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Ontario
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by

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PREFACE

The Sudbury Environmental Study (S.E.S.) was initiated in 1973 to investigate the causes of the acidification of lakes in the Sudbury area, to determine the geographical extent of lake acidification, to investigate chemical and biotic changes that might accompany lake acidification and to develop reclamation procedures for affected lakes of economic interest.

Input to the S.E.S. from the Limnology Unit of the Limnology and Toxicity Section has centred on detailing the chemistry and biology of very acidic (pH <4.6) lakes near Sudbury and studying the effects of ameliorating acid, heavy metal and low nutrient concentration stresses on these lakes with the hope of simulating recovery processes that would follow decreased rates of acid and metal input (Scheider *et al*. 1975, 1976a).

In 1975, intensive studies were initiated on Nelson Lake, a lake of intermediately acidic character (Scheider *et al*. 1976b). This report details changes in the chemistry and biology of Nelson Lake following a two-stage addition of base and carbonate.

ACKNOWLEDGEMENTS

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SUMMARY AND CONCLUSIONS

1. Calcium hydroxide and calcium carbonate additions raised the pH of Nelson Lake waters from 5.7 to 6.5.

2. Additions of base did not effect changes in Nelson Lake's temperature or oxygen structure, or nutrient content, but did result in decreases in water column concentrations of iron, manganese, aluminum and copper.

3. Phytoplankton and zooplankton communities of Nelson lake resembled those of non acidic shield lakes. Benthic and fish communities, in contrast, had apparently been affected by acidification. The increase in lake water pH to more natural levels had not changed phytoplankton, zooplankton or fish communities by the end of 1976.

INTRODUCTION

Many lakes in sparingly soluble bedrock basins in different parts of the world are being unnaturally acidified by atmospheric delivery of acidic materials to lake waters (Gorham 1955, Oden 1976). Most important of these acidic materials is sulphuric acid (Braekke 1976, Granat 1972, Galloway, Likens and Edgerton 1976) formed from the airborne oxidation and hydrolysis of pollutant sulphur dioxide (Brosset 1973). The existence of such abnormally acidic lakes has now been documented in Scandinavia (Wright and Gjessing 1976, Braekke 1976), in the United States (Schofield 1976) and in the region of Sudbury, Ontario (Gorham and Gordon 1960, Ont. Wat. Res. Comm. 1971, Conroy, Hawley, Keller and Lafrance 1975, Beamish, McFarlane, Van Loon and Lichwa 1975).

Acidic lakes near Sudbury and in other areas of the world are atypical of Precambrian Shield Lakes both chemically and biologically. Biotic changes which accompany acidification include reductions in the diversity and often in the biomass of all trophic levels (Bell 1971, Almer, Dickson, Ekström, Hörmström and Miller 1974, Sprules 1975a), most notably of fish stocks (Schofield 1976, Harvey 1975, Jensen and Snekvik 1972). In the Sudbury area, 23% of the 150 lakes surveyed by Conroy _et al_ (1975) had pH levels less than 5.5, a level at which damage to fish populations could be anticipated (Beamish and Harvey 1972, European Inland Fisheries Advisory Commission 1969). In fact, many lakes in the Sudbury area are now devoid of fish life (Ont. Wat. Res. Comm. 1971, Beamish and Harvey 1972). There is a clear need for the study of these lakes directed to an elucidation of the causes and rates of lake acidification, and of the biotic and chemical changes that accompany it.

In 1973, the Ministry of the Environment began an experimental program with the purpose of developing techniques to improve the water quality of acidified lakes in the Sudbury area to the point where reproducing fisheries could be sustained. Experiments completed by the end of 1975 had demonstrated that neutralization of acidic lakes by direct addition of calcium hydroxide and calcium carbonate elevated lake pH levels, reduced water column heavy metal burdens by up to 90%, and restored lake phytoplankton

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assemblages to those more typical of circumneutral Precambrian Shield Lakes (Scheider, Adamski and Paylor 1975; Scheider, Cave and Jones 1976). The duration of these effects was, however, not known.

In 1975, preliminary studies were conducted on a moderately acidic lake, Nelson Lake, to collect pretreatment data prior to a two-stage neutralization experiment (Scheider, Jones and Cave 1976).

The purpose of the 1976 Nelson lake work was twofold:

1) to extend knowledge of the influence of a gradual neutralization treatment on lake chemistry and biotic assemblages with the view to anticipating changes that might accompany reversion of the lake to pre-acidified conditions, and

2) to begin collection of lake, stream and precipitation data for eventual construction of an acid budget for a Sudbury area lake, a necessary tool for predicting the rate of acidification of the lake's waters, the speed with which natural recovery could occur following reduction of the acid input and the duration of any treatment effects.

NELSON LAKE AND ITS ENVIRONS

Scheider et al (1976b) described the geographic location, morphometry and bedrock and surficial geology of Nelson Lake and its watershed. Selected morphometric parameters (slightly changed from 1975 figures) are resummarized in Table 1.

TABLE 1. Selected morphometric parameters of Nelson Lake

Drainage Basin Area (excluding lake)	8.01×10^6 m^2
Lake Area	3.09×10^6 m^2
Lake Volume	35.9×10^6 m^3
Maximum Depth	50 m
Mean Depth	11.6 m
Water Replenishment Time	8.9 yr.
Area of Northwest Basin of Lake	0.276×10^6 m^2
Volume of Northwest Basin of Lake	2.73×10^6 m^3

METHODS

Scheider et al (1976b) found no significant differences among stations 1, 2, 3 in levels of most chemical parameters. Stations 2 and 3 were, in consequence, not sampled in 1976 for chemical parameters.

