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THE TROPHIC STATUS OF SHUSWAP LAKE

Regional Program Report 84-20

By

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ABSTRACT

Increasing land development in the Shuswap Lake watershed, particularly around the municipality of Salmon Arm, has created concern regarding the state of eutrophication in Shuswap Lake. In 1978 and 1979 a two-year program was conducted to document the state of eutrophication of the Salmon Arm section of Shuswap Lake. The studies included physical, chemical and biological monitoring in three main zones of the lake: Zone A - Tappen Bay area; Zone B - the main section of the Salmon Arm; Zone C - one transect in Seymour Arm.

Another study was conducted concurrently in the summer of 1978 to identify the phosphorus sources and loadings around the Salmon Arm section of Shuswap Lake where land development was greatest. The Salmon River and the District of Salmon Arm sewage treatment plant appeared to be the major sources of total phosphorus loading. Both sources discharged into lake study Zone A. The area around Zone B was less developed than the watershed around Zone A and no major sources of phosphorus inputs were identified. Zone C was located in a relatively undeveloped area.

Chemical and biological data indicated that: Zone A was mesotrophic; Zone B was oligo-mesotrophic; and Zone C was oligotrophic. The Salmon Arm sewage treatment plant could be enhancing eutrophication in Zone A.

RÉSUMÉ

Le développement croissant des terres dans le bassin versant du lac Shuswap, particulièrement près de la municipalité de Salmon Arm, a créé des inquiétudes regardant l'état d'eutrophisation du lac Shuswap. En 1978 et 1979, un programme de deux ans fut conduit pour documenter l'état d'eutrophisation de la section de Salmon Arm du lac Shuswap. Les études ont compris un contrôle physique, chimique et biologigue de trois principales zones du lac: Zone A - région de la baie Tappen; Zone B - la principale section de Salmon Arm; Zone C - une section transversale de Seymour Arm.

En été 1978, une autre étude a été conduite simultanément afin d'identifier les sources et les charges de phosphore aux environs de la section de Salmon Arm du lac Shuswap où le développement des terres fut le plus intense. La rivière Salmon et l'usine de traitement des eaux usées du district de Salmon Arm semblèrent être les majeures sources de la charge en phosphore total. Ces deux sources déversaient dans la Zone A de l'étude du lac. La région autour de la Zone B était moins développée que le bassin versant autour de la Zone A et aucune source majeure d'inputs de phosphore ne fut identifiée. La Zone C était située dans une région relativement non-développée.

Les données chimiques et biologigues démontrent que: la Zone A était mésotrophe; la Zone B oligo-mésotrophe; et la Zone C oligotrophe. L'usine de traitement des eaux usées de Salmon Arm pourrait contribuer à l'accroissement de l'eutrophisation de la Zone A.

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1. INTRODUCTION

Shuswap Lake, a large lake situated in the south-central region of B.C., supports a recreational fishery and provides an important rearing area for several species of commercial salmon (Figure 1). Concerns relating to the water quality and the welfare of the fishery resource have been increasing over the past decade along with increasing land development in the lake's watershed.

The Shuswap Lake system supports annual runs of approximately 5,100 coho (Oncorhynchus kisutch), 13,100 chinook (O. tshawytscha) and 342,000 sockeye salmon (O. nerka), according to ten year average escapement data from 1968 to 1977 (Graham and Russell, 1979) (Appendix I). In addition, there are resident populations of rainbow trout (Salmo gairdneri), mountain whitefish (Prosopium williamsoni), Dolly Varden char (Salvelinus malma) and kokanee (O. nerka).

Large numbers of juvenile fish appear to migrate and rear in littoral areas in the vicinity of Mara Lake - Sicamous Narrows, southern portions of Salmon Arm, the southerly regions of Anstey Arm, the northern tip of Seymour Arm and the outlet of Shuswap Lake. The Shuswap, Eagle, Salmon, Anesty, Seymour and Adams River are all used for spawning areas (Russell et al., 1981).

Fairly good escapements were observed in the Salmon River in the fall of 1978 (350 chinook, 1500 coho and 434 sockeye) (Brown, Musgrave and Marshal, 1979). However, extensive shallows characterized by high temperatures and turbidity in the vicinity of Salmon Arm probably limit the use of this area by rearing fish. Apparently, juvenile salmon utilize the Salmon Arm foreshore areas only briefly in April and early May before migrating to other basins in the Shuswap Lake system (Russell et al., 1981). Sockeye salmon beach spawn in dominant years along the north shore of the Salmon Arm, the east shore of Anesty Arm and throughout the Main Arm. There is little beach spawning in Seymour Arm (Stewart, DFO, pers. comm., 1984).

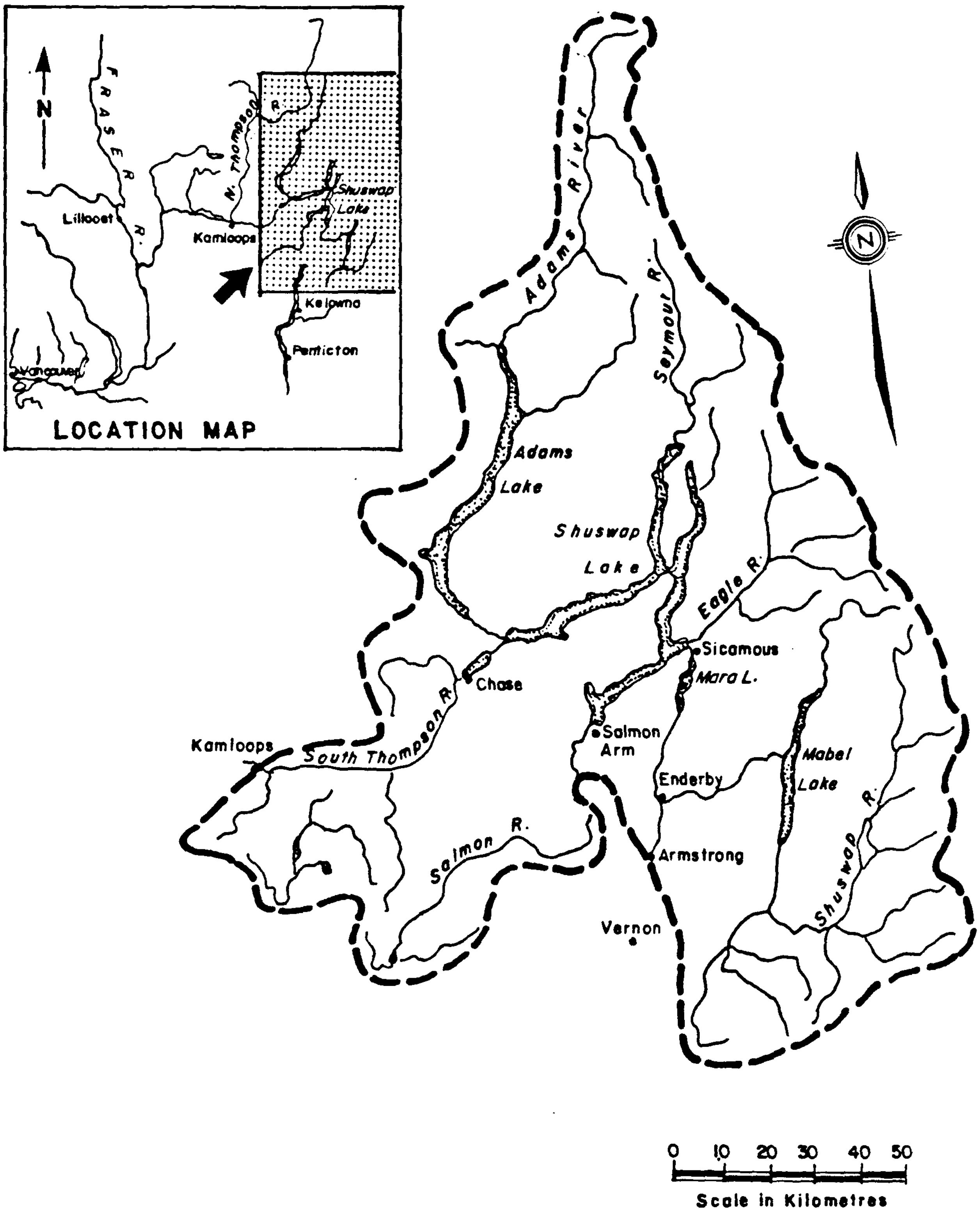

FIGURE 1 SHUSWAP LAKE WATERSHED

Very little work has been done on the water quality or limnology of Shuswap Lake. Ward (1957), reported on zooplankton populations in the lake. A small study, conducted by the B.C. Pollution Control Branch (now B.C. Waste Management Branch) in 1971 and 1972, indicated that Shuswap Lake was oligotrophic except perhaps in the Tappen Bay area of the Salmon Arm section of the lake.

The Salmon Arm section of the lake receives nutrient inputs from agricultural drainage, land development, and municipal wastes. At the time this study was initiated, the town of Salmon Arm was anticipating major improvements in its waste treatment plant. The study was therefore designed to better document the present state of eutrophication in that part of the lake, and to identify the phosphorus sources and loadings in the Salmon Arm area of the Shuswap Lake watershed.

2. STUDY AREA

2.1 Watershed

The Shuswap Lake watershed drains approximately 15,570 km^2 (Figure 1). The Adams, Eagle, and Shuswap Rivers flow from the Monashee Mountain Range, and eventually empty into Shuswap Lake. The Salmon River flows directly into Shuswap Lake from a sub-basin to the south. Shuswap Lake itself is the headwater for the South Thomspon River watershed which drains the south central region of British Columbia.

Some drainage basin characteristics are listed in Table 1.

TABLE 1 DRAINAGE BASIN CHARACTERISTICS

PARAMETER	Characteristics
Location of Lake	- most northern point (Seymour Arm) 51°13'45" - most southern point (Tappen Bay - town of Salmon Arm) 30°41'30" - most eastern point (east shore of Anstey Arm) 118°53'15" - most western point (outlet to South Thompson River) 119°33'30"
Mean Elevation of Lake	- 347 meters
Climate	- semi-arid continental
Area of Drainage Basin	- 15,570 km^2
Limnological Region	- 6 - Columbia Mountains (Northcote and Larkin, 1963)
Basin	- open basin

2.2 Geology

The rock formations of the area surrounding Shuswap Lake are primarily Pre-Cambrian in origin (Daly, 1915). Granitic masses characteristic of the area at the extremity of Salmon Arm are geologically more recent and are believed to be of Jurassic origin. There is a large formation of limstone on the northwest shores of Salmon Arm. A few smaller formations are present at other weakly separated localities. Granite formations make up most of the area surrounding Seymour and Anstey Arms. Most of the district surrounding the Main Arm is composed of greenstones which Daly (1915) suggests are basaltic (Ward, 1957).

2.3 Morphometry

Shuswap Lake's large surface area (Table 2) is characteristic of lake basins formed by river activity. The high shoreline development ratio of 5 is also characteristic of the dendritic outlines of rivers occupying flooded river valleys that then become lakes.

A high shoreline development ratio may reflect great potential for development of littoral communities. However littoral development, part of the eutrophication process, is dependent not only on shoreline development but on depth and shoreline slope as well. For example, Zone A is the shallowest section of the lake and shoreline slope is low (Figure 2); both characteristics favour littoral development. There is not as much potential for littoral development in Zone B or C because these areas are deeper and the shoreline slope is much greater than in Zone A.

Relative depth is measured as the ratio of maximum depth to the surface area of the lake. In the case of Shuswap Lake the small relative depth indicates that the lake has a relatively large surface area to maximum depth.

The mean to maximum depth ratio indicates the approach of a lake basin to that of a cone. Like most lakes, the value for Shuswap Lake is between 0.33 and 0.5, the value for a conical depression.

Volume development is a similar index to the mean to maximum depth ratio and is defined as an index of comparison of the shape of the basin to an inverted cone with a height equal to maximum depth and a base equal to the lake's surface area. The average value found for most lakes is 1.27 and 1.40 (Cole, 1975). Shuswap Lake has a slightly lower volume development with an index of 1.15.

TABLE 2 MORPHOMETRIC FEATURES OF SHUSWAP LAKE

PARAMETER	DIMENSIONS
Lake Surface Area	310 km^2
Shoreline Length	312 km
Shoreline Development Ratio[1]	5
Maximum Depth	162 m
Mean Depth	62 m
Relative Depth[2]	0.82 %
Volume	$1.91 \times 10^{10} m^3$
Mean Depth/Maximum Depth[3]	0.38
Volume Development	1.15

[1]Shoreline Development Ratio = ratio of the length of the shoreline to the length of a circumference of a circle of equal area.

[2]Relative Depth = 88.6 (Maximum Depth)/Surface Area).

[3]Mean Depth/Maximum Depth = mean depth divided by the maximum depth.

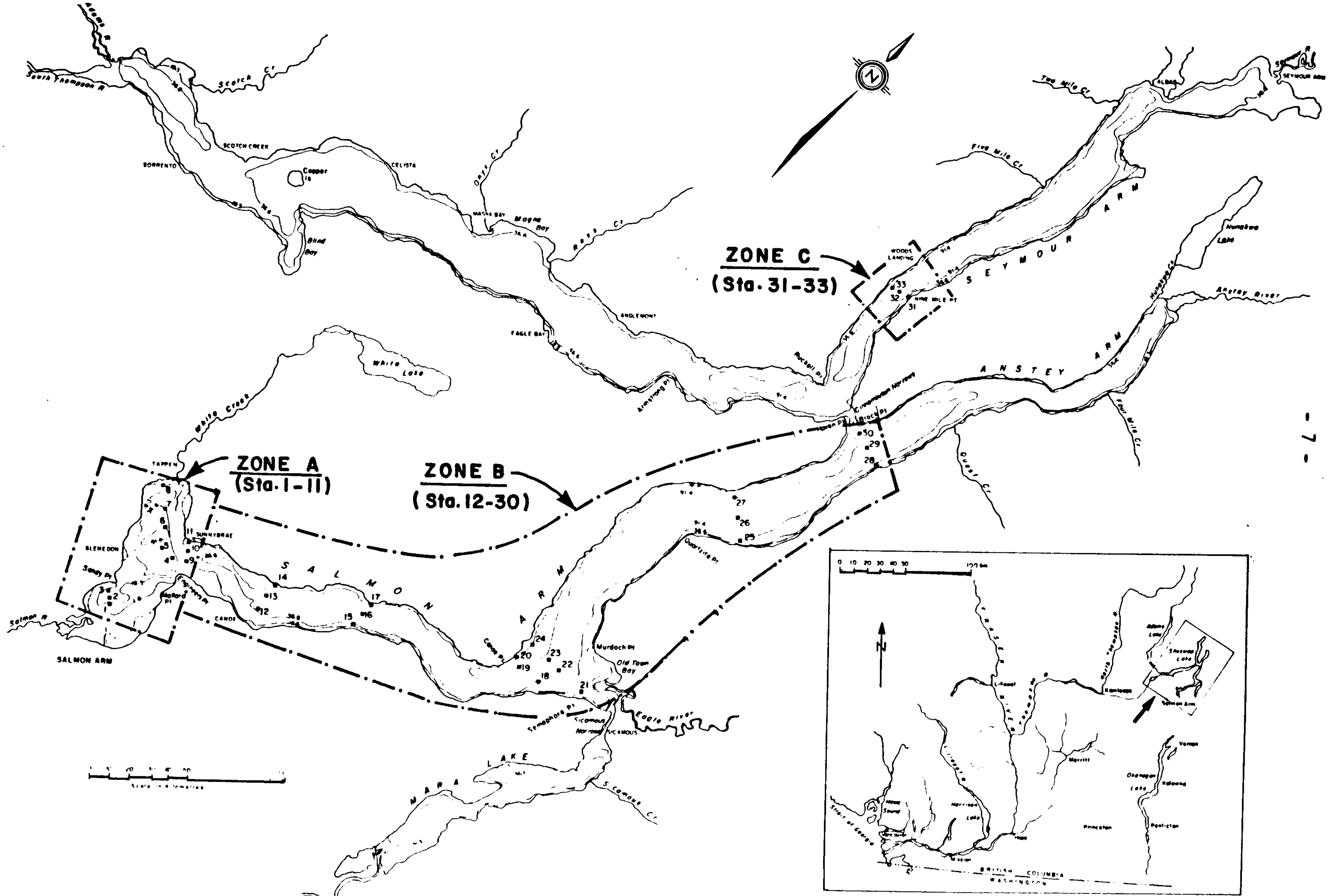

FIGURE 2 MORPHOMETRIC MAP OF SHUSWAP LAKE

3. MATERIAL AND METHODS

3.1 Phosphorus Loadings

Possible sources of phosphorus loadings into the Salmon Arm of Shuswap Lake were identified from land use maps and site investigations in May 1978 (Table 3, Figure 3). On August 15, 16 and 17, 1978, flow measurements were recorded with a Mead Velocity Probe, and single grab samples for total phosphorus were collected at the sample stations shown in Table 4 and Figure 4. The total phosphorus samples were sent to the Environmental Protection Service/Fisheries and Oceans laboratory for analysis.

On December 30, 1981 in a memo to File, R.T. Little (Waste Management Branch, [WMB], Kamploops) reported on the comparative nutrient impact on Shuswap Lake from the Salmon Arm sewage treatment plant and the Salmon River. R. Little used nutrient concentrations from the sewage treatment plant effluent and a flow of 1818 m^3/day to determine a mean daily nutrient load from the sewage treatment plant. To determine Salmon River nutrient loadings both on an average daily basis and a total annual basis, Little used file data for nutrient concentrations at the mouth of the Salmon River and historical mean flows from freshet and non-freshet periods.

TABLE 3 POTENTIAL SOURCES OF NUTRIENTS IN THE SALMON ARM AREA IN 1978*

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1. Area of grazing leases (issued by Columbia-Shuswap Regional District).

2. Tappin Sanitary Landfill (31 to 38 m^3/day).

3. Sandy Point Resort (septic tank - 45,460 litres/day of domestic wastewater to ground).

4. Area of grazing in Eden fire area (issued by B.C. Forestry).

5. Bernare and Linda Petty-Abattoir (Grease removal and septic tank - 1360 litres/day of abbattoir effluent to ground).

6. a) Salmon Arm Water Pollution Control Centre (secondary activated sludge - 2.7 x 10^6 litres/day - to open ditch to Salmon Arm).

   b) Noca Dairy (Shuswap Okanagan Dairy Ind., Co-op Assoc.) Creamery (Four 4546-litre holding tanks - emptied once per day - Whey to open ditch to Salmon Arm).

   c) Salmon Arm Meat and Produce - Abattoir (floor washing to storm drain to open ditch to Salmon Arm).

7. Reliance Septic Tank - septic tank pumpage (exfiltration basin - 2730 litres/day - to ground).

8. Salmon Arm Landfill (101 m/day).

9. Deep Creek Landfill (18 m/day).

10. Federated Co-op - sawmill (54370 liters of cooling water every 2 weeks - to Salmon Arm).

11. Silver Sands Beach Development (secondary package STP, 45460 litres/day of domestic wastewater to ground) - proposed.

