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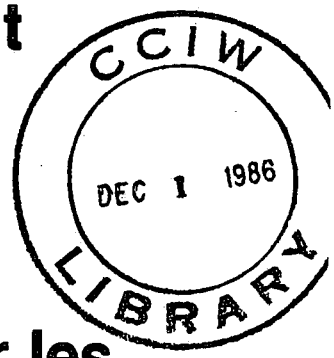

Summary Observations of Bacteriological Conditions in Lake Superior

S.S. Rao and A.A. Jurkovic

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For submission to the Chairman, IJC Lake Superior Surveillance Committee, IWD, Ontario Region

SUMMARY OBSERVATIONS OF BACTERIOLOGICAL CONDITIONS IN LAKE SUPERIOR - 1973, 1983*

by

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ABSTRACT

This report summarizes bacteriological data collected on Lake Superior during the 1973 and 1983 surveillance cruises. As part of the IJC Upper Lakes study, the report contains information on the nearshore and lakewide distribution patterns of bacteria of public health significance (fecal coliform, fecal streptococci & pseudomonas aeruginosa) and trophic indicator bacteria (aerobic heterotrophs).

Based on the information on bacterial types and densities in the lake, the lake is not experiencing an overall nutrient enrichment condition. Based on the nearshore-offshore densities of bacteria, existing or developing problem areas are identified. Data and methodology are presented.

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INTRODUCTION

This report summarizes microbiological data collected from May to November, 1973 and May to October, 1983. Bacteriological water quality studies of Lake Superior were performed by the Water Quality Assessment Unit, Microbiology Laboratory Section, Analytical Methods Division, NWRI, CCIW. These studies were performed for the IJC.

In a previous report (Rao and Henderson, 1973) on bacteriological studies of Lake Superior, based on the findings, it was stated that bacteriological water quality appears to be good and the main body of the lake was free of detectable fecal contamination of either human or animal sources. Waste discharge from the coastal areas did not have any significant effect on the main lake's water quality.

In this report bacteriological data on the distributions of organisms of public health significance (fecal coliforms, fecal streptococci and pseudomonas aeruginosa) and eutrophic indicator organisms (aerobic heterotrophs) in the nearshore and offshore areas of the lake are presented (Tables 1-5; Figures 2-7). Data collected during the 1983-84 surveys were compared to the data collected during the 1973 surveys in order to ascertain changes, if any, in the bacteriological water quality conditions.

WATER SAMPLING

During 1973 six water quality surveillance cruises covering approximately 2900 km each and sampling 117 stations (Figure 1) were made on the MV Martin Karlsen. Total coliforms (MF), fecal coliforms (MF), fecal streptococci (MF) and aerobic heterotrophs (20°C, 7 days) were the bacteriological water quality parameters tested. Samples were collected from depths of 1 m, 10 m and 50 m, except for a certain number of stations where an additional sample at 2 m from the bottom was colleted. During 1983 four water quality surveillance cruises were made sampling 77 stations on board the CSS Limnos. Bacterial parameters considered were fecal coliforms (MF), fecal streptococci (MF). Pseudomonas aeruginosa (MF) and aerobic heterotrophs and on selected stations additional parameters such as bacterial biomass, oligotrophic bacteria and aeromonas were measured. In 1983 the sampling depth for these stations were: during unstratified conditions, 1 m, 50 m, 100 m from the surface and 10 m and 2 m from the bottom and during stratified conditions 1 m, 1 m above the knee of the thermocline, mid thermocline, 1 m below thermocline and 2 m from the bottom.

Water samples were always collected using 1ℓ sterile glass bulbs.

Bacteriological Procedures

The bacteria were isolated using enrichment and selective media in combination with different incubation periods and temperature.

Fecal Coliform Density Determinations (MF) 1973, 1983

Sample quantities that would yield approximately 20-60 coloines per filter were chosen for the membrane filtration test. The membranes were placed on pads soaked with 2 ml of Bacto-MFC broth in tight fitting plastic petridishes. The petridishes were placed in waterproof plastic bags (whirl-pak), inverted and submerged in 44.5°C ± 0.5°C for 24 ± 2 hours. Counts were recorded in terms of fecal coliforms per 100 ml water sample.

Fecal Streptococci Density Determinations (MF) 1973, 1983

The APHA membrane filtration procedure (6) was used as the method for estimation of fecal streptococci concentrations. Water samples were tested using m-enterococcus agar. Membrane filtrations were made from appropriate volumes of each sample. Incubation was at 35 ± 0.5°C for 48 ± 2 hours in a well humidified incubator. The development of typical pink to maroon coloines was interpreted as direct evidence of the presence of fecal streptococci. The numbers of typical coloines appearing on MF preparations were determined with a

ten-power Steriomicroscope. Counts were expressed in terms of fecal streptococci per 100 ml of water sample (3). KF agar for ennumeration of fecal streptococci was used instead of m-enterococcus agar.

Aerobic Heterotrophs (20°C, 7 Days) 1973, 1983

Aerobic heterotrophic bacterial populations were determined on all 1973 & 1983 samples by a spread plate procedure on a pre-dried solid media (4). The composition of the media is given in "Methods for Microbiological Analysis of Water, Wastewater and Sediments"(2). One millilitre of an appropriate dilution of water sample was used. Plates were incubated after inoculation at 20°C for seven days. Counts were recorded in terms of heterotrophs per 1 ml of water.

Bacterial Distributions in Lake Superior 1973, 1983

Monthly variations in densities of fecal coliforms, fecal streptococci (bacteria of public health significance) and aerobic heterotrophs (eutrophic indicators) are presented in Tables 1 to 5 and Figures 2 to 7.

BACTERIOLOGICAL CONDITIONS IN THE LAKE

1. Elevated densities of bacteria of public health significance (fecal coliforms and fecal streptococci) include those genera which specifically originate in the intestinal tract of warm

blooded animals. They are indicators of fecal pollution (1). Data from the cruises in 1973 and 1983 permitted the establishment of some seasonal trends. The observed levels of fecal coliforms in 1973 remained relatively constant (i.e over 80% of the analysed water samples showed fecal coliform populations less than 1 per 100 ml. Some nearshore areas had relatively higher densities. These included Duluth, Thunder Bay, Whitefish Bay, Grand Island and Keweenaw Peninsula. Similar observations were made during the cruises in 1983.