Sample collection, preservation and analytical techniques were identical to those of Scheider et al (1976b) and Powell (1976) with the following exceptions. Phytoplankton biomass was reported as fixed cell volume l^{-1} in 1976 rather than as a.s.u. ml^{-1}, the parameter used in 1975. The mesh size of the Patalas zooplankton trap was reduced from 76 µm to 30 µm on July 6, 1976, to facilitate capture of rotatoria. Station 5 was eliminated from 1976 zooplankton stations. Dry weight estimates of zooplankton and zoobenthic chironomidae biomasses were obtained following the techniques of Winberg (1971) for zooplankton. Three hundred hand picked intact, washed, chironomid organisms were randomly distributed into six groups. Weights were recorded following drying to constant weight (approximately twenty-four hours) at 60 ± 2° C in a Sartorius model 2400 oven and thirty minutes of dessication over silica gel.

Between May 26 and June 1, 1976, 1.8×10^4 kg of each of calcium hydroxide and calcium carbonate was added to Nelson Lake. The method of addition and reasons for selection of neutralizing agents have been described previously (Scheider et al 1975). Five percent of each additive was dispersed into the northwest basin, the remainder over the rest of the lake in amounts roughly proportional to the volumes of the lake's other basins.

Total additions from the 1975 and 1976 treatments were 6.8×10^4 kg of calcium hydroxide and 5.1×10^4 kg of calcium carbonate.

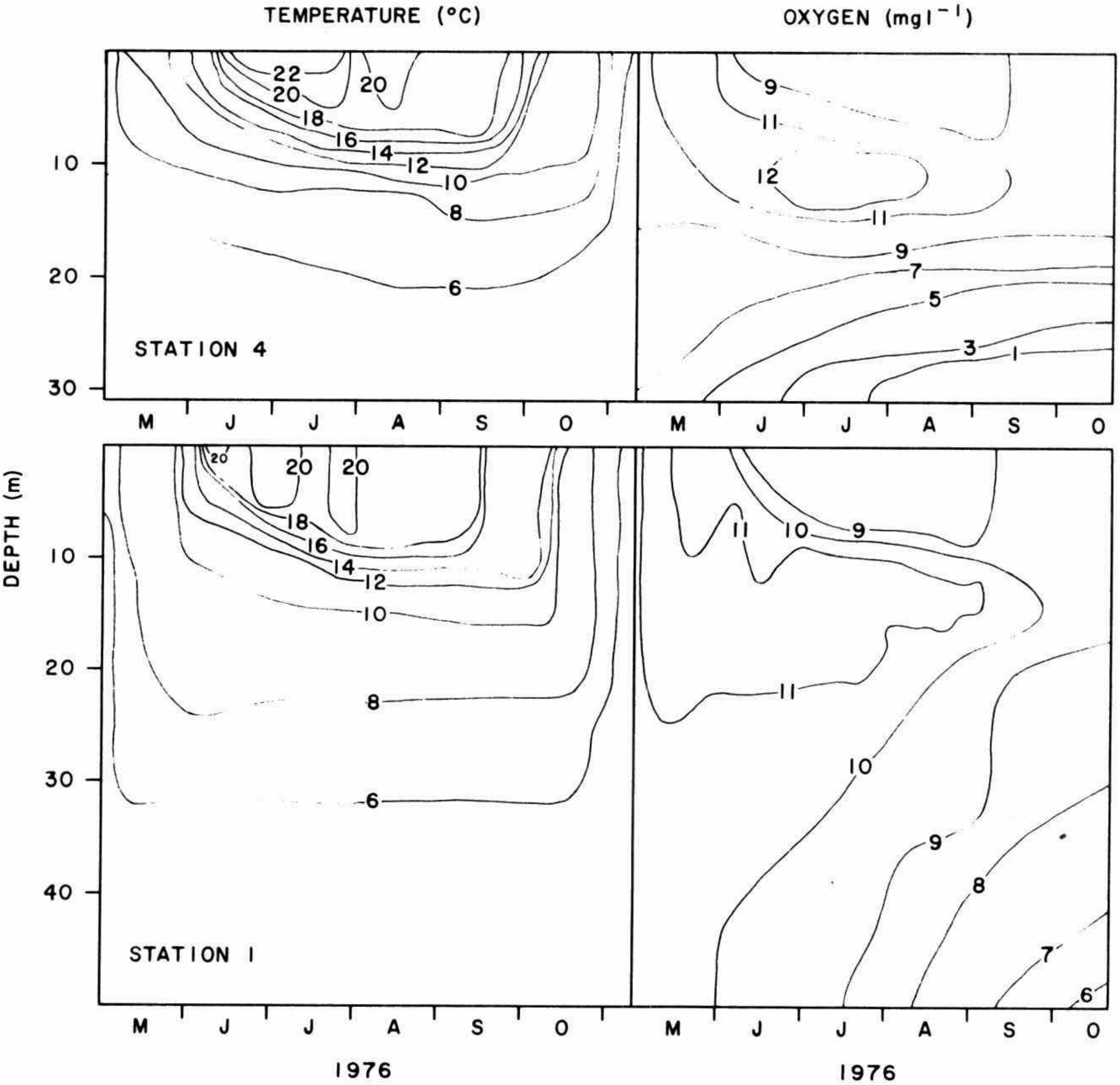

FIGURE 1 - ISOTHERM AND ISOPLETH DIAGRAMS FOR NELSON LAKE STATIONS 1 AND 4, 1977.

RESULTS AND DISCUSSION

a. Temperature and Oxygen

The temperature and oxygen regimes of Nelson Lake in 1976 were very similar to those of 1975 (Scheider et al 1976b).

Temperatures typical of large, deep, temperate lakes were observed in both sampled basins in 1976. The metalimnia were well established in early June, and migrated steadily downward before dissolution in October (Figure 1).

Late spring and summer oxygen profiles were of the positive heterograde type at both sampling stations in 1976. This phenomenon is frequently observed and has been attributed to localized photosynthetic activity in the metalimnion or upper hypolimnion of lakes with euphotic zones encompassing the metalimnion (Hutchinson 1957, Schindler 1971). Deep hypolimnetic waters of the northwest basin (Station 4) were depleted of oxygen by early August (Figure 1). The rate of oxygen consumption in the hypolimnion was not greater in this basin than at station 1 (Yan, Scheider and Dillon, unpublished manuscript). The oxygen depletion was the result of lower spring oxygen levels resulting from incomplete spring overturn (Figure 1).