12. Sicamous Landfill.

13. C.D. Dewar - Septic tank pumpage (exfiltration and evaporation lagoon - 400 IGPD).

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*Refer to Figure 3

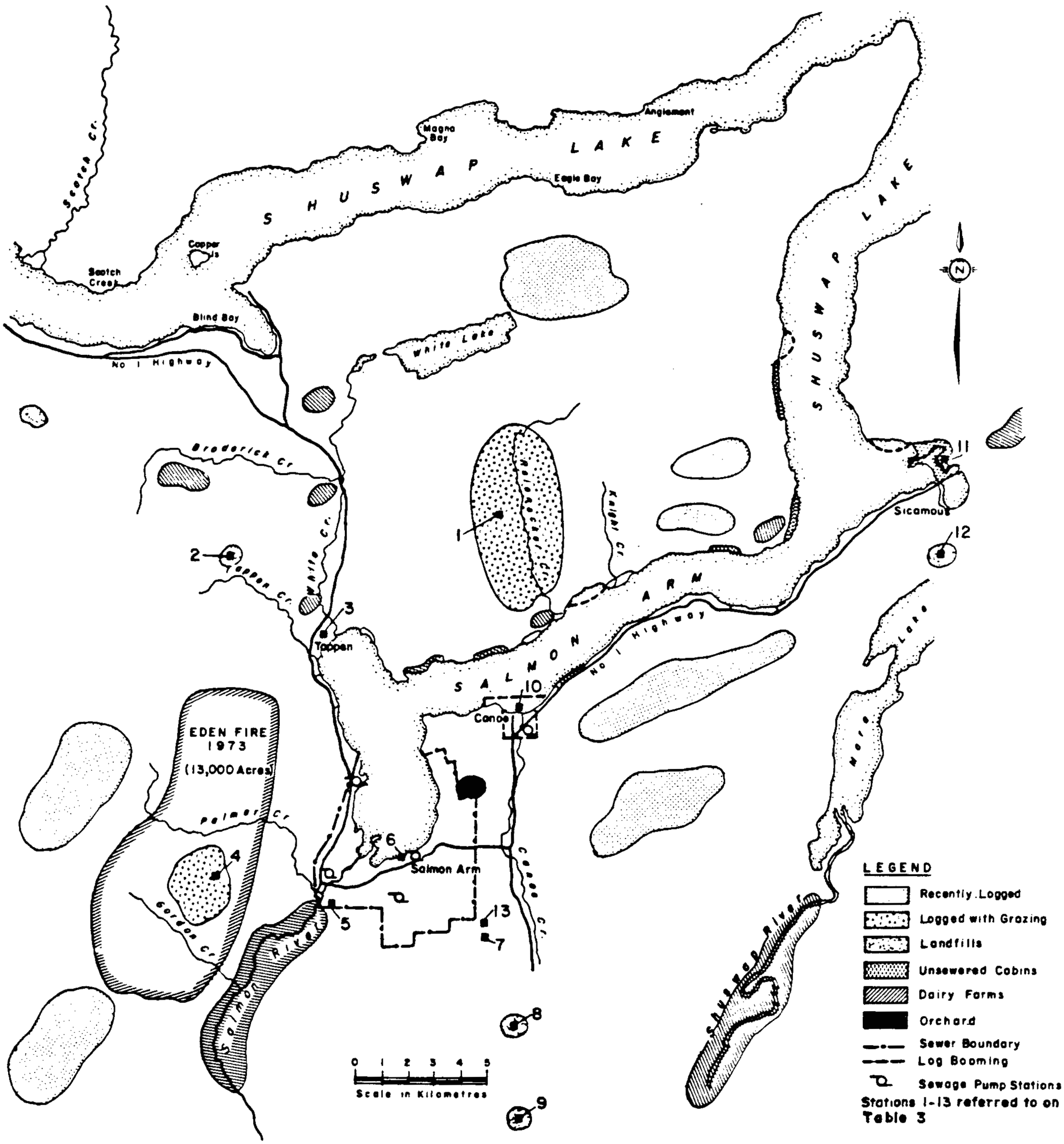

FIGURE 3 POTENTIAL SOURCES OF NUTRIENTS IN THE SALMON ARM AREA

TABLE 4 SAMPLE STATON LOCATIONS FOR PHOSPHORUS LOADING STUDY*

- August 15 to 17, 1978

STATION	NUMBER*
Reinecker Ck.	S1
White Ck.	S2
Tappen Ck.	S3
Salmon River	S4
Palmer Ck.	S5
Gordon Ck.	S6
Sewage Treatment Plant Stormdrain	S7
Stormdrain	S8
Stormdrain	S9
Canoe Creek	S10
Shuswap River	S11
Eagle River	S12
Salmon Arm Sewage Treatment Plant Discharge	STP

*Refer to Figure 4

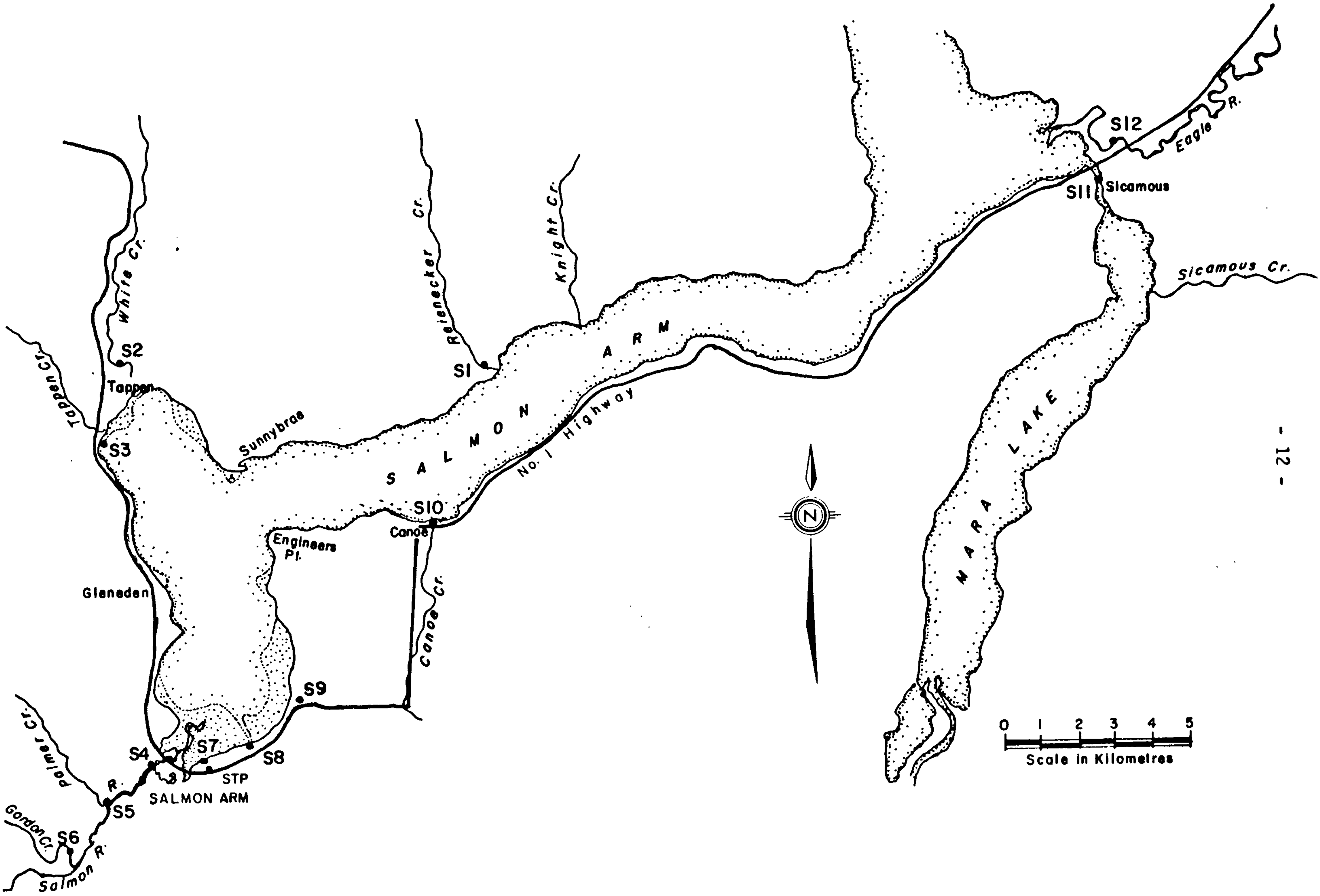

FIGURE 4 SAMPLE STATION LOCATIONS FOR PHOSPHORUS LOADING STUDY - August 15-17, 1978

3.2 Lake Study

The study area was separated into three main zones (Figure 5) in order to condense the large amount of data collected. Zone A (Tappen Bay Area) included stations 1 to 11 and was the area expected to show the greatest impact of nutrient loading. Zone B, the main section of Salmon Arm arm, included stations 12 to 30. Zone C was one transect (Stations 31 to 33) in Seymour Arm at Nine Mile Point and served as a control area in 1978. In 1979, a more intensive study was conducted in the Tappen Bay area with the same stations 1 to 11 used in Zone A while Station 16 in Zone B served as the control. Four shallow water stations (SA-S1 to SA-S4) were added in 1979 to monitor periphyton; Station SA-S4 served as the control (Figure 6).

3.2.1 Water Quality. Samples were collected at stations 1 through to 33 in June and September of 1978. Due to adverse weather conditions in November 1978, only Stations 1 to 11, 13 and 16 were sampled. In 1979, stations 1 to 11 and 16 were sampled in April, June, August and October.

Sample station location was determined with the aid of a Veb Freiberger Prazisionsmechanik yacht sextant (serial no. 108596) and a Model FE-502 Furuno Echo Sounder. Surface temperatures were recorded with a field thermometer and temperature profiles were recorded with a Kahl Scientific Instrument Corporation Bathythermograph.

Water samples for chemical analyses were collected with six litre Van Dorn water bottles at four depths: one meter below the surface, 1-2 meters above the thermocline, 1-2 meters below the thermocline and 1-2 meters from the bottom. The following chemical parameters were analysed:

pH	Total Phosphate Phosphorus	Nitrite/Nitrate Nitrogen
Oxygen	Total Dissolved Phosphate	Total Dissolved Nitrogen
Conductivity	Ammonia Nitrogen	Silica Dioxide
		Particulate Carbon/Nitrogen

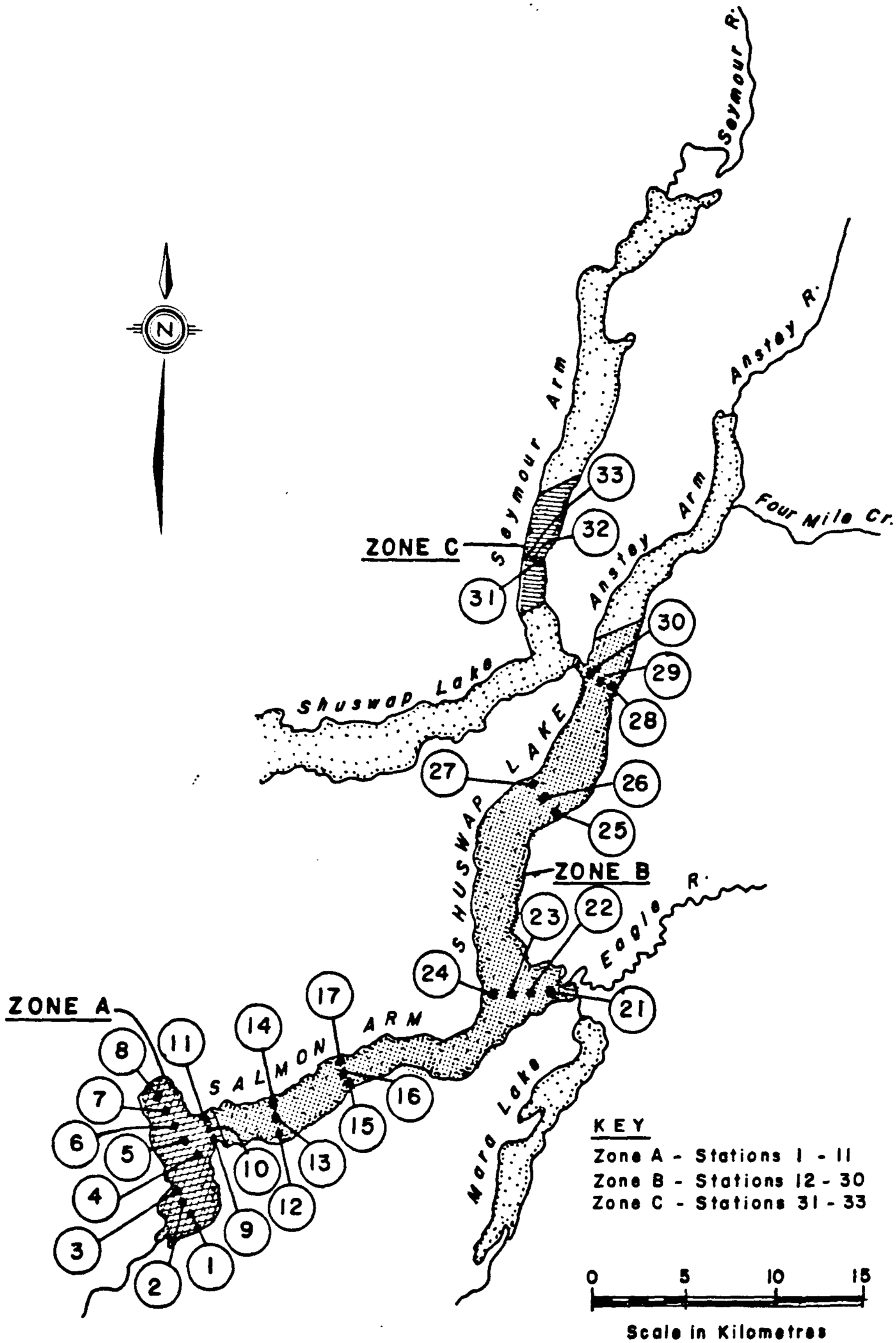

FIGURE 5 LAKE SURVEY- STUDY ZONES AND SAMPLE STATION LOCATIONS

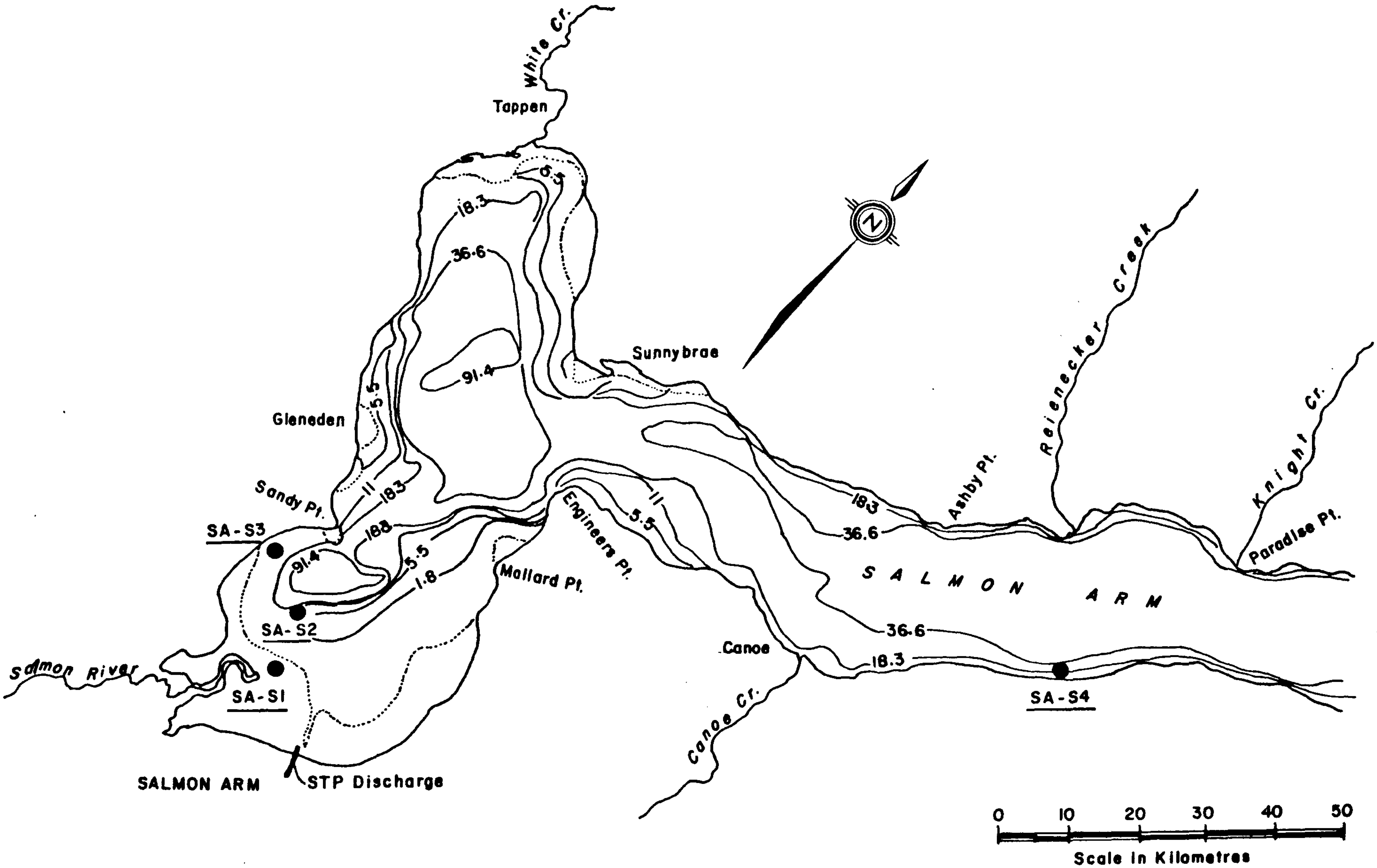

FIGURE 6 SHALLOW WATER STATIONS

The total dissolved phosphate sample was filtered immediately through a distilled water washed 0.45 micron Sartorius membrane filter.

At the end of each day, particulate carbon and nitrogen samples were filtered through roasted GF-C Whatman glass filters. Dissolved oxygen was determined according to the modified Winkler titration method. Samples were then packed in wet ice and shipped to the Inland Waters Directorate Water Quality Laboratory in West Vancouver in 1978 and to the Environmental Protection Service/Fisheries and Oceans Laboratory in 1979. The Inland Waters Laboratory analyzed the particulate carbon/nitrogen and total dissolved nitrogen samples in 1978 and 1979. Samples collected on a weekend were kept cool and shipped to the respective laboratories the following Monday.

The one meter water samples collected at the four shallow water stations in 1979 were analysed for the chemical parameters listed above with the exception of dissolved oxygen.

3.2.2 Periphyton. The shallow water periphyton samplers were first installed at stations SA-S2 to SA-S4 on April 23, 1979 and at station SA-S1 on May 29, 1979. The stations were subsequently sampled at three week intervals until October 23, 1979. The artificial substrate samplers at each station consisted of two plates of roughened plexiglass of 170 cm^2 surface area. The plates were attached to a float of wood and styrofoam suspended 1.5 meters below the surface and anchored to the bottom with a cable and concrete building block (Truscott and Kelso, 1979).

Periphyton plates were retrieved every three weeks and new plates were installed. The attached material was scraped off the plexiglass with the aid of a glass slide into a container of distilled water and then split into three aliquots using a Folsom plankton splitter. One-half of the sample was sent to the laboratory for ash-free dry weight analysis; one-quarter was filtered through a Whatman GF/C glass-fiber filter and shipped frozen to the laboratory for chlorophyll-a and pheopigment analysis; and one-quarter was preserved in Lugol's solution and sent to the laboratory for algal identification and enumeration as described by Ennis (Truscott & Kelso, 1979).

3.2.3 Phytoplankton. Starting in September 1978, an attempt was made to determine *in situ* chlorophyll-a profiles at stations 1 to 33 using a Turner Design Model 10-005R Field Fluorometer. An estimate of the photic zone was determined by multiplying the Secchi disk reading by 2.5 (Vollenweider, 1971). Fluorometer readings were taken from the surface to the bottom of the estimated photic zone by lowering a submersible pump and pumping water from 1 meter depth intervals. To correlate the fluorometer readings with a chlorophyll-a value, additional 1 or 2 litre grab samples were drawn off at 5 or 6 depths at every third or fourth station. These samples were filtered through a Whatman GF/C glass fiber filter and transported frozen to the laboratory for chlorophyll-a analysis. Unfortunately, the correlation between the fluorometer and laboratory analysis was less than .5; thus the actual values for the chlorophyll-a profiles could not be calculated.

Phytoplankton samples were collected at 4 depths within the photic zone over the range where the highest fluoremetric readings had been recorded. The samples were then preserved with Lugol's solution. Numerical identification and biovolumes were then determined at the EPS biology laboratory in North Vancouver as described by Ennis (Truscott & Kelso, 1979).

4. RESULTS AND DISCUSSION

4.1 Phosphorus Loading

The total phosphorus concentration from the Salmon Arm sewage treatment plant (STP) was an order of magnitude higher than concentrations from a stormdrain in the municipality of Salmon Arm and about two orders of magnitude greater than most stream inputs (Table 5).

Total phosphorus loadings were greatest from Shuswap River, Salmon River, Salmon Arm sewage treatment plant and the Eagle River, (Table 5). Both the Shuswap River and the Eagle River empty into Zone B. The significant sources of total phosphorus loading to Zone A were the Salmon River and the Salmon Arm sewage treatment plant. In August 1978, total phosphorus loadings from these two sources were approximately equal, and at least five times greater than any other loadings to Zone A.

In a memo to file dated December 30, 1981, R. Little (WMB, Kamloops) reported on the comparative nutrient impact to Shuswap Lake from the Salmon Arm STP and the Salmon River. A mean daily nutrient load from the STP was determined using mean effluent nutrient concentrations and mean daily recorded flows. Average daily and total annual nutrient loadings from the Salmon River were calculated using WMB nutrient concentration data for Salmon River and Water Survey of Canada (WSC) historical mean flows for freshet and non-freshet periods (Table 6).

The percentage of phosphorus loading, by the STP as compared to the Salmon River was calculated from R. Little's data. During freshet periods the STP only contributed about 3% of the total phosphorus loading and 12% of the total dissolved phosphorus loading to Zone A. During intermediate flow periods the STP contributed about 21% of the total phosphorus loading and 23% of the dissolved phosphorus loading. More importantly, during low flow periods i.e. early spring and late summer, the STP made a much more significant contribution to phosphorus loading: 40% of total phosphorus loading and 41% of dissolved phosphorus loading.