Based on the available data (1973), (Table 2), it is evident that fecal streptococci densities remained relatively constant. On a lakewide basis, over 85% of the analysed samples showed fecal streptococci populations less than 1 per 100 ml (Figure 6). In 1983 lakewide population levels of fecal streptococci changed drastically. Only 2% of the analysed samples showed fecal streptococci populations less than 1 per 100 ml. This could be attributable to the change from enterococcus agar to KF agar which is more selective.

Pseudomonas aeruginosa were not detected during these surveys.

The 1973 surveys being more intensive than 1983 probably allow some trends with regard to the distribution of aerobic heterotrophs. On a lakewide basis, 64% of the samples tested showed less than 100 per ml. A similar trend was also noticed during the

1983 surveys (Table 3, Figures 4 and 7). In 1973 and in 1983 in most inshore areas, however, heterotrophic bacterial densities were higher compared to offshore waters. These inshore areas included areas near Duluth, Marathon, the coastal area between Ashland and Keweenaw Peninsula, and Grand Island.

CAUSES AND EFFECTS OF OBSERVED BACTERIAL CONTAMINATION

It is indicated in the Great Lakes Water Quality Annual Report to the International Joint Commission (IJC), April 1973, that "It is not sufficient to monitor the quality of this lake in the open water in order to protect it. The water quality parameters of interest must be measured in those local areas of known waste loading." This must be done because the impact of pollution from specific sources is readily masked by the lakes large volume and their diluting capacity. It becomes essential then to consider those regions of the coastal zone which may be locally subjected to the addition of pollutants. Owing to the possibilities for exchange with the great volumes of main lake water, however, it is difficult to estimate the long-term effects of such organic loading. In most cases only certain generalizations can be drawn.

In the Western Basin the waters of the main body and most of the coastal zones of Lake Superior is of high quality. Fecal pollutants are almost nonexistant and heterotrophic bacterial populations are at levels consistant with oligotrophic waters (5).

Where heterotrophic bacterial populations do increase near some of the coastal areas, these areas are believed to be under the influence of high temperatures and an abundance of nutrients. These problem areas need to be considered for further studies.

In the Northeastern Basin of the lake bacterial populations in 1983 were similar to those found in 1973. In the Marathon area, aerobic heterotrophic populations in 1973 (in the nearshore areas) were slightly higher than in 1983. Nevertheless, this area had heterotrophic populations much higher than the offshore waters. It was found that sufficient nutrients were present in the 5 km^2 area to support the existing bacterial populations. However, these population levels eventually diluted to the extent that it is no longer detectable.

CONCLUSIONS

The present bacteriological water quality of Lake Superior is comparable to the bacteriological water quality conditions found in 1973. The main body of the lake is free from detectable fecal contamination from human sources. However, in the 1983 surveys, fecal streptococci values were considerably higher. This is partly due to a new medium which yields a higher percentage of these organisms. Also their circumstance may be attributable to greater fecal pollution from animal sources. In the western end of the lake near Duluth, Superior,

it is clear that high temperatures and good vertical mixing are important factors contributing to the increased bacterial populations.

In 1973 the nearshore areas in the western end of the lake FC/FS ratio (fecal coliforms and fecal streptococci ratio) in early summer was very low indicating a land wash type of contamination. The ratio, however, changed to values between 0.7 and 4.0 in the mid-summer and at times the ratio exceeded 4.0 during the fall indicating a sewage contamination. This is the only area of the lake where fecal streptococci counts were constantly available to permit this type of observation. In fact except for the odd random counts (usually 1 or 2 per 100 ml), fecal coliforms and fecal streptococci were practically absent from the majority of the samples processed. In 1983 for the majority of the cruises fecal coliforms were less than 1 per 100 ml. The coastal area between Ashland and Keweenan Peninsula has many such rivers flowing into the lake which may account for the observed increases in bacterial populations.

ACKNOWLEDGEMENTS

The authors wish to thank the Technical Operations Division personnel for collecting water samples during the surveillance cruises.

