STATISTICAL ANALYSIS OF THE NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION BACTERIOLOGICAL SAMPLING DATA FOR LAKE GEORGE

Robert Clifford, Jr., Donald B. Aulenbach
and Nicholas L. Clesceri

Rensselaer Polytechnic Institute
Troy, New York 12181

ABSTRACT

Bacterial indicator organisms are used to detect water contamination. Data reported by the New York State Department of Environmental Conservation concerning the bacteriological quality of Lake George for 1978, 1979, 1980, and 1981 were statistically analyzed. The total coliform (TC), fecal coliform (FC) and fecal streptococci (FS) counts were determined throughout the year from a continually revised sampling network directed toward the most likely sources of bacteriological contamination to the lake. The relationships between TC and FC, the TC counts, the FC:FS ratios, and the general trends of FC:FS ratios along the lake were investigated.

INTRODUCTION

The New York State Department of Environmental Conservation (DEC) has addressed the growing concern for the water quality of Lake George with its yearly program of bacteriological monitoring at selected "hot spots," i.e., areas of suspected bacterial contamination, along the shore of the lake. The database encompasses the four year period from 1978 to 1981. During this period 463 samples were taken from 130 sites. Of these 130 sites, however, only 36 were returned to at least once a year. Approximately 75% of the database, or 325 samples of the 463, was taken from these "chronic" hot spots.

Figures 1 and 2 outline the range of shoreline areas sampled by the DEC during the four year period. Almost 50% of the samples were collected along the southwest corner of the lake, in the Town of Lake George. With the exception of Northwest Bay Brook, all of the sampled areas are associated with population centers around the lake.

The samples are analyzed for three different groups of indicator organisms: total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS), (Figure 3). These bacteria were enumerated by membrane filtration onto growth-selective media. The lone member of the FC group, Escherichia coli, and several members of the FS group are found in their most significant percentages in the fecal matter of warm blooded mammals

