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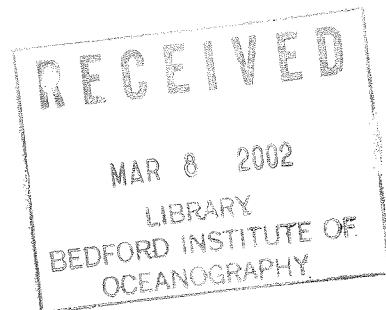
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Synoptic Water Quality Survey of Halifax/ Dartmouth Metro Area Lakes on April 16, 1991

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1993



Canadian Data Report of Fisheries and Aquatic Sciences 914



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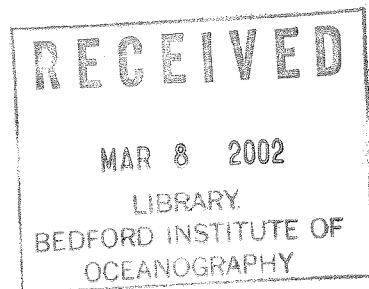
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**SYNOPTIC WATER QUALITY SURVEY
OF HALIFAX/DARTMOUTH METRO AREA LAKES
ON APRIL 16, 1991**

by



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INTRODUCTION

The Halifax-Dartmouth Metro Area has a large number of lakes which are valuable resources for water supply, recreation, and wildlife habitat. Urban development imposes various stresses on lakes and their watersheds; and careful environmental management is necessary to maintain an acceptable level of water quality, both in built-up areas and regions undergoing development. Proper lake and watershed management requires an adequate scientific understanding of the natural processes that control lake properties, the types of pollutants being added, and their origin, concentrations, and effects on important lake processes.

Due to the existence of numerous university and government environmental research laboratories, government environmental regulatory agencies, and citizen environmental groups in the Metro Area, many scientific studies have been conducted on regional lakes (e.g. Gorham 1957; Ogden 1972; Gordon 1978; Watt et al. 1979; Castell et al. 1984; Soil and Water Conservation Society of Metro Halifax 1991; Scott et al. 1991; and Hellebrand and Dalziel 1992). As a result, a substantial data base is being accumulated. Major pollutants that have been identified in Metro Area lakes are silt, road salt, nutrients, acid deposition, and micro-organisms.

To help develop a data base for regional lake management, it was decided that it would be useful to conduct periodic synoptic water quality surveys of Metro Area lakes. Therefore, on April 14, 1980, an initial survey of 50 lakes was carried out on a single day (Gordon et al. 1981). The sampling took place immediately after ice out. At this time of year, lake water is well mixed from surface to bottom; and the properties measured in surface samples are representative, within certain limits, of the entire lake volume. Standard water quality variables (e.g. pH, major ions, and nutrients) were measured, and the resultant data were used to rank Metro Area lakes with regard to water quality.

The original intent was to repeat the survey every 10 yr, but this was not possible in 1990. However, the same agencies were able to organize and conduct a second survey in 1991 using the same or similar methods. Two additional lakes were included. In addition, samples were analyzed for aluminum, chlorophyll, colour, dissolved organic carbon, and a large number of trace elements. This report briefly describes the methods, presents the results, and compares them, where possible, with results obtained in 1980. All data are presented in appendices for those who wish to carry the analysis and interpretation further.

METHODS

SAMPLING

Sampling was conducted on April 16, 1991, in 51 lakes (Fig. 1; Table 1). As in 1980, samples were collected the day after the ice left Fraser Lake. Ragged Lake was the

only lake sampled in 1980 that was not sampled in 1991 (by unintentional omission). Samples were also collected for the first time in Anderson Lake and Power Pond. Most of the samples were collected by helicopter between 10:00 and 15:00 h. Remaining samples were collected by boat in the early morning or evening of the same day. Single samples were taken in small lakes near their centre, while multiple samples were collected along the axis of larger lakes (Fig. 1).

Table 1. Lakes sampled and their location on Figure 1. A number in brackets following the name indicates the number of replicate samples taken at one site in the lake.

1-3	Grand Lake	48-49	Spider Lake
4-6	Kinsac Lake	50-53	Lake Major
7-8	Third Lake	54-55	Loon Lake
9-10	Second Lake	56-57	Lake Charles
11	Powder Mill Lake	58-59	Lake Micmac
12-13	Rocky Lake	60-61	Bissett Lake
14-15	Sandy Lake	62-64	Morris Lake
16	Paper Mill Lake	65-66	Russell Lake
17-18	Kearney Lake	67	Frenchman Lake
19-20	Susie Lake	68	Anderson Lake
21-22	Governor Lake	69-70	Lake Banook (3R)
23-24	Fraser Lake	71-72	First Lake (3R)
25	Bayers Lake	73	Lamont Lake
26	Second Chain Lake	74	Topsail Lake
27	First Chain Lake	75	Oathill Lake (3R)
28-30	Long Lake	76	Penhorn Lake
31	Williams Lake	77	Maynards Lake
32	Colbart Lake	78	Little Albro Lake
33	Parr Lake	79	Big Albro Lake
34	Spruce Hill Lake	80	Cranberry Lake
35-37	Lake Fletcher	81	Settle Lake
38-39	Lake Thomas	82	Bell Lake
40-42	Lake William	82	Chocolate Lake
43-45	Soldier Lake	83	Whimsical Lake
46-47	Miller Lake	84	Frog Pond
		85	Power Pond

Water samples were collected from a depth of 20-30 cm in 2-L polyethylene bottles which had been washed with Decon®, rinsed with distilled water, and then rinsed with lake water immediately prior to filling with the sample. Temperature was measured immediately with a mercury thermometer. Water column transparency was measured with a 20-cm, all-white Secchi disk. This was difficult to operate from the helicopter floats because of the down-draft, so the results should be interpreted with caution.

Three replicate samples for quality control were collected from Lake Major, Oathill Lake, Lake Banook, and First Lake. Water samples were returned to the laboratory and

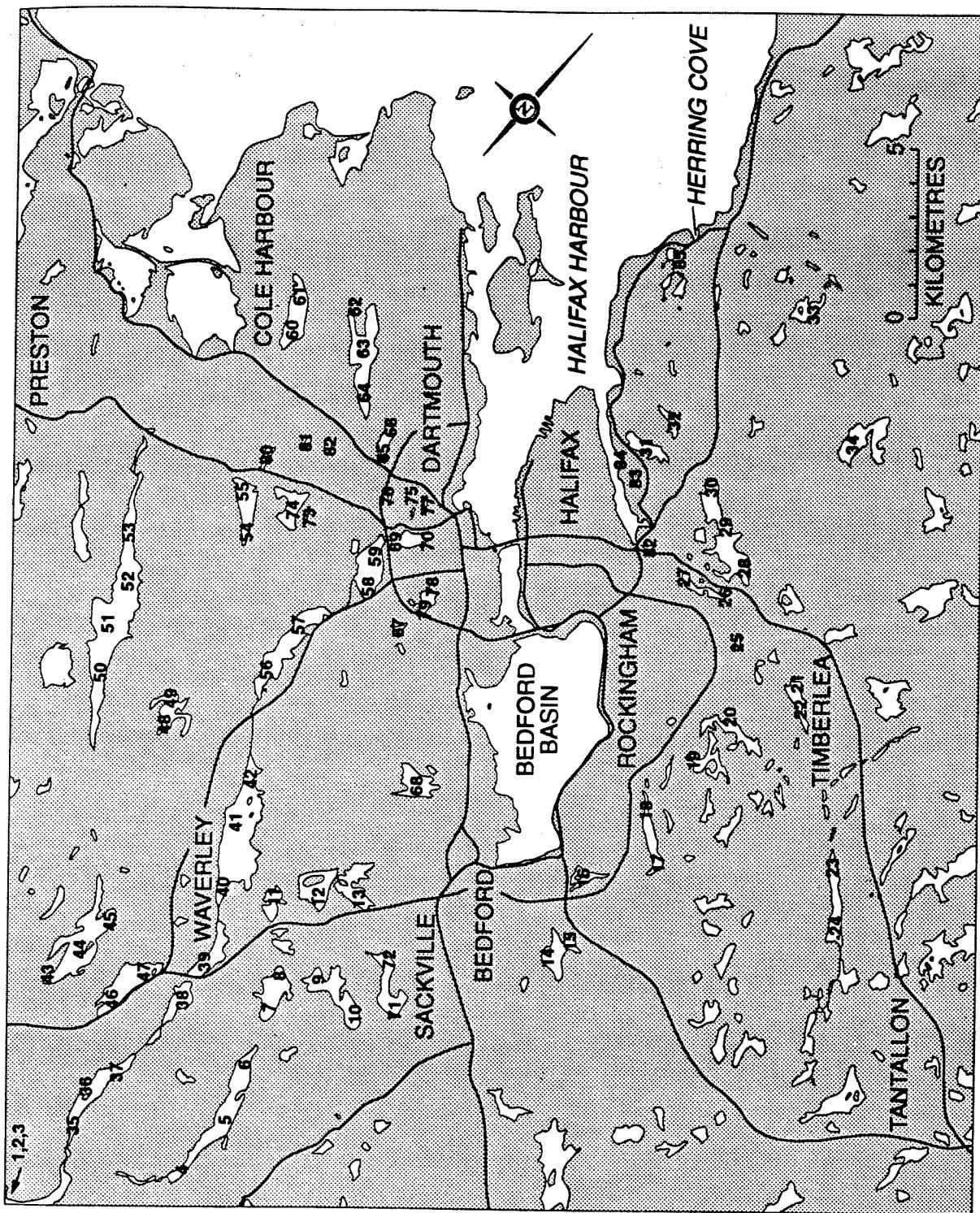


Figure 1. Map showing the location of the lakes that were sampled. See Table 1 for the number key.

processed within 4 h of collection. Aliquots were removed and analyzed immediately for initial pH, conductivity, chlorophyll, and ammonia. Subsamples for other analyses were transferred to other participating laboratories within 8 h of collection. A complete suite of analyses is not available for Bayers Lake because some subsamples were lost during transfer between laboratories.

CHEMICAL ANALYSIS

The variables measured, the responsible laboratory, the units used in this report, and the conversion factors to other commonly used units are listed in Table 2.

Table 2. Variables measured, the units used in this document, the laboratory responsible for the measurement, and the conversion factors to other commonly used units. NSDOE is the Nova Scotia Department of Environment (analyses were conducted under contract by the Environmental Chemistry Laboratory at the Victoria General Hospital); EC is the Environment Canada Water Resources Directorate; HED is the Habitat Ecology Division of the Department of Fisheries and Oceans (DFO); and MCD is the Marine Chemistry Division of DFO. Also included are the laboratories who conducted analyses in the 1980 survey. ($\mu\text{g at}$ is $\mu\text{g atoms}$ which is equivalent to μM or μmolar .)

Variable	Units	Laboratory		Conversion factors
		1991	1980	
Aluminum (Al)	mg L^{-1}	NSDOE		
Alkalinity	$\text{mg CaCO}_3 \text{ L}^{-1}$	EC, NSDOE	EC, NSDOE	$\times 20 = \mu\text{equiv. L}^{-1}$
Ammonia (NH_3)	mg N L^{-1}	HED	NSDOE	$\times 71 = \mu\text{g at N L}^{-1}$
Calcium (Ca)	mg L^{-1}	NSDOE	NSDOE	
Chlorophyll	$\mu\text{g L}^{-1}$	HED		
Chloride (Cl)	mg L^{-1}	NSDOE	NSDOE	
Colour	TCU	NSDOE	-	
Conductivity	μS	HED	HED	$\times 1 = \mu\text{mhos}$
Dissolved organic carbon (DOC)	mg C L^{-1}	EC	-	
Potassium (K)	mg L^{-1}	NSDOE	NSDOE	
Magnesium (Mg)	mg L^{-1}	NSDOE	NSDOE	
Sodium (Na)	mg L^{-1}	NSDOE	NSDOE	
Nitrate (NO_3^-)	mg N L^{-1}	MCD	NSDOE	$\times 71 = \mu\text{g at N L}^{-1}$
Phosphate (PO_4^{3-})	mg P L^{-1}	MCD	NSDOE	$\times 31 = \mu\text{g at P L}^{-1}$
Sulfate (SO_4^{2-})	$\text{mg SO}_4^{2-} \text{ L}^{-1}$	NSDOE	NSDOE	
Secchi disk depth	m	HED	-	
Silicate (Si)	mg Si L^{-1}	MCD	HED	$\times 36 = \mu\text{g at Si L}^{-1}$
Temperature	°C	HED	HED	
Total Nitrogen (TN)	mg N L^{-1}	NSDOE	NSDOE	$\times 71 = \mu\text{g at N L}^{-1}$
Total Phosphorus (TP)	mg P L^{-1}	NSDOE	NSDOE	$\times 31 = \mu\text{g at P L}^{-1}$
pH (after storage)		NSDOE, EC	NSDOE, EC	

pH

An attempt was made to measure pH as soon as samples were brought to the laboratory (by the Habitat Ecology Division), but unfortunately the data had to be discarded when subsequent quality control tests indicated a faulty electrode. pH was determined several weeks later by both the Nova Scotia Department of Environment (NSDOE) and Environment Canada (EC), and both data sets are presented in Appendix A. The NSDOE values are reported in the results.

Conductivity

Conductivity was measured with a Radiometer CDM83 conductivity meter at 25°C (EPA #120.1). Units are microSiemens (μS) which are equivalent to micromhos cm^{-1} (the units used for the 1980 data). Theoretical conductivity (TCond) was calculated from the equation:

$$TCond = \sum k_i \times [X_i]$$

where k_i is a constant for each anion and cation (Table 3) and $[X_i]$ is the concentration of the variable X in mg L^{-1} .

Table 3. Values of constants used by NSDOE for calculating the theoretical conductivity from the concentrations of the major anions and cations. Hydrogen ion concentration is calculated from pH.

Ion	k_i
Sodium	2.13
Potassium	1.84
Calcium	2.60
Magnesium	3.82
Alkalinity	0.872
Sulphate	1.54
Chloride	2.14
Hydrogen ion	350

Major Cations

Sodium and potassium were analyzed separately by atomic absorption spectrophotometry using standard methods (APHA #303A and EPA #273.1). Results are reported in mg L^{-1} .

Calcium, magnesium, and aluminum were analyzed simultaneously with an inductively coupled plasma spectrophotometer (ICAP) using a Jarrell Ash Model 975 upgraded to ICAP 61e with Thermo Spec Software Ver. 5.01 (APHA #305A and EPA #200.7). Results are reported in mg L⁻¹.

Major Anions

Alkalinity, reported as mg calcium carbonate L⁻¹, was determined by two separate methods. EC used the Gran titration method (NAQUADAT #10110L) while NSDOE used an automated para nitrophenol procedure. As can be seen in Appendix A, both methods gave similar results. NSDOE data are presented in the results. Alkalinity is commonly defined as that portion of acid neutralization contributed by the carbonate system. However, under low pH conditions, organic and metal ligands often contribute more to acid neutralization than the carbonate components. Therefore, strictly speaking, the results of this analysis should be called acid neutralization capacity (ANC); but alkalinity is used in this report for consistency with earlier studies.

Sulphate (as mg SO₄ L⁻¹) was determined by an automated colorimetric procedure using barium chloride and sulfanazo II after oxidation with ultraviolet irradiation. Results from this procedure compare well with the ion chromatographic results from the interlaboratory studies conducted under the Long-Range Transport of Airborne Pollutants (LRTAP) program.

Chloride, reported as mg L⁻¹, was determined by the standard automated ferric thiocyanate procedure (APHA #407D and EPA #325.2).

Nutrients

Subsamples for the determination of phosphate, nitrate, and silicate were filtered, frozen, and analyzed later using standard colorimetric methods on a Technicon Autoanalyzer II system. Units are mg P, N, and Si L⁻¹. Subsamples for ammonia were analyzed immediately after the samples were split using the indophenol method as adapted by Technicon for the Autoanalyzer II. Units are mg N L⁻¹.

Total phosphorus, reported as mg P L⁻¹, was determined using an automated ascorbic acid procedure after oxidation by ultra-violet irradiation in the presence of acid potassium persulfate. Total nitrogen, reported as mg N L⁻¹, was determined using an automated hydrazine reduction procedure after oxidation by ultra-violet irradiation in the presence of alkali persulfate.

Chlorophyll

Subsamples for chlorophyll analysis (200 mL) were filtered under vacuum through 0.45 µm Millipore filters to which 0.1 mL of saturated MgCO₃ was added. Filters were suspended in 10 mL of 90% acetone, and after 24 h the extracted chlorophyll was determined with a fluorescence spectrophotometer according to the method of Strickland and Parsons (1968). Units are µg L⁻¹.

Dissolved Organic Carbon

Subsamples for dissolved organic carbon analysis were filtered under vacuum. In an automated system, samples were sparged with N₂ in acidic medium to remove CO₂. Organic carbon was then converted to CO₂ in an in-line persulfate-UV digester. The CO₂ was separated by dialysis and its concentration determined colorimetrically by measuring the loss of colour in a borate buffered alkaline phenolphthalein solution. Units are mg L⁻¹.

Colour

Colour was determined visually by comparing the sample to known concentrations of coloured solutions of platinum-cobalt that are sealed in glass disks using the Heilge Aqua Tester®. True colour is determined on the supernatant only (APHA #204A,B and EPA #110.2). Units are true colour units (TCU).

Elements

A 50 mL aliquot was filtered and analyzed for rare earth elements, first-row transition elements, lead, cadmium, and uranium by the Applied geochemistry Laboratory of the Geological Survey of Canada. The sample was loaded onto a Dionex METPAC CC-1 column, eluted in 5 mL of 1N HNO₃, and analyzed by nebulisation ICP-MS. The column contained macroporous iminodiacetate chelating resin similar to Chelex-100. Therefore, this method determines the fraction of dissolved element chelated by this resin. Units are µg L⁻¹.

DATA QUALITY AND ANALYSIS

The data for replicate samples are shown in Table 4. In three-quarters of the cases, the variance of three analyses was very good (less than 5% of the mean). The variables with greater variance were aluminum, ammonia, silicate, chlorophyll, and dissolved organic carbon. Such high variance for these variables could be due to several factors including

dependence on variable biogeochemical processes and concentrations approaching the detection limits of analytical methods.

Data were checked for quality by plotting related variables against each other and searching for outliers. None were observed. All acceptable data collected in 1991 are listed in Appendix A. As discussed in the results, some data sets are probably more reliable than others.

There was good agreement between multiple samples taken from different locations in the same lake. Therefore, for the purpose of this report, an average concentration was calculated for each variable in each lake. Data for each variable measured were then plotted on a horizontal bar graph with concentration across the x-axis (horizontal) and lakes in ascending order along the y-axis (vertical) according to 1991 value. When available, data collected in 1980 were plotted on the same axes for comparison. The 1980 data are listed in Appendix B.

Table 4. Data for the three replicate samples collected in each of four lakes. Units are as given in Table 2 except for ammonia, nitrate, phosphate, and silicate which are μM .

Lake:	Major		Banook		Oathill		First	
Variable	Mean	% S.D.	Mean	% S.D.	Mean	% S.D.	Mean	% S.D.
pH	4.67	0.89	6.8	6.8	6.8	0.15	6.79	0.56
Conductivity	36.6	0.6	359.0	0.6	580.0	0.4	351.7	0.7
Na	2.9	0.0	55.7	1.1	89.9	1.4	51.1	1.8
Ca	0.999	1.605	10.200	0.800	18.867	0.250	14.000	0.583
Mg	0.47	1.74	1.44	0.33	2.89	0.43	1.87	1.16
K	0.3	14.1	1.3	0.0	2.5	0.0	1.9	0.0
Al	0.247	2.863	0.064	40.101	0.050	12.754	0.059	5.562
Cl	4.5	1.8	90.8	0.6	152.0	0.5	82.2	0.7
Sulfate	5.4	1.5	16.4	0.3	24.7	2.7	16.8	2.7
Alkalinity	0.0		9.6	1.3	21.0	0.0	19.3	0.7
Ammonia	0.72	24.78	0.80	33.42	0.79	23.50	0.42	30.82
Nitrate	3.88	1.58	15.96	0.23	45.11	1.53	8.02	0.48
Phosphate	0.05	4.31	0.07	3.36	0.22	2.78	0.16	6.51
Silicate	1.20	5.31	14.01	10.35	1.80	7.49	12.57	2.57
Total N	0.17	2.83	0.36	2.64	0.91	2.25	0.33	2.47
Total P	0.016	0.000	0.010	4.562	0.005	0.000	0.01	0.00
Chlorophyll	0.34	50.21	1.54	4.12	16.11	5.20	7.31	1.31
Colour	17.5	0.0	10.0	0.0	15.8	7.4	10.00	0.00
DOC	3.4	2.4	1.8	5.3	3.0	30.0	2.1	3.9

Trophic status index (TSI) was estimated from chlorophyll data using the equations developed by Carlson (1977). Statistical analyses were performed using Statgraphics Version 5.0 (STCS, Inc.) on an IBM-compatible PC.

RESULTS AND DISCUSSION

Before the data are presented, it must be emphasized that they should be interpreted with caution. The water quality variables measured can display strong spatial and temporal variability. The effects of spatial variability have been reduced in this study by collecting samples at the time of the spring turnover, when lakes are well-mixed, and by collecting multiple samples in large lakes; but they have not been completely eliminated. Temporal variability occurs over the scales of hours, days, and months. Major wind and precipitation events have a pronounced effect on lake water chemistry. These effects have been reduced but not completely eliminated by collecting all samples on the same day. While samples collected by helicopter were gathered within a 5-h period, 12 h elapsed between the collection of the first and last samples collected by boat. In addition, as is shown in the replicate sample data (Table 4), some variables are more difficult to measure precisely than others. For these reasons, one must be careful in comparing the average concentrations of chemical variables in individual lakes, either against those of other lakes in 1991 or against the 1980 data. They are based on a limited number of samples, and some of the apparent differences may not be statistically significant. It must be kept in mind that the purpose of this project was to provide a synoptic overview of the water quality of Metro Area lakes on a single date and to seek general trends of change over decadal time scales. Any indications of serious environmental concerns coming out of this project will require further investigation using more detailed sampling regimes to provide the precision necessary to answer the specific questions being asked.

TEMPERATURE

Water temperature ranged from 4.8 to 10.0°C (Fig. 2). The higher temperatures were generally found in the shallower, smaller lakes that lost their ice cover earlier. It is interesting to note that the temperatures were significantly higher (Table 5), by approximately 2°C, than observed during the 1980 sampling, even though in both years samples were collected the day after ice left Fraser Lake. It appears that in 1991 most of the lakes lost their ice earlier relative to Fraser Lake and had more chance to warm up. Warmer temperature could mean greater biological activity which complicates the comparison of biologically sensitive variables (i.e. nutrients) between years.

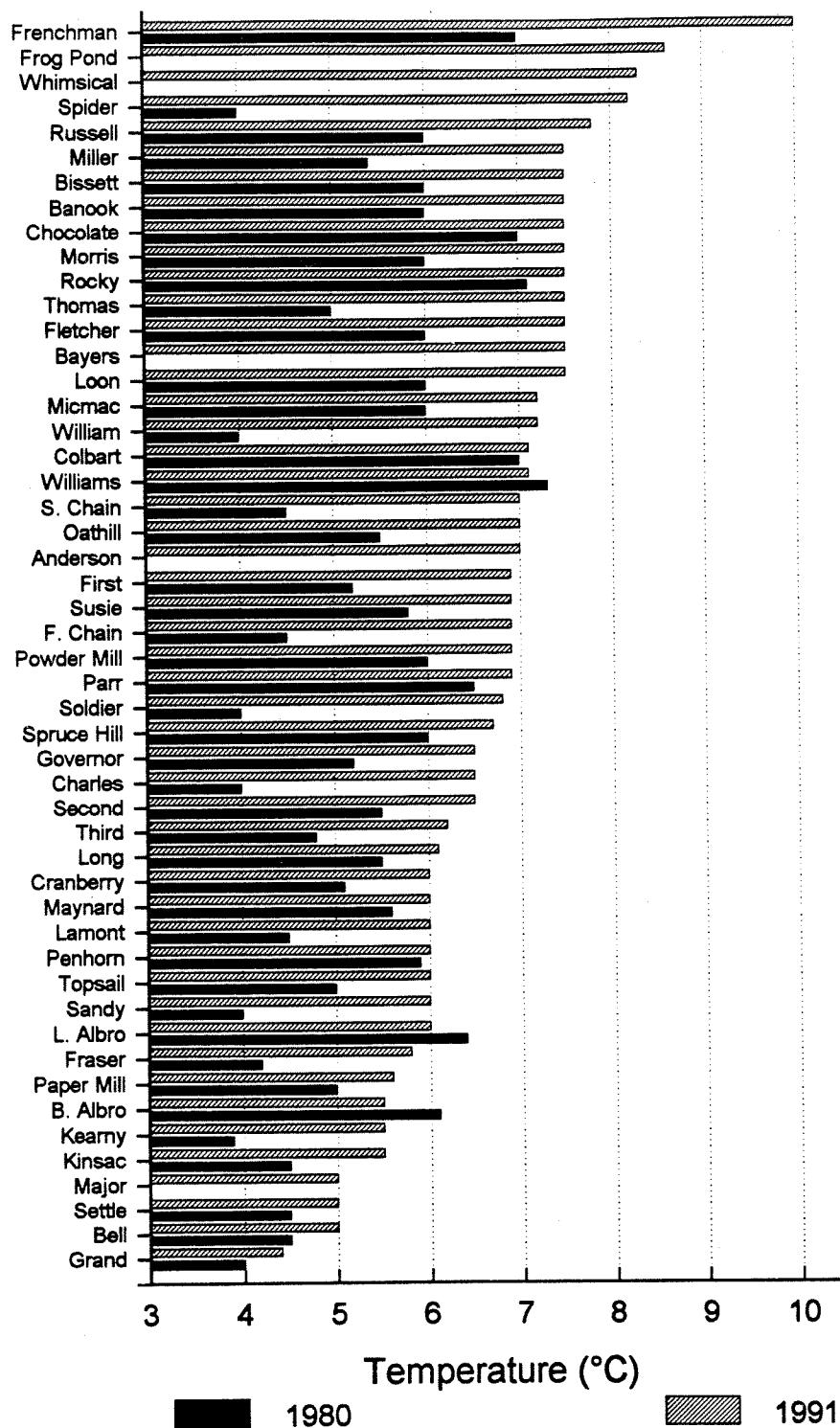


Figure 2. Surface water temperature (°C) for lakes sampled in 1980 and 1991.