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FIGURES

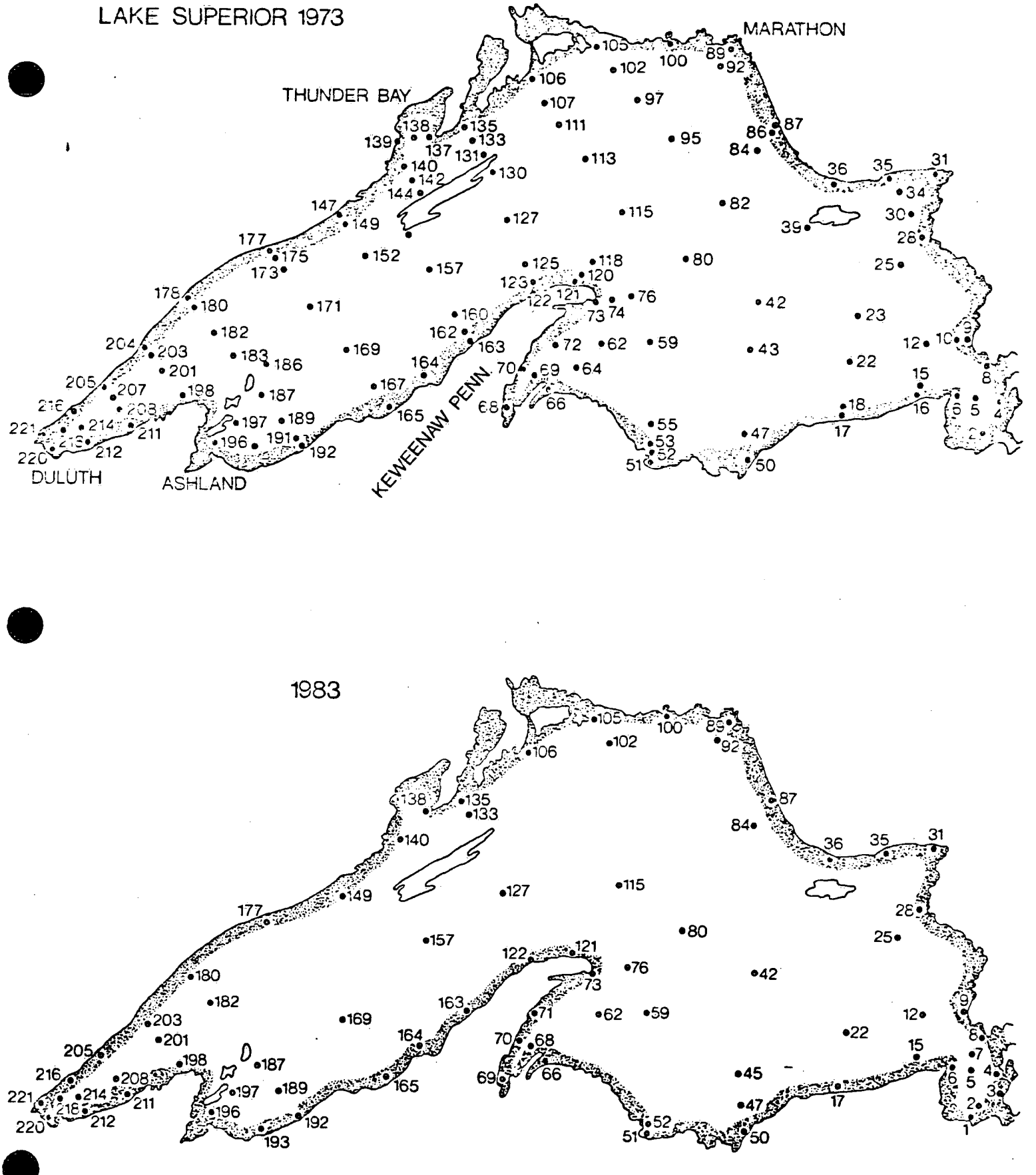
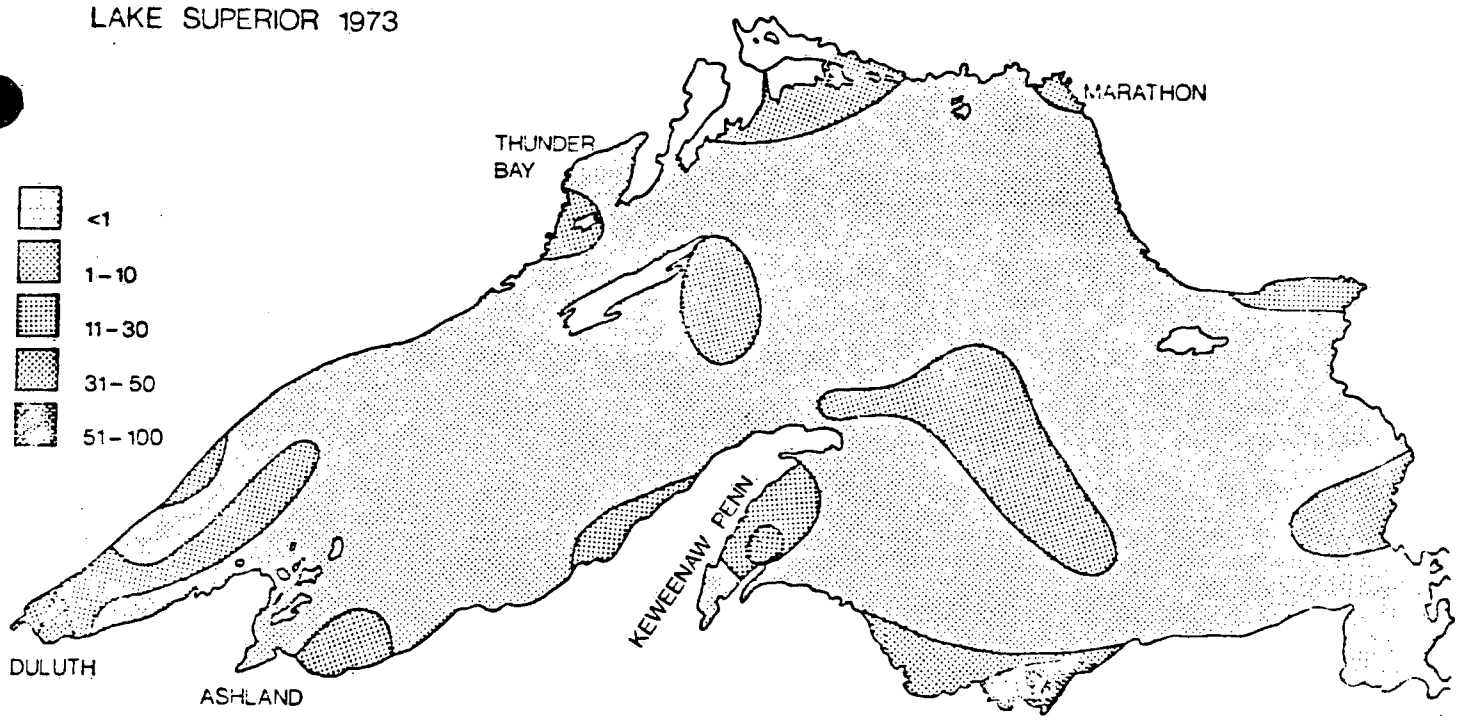