TABLE 5 CONCENTRATIONS AND LOADINGS OF TOTAL PHOSPHORUS SOURCES TO SHUSWAP LAKE - AUGUST 15 TO 17, 1978

STATION (see Figure 4)		CONCENTRATION OF SINGLE SAMPLE (mg/l)
STP	Salmon Arm STP	5.82
S8	Stormdrain	0.562
S2	White Creek	0.090
S4	Salmon River	0.069
S5	Palmer Creek	0.068
S10	Canoe Creek	0.0604
S3	Tappen Creek	0.040
S9	Stormdrain	0.021
S12	Eagle River	0.0152
S11	Shuswap River	0.012
S6	Gordon Creek	0.0050
S1	Reinecker Creek	< 0.0050
	STATION	LOADING (kg/day)
S11	Shuswap River	71.64
S4	Salmon River	10.43
STP	Salmon Arm STP	10.22
S12	Eagle River	4.68
S2	White Creek	1.93
S3	Tappen Creek	1.40
S10	Canoe Creek	0.86
S5	Palmer Creek	0.61
S8	Stormdrain	0.17
S1	Reinecker Creek	0.08
S6	Gordon Creek	0.03
S9	Stormdrain	0.004

TABLE 6 COMPARATIVE NUTRIENT IMPACT ON SHUSWAP LAKE FROM THE SALMON ARM STP AND THE SALMON RIVER

- Memo to File December 30, 1981, By R.T. Little (W.M.B., Kamloops)

1. Salmon Arm STP - average daily flow 1818 m^3/day (400,000 GPD).

(a) Total Phosphorus
mean concentration = 5.17 mg/l
(R = 3.56 - 8.89; S.D. = 1.63 n = 10)*
load = $5.17 \frac{gm}{m^3} \times 1818 \frac{m^3}{day}$ = 9.4 kg./d

(b) Ortho Phosphorus (Dissolved)
mean concentration = 3.87 mg/l
(R = 2.87 - 4.80; SD. = 6.2; n = 7)
load = $3.87 \frac{gm}{m^3} \times 1818 \frac{m^3}{day}$ = 7.0 kg./d

(c) Total Inorganic Nitrogen as ($NH_4^+ + NO_3$)
mean concentration = 19.42 mg/l
(R = 11.1 - 26.83, S.D. = 5.54; n = 9)
load = $19.42 \frac{gm}{m^3} \times 1818 \frac{m^3}{day}$ = 35.3 kg./d

2. Salmon River - flows determined from monthly means from Water Survey of Canada data 1961-1979.

i. Freshet Flow (May, June) - mean flow = 15.4 m^3/sec.

(a) Total Phosphorus
mean concentration = .233 mg/l
(R = .108 - .398 mg/l)
load = $.233 \frac{gm}{m^3} \times 15.4 \frac{m^3}{sec.} \times 86400 \frac{sec.}{day}$ = 310 kg./d

*R = range S.D. = standard deviation n = no. of samples

TABLE 6 COMPARATIVE NUTRIENT IMPACT ON SHUSWAP LAKE FROM THE SALMON ARM STP AND THE SALMON RIVER

(Continued)

(b) Total Dissolved Phosphorus
mean concentration = .038 mg/l
(R = .027 - .046; S.D. = .008; n = 5)
load = $.038 \frac{gm}{m^3} \times 15.4 \frac{m^3}{sec.} \times 86400 \frac{sec.}{day} =$ 50.6 kg./d

(c) Total Nitrogen ($NH_4^+ + NO_3$)
mean concentration = .097 mg/l
(R = .038 - .161; S.D. = .044, n = 5)
load = $.097 \frac{gm}{m^3} \times 15.4 \frac{m^3}{sec.}\ 86400 \frac{sec.}{day} =$ 132.7 kg./d

ii. Intermediate Flow (April, July) - and mean flow = 4.4 m^3/sec.

(a) Total Phosphorus
mean concentration = .092 mg/l
(R = .062 - .139; S.D. = .034; n = 4)
load = $.092 \frac{gm}{m^3} \times 4.4 \frac{m^3}{sec.} \times 86400 \frac{sec.}{day} =$ 35.0 kg./d

(b) Total Dissolved Phosphorus (Ortho)
mean concentration = .063 mg/l
(R = .051 - .085; S.D. = .019; n = 3)
load = $.063 \frac{gm}{m^3} \times 4.4 \frac{m^3}{sec.} \times 86400 \frac{sec.}{day} =$ 24.0 kg./d

(c) Total Nitrogen
mean concentration = .071 mg/l
(R = .036 - .160; S.D. = .050, n = 5)
load = $.071 \frac{gm}{m^3} \times 4.4 \frac{m^3}{sec.}\ 86400 \frac{sec.}{day} =$ 27 kg./d

TABLE 6 COMPARATIVE NUTRIENT IMPACT ON SHUSWAP LAKE FROM THE SALMON ARM STP AND THE SALMON RIVER

(Continued)

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iii. Non Freshet Flow (January to March, August to December) - mean flow = 2.43 m^3/sec.

(a) Total Phosphorus
mean concentration = .066 mg/l
(R = .054 - .085; S.D. = .010; n = 11)

$$\text{load} = .066\ \frac{gm}{m^3} \times 2.43\ \frac{m^3}{sec.} \times 86400\ \frac{sec.}{day} =$$ 13.9 kg./d

(b) Total Dissolved Phosphorus (Ortho)
mean concentration = .049 mg/l
(R = .043 - .051; S.D. = .003; n = 10)

$$\text{load} = .049\ \frac{gm}{m^3} \times 2.43\ \frac{m^3}{sec.} \times 86400\ \frac{sec.}{day} =$$ 10.3 kg./d

(c) Total Nitrogen

i. Winter
mean concentration = .211 mg/l
(R = .072 - .237, S.D. = .117, - n = 6)

load = .211 gm x 2.43 m^3 x 86400 sec. = 44.3 kg./d

ii. Non-winter
mean concentration = .034 mg/l
(R = .007 - .050, S.D. .034, n = 6)

$$\text{load} = .034\ \frac{gm}{m^3} \times 2.43\ \frac{m^3}{sec.} \times 86400\ \frac{sec.}{day} =$$ 7.14 kg./d

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4.2 Lake Study

4.2.1 Physical Characteristics.

4.2.1.1 Temperature. Shuswap Lake is monomictic, circulating freely in the winter and stratifying in the summer. During the 1978-79 study, the lake stratified in late April/early May, and turned over sometime in early November. Typical temperature profiles are represented by Station 2 and 6 in Zone A and Station 16 in Zone B (Figure 7).

Most of the lake stations were still isothermal in the early spring (April 1979) and had stratified by early summer (June 1979); therefore stratifiction of Shuswap Lake probably corresponded closely with the peak flows of the Salmon River (Figure 8) which occurred in late spring, near the end of May. In early summer (June) the depth of the epilimnion was between 5 and 10 meters. By the fall (October), temperatures dropped and the epilimnion deepened to between 15 and 20 meters. By late fall, early winter (November 1978) the lake was isothermal; so fall turnover probably occurred sometime in early November.

4.2.1.2 Photic zone. The photic zone, approximately equal to 2.5 x secchi depth (Vollenweider, 1971) increased from Zone A to Zone C (Figure 9) along with a corresponding decrease in turbidity (Figure 10) and decrease in phytoplankton biomass (Section 4.2.3.1, Table 12).

Seasonal variations as well as zonal differences were noted in the photic zone. The photic zone was shallowest in the spring (June 1978 and 1979), soon after the spring freshet peak flow; and then increased through to fall (June to November 1978 and June to October 1979) in all three zones.

4.2.1.3 Turbidity. Turbidity decreased from Zone A to Zone C (Figure 10) along with the amount of suspended matter in the water. Zone A is a smaller, shallower body of water than both Zone B or C. Therefore, the

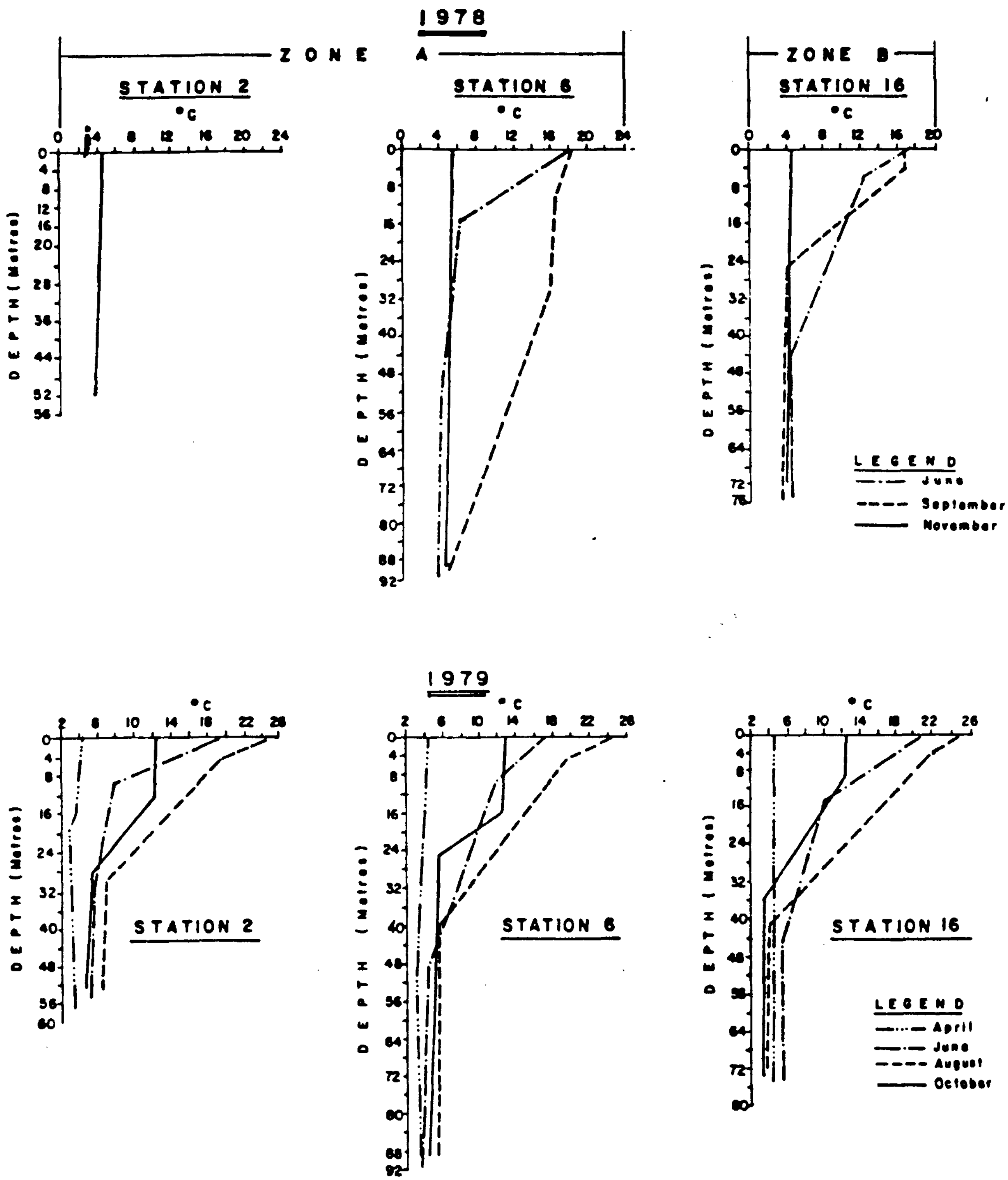

FIGURE 7 TEMPERATURE PROFILES FOR STATIONS 2,6, AND 16

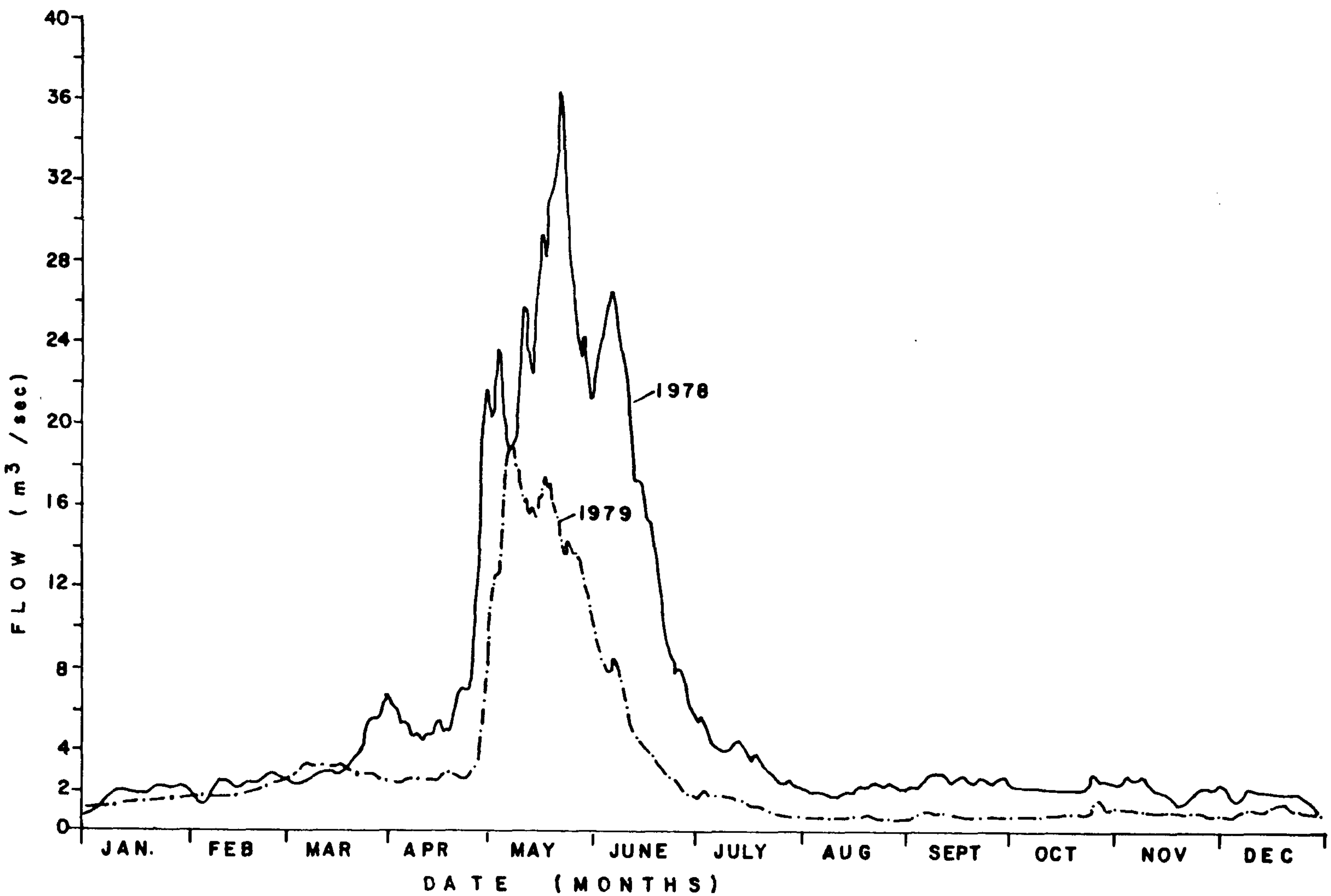

FIGURE 8 SALMON RIVER FLOW FOR 1978 AND 1979
(Water Survey of Canada, 1978 and 1979)

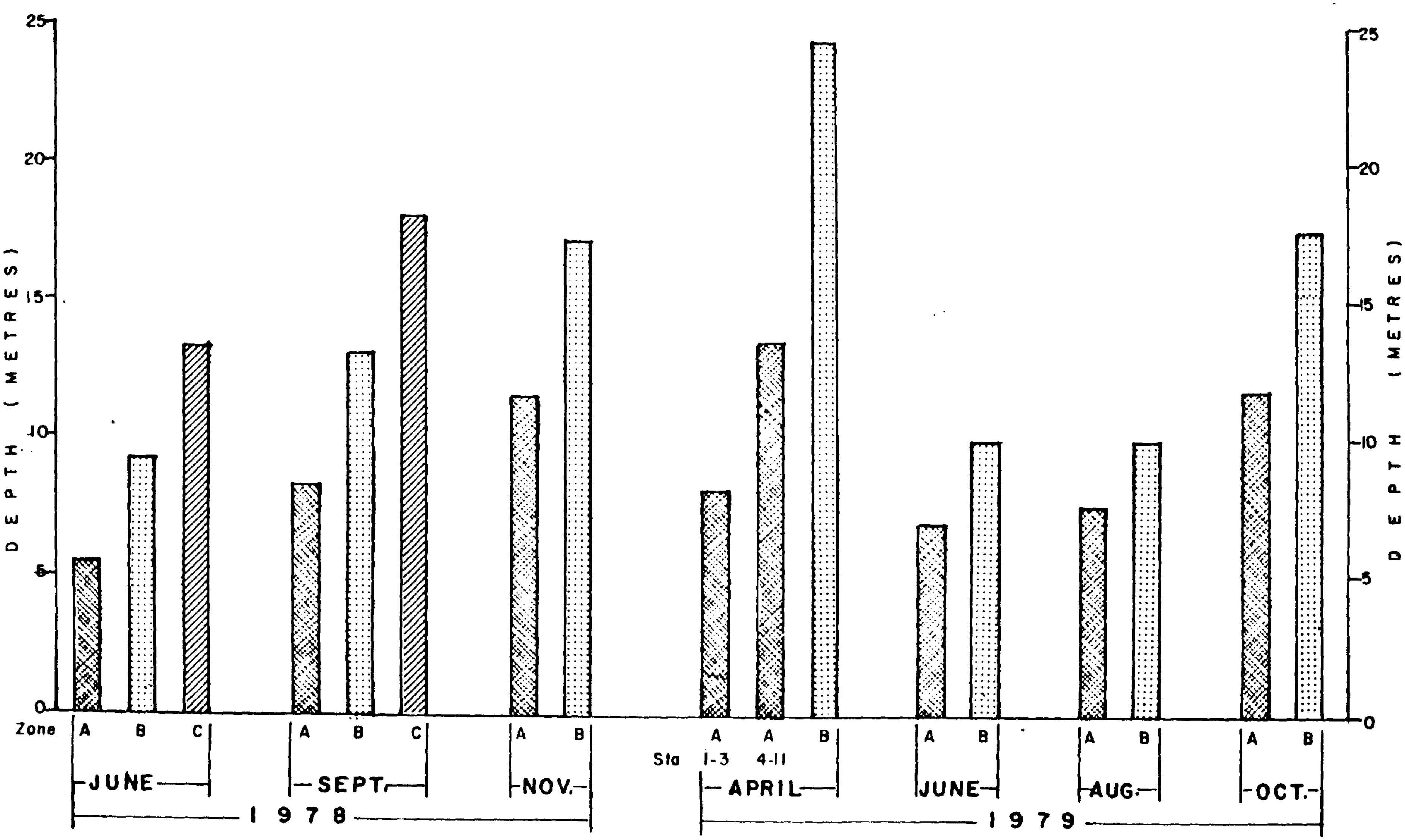

FIGURE 9 PHOTIC ZONE IN SHUSWAP LAKE DURING 1978 AND 1979

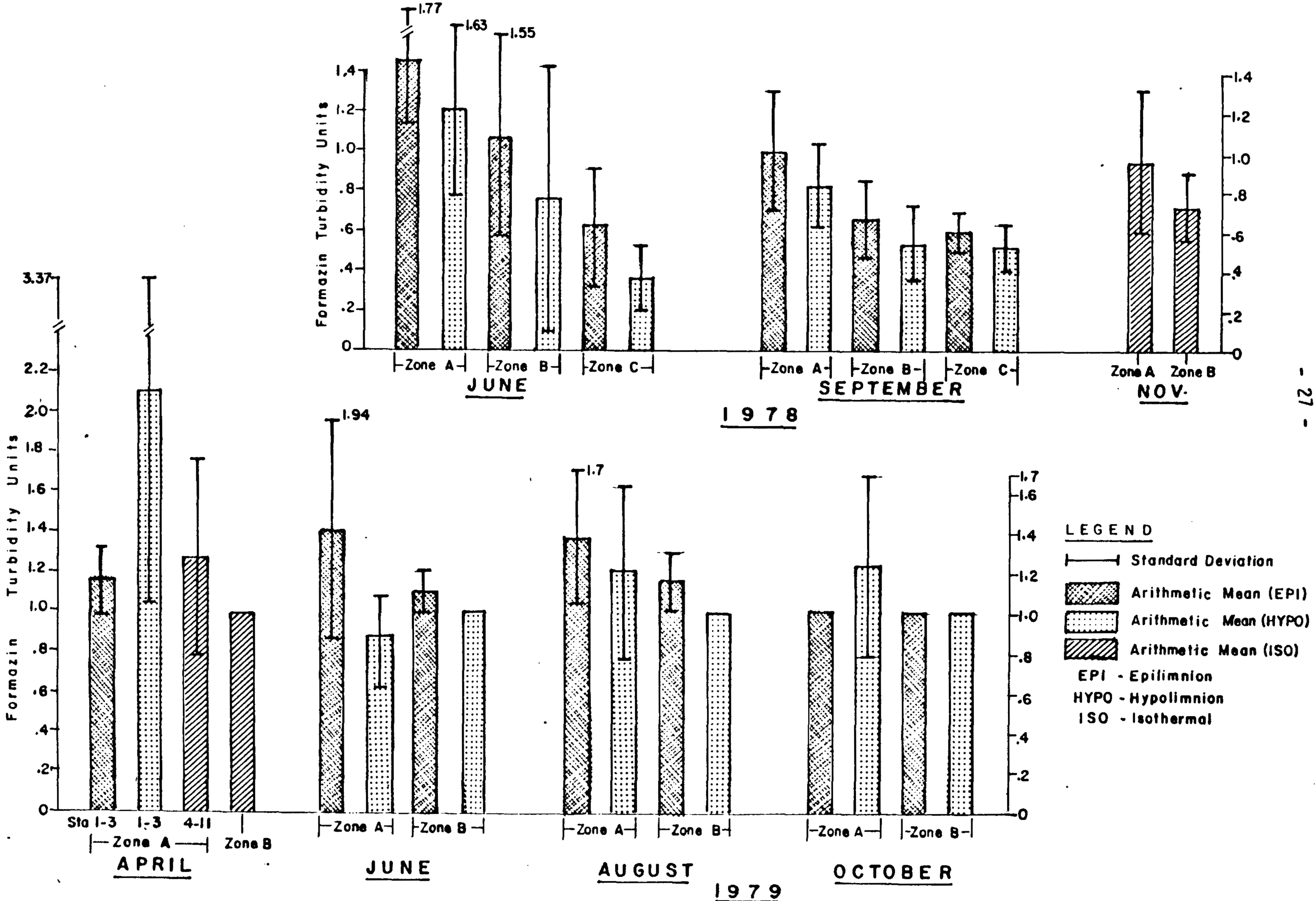

FIGURE 10 TURBIDITY READINGS IN SHUSWAP LAKE DURING 1978 AND 1979

sediment load from runoff and from anthropogenic sources, compared to the volume of the receiving water is possibly greater in Zone A than in Zone B or C. Phytoplankton biovolume was also more abundant in Zone A at the time of sampling (Section 4.2.3.1, Table 12) which would have increased turbidity.