Table 5. Results of t-test comparison of 1980 and 1991 data. The paired test results indicate if the data from individual lakes are different, and the independent test results indicate whether the means for the two data sets are different. Where differences are significant the value for P is in bold type face.

Variable	Paired		Independent	
	t	P	t	P
Temperature	-8.98	<0.001	-6.58	<0.001
pH	1.88	0.07	0.42	0.67
Conductivity	-7.77	<0.001	-4.13	<0.001
Na	-6.28	<0.001	-3.20	0.002
Ca	-4.06	<0.001	-1.05	0.30
Mg	-2.29	0.026	-0.82	0.41
K	-4.49	<0.001	-0.92	0.36
Cl	-6.02	<0.001	-2.88	0.005
SO ₄ ²⁻	-1.55	0.13	-0.04	0.96
Alkalinity	-3.02	0.004	-0.94	0.35
NH ₃	3.89	<0.001	3.46	<0.001
NO ₃ ⁻	-5.22	<0.001	3.45	<0.001
PO ₄ ³⁻	0.73	0.47	0.72	0.47
Silicate	3.36	0.002	3.43	<0.001
Total N	-2.27	0.30	-1.04	0.30
Total P	-2.82	0.007	-2.88	0.005

SECCHI DEPTH

The Secchi depth is a composite measure of the transparency (or turbidity) of the water. The deeper the Secchi disk can be seen, the clearer the water (or the less turbid). Water transparency is reduced by the presence of dissolved organic matter (colour) and suspended particulate matter, both inorganic (silt) and organic (plankton, detritus, etc.).

The values observed ranged from less than 1 m to over 7 m (Fig. 3). The Secchi depth could not be determined in five lakes (Little Albro, Rocky, Bayers, Paper Mill, Frenchman) because the disk hit bottom before it went out of sight.

Since Secchi depth was not measured in 1980, it is not possible to detect possible long term trends in water transparency. As mentioned above, it was difficult to get accurate readings from the helicopter so low confidence should be placed on the 1991 data set except for those lakes sampled by boat. Secchi depth can change markedly over just a few days due to meteorological events, especially in lakes having watersheds with exposed soils.

A much more dependable data base on Secchi depth was collected between April and November 1991 for selected lakes in and near Dartmouth (Hellebrand and Dalziel 1992) and the results were compared to similar readings in 1976 and 1977 (Gordon 1977;

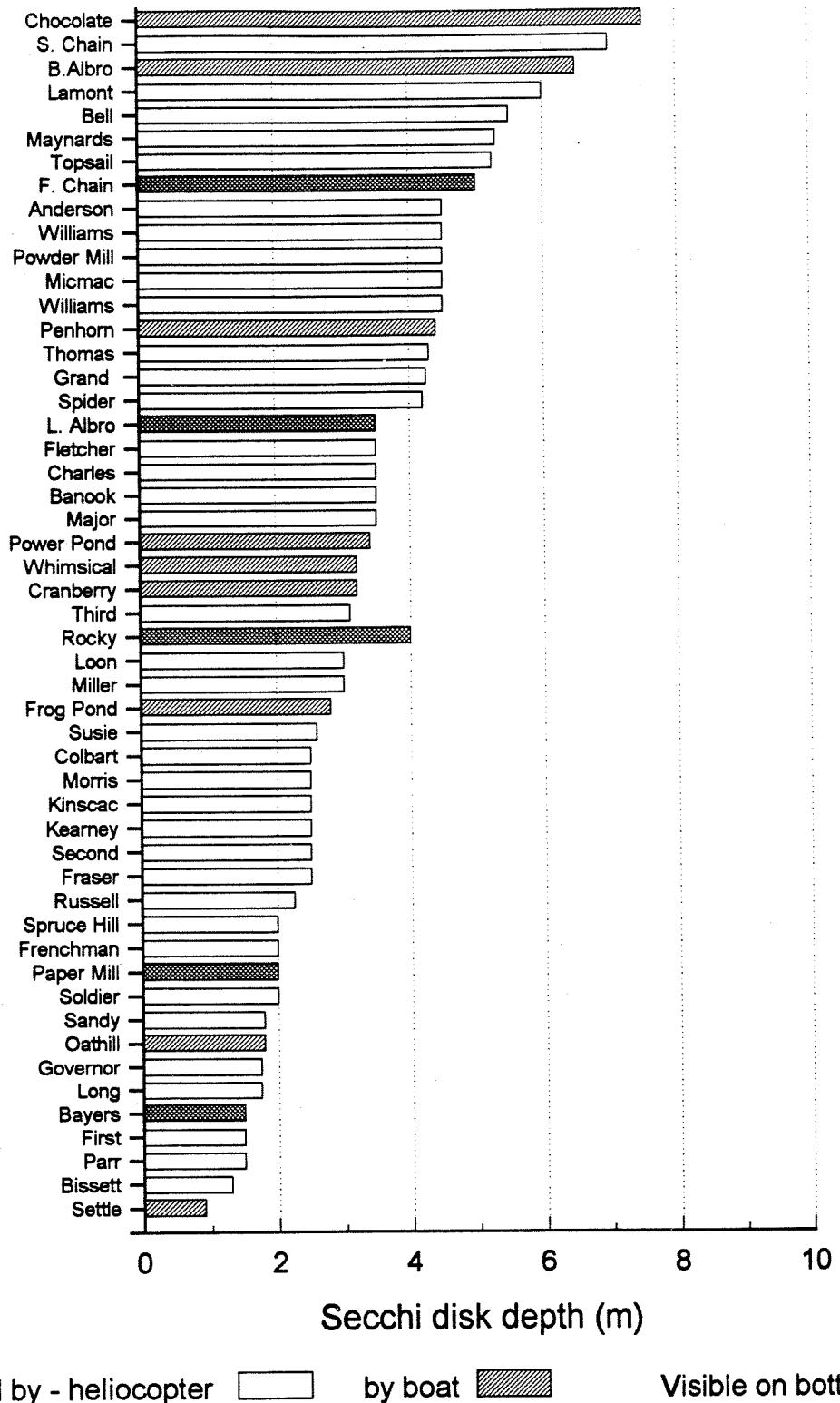


Figure 3. Secchi disk depths (m) for 1991.

Gordon 1978). With the exception of just two lakes (Lake Charles and Bell Lake), the mean Secchi depth increased during this period, that is transparency improved. The major source of turbidity in Metro Area lakes is suspended sediment. The improved transparency conditions in most of Dartmouth Lakes over the past 15 yr are probably due to a number of factors which include stabilization of watersheds after development, less current development activity, and better erosion control practices during development.

pH

pH is a measure of the hydrogen ion concentration in water. A pH reading of 7 represents neutral conditions, while lower values indicate acid conditions and higher ones indicate alkaline conditions. Because of their geological setting, Metro Area lakes are naturally acidic; and few probably had pH values above 6 a century ago. pH is determined by the chemistry of all dissolved ions present but is controlled largely by the carbonate system.

Values of pH ranged from just under 4.5 (First and Second Chain Lakes) to just over 7 (Penhorn Lake) (Fig 4). By and large, the lowest values are found in lakes with watersheds that have been subjected to little alteration (i.e. most of the natural vegetation cover remains intact) while lakes in developed watersheds tend to have the highest values. However, low pH values can also be found in lakes having disturbed watersheds underlain by acid-producing slates (e.g. First and Second Chain, Chocolate, etc.).

Human activity can both increase and decrease the pH of lakes. Decreases brought about by acid precipitation have been well documented in Halifax County lakes (Watt et al. 1979). Recent monitoring data suggest that international controls on sulphate emissions are having an effect and that some Nova Scotian lakes are beginning to show signs of recovery (Clair et al. 1992). Most of the Metro Area lakes with a pH of less than approximately 6 have probably been influenced by acid precipitation or have had acidic slates exposed during development of their watersheds. Increases in pH are brought about by removing naturally occurring acidic habitats, such as acid bogs, and from alkaline contaminants such as carbonate. Carbonate is the major component of agricultural limestone (calcium carbonate) which is used extensively on lawns and gardens in the Metro Area. Hence, the highest pH values are found in lakes with well-developed watersheds.

The overall range of pH values was practically identical in 1980 and 1991 (Fig. 4). There is no significant difference between the values for the 2 yr (Table 5). However, it is possible that changes did take place that could not be detected in this study because of the unstable nature of pH and the difficulties in measuring it accurately. Long-term trends in pH are better resolved by monitoring programs involving long data sequences which are expressly designed for their detection, such as the one reported by Clair et al. (1992). Most Metro Area lakes do not suffer from acidification problems because of the buffering capacity offered by other dissolved contaminants. However, the sporadic disturbances of

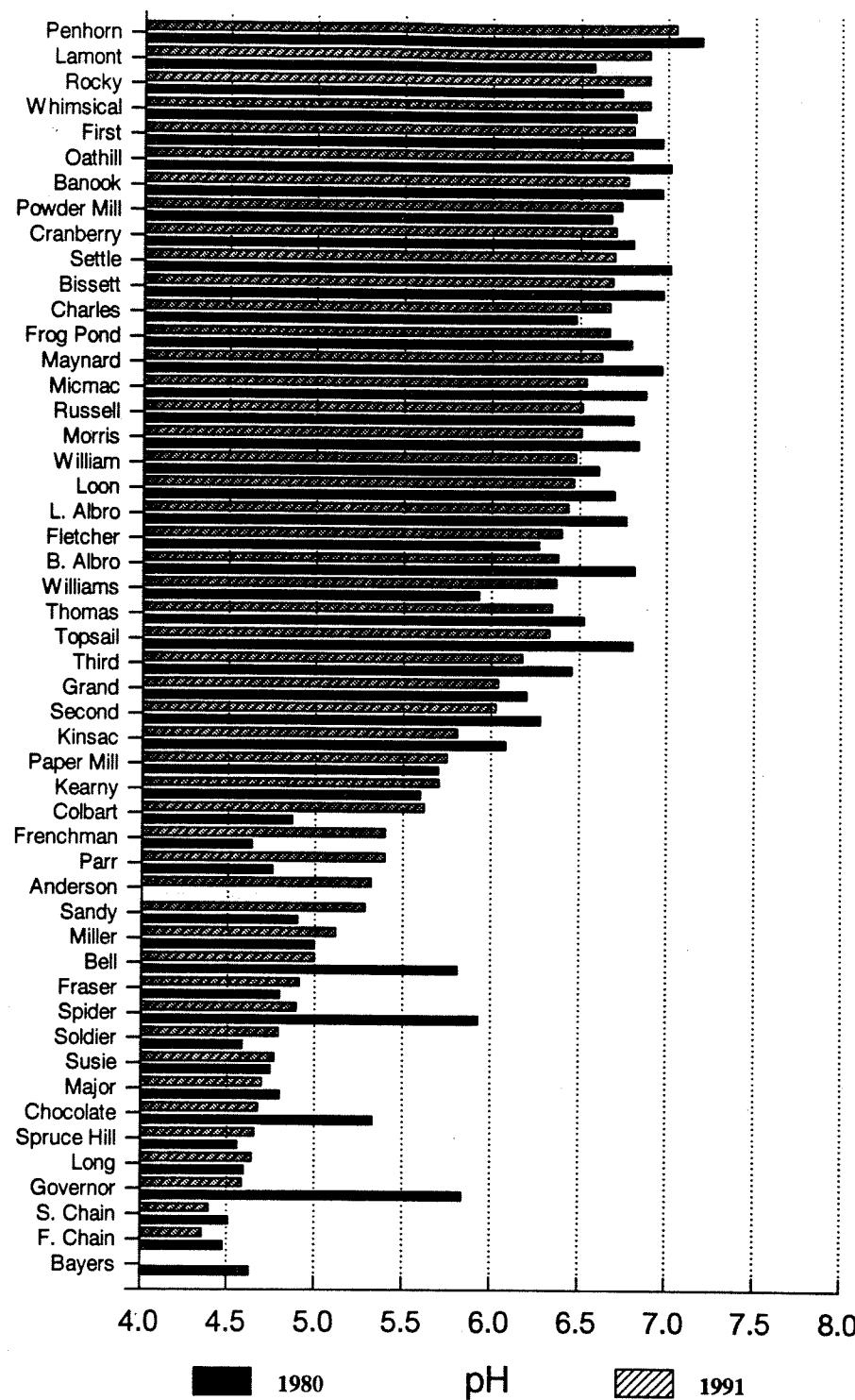


Figure 4. pH measured in water samples from lakes in 1980 and 1991.

acid-producing bedrock during site development has influenced local water quality in at least one watershed (e.g. Bayers Lake) by reducing pH and elevating aluminum concentrations. Although lakes in this watershed have natural background water quality reflective of this type of bedrock geology, remedial measures have been implemented to reduce influences from development.

CONDUCTIVITY

Conductivity is a measure of total dissolved ions in a water sample. All dissolved ions contribute, but most conductivity measured is due to the most abundant cations and anions. Conductivity is a relatively robust variable which is easily measured and not greatly influenced by highly variable biogeochemical processes. Therefore, a high degree of confidence can be placed on this data set.

A wide range of conductivity readings is found in Metro Area lakes (Fig. 5). The lowest readings, on the order of 30 μS or less, reflect natural levels of conductivity which are caused by dissolved ions derived from the weathering of rock and soil and wind-blown sea salt. Not surprisingly, these low levels are found only in lakes with relatively undisturbed watersheds (Fraser, Lamont, Topsail, Major, Spruce Hill, and Spider Lakes). The rest of the lakes have levels that have been increased by human activity, some to a considerable degree. As expected, lakes with the highest readings all have well-developed watersheds.

The elevated conductivity readings reflect increased concentrations of dissolved ions which are derived from the use of chemicals such as road salt, lime, and fertilizers in watershed areas. These chemicals are water soluble and enter the lakes in storm water runoff. Air pollutants added to lakes by precipitation can also elevate conductivity readings.

The most striking feature of this data set is that conductivity has approximately doubled between 1980 and 1991 in every lake sampled, even in those lakes with the lowest readings (Fig. 5 and Table 5).

Theoretical conductivity, calculated from the concentration of individual cations and anions measured by different analytical methods, is in excellent agreement with measured values ($\text{slope}=1.103$, $r^2=0.998$). In 1980, the correlation was also strong ($r^2=0.989$), but there was a greater difference between the theoretical and measured values ($\text{slope}=1.317$).

MAJOR CATIONS

Cations are those ions that carry a positive charge. Those measured in this study are sodium, calcium, magnesium, potassium, and aluminum.

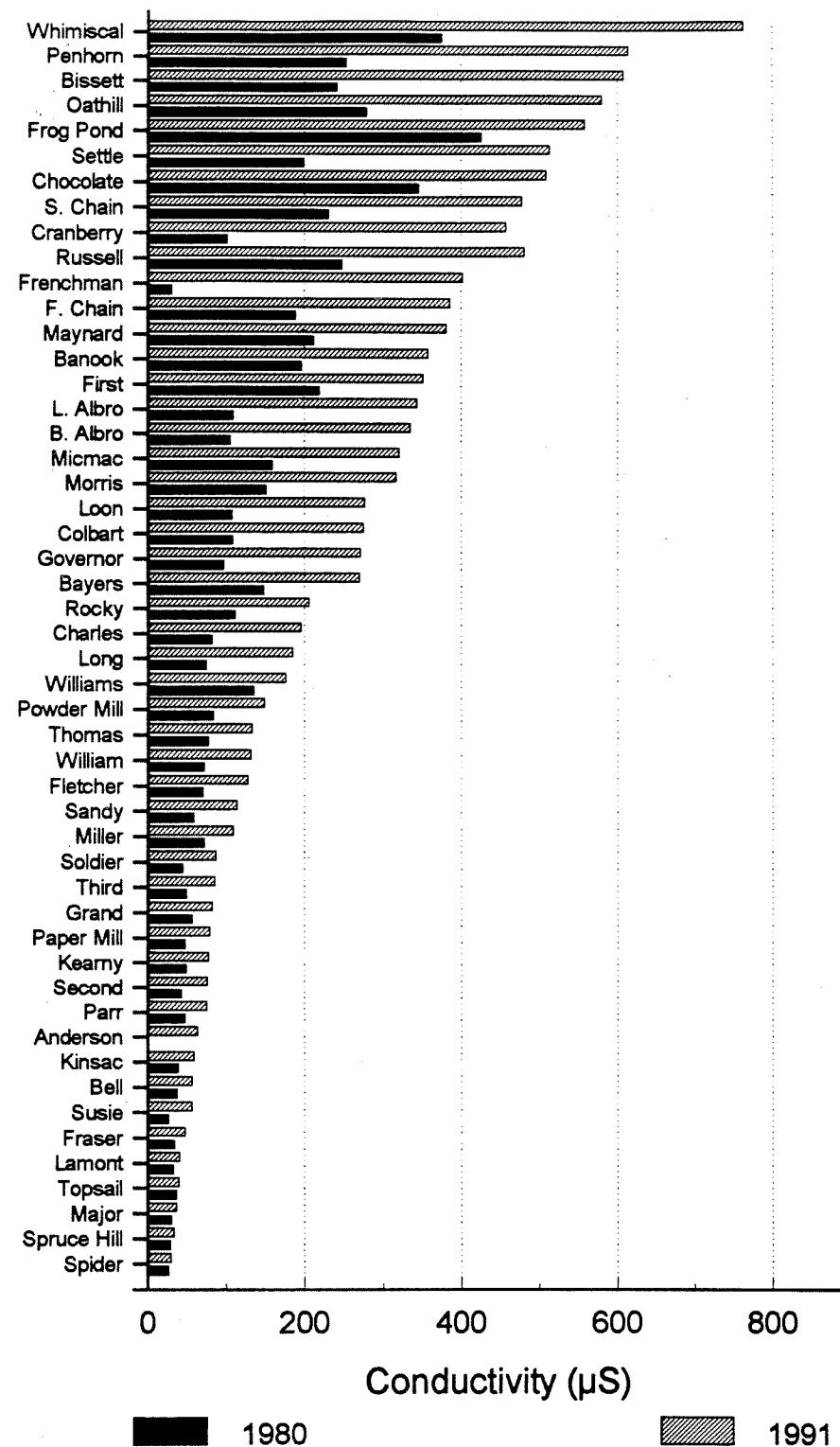


Figure 5. Conductivity (μS) measured in water samples from lakes in 1980 and 1991.

The concentrations of sodium, calcium, magnesium, and potassium observed are plotted in Figures 6 to 9. As with conductivity, the lowest values observed reflect natural levels derived from the weathering of rock and soil and the atmospheric input of sea salts. Those lakes with the lowest conductivity readings also have the lowest concentrations of sodium, calcium, magnesium and potassium. However, most of the lakes sampled appear to have concentrations of these four cations that are substantially above background levels. These higher concentrations are due primarily to contributions from road salt, agricultural limestone and fertilizers associated with urban development. The most abundant cation is sodium (Fig. 6), followed by calcium (Fig 7). In comparison, concentrations of both magnesium and potassium are much lower but similar (Fig. 8 and 9). It is interesting to note that the relative ranking of the lakes is similar for each of these four cations indicating that their ratios are quite constant. The highest concentrations tend to occur in lakes with the highest pH (Fig. 4).

In comparing 1991 with 1980, it is clear that there has been a substantial increase in sodium concentrations, on average almost by a factor of two (Fig. 6 and Table 5). There also was a measurable increase of calcium in most of the lakes sampled (Fig. 7), but this difference was not consistent (Table 5). There was a similar trend in the potassium concentrations (Fig. 9 and Table 5), but there was no detectable trend in magnesium concentrations (Fig. 8 and Table 5).

Aluminum in lake water is derived primarily by leaching from rock and soil. Concentrations are lower than the other major cations measured in most of the lakes sampled (Fig. 10). In contrast to sodium, calcium, magnesium, and potassium, the highest concentrations of aluminum tend to occur in those lakes with the lowest pH ($r^2=0.849$) (e.g. Bayers, First and Second Chain, Chocolate, Governor, and Long) (Fig. 4 and Appendix C).

MAJOR ANIONS

Anions are those ions which carry a negative charge. The major anions measured in this study were chloride, sulphate, and those that contribute to alkalinity (e.g. carbonate, bicarbonate). Under natural conditions, the concentrations of anions in Metro Area lakes are low and, like both conductivity and major cations, the major sources are the weathering of rock and soil and the input of sea salt by precipitation.

A wide range of chloride, sulphate, and alkalinity concentrations are found in Metro Area lakes (Fig. 11 to 13). The lakes with lowest concentrations are also those with the lowest values for conductivity and major cations. Most of the lakes sampled have concentrations that appear to exceed background levels. The only exception to this is alkalinity because approximately one-third of the lakes sampled still have values at or below the level of detection (Fig. 13). Chloride is by far the most abundant anion. As expected, there is very close relationship between alkalinity and pH. Lakes with high alkalinity (i.e. well-

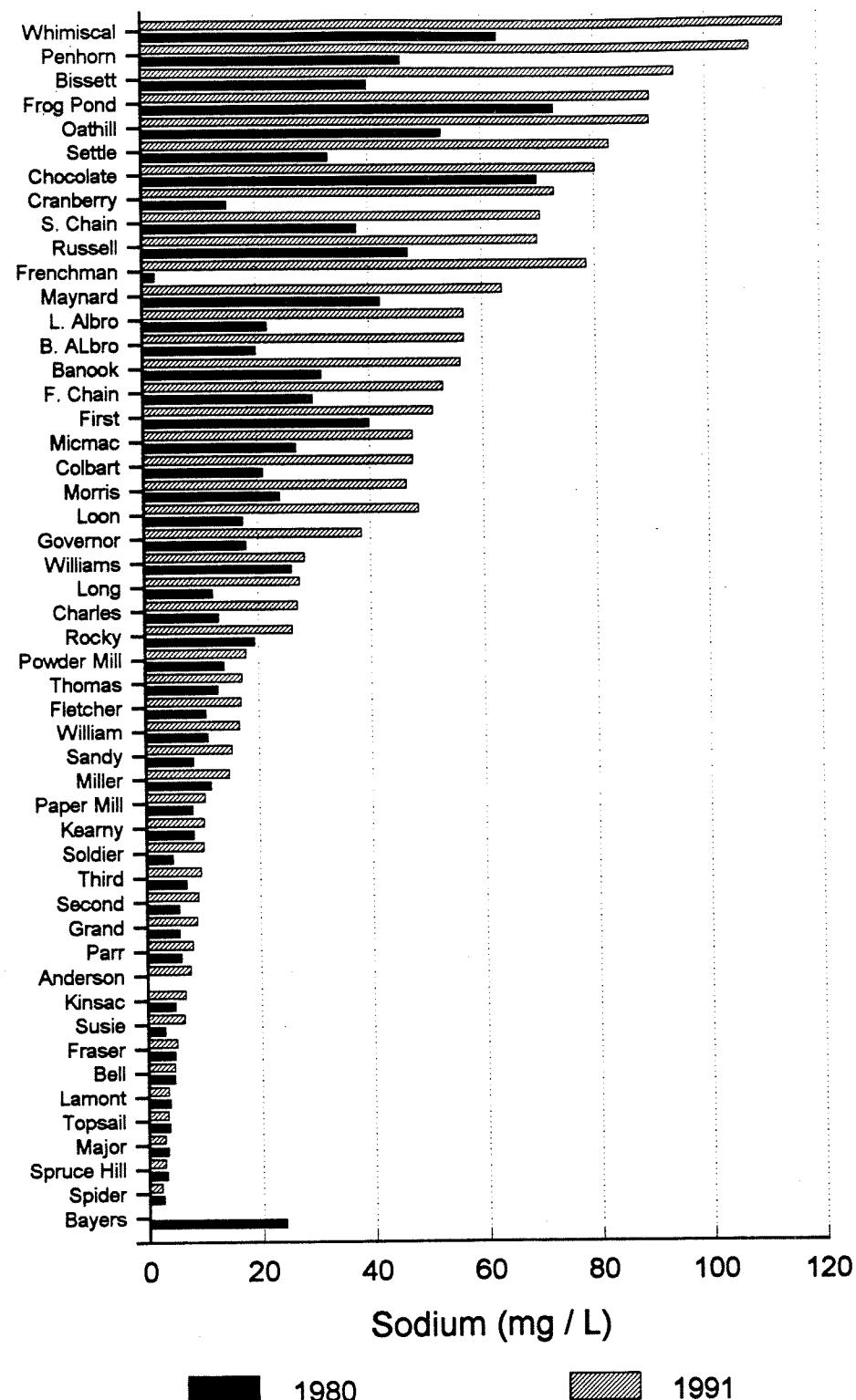


Figure 6. Sodium (Na) concentrations in lakes sampled in 1980 and 1991.