Figure 1 Inshore and offshore microbiological sampling stations



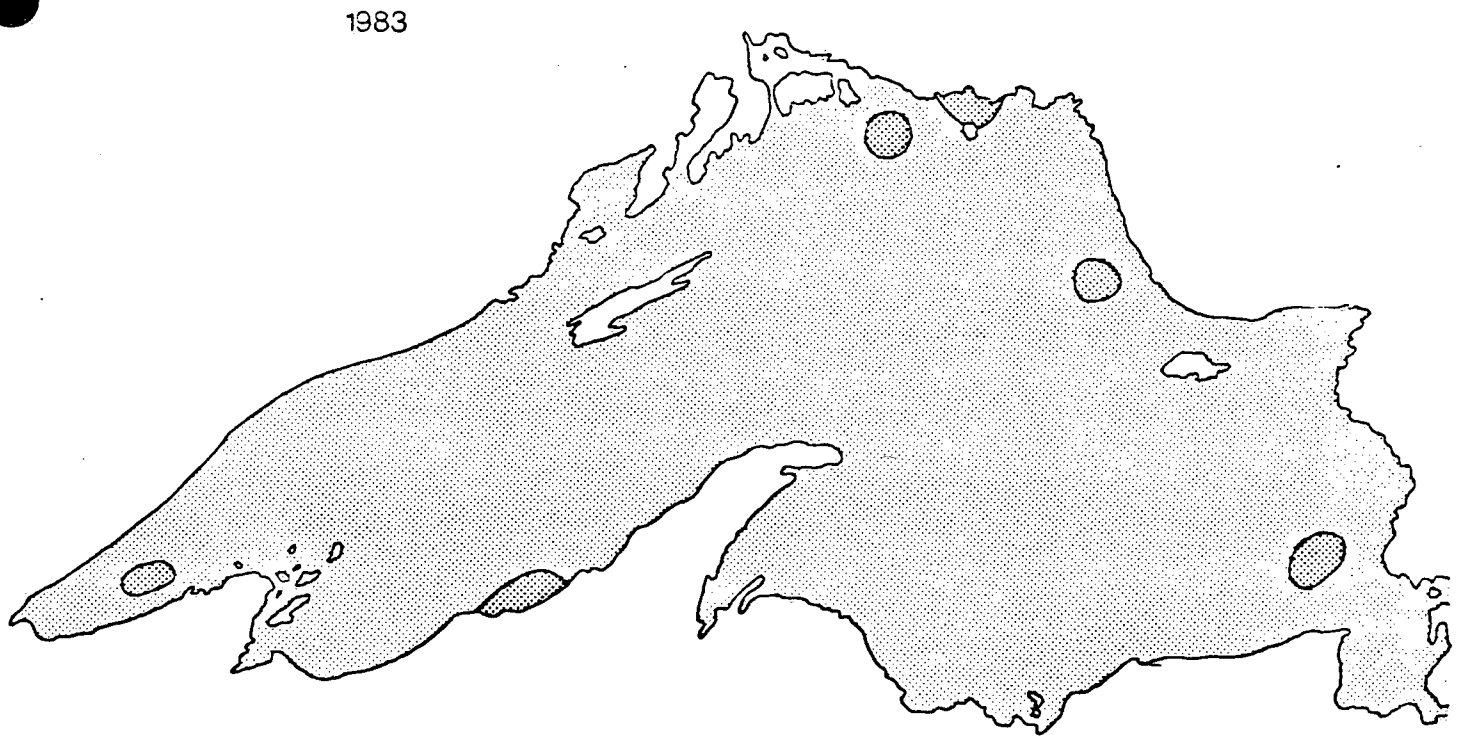
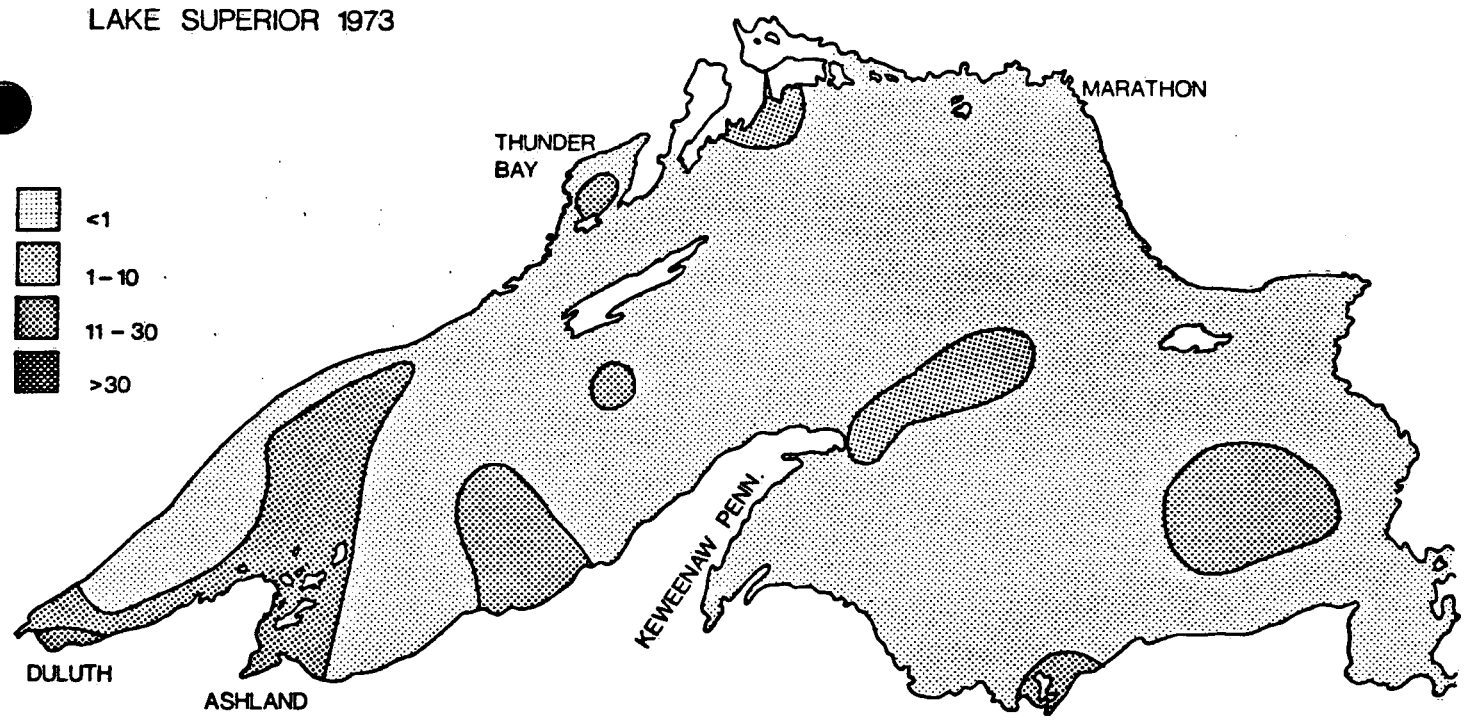


Figure 2 Distribution of fecal coliforms (MF #/100 ml) in Lake Superior (Average values of all depths, all cruises)



