke with aptly described, "There's nothing wrong with the lakes. People who swim in them are dirtier than they are."

If hot weather inspires swimmers, who adds to the fecal streptococci levels it is logical that temperature should positively correlate with the indicator. The coefficient calculated (Table X) was .504 which, given 32 degrees of freedom, was significant. The correlation is also apparent in Figure 9 in which the minimum air temperatures of July 20th, August 17th and August 30th coincide with the lowest inflexion points of the fecal streptococci counts. Since the coliforms were not equally susceptible to density changes the correlation with temperature was less with a coefficient of .216.

The pH changes may also have been density dependent but I did not take sufficient samples during swimming classes to ascertain any trends. At the Rutland pool neither pH nor temperature correlated with the unpredictable fecal streptococci counts.

Table X

Statistical Analysis: Comparison of Fecal Contamination Indicator Counts

Paired "t" Tests

H_0: $\bar{d} = 0$ H_1: $\bar{d} > 0 < \bar{d}$ α: TWO TAIL $^*\alpha = .05$ for all one and two tailed tests

d.f. = degrees of freedom

Data from Table XX

1. <u>Ogopogo Pool vs. Hot Sands Beach</u>

a. June Fecal Coli.	b. August Fecal Coli.	c. August Fecal Strep.
n = 15 d.f. = 14 $"t"_\alpha = 1.776$ $"t"_{calc} = .350$.˙. ACCEPT H_0 Counts from Ogopogo Pool were accepted as equal and hence a substitute for counts from the Hot Sands	n = 18 d.f. = 17 $"t"_\alpha = 2.110$ $"t"_{calc} = .360$.˙. ACCEPT H_0	n = 17 d.f. = 16 $"t"_\alpha = 2.120$ $"t"_{calc} = .9809$.˙. ACCEPT H_0

2. <u>Ogopogo Pool: Surface vs. Sediment Samples</u>

Data from Table XIX

H_0: $\bar{d} = 0$ H_1: $\bar{d} < 0 > \bar{d}$ α: TWO TAIL

a. Fecal Coli.	b. Fecal Strep.
n = 10 d.f. = 9 $"t"_\alpha = 2.262$ $"t"_{calc} = 2.416$.˙. *REJECT* H_0 There was a significant difference between surface and sediment fecal coli.	n = 12 d.f. = 10 $"t"_\alpha = 2.201$ $"t"_{calc} = .637$.˙. ACCEPT H_0

CONTINUED

Table X (Continued)

3. <u>Ogopogo: 8 a.m., 12 p.m., 4 p.m.</u>
Data from Tables I and II
H_0: $\bar{d} \leq 0$ H_1: $\bar{d} > 0$ α: ONE TAIL

a. Fecal Coli., 8 a.m. vs. 12 p.m.	b. Fecal Coli., 8 a.m. vs. 4 p.m.	c. Fecal Strep., 8 a.m. vs. 12 p.m.
n = 30 d.f. = 29 "t"$_\alpha$ = 1.699 "t"$_{calc}$ = .386 .˙. ACCEPT H_0	n = 25 d.f. = 24 "t"$_\alpha$ = 1.711 "t"$_{calc}$ = 1.489 .˙. ACCEPT H_0	n = 30 d.f. = 29 "t"$_\alpha$ = 1.699 "t"$_{calc}$ = 1.832 .˙. *REJECT* H_0
d. Fecal Strep., 8 a.m. vs. 4 p.m.		**e. Fecal Strep., 12 p.m. vs. 4 p.m.**
n = 23 d.f. = 22 "t" = 1.717 "t"$_{calc}$ = 2.459 .˙. *REJECT* H_0 The fecal strep. counts at 12 p.m. were significantly higher than 8 a.m. counts		n = 18 d.f. = 17 "t"$_\alpha$ = 1.740 "t"$_{calc}$ = 1.681 .˙. ACCEPT H_0

4. <u>Ogopogo Pool: Fecal Coli. vs. Fecal Strep. Counts</u>
Data from Tables I and II
H_0: $\bar{d} \leq 0$ H_1: $\bar{d} > 0$ α: ONE TAIL

a. 8 a.m. Samples	b. 12 p.m. Samples	c. 4 p.m. Samples
n = 35 d.f. = 34 "t"$_\alpha$ = 1.690 "t"$_{calc}$ = 1.908 .˙. *REJECT* H_0	n = 27 d.f. = 28 "t"$_\alpha$ = 1.701 "t"$_{calc}$ = 2.871 .˙. *REJECT* H_0	n = 23 d.f. = 22 "t"$_\alpha$ = 1.717 "t"$_{calc}$ = 2.623 .˙. *REJECT* H_0 There was a significant difference between each set of fecal coli. and fecal strep. counts

Table X (Continued)

5. Temperature Correlation with Fecal Indicators

Data from Tables I, II and XVII

H_0: $r \leq 0$ positive correlation not significant H_1: $r \leq 0$ significant positive correlation α = ONE TAIL

a. Temperature and Ogopogo Fecal Coli.	b. Temperature and Ogopogo Fecal Strep.	c. Temperature and Rutland Fecal Strep.
n = 37 d.f. = 35 "t"$_\alpha$ = 1.69 "t"$_{calc}$ = 1.310 ∴ ACCEPT H_0 r = .216	n = 35 d.f. = 33 "t"$_\alpha$ = 1.693 "t"$_{calc}$ = 3.352 ∴ *REJECT* H_0 r = .504 Significant correlation between fecal strep. counts and air temperatures	n = 33 d.f. = 31 "t"$_\alpha$ = 1.896 "t"$_{calc}$ = .698 ∴ ACCEPT H_0 r = .124

6. *Pseudomonas aeruginosa* (1973)

Data from Table V

H_0: $r \leq 0$ positive correlation not significant H_1: $r \geq 0$ significant positive correlation α: ONE TAIL

a. *Ps. aeruginosa* and Temperature	b. *Ps. aeruginosa* and Ogopogo Fecal Coli.
n = 24 d.f. = 22 "t"$_\alpha$ = 1.717 "t"$_{calc}$ = -.496 ∴ ACCEPT H_0 r = -.042	n = 22 d.f. = 20 "t"$_\alpha$ = 2.086 "t"$_{calc}$ = -.857 ∴ ACCEPT H_0 r = -.180

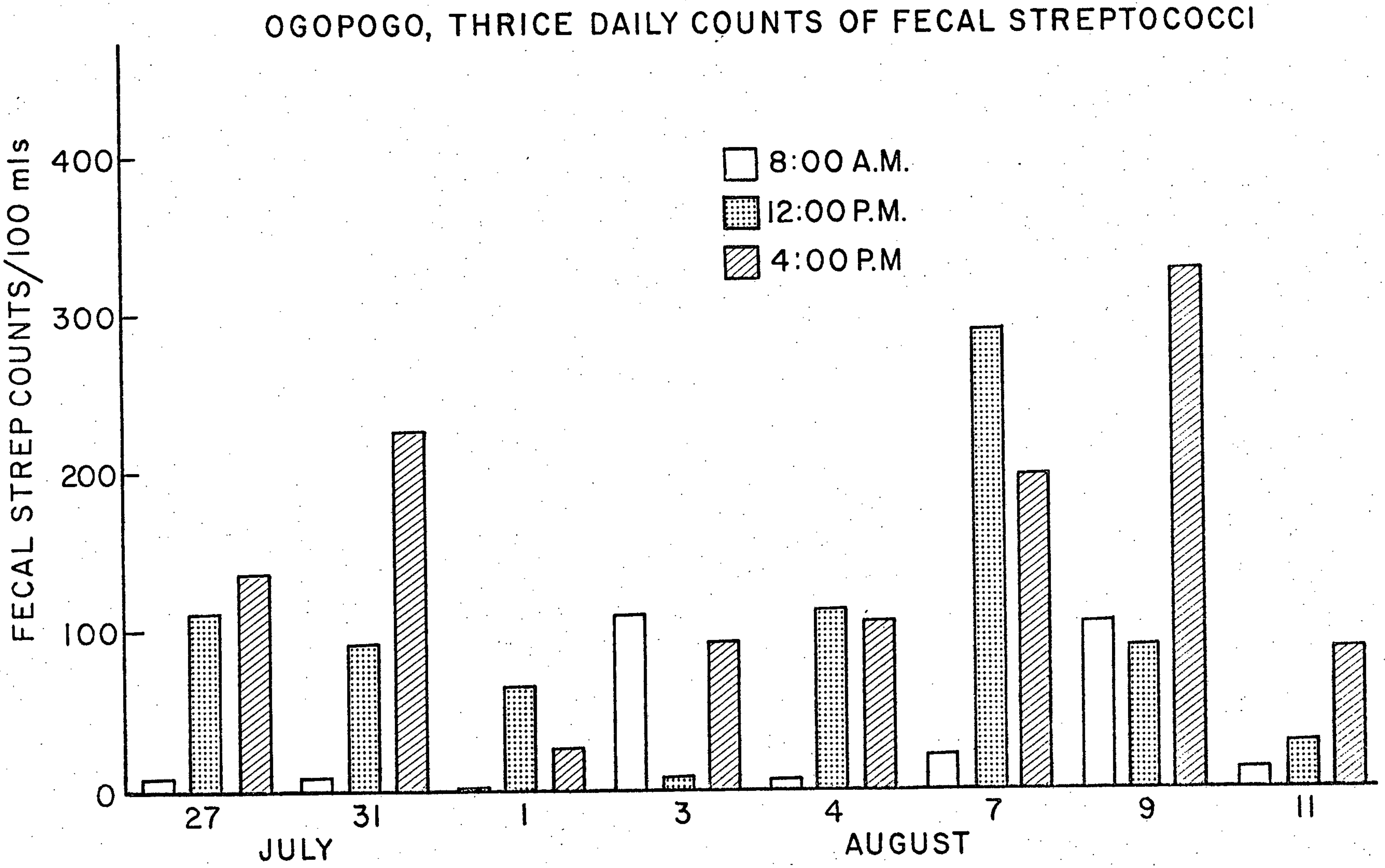
OGOPOGO, THRICE DAILY COUNTS OF FECAL STREPTOCOCCI
FECAL STREP COUNTS/100 mls
400
300
200
100
0
8:00 A.M.
12:00 P.M.
4:00 P.M
27
31
1
3
4
7
9
11
JULY
AUGUST