Neutralization did not appreciably change the thermal or oxygen regimes of Nelson Lake.

b. Chemistry

Before treatment, Nelson Lake waters were soft, poorly buffered and moderately acidic (Table 2 and Scheider et al, 1976b). Typical bicarbonate : sulphate ratios for Precambrian Shield Lakes (Armstrong and Schindler 1971) range from 1:1 to greater than 10:1 (ratio of charge contribution from each ion to a unit volume of water). The ratio in Nelson lake waters was 0.16:1, and sulphate ions contributed 91% of the charge per unit volume attributable to anions. This unusually low ratio indicates that input of sulphuric acid to the lake was the cause of the low pre-treatment pH.

TABLE 2: Input data for prediction of change in calcium concentration after base and carbonate additions.

Input Data		Source
Lake volume, excluding northwest basin	32.2×10^6 m^3	Table 1
Total $Ca(OH)_2$ added, " " "	6.72×10^4 kg	This Report
Total $CaCO_3$ added, " " "	5.02×10^4 kg	This report
Ca content of $Ca(OH)_2$	48.7%	Scheider _et al_ (1975)
Ca content of $CaCO_3$	38.0%	" " "
1976 outflow volume	4.45×10^6 m^3	Figure 5

TABLE 3. Comparison between pre-base addition (1975) and post-base addition (1976) water chemistry of Nelson Lake, Station 1

	Parameter	1975[1] mean	1975[1] range	1976 mean	1976 range	t	p[2]	% Change[3]
	pH	5.7	5.5-6.0	6.5	6.3-7.0	11.5	<.001	
alk. (mg l^{-1} $CaCO_3$)		2.5	1.0-7.0	3.8	3.0-6.5	5.65	<.001	+49
Cond. (μ mhos cm^{-1} at 25°C)		46.4	45-54	49.2	46-54	4.08	<.001	+ 6
Hard. (mg l^{-1} $CaCO_3$)		13.8	13-21	16.8	15-19	5.68	<.001	+22
major ions (mg l^{-1})	SO_4	15.7	14-17	15.3	14-17	1.13		
	NO_3	0.02	<.01-.05	0.018	<.005-.015	1.13		
	Cl	0.44	0.4-0.5	0.48	0.4-0.6	1.14		
	NH_3	0.019	0.01-0.03	0.023	0.015-0.035	1.3		
	Ca	4.06	4-5	5.41	4-6	9.7	<.001	+33
	Mg	-	<1.0-1.0	-	<1.0-1.0			
	K	0.46	0.39-0.50	0.48	0.45-0.50	0.43		
	Na	0.96	0.9-1.1	0.96	0.9-1.1	0		
	Si	0.26	0.1-0.4	0.28	0.15-0.35	1.04		
	Kj-N	0.178	0.13-0.22	0.157	0.08-0.26	1.67		
	P-tot.	0.0047	0.001-0.008	.005	.001-.010	0.28		
heavy metals (μg l^{-1})	Cu	22	<10-35	13	3-20	2.36	<.01	-41
	Ni	16	12-17	10	4-20	1.67		
	Zn	18	13-26	16	4-30	0.7		
	Mn	63	59-70	18	10-30	11.2	<.001	-71
	Al	81	60-99	13	6-21	7.31	<.001	-84
	Fe	61	23-90	19	14-21	3.04	<.01	-69

[1] data from Scheider et al (1976b)

[2] only probabilities <0.1 reported.

[3] (+) indicates increase, (-) indicates decrease

It is readily calculated, by summing the calcium additions from the calcium carbonate and calcium hydroxide and reducing the total by the amount lost to the outlet (Table 2) that the treatment-associated calcium load to Nelson Lake was 4.49 x 10^4 kg. This amount distributed throughout the lake volume should have increased the calcium concentrations of the lake water by 1.35 mg l^{-1}, an amount equal to the measured change (Table 3). It can be concluded that all base added to the lake in 1976 was at least initially available for acid neutralization.

The neutralization of Nelson Lake resulted in an increase in main basin pH level from 5.7 to 6.5 (Table 2). The pH level increased from 6.4 to 7.0 (Figure 2) immediately after the 1976 treatment, an increase close to the predicted increase of 6.4 to 6.9 based on titration of raw lake water with calcium hydroxide, then decreased rapidly such that the 1976 post treatment pH (6.44) was not significantly different from the 1975 post treatment level (pH - 6.48). A decrease in lake pH following an initial increase after base additions has been previously observed (Scheider et al, 1975). It is probably related to an influx of strong acid to the lake, to buffering of the base by the added carbonate, or to increased rates of influx to the lake of atmospheric carbon dioxide. This last process would be favoured by the increased pH of the lake, and would lead to increased buffering capabilities.

The pH of the northwest basin increased from 5.75 to 6.2 after the 1976 base additions (Figure 2). Scheider et al (1976b) expected that mixing of treated waters of the main basins with those of the northwest basin would have led to a gradual elevation in pH of the northwest basin prior to its 1976 treatment. This expectation was not realized (Figure 2).

The treatment did not change the nutrient content of the lake but did cause slight but significant increases in calcium concentration (as discussed), alkalinity, conductivity and hardness (Table 3). Since 98% of the measured conductivity in 1976 was attributable to eight ions (listed in Table 4) and since, of these ions, the concentrations of only calcium and carbonate increased significantly from 1975 to 1976 (Table 4) it is reasonable to conclude that the increase in alkalinity, conductivity, hardness and calcium concentration were direct manifestations of calcium and carbonate additions.