Seasonal variation, as well as zonal variation was evident. Turbidity was highest in all three zones during the spring and summer and decreased in the fall. In the spring, turbidity was probably caused by abiotic sources, i.e. an increase in sediment loading and disturbance of settled particulate matter by spring runoff. For example, in April 1979, approximately a week before peak freshet flow, when Stations 1-3 were stratified, turbidity was higher in the hypolimnion than the epilimnion. Sediment, or abiotic particles, may have settled out and become trapped below the thermocline, increasing turbidity in the hypolimnion. By summer, river flows decreased, phytoplankton populations increased and turbidity was greater in the epilimnion than the hypolimnion. In Zone A, in October 1979, after phytoplankton populations declined sharply, sinking algae and abiotic suspended particles increased turbidity in the hypolimnion making it greater than epilmnetic turbidity.

4.2.2 Chemical Characteristics.

4.2.2.1 pH. By definition, pH values cannot be averaged arithmetically, but must be estimated by the logrithm of the reciprocals (Wetzel, 1975). the following equation was used to calculate mean pH;

$$\text{Log } 10 \; \frac{1}{\dfrac{\dfrac{1}{10^{pH1}} + \dfrac{1}{10^{pH2}} + \dfrac{1}{10^{pHn}}}{n}}$$

Mean pH did not vary greatly. The waters were slightly alkaline with zonal averages ranging between 7.3 and 8.1 (Table 7).

TABLE 7 pH IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION		JUNE			SEPTEMBER			STATION		NOVEMBER		
		n	Range	Mean	n	Range	Mean			n	Range	Mean
A 1-11	EPI*	19	7.7-8.1	7.9	22	7.7-7.9	7.8					
	HYP	19	7.6-8.0	7.8	18	7.4-7.9	7.6					
								1-11	ISO	22	7.5-7.7	7.6
B 12-17,												
21-30	EPI	32	7.7-8.0	7.8	32	7.6-7.8	7.7					
	HYP	32	7.6-8.0	7.8	32	7.2-7.8	7.4	13-16	ISO	8	7.4-7.6	7.6
C 31-33	EPI	6	7.5-7.9	7.7	6	7.3-7.7	7.6					
	HYP	6	7.5-7.8	7.6	6	7.3-7.7	7.4					

1979

ZONE & STATION		APRIL			ZONE & STATION		JUNE			AUGUST			OCTOBER		
		n	Range	Mean			n	Range	Mean	n	Range	Mean	n	Range	Mean
A 1-3	EPI	6	8.0-8.1	8.0	A 1-11	EPI	22	7.4-8.3	7.7	22	7.9-8.4	8.1	22	7.7-7.8	7.8
	HYP	6	8.1-8.2	8.1		HYP	22	7.3-7.7	7.5	22	7.3-8.1	7.4	19	7.3-7.6	7.5
	ISO	32	7.9-8.0	7.9											
B					B 16	EPI	2	7.3-7.6	7.4	2	8.1	8.1	2	7.8	7.8
						HYP	2	7.3	7.3	2	7.6	7.6	2	7.5	7.5
16	ISO	4	7.9	7.9											

* EPI = Epilimnion
HYP = Hypolimnion
ISO = Isothermal

Notably, the difference between epilimnetic and hypolimnetic pH values was greatest in the late summer (August) when phytoplankton biovolume in Shuswap Lake was highest (Section 4.2.3.1, Table 12). Generally as the phytoplankton growing season progresses, photosynthetic activity increases in the epilmnion which results in an increase in oxygen (O_2) levels and a decrease in carbon dioxide (CO_2) levels. Consequently the pH increases when CO_2 is taken up by the algae at a faster rate than it can be replaced through atmospheric CO_2 diffusion, respiration, or readjustment of solid carbonate equilibruim. With the increase in phytoplankton growth in the epilimnion, there is a subsequent increase in organic degradation in the hypolimnion; the decrease in O_2 levels and increase in CO_2 levels, lowers the pH. Therefore, with increasing phytoplankton productivity in a system, the difference between epilimnetic and hypolimnetic pH values can increase (Wetzel, 1975).

4.2.2.2 Oxygen (percent saturation). The degree of oxygen saturation can be affected by primary productivity. While not a direct measure of primary productvity, phytoplankton biovolume, does measure the standing crop of primary producers and can be used to indicate the trophic status of a lake. When phytoplankton primary productivity (as indicated by increased biovolumes) increases, the photosynthetic activity in the water increases and oxygen levels increase. The epilimnion became saturated or near saturated during the phytoplankton growing season. As early as April in 1979, when there was already a noticeable increase in phytoplankton biovolume, the epilimnion in Zone A at Stations 1-3 was saturated (Table 8). Supersaturations in the epilimnion corresponded with periods of increased productivity, ie. June and August (Figure 11).

In all zones, oxygen saturation decreased in the hypolimnion from summer to fall and the difference between epilimnetic and hypolimnetic oxygen values increased during this period. As the growing season progressed, more phytoplankton died off and sank along with other detritus; decompostion increased below the thermocline and oxygen levels decreased correspondingly.

TABLE 8 OXYGEN (PERCENT SATURATION) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER			
			n	Range	Mean	S. Dev.**	n	Range	Mean	S. Dev.
A	1-11	EPI*	19	88.34-114.82	103.78	6.73	14	91.44-103.14	97.93	2.96
		HYP	18	76.51-92.92	85.73	5.37	11	72.71-83.75	79.99	3.20
B	12-17,	EPI	32	91.08-115.67	103.56	5.55	31	94.38-101.62	98.30	2.10
	21-30	HYP	32	75.69-90.17	84.41	3.25	32	62.36-88.32	82.48	6.19
C	31-33	EPI	5	105.24-107.56	106.67	0.86	5	99.43-101.49	100.40	0.65
		HYP	4	83.54-86.09	84.38	1.00	6	76.91-86.75	84.56	3.50

1979

		APRIL				STATION	JUNE				AUGUST				OCTOBER			
		n	Range	Mean	S. Dev.		n	Range	Mean	S.Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A 1-3	EPI	6	93.05-107.83	100.84	4.96	1-11 EPI	22	92.89-135.27	110.31	10.08	22	105.85-133.56	121.22	6.80	22	89.69-97.89	93.11	2.31
	HYP	6	76.32-87.98	79.65	4.35	HYP	22	78.78-103.33	87.74	5.34	22	74.72-94.3	85.83	5.19	19	48.54-78.36	69.86	8.01
4-11	ISO	22	81.75-101.73	96.91	4.75													
B						16 EPI	2	02.47-132.35	117.41	21.31	2	118.0-120.79	119.40	1.97	2	93.78-94.22	94.0	0.31
						HYP	2	88.35-94.12	91.24	4.08	2	84.97-91.22	88.10	4.42	2	75.51-79.17	77.34	2.59
16	ISO	4	95.04-95.78	95.29	0.29													

* EPI = epilimnion
HYP = hypolimnion
ISO = isothermal
**S. Dev. = standard deviation

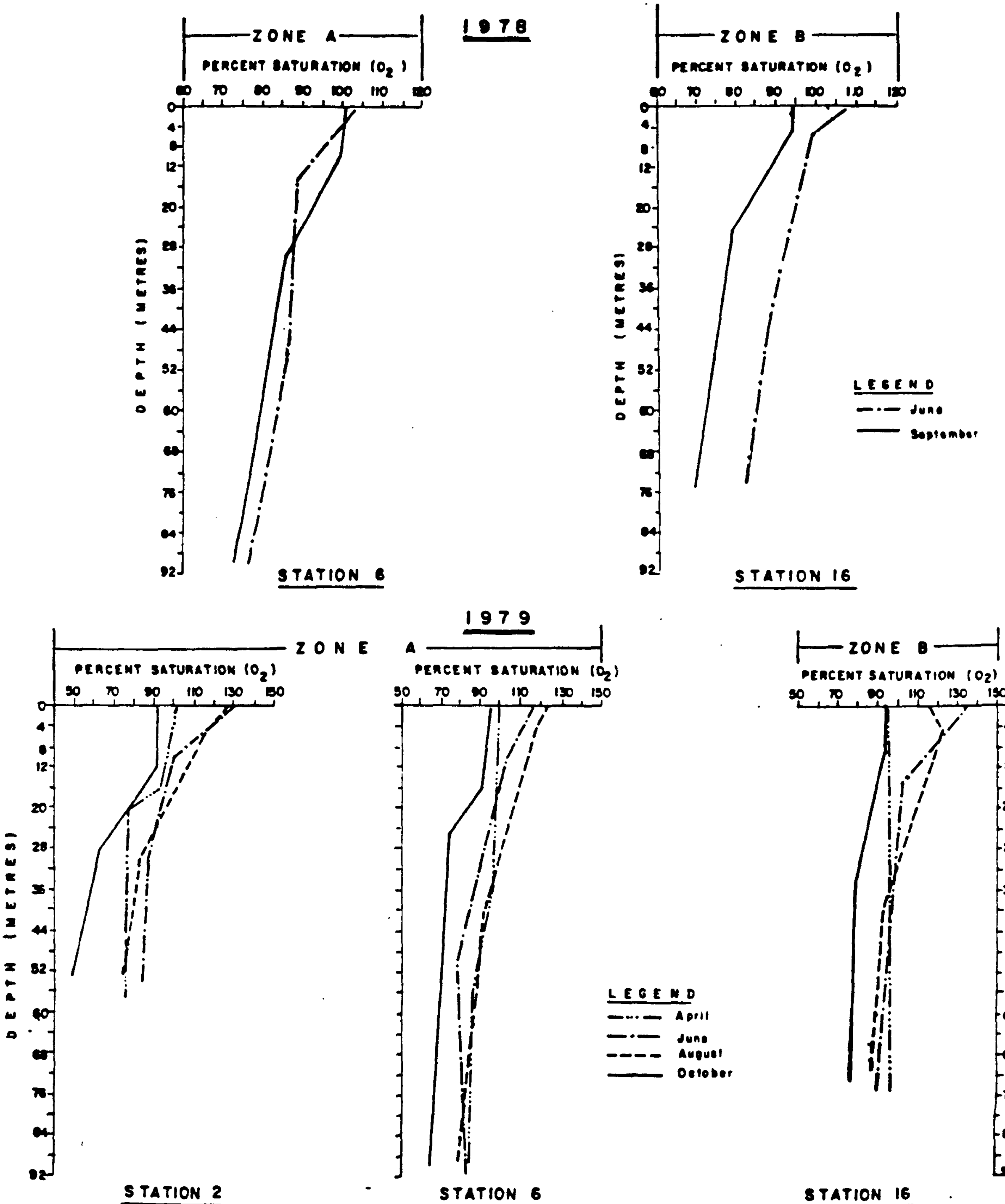

FIGURE 11 PERCENT SATURATION OF OXYGEN AT REPRESENTATIVE SITES IN SHUSWAP LAKE DURING 1978 AND 1979

4.2.2.3 Conductivity. Since conductivity is proportional to total dissolved solids (Wetzel, 1975), the decrease in conductivity from Zone A to Zone C (Figure 12) implies a respective decrease in total dissolved solids. Both the Salmon River and the Salmon Arm sewage treatment plant may be responsible for the greater total dissolved solid levels and therefore, the higher conductivity in Zone A. Zone C had the lowest conductivity where major rivers or anthropogenic sources contributed to total dissolved solid levels.

The highest conductivities throughout the study were recorded in the hypolimnion at the three stations nearest to the STP (1 to 3) in Zone A in April 1979. During the sampling period, Salmon River flows were at their lowest and the STP continued to discharge at its average annual rate. By mid-April, stations 1 to 3 were the only stations that had started to stratify thereby preventing free mixing of the water column. Total dissolved solids from possibly both the Salmon River and the STP may have settled and become trapped below the forming thermocline to increase conductivity levels.

The small decrease in conductivity in each zone from spring to fall is possibly a reflection of a decrease in allochthonous loadings.

4.2.2.4 Phosphorus. Phosphorus levels decreased from Zone A through to Zone C (Figures 13 and 14). Two major sources of phosphorus loading, the Salmon Arm sewage treatment plant and the Salmon River, empty into Zone A. In contrast, no major rivers empty into Zone C and the shores are sparsely populated.

Along with zonal variation, seasonal variation in phosphorus levels occurred. In Zone A total phosphorus levels in the epilimnion decreased over the summer with phytoplankton biovolume increases. However by late summer or early fall phosphorus levels in Zone B and C had remained the same or increased.

Previous studies have pointed out that using ambient and loading models to predict the trophic state of a lake is not entirely satisfactory.