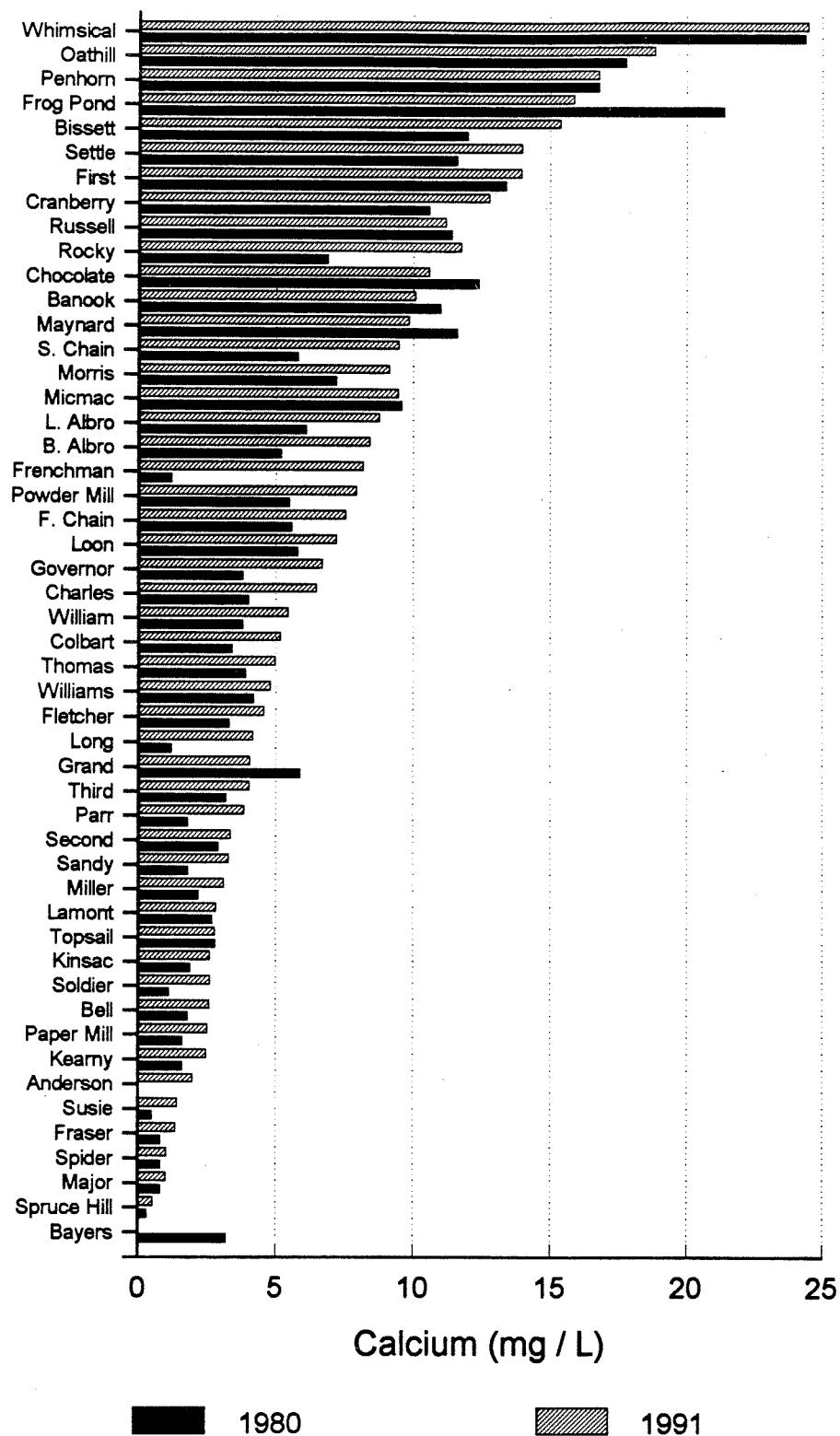


Figure 7. Calcium (Ca) concentrations in lakes sampled in 1980 and 1991.

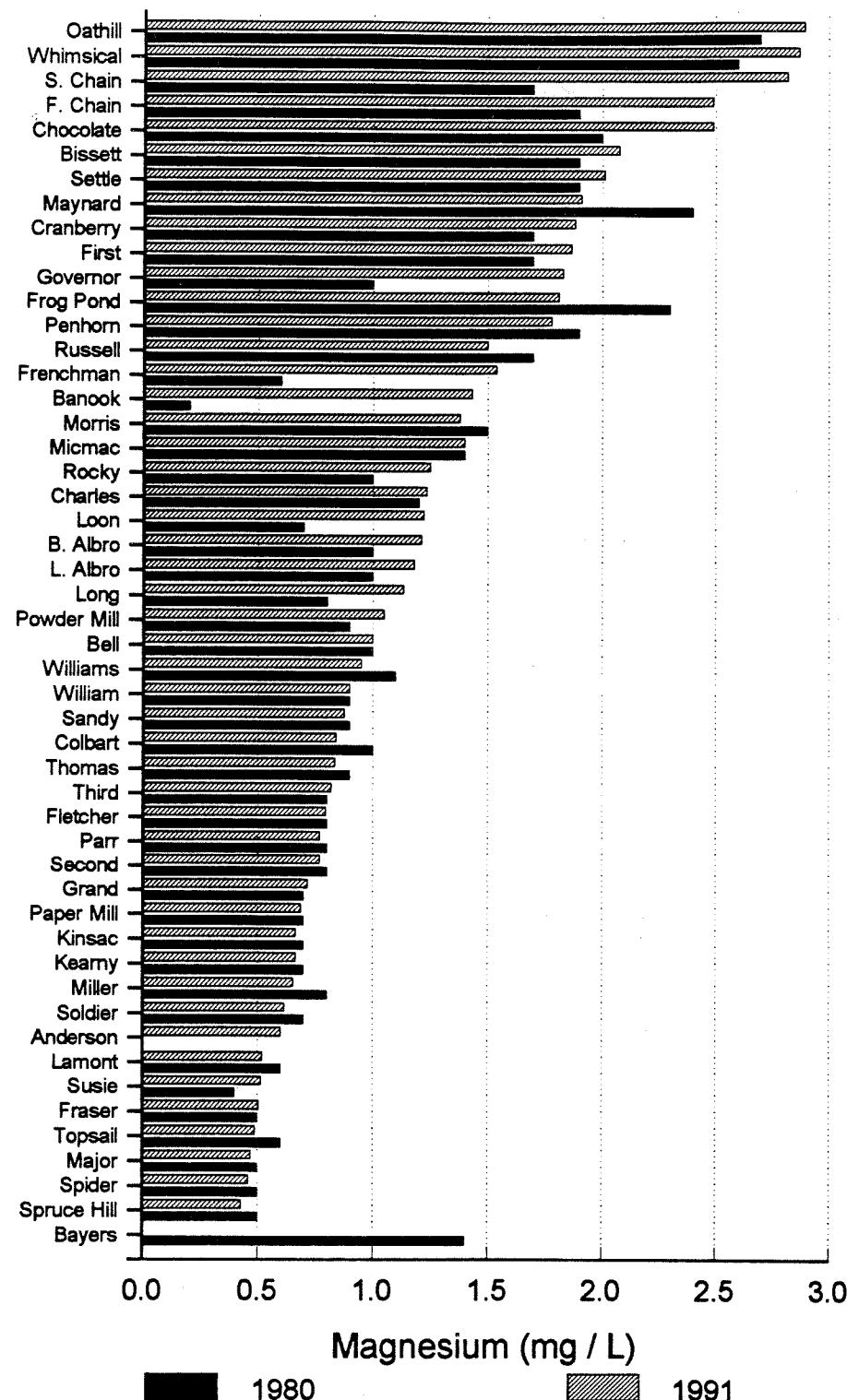


Figure 8. Magnesium (Mg) concentrations in lakes sampled in 1980 and 1991.

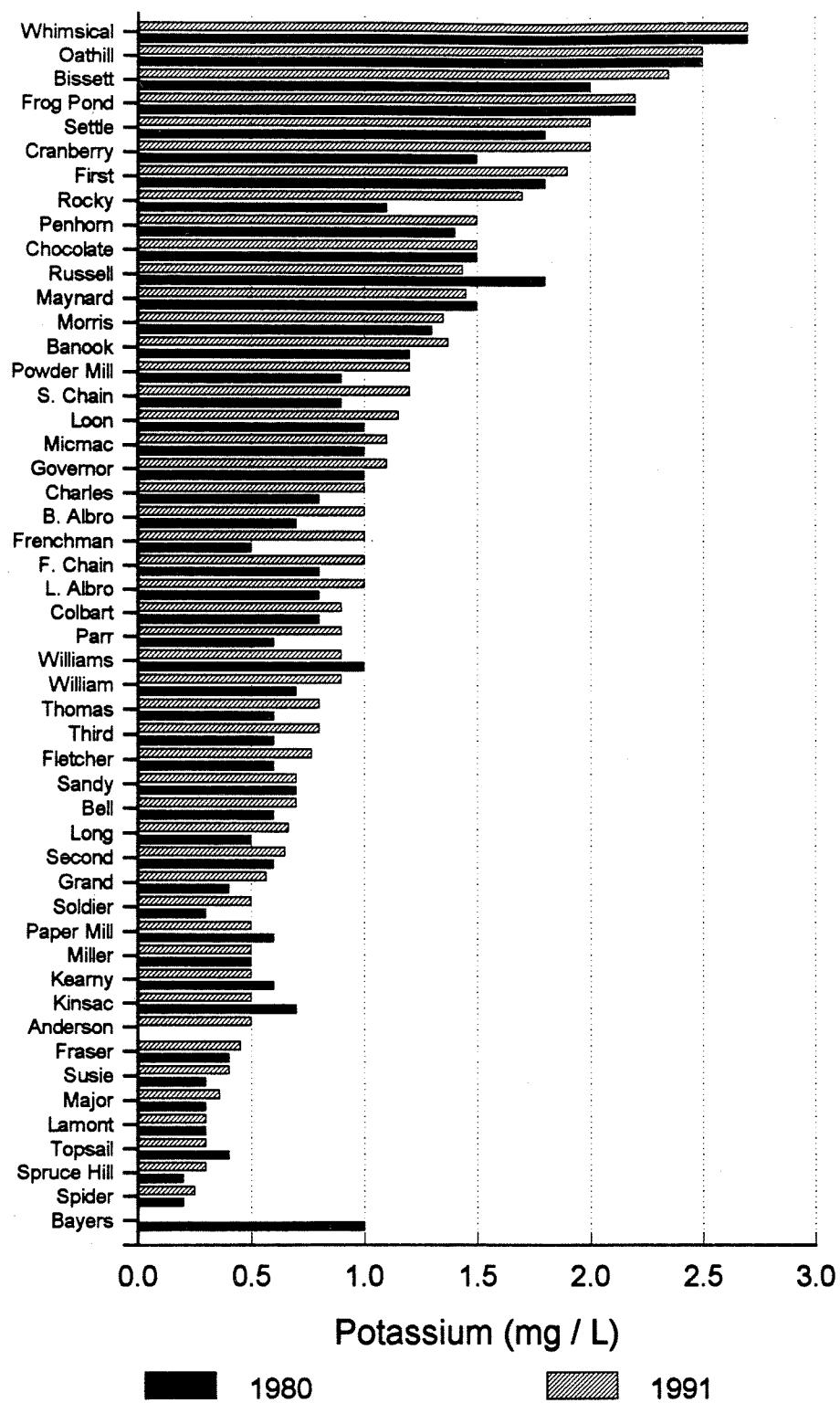


Figure 9. Potassium (K) concentrations in lakes sampled in 1980 and 1991.

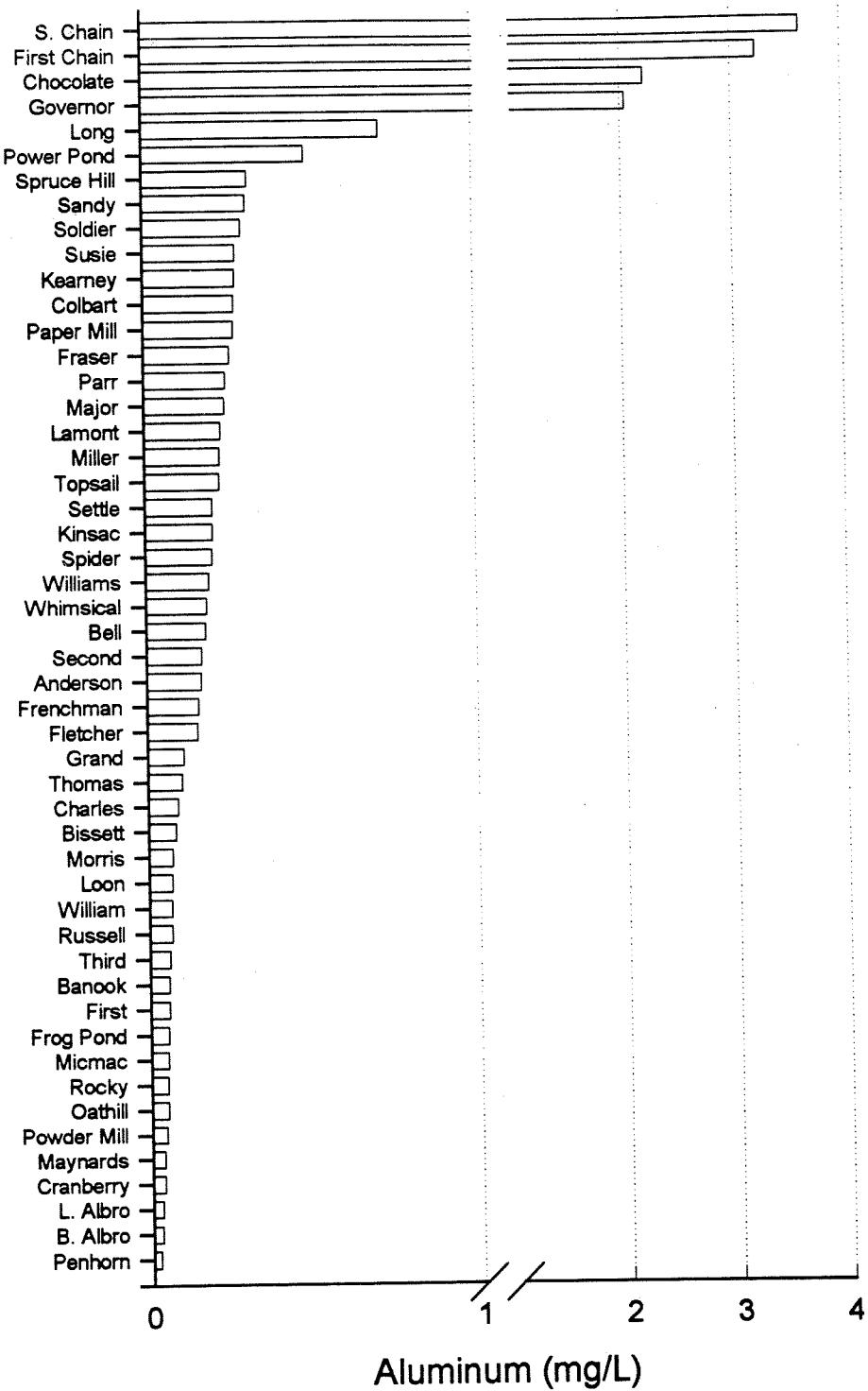


Figure 10. Aluminum (Al) concentrations in lakes sampled in 1991.

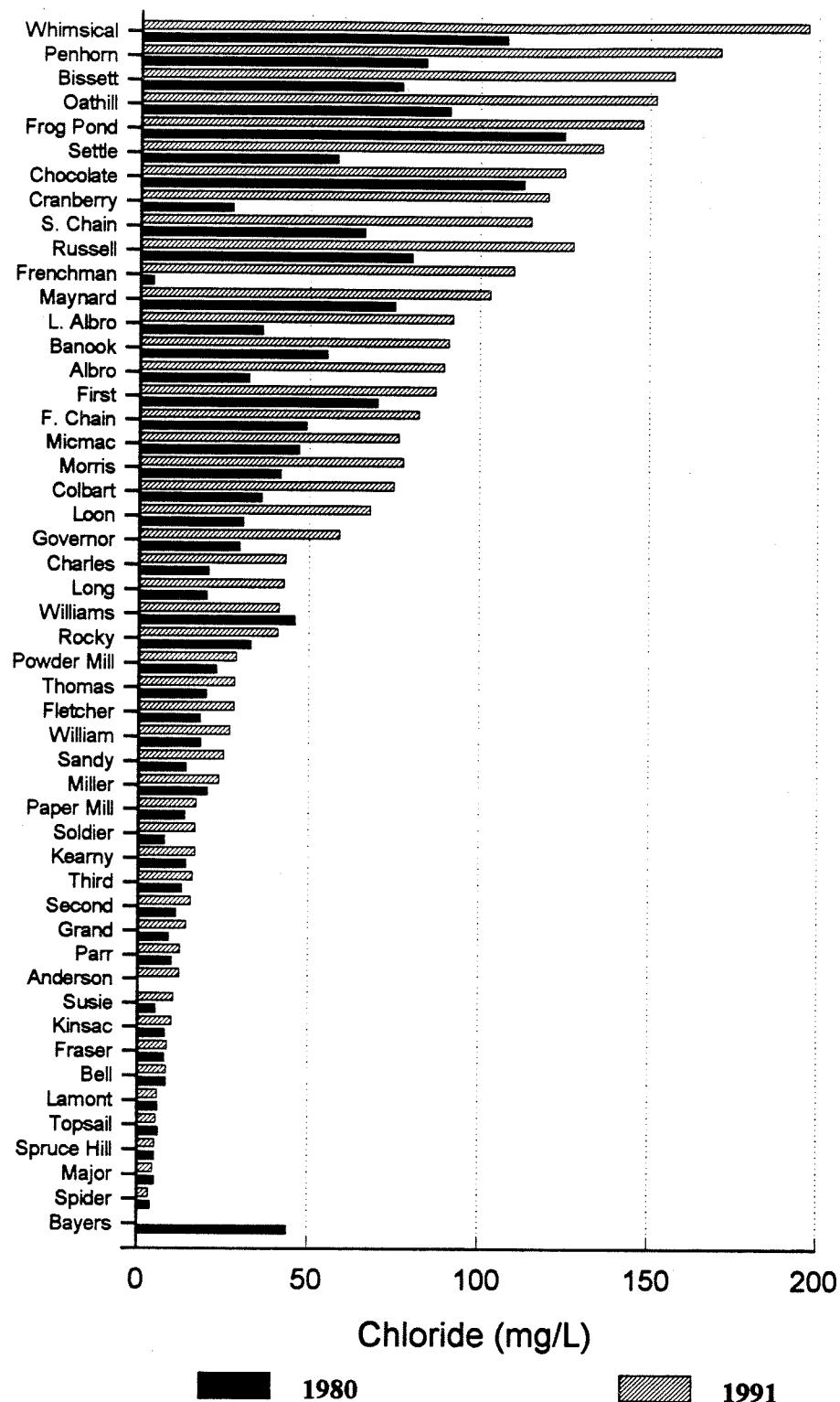


Figure 11. Chloride (Cl) concentrations in lakes sampled in 1980 and 1991.

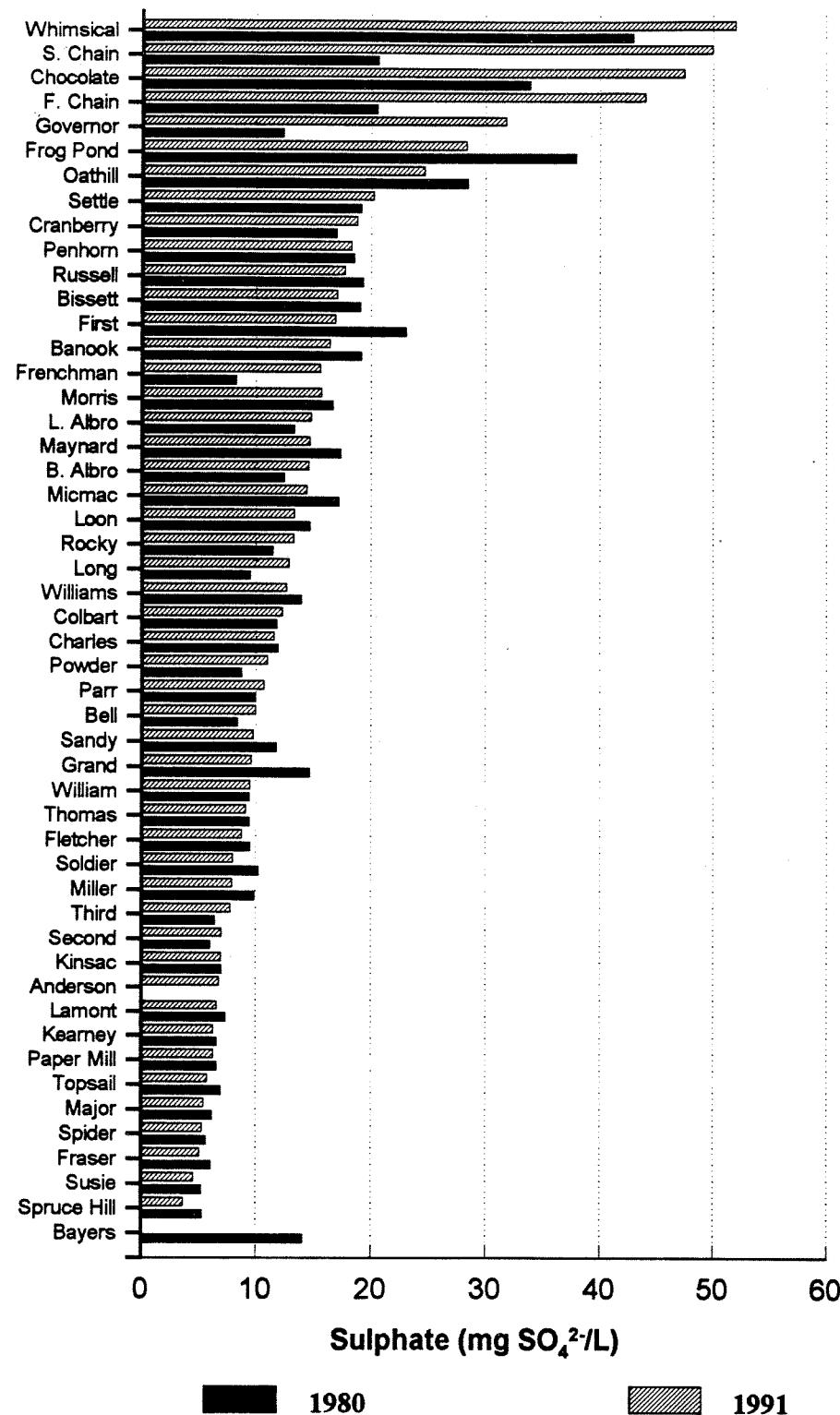


Figure 12. Sulphate (SO₄²⁻) concentrations in lakes sampled in 1980 and 1991.

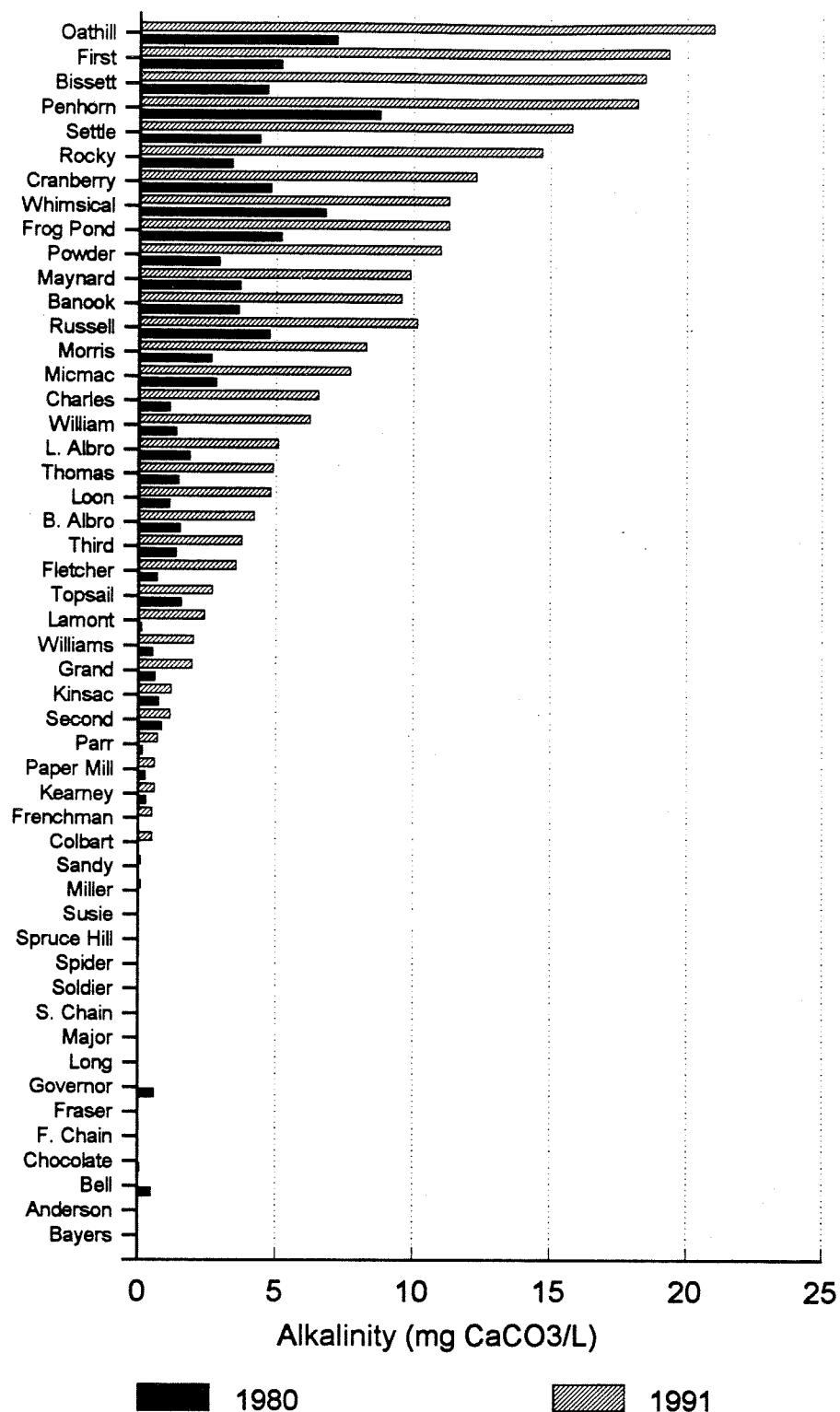


Figure 13. Alkalinity measured in lakes sampled in 1980 and 1991.

buffered) have high pH while lakes with no alkalinity (i.e. poorly-buffered) have low pH (Fig. 4 and 13).