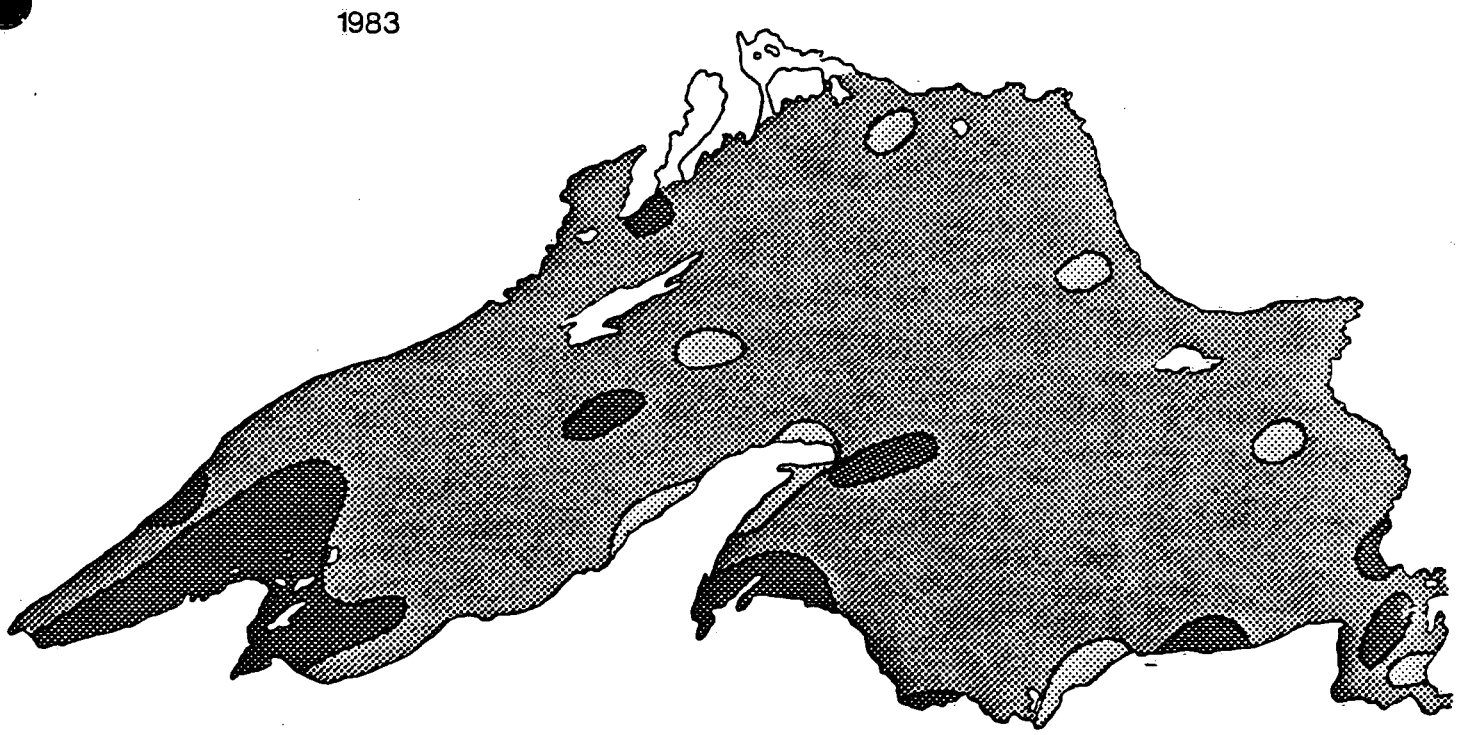
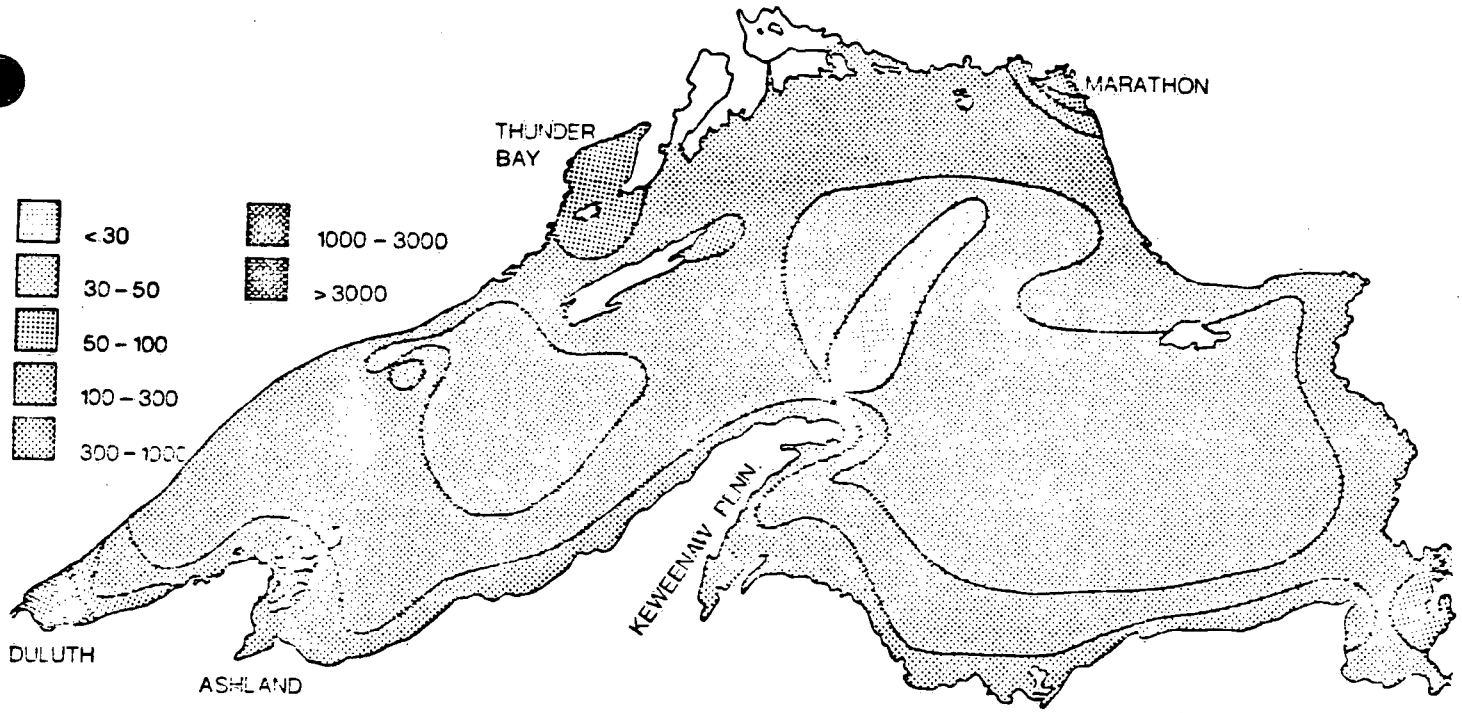


Figure 3 Distribution of fecal streptococci (MF #/100 ml) in Lake Superior (Average values of all depths, all cruises)