Pre-treatment levels of ten heavy metals were presented by Scheider et al. 1976b). Values were at the low end of the range of levels found in Sudbury area lakes (Conroy et al. 1975). They were, however, several times greater than those of other oligotrophic Precambrian lakes in the Haliburton

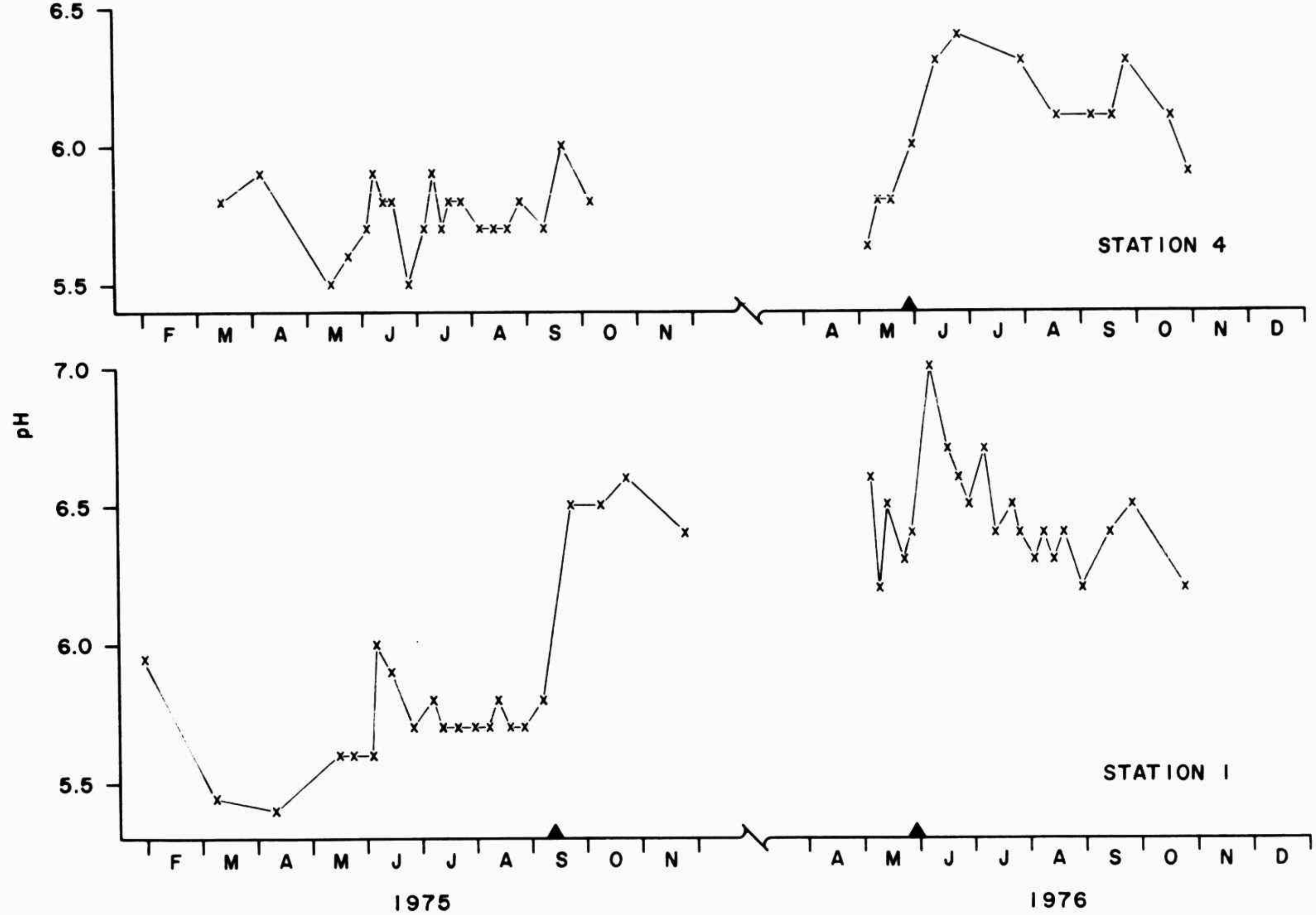

FIGURE 2 - pH LEVELS OF NELSON LAKE STATIONS I AND 4, 1975 AND 1976.
(▲ DATES OF CHEMICAL ADDITIONS).

TABLE 4. Major ion balance of Nelson Lake, 1975 and 1976

Cations	Concentration (μequ. l^{-1}) 1975	1976	Change[1]
Ca	204	268	+ 64
Mg	82	82	0
Na	43	42	- 1
K	13	12	- 1
Σ	342	404	+ 62
Anions			
CO_3	21	37	+ 16
SO_4	328	318	- 10
NO_3	1	1	0
Cl	12	14	+ 2
Σ	362	370	+ 8
Conductivity			
measured	46.4	49.2	
calculated[2]	44	48	

[1] (+) indicates increase from 1975 to 1976, (-) indicates decrease.

[2] Calculated as $\sum_{i=1}^{\eta} \lambda_i$ for all above ions

where $\lambda_i = c_i \left[\lambda o_i \quad (60.2 + 0.229\ \lambda o_i) \quad \frac{c_i}{1000}\right]$

λo_i equivalent conductance of ion_i

c_i concentration of ion_i in mg l^{-1}

area, 150 km to the southeast (Dillon et al. unpub. manuscript).

Neutralization significantly reduced water column levels of copper, manganese, aluminum and iron (Table 3), a pattern observed in previous studies (Scheider et al. 1975, 1976a) but one as yet not completely explicable. Decreases in metal solubility leading to precipitation of metals from the water column could not have been caused by changes in temperature or oxygen tension as these were not affected by neutralization, nor could decreases in levels of all metals be linked to pH dependent solubility changes (Norton 1976, Stumm and Morgan 1970). As the phytoplankton community remained essentially unchanged by treatments (to be discussed) it was unlikely that the observed decreases in metal levels could be explained by changes in biotic uptake rates. Reductions were most probably caused by simple physical transport to the lake sediments of metals loosely bound in particulate or colloidal form. This explanation suggests that the reduction in water column heavy metal levels may be only temporary (Stokes and Szokalo 1977). However, concentration of heavy metals in the water of lakes have not increased up to three years after treatment (Dillon et al. unpub. manuscript).