Comparing 1980 and 1991, there is a very pronounced increase in the concentrations of chloride in most of the lakes, especially those in well-developed watersheds (Fig. 11 and Table 5). Sulphate concentrations (Fig. 12 and Table 5) did not change significantly overall during this period. Alkalinity values changed significantly in many of the lakes during the 11-yr period (Fig. 13 and Table 5).

Without any doubt, there has been a definite increase in conductivity in most if not all Metro Area lakes during the past 11 yr (Fig. 5). This same change has also been documented by the Soil and Water Conservation Society of Metro Halifax (1991). The major ions causing this increase (in decreasing order of influence) are sodium, chloride, calcium, and sulphate (Fig. 6, 11, 7, and 12 respectively). Contributions from increases in magnesium, potassium, and alkalinity are minor and probably not significant. If these increases were the result of local natural processes of rock weathering and sea salt input, they would tend to be consistent in all lakes (but with some variation related to watershed size and distance from the coast). Instead, increases were greatest in those lakes having well-developed watersheds and least in those lakes having watersheds with a large amount of terrain still in a natural state. These increases are clearly due to the increased use of sodium, chloride, and calcium in the developed parts of the Metro Area. The prime source is road salt (sodium chloride) which is used for de-icing purposes during the winter months. Another likely source is calcium chloride which is used for dust control on unpaved streets. Agricultural limestone (calcium carbonate) is also used extensively on lawns and gardens to enhance plant growth. Increasing sulphate concentrations in some lakes have also contributed to the increase in conductivity. The prime source of sulphate is from development which exposes acid-producing slate bedrock containing high concentrations of sulphides.

This increase in conductivity does not constitute a serious environmental impact at this time but does warrant concern and continued investigation. Sodium, chloride, calcium, and sulphate are all naturally occurring substances that are not toxic to life at the present concentrations found in Metro Area lakes. The concern is that dissolved ions do influence the density of water and if concentrations do get high enough they could interfere with the normal spring and fall mixing events that are essential to maintain lake water quality. This phenomenon occurred in Irondequoit Bay near Rochester, NY, during the winter of 1969/70 (Bubeck et al. 1971). No corrective action seems necessary at this time, but it obviously would be prudent to take preventative action by limiting the use of the responsible chemicals as much as is practical.

Lakes Major, Topsail, and Lamont are part of the City of Dartmouth water supply. Water is pumped from Lake Major to Topsail and Lamont Lakes after being treated with lime to increase the pH to 6.5-7.2. This treatment is undertaken to combat slime build-up on

pipeline walls caused by iron and manganese concentrations, and the effects are apparent in the pH and alkalinity values for these lakes (Fig. 4 and 13).

NUTRIENTS

Nutrients are compounds of elements such as nitrogen, phosphorous, and silicon that are required for the growth of aquatic plants. Under natural conditions, their concentrations are very low (less than 1 mg L⁻¹) so that they contribute very little to conductivity readings. Natural sources include weathering of rock and soil, decay of organic matter, and atmospheric input. There are numerous anthropogenic sources which include sewage and fertilizers. Four specific inorganic nutrients were measured in this study: ammonia, nitrate, phosphate, and silicate. In addition, total nitrogen and phosphorus, which include organic as well as inorganic forms, were also measured.

Ammonia concentrations are low (Fig. 14). There was no obvious correlation between concentration and degree of lake watershed development. Nitrate concentrations are substantially higher (Fig. 15). Generally speaking, the highest values are found in lakes with well-developed watersheds. Phosphate concentrations are very low (Fig. 16), and most are close to the limits of detection. Again, highest values are found in lakes with well-developed watersheds. There was no correlation with nitrate ($r^2=0.001$) but a good correlation with chlorophyll ($r^2=0.86$). Silicate (Fig. 17) concentrations were in the same range as nitrate (Fig. 14), and the highest values tended to occur in more-developed watersheds.

Total nitrogen and total phosphorous are plotted in Figures 18 and 19. On average, approximately one-half of the total nitrogen is nitrate while approximately one-quarter of the total phosphorous is phosphate. Surprisingly, there was a poor correlation ($r=-0.48$, $n=91$) between total phosphorous and chlorophyll, which suggests a problem with sample splitting or the analytical method for either chlorophyll or total phosphorus. Universally there is a strong positive correlation between these two variables (Vollenweider and Kerekes 1981).

Ammonia concentrations measured in 1991 were substantially lower in most cases than those detected in 1980 (Fig. 14 and Table 5). While these decreases may be real in some instances, they probably reflect improved handling procedures in 1991. Ammonia is a very labile compound which must be measured immediately before it undergoes chemical and/or biological transformations. In 1980, samples were stored for 2 d before analysis, while in 1991 they were analyzed immediately upon return to the laboratory.

Nitrate concentrations measured in 1991, on the other hand, were substantially higher in most instances than those detected in 1980 (Fig. 15 and Table 5), even in the lower concentration range. These results suggest a general enrichment in nitrate in Metro Area lakes over the past 11 yr. While this is certainly possible, more-detailed studies should be

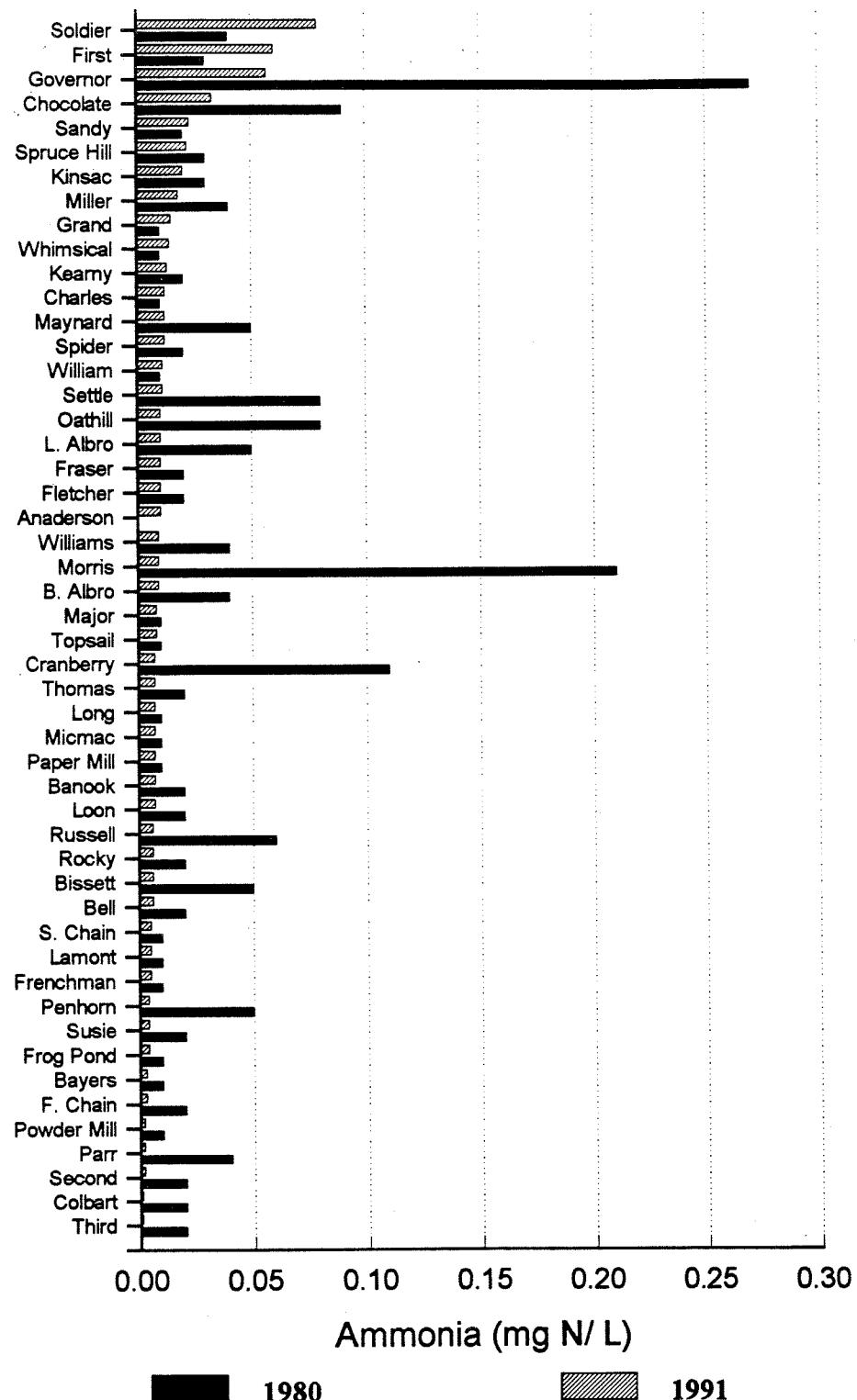


Figure 14. Ammonia (NH_4^+) concentrations in lakes sampled in 1980 and 1991.

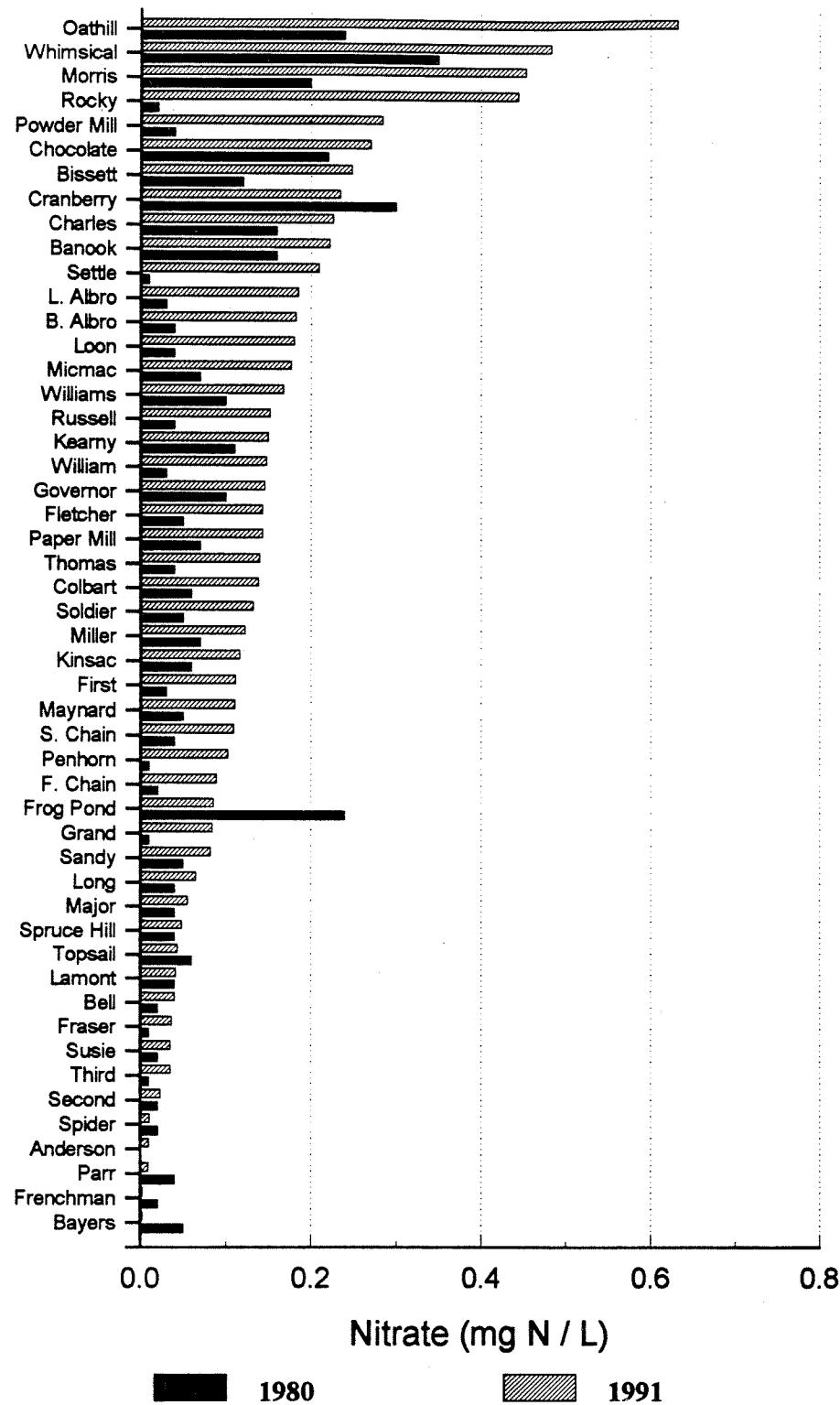


Figure 15. Nitrate (NO_3^-) concentrations in lakes sampled in 1980 and 1991.

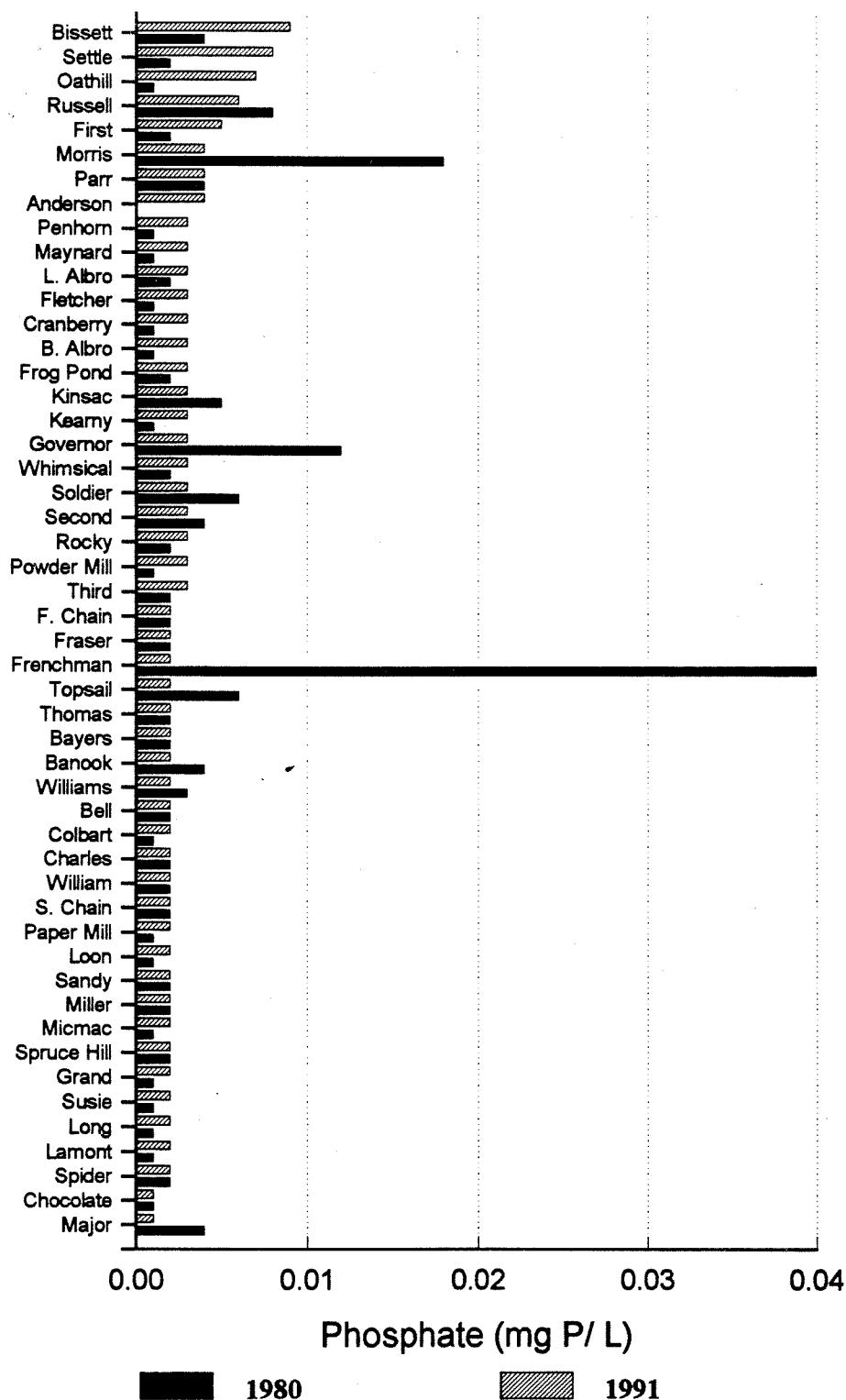


Figure 16. Phosphate (PO_4^{3-}) concentrations in lakes sampled in 1980 and 1991.

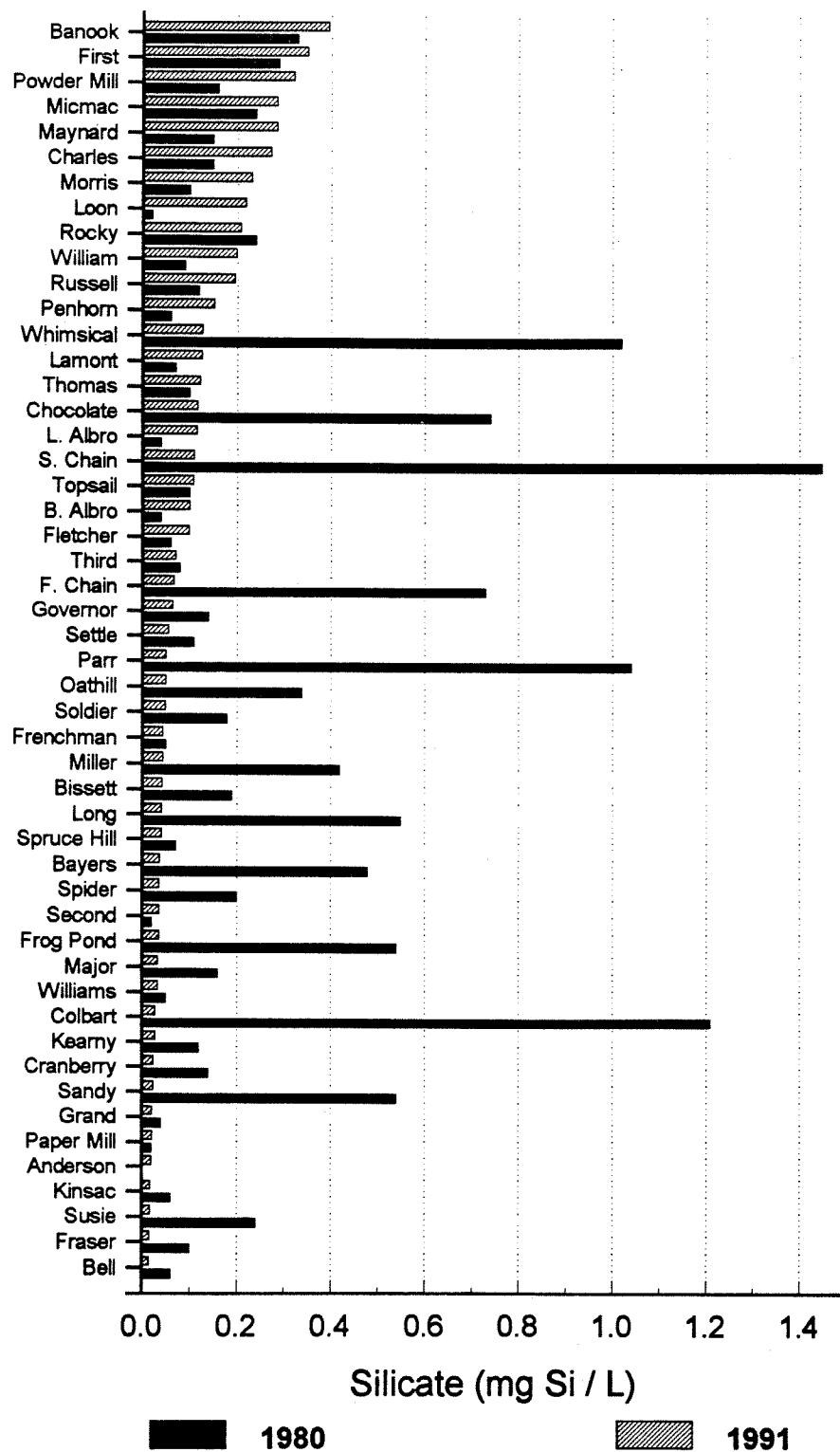


Figure 17. Silicate (Si) concentrations in lakes sampled in 1980 and 1991.

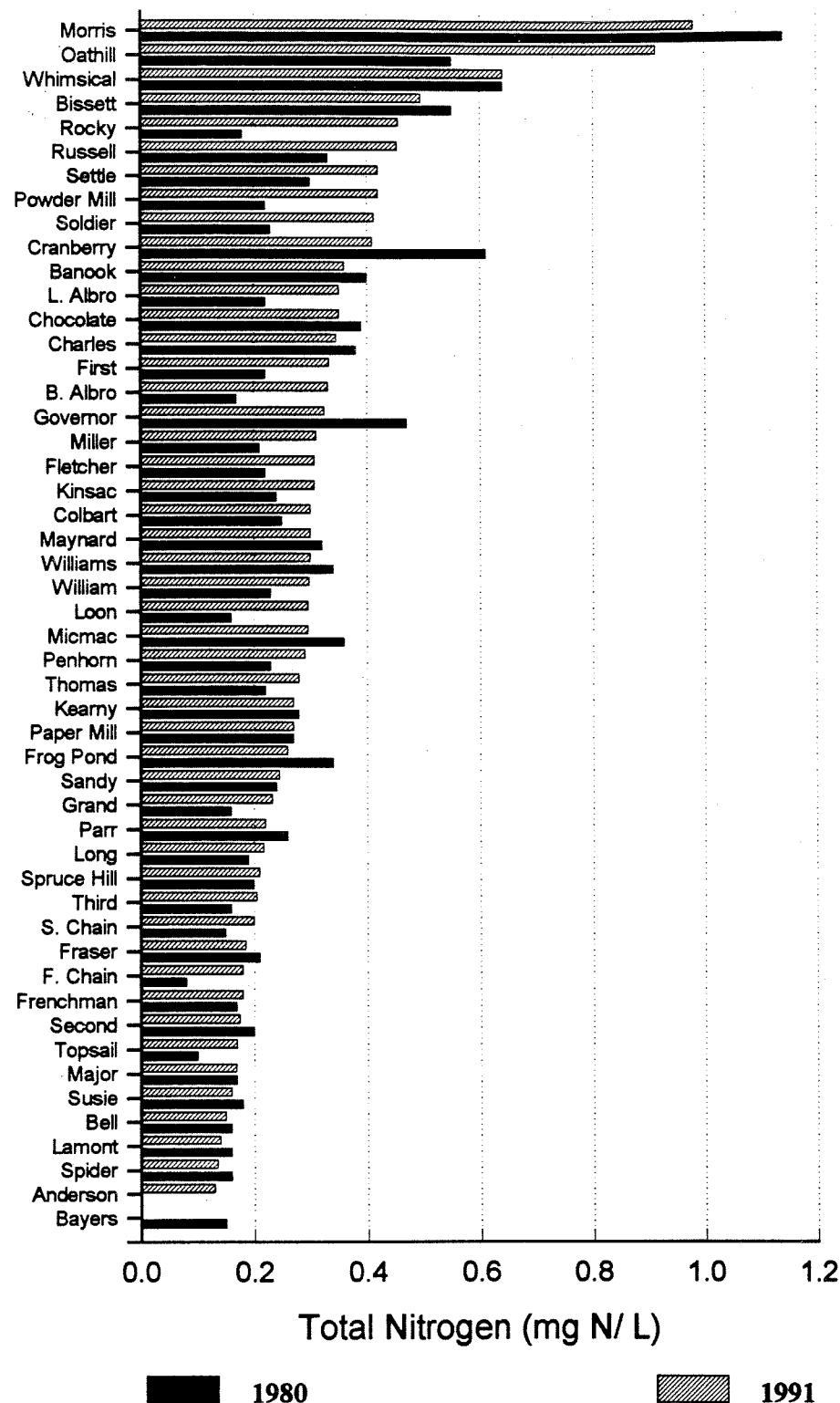


Figure 18. Total nitrogen (TN) concentrations in lakes sampled in 1980 and 1991.