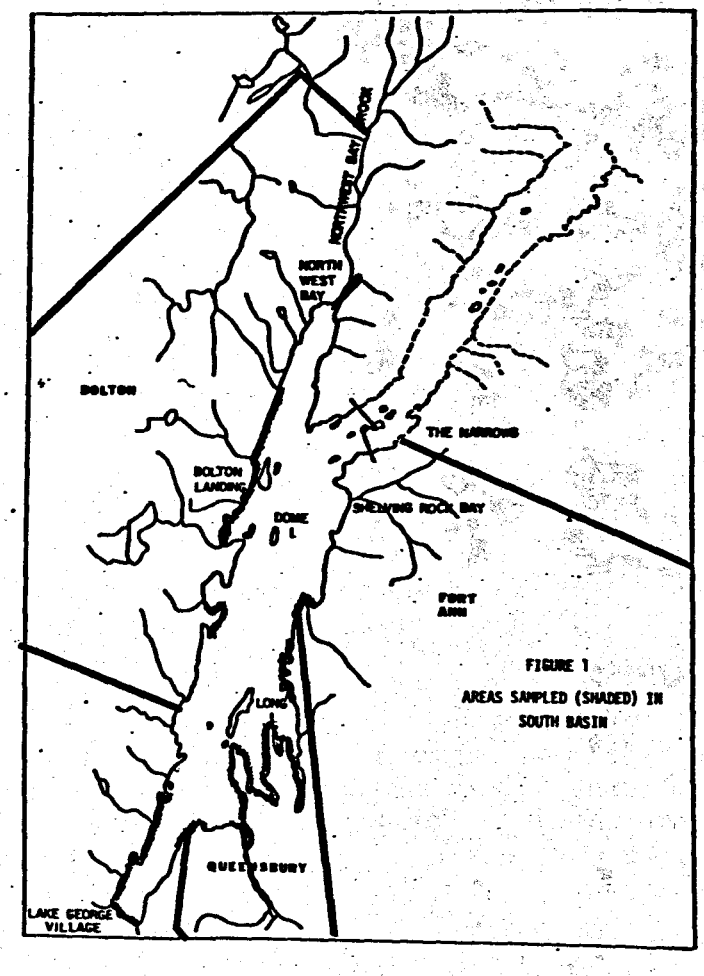

FIGURE 1
AREAS SAMPLED (SHADED) IN
SOUTH BASIN

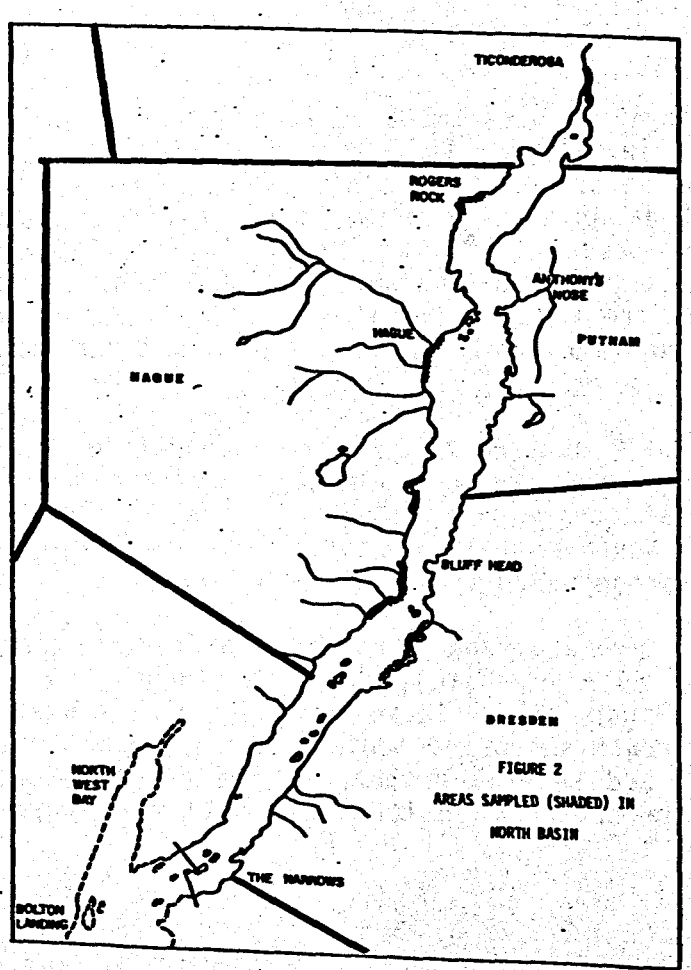

FIGURE 2
AREAS SAMPLED (SHADED) IN
NORTH BASIN

[5]. However, several members of the TC group as well as Streptococcus faecalis var. liquefaciens, in the FS group, are ubiquitous within the natural environment [1,5].

FIGURE 3
Enumerative Tests Performed

	Genus	Species
Total Coliforms (TC)	Escherichia	
	Citrobacter	
	Enterobacter	
	Klebsiella	
Fecal Coliforms (FC)	Escherichia	coli
Fecal Streptococci (FS)	Streptococcus	faecalis
	"	faecalis var. liquefaciens
	"	faecalis var. zymogenes
	"	faecium
	"	bovis
	"	equinus
	"	avium

A useful tool in determining whether the source of fecal contamination is human or animal in origin is the FC:FS ratio. Figure 4 shows the values of this ratio for various animal species. In man the ratio is greater than

FIGURE 4
FC:FS Ratios in Warm-Blooded Animal Waste

Man	4.4
Duck	0.6
Chicken	0.4
Sheep	0.4
Cat	0.3
Cow	0.2
Rodents	0.04
Pig	0.04
Dog	0.02

4.0 while for all animals the ratio is less than 0.7. However, this arithmetic ratio must be used with reservation. Each of the members of the bacterial indicator groups responds differently upon its introduction to the lake environment. In general, certain members of the TC and FS groups are hardier than the sole member of the FC group [4]. This survivability is a composite function of water temperature, depth, amount of available food, and the density of protozoan predators [5,6,8]. Significant "die-off" of the less hardy bacterial species will occur within 24 hours after their release from a wastewater source. It is essential that the sampling regimen be such that samples are obtained close to a suspected source of contamination; otherwise the FC:FS ratios in these samples would be skewed away from their actual values at that source. Most of the DEC sampling was done at the mouths of streams or culverts, where travel time of the water from the head of the stream was only a few hours at most. However, the nature of the suspected contamination was not determined for any of the DEC sites, hence it may not be correct to conclude that the contamination was a direct input to the receiving stream or culvert. At the least, the FC:FS ratio will give an indication of the relative contribution of the FC group versus the FS group at the point of introduction to the lake. The FC:FS ratio was not applied to any samples where the FS count was less than 100 colonies/100 ml. Counts below this value may be representative of ambient concentrations of S. Faecalis var. liquefaciens, found in waters unaffected by fecal contamination [2,3].