FIGURE 8

LAKE FECAL STREPTOCOCCI VS. AIR TEMPERATURE AND WATER TEMPERATURE

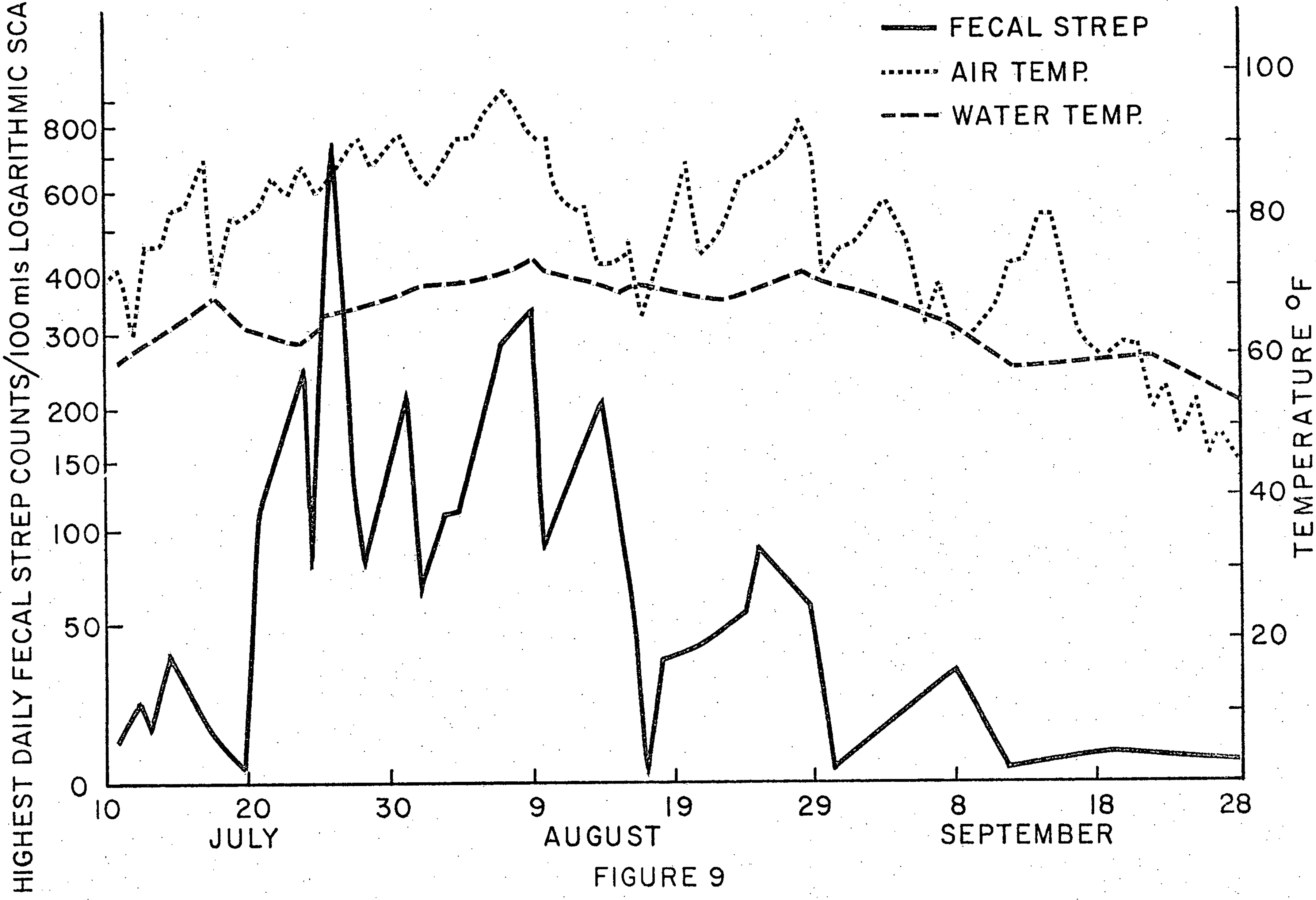

FIGURE 9

CORRELATION OF THE CREEK AND LAKE WATER QUALITY

Crowding was not the sole source of the colonies which grew from the lake waters. Into Lake Okanagan through numerous villages and cities lead 2,340 square miles of tributaries. With regard to fecal indicators, which survive at most several weeks, the nearby outfalls provided another source of fecal organisms. For Ogopogo pool and the Hot Sands beach, Mill and Brandt's Creek were closest with wind direction favouring Mill Creek. Another five miles to the south of the Hot Sands beach was the outlet from the Kelowna primary waste treatment plant and of all inputs into the lake, the sewage plant releases the highest bacteria and nutrient loading (Health Branch, 1973). I did not investigate the possible impact of this effluent on the Hot Sands beach because I assumed that the outfall was too distant to cause a substantial effect.

To determine the influence of Mill and Brandt's Creeks on the water quality of Ogopogo pool or the Hot Sands beach I correlated the bacterial data from the separate locations using first a four hour lag and then a 24 hour lag (Table XI). Computations from another series with an eight hour lag were not listed since results were analogous to the first set. For the four hour lag the morning creek counts were compared with the noon lake counts and for the one day lag the morning creek counts were paired with the

8 a.m. lake counts of the next day. As the mouths of both creeks were within one mile of the Ogopogo pool, it seemed reasonable that potential bacterial correlations would occur within a one day time span. The data were analyzed separately for July and August because the fecal indicators in Brandt's Creek were more irratic in the latter month.

From Mill Creek both fecal coliform and fecal streptococci counts correlated positively, during July, with Ogopogo fecal indicators. The coefficients imply that Mill Creek contributed bacterial loading to the Hot Sands Beach. Although the fecal streptococci counts in Mill Creek were higher than the fecal coliform counts it was the fecal coliform count correlation which produced the stronger coefficient ($r = .887$). This irregularity was due probably to the sensitivity of fecal streptococci to the influence of alternate variables such as swimming density.

Brandt's Creek and Ogopogo Pool provided one, significant but likely accidential, correlation during July when the coefficient for fecal streptococci was $r = .578$. The coefficients during August for both fecal coliforms and fecal streptococci were insignificant.

As a verification of the creeks and lake coefficients I then cross related the counts from the two creeks. The July fecal streptococci were coincidentally in phase ($r = .812$). It was this correlation which probably accounted for the chance fecal streptococci correspondence between Brandt's Creek and Ogopogo Pool.

Not one of the creek and lake correlation coefficients during August was significant. Does this indicate that after July neither of the creeks continued to influence beach water quality? It may, but it may also indicate that wind and water current changes created too much interference for a significant correlation without more elaborate analysis. Since there appears to be a potential fecal contamination correlation between the creeks and the lake, spring would be a preferable season toqquestion, without swimming load interference, the association of lake and creek water quality.

Table XI

Statistical Analysis: Correlation of Fecal Indicator Counts

H_0: $r \leq 0$ Positive Correlation Not Significant

H_1: $r > 0$ Significant Positive Correlation

α : .05, ONE TAIL

Data from Tables I and II in Product Moment Correlations.