LAKE SUPERIOR 1973



1983

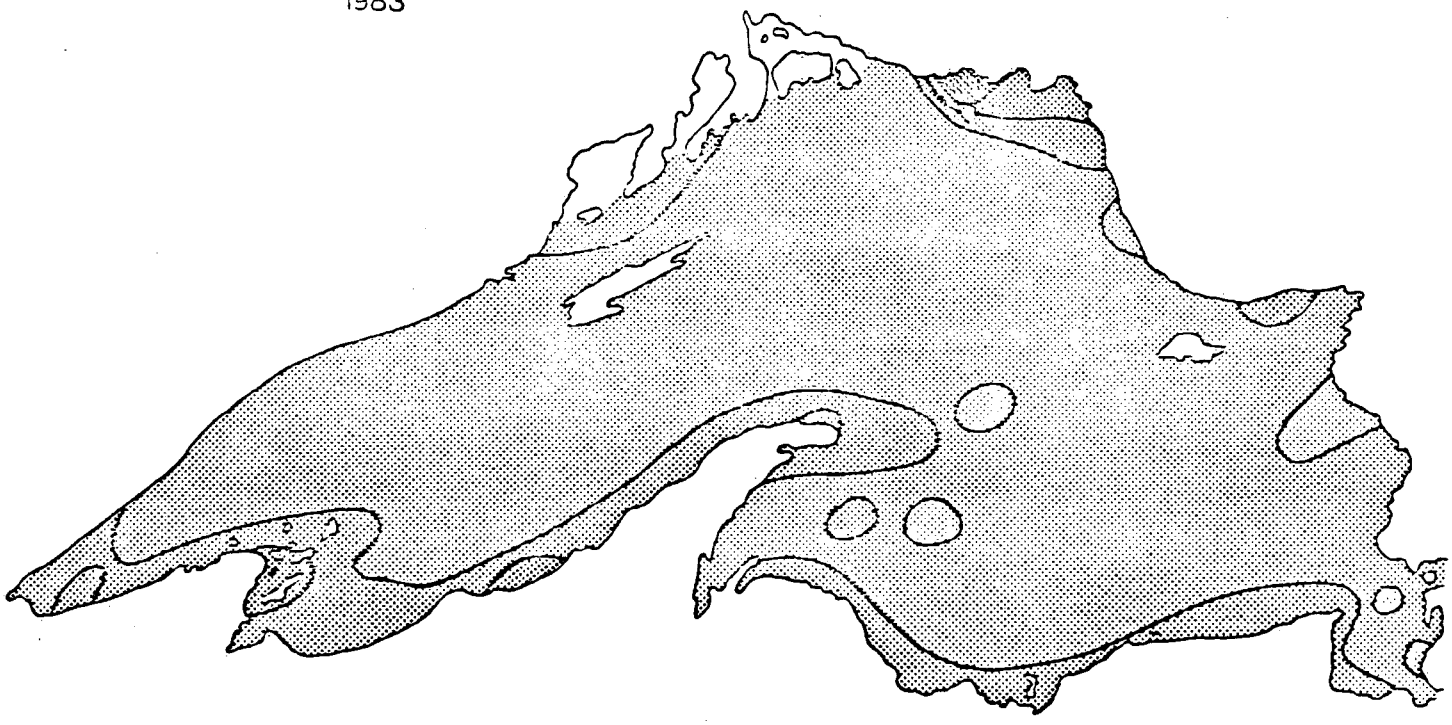


Figure 4 Distribution of aerobic heterotrophs (F&T #/ml 20°C/7 days in Lake Superior (Average values of all depths, all cruises)