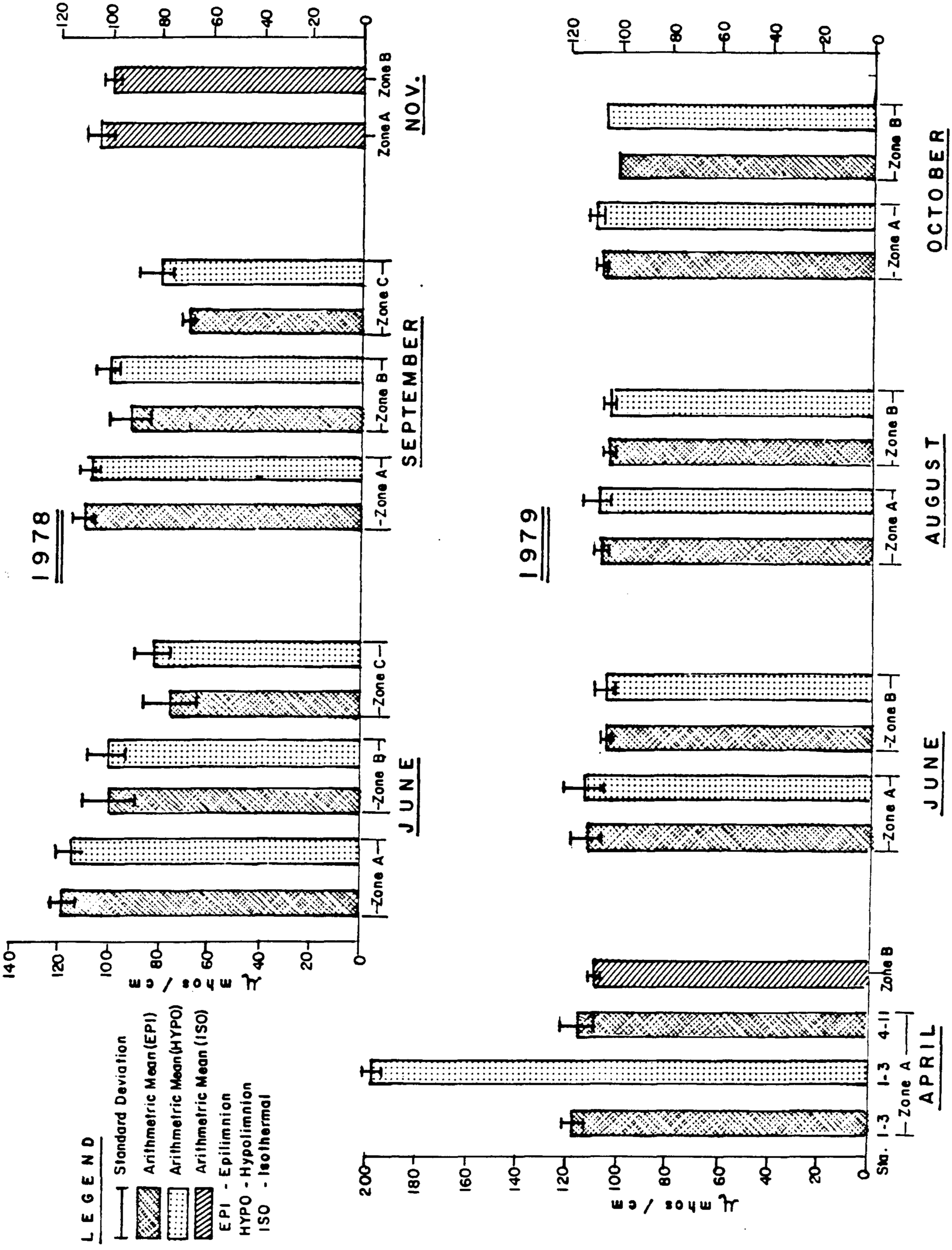

FIGURE 12 CONDUCTIVITY READINGS IN SHUSWAP LAKE DURING 1978 AND 1979

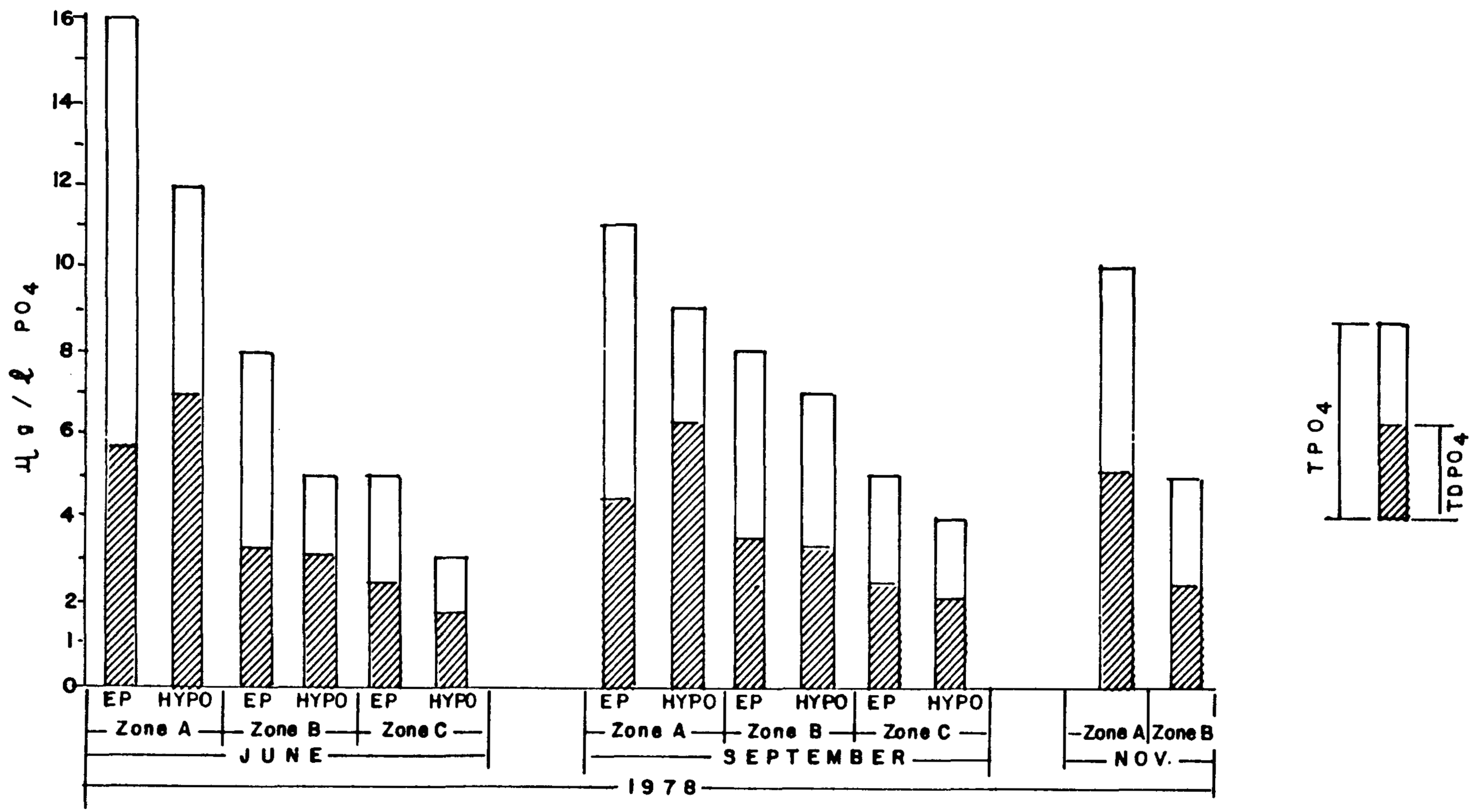

FIGURE 13 TOTAL AND DISSOLVED MEAN PHOSPHORUS CONCENTRATIONS IN SHUSWAP LAKE DURING 1978

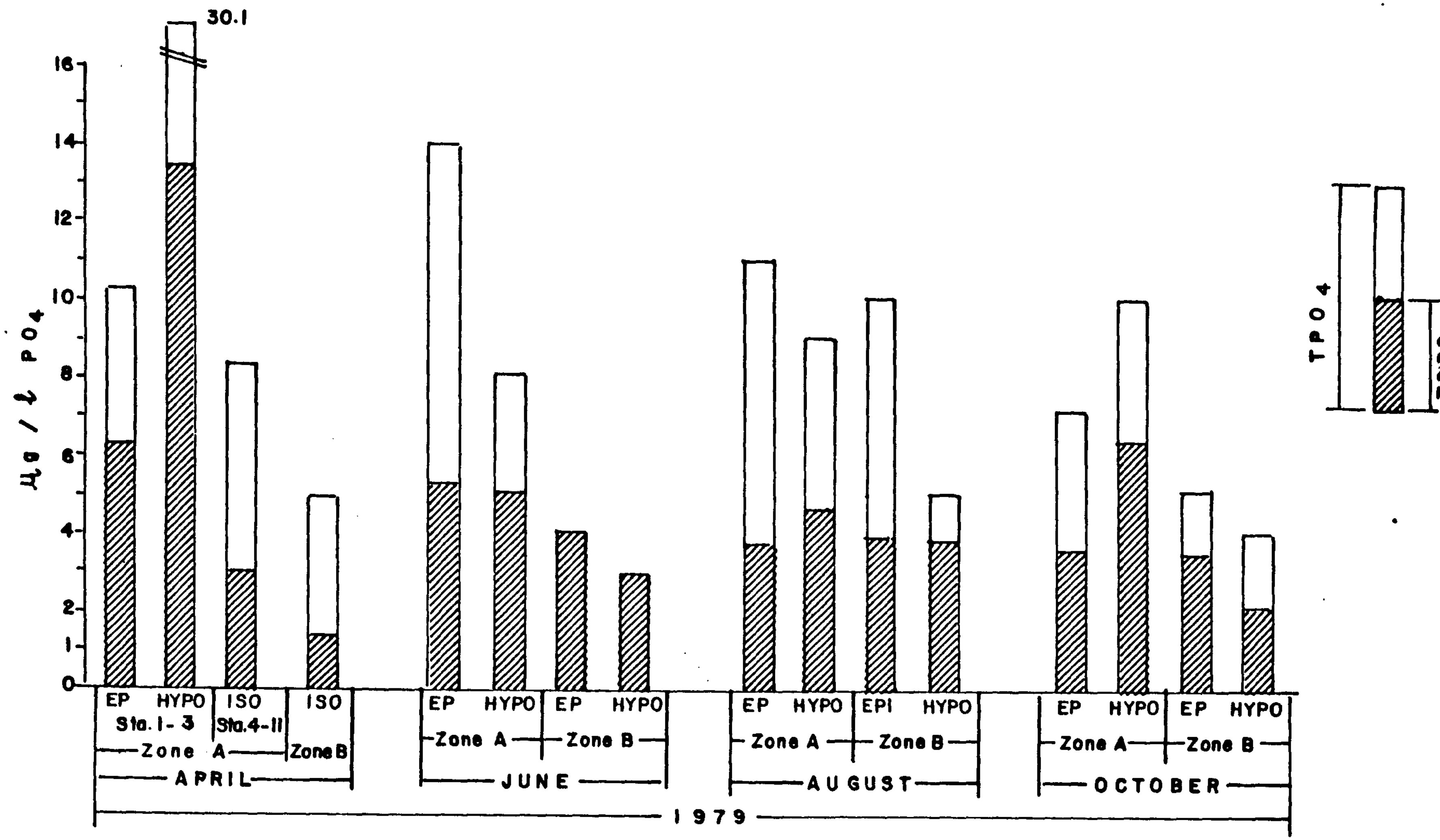

FIGURE 14 TOTAL AND DISSOLVED MEAN PHOSPHORUS CONCENTRATIONS IN SHUSWAP LAKE DURING 1979

Use and incorporation of phosphorus into phytoplankton biomass varies significantly from lake to lake depending on availability of light, sufficient supply of other nutrients and biological availability of various phosphorus species (Hern, et al, 1981). However, general relationships can be used to highlight differences between zones. Wetzel (1975) categorized the trophic type of lakes according to general ranges of various limnological characteristics including total phosphorus (Table 9). The epilimnetic total phosphorus values for June 1978, and June and August 1979 in Shuswap Lake suggest Zone A was mesotrophic to meso-eutrophic, Zone B was oligotrophic to oligo-mesotrophic, and Zone C was oligotrophic. Eutrophication appeared more advanced in Zone A than B or C.

4.2.2.5 Nitrate/Nitrite Nitrogen. Nitrate-nitrite concentrations are considered more a reflection of nitrate levels than nitrite levels because of the very low nitrite concentrations found in freshwater (Wetzel, 1975). There can be a significant drop in levels with an increase in phytoplankton production because nitrate is readily assimlated by algae. In June and September 1978, nitrate levels in both the epilimnion and hypolimnion increased from Zone A to Zone C (Figures 15 and 16) perhaps a reflection of a respective decrease in phytoplankton productivity as measured by biovolume. By September 1978, after the summer growing season, the epilimnetic values had decreased in all the zones. The epilimnetic values in Zone A and B were reduced to less than the 2 ug/l detection limit. By November 1978, under isothermal conditions and low primary production, Zone A and Zone B mean nitrate concentrations had increased to approximately 73 ug/l.

In April 1979, mean nitrate concentrations at Stations 4 to 11 in Zone A and at Station 16 in Zone B were similar. However, at Stations 1 to 3 in Zone A, where phytoplankton biovolume had increased, the epilimnetic value had already dropped to 42.6 ug/l and nitrate levels had built up in the hypolimnion to a mean concentration of 142.8 ug/l.

TABLE 9 GENERAL RANGES OF VARIOUS LIMNOLOGICAL CHARACTERISTICS OF LAKES OF DIFFERENT TROPHIC CATEGORIES

TROPHIC TYPE	PHYTOPLANKTON BIOVOLUME (cm^3/m^3)	CHLOROPHYLL A (mg/m^3)	DOMINANT PHYTOPLANKTON	TOTAL P (ug/l)	TOTAL N (ug/l)
Ultra-oligotrophic	1	0.01-0.05		1-5	1-250
Oligotrophic		0.3-3	Chrysophyceae		
			Cryptophyceae		
Oligo-mesotrophic	1-3		Dinophyceae	5-10	250-600
			Bacillariophyceae		
Mesotrophic		2-15			
Meso-eutrophic	3-5			10-30	500-1100
Eutrophic		10-500	Bacillariophpycea		
			Cyanophyceae		
Hypereutrophic	10		Chlorophyceae	30-5000	500-15000
			Euglenophyceae		
Dystrophic		0.1-10		1-10	1-500

*Modified from Wetzel (1975), after many authors and sources

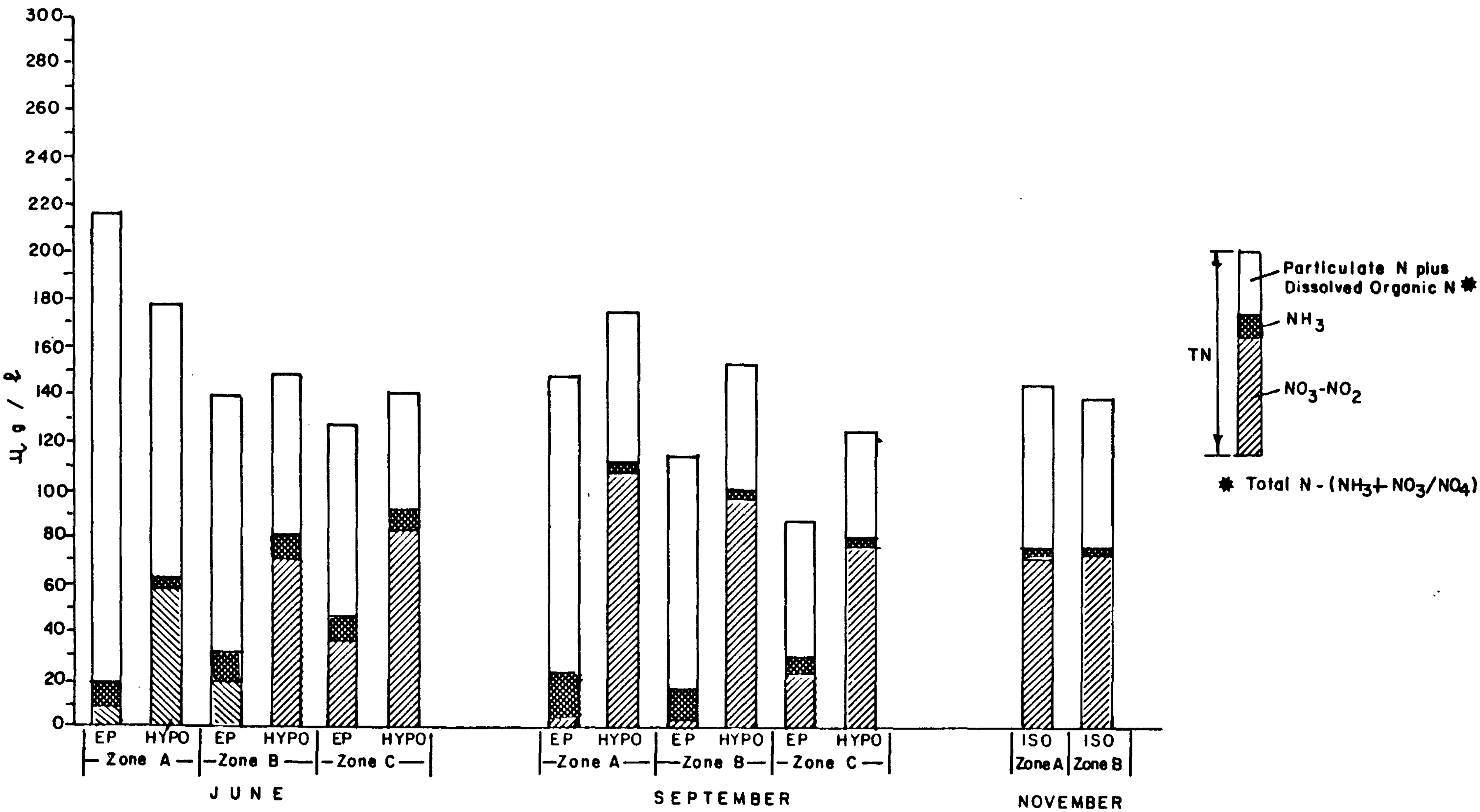

FIGURE 15 MEAN NITROGEN CONCENTRATIONS IN SHUSWAP LAKE DURING 1978

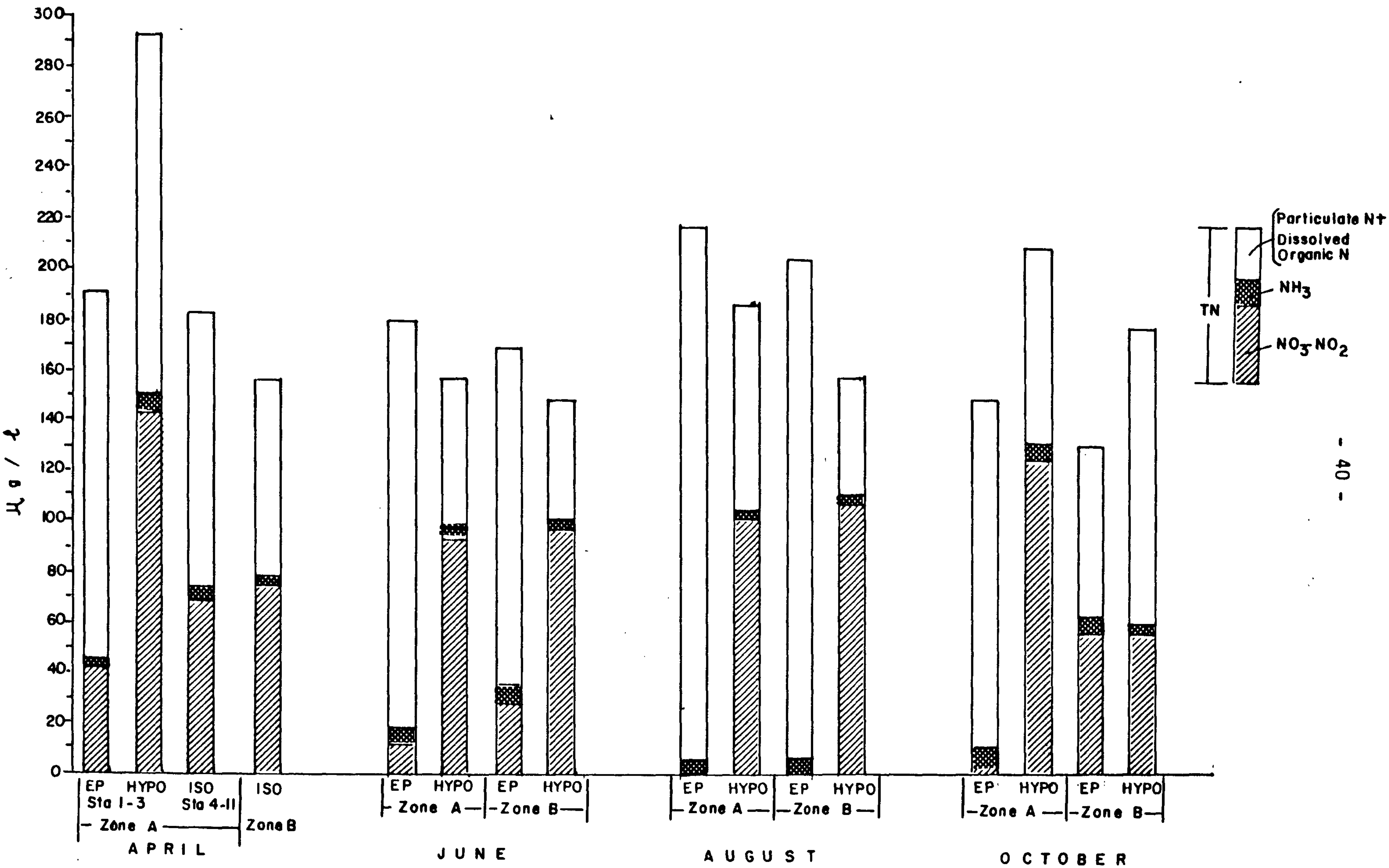

FIGURE 16 MEAN NITROGEN CONCENTRATIONS IN SHUSWAP LAKE DURING 1979

In June 1979, after there had already been a major increase in phytoplankton biovolume in Zone A, the epilimnetic mean nitrate concentration in Zone A was about half that of Zone B. In August 1979, at the end of the phytoplankton growing season, the mean epilimnion values in both Zone A and B had decreased to below the detection limit of 2 ug/l, but the hypolimnetic values continued to increase to over 100 ug/l.

Nitrate levels were lowest in the epilimnion in late summer, at the end of the growing season, as a result of uptake of nitrate by the algae. Zone C had the lowest phytoplankton biovolume and the highest nitrate levels possibly because there were less nutrients being utilized by the smaller algal population.

Nitrate can be trapped below the thermocline when a lake is stratified. Dying algae and other detritus sink to the hypolimnion where they decompose and add to the nitrogen pool. Nonetheless, hypolimnetic nitrate values appear to be unusually high in Zone A in October. Perhaps input of nitrate from allocthonous sources such as the Salmon River and Salmon Arm sewage treatment plant contribute to the high levels.

4.2.2.6 Ammonia Nitrogen. Ammonia (NH_3) levels did vary significantly between zones or from month to month (Figures 15 and 16). However, ammonia levels in the epilimnion of Zone A decreased by almost half from early summer (June) to late summer (August), when phytoplankton populations increased. By fall (September 1978; October 1979) ammonia levels doubled in the epilmnion of Zone A again. The sewage treatment plant discharge and agricultural runoff, via the Salmon River, provided a continued supply of ammonia in the late summer and fall. Little NH_3 was utilized by algae after the phytoplankton population had declined so NH_3 levels increased over the winter. Comparatively, there was little fluctuation in ammonia levels in Zone B.

4.2.2.7 Nitrogen/Phosphorus Ratio. Waters having a total nitrogen: total phosphorus ratio by weight of greater than 15 to 17 are considered phosphorus limiting while waters with a N:P ratio of less than 9 to 10 are nitrogen limiting. In waters having a N:P ratio of 9 to 15, nitrogen and phosphorus concentrations are nearly balanced with the ratio required for phytoplankton growth (Sakamoto, 1966). Shuswap Lake appears to be phosphorus limiting with a N:P ratio greater than 15 to 17 throughout most of the year (Table 10). The N:P ratio was between 9 to 15 in Zone A on four occasions: June, September and November 1978 and June 1979; and the N:P ratio was never less than 9 to 10. Therefore, Shuswap Lake does not appear to be nitrogen limiting.

4.2.2.8 Particulate Carbon/Particulate Nitrogen Ratio. The PC:PN ratio is used to indicate whether the major source of carbon for a lake is autochthonous or allochthonous. Autochthonous organic matter is produced by decomposition of plankton within the lake and contains about 24% crude protein with a C:N ratio of about 12:1 (Wetzel, 1975). Allochthonous organic matter has most of the N removed and contains about 6% crude protein with a C:N ratio of 45:1 to 50:1 (Hutchinson, 1957).

The epilimnetic C:N ratio for Zones A, B, and C in both 1978 and 1979 were all less than or equal to 12:1 suggesting that Shuswap Lake's major source of organic matter is from within the lake itself by decomposition of plant and animal material (Table 11).

4.2.2.9 Silicon Dioxide. Silicon dioxide concentrations in Shuswap Lake were comparable to other B.C. lakes such as Okanagan Lake where the range was between 3.5 to 5.3 mg/l (Truscott & Kelso, 1979), and Kamloops Lake where the annual range was from 4.0 to 6.9 mg/l (St. John et al, 1976).

Silicon dioxide in epilimnetic waters ranged from an average of 3.5 mg/l for Zone B at Station 16 in August 1979 to an average of 7 mg/l for Zone A in June 1978 (Figure 17). As expected, the concentrations were lowest during the late spring and summer when silicon dioxide was utilized by diatoms.