1. Mill Creek vs. Ogopogo Pool Samples

a. July fecal coli.: 4 hour lag (8 a.m. and 12 p.m.)	b. August fecal coli.: 4 hour lag	c. July fecal strep.: 4 hour lag
n = 13 d.f. = 11 "t"$_{\alpha}$ = 1.796 "t"$_{calc}$ = 6.365 ∴ *REJECT* H_0 r = .887 July fecal coli levels in Ogopogo correlated strongly with Mill Creek fecal coli	n = 10 d.f. = 8 "t"$_{\alpha}$ = 1.860 "t"$_{calc}$ = .207 ∴ ACCEPT H_0 r = .073	n = 12 d.f. = 10 "t"$_{\alpha}$ = 1.812 "t"$_{calc}$ = 2.265 ∴ *REJECT* H_0 r = .582 July fecal strep also correlated with Ogopogo counts
d. August fecal strep.: 4 hour lag	**e. July and August fecal coli.: 1 day lag (8 a.m. & 8 a.m.)**	**f. July and August fecal strep.: 1 day lag**
n = 9 d.f. = 7 "t"$_{\alpha}$ = 1.895 "t"$_{calc}$ = -.450 ∴ ACCEPT H_0 r = -.450	n = 19 d.f. = 17 "t"$_{\alpha}$ = 1.729 "t"$_{calc}$ = .8526 ∴ ACCEPT H_0 r = .203	n = 18 d.f. = 16 "t"$_{\alpha}$ = 1.746 "t"$_{calc}$ = 1.712 ∴ ACCEPT H_0 r = .393

2. Brandt's Creek vs. Ogopogo

a. July fecal coli.: 4 hour lag	b. August fecal coli.: 4 hour lag	c. July fecal strep.: 4 hour lag
n = 12 c.f. = 10 "t"$_{\alpha}$ = 1.812 "t"$_{calc}$ = .102 ∴ ACCEPT H_0 r = .032	n = 10 d.f. = 8 "t"$_{\alpha}$ = 1.860 "t"$_{calc}$ = .231 ∴ ACCEPT H_0 r = .231	n = 14 d.f. = 12 "t"$_{\alpha}$ = 1.782 "t"$_{calc}$ = 2.455 ∴ *REJECT* H_0 r = .578

CONTINUED

Table XI (Continued)

2. Brandt's Creek vs. Ogopogo (Continued)

d. August fecal strep.: 4 hour lag	e. July and August fecal coli.: 1 day lag	f. July and August fecal strep.: 1 day lag
n = 8 d.f. = 6	n = 22 d.f. = 20	n = 17 d.f. = 15
"t"$_{\alpha}$ = 1.943	"t"$_{\alpha}$ = 1.725	"t"$_{\alpha}$ = 1.753
"t"$_{calc}$ = 1.094	"t"$_{calc}$ = .642	"t"$_{calc}$ = 1.165
∴ ACCEPT H$_0$	∴ ACCEPT H$_0$	∴ ACCEPT H$_0$
r = .408	r = .142	r = .288

3. Mill Creek vs. Brandt's Creek

a. July fecal coli.	b. August fecal coli.	c. July fecal strep.
n = 13 d.f. = 11	n = 9 d.f. = 7	n = 12 d.f. = 10
"t"$_{\alpha}$ 1.796	"t"$_{\alpha}$ = 1.895	"t" = 1.812
"t"$_{calc}$ = -.071	"t"$_{calc}$ = -1.145	"t"$_{calc}$ = 4.397
∴ ACCEPT H$_0$	∴ ACCEPT H$_0$	∴ *REJECT* H$_0$
r = -.022	r = -.397	r = .812
		Fecal strep. levels correlated in Brandt's and Mill Creeks during July

d. August fecal strep.
n = 12 d.f. = 10
"t"$_{\alpha}$ = 1.812
"t"$_{calc}$ = .215
∴ ACCEPT H$_0$
r = .068

Chapter 6

INTERPRETATION OF ILLNESS DATA

INCIDENCE AND EXPOSURE

Throughout the study I deleted the variables which I did not consider necessary for exposing the initially hypothesized interactions. I extracted only those facets which were required for a linear description of the relationship between water quality and the health of swimmers. One of the neglected variables was economic status. I assumed a minimal social and economic difference between Rutland and Hot Sands swimmers but there were likely certain distinguishing reasons as to why some parents and children preferred one location to another. Whatever the reason, I have continued to assume that such differences did not affect illness patterns described earlier.

Another important variable which I only partially accounted for was swimming exposure. I did not attempt to assess total swimming time for participants either during the weeks they were being surveilled or prior to their participation. I treated each two-week swimming session as a separate group even though some of the Rutland and Hot Sands swimmers either had been enrolled in an earlier session or continued into the next. Total swimming exposure was relevant to the opportunity for contact with other swimmers and water quality and hence was relevant to the probability of contracting an illness.

Although the maximum was not measured the number of minimum swimming hours was known and for the Rutland and Hot Sands swimmers it was equivalent. Therefore all illness incidences listed in Table XII were based on identical minimum water exposure. Ogopogo swimmers however swam not only regularly for the entire summer but an additional two hours per week more than other participants. To clarify the illness comparisons between Ogopogo pool and other sites the incidences per 1000 person hours exposure were calculated as shown in Tables XII and XXI. Since children tend to romp in and out of the water all day the figures quoted may be severely underestimated for the Rutland and Hot Sands swimmers. The Ogopogo swimmers, especially the older ones, were concerned with competition and not frolicing and so in their case the discrepancy between maximum and minimum exposure depended on the frequency of swim meets.

One of the introductory hypotheses was that incidence of illness was higher amongst lake swimmers. The most concise result supporting the hypothesis was the incidence of otitis externa and although percentages from Table VIII indicate the incidence at Ogopogo to be far greater than at Hot Sands the calculation in Table XII described the two location as having a surprisingly close incidence in terms of water exposure.

I had assumed that the two lake groups would exhibit concurring illness patterns for each categoryes not just otitis externa. Again from Table XII this was evidently not the case for upper respiratory infections or gastroenteritis. The Ogopogo incidences per 1000 person hours exposure were even lower than incidences for the same ailments at Rutland. This contradiction of expectations may be explained by two possibilities. The chlorinated pool water, which is recycled for several days before renewal, may harbour viruses not prevalent in the continually moving lake water. Also the Ogopogo swimmers may develop an immunity to some of the infectious strains of gastroenteritis and upper respiratory viruses. An increased resistance would explain the lower incidence.ofOf those Ogopogo swimmers who did suffer infections, attack was not confined to one age bracket or new members. There were six new members in 1972 but even the youngest had learned to swim in the lake in years previous and perhaps they too had developed immunity.

When compared with the Hot Sands swimmers, Rutland swimmers exhibited lower incidences per 1000 person hours