RESULTS

Geometric means for each of the indicator groups and the FC:FS ratio for all sites and the "chronic sites" are provided in Table 1. These means may be judged against the New York State Health Department criterion

TABLE 1
GEOMETRIC MEANS
(All Data from all Sites)

	1978	1979	1980	1981	4 year mean
TC	229	611	514	804	442
FC	66	78	64	68	69
FS	123	160	75	123	119
FC:FS	.30	.31	.70	.31	.36

(Data from "Chronic" Sites, Those Sampled 4 Times or More)

	1978	1979	1980	1981	4 year mean
TC	394	980	808	839	694
FC	105	102	90	73	97
FS	184	189	111	112	155
FC:FS	.43	.36	.69	.46	.45

for recreational waters, which sets geometric mean limits of 2400 colonies/100 ml for total coliforms, and 400 colonies/100 ml for fecal coliforms , for 5 samples taken within a 30 day period [9]. There are no standards for fecal streptococci. For each year in the sampling program, the FC:FS ratio was less than 0.7. Total coliform counts may be erroneously interpreted as indicators of fecal contamination to a water body. Table 2 gives correlation coefficients between bacteriological water quality indicator groups. The only significant correlation occurs between

TABLE 2
Correlation Between Bacteriological Quality Parameters

	Coefficients of Determination (r^2) (All data, all sites)				
	1978	1979	1980	1981	1978-1981
log (TC) vs. log (FC:FS)	.206	.159	.396	.472	.251
log (TC) vs. log (FC)	.638	.382	.681	.533	.517
log (FC) vs. log (FS)	.347	.437	.482	.238	.390
log (FC) vs. log (FS) where FS > 100	.244	.404	.168	.150	.263

A Coefficient of Determination (r^2) of .500 or greater would mean that 50% or more of the variation observed in one variable would be explainable by its linear relationship with the other.

the log TC and log FC counts, however, only slightly more than half the observed variation is explainable. (This is probably due to the fact that the sole member of the FC group, E. coli, is also a member of the TC group.) Several members of the TC group occur naturally in the environment, and this is evidenced by the peak, during May, of a graph of monthly averages of the TC counts (Figure 5). This high monthly average may be associated with the increased runoff during this month, which would wash out many of the soil-associated bacterial species in the TC group.

CONCLUSIONS

A previous study [7] of the 1978 DEC Bacteriological concluded with three observations, which have been substantiated upon analysis of this larger dataset:

1. The high coliform counts observed have been associated with relatively few nearshore stations, most associated with sources of overland runoff. These runoff streams, however, exhibit bacterial water quality within the limits set by the New York State Department of Health for recreational waters.

2. Samples taken by the DEC show FC:FS ratios below 0.7, indicative of non-human sources of contamination. However, there is no evidence that these samples give an adequate representation of the nature of the contaminant sources. It may only be accurately said that the FC:FS ratio reflects the nature of the runoff from these contaminant sources when it reaches the lake.

3. There is no significant correlation between FC:FS ratios and total coliform counts, and only a slight relation between total and fecal coliform counts. Total coliform counts show a significant seasonal correlation. For these reasons fecal coliform counts, and not total coliform counts, should be looked at as a first cut indicator of bacteriological water quality.

REFERENCES

1. Ballentine, R.K., 1968. "Observation of Fecal Coliforms in Several Recent Stream Pollution Studies." Proceedings of Symposium on Coliform Bacteria in Water and Wastewater. California Department of Health.

2. Bordner, R. and J. Winter, Eds., 1978. Microbiological Methods for Monitoring the Environment -- Water and Wastes. EPA-600/8-78-017.

3. Geldrich, E., 1970. "Appplying Bacteriological Parameters to Recreational Water Quality." Journal of the American Water Works Association, 62:113-119.

4. Geldrich, E., L.C. Best, B. Kenner, D. Van Donsel, 1968. "The Bacteriological Aspects of Stormwater Pollution." Journal of the Water Pollution Control Federation, 40:1861-1872.

5. Geldrich, E. and B. Kenner, 1969. "Concepts of Fecal Streptococci in Stream Pollution." Journal of the Water Pollution Control Federation, 41:R336-R352.

6. Geldrich, E., H.D. Nash, D.F. Spino and D.F. Reasoner, 1980. "Bacterial Dynamics in a Water Supply Reservoir: A Case Study." Journal of the American Water Works Association, 72(L):31-40.

7. Haas, C.N. and R. Clifford, Jr., 1981. "Statistical Analysis of the New York State Department of Environmental Conservation Bacteriological Sampling Data." The Lake George Ecosystem, Charles W. Boylen, Ed.

8. Johnstone, D. and A. Kubinski, 1974. "Survival of Escherichia coli in Oligotrophic Waters." OWRR Project: A-063-WASH. Washington State University.

9. Personal communication, Mr. Ramesh Kapur, NYS Department of Health, Bureau of Community Sanitation and Food Protection.

DISCUSSION

Fuhs - The ratio of 0.7 for fecal coli. : fecal streptococci was developed for the midwest from data on domestic sewage and barnyard wastes. However, there are few barnyards in the Lake George region. There are mostly dogs and rodents, therefore the ratio of 0.7 is high for this region.