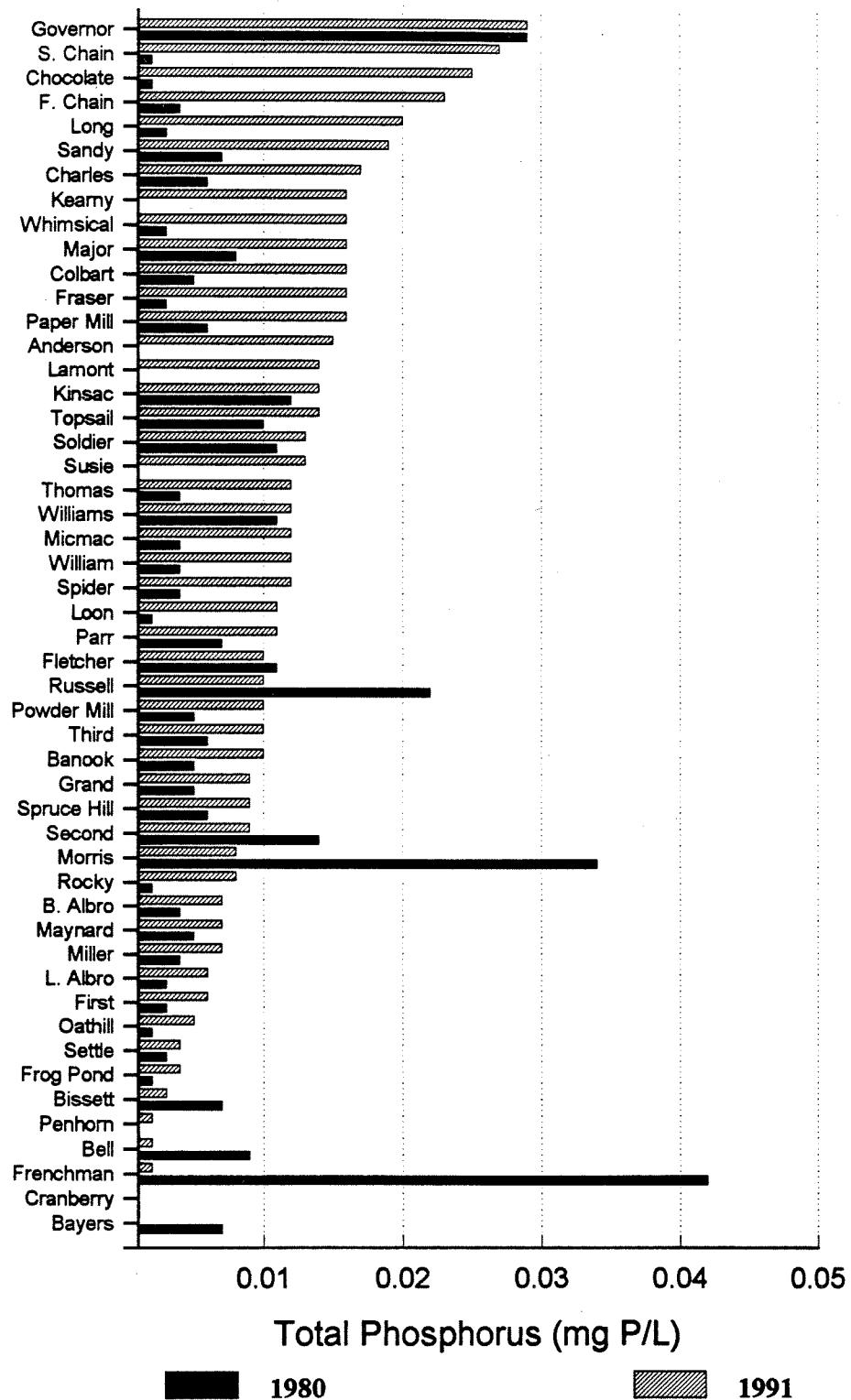


Figure 19. Total phosphorus (TP) concentrations in lakes sampled in 1980 and 1991.

done to confirm this suggested trend. Differences of the same scale could also be caused by slight changes in the timing of biological cycles at the time of sampling.

There was no significant overall difference in the phosphate concentrations observed in 1991 and 1980 (Fig. 16 and Table 5). However, the high values detected in Morris, Governor, and Frenchman Lakes in 1980 were not repeated in 1991.

Silicate concentrations measured in 1991 were much less variable than measured in 1980 (Fig. 17). In some lakes the concentrations were higher while in others they were lower. Overall, concentrations in 1991 were significantly less (Table 5).

While concentrations did appear to increase in some lakes, there was no significant overall difference in total nitrogen between 1980 and 1991 (Fig. 18 and Table 5). However, total phosphorous did increase in most lakes (Fig. 19 and Table 5). The high values in Russell, Morris, and Frenchman Lakes were not repeated in 1991.

The data do suggest a trend of increasing nitrate and total phosphorous concentrations, but additional and more-detailed studies are needed to confirm this. As stated above, there is some question about the accuracy of the 1991 total phosphorous data; and nitrate was measured by different laboratories in 1980 and 1991 (Table 2). Overall, however, the nutrient levels in Metro Area lakes remain relatively low. Metro Area lakes do not usually receive any direct sewage but may be affected in some instances by faulty septic fields in Halifax County. However, it is expected that lawn and garden fertilizers will increase the nutrient concentrations of lakes in developed watersheds. Wherever possible, steps should be taken to limit the human input of nutrients to the lakes. These could include public education programs, periodic testing of private septic systems, retention of natural vegetation around lakes, and protection of freshwater wetlands.

ORGANIC MATTER

Chlorophyll is a pigment produced by plants which plays a critical role in photosynthesis. It has been shown to be a good indicator of phytoplankton biomass. Because of their naturally low nutrient concentrations, Metro Area lakes tend to have low levels of chlorophyll. As nutrient enrichment takes place due to anthropogenic activity, chlorophyll concentrations can be expected to increase.

Chlorophyll concentrations are plotted in Figure 20. The highest concentrations occurred in Bissett, Oathill, and Settle Lakes. Not surprisingly, these three lakes also had the highest concentrations of phosphate (Fig. 16). Phosphate usually is the limiting nutrient for phytoplankton growth in freshwater.

The yellow-brown colour found in many Metro Area lakes is due primarily to the presence of dissolved humic materials. These large organic molecules are produced naturally by

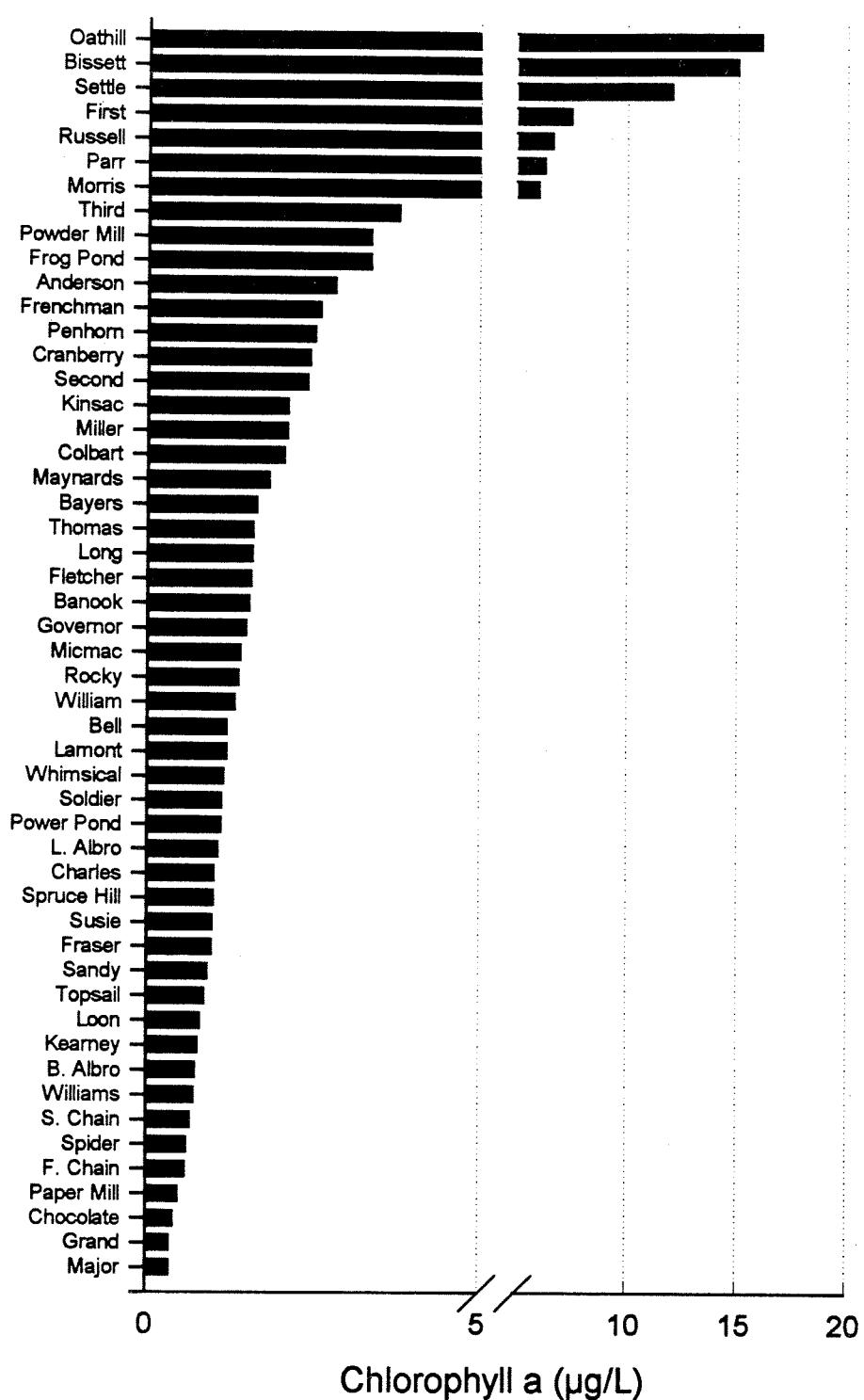


Figure 20. Concentrations of chlorophyll a extracted from lake samples in 1991.

vegetation growing in watershed areas, especially in acid bogs, and are transported by streams and runoff to the lakes. Lake colour varied over a large range from the very clear waters of Bayers, Bell, and First Chain Lakes to the highly coloured waters of Spruce Hill, Frenchman, and Long Lakes (Fig. 21). Colour can have a pronounced effect on Secchi depth as lakes with high colour tend to have lower Secchi depths (Fig. 3). The regression of chlorophyll concentration against Secchi disk depth for lakes with colour less than 20 TCU is similar to that reported by Canfield and Bachmann (1981) for 193 natural lakes in the United States.

Dissolved organic carbon (DOC) is a direct measure of all organic substances that pass through a fine filter. Under natural conditions, it includes humic materials as well as exudates from phytoplankton and rooted aquatic vegetation. DOC in Metro Area lakes ranges from approximately 1 to 6 mg L⁻¹ (Fig. 22). As expected, lakes with high DOC also have high colour (Fig. 21) since both methods are measuring the same substances ($r^2=0.77$).

Since colour, chlorophyll, and DOC were not analyzed in 1980, it is not possible to reach any conclusions on possible long-term trends in organic matter properties. It does appear that in 1991 colour and DOC concentrations represent primarily natural conditions unaffected by human activity. However, chlorophyll concentrations are clearly elevated in some lakes, especially Bissett, Oathill, and Settle.

ELEMENTS

The full data set of elemental analysis conducted by Energy, Mines and Resources Canada is presented in Appendix C. A detailed analysis and interpretation of these data is beyond the scope of this report. However, it is clear that the highest concentrations of trace elements such as nickel, cobalt, and zinc occur in those lakes with the lowest pH (e.g. Bayers, First and Second Chain, Governor, and Long) (Fig. 4).

TROPHIC STATUS OF LAKES

Lakes can be classified on the basis of their general level of biological production. Oligotrophic (poorly fed) lakes are low in nutrients, low in plant biomass, and maintain high oxygen levels in deep water. Eutrophic (well fed) lakes are rich in nutrients, high in plant biomass, and can have markedly reduced oxygen levels in deep water during the summer months. Lakes with intermediate conditions are called mesotrophic. Extreme conditions are termed ultra-oligotrophic and hypereutrophic. The progression from an oligotrophic to eutrophic condition is a natural process called eutrophication. Lakes in the Metro Area are naturally oligotrophic; but the addition of anthropogenic nutrients, especially phosphorous, is accelerating the eutrophication process.

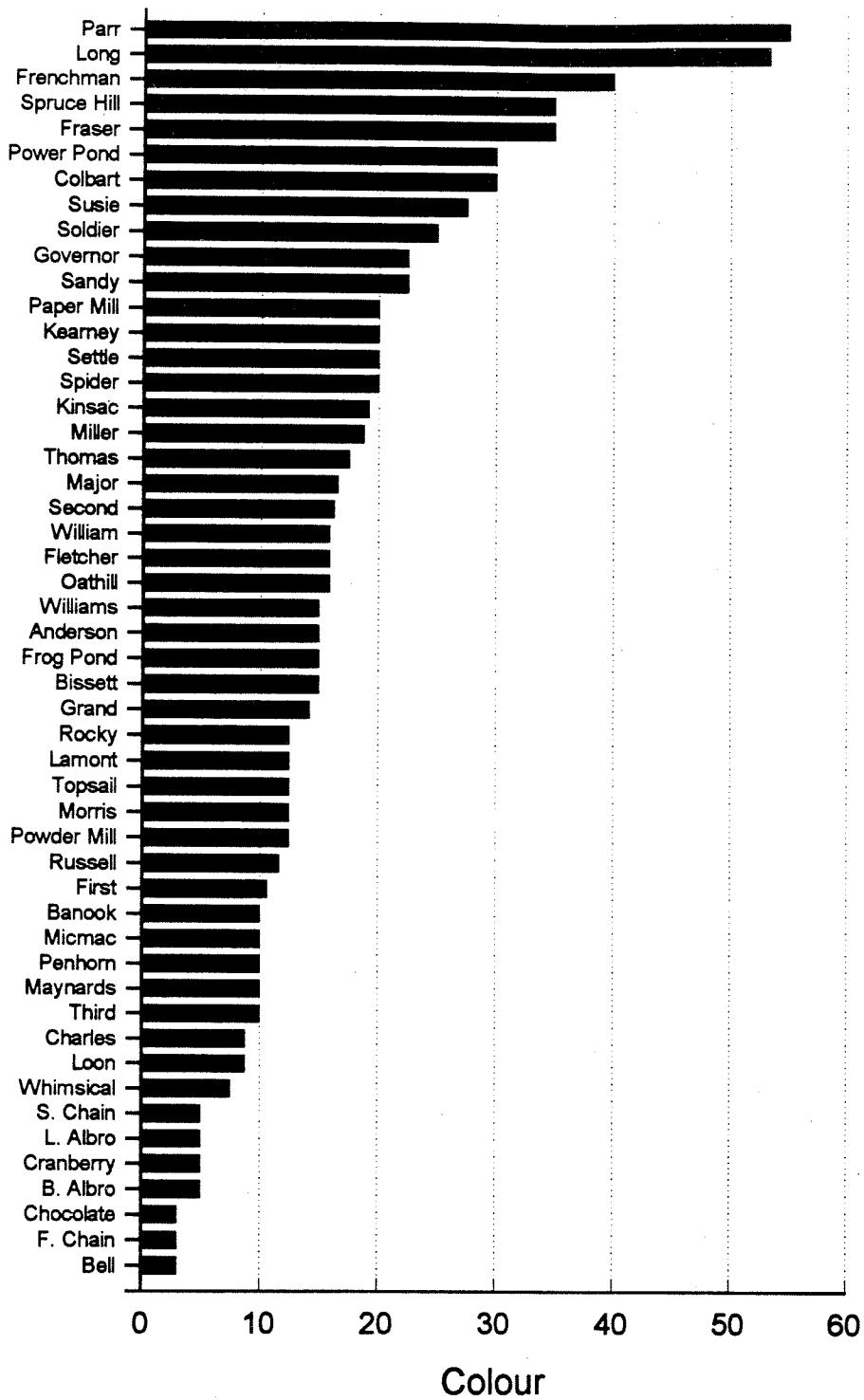


Figure 21. Colour (TCU) in water from lakes sampled in 1991.

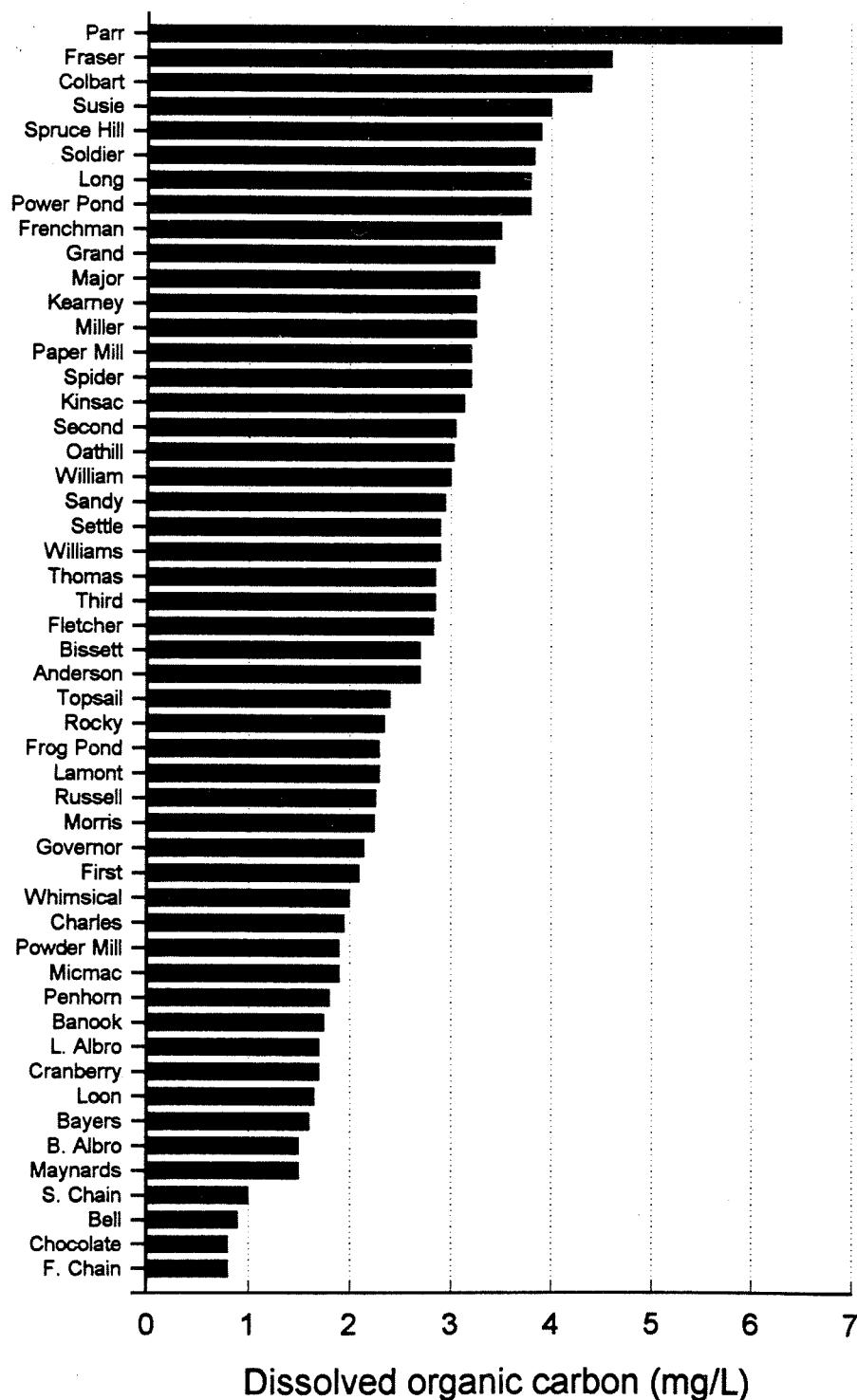


Figure 22. Dissolved organic carbon (DOC) in water from lakes sampled in 1991.

The lakes in the Metro Area are widely used for recreation, and it is from this perspective that most people view water quality. They want lakes which have clean shorelines, clear water, and support desirable species of fish (e.g. trout). Such lakes generally fall into the oligotrophic category. As lakes become more enriched with nutrients, their attractiveness for recreation decreases as plant abundance increases and water clarity decreases. Therefore, it is important to estimate the trophic status of individual lakes so that corrective action can be taken if nutrient conditions become, or are predicted to become, unacceptable.

The trophic status of a lake can be estimated using two methods. One is on the basis of the mean annual value of total phosphorous, chlorophyll, or Secchi disk (OECD approach) (Vollenweider and Kerekes 1981). The other is to calculate a trophic state index (TSI) based on the mean annual value of total phosphorus, chlorophyll, or Secchi disk (Carlson 1977). Both methods give similar results.

Due to the high levels of colour in some Metro Area lakes (Fig. 21), trophic status estimates based on Secchi disk are not always reliable. Those based on total phosphorous (Fig. 19) are also judged to be unreliable because of some question over the accuracy of this data set. Therefore, estimates of trophic status in this report are based solely on the chlorophyll data (Fig. 20). Also, this assessment is limited and should be viewed with some reservation because it is based on a single early-spring measurement and not an average growing season value.

Based on the TSIs calculated from chlorophyll concentrations, Oathill, Bissett, and Settle Lakes can be categorized as eutrophic, First Lake as borderline between eutrophic and mesotrophic, Russell, Parr, and Morris Lakes as mesotrophic, and Third, Powder Mill, Frog Pond, Anderson, and Frenchman Lakes as borderline between mesotrophic and oligotrophic (Fig. 23). The remaining lakes can be classified as oligotrophic or ultraoligotrophic.

TSIs based on chlorophyll were calculated from mean annual concentrations determined from multiple samples collected from selected Metro Area lakes during 1990 (Soil and Water Conservation Society of Metro Halifax 1991). While the absolute values were generally lower, the highest values were found in the same four lakes (Oathill, Bissett, Settle, and First). Although not technically classified as eutrophic, Bissett and Settle Lakes were judged as showing eutrophic tendencies.

SUMMARY

Most, if not all, of the Metro Area lakes sampled in this study show the impacts of human activity, especially those with watersheds which have extensive urban or industrial development. In most instances, the general water quality remains at relatively good

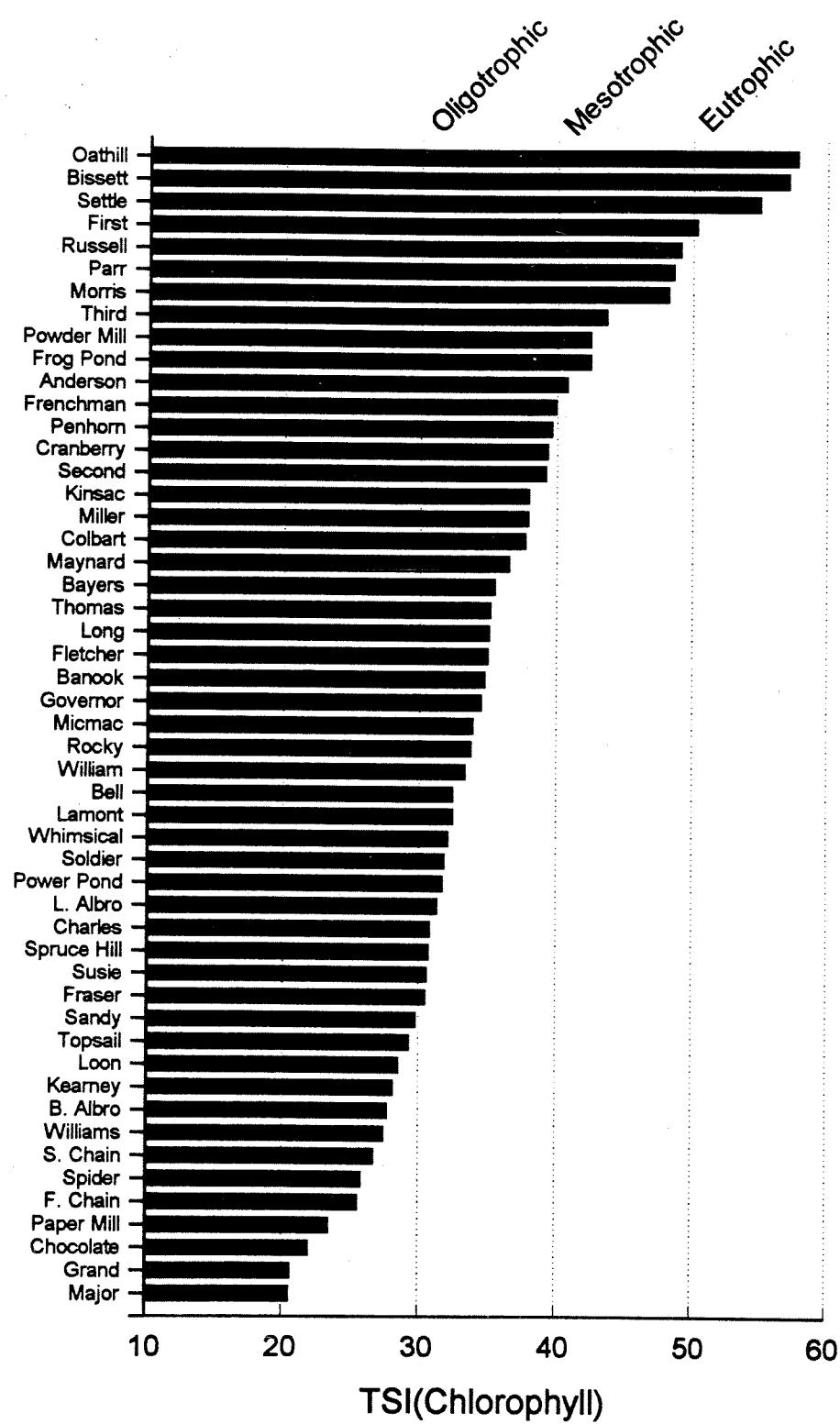


Figure 23. Trophic Status Index (TSI) calculated from chlorophyll data for 1991.

levels and the lakes continue to be important recreational resources. However, there are some changes taking place that warrant concern.