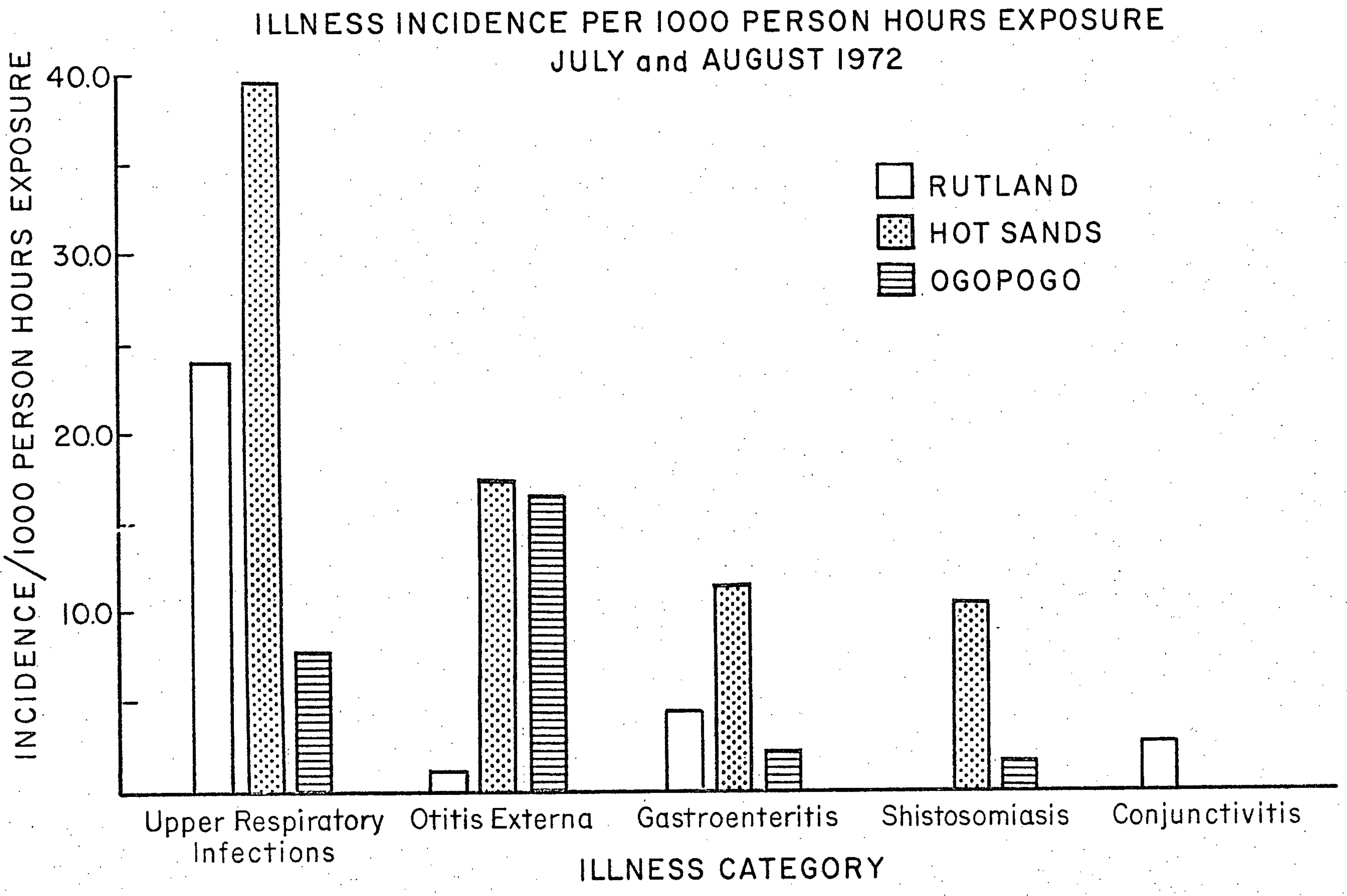
ILLNESS INCIDENCE PER 1000 PERSON HOURS EXPOSURE
JULY and AUGUST 1972
INCIDENCE/1000 PERSON HOURS EXPOSURE
40.0
30.0
20.0
10.0
RUTLAND
HOT SANDS
OGOPOGO
Upper Respiratory Infections
Otitis Externa
Gastroenteritis
Shistosomiasis
Conjunctivitis
ILLNESS CATEGORY

FIGURE 10

Table XII

Illness Incidence per Thousand Person Hours Swimming Exposure

July and August 1972

Location	Upper Respiratory	Otitis Externa	Gastroenteritis	Shistosomiasis	Conjunctivtis
Rutland Pool	25.538	.672	4.032	--	2.688
Hot Sands Beach	39.832	17.820	11.530	10.482	--
Ogopogo Aquatic Pool	7.142	16.484	1.648	1.099	--

Equation: $\frac{\sum \text{Observed Illness} \times 1000}{\sum (\#\text{ in Group})(\text{Min Swim Hrs Per Week})(\text{Weeks Exposed})}$

Table XIII

Statistical Analysis: Comparison of Weekly Illness Incidence for Chlorinated Pool and Lake Swimmers

Paired "t" tests

Illness Comparison of Chlorinated Pool and Lake Swimmers

Data from Tables VIII and XXI

H_0: $d \leq 0$ H_1: $d > 0$ α: ONE TAIL

1. Rutland Illnesses vs. Hot Sands

a. Upper respiratory infections	b. Gastroenteritis	c. Otitis Externa
n = 8 d.f. = 7 "t"$_\alpha$ = 1.895 "t"$_{calc}$ = .416 .˙. ACCEPT H_0	n = 8 d.f. = 7 "t"$_\alpha$ = 1.895 "t"$_{calc}$ = 1.798 .˙. ACCEPT H_0	

2. Rutland Illnesses vs. Ogopogo

n = 7 d.f. = 6 "t"$_\alpha$ = 1.943 "t"$_{calc}$ = 2.426 .˙. *REJECT* H_0 Significant difference in incidence of upper respiratory infections between Rutland and Ogopogo swimmers.	n = 7 d.f. = 6 "t"$_\alpha$ = 1.943 "t"$_{calc}$ = .5992 .˙. ACCEPT H_0

3. Hot Sands Illnesses vs. Ogopogo

n = 7 d.f. = 6 "t"$_\alpha$ = 1.943 "t"$_{calc}$ = 3.365 .˙. ACCEPT H_0 Significant difference between lake swimmers	n = 7 d.f. = 6 "t"$_\alpha$ = 1.943 "t"$_{calc}$ = 2.413 .˙. ACCEPT H_0 Significant difference between lake swimmers	n = 7 d.f. = 6 "t"$_\alpha$ = 1.943 "t"$_{calc}$ = .055 .˙. ACCEPT H_0

exposure in all categories except conjunctivitis. However when the upper respiratory and gastroenteritis incidences of the two sites were compared on a weekly basis using paired one tailed "t" tests the differences measured were not significant (Table XIII). In other words, for upper respiratory ailments and gastroenteritis the weekly percentage differences were small enough to be accepted by a "t" test but the total differences for the summer were significant in terms of person hours exposure.

Generally the results indicate that Hot Sands swimmers suffered the highest incidence per 1000 person hours exposure for each category except conjunctivitis while Ogopogo swimmers experienced the lowest incidence of the gastroenteric and upper respiratory illnesses.

OTISIS EXTERNA AS A SWIMMING RELATED PROBLEM

Ps. aeruginosa is the causative organisms most often associated with otitis externa (Hardy, 1954; Wright, 1974) and as was recorded earlier this potential pathogen was present in the lake and creeks but not in the chlorinated pool. I do not have enough evidence to verify a correlation between the quantitative presence of pseudomonas and the incidence of otitis externa but the literature lends support to the probability that *Ps. aeruginosa* is, at least, a secondary etiological agent of the ear problems which for years have afflicted Okanagan swimmers.

If one were to be suddenly immersed in water densely contaminated with *Ps. aeruginosa* an ear infection would not develop. A series of changes must occur to the ear canal prior to infection and these changes are related to the frequency of water exposure.

The resident bacterial flora of a healthy ear canal isSGram positive (Wright, 1974) and does not vary with geographic location, sex or season (Lindsay, 1958). The canal has an oily acidic coating released from sebaceous glands and this coating acts as a mechanical barrier and bacteriocidal agent against penetration by micro-organisms (Carr, 1961). When the canal is exposed frequently to water the epithelial lining is disrupted, ducts become plugged, lipids are removed (Senturia, 1954) and the pH becomes alkaline. This process is hastened by warm temperatures and high humidity and it would also, I presume, be hastened by alkaline water. At this stage the ear is predisposed to otitis externa and if *Ps. aeruginosa* is introduced into the ear the inflammatry dermatitis of otitis externa is produced. This process has been observed to occur naturally in swimmers (Wright, 1974) and divers (Cobet, 1970) and has been artificially induced in cats (Senturia, 1954) and guinea pigs (Wright, 1972). Recently Wright (1974) hypothesized that the crucial period is when the flora in the ear canal changes from Gram positive organisms to Gram negative. Gram negative organisms other than pseudomonas such as E. coli have also been confirmed as causative agents but not as frequently.

Swimmers in Lake Okanagan were in contact with fecal coliform and *Ps. aeruginosa*, both Gram negative organisms. According to the literature, it is the water which damages the meatal surface presetting conditions for infection and according to my data it is the lake water which harbours the Gram negative pathogens responsible for otitis externa. The water plays the sequential role of leaching the lipid coating and then introducing the pathogens.

It would have been interesting to ascertain how the incidence of otitis externa corresponded with the presence of *Ps. aeruginosa*. In Table XI (page 64) pseudomonas did not positively correlate with either air temperature or the 1973 fecal coliform counts and samples were too infrequent to test for a lag correlation. Presumably if *Ps. aeruginosa* did not correlate with fecal coliforms it would also not correlate with fecal streptococci. I hesitate to draw inferences from the intermittent data of one summer.

One of the physicians interviewed remarked that the swimmer's ear problems occurred generally two weeks after the beginning of summer weather. This concurs with the data collected in which the highest incidence of inflammation was the latter half of July. Otitis externa does not spread to other areas of the ear and so is usually treated with pain relievers and auralgen or glycerol.