TABLE 10 TOTAL NITROGEN:TOTAL PHOSPHORUS RATIO BY WEIGHT IN SHUSWAP LAKE DURING 1978 AND 1979

	1978			1979						
ZONE	JUNE (epilimnion)	SEPTEMBER (epilimnion)	NOVEMBER (isothermal)	STATION		APRIL	STATION	JUNE (epilimnion)	AUGUST (epilimnion)	OCTOBER (isothermal)
A	14:1	13:1	13:1	1-3	epilimnion	17:1	1-11	13:1	26:1	22:1
				4-11	isothermal	22:1				
B	18:1	17:1	30:1	16		32:1	16	40:1	21:1	25:1
C	26:1	35:1	--							

TABLE 11 PARTICULATE CARBON:PARTICULATE NITROGEN RATIO BY WEIGHT IN SHUSWAP LAKE DURING 1978 AND 1979

		1978			1979			
ZONE		JUNE	SEPT.	NOV.	APRIL	JUNE	AUG.	OCT.
A	EPI	8:1	8:1	9:1	8:1	10:1	9:1	9:1
B	EPI	9:1	8:1	10:1	10:1	4:1	9:1	9:1
C	EPI	12:1	9:1	--				

NOTE: See Table 22 for Particulate Carbon Results and Table 18 for Particulate Nitrogen Results

EPI = epilimnion

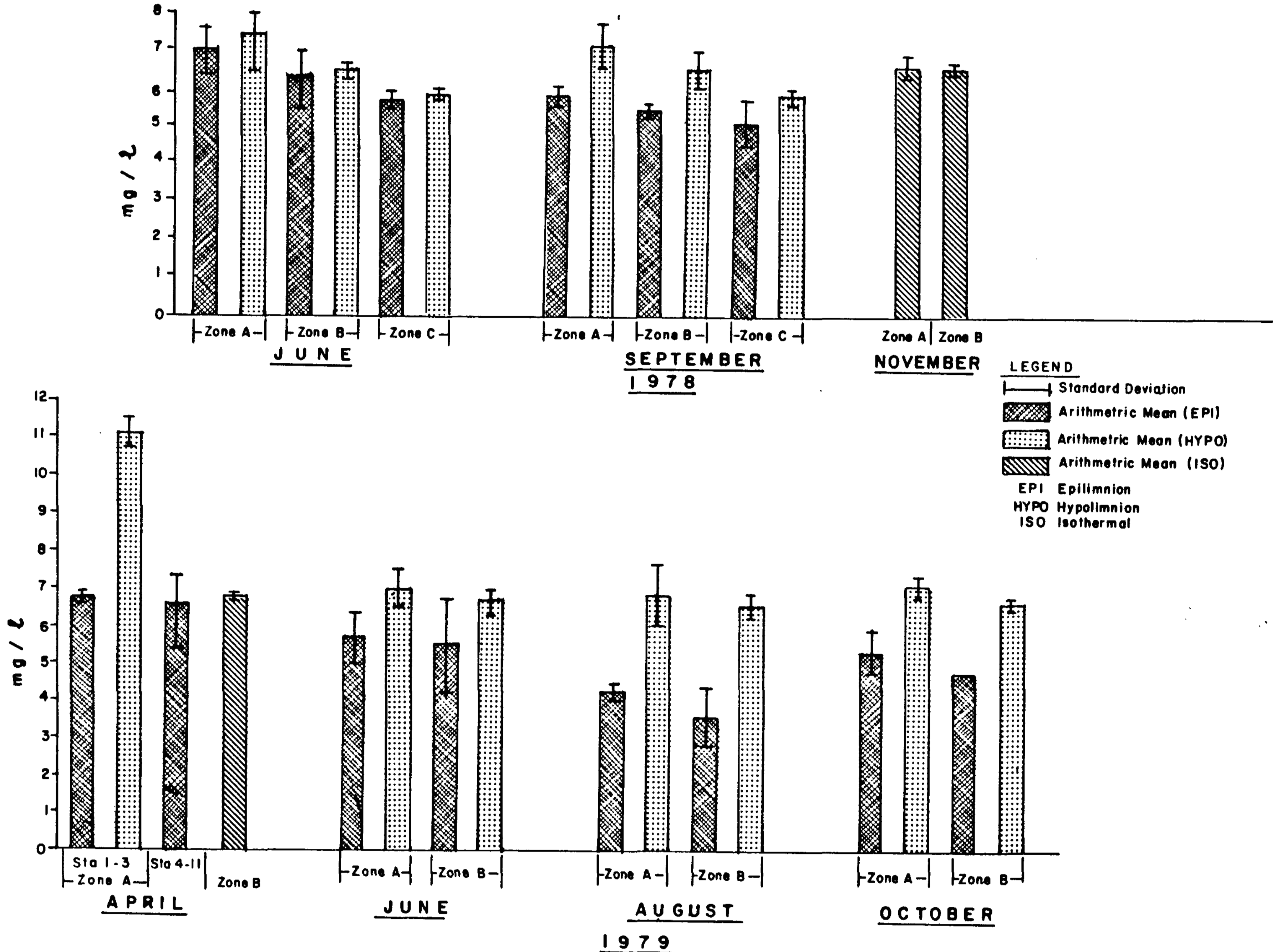

FIGURE 17 MEAN SILICA DIOXIDE CONCENTRATIONS IN SHUSWAP LAKE DURING 1978 AND 1979

4.2.3 Biological Characteristics.

4.2.3.1 Phytoplankton. A decrease in phytoplankton biovolume (Table 12), indicates a shift in trophic status from Zone A to Zone C according to Wetzel's (1975) categorization (Table 9). Phytoplankton biovolumes in June 1978 and August 1979 suggest Zone A was mesotrophic to meso-eutrophic, Zone B was oligo-mesotrophic and Zone C was ultra-oligotrophic to oligotrophic. This trophic categorization of the three study zones based on phytoplankton biovolume corresponds with the categorization based on total phosphorus concentrations (Section 4.2.2.4).

Phytoplankton biovolume decreased in all three zones between June 1978 and September 1978 (Figure 18). After the summer algal bloom, the phytoplankton population declined when nutrients were depleted. The population then remained low because of light/temperature limiting factors.

In April 1979, phytoplankton biovolume at Stations 1 to 3 in Zone A was already high and was comparable to the Zone A average phytoplankton biovolume in June 1979. Phytoplankton biovolume at Stations 4 to 11 in April 1979 was approximately one-half of the average June Zone A average biovolume.

Phytoplankton in Zone A continued to increase from early summer 1979 (June) to late summer (August) possibly because of increased anthropogenic nutrient sources, then declined sharply in the fall (October) when light and temperature were limiting. Phytoplankton biovolume in Zone B peaked in early summer (June) and had already declined by late summer (August) possibly because of lack of nutrients.

The shift in the major algal groups from Zone C to Zone A (Figure 19) also reflects a shift from oligotrophy to meso-eutrophy or eutrophy. As oligotrophic conditions become eutrophic, there is a shift in the dominant phytoplankton populations from Chrysophyceae, Cryptophyceae,

TABLE 12 MEAN PHYTOPLANKTON BIOVOLUME (cm^3/m^3) FOR SHUSWAP LAKE IN 1978 AND 1979

1978

ZONE	& STATION	JUNE	SEPTEMBER	STATION	NOVEMBER
A	1-11	3.30	0.66	1-11	0.61
B	12-17, 21-30	1.42	0.45	13,16	0.52
C	31-33	0.79	0.26		NS

1979

ZONE	& STATION	APRIL	STATION	JUNE	AUGUST	OCTOBER
A	1-3	2.73	1-11	2.63	3.06	0.42
	4-11	1.57				
B	16	0.41	16	3.27	1.18	0.51

NS = not sampled

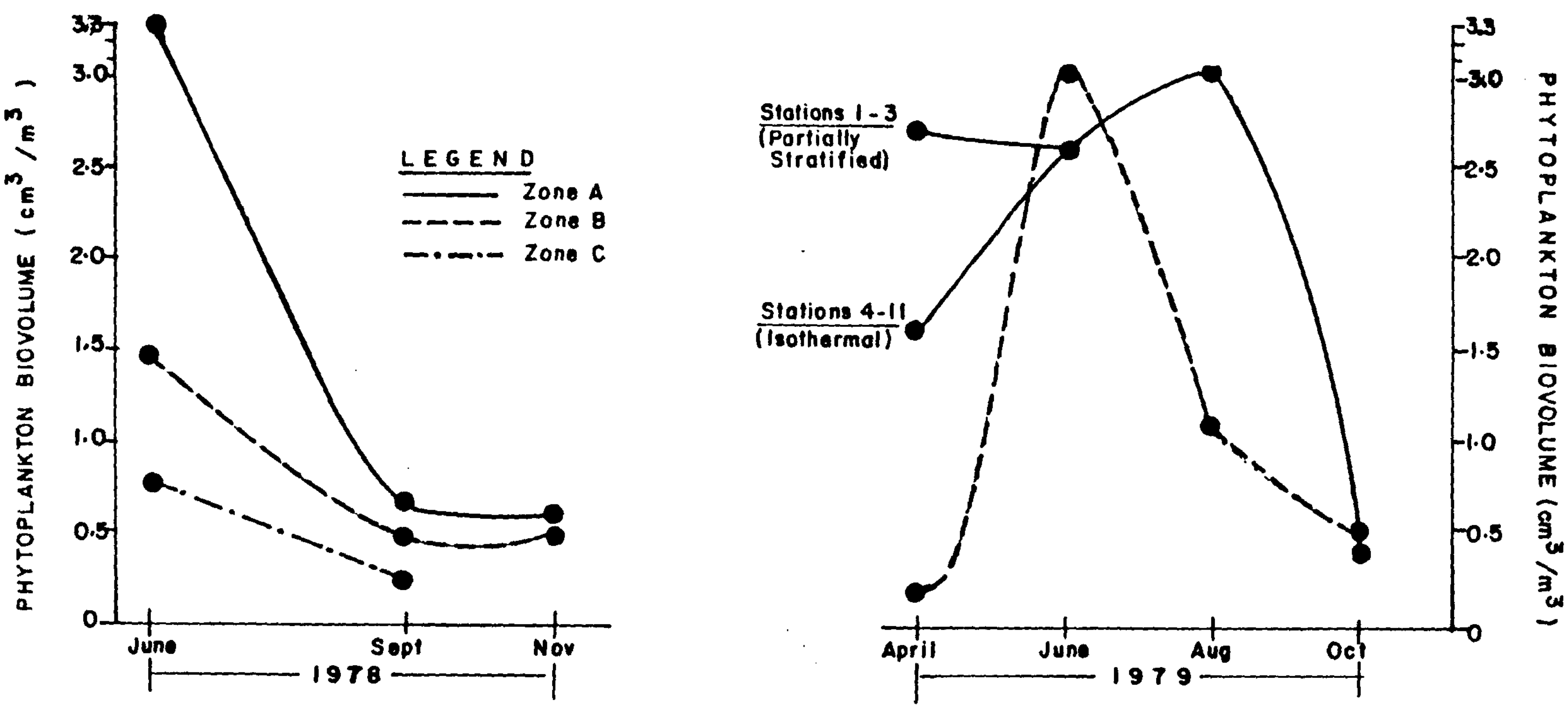

FIGURE 18 PHYTOPLANKTON BIOVOLUME IN SHUSWAP LAKE DURING 1978 AND 1979

Dinophyceae and Bacillariophyceae to Bacillariophyceae, Cyanophyceae, Chlorophyceae and Euglenophyceae.

In Zone A (Table 13), cryptomonads predominated only in the spring (April 1979). Diatoms (Bacillariophyceae) and blue-green (Cyanophyceae) dominated during the summer and fall. In Zone B (Table 14), cryptomonads predominated only in the spring (April 1979). Diatoms and dinoflagellates (Dinophyceae) dominated during the summer and fall. Blue-greens did not make up more than 40% of the total population until the late summer (August 1979) and fall (October 1979). By early winter (November 1978) diatoms predominated again. In Zone C (Table 15), diatoms dominated in the summer (June 1978) and fall (September 1978). Chrysophytes, often associated with oligotrophic waters, were abundant in the summer; cryptomonads, also associated with oligotrophic waters, were abundant in the fall.

Individual genera and/or species of algae can indicate the trophic status of a lake (Hutchinson, 1967). Three dominant genera were found to constitute between 50% to 80% of the total phytoplankton biovolume in each zone (Figure 20 and 21). Plankton often associated with eutrophic lakes and that were among the dominant algae in Zone A and B were Fragilaria crotonensis, Synedra spp., and Anabaena (Round, 1973). However, the biovolumes of these algae were greater in Zone A than Zone B. Surirella ovata, Synedra delicatissima, and Asterionella formosa were all prominent algal species in Zone A and are also associated with eutrophic waters (Palmer, 1977).

Cyclotella comta, the prominent alga found in Zone C in June and September 1978, is the dominant alga most often found in oligotrophic lake water (Wetzel, 1975).

The chlorophyll-a values (Table 16) cannot be compared with values from other lakes because an error was made in the chlorophyll analysis. However, the error was consistent; therefore, the values can be used qualitatively to compare between zones within Shuswap Lake.

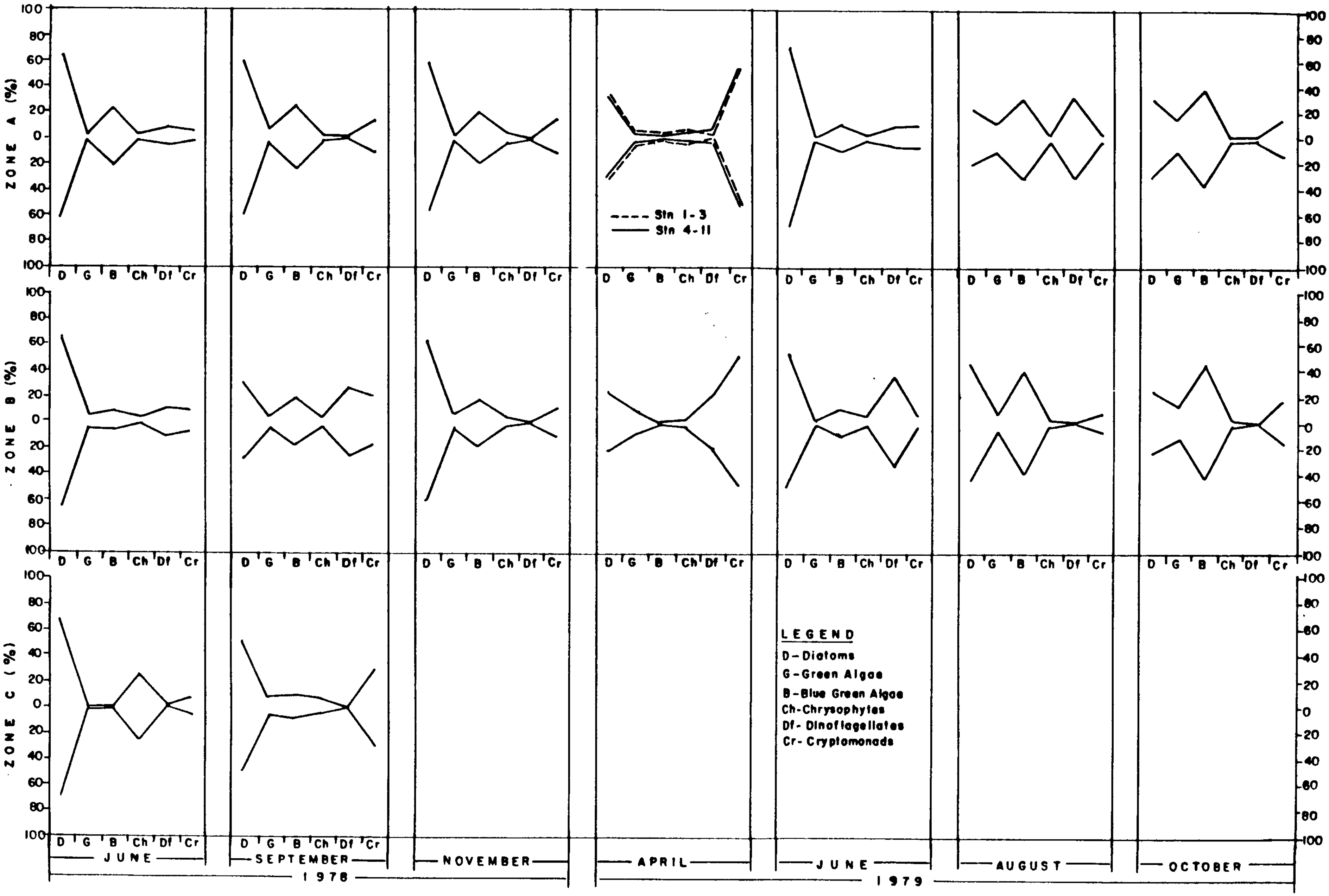

FIGURE 19 PERCENT COMPOSITION BY VOLUME OF MAJOR ALGAL GROUPS IN SHUSWAP LAKE DURING 1978 AND 1979

TABLE 13 MEAN PHYTOPLANKTON BIOVOLUMES (cm^3/m^3) AND PERCENT COMPOSITION OF MAJOR ALGAL GROUPS IN ZONE A DURING 1978 AND 1979

	June 1978		Sept. 1978		Nov. 1978		April 1979*		June 1979		Aug. 1979		Oct. 1979	
	Volume	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Diatoms	2.29	63.7	0.39	59.6	0.37	58.3	0.97	35.0	1.92	69.4	0.71	21.5	0.13	30.9
(Bacillariophyceae)							0.55	33.3						
Green Algae	0.03	0.7	0.03	4.0	0.02	3.3	0.18	6.5	0.05	1.7	0.37	11.3	0.06	13.6
(Chlorophyta)							0.09	5.7						
Blue-Green Algae	0.76	21.1	0.15	23.1	0.13	20.4	0.07	2.5	0.28	0.10	1.04	31.6	0.16	37.5
(Cyanophyta)							0.02	0.9						
Chrysophytes	0.06	1.6	0.004	0.5	0.03	4.0	0.16	6.0	0.07	2.6	0.02	0.6	0.009	2.0
(Chrysophyta)							0.05	2.8						
Dinoflagellate	0.29	8.1	0	0	0.0005	0.1	0.02	0.8	0.21	7.7	1.06	32.1	0.0006	0.1
(Pyrrhophyta)							0.10	6.2						
Cryptomonads	0.17	4.7	0.08	12.7	0.09	13.9	1.36	49.2	0.24	8.6	0.10	2.9	0.07	16.0
(Cryptophyta)							0.84	51.0						
TOTAL	3.60	100	0.65	100	0.64	100	2.76	100	2.77	100	3.30	100	0.43	100
							1.65	100						

*For April 1979 the average phytoplankton biovolume of each major algal group was calculated for Stations 1-3 (first number under each grouping) and for Stations 4-11 (second number under each grouping).

TABLE 14 MEAN PHYTOPLANKTON BIOVOLUMES (cm^3/m^3) AND PERCENT COMPOSITION OF MAJOR ALGAL GROUPS IN ZONE B DURING 1978 AND 1979

	June 1978		Sept. 1978		Nov. 1978		April 1979*		June 1979		Aug. 1979		Oct. 1979	
	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Diatoms (Bacillariophyceae)	1.01	65.5	0.17	29.3	0.32	62.2	0.10	22.7	2.13	47.5	0.53	45.1	0.12	23.6
Green Algae (Chlorophyta)	0.08	5.1	0.02	3.9	0.03	5.4	0.04	8.2	0.03	0.8	0.07	5.9	0.07	12.9
Blue-Green Algae (Cyanophyta)	0.11	7.2	0.10	17.5	0.10	18.4	0	0	0.38	8.4	0.47	39.5	0.22	43.6
Chrysophytes (Chrysophyta)	0.03	1.7	0.02	3.9	0.01	2.9	0.006	1.4	0.12	2.7	0.04	3.3	0.007	1.5
Dinoflagellate (Pyrrhophyta)	0.17	10.7	0.15	26.2	0	0	0.09	19.8	1.61	36.0	0	0	0	0
Cryptomonads (Cryptophyta)	0.15	9.7	0.11	19.2	0.06	11.2	0.21	47.9	0.20	4.5	0.07	6.3	0.09	18.4
TOTAL	1.55	100	0.57	100	0.52	100	0.45	100	4.47	100	1.18	100	0.51	100

*For April 1979 the average phytoplankton biovolume of each major algal group was calculated for Stations 1-3 (first number under each grouping) and for Stations 4-11 (second number under each grouping).