In summary, the addition of base did not change the nutrient content of Nelson Lake, but did result in increases in pH, alkalinity, conductivity and calcium concentration. These changes, and decreases in heavy metal levels, were direct manifestations of the treatment.

c. Biota

i. Phytoplankton - Biomass and Community Composition

According to the morphometric classification scheme devised for Precambrian lakes by Schindler and Holmgren (1971), Nelson Lake is a class 'A' lake. The maximum and weighted mean phytoplankton biomass of Nelson Lake were similar to lakes in northwestern Ontario of the same class (Kling and Holmgren 1972). Low biomass and chlorophyll a levels during the ice-free period of 1976 (Table 5) were indicative of the nutrient-poor status of the lake. The slightly higher biomass of the northwest basin was reflected in slightly greater chlorophyll a levels and shallower Secchi transparencies. Secchi disc depth at station 1 was 8.2 (5.5-11.0)m and at station 4 was 7.4 (5.5-10.0)m.

There were only minor differences in community structure between both sampled basins in 1976. Approximately half of the volumetric biomass in each basin was composed of bacillariophyceae with lesser and approximately equal contributions of chlorophyta, chrysophyceae and cryptophyceae (Table 4, Figure 3). In mid-summer, bacillariophyceae formed 50-70% of the biomass, most of this attributable to *Rhizosolenia eriensis*, a species commonly found in circumneutral shield lakes (Schindler and Holmgren 1971). *Tabellaria* sp. formed

TABLE 5. Summary of selected phytoplankton parameters of Nelson Lake, May to October, 1975 and 1976.

	1976		1975	
	Stn. 1	Stn. 4	Stn. 1	Stn. 4
mean total volume $ml\ m^{-3}$	469	745	410*	660*
maximum total volume $ml\ m^{-3}$	1050	1600		
chl <u>a</u> $mg\ m^{-3}$	1.2(0.6-1.7)†	1.9(0.9-2.9)	1.0(0.5-1.8)	1.2(0.5-2.4)
Mean volume (%)				
myxophyceae	1	1	2*	9*
dinophyceae	8	9	7*	5*
cryptophyceae	13	16	11*	9*
chrysophyceae	15	14	14*	22*
chlorophyceae	21	16	19*	19*
bacillariophyceae	42	44	47*	36*

*data from Scheider et al (1976b) converted from a.s.u. ml^{-1} to $ml\ m^{-3}$ following Nicholls (1977).

†Mean ranges in brackets

Figure 3. Total and percent volume of phytoplankton of Nelson Lake, Stations 1 and 4, 1976.