Swimmers in the chlorinated pool, except for one case, did not develop otitis externa.[1] Had *Ps. aeruginosa* been present in the chlorinated water then conditions would also have favoured the development of external ear dermatitis amongst Rutland swimmers. In a survey of 205 Colorado chlorinated pools, 32 were deemed "unsafe" because of the qualitative presence of *Ps. aeruginosa* and of the pools registered "unsafe" only 54.3% were positive for total coliforms (Palmquist, 1973). The conclusion from this survey was that *Ps. aeruginosa,* because of its "ability to cause otitis externa infections in swimmers," should be included as a bacterial indicator in the examination of chlorinated pools. I agree with this suggestion and think it should be extended to include fresh water bathing areas if and when useful quantitative *Ps. aeruginosa* levels can be agreed upon. It is the responsibility of public health departments to settle on suitable and useful preventative standards.

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[1]During 1973 the chlorinated water of a Kelowna motel was checked because of complaints of external ear infections. Counts average 14/100 mls *Ps. aeruginosa.*

Chapter 7

CORRELATION OF ILLNESS INCIDENCE AND WATER QUALITY

STATISTICAL ANALYSIS

Product-moment correlation analysis was used to describe the concomitant fluctuations between illness incidence and water quality (Tables XIV and XV). In the first series illnesses were paired with bacterial counts from the same week. Two sets of bacterial counts were used to counterbalance the fact that within each swimming group different children swam at separate times throughout the morning and afternoon, and so were exposed to differing levels of contamination. In one set weekly illness incidence was paired with the highest fecal index counts from the same week. In the alternate set, illness incidence was matched with the corresponding weekly mean count.

Then, because of differences in illness incubation periods, two additional correlation series were calculated. Into one series a two day lag was introduced which was intended particularly for the gastroenteritis incubation period and into the other a seven day lag was introduced to account for upper respiratory problems. Since correlations were on a weekly rather than a day to day basis the implications of introducing a lag would depend on when during the week illness events occurred relative to maximum fecal contamination levels. For instance if illnesses were maximum toward the end of a given week and bacterial counts towards the beginning then the resultant correlation coefficients would be similar both with or without a two day lag.

The correlation coefficients were transformed into "t" values to test whether the correlations were positively significant. The length of swimming season varied for locations and so coefficients were based on different degrees of freedom.

There were two inherent weaknesses in the correlation analysis. One as mentioned earlier was loss of degrees of freedom due to amalgamation of illness data and the other weakness concenned the relevance of fecal contamination data. Since water quality, especially fecal streptococci counts change significantly within hours or even within minutes it must be assumed that the measured water samples were typical of the bacterial density to which individual swimmers were exposed. In actuality the bacterial level encountered by a swimmer was dependent on swimming density, time of day and location with the pool or beach and even within one sub-group of swimmers the range of water quality varied far more than the tabulated figures indicate.

DISCUSSION OF CORRELATION ANALYSIS

Does the measured disparity in illness incidence vary dependently or independently with the measured fluctuations in water quality? Are the periods of high illness incidence paralleled by higher levels of fecal contamination? The main objective of the study was to answer this question of correlation between recreational water quality and the health of swimmers. If significant positive correlations were defined it signified support of the basic hypothesis. Conversely if positive correlations were not statistically revealed then either the hypothesis was unsupported or the wrong indicator organisms were used. Positive statistical correlations give credibility to the hypothesis but the lack of correlations does not necessarily invalidate the hypothesis. I stressed the logic of correlations because the intended function of water quality indicators is often overlooked and water is judged to be clean or degraded on pre-set unquestioned standards.

The coefficients calculated in Table XV offer convincing support to the hypothesis of water influenced illnesses. Fecal streptococci and illness data consistently provided stronger and more frequently significant correlations than fecal coliforms. There were eight instances in which illness correlations with fecal streptococci were significant while the corresponding correlations with fecal coliform were not significant.

Rutland Correlations

As the control group, Rutland illness incidence ideally would not have required correlation analysis. However, not only were fecal streptococci present but on occasion chlorinated pool counts were higher than morning lake counts. It was therefore necessary to determine the coefficient in Table XIV. Not one of the coefficients was significant but the gastroententis coefficient (r = .599) was more suggestive than the other illnesses of a positive correspondence and was certainly stronger than the zero value expected. The .599 correlation was in fact identical to the fecal streptococci coefficient for gastroententis amongst Hot Sands swimmers. Fecal indicators do not confirm the presence of pathogens and so the correlation of gastroententis and fecal streptococci does not implicate the water as a disease transmitter but merely reinforces the usefulness of fecal streptococci as an indicator measurement for chlorinated water.

Rutland illnesses were also correlated with Ogopogo fecal streptococci (Table XIV). Coefficients were reassuringly and insignificantly negative.

Lake Water Quality and Illness Correlations

Generally the correlations without lags yielded the strongest coefficients. Even when two day lags were significant, coefficients were still weaker than results without lags. For Ogopogo swimmers the use of fecal streptococci highest counts rather than of mean counts yielded the stronger correlation while with Hot Sands swimmers the reverse occurred and use of fecal streptococci mean counts rejected three hypothesis where highest count correlations had rejected two. Since Hot Sands swimmers were dispersed over a more expansive area than the Ogopogo swimmers, mean counts rather than highest were likely a more realistic representation of water quality. The use of fecal coliform mean or fecal coliform highest counts did not affect the significance of any tests due probably to the fact that daily fecal coliform counts were far more stable than fecal streptococci levels.

With Ogopogo upper respiratory infections neither fecal coliform nor fecal streptococci provided a significant positive correlation whereas with Hot Sands incidence fecal streptococci counts yielded a coefficient of .836 without a lag and .639 with the two day log. The weak Ogopogo correlation was compatible with the low incidence per 1000 person hours exposure (Table XXI) and the rejected "t" test (Table XIII) and again a possible reflection of the resistance factor mentioned previously. The substantial fecal streptococci correlation with Hot Sands respiratory data was a decisive indication that the 39.83 incidence per 1000 person hours was directly associated with swimming water quality. In Rutland the incidence for equal exposure was 25.53 with a correlation coefficient of -.317, a distinct contrast to the beach correlation. In response to upper respiratory correlations for all locations the fecal coliform were perceptibly less sensitive.

For Ogopogo swimmers gastroenteritis was significantly positive with both fecal streptococci and fecal coliform. The three recorded cases occurred not only during the same week but on the same day which happened to be July 26, 1972, the day of the highest fecal streptococci counts isolated throughout the summer (775/100 mls). Two days earlier the count had been 350/100 mls which was the second highest sample recorded. It is apparent why the Ogopogo gastroenteritis correlated with water quality in spite of its low incidence per swimming hours exposure.

With respect to otitis externa all fecal coliform correlations were insignificant. For Hot Sands swimmers the fecal streptococci and otitis externa correlation were significant without a lag (r = .866) and with a two day lag (r = .802) while for Ogopogo participants the fecal streptococci coefficients were strongly positive (r = .629) but not significantly so. The correlation for Ogopogo would likely have been significant had prevalence rather than incidence been measured.

The correlation for otitis externa and lake swimmers becomes even clearer when as with gastroenteritis it is viewed relative to days rather than weeks. Table XVI (page 93) lists water quality and the respective days on which Ogopogo bathers reported ear aches. Again July 24th and 26th were unfavourable days for fecal streptococci counts and otitis externa.

The fecal streptococci and otitis externa correlation expressed certainly warrants further investigation and it is to my knowledge the first time such a correlation has been demonstrated. If as indicated *Ps. aeruginosa* is the causative organism it would be interesting to clarify what relation, if any, pseudomonas has in time and density with fecal streptococci. The 1973 *Ps. aeruginosa* counts did not correlate with fecal coliforms but then otitis externa also did not correlate to a significant degree (r = .498) with fecal coliform. Does the presence of high fecal streptococci density imply the presence of *Ps. aeruginosa* and if so why? Since pseudomonas is not common to skin flora why would

Ps. aeruginosa increase conjointly with fecal streptococci? There is really negligible information on the correlation of *Ps. aeruginosa* or fecal streptococci with otitis externa, on the behaviour of *Ps. aeruginosa* in natural waters and on therrelationship of fecal streptococci with pseudomonas. Because of this dirth of information or investigation, I cannot fully explain why the 1972 Lake Okanagan fecal streptococci correlated with otitis externa. There is perhaps a proportionality between fecal streptococci and pseudomonas similar to Geldreich's ratio in which case fecal streptococci counts would implicate potential pseudomonas levels. For future investigations on the behaviour of *Ps. aeruginosa* and its relation to other fecal contaminants I would recommend that water samples greater than 100 mls be filtered in order to set a baseline of fluctuations and avoid the likelihood of zero readings.

Value of Indicator Organisms

The fecal contamination indicators, fecal streptococci in particular, corresponded more closely with the illness patterns of lake swimmers than with the illness incidence of chlorinated pool swimmers. The strongest correlations were displayed with upper respiratory and otitis externa infections and then to a lesser extent with gastroenteritis. These positive correlations confirm the introductory hypothesis that the incidence of illness amongst lake swimmers was associated with water quality.