The most significant long-term change detected in this study is a marked increase in conductivity and major ions. This is due to the use of road salt, agricultural lime, and other chemicals in the watershed areas. At the present time, biological effects are not evident; but it would be prudent not to let present trends continue.

Acid precipitation and/or acid runoff from slate bedrock has decreased pH in some lakes to the level that salmonid fish species are unable to breed successfully ($\text{pH} < 5.0$). In several lakes impacted by acid runoff, high aluminum concentrations may also be detrimentally affecting fish populations. However, impacts are localized, remedial action has been taken, and concentrations are progressing toward background levels.

There is evidence that nutrient concentrations are increasing in some lakes which in turn are increasing the rate of biological production. Although TSIs based on mean annual concentrations are more accurate, the TSIs based on the chlorophyll concentrations determined in this study suggest that three Metro Area lakes have reached a eutrophic state and ten others are mesotrophic. This suggests that increased attention should be given to the management of nutrient loading to Metro Area lakes, especially in regard to phosphorous.

This study has only considered a selected number of water quality variables because of the limits of time and funding. It has not measured other important contaminants such as silt, micro-organisms, and synthetic organic compounds (herbicides, pesticides, etc.). In addition, it has not considered other potential problems such as chemical contaminants in lake sediments, changes in the species composition of biological communities, and increases in rooted aquatic vegetation. Therefore, there may be additional environmental concerns associated with Metro Area lakes that are not covered by this report.

The authors intend to repeat this survey in the Year 2000.

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The authors thank E.A. Orr and G.A. Phillips (Department of Fisheries and Oceans) and G. Eisan (City of Dartmouth) for their help in collecting and processing the water samples and to the laboratory staff of the Monitoring and Evaluation Branch for their analytical expertise. Special thanks are due to R. Falk of Cougar Helicopters Inc. for piloting the helicopter. J. Kerekes of the Canadian Wildlife Service provided guidance on calculating trophic status indices. J. Kerekes, W. White, and R. Rutherford kindly reviewed this manuscript. The authors acknowledge the support of their respective agencies for the time and financial resources to carry out this study.

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APPENDIX A. DATA COLLECTED IN 1991

These data can be obtained on disk in a QuattroPro spreadsheet from P.D. Keizer.

Table A-1. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Anderson (68)	B. Albion (79)	Banook (69)	Banook (R)	Banook (70)	Bayers (25)	Bell (82)	Bissett (60)	Bissett (61)
Temp (°C)	7	5.5	7.5	nd	nd	7.5	7.5	5	7.5
Secchi depth (m)	4.5	6.5	3.5	nd	nd	4	>1.5	5.5	1.5
pH (NSDOE)	5.32	6.38	6.78	6.89	6.72	6.72		5.00	6.63
pH (EC)	5.4	6.8	7.1	7	7.1	7.2	4.3	5.5	7.2
Conductivity (µS)	63.5	335	362	357	358	354	270	56.4	61.9
Theo. Conductivity	62.78	366.55	378.53	381.14	383.41	383.61		58.49	634.13
Na (mg L ⁻¹)	7.6	56.7	55.3	55.3	56.6	57.4		4.6	9.4
Ca (mg L ⁻¹)	1.97	8.43	10.1	10.2	10.3	9.78		2.58	15.4
Mg (mg L ⁻¹)	0.6	1.21	1.44	1.44	1.43	1.42		1	2.07
K (mg L ⁻¹)	0.5	1	1.3	1.3	1.3	1.3		0.7	2.4
Al (mg L ⁻¹)	0.165	0.029	0.05	0.042	0.1	0.042		0.18	0.068
Cl (mg L ⁻¹)	12.2	89.3	90.1	91.4	90.9	90.7		8.4	158.0
SO ₄ ²⁻ (mg SO ₄ ^{2- L⁻¹)}	6.8	14.6	16.4	16.3	16.4	16.6		10	17.5
Alkalinity (mg CaCO ₃ L ⁻¹)	0	4.2	9.7	9.4	9.6	9.6		0	18.8
Gran Alk (mg CaCO ₃ L ⁻¹)	0.5	4.6	10.4	9.9	10	10.1	-1.5	0.4	21.8
NH ₄ ⁺ (mg N L ⁻¹)	0.010	0.009	0.004	0.007	0.011	0.008	0.003	0.006	0.005
NO ₃ (mg N L ⁻¹)	0.01	0.18	0.22	0.22	0.22	0.22	0.00	0.04	0.25
PO ₄ ³⁻ (mg P L ⁻¹)	0.004	0.003	0.002	0.002	0.003	0.003	0.002	0.008	0.009
Silicate (mg Si L ⁻¹)	0.02	0.10	0.34	0.44	0.40	0.40	0.04	0.01	0.04
Total N (mg N L ⁻¹)	0.13	0.33	0.35	0.37	0.35	0.37		0.15	0.49
Total P (mg P L ⁻¹)	0.015	0.007	0.011	0.01	0.01	0.01		0.002	0.003
Chlorophyll (µg L ⁻¹)	2.835	0.749	1.609	1.543	1.455	1.543	1.653	1.212	14.551
Color (TCU)	15	5	10	10	10	10	<3.0	15	15
DOC (mg C L ⁻¹)	2.7	1.5	1.9	1.7	1.7	1.7	1.6	0.9	2.7

Table A-2. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Charles (56)	Charles (57)	Chocolate (82)	Colbart (32)	Cranberry (80)	First (71)	First (72)	First (R)	First (R)	First Chain (27)
Temperature (oC)	6.5	6.5	7.5	7.1	6	6.5	nd	nd	7.3	6.9
Secchi depth (m)	3.5	3.5	7.5	2.5	3.2	1.5	nd	nd	1.5	>5
pH (NSDOE)	6.75	6.60	4.68	5.62	6.71	6.76	6.77	6.83	6.87	4.36
pH (EC)	6.9	6.9	4.8	5.5	7.2	7.6	7.5	7.5	7.4	4.4
Conductivity (μS)	196	195	509	275	458	355	351	349	352	386
Theo. Conductivity	197	196	558	299	496	376	370	376	373	413
Na (mg L^{-1})	27	27	80.3	47.5	73	51.5	49.9	52	51	53
Ca (mg L^{-1})	6.46	6.5	10.6	5.18	12.8	13.9	14.1	14	13.9	7.56
Mg (mg L^{-1})	1.23	1.24	2.49	0.84	1.88	1.85	1.9	1.86	1.85	2.49
K (mg L^{-1})	1	1	1.5	0.9	2	1.9	1.9	1.9	1.9	1
Al (mg L^{-1})	0.076	0.105	2.21	0.276	0.037	0.063	0.06	0.055	0.056	3.23
Cl (mg L^{-1})	43.3	43.1	125.0	74.8	120.0	83.0	81.6	81.9	81.7	87.0
SO_4^2- ($\text{mg SO}_4^2- \text{L}^{-1}$)	11.6	11.6	47.5	12.3	18.8	16.8	16.2	17.3	17.3	44
Alkalinity ($\text{mg CaCO}_3 \text{ L}^{-1}$)	6.5	6.6	0	0.5	12.3	19.5	19.2	19.2	19.5	0
Gran Alk ($\text{mg CaCO}_3 \text{ L}^{-1}$)	7.1	6.7	-0.2	1	14	21.9	21.8	21.9	22.2	-1.8
NH_4^+ (mg L^{-1})	0.016	0.009	0.033	0.001	0.007	0.066	0.076	0.091	0.005	0.003
NO_3^- (mg L^{-1})	0.22	0.23	0.27	0.14	0.23	0.11	0.11	0.11	0.11	0.09
PO_4^{3-} (mg P L^{-1})	0.002	0.003	0.001	0.002	0.003	0.005	0.005	0.005	0.006	0.002
Silicate (mg L^{-1})	0.34	0.21	0.12	0.03	0.02	0.35	0.36	0.34	0.35	0.07
Total N (mg L^{-1})	0.35	0.34	0.35	0.3	0.41	0.32	0.34	0.33	0.34	0.18
Total P (mg L^{-1})	0.017	0.017	0.025	0.016	0.001	0.006	0.006	0.006	0.006	0.023
Chlorophyll ($\mu\text{g L}^{-1}$)	1.807	0.243	0.417	2.072	2.452	7.203	7.433	7.290	8.046	0.599
Color (TCU)	7.5	10	<3.0	30	5	10	10	10	12.5	<3.0
DOC (mg C L^{-1})	2.1	1.8	0.8	4.4	1.7	2.1	2	2.2	2.1	0.8

Table A-3. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Fletcher (35)	Fletcher (36)	Fletcher (37)	Fraser (23)	Fraser (24)	Frenchman (67)	Frog Pond (84)	Governor (21)	Governor (22)
Temperature (C)	7.5	7.5	7	5.8	5.8	10	8.6	6.8	6.2
Secchi depth (m)	3.5	B	3.5	>1.5	2.5	B	2.8	1.75	1.75
pH (NSDOE)	6.29	6.41	6.50	4.94	4.88	5.40	6.67	4.61	4.57
pH (EC)	6.5	6.6	6.5	4.8	4.8	5.6	7.1	4.5	4.5
Conductivity (μS)	126.7	127.4	130.5	46.9	48.1	402	558	269	274
Theo. Conductivity	129	127	130	45	48	437	614	290	294
Na (mg L^{-1})	46.8	16.7	17.2	4.8	5.2	69.2	90	38.4	38.4
Ca (mg L^{-1})	4.58	4.58	4.55	1.28	1.4	8.18	15.9	6.66	6.72
Mg (mg L^{-1})	0.8	0.8	0.79	0.49	0.52	1.49	1.81	1.82	1.84
K (mg L^{-1})	0.8	0.8	0.7	0.4	0.5	1	2.2	1.1	1.1
Al (mg L^{-1})	0.143	0.172	0.143	0.268	0.264	0.155	0.054	2.03	2.06
Cl (mg L^{-1})	28.6	27.3	28.0	8.3	8.7	110.0	148.0	59.0	58.8
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{ L}^{-1}$)	8	9.1	9.3	5.1	5.1	15.6	28.4	30.8	32.8
Alkalinity ($\text{mg CaCO}_3 \text{ L}^{-1}$)	3.6	3.5	3.5	0	0	0.5	11.3	0	0
Gran Alk ($\text{mg CaCO}_3 \text{ L}^{-1}$)	3.9	3.8	3.7	0.1	-0.2	0.9	13.6	-0.8	-0.8
NH_4^+ (mg L^{-1})	0.012	0.011	0.008	0.010	0.010	0.005	0.004	0.057	0.057
NO_3^- (mg L^{-1})	0.14	0.14	0.15	0.03	0.04	0.00	0.09	0.15	0.14
PO_4^{3-} (mg P L^{-1})	0.003	0.002	0.003	0.002	0.002	0.002	0.003	0.003	0.003
Silicate (mg L^{-1})	0.11	0.10	0.09	0.02	0.02	0.04	0.03	0.06	0.07
Total N (mg L^{-1})	0.31	0.3	0.31	0.18	0.19	0.18	0.26	0.33	0.32
Total P (mg L^{-1})	0.01	0.01	0.011	0.016	0.015	0.002	0.004	0.028	0.029
Chlorophyll ($\mu\text{g L}^{-1}$)	1.521	1.587	1.609	0.948	1.036	2.605	3.372	0.622	2.376
Color (TCU)	15	15	17.5	35	35	40	15	25	20
DOC (mg C L^{-1})	2.8	2.8	2.9	4.7	4.5	3.5	2.3	2.2	2.1

Table A-4. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Grand (2)	Grand (1)	Grand (3)	Kearney (17)	Kearney (18)	Kinsac (4)	Kinsac (5)	Kinsac (6)	L. Albro (78)	Lamont (73)
Temperature (C)	4.2	4.2	4.8	5.3	5.7	5.2	5.2	6	6	6
Secchi depth (m)	nd	nd	4.25	2.25	2.75	2.5	>2	2.25	>3.5	6
pH (NSDOE)	6.13	5.83	6.16	5.63	5.78	5.68	5.90	5.84	6.44	6.90
pH (EC)	6.8	6.3	6.3	5.6	5.6	6.6	5.7	5.9	6.9	6.7
Conductivity (μS)	81.3	82.2	81.6	77.7	77.0	62.8	46.8	67.4	344	40.5
Theo. Conductivity	80	79	80	77	78	60	47	66	374	41
Na (mg L^{-1})	8.9	8.7	8.9	10	10.2	7	4.8	7.9	56.7	3.5
Ca (mg L^{-1})	4.01	4.12	4.03	2.49	2.46	2.75	2.14	2.95	8.78	2.83
Mg (mg L^{-1})	0.71	0.73	0.71	0.67	0.66	0.7	0.57	0.73	1.18	0.52
K (mg L^{-1})	0.6	0.5	0.6	0.5	0.5	0.5	0.4	0.6	1	0.3
Al (mg L^{-1})	0.113	0.113	0.104	0.28	0.277	0.217	0.177	0.216	0.03	0.231
Cl (mg L^{-1})	14.3	13.8	14.1	16.6	16.7	10.0	8.1	11.7	92.0	5.7
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{L}^{-1}$)	9.6	9.8	9.5	6.2	6.4	7.3	6.4	7.2	14.8	6.6
Alkalinity ($\text{mg CaCO}_3 \text{L}^{-1}$)	1.9	2	2	0.6	0.6	1.3	0.8	1.5	5.1	2.4
Gran Alk ($\text{mg CaCO}_3 \text{L}^{-1}$)	3.9	2.5	2.4	1.1	0.5	3.1	0.9	2	5.4	2.7
NH_4^+ (mg L^{-1})	0.016	0.014	0.014	0.010	0.016	0.025	0.009	0.027	0.010	0.005
NO_3^- (mg L^{-1})	0.08	0.08	0.08	0.15	0.15	0.13	0.06	0.15	0.19	0.04
PO_4^{3-} (mg P L^{-1})	0.002	0.003	0.002	0.003	0.003	0.003	0.004	0.004	0.003	0.002
Silicate (mg L^{-1})	0.01	0.02	0.03	0.02	0.03	0.02	0.01	0.03	0.12	0.13
Total N (mg L^{-1})	0.23	0.24	0.23	0.27	0.27	0.31	0.25	0.36	0.35	0.14
Total P (mg L^{-1})	0.009	0.008	0.009	0.016	0.016	0.011	0.016	0.006	0.014	
Chlorophyll (ug L^{-1})	0.453	0.260	0.380	0.749	0.815	2.044	2.044	2.299	1.080	1.212
Color (TCU)	15	12.5	15	20	20	20	17.5	20	5	12.5
DOC (mg C L^{-1})	3.4	3.6	3.3	3.3	3.2	3.5	2.8	3.1	1.7	2.3

Table A-5. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Long (29)	Long (28)	Long (30)	Long (54)	Loon (55)	Major (R)	Major (53)	Major (50)	Major (51)	Major (52)	Maynard (77)
Temperature (C)	6	6.2	6	7.5	7.5	nd	nd	5	5	4.5	6
Secchi depth (m)	1.75	1.75	1.75	3	B	nd	nd	4.5	3.5	3.5	5.3
pH (NSDOE)	4.67	4.62	4.65	6.37	6.57	4.66	4.72	4.64	4.73	4.75	6.63
pH (EC)	4.7	4.7	4.7	7	6.8	4.8	4.8	4.8	4.9	4.9	7.1
Conductivity (μS)	185	183	186	277	277	36.8	36.6	36.3	36.7	36.5	381
Theo. Conductivity	194	189	196	286	287	37	35	36	36	36	422
Na (mg L^{-1})	28	26	28	43	43	2.9	2.9	2.9	3	2.9	63.5
Ca (mg L^{-1})	4.04	4.32	4.12	7.21	7.23	1.01	1.01	0.976	1.02	1	9.85
Mg (mg L^{-1})	1.12	1.12	1.16	1.22	1.22	0.48	0.47	0.46	0.48	0.47	1.91
K (mg L^{-1})	0.7	0.6	0.7	1.1	1.2	0.4	0.3	0.3	0.4	0.4	1.4
Al (mg L^{-1})	0.727	0.712	0.724	0.079	0.062	0.257	0.242	0.242	0.241	0.24	0.038
Cl (mg L^{-1})	42.6	42.1	43.1	67.5	68.2	4.6	4.4	4.5	4.7	4.6	103.0
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{L}^{-1}$)	13	12.6	13.1	13.5	13.2	5.4	5.5	5.3	5.5	5.6	14.7
Alkalinity ($\text{mg CaCO}_3 \text{L}^{-1}$)	0	0	0	4.7	4.9	0	0	0	0	0	9.9
Gran Alk ($\text{mg CaCO}_3 \text{L}^{-1}$)	-0.6	-0.8	-0.8	5.5	5.4	-0.6	-0.9	-0.5	-0.5	-0.4	10.1
NH_4^+ (mg N L^{-1})	0.007	0.006	0.009	0.004	0.009	0.013	0.007	0.006	0.007	0.007	0.012
NO_3^- (mg N L^{-1})	0.07	0.06	0.07	0.18	0.18	0.05	0.06	0.05	0.06	0.06	0.11
PO_4^{3-} (mg P L^{-1})	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.002	0.001	0.002	0.003
Silicate (mg L^{-1})	0.04	0.04	0.04	0.23	0.21	0.03	0.03	0.04	0.03	0.03	0.29
Total N (mg L^{-1})	0.21	0.22	0.22	0.29	0.3	0.17	0.16	0.17	0.17	0.17	0.3
Total P (mg L^{-1})	0.019	0.02	0.02	0.011	0.011	0.016	0.016	0.016	0.016	0.016	0.007
Chlorophyll ($\mu\text{g L}^{-1}$)	1.344	1.653	1.763	0.815	0.815	0.447	0.470	0.099	0.402	0.387	1.839
Color (TCU)	55	55	50	10	7.5	17.5	17.5	15	15	10	10
DOC (mg C L^{-1})	3.7	3.7	4	1.6	1.7	3.3	3.4	3.5	3.2	3	1.5

Table A-6. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Micmac (58)	Micmac (59)	Miller (46)	Miller (47)	Miller (64)	Morris (63)	Morris (62)	Morris (75)	Oathill (R)	Oathill (R)
Temperature (C)	7	7.5	7.5	7.5	7.5	7.5	8	7	nd	nd
Secchi depth (m)	B	4.5	3	3	2.5	2.5	2.75	1.8	nd	nd
pH (NSDOE)	6.80	6.48	5.13	5.11	6.50	6.52	6.55	6.81	6.80	6.79
pH (EC)	7	7.1	5.4	5.2	7	7	7	7.4	7.4	7.4
Conductivity (μS)	311	332	115.9	102.8	302	316	333	581	577	582
Theo. Conductivity	324	322	114	101	313	327	358	638	637	637
Na (mg L ⁻¹)	47.5	47.5	15.6	13.7	45.7	47	52.8	91.7	89	89
Ca (mg L ⁻¹)	8.82	8.89	3.25	2.95	9.03	9.25	10.1	18.9	18.9	18.8
Mg (mg L ⁻¹)	1.34	1.34	0.67	0.64	1.37	1.39	1.43	2.91	2.89	2.88
K (mg L ⁻¹)	1.1	1.1	0.5	0.5	1.3	1.4	1.4	2.5	2.5	2.5
Al (mg L ⁻¹)	0.056	0.048	0.223	0.234	0.074	0.081	0.064	0.059	0.046	0.045
Cl (mg L ⁻¹)	75.8	76.6	25.6	21.7	72.6	77.2	82.9	151.0	153.0	152.0
SO ₄ ²⁻ (mg SO ₄ ²⁻ L ⁻¹)	15.5	13.4	7.9	8	14.8	14.9	17.5	24.1	24.3	25.6
Alkalinity (mg CaCO ₃ L ⁻¹)	7.6	7.8	0.2	0	8.1	8.5	8.3	21	21	21
Gran Alk (mg CaCO ₃ L ⁻¹)	8.1	8.3	0.5	0.2	8.7	9.1	9.1	24	24.2	23.6
NH ₄ ⁺ (mg N L ⁻¹)	0.012	0.001	0.016	0.019	0.008	0.010	0.008	0.015	0.008	0.008
NO ₃ (mg N L ⁻¹)	0.18	0.18	0.12	0.12	0.47	0.44	0.43	0.64	0.63	0.62
PO ₄ ³⁻ (mg P L ⁻¹)	0.002	0.002	0.003	0.002	0.004	0.004	0.004	0.007	0.007	0.007
Silicate (mg L ⁻¹)	0.25	0.32	0.05	0.04	0.27	0.20	0.21	0.05	0.05	0.05
Total N (mg L ⁻¹)	0.29	0.3	0.29	0.33	0.99	0.97	0.92	0.91	0.89	0.94
Total P (mg L ⁻¹)	0.012	0.012	0.007	0.007	0.008	0.007	0.007	0.005	0.005	0.005
Chlorophyll (µg L ⁻¹)	1.433	1.389	2.452	1.785	4.675	7.399	6.973	15.784	17.263	15.290
Color (TCU)	10	10	17.5	20	12.5	12.5	12.5	15	15	17.5
DOC (mg C L ⁻¹)	2	1.8	3.3	3.2	2.4	2.1	2.4	2.2	2.6	4.3

Table A-7. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Paper Mill (16)	Parr (33)	Penthorn (76)	Powder Mill (11)	Power Pond (85)	Rocky (13)	Rocky (12)	Russell (65)	Russell (66)
Temperature	5.6	6.9	6	6.9	9.9	7.8	7.2	7.5	8
Secchi depth (m)	>2	1.5	4.4	4.5	3.4	>4	>2	2.25	2.25
pH (NSDOE)	5.75	5.40	7.05	6.74	4.82	6.86	6.94	6.47	6.54
pH (EC)	5.9	5.5	7.5	7.3	4.9	7.4	7.2	7.2	7.1
Conductivity (µS)	78.9	74.6	614	149	161	193	218	480	482
Theo. Conductivity	79	76	693	152.79	169	197	228	514	516
Na (mg L⁻¹)	10.3	8	108	17.8	23	23	29	78.6	78.6
Ca (mg L⁻¹)	2.51	3.83	16.8	7.94	4.06	11.2	11.1	11.7	11.8
Mg (mg L⁻¹)	0.69	0.77	1.78	1.05	1.04	1.2	1.3	1.53	1.54
K (mg L⁻¹)	0.5	0.9	1.5	1.2	0.7	1.7	1.7	1.5	1.4
Al (mg L⁻¹)	0.273	0.248	0.023	0.044	0.492	0.051	0.05	0.066	0.071
Cl (mg L⁻¹)	17.0	12.3	171.0	28.7	37.9	36.7	45.1	127.0	128.0
SO₄²⁻ (mg SO₄²⁻ L⁻¹)	6.3	10.7	18.3	11	11.8	13.2	13.4	17.9	17.8
Alkalinity (mg CaCO₃ L⁻¹)	0.6	0.7	18.2	11	0	15.2	14.2	10	10.3
Gran Alk (mg CaCO₃ L⁻¹)	0.9	1.3	20.9	11	-0.5	18.2	16.4	11.9	11.6
NH₄⁺ (mg N L⁻¹)	0.007	0.002	0.004	0.002	0.008	0.009	0.003	0.007	0.005
NO₃⁻ (mg N L⁻¹)	0.14	0.01	0.10	0.28	0.03	0.49	0.40	0.01	0.02
PO₄³⁻ (mg P L⁻¹)	0.002	0.004	0.003	0.003	0.002	0.004	0.003	0.007	0.007
Silicate (mg Si L⁻¹)	0.02	0.05	0.15	0.32	0.03	0.25	0.17	0.21	0.17
Total N (mg L⁻¹)	0.27	0.22	0.29	0.42	0.18	0.62	0.29	0.22	0.22
Total P (mg L⁻¹)	0.016	0.011	0.002	0.01	0.01	0.008	0.007	0.011	0.011
Chlorophyll (µg L⁻¹)	0.485	6.284	2.529	3.372	1.124	0.970	1.807	6.437	6.514
Color (TCU)	20	55	10	12.5	30	12.5	12.5	10	10
DOC (mg C L⁻¹)	3.2	6.3	1.8	1.9	3.8	1.9	2.8	2.3	2.1