6. Bacillariophyceae
5. Chlorophyceae
4. Chrysophyceae
3. Dinophyceae
2. Cryptophyceae
1. Myxophyceae

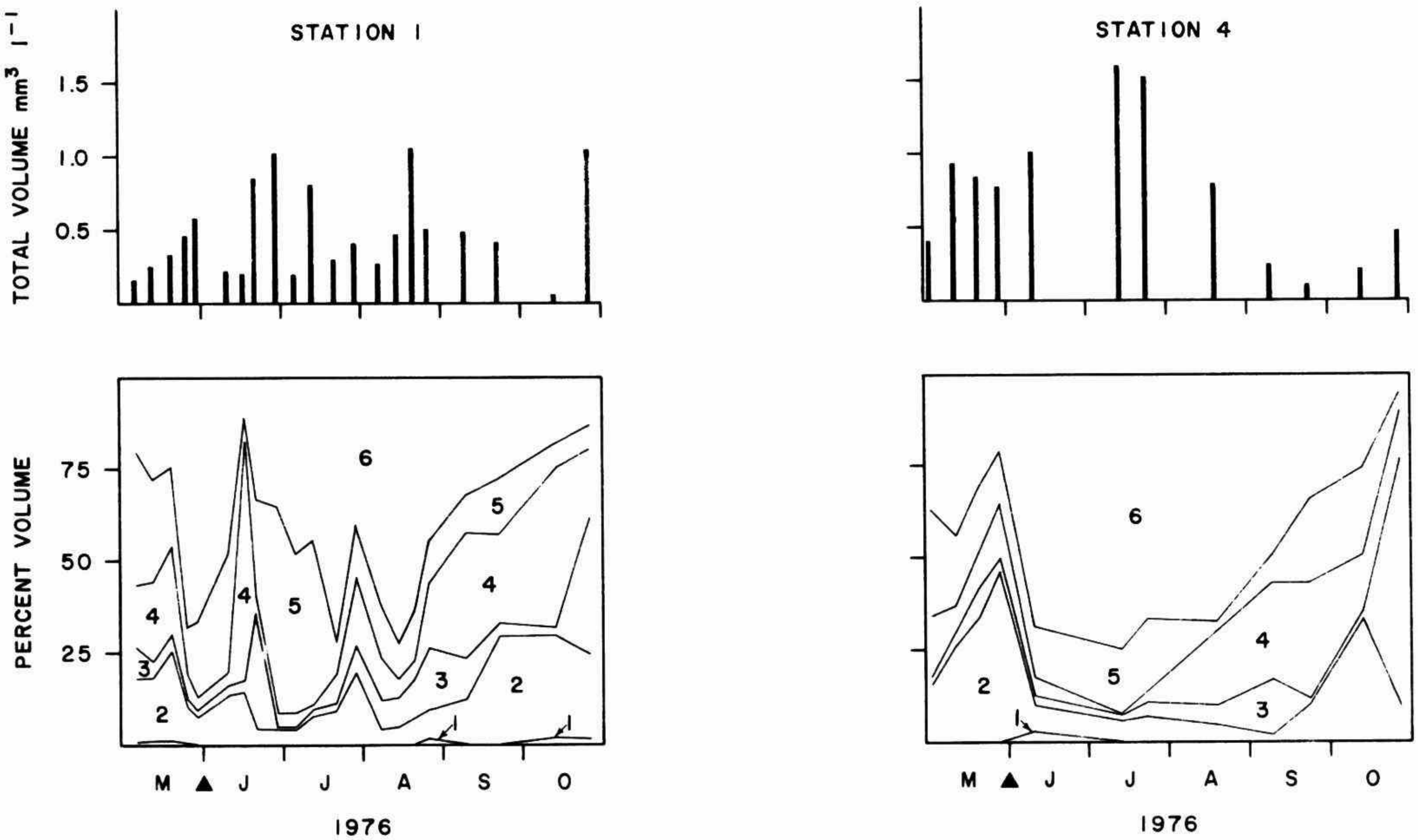

FIGURE 3 - TOTAL AND PERCENT VOLUME OF PHYTOPLANKTON OF NELSON LAKE, STATIONS 1 AND 4, 1976. (▲ DATES OF CHEMICAL ADDITIONS).

most of the vernal diatom biomass. Cryptophyceae, represented mainly by Cryptomonas erosa, had spring and fall biomass maxima in each basin (Figure 3). The mid-summer increase in chlorophyta biomass was mainly attributable to the desmidiaceae Arthrodesmus triangularis and Cosmarium sp.

Scheider et al (1976b) observed that the phytoplankton community structure of Nelson Lake was not similar to other lakes with pH levels less than 5.0, but more closely resembled those of non acidic oligotrophic lakes such as those studied by Schindler and Holmgren (1971) and Ostrovsky and Duthie (1975). The generally similar 1976 and 1975 community composition (Figure 4 and Scheider et al 1976b) reaffirm this observation.

Since the northwest basin of Nelson lake was not treated in 1975 and the main basin not treated until the fall of 1975, a comparison of 1975 and 1976 community structure could provide some understanding of the resistance of phytoplankton community assemblages to change through a pH continuum. The community compositions in each year were, in fact, very similar. The magnitude of the differences observed did not exceed those normally observed and attributable to natural variation (see, for example, Willen 1969; Stankovic 1960). This similarity suggests either that the phytoplankton community retained its integrity down to a pH of 5.7, or that neutralizing effects are not manifested within one season of treatment. As Scheider et al (1975, 1976a) have observed very rapid responses of phytoplankton to neutralization treatments, the first alternative appears the more attractive. Other workers (Almer et al 1974, Hörnstrom et al 1973, Kwiatkowski and Roff 1976) have demonstrated reductions in phytoplankton community diversity in lakes with pH levels less than 5.8. Because of the methods used in obtaining biomass estimates in these studies, (Dillon et al unpub. manuscript), however, no conclusions other than those for species number can be firmly stated.

ii. Zooplankton

Species Composition and Biomass

A total of eleven species of crustacean zooplankton were identified in Nelson Lake in 1976. Six to eight of these, in accordance with numbers occurring in other Ontario Shield Lakes (Sprules 1975a, Patalas 1971), were observed in each sample collection. In all collections, one or two

TABLE 6. Summary of zooplankton biomass and crustacean zooplankton composition of Nelson Lake, May to October, 1975 and 1976

	Total Zooplankton mg m^{-3}	Crustacea mg m^{-3}	% Crustacea nauplii	calanoidea	cyclopoidea	cladocera
1975[1]	34.1	34.0	21	46	29	4
1976[1]	36.1	35.2	11	35	38	16

[1] converted from numbers data using weights listed in Appendix 2.

of the taxa Diaptomus minutus, Cyclops bicuspidatus thomasi, Bosmina longirostris, and Daphnia longiremis were dominant as defined by Patalas (1971). Of these, B. longirostris and C. bicuspidatus thomasi are known to be acid tolerant in some situations (DeCosta 1975). All excepting D. longiremis occur in Ontario lakes ranging in pH from 4 to 7 (Sprules 1975b).

The species most frequently observed (Appendix 1) are common inhabitants of large Ontario lakes that are base and nutrient poor (Sprules 1975b, Patalas 1971).

The average zooplankton biomass in 1976 was 36.1 mg/m^3 as dry weight (Table 6). This is in agreement with other oligotrophic lakes, e.g. Lake Baikal had 24-48 mg m^{-3} (Kozhov 1963, in Schindler and Novén 1971) and Ravera (1969) found 7.5 to 57 mg m^{-3} in Lago Maggiore[1]. Although the change in zooplankton trap mesh size from 76 μ to 30 μ increased the capture of rotatoria from about 20,000 to 200,000 animals m^{-3}, rotatoria formed, on the average, only 2% of the total zooplankton biomass (Table 6).

An average of eighty-four percent of the crustacean zooplankton biomass was comprised of copepoda in 1976 (Table 6, Figure 4a), a proportion that was almost identical to that of 1966-1968 collections from Lake Maggiore (Ravera 1969). D. minutus was the only adult calanoid species observed (Figure 6c). C. scutifer and C. bicuspidatus thomasi alternated as major contributors to the cyclopoid community (Figure 6d).

Effects of Chemical Additions

Cladocera biomasses were greater in 1976 than in 1975 (Figure 6b). The seasonal succession pattern of cladocera was, however, similar in each year despite changes in the season of base additions. Differences between 1975 and 1976 in the relative importance of different species of cyclopoida probably represent normal annual variation.

Despite these differences, the community was quite similar in each year (Table 6, Figure 6). It had the same numbers and types of species, similar biomass and domination of the crustacean community by copepoda.

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[1]For other examples of zooplankton biomass see Schindler and Novén (1971).

Figure 4. Seasonal variation in biomass (as mg m^{-3} of crustacean) zooplankton of Nelson Lake, 1975 and 1976.