Fecal streptococci was throughout the study the more flexible and responsive indicator and it was evident that fecal streptococci correlated more positively than fecal coliform with all lake illnesses and with gastroenteritis from the Rutland swimmers. However, neither fecal coliform nor fecal streptococci correlations can clarify causes, and water quality, although it correlated with illness was not at any time actually proven as the direct carrier of pathogens or the direct cause of observed illness incidence. Contact with crowds at the beach, the fruit season, tourist influx plus other factors also contributed to the routes and rates of illness incidence.

If recreational water quality does influence the incidence of some illnesses then where is the demarcation point for fecal indicators at which correlations either become positive or convincingly more positive? The data collected from one beach for one season was not sufficient in scope to set a basic limit. The highest coinciding levels of bacteria and illness were during the fourth week in July when fecal streptococci reached 775/100 mls and fecal coliform 251/100 mls, and for Hot Sands swimmers the incidence of upper respiratory infections was 24% and for otitis externa

13%. However, standards cannot be extrapolated from the evidence of one week of unreplicated data. Extracting the limits of water quality acceptability is not only a statistical task but a subjective one arbitrarily dependent on the potential health risks one is willing to accept.

Table XIV

Correlation of Fecal Indicator Counts and Illness Amongst Chlorinated Pool Swimmers

H_0: $r \leq 0$ Positive Correlation Not Significant H_1: $r > 0$ Significant Positive Correlation α = .05, ONE TAIL

1. Rutland Fecal Streptococci Counts and Illness Incidence
   Data from Tables VIII and XXII

   a. Fecal Streptococci Using Highest Counts, No Lag

   n = 7   d.f. = 5   "t"$_\alpha$ = 2.015

UPPER RESPIRATORY	GASTROENTERITIS	CONJUNCTIVITIS
"t"$_{calc}$ = 0.748	"t"$_{calc}$ = 1.306	"t"$_{calc}$ = .814
∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0
r = -.317	r = .504	r = .342

   b. Fecal Streptococci Using Mean Counts, No Lag

   n = 7   d.f. = 5   "t"$_\alpha$ - 2.015

"t"$_{calc}$ = .0499	"t"$_{calc}$ = 1.673	"t"$_{calc}$ = .659
∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0
r = .022	r = .599	4 = .283

   c. Fecal Streptococci Using Highest Counts, 2 Day Lag

   n = 8   d.f. = 6   "t"$_\alpha$ = 1.943

"t"$_{calc}$ = .0713	"t"$_{calc}$ = 1.332	"t"$_{calc}$ = .828
∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0
r = .0319	r = .512	r = .347

2. Rutland Illness Incidence Correlated with Ogopogo Fecal Streptococci, No Lag

   n = 7   d.f. = 5   "t"$_\alpha$ = 2.015

Rutland fecal streptococci levels did not significantly correlate with illness incidence in previous tests. Following tests done to check possibility of coincidental positive correlation between Rutland illness incidence and lake fecal streptococci counts.

UPPER RESPIRATORY	GASTROENTERITIS
"t"$_{calc}$ = -.779	"t"$_{calc}$ = -.294
∴ ACCEPT H_0	∴ ACCEPT H_0
r = -.329	r = -.131

Table XXVII

Statistical Analysis: Correlation of Fecal Indicator Counts and Illness Amongst Lake Swimmers

H_0: $r \leq 0$ — Positive Corr. Not Significant

H_1: $r > 0$ — Significant Positive Correlation

α : .05, ONE TAIL

1. Ogopogo Fecal Indicator Counts and Illness Incidence

   Data from Tables VIIIa and XXIII

   a. Fecal indicators Using Highest Counts: No Lag

   $n = 6 \quad d.f. = 4 \quad "t"_\alpha = 2.132$

UPPER RESPIRATORY		GASTROENTERITIS		OTITIS EXTERNA	
Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.
$"t"_{calc} = .0243$	$"t"_{calc} = .783$	$"t"_{calc} = 2.418$	$"t"_{calc} = 3.598$	$"t"_{calc} = 1.149$	$"t"_{calc} = 1.617$
∴ ACCEPT H_0	∴ ACCEPT H_0	∴ *REJECT* H_0	∴ *REJECT* H_0	∴ ACCEPT H_0	∴ ACCEPT H_0
r = .0124	r = .364	r = .734	r = .874	r = .498	r = .629

CONTINUED

Table XV (Continued)

b. Fecal Indicators Using Mean Counts: No Lag

$n = 6$ d.f. $= 4$ $"t"_{\alpha} = 2.132$

UPPER RESPIRATORY		GASTROENTERITIS		OTITIS EXTERNA	
Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.
$"t"_{calc} = -.271$	$"t"_{calc} = .751$	$"t"_{calc} = .854$	$"t"_{calc} = 3.054$	$"t"_{calc} = .409$	$"t"_{calc} = 1.325$
∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0	∴ *REJECT* H_0	∴ ACCEPT H_0	∴ ACCEPT H_0
$r = -.134$	$r = .351$	$r = .393$	$r = .837$	$r = .200$	$r = .552$

c. Fecal Indicators Using Highest Counts: Two Day Lag

$n = 6$ d.f. $= 4$ "t" $= 2.132$

UPPER RESPIRATORY		GASTROENTERITIS		OTITIS EXTERNA	
Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.
$"t"_{calc} = 1.689$	$"t"_{calc} = .489$	$"t"_{calc} = .0975$	$"t"_{calc} = 2.441$	$"t"_{calc} = -.0716$	$"t"_{calc} = 1.0132$
∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0	∴ *REJECT* H_0	∴ ACCEPT H_0	∴ ACCEPT H_0
$r = .645$	$r = .238$	$r = .0487$	$r = .774$	$r = -.358$	$r = .452$

CONTINUED

Table XXV (Continued)

2. <u>Hot Sand Fecal Indicator Counts</u>

Data from Tables XII and XXVIII

a. <u>Fecal Indicators Using Highest Counts: No Lag</u>

$n = 7 \quad d.f. = 5 \quad "t"_{\alpha} = 2.015$

UPPER RESPIRATORY		GASTROENTERITIS		OTITIS EXTERNA	
Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.
$"t"_{calc} = .432$	$"t"_{calc} = 2.352$	$"t"_{calc} = .836$	$"t"_{calc} = 1.674$	$"t"_{calc} = .880$	$"t"_{calc} = 3.421$
∴ ACCEPT H_0	∴ *REJECT* H_0	∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0	∴ *REJECT* H_0
r = .174	r = .725	r = −.350	r = .599	r = .366	r = .837

CONTINUED

Table XV (Continued)

b. Fecal Indicators Using Mean Counts: No Lag

n = 7 d.f. = 5 $"t"_{\nabla\alpha}$ = 2.015

UPPER RESPIRATORY		GASTROENTERITIS		OTITIS EXTERNA	
Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.
$"t"_{calc}$ = .117	$"t"_{calc}$ = 3.400	$"t"_{calc}$ = 1.326	$"t"_{calc}$ = 2.083	$"t"_{calc}$ = .583	$"t"_{calc}$ = 3.865
∴ ACCEPT H_0	∴ *REJECT* H_0	∴ ACCEPT H_0	∴ *REJECT* H_0	∴ ACCEPT H_0	∴ *REJECT* H_0
r = .068	r = .836	r = .608	r = .682	r = .253	r = .866

c. Fecal Indicator Using Highest Counts: Two Day Lag

n = 8 d.f. = 6 $"t"_{\alpha}$ = 1.943

UPPER RESPIRATORY		GASTROENTERITIS		OTITIS EXTERNA	
Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.	Fecal coli.	Fecal strep.
$"t"_{calc}$ = -.631	$"t"_{calc}$ = 1.855	$"t"_{calc}$ = 6630	$"t"_{calc}$ = 1.881	$"t"_{calc}$ = -.220	$"t"_{calc}$ = 2.998
∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0	∴ ACCEPT H_0	∴ *REJECT* H_0
r = -2.71	r = .639	r = .271	r = .644	r = -.098	r = .802

CONTINUED

Table XV (Continued)