Table A-8. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Sandy (14)	Sandy (15)	Second (9)	Second (10)	2nd Chain (26)	Settle (81)	Settle (43)	Soldier (44)	Soldier (45)
Temp (°C)	5.9	6.2	6.2	6.8	7	5	7	6	7
Secchi depth (m)	1.75	2	2	3	7	0.9	2	2	2
pH (NSDOE)	5.23	5.34	5.96	6.09	4.40	6.70	4.76	4.75	4.87
pH (EC)	5.3	5.5	6.2	6.4	4.4	7.3	5	5	4.9
Conductivity (µS)	115.4	112.0	78.9	73.2	478	514	87.6	86.1	85.6
Theo. Conductivity	118.20	113.83	81.81	72.90	524.83	560.06	84.95	86.92	83.68
Na (mg L ⁻¹)	15.5	15	9.2	8.8	70.5	82.7	10	10.2	10
Ca (mg L ⁻¹)	3.34	3.2	3.45	3.23	9.48	14	2.58	2.64	2.57
Mg (mg L ⁻¹)	0.89	0.86	0.79	0.75	2.82	2.01	0.62	0.62	0.61
K (mg L ⁻¹)	0.7	0.7	0.7	0.6	1.2	2	0.5	0.5	0.5
Al (mg L ⁻¹)	0.326	0.302	0.196	0.138	3.63	0.204	0.28	0.334	0.286
Cl (mg L ⁻¹)	25.4	24.5	16.5	14.5	115.0	136.0	16.4	17.2	16.4
SO ₄ ²⁻ (mg SO ₄ ²⁻ L ⁻¹)	10	9.6	7.3	6.8	50	20.3	8.1	7.8	8.2
Alkalinity (mg CaCO ₃ L ⁻¹)	0	0.2	2.3	0	0	15.8	0	0	0
Gran Alk (mg CaCO ₃ L ⁻¹)	0.5	0.3	2.6	2.7	-1.9	18.8	-0.2	-0.1	-0.1
NH ₄ ⁺ (mg N L ⁻¹)	0.025	0.022	0.002	0.002	0.005	0.011	0.092	0.077	0.070
NO ₃ ⁻ (mg N L ⁻¹)	0.09	0.08	0.04	0.01	0.11	0.21	0.13	0.13	0.13
PO ₄ ³⁻ (mg P L ⁻¹)	0.002	0.003	0.003	0.003	0.002	0.008	0.002	0.003	0.002
Silicate (mg SiL ⁻¹)	0.02	0.02	0.03	0.04	0.11	0.05	0.05	0.04	0.06
Total N (mg N L ⁻¹)	0.26	0.23	0.19	0.16	0.2	0.42	0.4	0.43	0.41
Total P (mg P L ⁻¹)	0.019	0.018	0.01	0.007	0.027	0.004	0.014	0.013	0.013
Chlorophyll (µg L ⁻¹)	0.904	0.948	2.682	2.146	0.675	12.084	1.146	1.212	1.058
Color (TCU)	25	20	17.5	15	5	20	25	25	25
DOC (mg C L ⁻¹)	3	2.9	3.1	3	1	2.9	3.9	3.9	3.7

Table A-9. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Spider (48)	Spider (49)	Spruce Hill (34)	Susie (19)	Susie (20)	Third (8)	Third (7)	Thomas (38)	Thomas (39)
Temperature (C)	8.5	8	6.7	6.8	7	6.2	6.2	7.5	7.5
Secchi depth (m)	5	3.5	2	2.75	2.5	2.75	3.5	4.3	4
pH (NSDOE)	5.03	4.76	4.66	4.78	4.76	6.29	6.06	6.46	6.23
pH (EC)	5	4.8	4.7	4.8	4.8	6.8	6.8	6.9	6.6
Conductivity (μS)	29.2	30.9	33.7	53.6	59.0	84.5	85.2	138.1	129.6
Theo. Conductivity	28	30	33	53	57	84	85	136	128
Na (mg L^{-1})	2.2	2.2	2.9	6.1	6.7	9.5	9.5	17.4	16.8
Ca (mg L^{-1})	1.09	0.952	0.521	1.36	1.48	4.02	4.04	5.46	4.51
Mg (mg L^{-1})	0.46	0.46	0.43	0.5	0.53	0.81	0.83	0.88	0.79
K (mg L^{-1})	0.2	0.3	0.3	0.4	0.4	0.7	0.9	0.9	0.7
Al (mg L^{-1})	0.199	0.206	0.319	0.292	0.27	0.062	0.061	0.059	0.15
Cl (mg L^{-1})	3.4	3.4	5.0	9.9	11.0	15.9	16.0	28.2	27.9
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{L}^{-1}$)	5.3	5.3	3.7	4.6	4.6	7.7	7.9	9.2	9.1
Alkalinity ($\text{mg CaCO}_3 \text{L}^{-1}$)	0	0	0	0	0	3.8	3.7	6.5	3.3
Gran Alk ($\text{mg CaCO}_3 \text{L}^{-1}$)	-0.1	-0.4	-0.5	-0.5	-0.4	4	4.8	6.8	3.5
NH_4^+ (mg N L^{-1})	0.010	0.014	0.022	0.004	0.004	0.002	0.000	0.004	0.009
NO_3^- (mg N L^{-1})	0.01	0.01	0.05	0.04	0.03	0.04	0.03	0.14	0.14
PO_4^{3-} (mg P L^{-1})	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002
Silicate (mg Si L^{-1})	0.03	0.04	0.04	0.02	0.01	0.07	0.07	0.17	0.07
Total N (mg L^{-1})	0.12	0.15	0.21	0.16	0.16	0.2	0.21	0.26	0.3
Total P (mg L^{-1})	0.011	0.012	0.009	0.012	0.014	0.01	0.01	0.014	0.009
Chlorophyll ($\mu\text{g L}^{-1}$)	0.568	0.661	1.014	1.102	0.904	3.219	4.388	1.565	1.631
Color (TCU)	15	25	35	25	30	10	10	17.5	17.5
DOC (mg C L^{-1})	2.7	3.7	3.9	4.1	3.9	2.8	2.8	2.8	2.9

Table A-10. Data for individual lake samples collected on April 16, 1991. Number in brackets after lake name is the location in Figure 1; R indicates replicate sample; B, Secchi disk hit bottom while still visible.

	Topsail (74)	Whimsical (83)	William (40)	William (41)	William (42)	Williams (31)
Temperature (C)	6	8.3	7	7	7.5	7.1
Secchi depth (m)	5.25	3.2	4	4.5	4.5	4.5
pH (NSDOE)	6.33	6.90	6.52	6.50	6.42	6.37
pH (EC)	6.7	7.3	6.9	7	6.9	6.3
Conductivity (μS)	39.7	763	132.9	133.1	130.1	176
Theo. Conductivity	40	834	132	134	128	187
Na (mg L ⁻¹)	3.4	114	16.8	16.6	16.2	28.3
Ca (mg L ⁻¹)	2.77	24.5	5.52	5.53	5.32	4.8
Mg (mg L ⁻¹)	0.49	2.87	0.9	0.91	0.89	0.95
K (mg L ⁻¹)	0.3	2.7	0.9	0.9	0.9	0.9
Al (mg L ⁻¹)	0.225	0.183	0.067	0.075	0.067	0.19
Cl (mg L ⁻¹)	5.5	197.0	26.8	27.3	26.1	41.2
SO ₄ ²⁻ (mg SO ₄ ²⁻ L ⁻¹)	5.8	52	9.4	10	9.2	12.7
Alkalinity (mg CaCO ₃ L ⁻¹)	2.7	11.3	6.4	6.4	5.9	2
Gran Alk (mg CaCO ₃ L ⁻¹)	3	14.1	6.7	6.6	6.2	2
NH ₄ ⁺ (mg N L ⁻¹)	0.008	0.014	0.004	0.012	0.018	0.009
NO ₃ ⁻ (mg N L ⁻¹)	0.04	0.48	0.15	0.15	0.14	0.17
PO ₄ ³⁻ (mg P L ⁻¹)	0.002	0.003	0.002	0.002	0.002	0.002
Silicate (mg Si L ⁻¹)	0.11	0.13	0.15	0.18	0.26	0.03
Total N (mg L ⁻¹)	0.17	0.64	0.31	0.3	0.28	0.3
Total P (mg L ⁻¹)	0.014	0.016	0.013	0.012	0.012	0.012
Chlorophyll (ug L ⁻¹)	0.882	1.168	1.212	1.499	1.278	0.727
Color (TCU)	12.5	7.5	15	17.5	15	15
DOC (mg C L ⁻¹)	2.4	2	3.1	3.1	2.8	2.9

APPENDIX B. DATA COLLECTED IN 1980

These data can be obtained on disk in a QuattroPro spreadsheet from P.D. Keizer.

Table B-1. Data for individual lake samples collected on April 14, 1980. Only average values for each lake are listed. The complete data can be found in Gordon et al. 1981.

	B. Albro	Banook	Bayers	Bell	Bissett	Charles	Chocolate	Colbar t	Cranberry
pH	6.82	6.97	4.63	5.81	6.98	6.48	5.33	4.87	6.81
Conductivity (μS)	105	1962	148.5	38	241.8	82.4	346	108.8	101.8
Theo. Conductivity	137	229	176	42	306	95	453	147	140
Na (mg L^{-1})	20	31.5	24	4.6	40	13	70	21	15
Ca (mg L^{-1})	5.2	11	3.2	1.8	12	4	12.4	3.4	10.6
Mg (mg L^{-1})	1	0.2	1.4	1	1.9	1.2	2	1	1.7
K (mg L^{-1})	0.7	1.2	1	0.6	2	0.8	1.5	0.8	1.5
Cl (mg L^{-1})	32	55	44	8.3	77	20.5	113	36	27
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{L}^{-1}$)	12.4	19.2	14.1	8.4	19.1	12.0	34.0	11.9	17.0
Alkalinity ($\text{mg CaCO}_3 \text{L}^{-1}$)	1.52	3.62	0.02	0.48	4.674	1.134	0.06	0.02	4.8
NH_3 (mg N L^{-1})	0.04	0.02	0.01	0.02	0.05	0.01	0.09	0.02	0.11
NO_3^- (mg N L^{-1})	0.04	0.16	0.05	0.02	0.12	0.16	0.22	0.06	0.3
PO_4^{3-} (mg P L^{-1})	0.001	0.004	0.002	0.002	0.004	0.002	0.001	0.001	0.001
Silicate (mg Si L^{-1})	0.04	0.33	0.48	0.06	0.19	0.15	0.74	1.21	0.14
Total N (mg N L^{-1})	0.17	0.4	0.15	0.16	0.55	0.38	0.39	0.25	0.61
Total P (mg P L^{-1})	0.004	0.005	0.007	0.009	0.007	0.006	0.002	0.005	0.001

Table B-2. Data for individual lake samples collected on April 14, 1980. Only average values for each lake are listed. The complete data can be found in Gordon et al. 1981.

	Lamont	L. Albro	Long	Loon	Major	Maynard	Micmac	Miller	Morris	Oathill
pH	6.58	6.77	4.6	6.7	4.8	6.97	6.88	5	6.84	7.02
Conductivity (μS)	33.2	109	74.2	108.2	30.9	212	159.2	71.6	151.5	280
Theo. Conductivity	35	154	89	131	31	304	202	86	178	390
Na (mg L^{-1})	3.8	22	12	17.5	3.4	42	27	11.5	24	53
Ca (mg L^{-1})	2.7	6.1	1.2	5.8	0.8	11.6	9.6	2.2	7.2	17.8
Mg (mg L^{-1})	0.6	1	0.8	0.7	0.5	2.4	1.4	0.8	1.5	2.7
K (mg L^{-1})	0.3	0.8	0.5	1	0.3	1.5	1	0.5	1.3	2.5
Cl (mg L^{-1})	6	36	20	30.5	5.1	75	47	20.3	41.7	91
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{L}^{-1}$)	7.4	13.4	9.5	14.7	6.2	17.4	17.2	9.9	16.7	28.5
Alkalinity ($\text{mg CaCO}_3 \text{L}^{-1}$)	0.12	1.87	0.02	1.14	0.026	3.68	2.816	0.026	2.654	7.2
NH_3 (mg N L^{-1})	0.01	0.05	0.01	0.02	0.01	0.05	0.01	0.04	0.21	0.08
NO_3^- (mg N L^{-1})	0.04	0.03	0.04	0.04	0.04	0.05	0.07	0.07	0.2	0.24
PO_4^{3-} (mg P L^{-1})	0.001	0.002	0.001	0.001	0.004	0.001	0.001	0.002	0.018	0.001
Silicate (mg Si L^{-1})	0.07	0.04	0.55	0.02	0.16	0.15	0.24	0.42	0.1	0.34
Total N (mg N L^{-1})	0.16	0.22	0.19	0.16	0.17	0.32	0.36	0.21	1.14	0.55
Total P (mg P L^{-1})	0.001	0.003	0.002	0.008	0.005	0.004	0.004	0.034	0.002	

Table B-3. Data for individual lake samples collected on April 14, 1980. Only average values for each lake are listed. The complete data can be found in Gordon et al. 1981.

	First	F. Chain	Fletcher	Fraser	Frenchman	Frog Pond	Governor	Grand	Kearny	Kinsac	Paper Mill
pH	6.97	4.48	6.27	4.8	4.64	6.8	5.84	6.2	5.6	6.08	5.7
Conductivity (μS)	219	189	70.3	34.5	31	426.5	97	56.2	49.5	39.2	47.5
Theo. Conductivity	295	215	80	40	32	516	124	58	60	41	59
Na (mg L^{-1})	40	30	10.7	4.7	2.3	73	18	5.7	8.4	4.8	8.1
Ca (mg L^{-1})	13.4	5.6	3.3	0.8	1.2	21.4	3.8	5.9	1.6	1.9	1.6
Mg (mg L^{-1})	1.7	1.9	0.8	0.5	0.6	2.3	1	0.7	0.7	0.7	0.7
K (mg L^{-1})	1.8	0.8	0.6	0.4	0.5	2.2	1	0.4	0.6	0.7	0.6
Cl (mg L^{-1})	70	49	18.2	7.8	3.8	125	29.5	9	14	8.1	13.7
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{L}^{-1}$)	20.6	23.1	9.5	6.1	8.3	38.0	12.3	14.7	6.6	6.7	6.6
Alkalinity ($\text{mg CaCO}_3 \text{L}^{-1}$)	5.214	0	0.688	0.02	0	5.2	0.6	0.61	0.28	0.74	0.26
NH_3 (mg N L^{-1})	0.03	0.02	0.02	0.02	0.01	0.01	0.27	0.01	0.02	0.03	0.01
NO_3^- (mg N L^{-1})	0.03	0.02	0.05	0.01	0.02	0.24	0.1	0.01	0.11	0.06	0.07
PO_4^{3-} (mg P L^{-1})	0.002	0.002	0.001	0.002	0.04	0.002	0.012	0.001	0.001	0.005	0.001
Silicate (mg Si L^{-1})	0.29	0.73	0.06	0.1	0.05	0.54	0.14	0.04	0.12	0.06	0.02
Total N (mg N L^{-1})	0.22	0.08	0.22	0.21	0.17	0.34	0.47	0.16	0.28	0.24	0.27
Total P (mg P L^{-1})	0.003	0.004	0.011	0.003	0.042	0.002	0.029	0.005	0.001	0.012	0.006

Table B-4. Data for individual lake samples collected on April 14, 1980. Only average values for each lake are listed. The complete data can be found in Gordon et al. 1981.

	Parr	Penhorn	Powder Mill	Ragged	Rocky	Russell	Sandy	Second	S. Chain	Settle
pH	4.76	7.2	6.68	4.64	6.74	6.81	4.9	6.28	4.51	7.02
Conductivity (μS)	47.5	253.5	83.5	25.6	111.9	247.5	58.9	43.1	231	200
Theo. Conductivity	54	348	106	28	145	325	68	52	267	249
Na (mg L^{-1})	6	46	14	2.6	19.4	47	8.4	5.7	38	33
Ca (mg L^{-1})	1.8	16.8	5.5	0.4	6.9	11.4	1.8	2.9	5.8	11.6
Mg (mg L^{-1})	0.8	1.9	0.9	0.4	1	1.7	0.9	0.8	1.7	1.9
K (mg L^{-1})	0.6	1.4	0.9	0.2	1.1	1.8	0.7	0.6	0.9	1.8
Cl (mg L^{-1})	10	84	23	4.5	33	80	14	11.2	66	58
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{L}^{-1}$)	10.0	18.6	8.8	4.6	11.5	19.3	11.8	6.1	20.7	19.2
Akalinity ($\text{mg CaCO}_3 \text{L}^{-1}$)	0.16	8.8	2.92	0.02	3.38	4.764	0.02	0.86	0	4.4
NH_3 (mg N L^{-1})	0.04	0.05	0.01	0.03	0.02	0.06	0.02	0.02	0.01	0.08
NO_3^- (mg N L^{-1})	0.04	0.01	0.04	0.07	0.02	0.04	0.05	0.02	0.04	0.01
PO_4^{3-} (mg P L^{-1})	0.004	0.001	0.001	0.002	0.008	0.002	0.004	0.002	0.002	0.002
Silicate (mg Si L^{-1})	1.04	0.06	0.16	0.09	0.24	0.12	0.54	0.02	1.45	0.11
Total N (mg N L^{-1})	0.26	0.23	0.22	0.19	0.18	0.33	0.24	0.2	0.15	0.3
Total P (mg P L^{-1})	0.007	0.001	0.005	0.004	0.002	0.022	0.007	0.014	0.002	0.003

Table B-5. Data for individual lake samples collected on April 14, 1980. Only average values for each lake are listed. The complete data can be found in Gordon et al. 1981.

	Soldier	Spider	Spruce Hill	Susie	Third	Thomas	Topsall	Whimsical	William	Williams
pH	4.59	5.93	4.56	4.75	6.46	6.53	6.81	6.82	6.61	5.93
Conductivity (μS)	45	26.6	29.3	27.1	49.4	77.2	36.9	376	71.8	136
Theo. Conductivity	47	21	33	30	60	91	36	472	84	179
Na (mg L^{-1})	4.6	2.5	3.2	3	7	12.8	3.7	63	11	26
Ca (mg L^{-1})	1.1	0.8	0.3	0.5	3.2	3.9	2.8	24.4	3.8	4.2
Mg (mg L^{-1})	0.7	0.5	0.5	0.4	0.8	0.9	0.6	2.6	0.9	1.1
K (mg L^{-1})	0.3	0.2	0.2	0.3	0.6	0.6	0.4	2.7	0.7	1
Cl (mg L^{-1})	7.7	3.9	5	5.2	12.9	20	6.1	108	18.4	46
SO_4^{2-} ($\text{mg SO}_4^{2-} \text{ L}^{-1}$)	10.3	5.7	5.3	5.2	6.5	9.5	7.0	43.0	9.5	14.0
Alkalinity ($\text{mg CaCO}_3 \text{ L}^{-1}$)	0.03	0.02	0.03	0.02	1.36	1.454	1.56	6.8	1.36	0.53
NH_3 (mg N L^{-1})	0.04	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.04
NO_3^- (mg N L^{-1})	0.05	0.02	0.04	0.02	0.01	0.04	0.06	0.35	0.03	0.1
PO_4^{3-} (mg P L^{-1})	0.006	0.002	0.001	0.002	0.002	0.006	0.002	0.002	0.002	0.003
Silicate (mg Si L^{-1})	0.18	0.2	0.07	0.24	0.08	0.1	0.1	1.02	0.09	0.05
Total N (mg N L^{-1})	0.23	0.16	0.2	0.18	0.16	0.22	0.1	0.64	0.23	0.34
Total P (mg P L^{-1})	0.011	0.004	0.006	0.001	0.006	0.004	0.01	0.003	0.004	0.011

APPENDIX C. ELEMENT DATA COLLECTED IN 1991

These data can be obtained on disk by contacting G.E.M. Hall.

Table C-1. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various elements in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Anderson (68)	B. Albro (79)	Banook (69)	Banook (R)	Banook (R)	Bayers (25)	Bell (82)	Bisnett (60)	Bisnett (61)
Al	10	400	39	44	61	26	46	11380	301	23
Tl	0.05	1.49	0.52	0.45	1.45	0.29	0.38	4.89	4.53	0.5
V	0.01	1.11	0.75	0.61	0.67	0.6	0.61	2.06	0.9	0.28
Mn	1	61	47	75	88	76	81	590	114	8
Fe	10	267	84	81	158	56	84	762	295	101
Co	0.005	0.265	0.081	0.082	0.083	0.075	0.091	31.544	0.295	0.045
Ni	0.1	1.293	1.06	1.843	5.052	1.258	1.722	84.694	2.333	1.194
Cu	0.1	0.7	1.2	1.9	2.4	1.9	2	5.5	0.7	3.8
Zn	0.1	8.8	8.1	11.2	10.6	9.7	11.9	194.2	7	7.7
Y	0.01	0.29	0.07	0.21	0.2	0.18	0.22	4.99	0.15	0.06
Cd	0.01	0.12	0.04	0.06	0.09	0.08	0.07	0.63	0.05	0.18
In	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
La	0.01	0.68	0.13	0.53	0.49	0.49	0.63	3.86	0.32	0.14
Ce	0.01	0.57	0.12	0.32	0.39	0.29	0.34	5.97	0.43	0.07
Pr	0.005	0.101	0.024	0.081	0.094	0.078	0.086	0.624	0.067	0.015
Nd	0.01	0.38	0.09	0.32	0.36	0.3	0.32	2.24	0.24	0.07
Sm	0.005	0.059	0.014	0.051	0.055	0.047	0.055	0.454	0.041	0.014
Eu	0.001	0.014	0.004	0.012	0.013	0.012	0.013	0.157	0.01	0.004
Tb	0.001	0.007	0.002	0.006	0.008	0.005	0.006	0.109	0.006	0.002
Gd	0.005	0.062	0.02	0.052	0.087	0.049	0.067	0.658	0.063	0.015
Dy	0.005	0.04	0.011	0.029	0.032	0.025	0.031	0.653	0.027	0.01
Ho	0.001	0.009	0.002	0.006	0.007	0.006	0.007	0.142	0.005	0.002
Er	0.001	0.024	0.007	0.015	0.022	0.015	0.017	0.39	0.017	0.006
Tm	0.001	0.003	<0.001	0.002	0.002	0.002	0.002	0.054	0.002	<0.001
Yb	0.001	0.019	0.005	0.013	0.013	0.01	0.013	0.294	0.012	0.006
Lu	0.001	0.002	<0.001	0.002	0.002	0.002	0.002	0.038	0.002	<0.001
Pb	0.02	1.11	0.3	0.29	1.52	0.55	0.42	3.79	0.47	0.66
As	0.1	0.3	2.3	2.2	2.1	2	0.6	0.3	0.2	0.2
U	0.005	0.01	0.013	0.067	0.057	0.124	0.06	1.218	0.016	0.08
										0.101

Table C-2. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various metals in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Charles (56)	Charles (57)	Chocolate (82)	Colbart (32)	Cranberry (80)	First (71)	First (72)	First (R)	First (R)	First Chain (27)
Al	10	160	127	2938	197	34	65	106	64	25	2927
Tl	0.05	3.3	0.75	4.57	0.61	0.57	2.16	0.83	1.63	0.52	1.06
V	0.01	0.94	0.56	1.87	1.24	0.29	0.45	0.3	0.35	0.19	0.54
Mn	1	96	90	349	24	23	41	34	33	35	279
Fe	10	389	180	1099	120	70	494	149	352	210	257
Co	0.005	0.223	0.185	10.246	0.364	0.049	0.107	0.065	0.077	0.061	11.2866
Ni	0.1	1.97	1.523	25.302	1.86	1.441	1.638	1.809	1.293	1.536	27.431
Cu	0.1	2.4	2.1	6.1	2.7	1.6	1.7	1.3	1.3	1.8	4.9
Zn	0.1	8.2	9	95.1	20.1	7.5	6.9	3.6	4.7	5.9	83.9
Y	0.01	0.32	0.19	1.9	0.15	0.07	0.12	0.09	0.07	0.07	1.93
Cd	0.01	0.34	0.48	0.3	0.1	0.05	0.04	0.03	0.03	0.06	0.46
In	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
La	0.01	0.75	0.51	1.99	0.17	0.11	0.2	0.11	0.1	0.16	2.13
Ce	0.01	0.78	0.46	2.92	0.31	0.07	0.27	0.12	0.13	0.1	3.25
Pr	0.005	0.137	0.085	0.355	0.043	0.02	0.044	0.024	0.022	0.018	0.381
Nd	0.01	0.55	0.33	1.33	0.15	0.08	0.19	0.1	0.09	0.08	1.41
Sm	0.005	0.088	0.053	0.224	0.033	0.014	0.046	0.022	0.02	0.015	0.274
Eu	0.001	0.021	0.013	0.079	0.009	0.003	0.01	0.006	0.005	0.004	0.096
Tb	0.001	0.01	0.005	0.042	0.006	0.002	0.006	0.004	0.003	0.002	0.054
Gd	0.005	0.095	0.062	0.264	0.05	0.021	0.055	0.038	0.027	0.019	0.41
Dy	0.005	0.05	0.027	0.231	0.031	0.009	0.029	0.016	0.013	0.01	0.29
Ho	0.001	0.009	0.006	0.05	0.007	0.002	0.005	0.003	0.003	0.002	0.061
Er	0.001	0.023	0.015	0.137	0.02	0.007	0.015	0.011	0.008	0.006	0.177
Tm	0.001	0.003	0.002	0.02	0.003	<0.001	0.002	0.001	<0.001	<0.001	0.024
Yb	0.001	0.018	0.013	0.111	0.016	0.006	0.013	0.009	0.006	0.005	0.135
Lu	0.001	0.003	0.002	0.018	0.002	<0.001	0.002	0.002	<0.001	0.001	0.018
Pb	0.02	1.24	0.75	3.8	1.94	0.34	3.59	0.27	1	1.07	3.6
As		6.4	6.3	0.5	0.1	0.3	0.5	0.3	0.4	0.1	0.1
U	0.005	0.079	0.036	0.34	0.181	0.021	0.074	0.064	0.059	0.061	0.652