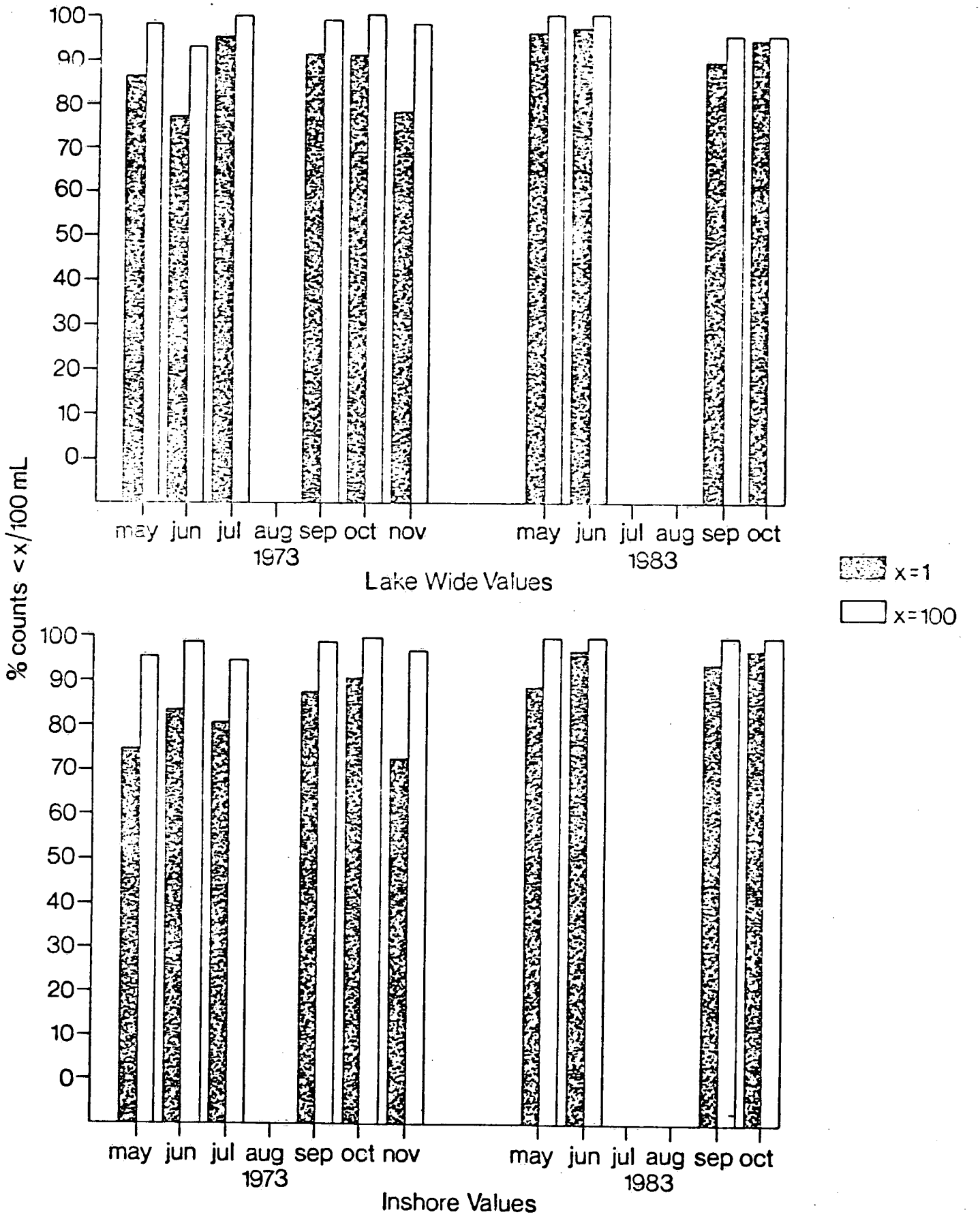


Figure 5 Bacterial Distributions in Lake Superior 1973, 1983
Fecal Coliforms (MF)

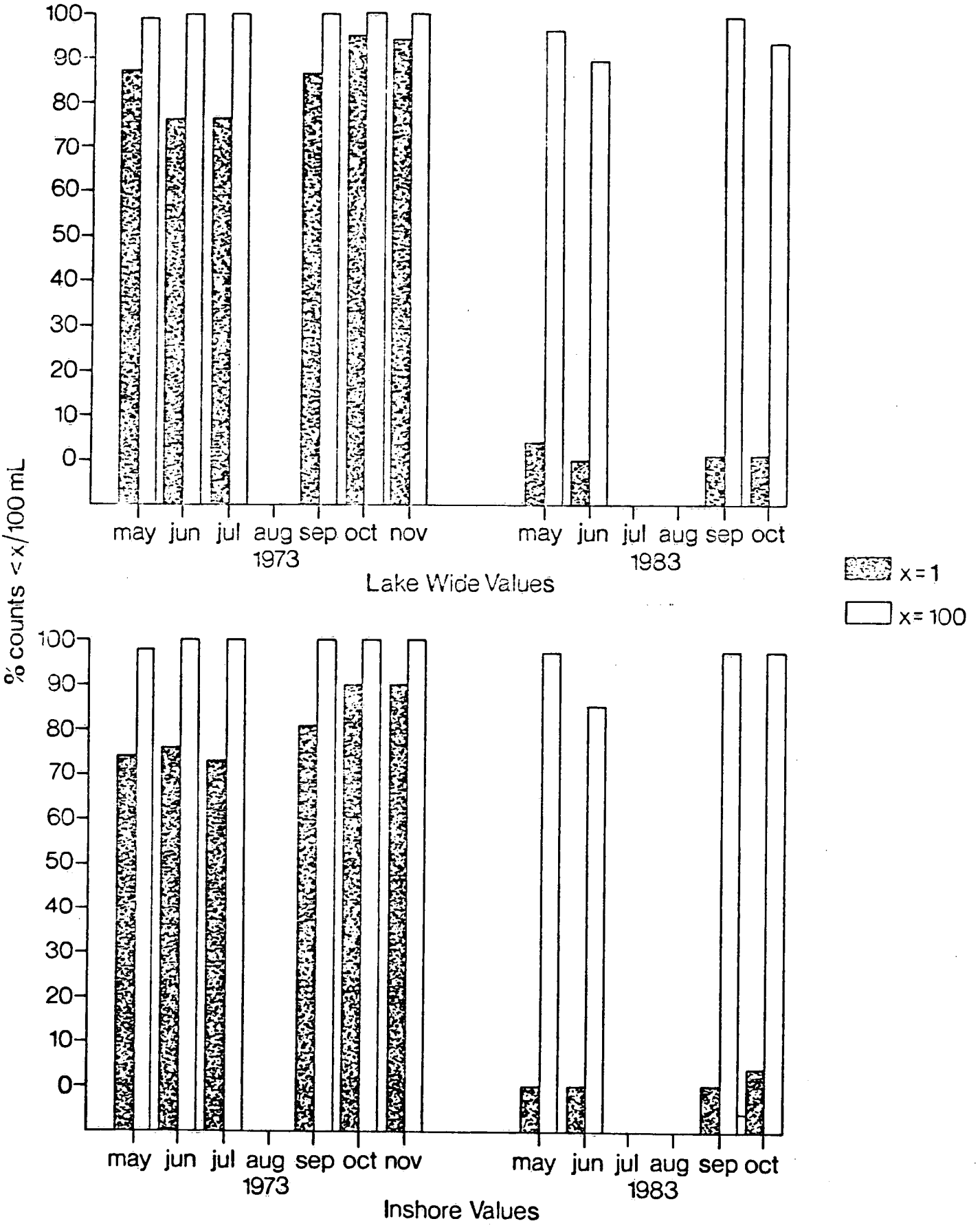


Figure 6 Bacterial Distributions in Lake Superior 1973, 1983
Fecal Streptococci (MF)