3. <u>Fecal Indicators Using Highest Counts: One Week Lag</u>

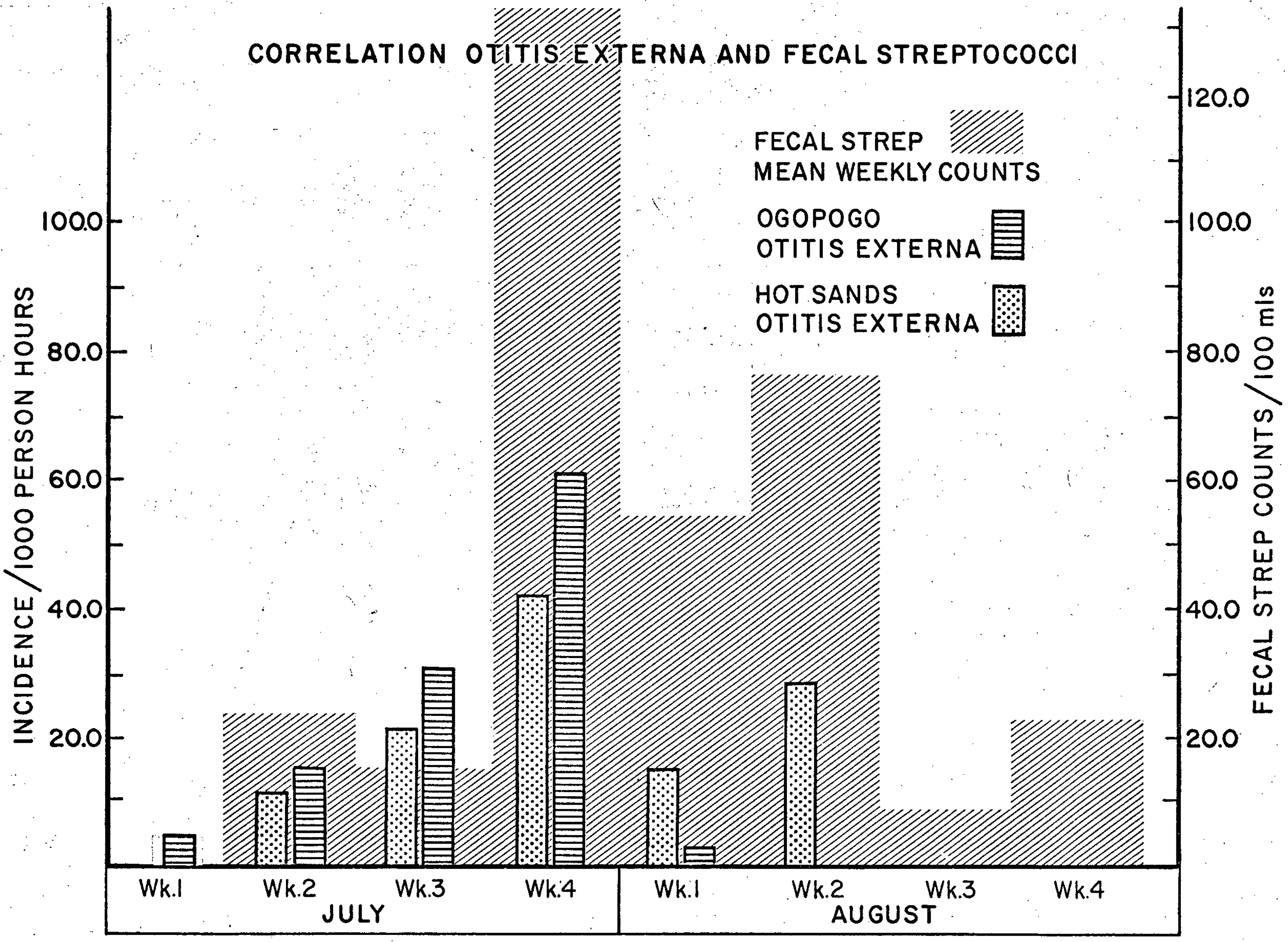
$n = 5$ d.f. $= 3$ $"t"_{\alpha} = 2.353$

Ogopogo Swimmers

UPPER RESPIRATORY	
Fecal coli.	Fecal strep.
$"t"_{calc} = .0656$	$"t"_{calc} = -1.587$
$\therefore$ ACCEPT H_0	$\therefore$ ACCEPT H_0
$r = .0378$	$r = -.676$

Hot Sands Swimmers

UPPER RESPIRATORY	
Fecal coli.	Fecal strep.
$"t"_{calc} = -1.341$	$"t"_{calc} = -1.059$
$\therefore$ ACCEPT H_0	$\therefore$ ACCEPT H_0
$r = -6612$	$r = -.522$



OTITIS EXTERNA INCIDENCE/1000 PERSON HOURS and WEEKLY MEAN FECAL STREP

FIGURE II

Table XVI

Otitis Externa and Fecal Indicator Correlation

Ogopogo Pool Swimmers

Date	Cases of Otitis Externa	Fecal Coliform Highest Daily Count	Fecal Streptococci Highest Daily Count
July 7	1	-	=
10	2	-	-
11	2	8	5
16	3	75 (July 14th)*	39 (July 14)*
17	2	4	15
18	1	0	18
20	2	0	1
23	2	9 (July 21st)	113 (July 21)
24	5	8	350
25	1	2	75
26	4	72	775
31	1	0	226
August 6	1	80 (August 4th)	113 (Aug. 4)

*If counts not available for that particular day closest alternate sample listed.

Chapter 8

CONCLUSION

Both pertinent and tenuous relationships were observed from the data documented. In brief, lake swimmers experienced higher illness rates than chlorinated pool swimmers and these incidences correlated positively in varying degrees with fecal bacteria counts. These counts in turn were contributed by several sources including the creeks and swimmers. The evidence gathered, which pertained to one specific age bracket and one beach, affirmed the hypothesis that illness patterns varied concomitantly with bacterial recreational water quality.

The lake water quality, which remained within the bounds of today's standards, was traced to contamination from the creeks and swimmers. Fecal coliform and fecal streptococci data provided the basis for this conclusion. The relative ratio of fecal coliform to fecal streptococci also assisted in the differentiation of agricultural and human contamination. The contamination in Mill Creek was mainly from livestock origin while the lake water contamination was a combination predominated by fecal streptococci of human origin.

Fecal streptococci was a more versatile indicator than fecal coliform. It represented chlorine resistent microbial growth in the Rutland pool and was sensitive to increases in swimming density. Fecal streptococci was also the preferable organism in terms of positive correlation with lake illnesses. I concur with the commonly expressed opinion that coliform organisms alone are not a sufficient criteria for estimating recreational water quality.

The overall illness patterns observed were distinctly different for each of the three groups surveyed. The Hot Sands swimmers suffered a significantly greater incidence than chlorinated pool swimmers of upper respiratory and otitis externa infections. The hardier Ogopogo swimmers were afflicted continuously with otitis externa but suffered infrequently from respiratory problems.

The fecal streptococci convincingly correlated with gastroenteritis upper respiratory and otitis externa infections of lake swimmers while fecal coliform correlated only with gastroenteritis. I did not determine whether the measured concordance between water quality and illness was causally related to water harboured pathogens or to other variables such as contact with beach density. The incidence, however, of otitis externa amongst lake swimmers was quite striking and I don't think it would be premature to implicate water quality as the variable responsible. The presence of

Ps. aeruginosa in the lake and surrounding creeks was verified but whether this organism was the provoking pathogen was not proven.

My research evolved from the longstanding supposition that the health of swimmers suffered because of exposure to degraded or unsafe water quality and in essence the data validated the hypothesis. However it is equally important to realize that the water quality correlation with illness incidence was far less damaging than it potentially could have been. From the viewpoint of most tourists and residents it is the intangible aspects of relaxation, fresh air or sunshine which are memorable and not the inconveniences related in this study. One cannot chart the enjoyment gained from splashing about in a blue lake as concisely as one can count bacteria grown from the same water and the comfort of ignorance helps the lake to feel as refreshing as it looks. For some families the problems which I outlined in this study are just now beginning to become serious enough to interfere with leisure enjoyment. The influence of Lake Okanagan's bathing water quality is starting to spread beyond the immediate relationshp with health and into the realm of social implications.

In consideration of both the research findings presented and the future potential impact of water quality on recreational enjoyment I have two conclusions or recommendations to make. One suggestion is that additional public beaches should be made available in Kelowna to relieve the density of the park beach. The beach itself has only a narrow periphery of sand where sometimes crowding is so extreme there is insufficient space on the sand and people must occupy the bleachers. The Hot Sands or city park beach is the only lake bathing area in the vicinity of Kelowna which provides life guarding. Extended services to other beaches would also help reduce density.

My second suggestion is that the British Columbia recreational water standards for both chlorinated and fresh water areas should be re-examined for their purpose and protective value. If checking water quality intermittently for total or fecal coliform is not relevant to existent problems such as the otitis externa incidence described, then the standards should be changed or augmented to suitably represent recreational water quality.

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APPENDIX 1

HEALTH BRANCH PROVINCE OF B.C. RECOMMENDED WATER QUALITY STANDARDS

Public Swimming Pools (1968)

6.04 Water sample from pools for bacteriological examination shall be taken at a time when the pool is in use at a point near the outlet of the swimming-pool and at such additional sampling points as may be selected to indicate the quality of the water is being maintained throughout the swimming-pool. Not more than 15 per cent of any series of samples, nor more than two consecutive samples in any series of samples, taken at least one week apart, shall show the presence of organisms of the coliform group in any of the five 10-millilitre portions examined.