A. Total Crustacea

1. nauplii
2. calanoida
3. cyclopoda
4. cladocera

B. Cladocera

1. _B. longirostris_
2. _D. longiremis_

C. Calanoidea

1. _D. minutus_
2. copepodids

D. Cyclopoidea

1. _Cyclops scutifer_
2. _T. prasinus mexicanus_
3. _C. bicuspidatus mexicanus_
4. _M. edax_
5. copepodids

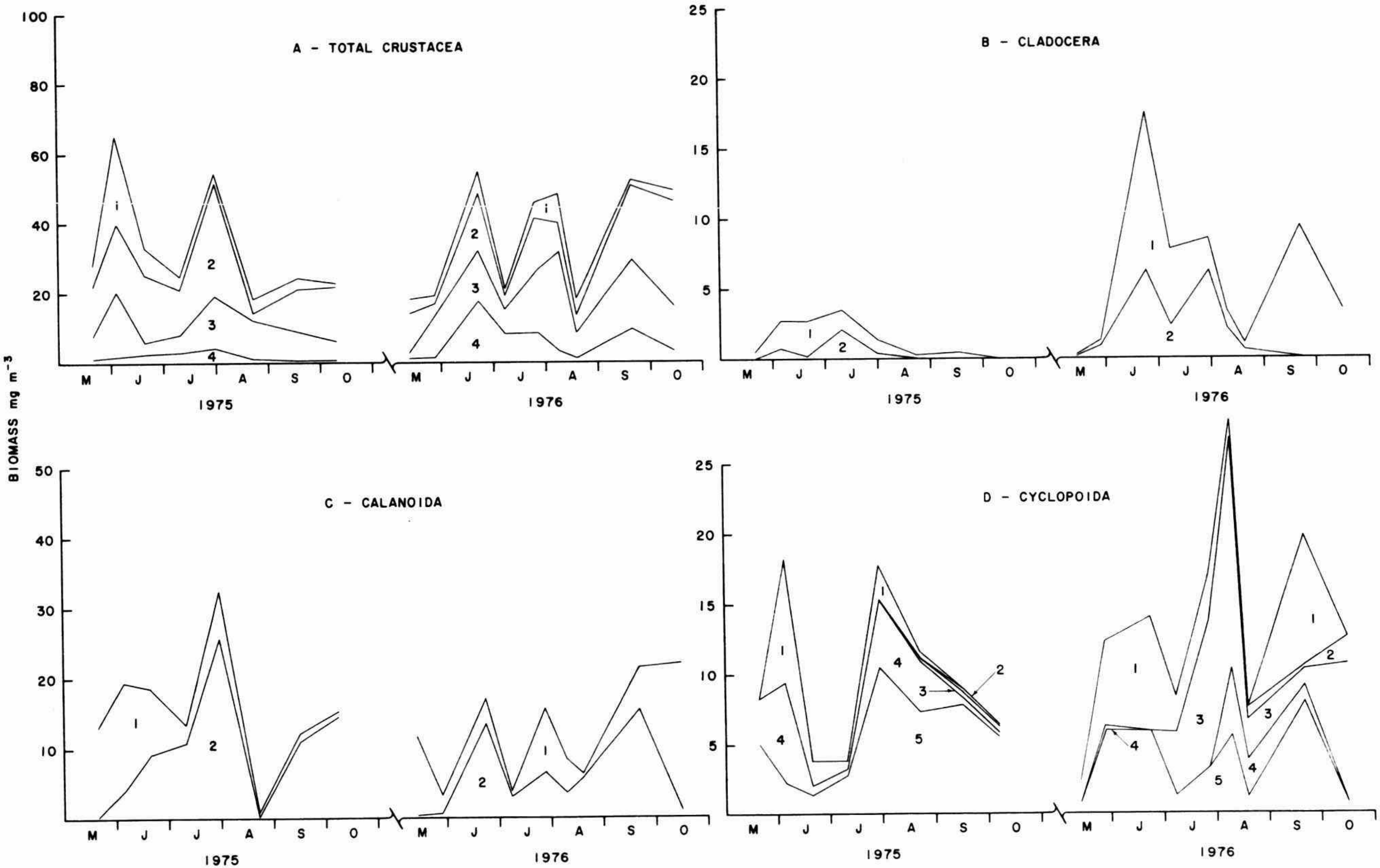

FIGURE 4 - SEASONAL VARIATION IN BIOMASS (AS DRY WEIGHT m^{-3}) OF CRUSTACEAN ZOOPLANKTON OF NELSON LAKE, 1975 AND 1976

Based on species occurrence and numbers of animals m^{-3}, Scheider et al (1976b) concluded that the zooplankton community of Nelson Lake was similar to those of non acidic shield lakes. Support for this conclusion is provided by the 1976 zooplankton data. Sprules (1975a) demonstrated that zooplankton communities in Ontario lakes maintained their integrity down to a pH of 5.0. The zooplankton community of Nelson lake was not affected by chemical additions and had apparently not been affected at the lake's pretreatment pH of 5.6.

iii. Zoobenthos

An average of 2370 macrozoobenthic organisms were found m^{-2} of lake sediment. Of these, 88% were chironomidae. The total numbers and relative importance of chironomidae were similar in 1975 collections (Scheider et al 1976b). Other taxa observed, listed in decreasing average occurrence, were oligochaetae, chaoborinae, nematoda, hydracarina, hirudinea, ceratopogonidae, trichoptera and sialidae. Scheider et al (1976b) suggested that the low densities of pelecypoda and the absence of ephemeroptera in Nelson Lake were indicative of the onset of acid stress. These taxa were not observed in 1976 collections. Benthic communities, however, have been observed to respond very slowly to experimental neutralization of lake waters (Scheider et al 1976a).