Table C-3. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various elements in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Fletcher (35)	Fletcher (36)	Fletcher (37)	Fraser (23)	Fraser (24)	Frenchman (67)	Frog Pond (84)	Governor (21)	Governor (22)
Al	10	117	88	127	308	341	149	839	2426	2513
Tl	0.05	1.02	0.69	1.52	0.69	2.72	2.14	6.53	1.51	3.05
V	0.01	0.37	0.23	0.26	0.62	0.62	2.95	2.16	0.48	0.76
Mn	1	74	67	70	69	68	61	38	209	218
Fe	10	142	103	150	168	201	199	1265	361	409
Co	0.005	0.267	0.323	0.309	0.53	0.696	0.141	0.779	8.053	8.069
Ni	0.1	1.556	1.524	1.674	1.686	1.862	3.339	4.306	21.746	21.721
Cu	0.1	1.3	1	1.2	1.7	1.1	1.3	2.2	5	4.1
Zn	0.1	8.3	12.6	10.4	14.1	16.5	18.3	20.6	84.3	82.5
Y	0.01	0.15	0.15	0.17	0.15	0.17	0.16	0.31	1.45	1.38
Cd	0.01	0.48	0.28	0.22	0.08	0.1	0.3	0.06	0.35	0.32
In	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
La	0.01	0.49	0.32	0.42	0.13	0.14	0.31	0.28	0.99	0.95
Ce	0.01	0.6	0.43	0.52	0.24	0.26	0.24	0.43	1.64	1.6
Pr	0.005	0.085	0.065	0.081	0.033	0.034	0.057	0.063	0.189	0.175
Nd	0.01	0.33	0.24	0.31	0.13	0.14	0.2	0.25	0.73	0.69
Sm	0.005	0.053	0.045	0.054	0.027	0.03	0.032	0.043	0.151	0.136
Eu	0.001	0.013	0.012	0.014	0.008	0.009	0.007	0.012	0.05	0.044
Tb	0.001	0.006	0.005	0.008	0.005	0.005	0.004	0.007	0.032	0.031
Gd	0.005	0.069	0.063	0.09	0.036	0.043	0.037	0.055	0.233	0.209
Dy	0.005	0.032	0.029	0.037	0.025	0.026	0.024	0.035	0.194	0.175
Ho	0.001	0.007	0.006	0.007	0.005	0.005	0.005	0.008	0.039	0.036
Er	0.001	0.019	0.018	0.019	0.014	0.016	0.013	0.025	0.109	0.109
Tm	0.001	0.002	0.003	0.003	0.002	0.002	0.002	0.004	0.015	0.014
Yb	0.001	0.013	0.013	0.013	0.011	0.013	0.012	0.025	0.086	0.075
Lu	0.001	0.002	0.002	0.002	0.001	0.002	0.001	0.004	0.012	0.01
Pb	0.02	1.47	0.86	1	0.97	0.86	1.38	0.77	2.12	1.55
As		0.7	0.8	0.7	0.2	0.2	0.3	0.3	0.2	0.2
U	0.005	0.042	0.038	0.04	0.091	0.079	0.012	0.056	0.486	0.431

Table C-4. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various metals in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Grand (2)	Grand (1)	Grand (3)	Kearny (17)	Kearny (18)	Kinsac (4)	Kinsac (5)	Kinsac (6)	L. Albion (78)	Lamont (73)
Al	10	76	86	95	1193	404	192	221	304	83	370
Tl	0.05	0.19	0.69	0.77	6.49	0.76	0.68	1.08	2.82	1.61	2.18
V	0.01	0.14	0.29	0.12	2.66	0.81	0.23	0.45	0.52	1.89	0.94
Mn	1	17	23	18	69	59	107	77	106	31	45
Fe	10	45	96	54	1002	116	121	197	339	395	256
Co	0.005	0.085	0.215	0.085	0.948	0.646	0.529	0.412	0.585	0.098	0.274
Ni	0.1	3.795	6.439	1.789	5.264	2.821	3.522	2.807	8.324	1.161	1.579
Cu	0.1	2.8	5.6	1.2	2	1.8	1.5	7	2.9	1.6	1.3
Zn	0.1	15	30.7	14.1	17.4	13.1	21.1	11.3	21	10	5.6
Y	0.01	0.07	0.11	0.08	0.39	0.34	0.16	0.11	0.22	0.09	0.22
Cd	0.01	0.19	0.3	0.06	0.11	0.09	0.11	0.08	0.29	0.04	0.05
In	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
La	0.01	0.12	0.12	0.15	0.5	0.39	0.21	0.2	0.36	0.18	0.47
Ce	0.01	0.15	0.16	0.2	0.85	0.5	0.3	0.36	0.55	0.23	0.56
Pr	0.005	0.028	0.028	0.035	0.113	0.071	0.043	0.045	0.076	0.041	0.082
Nd	0.01	0.11	0.11	0.14	0.44	0.28	0.17	0.17	0.3	0.16	0.3
Sm	0.005	0.022	0.021	0.024	0.078	0.052	0.034	0.036	0.058	0.03	0.049
Eu	0.001	0.006	0.006	0.019	0.013	0.01	0.008	0.014	0.007	0.011	
Tb	0.001	0.004	0.003	0.004	0.012	0.009	0.005	0.008	0.004	0.007	
Gd	0.005	0.029	0.023	0.03	0.11	0.083	0.043	0.036	0.057	0.042	0.063
Dy	0.005	0.014	0.015	0.016	0.059	0.045	0.023	0.021	0.037	0.015	0.03
Ho	0.001	0.003	0.003	0.003	0.012	0.009	0.005	0.004	0.007	0.003	0.006
Er	0.001	0.008	0.008	0.009	0.037	0.03	0.014	0.011	0.021	0.009	0.02
Tm	0.001	0.001	0.001	0.005	0.004	0.002	0.002	0.002	0.001	0.002	
Yb	0.001	0.006	0.007	0.009	0.029	0.022	0.011	0.009	0.012	0.007	0.014
Lu	0.001	<0.001	<0.001	0.001	0.004	0.003	0.001	0.001	0.002	0.001	0.002
Pb	0.02	1.51	1.85	0.64	4.22	5.25	0.91	1.36	1.18	4.47	0.77
As	0.2	0.2	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.9	0.3
U	0.005	0.013	0.016	0.018	0.08	0.054	0.016	0.016	0.03	0.034	0.074

Table C-5. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various metals in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Long (29)	Long (28)	Long (30)	Loon (54)	Loon (55)	Major (R)	Major (53)	Major (50)	Major (51)	Major (52)
Al	10	599	896	2559	148	86	236	282	375	366	244
Tl	0.05	1.12	2.79	0.95	3.09	2.82	2.29	1.94	0.65	5.62	1.29
V	0.01	0.77	2.16	0.79	0.81	1.12	1	1.28	1.44	1.5	1
Mn	1	138	135	134	88	83	65	68	64	63	62
Fe	10	217	842	203	254	387	183	239	224	393	131
Co	0.005	2.711	3.069	3.045	0.204	0.198	0.292	0.298	0.35	0.373	0.308
Ni	0.1	6.467	9.981	7.325	1.553	1.66	0.937	0.999	1.023	1.389	1.404
Cu	0.1	1.5	4.8	7.9	2.4	2.7	1.6	1.6	2	1.9	4
Zn	0.1	26.8	31.6	28.9	8.7	8.8	8.7	10.1	6	6.7	8.8
Y	0.01	0.56	0.75	0.72	0.21	0.11	0.14	0.17	0.19	0.22	0.15
Cd	0.01	0.11	0.11	0.43	0.34	0.91	0.17	0.07	0.1	0.12	0.38
In	0.0001	<0.001	0.001	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001
La	0.01	0.65	0.93	0.84	0.52	0.28	0.45	0.51	0.41	0.51	0.34
Ce	0.01	1.13	1.64	1.38	0.59	0.28	0.48	0.57	0.49	0.69	0.43
Pr	0.005	0.125	0.201	0.157	0.097	0.044	0.062	0.069	0.068	0.092	0.061
Nd	0.01	0.46	0.73	0.58	0.38	0.18	0.25	0.25	0.24	0.38	0.23
Sm	0.005	0.096	0.134	0.109	0.064	0.032	0.046	0.048	0.044	0.065	0.043
Eu	0.001	0.028	0.036	0.033	0.014	0.008	0.01	0.011	0.011	0.015	0.009
Tb	0.001	0.02	0.024	0.021	0.007	0.004	0.006	0.006	0.006	0.008	0.005
Gd	0.005	0.139	0.186	0.153	0.07	0.034	0.067	0.054	0.059	0.09	0.057
Dy	0.005	0.097	0.126	0.106	0.034	0.021	0.03	0.032	0.032	0.04	0.029
Ho	0.001	0.022	0.03	0.025	0.006	0.004	0.006	0.007	0.007	0.008	0.006
Er	0.001	0.063	0.082	0.071	0.017	0.01	0.017	0.019	0.018	0.022	0.015
Tm	0.001	0.008	0.011	0.01	0.002	0.002	0.002	0.002	0.003	0.003	0.002
Yb	0.001	0.051	0.063	0.058	0.014	0.01	0.012	0.012	0.014	0.019	0.011
Lu	0.001	0.007	0.009	0.008	0.002	0.002	0.002	0.002	0.002	0.003	0.002
Pb	0.02	1.91	4.66	5.06	1.79	10.28	1.91	1.12	2.82	2.15	2.24
As	0.2	0.4	0.3	0.3	0.3	0.3	0.2	0.1	0.4	0.1	0.1
U	0.005	0.196	0.251	0.066	0.024	0.079	0.12	0.077	0.115	0.08	0.08

Table C-6. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various elements in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Maynard (77)	Milemac (58)	Milemac (59)	Miller (46)	Miller (47)	Morris (64)	Morris (63)	Morris (62)
Al	10	169	97	41	187	184	177	207	142
Tl	0.05	6.95	2.59	0.26	1.18	0.95	2.72	0.95	1.6
V	0.01	0.99	0.96	0.62	0.2	0.23	0.38	0.84	0.82
Mn	1	69	72	65	130	127	118	96	137
Fe	10	569	220	59	127	141	236	278	192
Co	0.005	0.112	0.143	0.106	0.677	0.687	0.131	0.161	0.146
Ni	0.1	1.861	4.095	1.547	2.299	2.609	2.282	3.008	2.419
Cu	0.1	1.9	3.1	2.5	1.2	1.5	2.2	1.9	2.2
Zn	0.1	22.5	20.2	8.4	10.2	12.6	8.4	9.9	10.7
Y	0.01	0.12	0.21	0.16	0.17	0.21	0.17	0.18	0.18
Cd	0.01	0.08	0.47	0.21	0.15	0.2	0.15	0.3	0.19
In	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
La	0.01	0.22	0.47	0.4	0.46	0.44	0.43	0.38	0.36
Ce	0.01	0.37	0.41	0.27	0.67	0.79	0.46	0.45	0.33
Pr	0.005	0.057	0.085	0.064	0.08	0.098	0.07	0.08	0.067
Nd	0.01	0.22	0.32	0.26	0.3	0.38	0.28	0.31	0.27
Sm	0.005	0.04	0.054	0.043	0.058	0.075	0.052	0.053	0.051
Eu	0.001	0.009	0.013	0.01	0.015	0.019	0.013	0.014	0.012
Tb	0.001	0.005	0.006	0.005	0.01	0.011	0.006	0.007	0.006
Gd	0.005	0.056	0.066	0.054	0.086	0.136	0.075	0.07	0.061
Dy	0.005	0.022	0.032	0.026	0.039	0.047	0.029	0.032	0.033
Ho	0.001	0.004	0.007	0.005	0.007	0.009	0.007	0.006	0.007
Er	0.001	0.014	0.016	0.014	0.02	0.029	0.017	0.017	0.017
Tm	0.001	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.003
Yb	0.001	0.01	0.015	0.012	0.014	0.021	0.015	0.014	0.016
Lu	0.001	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002
Pb	0.02	0.43	1.15	0.67	1.45	0.93	1	1.42	1.2
As	0.2	2.9	2.8	0.2	0.1	0.2	0.2	0.2	0.2
U	0.005	0.044	0.05	0.045	0.055	0.069	0.045	0.05	0.055

Table C-7. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various elements in lake water samples. Number in brackets after lake name is the location in Figure1; R indicates a replicate sample.

Metal	Detection Limit	Oathill (75)	Oathill (R)	Paper Mill (16)	Parr (33)	Pemhorn (76)	Parr (11)	Powder Mill (11)	Power Pond (85)
Al	10	58	46	21	403	183	64	63	680
Tl	0.05	1.16	1.16	0.46	0.83	1.06	1.39	0.56	4.18
V	0.01	0.46	0.56	0.45	0.8	0.91	0.45	0.21	1.16
Mn	1	71	74	77	54	16	27	17	107
Fe	10	115	128	62	148	126	68	81	310
Co	0.005	0.062	0.067	0.065	0.544	0.21	0.029	0.049	2.515
Ni	0.1	1.975	1.605	1.656	3.21	1.306	1.799	4.339	7.722
Cu	0.1	2.6	2.4	2.3	1.5	0.8	1.7	1.4	2.2
Zn	0.1	16.6	11.4	26.1	11.9	13.7	8.8	8.6	31.5
Y	0.01	0.14	0.12	0.1	0.33	0.12	0.06	0.11	0.57
Cd	0.01	0.09	0.07	0.08	0.11	0.06	0.06	0.08	0.12
In	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
La	0.01	0.18	0.15	0.12	0.37	0.11	0.07	0.13	0.6
Ce	0.01	0.13	0.12	0.09	0.48	0.21	0.06	0.13	1.02
Pr	0.005	0.036	0.03	0.024	0.069	0.028	0.015	0.027	0.123
Nd	0.01	0.14	0.12	0.1	0.28	0.11	0.06	0.11	0.48
Sm	0.005	0.028	0.023	0.018	0.052	0.023	0.01	0.023	0.085
Eu	0.001	0.007	0.006	0.005	0.013	0.005	0.003	0.006	0.021
Tb	0.001	0.004	0.004	0.003	0.009	0.003	0.002	0.004	0.015
Gd	0.005	0.032	0.034	0.022	0.081	0.029	0.013	0.031	0.141
Dy	0.005	0.017	0.017	0.013	0.043	0.022	0.007	0.014	0.075
Ho	0.001	0.004	0.004	0.003	0.009	0.004	0.002	0.003	0.017
Er	0.001	0.012	0.011	0.009	0.027	0.011	0.006	0.008	0.047
Tm	0.001	0.001	0.001	<0.001	0.004	0.001	<0.001	0.001	0.006
Yb	0.001	0.009	0.01	0.008	0.02	0.009	0.005	0.007	0.035
Lu	0.001	0.001	0.001	0.001	0.003	0.001	<0.001	<0.001	0.005
Pb	0.02	0.2	0.28	0.26	1.81	1.61	0.25	0.8	1.96
As	0.2	0.3	0.4	0.2	0	0.2	0.9	0.4	0.4
U	0.005	0.076	0.036	0.03	0.049	0.082	0.051	0.038	0.217

Table C-8. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various elements in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Rocky (13)	Rocky (12)	Russell (65)	Russell (66)	Sandy (14)	Sandy (15)	Second Chain	Second (9)	Second (10)	Settle (81)
Al	10	73	227	259	174	473	561	4883	63	92	62
Tl	0.05	1.17	1.31	1.72	1.26	0.92	2.77	3.98	0.79	0.44	0.97
V	0.01	0.37	0.72	0.9	0.81	0.41	0.92	1.34	0.33	0.2	0.34
Mn	1	8	17	658	658	196	188	338	17	37	108
Fe	10	118	228	217	201	175	418	711	116	100	185
Co	0.005	0.049	0.16	0.261	0.247	1.94	1.937	13.198	0.08	0.12	0.107
Ni	0.1	1.87	2.161	2.187	2.147	5.655	5.53	33.695	3.239	1.972	2.213
Cu	0.1	1.3	1.3	1.7	1.8	3.6	2	6.4	2.2	1.3	3
Zn	0.1	7.6	12.1	12.8	12	23.7	22.1	94.9	11.6	16.8	11.6
Y	0.01	0.11	0.19	0.14	0.12	0.49	0.46	2.59	0.09	0.13	0.23
Cd	0.01	0.07	0.05	0.27	0.24	0.14	0.13	0.37	0.15	0.08	0.07
In	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
La	0.01	0.17	0.2	0.29	0.27	0.69	0.65	2.53	0.1	0.18	0.28
Ce	0.01	0.16	0.21	0.3	0.29	1.03	1.03	4.23	0.14	0.26	0.27
Pr	0.005	0.033	0.04	0.052	0.052	0.142	0.138	0.531	0.026	0.048	0.065
Nd	0.01	0.13	0.16	0.21	0.2	0.55	0.55	2.01	0.11	0.2	0.26
Sm	0.005	0.023	0.028	0.032	0.033	0.101	0.1	0.415	0.026	0.044	0.051
Eu	0.001	0.006	0.007	0.008	0.009	0.024	0.025	0.137	0.006	0.011	0.014
Tb	0.001	0.003	0.004	0.005	0.005	0.016	0.016	0.075	0.004	0.007	0.008
Gd	0.005	0.028	0.035	0.035	0.045	0.129	0.144	0.598	0.027	0.054	0.068
Dy	0.005	0.015	0.024	0.021	0.02	0.076	0.07	0.436	0.015	0.028	0.033
Ho	0.001	0.003	0.005	0.005	0.005	0.015	0.015	0.09	0.003	0.005	0.007
Er	0.001	0.01	0.017	0.012	0.012	0.041	0.044	0.252	0.009	0.015	0.021
Tm	0.001	0.001	0.002	0.002	0.002	0.005	0.006	0.034	0.001	0.002	0.003
Yb	0.001	0.007	0.013	0.011	0.011	0.033	0.028	0.197	0.007	0.01	0.015
Lu	0.001	<0.001	0.002	0.002	0.002	0.004	0.004	0.028	<0.001	0.002	0.002
Pb	0.02	1.13	1.28	1.03	1.12	1.86	1.74	4.11	0.68	0.78	1.51
As	0.3	0.3	0.2	0.3	0.1	0.2	0.2	0.2	0.2	0.2	0.4
U	0.005	0.084	0.088	0.022	0.02	0.039	0.038	0.917	0.009	0.041	0.079

Table C-9. Concentrations (ppb or $\mu\text{g L}^{-1}$) of various metals in lake water samples. Number in brackets after lake name is the location in Figure1; R indicates a replicate sample.

Metal	Detection Limit	Soldier (43)	Soldier (44)	Soldier (45)	Spider (48)	Spider (49)	Spruce Hill (34)	Susie (19)	Susie (20)	Third (8)
Al	10	300	255	308	449	153	254	376	643	72
Ti	0.05	0.8	1.53	1.59	6.88	0.65	0.86	1.31	4.71	0.71
V	0.01	0.48	0.42	1.49	2.18	0.65	0.61	1.16	3.31	0.35
Mn	1	143	133	147	83	64	35	54	68	17
Fe	10	227	200	386	736	79	202	142	494	119
Co	0.006	0.975	0.929	1.077	0.467	0.153	0.232	0.467	0.583	0.062
Ni	0.1	2.863	5.934	5.799	1.424	1.295	1.345	1.56	2.315	3.236
Cu	0.1	1.4	4.7	2.2	0.9	1.4	1.1	1.9	3	1.6
Zn	0.1	12.9	58.9	14.7	8.9	8.5	10.5	10.9	13.8	20.4
Y	0.01	0.22	0.21	0.3	0.22	0.15	0.13	0.15	0.57	0.11
Cd	0.01	0.1	0.43	0.13	0.11	0.1	0.06	0.08	0.11	0.09
In	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
La	0.01	0.52	0.48	0.59	0.7	0.51	0.13	0.12	0.35	0.26
Ce	0.01	1.04	0.87	1.11	1.25	0.55	0.28	0.21	0.57	0.36
Pr	0.005	0.115	0.096	0.129	0.166	0.089	0.032	0.029	0.085	0.058
Nd	0.01	0.44	0.35	0.5	0.68	0.33	0.12	0.12	0.35	0.21
Sm	0.005	0.079	0.069	0.103	0.109	0.051	0.027	0.025	0.066	0.043
Eu	0.001	0.021	0.017	0.025	0.024	0.012	0.006	0.006	0.013	0.01
Tb	0.001	0.012	0.01	0.015	0.013	0.007	0.004	0.005	0.01	0.006
Gd	0.005	0.144	0.103	0.182	0.157	0.104	0.04	0.035	0.09	0.05
Dy	0.005	0.055	0.043	0.074	0.062	0.035	0.022	0.023	0.057	0.026
Ho	0.001	0.01	0.008	0.013	0.011	0.008	0.005	0.004	0.011	0.005
Er	0.001	0.026	0.018	0.036	0.029	0.023	0.013	0.013	0.032	0.012
Tm	0.001	0.003	0.003	0.004	0.004	0.003	0.002	0.002	0.005	0.002
Yb	0.001	0.018	0.016	0.028	0.023	0.015	0.011	0.011	0.026	0.007
Lu	0.001	0.003	0.002	0.004	0.003	0.002	0.001	0.001	0.004	0.001
Pb	0.02	1.4	1.81	6.68	3.06	1.57	1.26	1.01	3.89	0.5
As	0	0.1	0.3	0.6	0.1	0.2	0.1	0.1	0.7	0.2
U	0.005	0.086	0.062	0.14	0.049	0.009	0.052	0.057	0.241	0.046

Table C-10. Concentrations (ppb or mg L⁻¹) of various metals in lake water samples. Number in brackets after lake name is the location in Figure 1; R indicates a replicate sample.

Metal	Detection Limit	Third (7)	Thomas (38)	Thomas (39)	Topsail (74)	Whimsical (83)	William (40)	William (41)	William (42)	Williams (31)
Al	10	70	122	57	229	242	54	171	78	78
Tl	0.05	0.59	1.62	0.55	1.14	1.42	0.24	0.66	0.77	1.05
V	0.01	0.2	0.32	0.25	0.72	1.03	0.28	0.79	0.32	0.31
Mn	1	21	83	32	45	85	30	19	31	29
Fe	10	96	144	61	82	160	43	110	83	69
Co	0.005	0.051	0.357	0.071	0.245	2.049	0.071	0.324	0.075	0.071
Ni	0.1	2.872	1.753	0.9	1.243	16.432	0.702	2.01	0.981	0.737
Cu	0.1	2.3	1	0.8	3.1	4	1	1.5	0.9	0.6
Zn	0.1	21.1	8.6	7.5	12.2	35.7	12.3	16.2	8.9	6.9
Y	0.01	0.17	0.19	0.13	0.16	0.38	0.13	0.17	0.13	0.13
Cd	0.01	0.21	0.25	0.2	0.13	0.14	0.15	0.08	0.24	0.14
In	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
La	0.01	0.19	0.44	0.56	0.3	0.42	0.39	0.16	0.53	0.38
Ce	0.01	0.24	0.6	0.3	0.34	0.39	0.31	0.21	0.34	0.31
Pr	0.005	0.044	0.092	0.067	0.056	0.068	0.07	0.032	0.074	0.067
Nd	0.01	0.19	0.38	0.28	0.2	0.25	0.26	0.11	0.31	0.27
Sm	0.005	0.043	0.062	0.046	0.034	0.037	0.046	0.024	0.052	0.044
Eu	0.001	0.011	0.016	0.011	0.008	0.009	0.011	0.007	0.013	0.011
Tb	0.001	0.008	0.009	0.005	0.005	0.007	0.006	0.004	0.006	0.007
Gd	0.005	0.046	0.113	0.069	0.043	0.061	0.069	0.028	0.087	0.074
Dy	0.005	0.027	0.039	0.031	0.022	0.035	0.027	0.021	0.032	0.027
Ho	0.001	0.005	0.008	0.006	0.005	0.009	0.008	0.004	0.006	0.006
Er	0.001	0.013	0.022	0.016	0.014	0.029	0.015	0.013	0.019	0.019
Tm	0.001	0.002	0.003	0.002	0.002	0.004	0.002	0.002	0.002	0.002
Yb	0.001	0.009	0.017	0.01	0.012	0.027	0.011	0.011	0.012	0.011
Lu	0.001	0.001	0.002	0.002	0.001	0.004	0.002	0.002	0.002	0.002
Pb	0.02	2.14	0.65	2.38	0.94	1.03	1.72	1.38	2.15	1.16
As		0.2	0.7	1.7	0.2	0.3	1	0.2	0.9	0.9
U	0.005	0.046	0.044	0.025	0.053	0.098	0.021	0.092	0.023	0.022

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