6.04 All bacteriological tests shall be made in accordance with the procedure recommended in the latest edition of "Standard Methods for the Examination of Water and Waste-water," published by the American Public Health Association.

6.06 The pH (hydrogen ion concentration) test shall be made on the pool water at least once every day the pool is in operation. A pH value of not less than 7.4 shall be maintained.

Recreation Waters (1969)

The standards stipulate that bathing, swimming and recreational areas in clear water lakes and upper areas of streams should have median less than 240 organisms per 100 milliliters for total coliforms and that this value should not be exceeded in more than 20% of the samples.

Recently, the Health Branch has adopted, for primary contact recreational waters, a fecal coliform standard of a log mean of 200 organisms per 100 mls; with not more than 10% of the total samples during any 30 day period to exceed 400 organisms per 100 mls. This standard is based on a minimum of not less than 5 samples for any 30 day period of the recreational season.

APPENDIX 2

LIMNOLOGICAL INFORMATION, 1972[1]

Lake Okanagan

Mean Annual Temperature	46°F
Average Annual Precipitation	12.2"
Average Net Inflow	355,000 acre feet
pH Range	7.4 - 8.6
pH Mean	8.0

Streams	pH	Mean Flow C.F.S.	Max. Flow C.F.S.	Nitrate N mg/l	B.O.D. Average	Total Coliforms Median MPN	Fecal Coliforms Log Mean
Mill Creek	8.0	40	178	3.5	1.6	>> 5,420	<1,122
Brandt's Creek	8.0	2.9	19.8	.5	287	>169,000	< 980

Mill Creek: Highest flow is during July and August, 1972 Unusually high run off

Brandt's Creek: Highest flow is during March.

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[1] Lynch, 1972, Okanagan Basin Study Bulletin 2, Okanagan Basin Study Bullentin 4.

APPENDIX 3 V

Tables XVII - XXII

Table XVII

Lake Okanagan Air and Water Temperatures, 1972

Air: Highest Daily Temperature °F
Water: Surface Temperature °F

Date	Highest Air Temperature	Water Temperature
July 1	72	
2	79	
3	82	59°
4	87	60°
5	91	
6	88	
7	80	
8	65	
9	64	
10	71	
11	72	
12	63	60°
13	76	62°
14	76	
15	81	
16	82	
17	88	68°
18	70	60°
19	80	
20	80	63°
21	81	63°
22	85	
23	83	
24	87	
25	83	62°
26	86	67°
27	88	67°
28	91	67°
29	87	
30	89	
31	91	69°
Aug. 1	86	70°
2	85	
3	88	70°
4	91	
5	91	
6	95	
7	97	72°
8	95	72°
9	92	74°
10	91	72°
11	83	72°
12	81	
13	81	
14	73	70°
15	73	69°
Aug. 16	76	70°
17	66	
18	72	
19	79	
20	87	
21	75	
22	76	68°
23	80	68°
24	85	
25	86	
26	87	
27	89	
28	93	72°
29	89	
30	72	
31	75	
Sept. 1	76	
2	79	
3	82	
4	80	
5	75	
6	65	
7	70	
8	63	64°
9	63	
10	65	
11	67	
12	73	58°
13	74	
14	80	
15	80	
16	71	
17	63	
18	61	
19	60	
20	62	
21	62	
22	53	60°
23	56	
24	48	
25	54	
26	56	56°
27	49	
28	47	
29	60	58°
30	64	

Table XVIII

Water pH of Sampling Sites

Brandt's Creek Mouth

Date	pH
July 4, 1972	9.1
11, "	8.0
18, "	8.7
27, "	8.6
Aug. 4, "	7.8
11, "	6.8
25, "	8.1
Sept. 3, "	8.4
8, "	8.0
20, "	8.4

Mill Creek

Date	pH
July 4, 1972	8.5
11, "	7.5
18, "	8.6
27, "	8.5
Aug. 4, "	8.1
11, "	8.4
25, "	8.4
Sept. 3, "	8.2
8, "	7.9
20 "	8.3

Rutland Pool

Date	pH
July 22, 1972	8.4
27, "	8.1
Aug. 6, "	7.4
11, "	6.9
23, "	6.8
Sept. 3, "	8.4
8, "	7.1
17, "	8.6

Ogopogo Pool

Date	pH
July 4, 1972	8.4
11, "	7.2
18, "	8.0
27, "	8.3
Aug. 4, "	7.9
11, "	8.3
25, "	7.6
Sept.3, "	8.2
8, "	(8.4)
20, "	8.4
24, "	8.1

TABLE XIX

Ogopogo Pool: Fecal indicator counts: surface vs. sediment water samples.

Date August 1972	Surface Fecal Coliform	Sediment Fecal Coliform	Surface Fecal Streptococci	Sediment Fecal Streptococci
8	0	40	8	88
9	8	36	102	64
10	4	44	18	35
11	14	52	12	72
14	4	14	206	6
15	12	0	9	1
16	0	5	6	0
17	6	0	0	2
18	0	0	35	68
21	0	8	12	124
22			12	150
23			0	0

Depth: 6 feet to 9 feet.

Table XX

Fecal Indicator Counts: Ogopogo Pool vs. Hot Sands

Date	Ogopogo Fecal Coliform	Hot Sands Fecal Coliform	Ogopogo Fecal Streptococci	Hot Sands Fecal Streptococci
<u>June 1972</u>				
4	4	8		
5	0	2		
7	0	0		
9	14	0		
12	12	2		
13	40	10		
15	2	32		
17	100	126		
20	16	2		
21	7	10		
22	7	16		
23	30	24		
26	2	18		
27	0	2		
28	1	4		
<u>August</u>				
1	2	14	0	50
2	10		27	
3	22	10	110	16
4	80		6	
7	20	18	21	135
8	0	34	8	62
9	8	1	102	94
10	4	16	18	35
11	14	22	12	82
14	4	0	206	4
15	12	0	9	
16	0	4	6	57
17	6		0	
18	0	0	35	9
21	0	20	12	338
22	0	2	12	0
23	100	0	0	2
24	0		1	
25	2	8	37	45
28	18	12	8	62
30	10	4	0	21
31	0	0	1	0

Table XXI

Weekly Illness Incidence per 1000 Person Hours Swimming Exposure

July and August 1972

	Date	Upper Respiratory	Otitis Externa	Gastroenteritis	Conjunctivitis	Shistosomiasis
Rutland Swimmers	July 1st wk	17.23	-	-	-	-
	2nd wk	57.66	-	-	-	-
	3rd wk	16.66	-	-	-	-
	4th wk	11.10	-	-	-	-
	Aug. 1	8.33	4.16	12.5	4.16	-
	2	45.83	-	4.16	4.16	-
	3	40.00	-	6.66	-	-
	4	6.66	-	6.66	13.3	-
Hot Sands Swimmers	July 1	10.76	-	-	-	5.43
	2	34.30	10.73	16.16	-	32.3
	3	47.63	21.16	-	-	5.30
	4	79.33	42.3	21.16	-	-
	Aug. 1	28.96	14.5	29.0	-	29.0
	2	43.46	29.0	29.0	-	-
	3	-	-	-	-	-
	4	-	-	-	-	-
Ogopogo Swim Team	July 1	-	38.60	-	-	7.69
	2	3.84	15.38	-	-	-
	3	15.38	30.78	-	-	-
	4	11.54	61.54	11.54	-	-
	Aug. 1	11.54	3.86	-	-	-
	2	7.77	-	-	-	-
	3	-	-	-	-	-

Table XXII

Ogopogo Fecal Indicator Counts Used for Product Moment Correlations

Weekly Highest Total: Total of highest daily counts for five days in a given week.

Weekly Mean: Arithmetic mean of all counts in a given week including zero counts.

DATE	WEEKLY HIGHEST TOTAL			WEEKLY MEAN		
	Ogopogo Fecal Coliform	Ogopogo Fecal Streptococci	Rutland Fecal Streptococci	Ogopogo Fecal Coliform	Ogopogo Fecal Streptococci	Rutland Fecal Streptococci
July						
2nd wk	127	111	3	31.286	24.428	1.0
3rd wk	13	142	0	1.875	14.700	0
4th wk	339	1560	38	27.625	133.334	6.33
August						
1st wk	172	603	107	24.428	55.714	26.75
2nd wk	168	758	173	16.667	77.134	34.60
3rd wk	122	135	32	8.714	9.650	8.00
4th wk	242	267	54	16.500	23.50	9.00