The mean chironomid biomass was 870 mg m^{-2} as dry weight. As the chironomid biomass approximates the total macrozoobenthic biomass, this estimate is not dissimilar from the biomass of non acidic oligotrophic lakes (Deevey 1941).

iv. Fish

Powell (1976) surveyed fish populations of Nelson Lake (Table 7) and concluded that, prior to base additions, the fisheries were in the preliminary stages of decline. Smallmouth bass had completely disappeared from the lake in the late 1960's. As Beamish et al (1975a) have observed complete disappearances of smallmouth bass populations from lakes of pH 5.5, the elimination of this population from Nelson lake was anticipated.

The yellow perch population totally dominated the fish community

TABLE 7. Trap net and plastic trap fish catches in Nelson Lake (after Powell 1976).

	Mean Catch set^{-1}			
	Trap net		Plastic trap	
	1975	1976	1975	1976
number of sets	28	40	27	26
Species				
Yellow Perch *Perca flavescens*	550	350	210	15
Brown Bullhead *Ictalurus nebulosus*	6.4	5.9	1.4	0.7
White Sucker *Catostomus commersoni*	4.3	2.4	0	0
Lake Chub *Couesius plumbeus*	3.3	5.1	0	0.1
Northern Pike *Esox lucius*	0.2	0.2	0	0
Brook Trout *Salvelinus fontinalis*	0.4	0	0.1	0
Iowa Darter *Etheostoma exile*	0	0	0.3	0.9
Lake Trout *Salvelinus namaycush*	0.04	0.05	0	0
Central Mudminnow *Umbra limi*	0	0	0.1	0.04

of Nelson Lake (Table 7). This species is very tolerant of low pH and has been reported to have replaced smallmouth bass in moderately acidic George Lake (Beamish 1974). Small populations of brook trout and northern pike were attributed to poor competitive success with yellow perch, and unsuitability of the shoreline for spawning, respectively (Powell 1976).

The growth rate of lake trout was very good in the lake, probably because of the large perch food source. White suckers were also growing quickly in Nelson Lake, however, poor representation of age 2+ fish was suggestive of heavy fry mortality in the spring of 1974. Interestingly, surface water pH levels in May 1974 were just above 4.0 (Conroy & Hawley, unpub. data).

Powell (1976) considered that the disappearance of smallmouth bass from the lake and the great increase in the size of the perch populations, when this species had historically been present in only nominal numbers, were symptomatic of an acid stressed community. Base additions had no discernable immediate effect on the fish community.

v. <u>Biota Summary</u>

Comparison of 1975 and 1976 data indicate that the biota of Nelson Lake were not affected by base additions. As phytoplankton and zooplankton communities are typical of non acidic Precambrian Shield lakes, any reduction of acid input to the lake resulting in increases in lake pH should not bring about changes in these communities.

Powell (1976) anticipates that the present fish community, heavily dominated by yellow perch, may be of sufficient stability that little or no detectable change in community structure will follow decreased acid loading.

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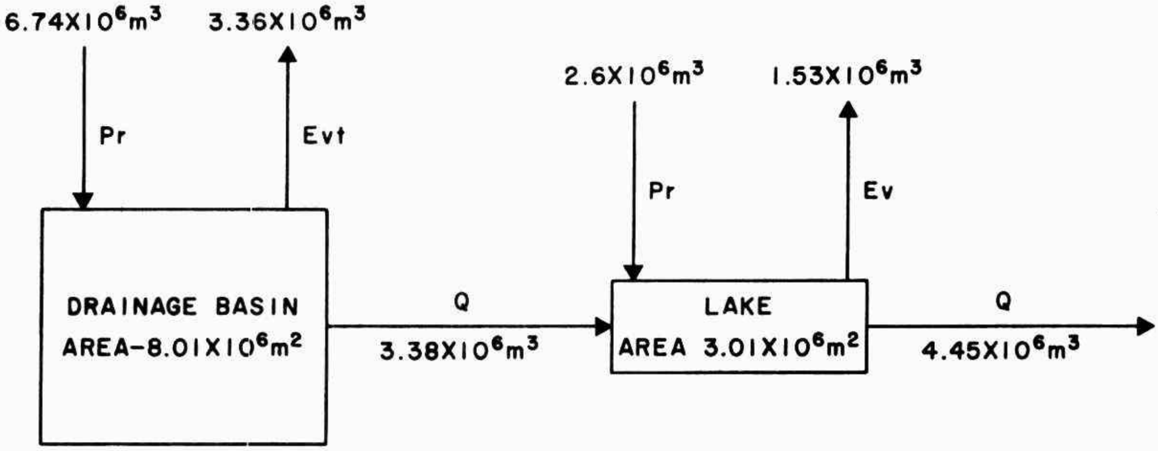

LEGEND

Pr - PRECIPITATION

Ev - EVAPORATION

Evt - EVAPOTRANSPIRATION

Q - DISCHARGE VOLUME

-- PRECIPITATION DEPTH 0.842m (ENV. CAN. 1976)

-- EVAPORATION AND EVAPOTRANSPIRATION FROM BRUCE AND WEISMAN (1966)

FIGURE 5 - HYDROLOGIC BUDGET OF NELSON LAKE IN 1976

APPENDIX 1

Weights used in conversions of zooplankton numbers to biomass as dry weight

Species	dry weight (μg animal^{-1})
nauplii	0.37[1]
calanoid copepodid	1.17[2]
cyclopoid copepodid	1.75[2]
Tropocyclops prasinus mexicanus	0.87[2]
Cyclops bicuspidatus thomasi	4.60[2]
C. scutifer	5.74[2]
Mesocyclops edax	10.7[3]
Diaptomus minutus	2.00[2]
Bosmina longirostris	0.78[2]
Daphnia longiremis	5.59[2]
rotatoria	0.004[4]

[1] from Schindler and Novén, 1971

[2] determined in this study

[3] from Nicholls, Strus, Kennedy (unpublished data)

[4] weighted average of different shape classes computed by measuring dimensions of most similar geometric shapes and assuming specific gravity of unity, dry weight = 0.05 wet weight.