TABLE 15 MEAN PHYTOPLANKTON BIOVOLUMES (cm^3/m^3) AND PERCENT COMPOSITION OF MAJOR ALGAL GROUPS IN ZONE C DURING 1978 AND 1979

	June 1978		Sept. 1978	
	Value	%	Value	%
Diatoms (Bacillariophyceae)	0.53	67.9	0.14	51.7
Green Algae (Chlorophyta)	0.004	0.5	0.02	6.6
Blue-Green Algae (Cyanophyta)	0.002	0.2	0.02	8.4
Chrysophytes (Chrysophyta)	0.20	24.9	0.01	4.8
Dinoflagellate (Pyrrhophyta)	0	0	0	0
Cryptomonads (Cryptophyta)	0.05	6.5	0.08	28.5
TOTAL	0.79	100	0.27	100

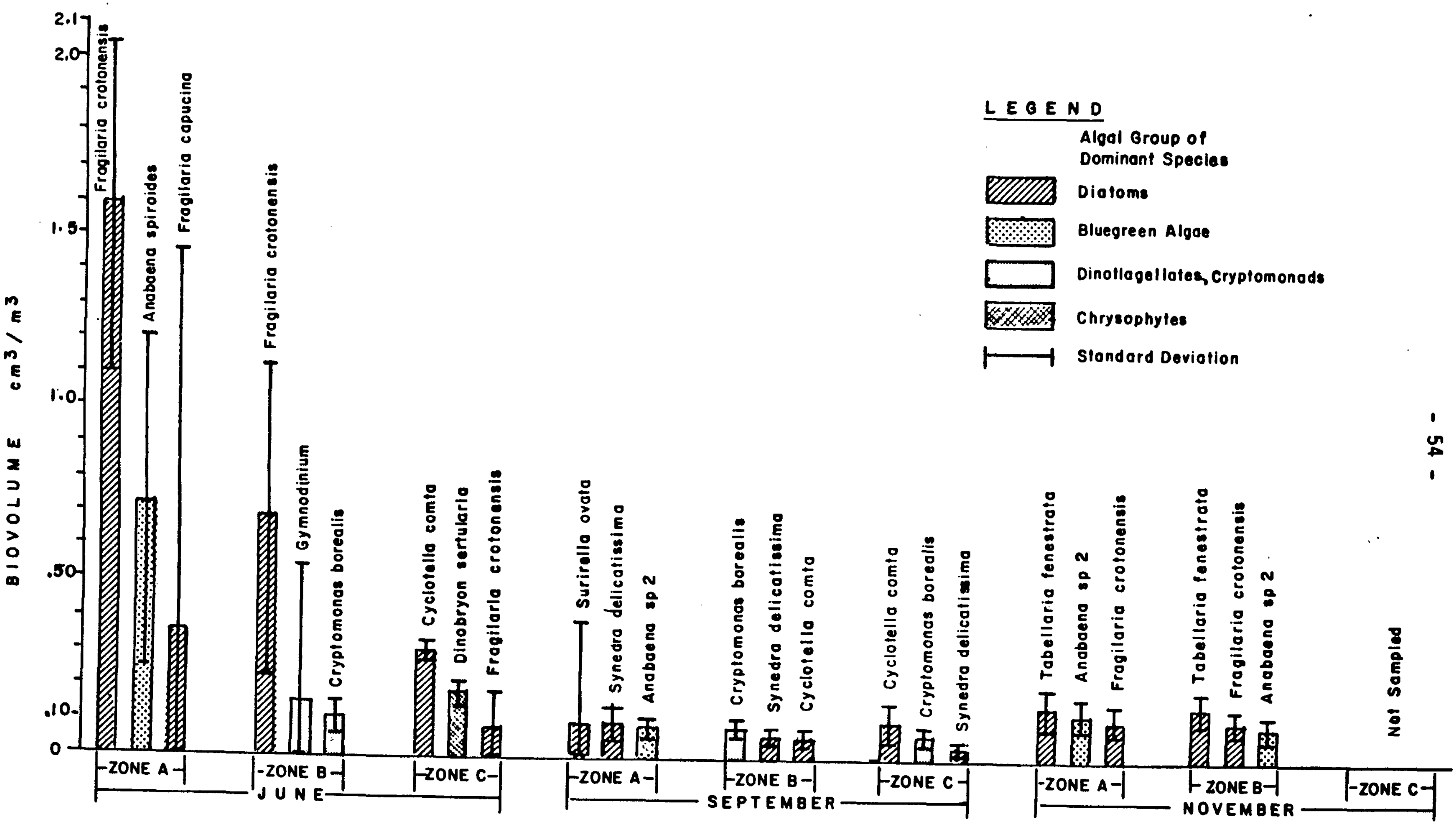

FIGURE 20 MEAN BIOVOLUME FOR THREE DOMINANT PHYTOPLANKTON SPECIES IN SHUSWAP LAKE DURING 1978

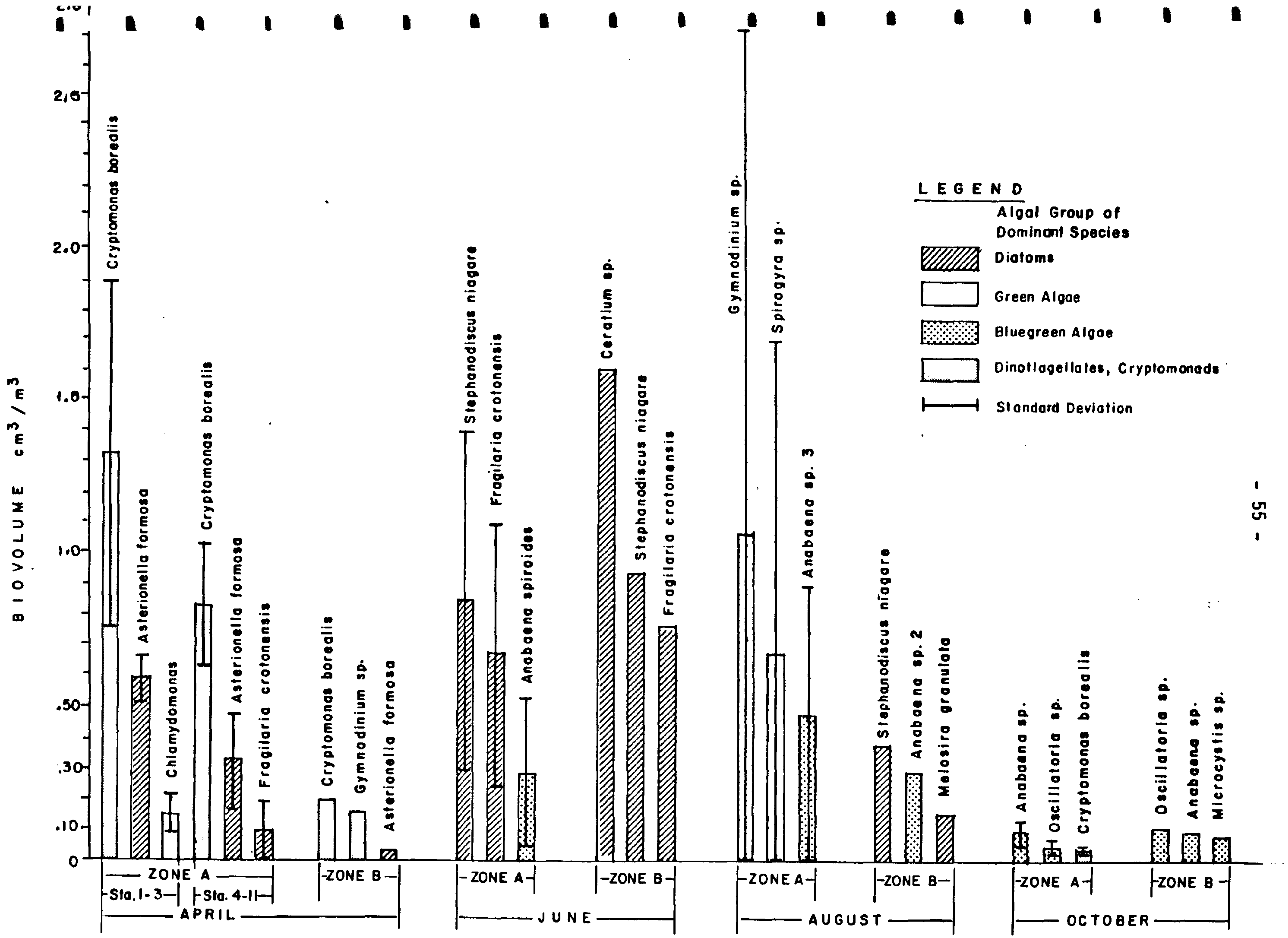

FIGURE 21 MEAN BIOVOLUME FOR THREE DOMINANT PHYTOPLANKTON SPECIES IN SHUSWAP LAKE DURING 1979

TABLE 16 CHLOROPHYLL-a + PHAEOPHYTIN VALUES (mg/m^3) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION		SEPTEMBER				NOVEMBER			
		n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-11	11	2.620-3.620	3.215	0.261	11	3.150-3.570	3.315	0.145
B	12-17 and 21-30	16	1.520-2.170	1.826	0.264	2	2.810-7.020	2.977	4.915
C	31-33	3	1.870-0.006						

1979

ZONE & STATION		JUNE				AUGUST				OCTOBER	
		n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range
A	1-11	11	4.170-8.482	6.587	1.321	11	3.133-17.655	6.824	4.283	11	2.867-4.514
B	16	1	-	5.904	0	2	-	6.000	0	1	-

Chlorophyll-a values were twice as high in the summer as they were in the fall. Zone A had the highest chlorophyll-a values throughout the study.

4.2.3.2 Periphyton. Eutrophication of a system as a result of increased nutrient loading is not only reflected by an increase in phytoplanktonic productivity but can also be reflected by an increase in littoral productivity. Development of littoral communities may be a significant part of the eutrophication process in Shuswap Lake because shoreline development is high.

In the initial stages of eutrophication, submerged macrophytes, and phytoplankton are important to total primary productivity. Once the lake is subjected to severe light attenuation, usually associated with intense phytoplankton productivity, emergent vegetation assumes greater dominance in the lake ecosystem. Attached algae (periphyton) develop in strong association with emergent flora. Therefore, in those littoral zones where emergent vegetation is prevalent, larger populations of periphyton are expected.

Stations SA-S1, SA-S2 and SA-S3 were located in Zone A near marshy areas dominated by emergent flora (Figure 7). The shoreline slope was very low allowing for further development of the littoral area. The muddy, silty bottom may have reflected the accumulation of detritus from anthropogenic sources and organic material from decaying plant matter. Station SA-S4 in Zone B served as the control site for the shallow water stations. In contrast to the first three shallow water stations, there were no emergent or submergent macrophytes in the area and periphyton growth was not readily visible on the rocks. Shoreline slope was much greater. The bottom was rocky and the water clear.

Dry weight is often used as an indicator of biological production and is a measure of the standing crop or biomass of periphyton at any given time. However, ash-free dry weight, the organic fraction of the dry weight measurement, is a better estimate of standing crop. Ash-free dry weight was greatest at Station SA-S1 (Figure 22). Both stations SA-S1 and SA-S2,

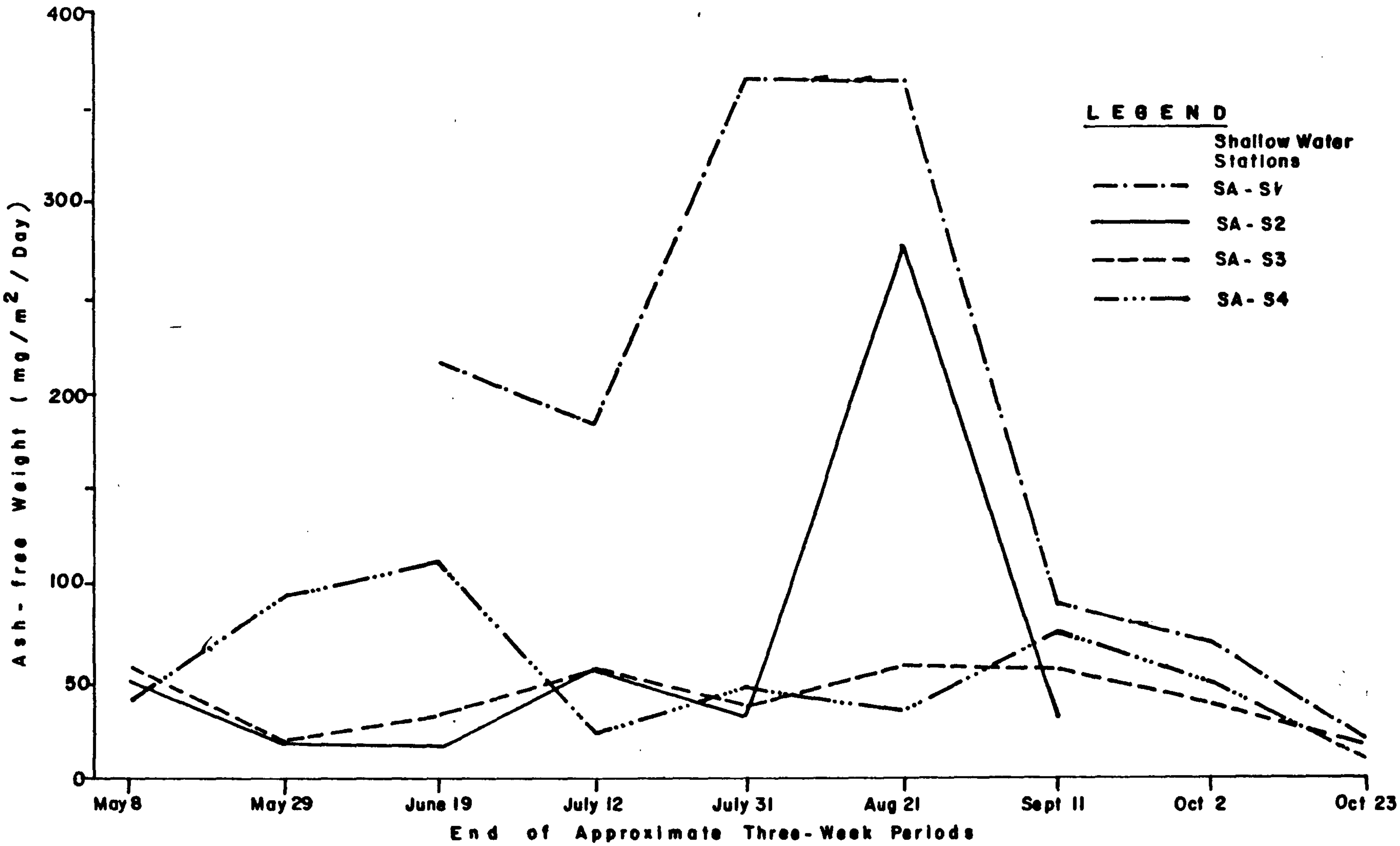

FIGURE 22 PERIPHYTON ASH-FREE WEIGHT AT SHALLOW WATER STATIONS IN SHUSWAP LAKE DURING 1979

the two stations closest to the sewage discharge and Salmon River, had sudden peaks in ash-free weight in mid to late summer. Stations SA-S3 and SA-S4 (control) remained relatively constant throughout the study.

Periphyton biovolume followed much the same pattern as ash-free dry weight measurements (Figure 23). Biovolume peaked in August at all four stations with the least fluctuation in biovolume at Station SA-S4. Generally mean seasonal periphyton biovolume values of over 0.2 mm^3/cm^2/ three week period are characteristic of eutrophic areas of a lake and seasonal periphyton biovolumes under 0.2 mm^3/cm^2 are characteristic of oligotrophic to mesotrophic areas (Ennis, 1972). Mean biovolumes did not exceed 0.2 mm^3/cm^2 (Table 17). However periphyton biovolume at Station SA-S1 (0.16 mm^3/cm^2) approached 0.2 mm^3/cm^2. Mean values decreased from Station SA-S1 to SA-S4 (control).

The late summer algal assemblages at all four stations were dominated by the chlorophytes, *Ulothrix* and *Spirogyra*. *Cladophora* was prevelant at Stations SA-S1 (Figure 24) and SA-S2 (Figure 25) in the fall. *Spirogyra* continued to dominate the algal assemblage at SA-S3 (Figure 26) in the fall. There was no clear dominant species at SA-S4 (Figure 27) in the fall.

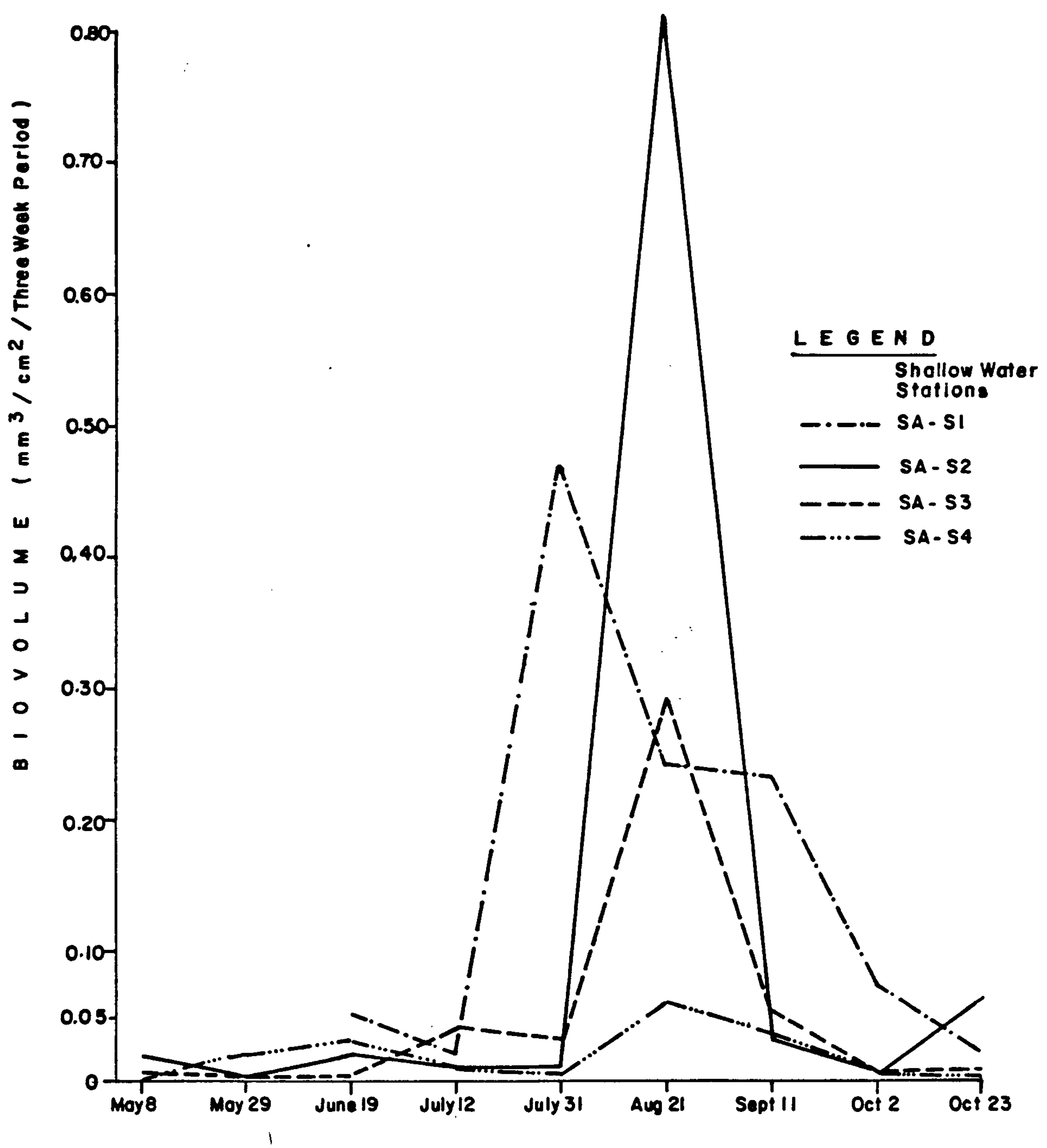

FIGURE 23 PERIPHYTON BIOVOLUME AT SHALLOW WATER STATIONS IN SHUSWAP LAKE DURING 1979

TABLE 17 PERIPHYTON BIOVOLUME ($mm^3/cm^2/day$) AT SHALLOW WATER STATIONS IN SHUSWAP LAKE DURING 1979

STATIONS	END OF APPROXIMATE THREE-WEEK PERIODS										
	May 8	May 29	June 19	July 12	July 31	Aug. 21	Sept. 11	Oct. 2	Oct. 23	Mean	S. Dev.
SA-S1	--	--	0.05	0.02	0.47	0.24	0.23	0.07	0.02	0.16	
SA-S2	0.02	0.003	0.02	0.01	0.009	0.81	0.03	0.003	0.06	0.11	
SA-S3	0.007	0.0006	0.005	0.005	0.03	0.29	0.05	0.007	0.004	0.05	
SA-S4	0.0006	0.02	0.03	0.03	0.002	0.06	0.03	0.007	0.0005	0.02	