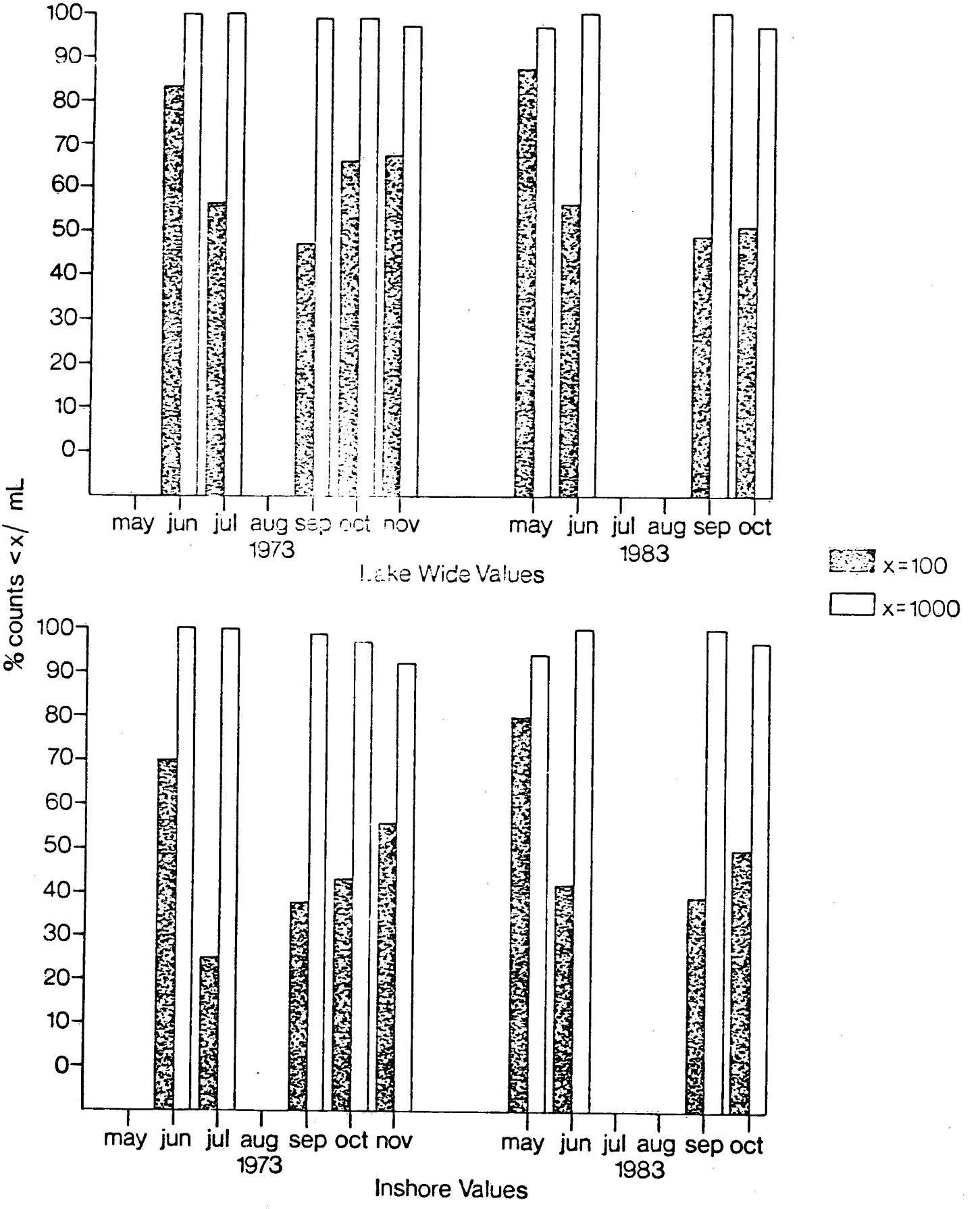


Figure 7 Bacterial Distributions in Lake Superior 1973, 1983
Aerobic Heterotrophs (F & T., 20°C/7 days)

TABLES

Table 1. Trends in Fecal Coliform (MF) Organisms %<X/100 mL in Lake Superior 1973, 1983

		1973	1983
May			
Inshore value	< 1	75	89
	< 100	96	100
Lake-wide value	< 1	86	96
	< 100	98	100
June			
Inshore value	< 1	84	97
	< 100	99	100
Lake-wide value	< 1	77	97
	< 100	93	100
July			
Inshore value	< 1	81	
	< 100	95	
Lake-wide value	< 1	95	
	< 100		
September			
Inshore value	< 1	88	94
	< 100	99	100
Lake-wide value	< 1	91	94
	< 100	99	100
October			
Inshore value	< 1	91	97
	< 100	100	100
Lake-wide value	< 1	91	99
	< 100	100	100
November			
Inshore value	< 1	73	
	< 100	97	
Lake-wide value	< 1	83	
	< 100	98	

Table 2. Trends in Fecal Streptococci (MF) Organisms %<X/100 mL in Lake Superior 1973, 1983

Month		1973	1983
May			
Inshore value	< 1	74	0
	< 100	98	97
Lake-wide value	< 1	87	4
	< 100	99	96
June			
Inshore value	< 1	76	0
	< 100	100	85
Lake-wide value	< 1	76	0
	< 100	100	89
July		73	
Inshore value	< 1	100	
	< 100	76	
Lake-wide value	< 1	100	
	< 100		
September			
Inshore value	< 1	81	0
	< 100	100	97
Lake-wide value	< 1	86	1
	< 100	100	99
October			
Inshore value	< 1	90	3
	< 100	100	97
Lake-wide value	< 1	95	1
	< 100	100	93
November			
Inshore value	< 1	90	
	< 100	100	
Lake-wide value	< 1	94	
	< 100	100	

Table 3. Trends in Aerobic Heterotroph Distributions %<X/100 mL in Lake Superior 1973, 1983

Month		1973	1983
May			
Inshore value	< 100	no data	80
	< 1000	no data	94
Lake-wide value	< 100	no data	87
	< 1000	no data	97
June			
Inshore value	< 100	70	42
	< 1000	100	100
Lake-wide value	< 100	83	56
	< 1000	100	100
July		25	
Inshore value	< 100	100	
	< 1000	56	
Lake-wide value	< 100	100	
	< 1000		
September			
Inshore value	< 100	37	39
	< 1000	99	100
Lake-wide value	< 100	47	49
	< 1000	99	100
October			
Inshore value	< 100	43	50
	< 1000	97	97
Lake-wide value	< 100	66	51
	< 1000	99	97
November			
Inshore value	< 100	56	
	< 1000	92	
Lake-wide value	< 100	67	
	< 1000	97	

Table 4. **Bacterial Distributions in Lake Superior 1973 and 1983 Average Values of all Cruises (Nearshore Stations)**

Month	Fecal Coliforms #/100 mL		Fecal streptococci #/100 mL		Aerobic Heterotrophs #/mL	
	1973	1983	1973	1983	1973	1983
May	4	3	3	21	N.D.	220
June	2	1	1	65	65	170
July	9	-	2	-	160	-
September	2	<1	1	25	170	190
October	1	<1	<1	19	190	260
November	7	-	1	-	180	-

Table 5. Bacterial Distributions in Lake Superior 1973 and 1983 Average Values of all Cruises (All Stations Lake Wide)

Month	Fecal Coliforms #/100 mL		Fecal streptococci #/100 mL		Aerobic Heterotrophs #/mL	
	1973	1983	1973	1983	1973	1983
May	2	2	3	22	N.D.	120
June	1	1	1	55	47	140
July	6	-	1	-	110	-
September	2	<1	1	19	130	160
October	1	<1	<1	29	120	220
November	6	-	1	-	120	-

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