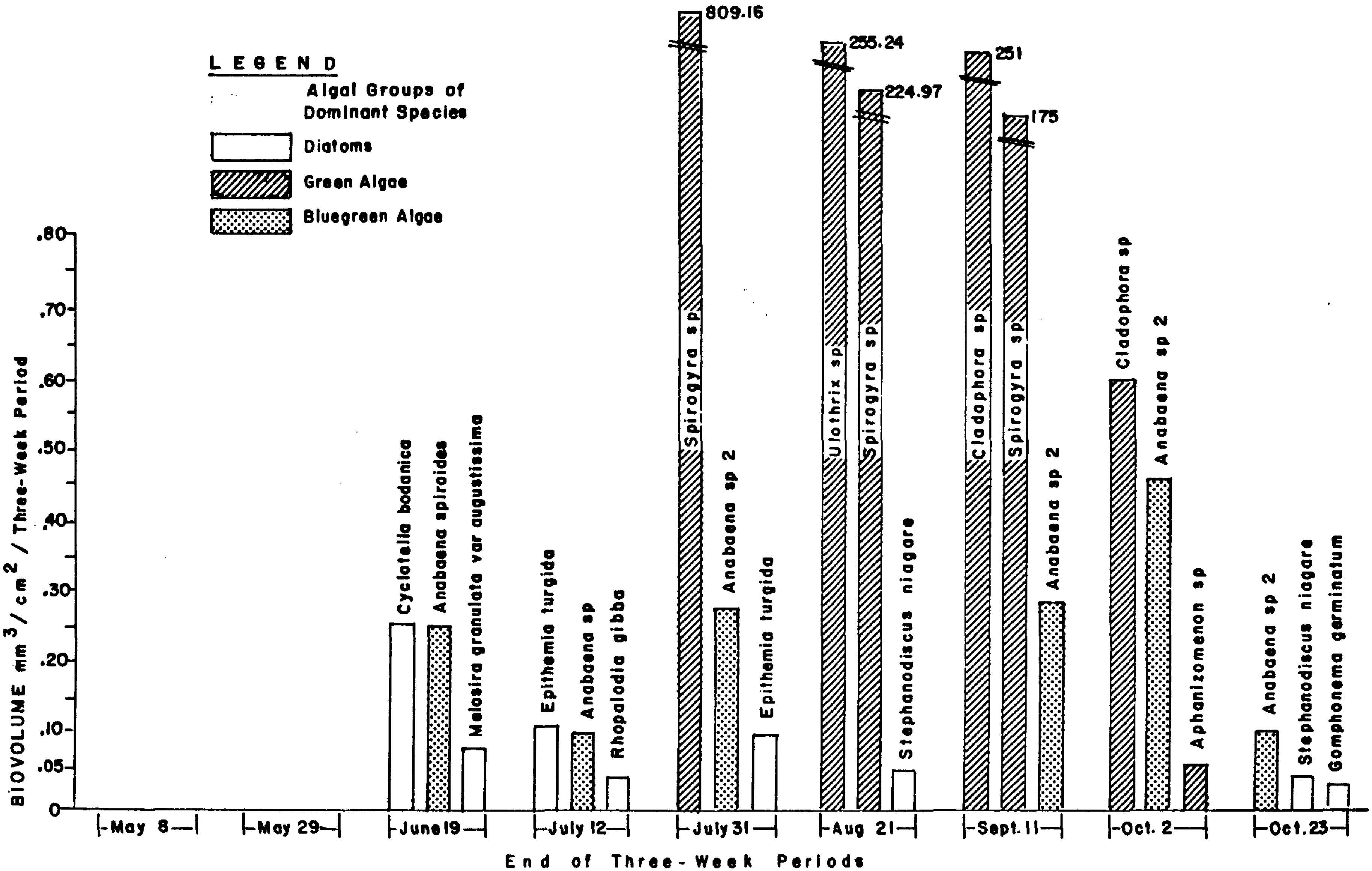

FIGURE 24 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA-SI IN 1979

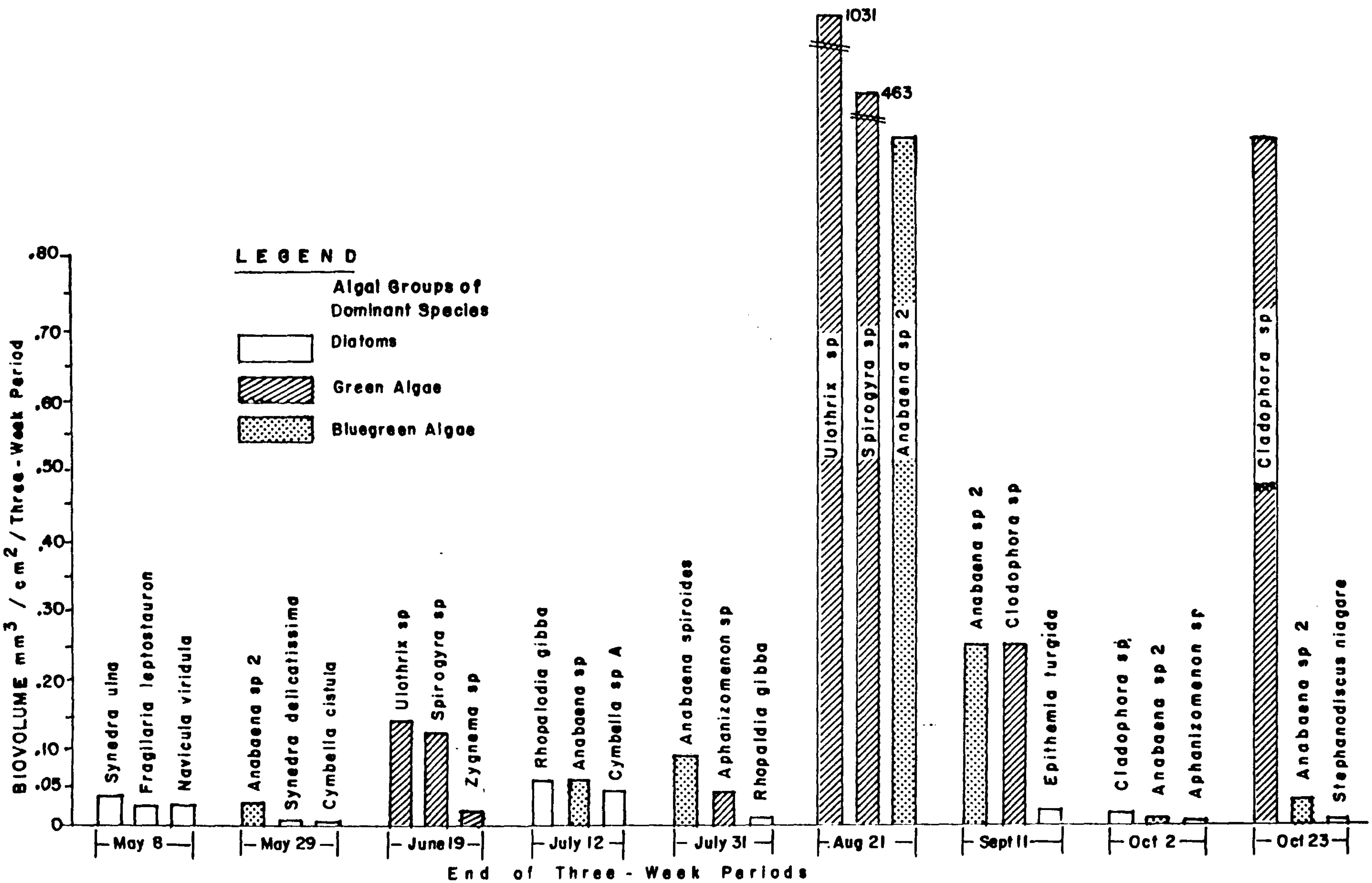

FIGURE 25 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA-S2 IN 1979

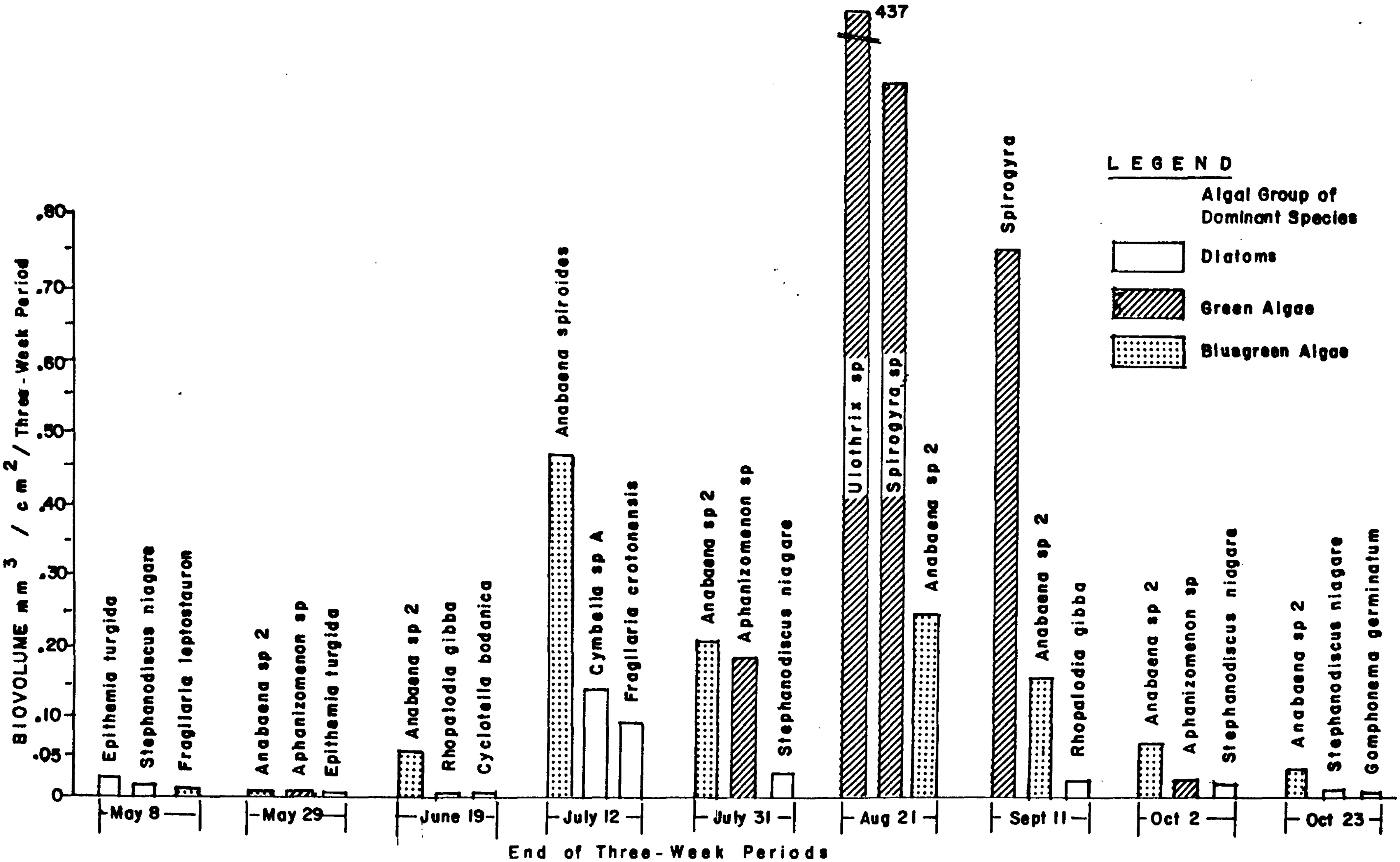

FIGURE 26 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA - S3 IN 1979

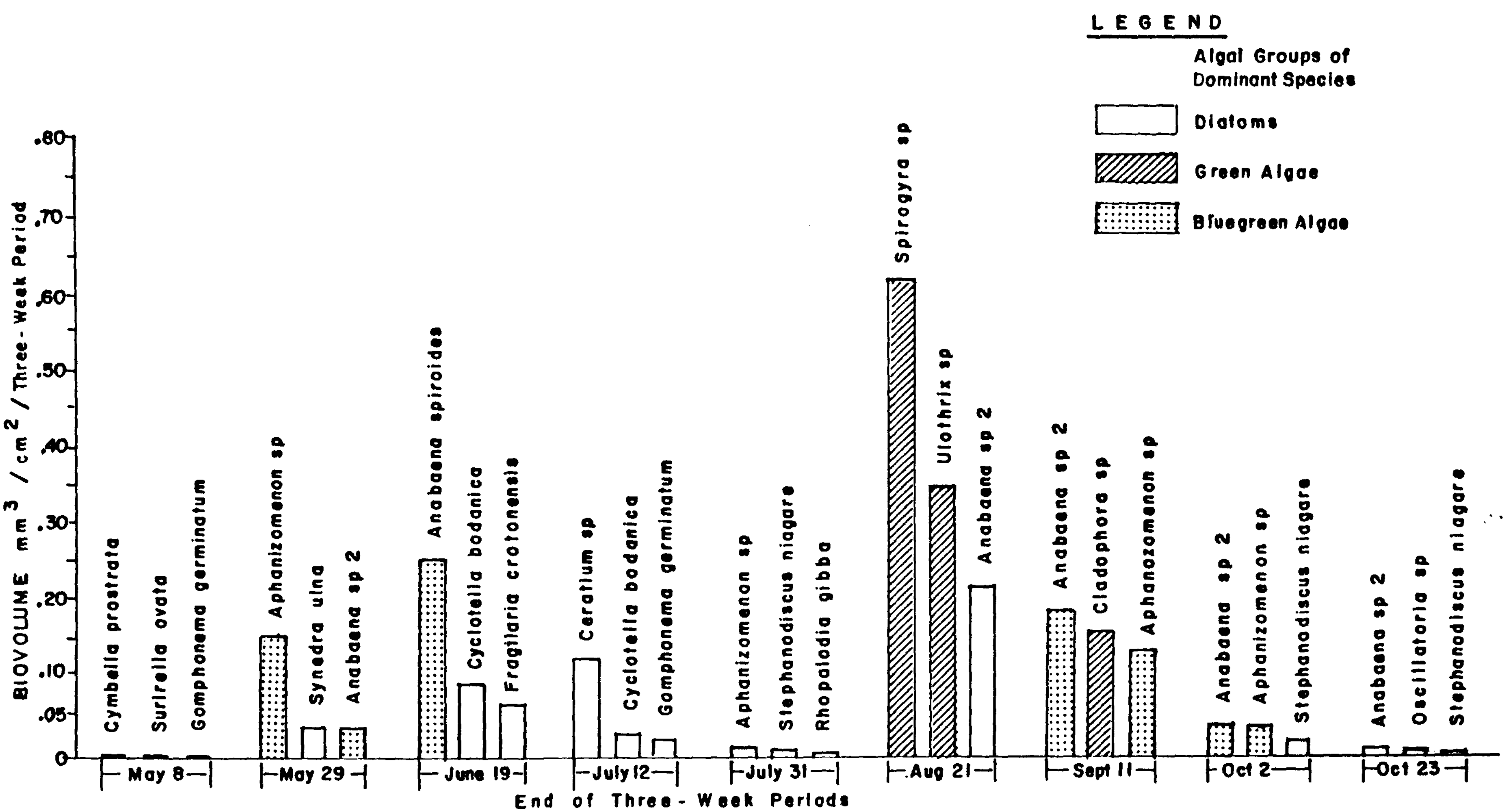

FIGURE 27 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA - S4 IN 1979

5.0 SUMMARY AND CONCLUSIONS

1) Eutrophication in Shuswap Lake was more advanced in Zone A (Tappen Bay area) than in Zone B (Salmon Arm) and C (Seymour Arm).

According to general ranges of various limnological characteristics such as total phosphorus, phytoplankton biovolume and dominant phytoplankton measured in 1978 and 1979, the trophic status of:

Zone A was mestrophic to eutrophic
Zone B was oligotrophic to meso-eutrophic
Zone C was ultra-oligotrophic to oligotrophic

2) The two major sources of phosphorus loading to Zone A were identified in 1978 as the Salmon Arm sewage treatment plant and the Salmon River.

3) The District of Salmon Arm's sewage treatment plant could be responsible for enhancing eutrophication in Zone A by supplying additional phosphorus to the system at critical times of the year (early-spring and late-summer) and thereby lengthening the phytoplankton growing season.

Generally, before spring freshet and after winter mixing, phosphorus levels are high and biovolume is low. However, both phosphorus levels and phytoplankton biovolume seemed unusually high in the spring at Stations 1 to 3 (Zone A). Approximately a week before peak flow from the Salmon River in April, 1979, these stations were weakly stratified and total dissolved phosphorus levels in the epilimnion were the highest recorded throughout the study. Correspondingly, the phytoplankton biovolume in April at Stations 1 to 3 was already as high as post-freshet (June 1979) biovolumes in Zone B. During April, before freshet, the sewage treatment plant contributed approximately 21% of the total dissolved phosphorus loading to Zone A. This added phosphorus load from the STP may have been sufficient to allow algae to bloom sooner in Zone A than in Zone B or C. The latter zones received an allochthonous supply from the rivers alone. As expected, phytoplankton biovolumes in Zone B did not increase until after spring freshet (June 1979) when there was an increase in phosphorus loading from the rivers.

During the post-freshet flow period, the Salmon Arm sewage treatment plant contributed approximately 40% of the total phosphorus loading and 41% of the dissolved phosphorus loading to Zone A. Phytoplankton biovolume in Zone A was higher in August than in June 1979; whereas phytoplankton biovolume in Zone B was equivalent to the lower pre-freshet biovolumes. When the post-freshet algal population in Zone B appeared to have declined from lack of nutrients, the additional phosphorus loading to the lake from the sewage treatment plant may have been enough to allow phytoplankton in Zone A to continue to grow into the late summer.

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APPENDIX I

FISHERIES RESOURCES IN SHUSWAP LAKE

(a) Commercial Salmon Species Found in the Shuswap Lake System

(b) Estimates of Annual Salmon Escapements By Species to the Shuswap Lake System

APPENDIX Ia COMMERCIAL SALMON SPECIES FOUND IN THE SHUSWAP LAKE SYSTEM

Sockeye - The area is known primarily for its large sockeye runs. The majority of the sockeye spawn in the adams and Little Rivers with smaller runs spawning in the Seymour, Lower Shuswap and Eagle Rivers. Sockeye populations in this system exhibit cyclic dominance (4 years) which causes wide variations in spawning populations.

Chinook - Chinook salmon spawn in most streams tributary to the Shuswap Lake system with major runs occurring in the Lower Shuswap and Adams Rivers.

Coho - Coho salmon spawn in the most streams tributary to the Shuswap Lake system with majro runs occurring in the Upper Adams, Bessette and Eagle Rivers.

Pink - Pink Salmon only occassionally in the Shuswap Lake system.

*Taken from Graham and Russell, 1979

APPENDIX Ib ESTIMATES OF ANNUAL SALMON ESCAPEMENTS BY SPECIES TO THE SHUSWAP LAKE SYSTEM (GRAHAM & RUSSEL, 1979)

SPECIES	NAME OF STREAM	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Sockeye	Adams River	3,983	45,908	1,315,000	280,000	4,325	40,546	1,000,000	30,000	5,100	1,500
	Upper Adams R.	0	0	25	0	25	0	25	25	25	0
	Anstey River	0	0	500	50	0	0	1,500	25	0	NR
	Eagle River	0	75	7,525	200	25	50	3,700	200	0	444
	Little River	0	6,775	222,400	12,500	75	1,500	100,000	15,000	175	8,000
	Momich River	617	0	200	25	750	0	25	0	3,000	30
	Scotch Creek	126	3,395	6,300	750	0	7,500	3,900	25	38	13,636
	Seymour River	3,879	7,327	14,275	15,000	3,500	3,500	35,000	30,000	8,500	6,018
	Lower Shuswap R.	25	1,500	29,000	7,500	200	7,452	75,000	15,000	82	7,500
	Middle Shuswap R.	0	0	4,559	200	0	0	3,500	25	0	32
	Sinmax River	0	50	200	3	25	69	200	0	25	70
Chinook	Adams River	3,500	5,000	1,500	750	1,900	16,500	1,500	1,500	400	1,700
	Upper Adams R.	0	0	0	0	0	0	150	0	0	0
	Bessette R.	0	0	25	25	25	0	25	25	0	15
	Eagle River	200	400	300	740	300	350	400	400	0	756
	Little River	400	200	750	200	200	200	300	400	100	600
	Salmon River	275	200	200	400	0	0	200	150	50	320
	Scotch Creek	25	0	0	0	0	0	0	0	0	0
	Seymour River	0	25	0	0	0	0	0	0	0	25
	Lower Shuswap R.	7,500	7,500	7,500	7,500	4,500	9,000	10,000	15,000	2,500	9,500
	Middle Shuswap R.	400	500	750	750	300	400	750	750	400	550
Coho	Adams River	400	750	400	300	200	300	150	200	10	338
	Upper Adams R.	NR	P	P	P	P	P	150	75	NR	150
	Anstey River	25	25	25	0	25	25	25	25	25	NR
	Bessette River	1,500	1,500	750	750	2,000	750	1,500	750	25	70
	Eagle River	1,500	750	1,500	1,500	1,200	1,800	3,500	1,500	1,100	2,694
	Tappen Creek	25	25	25	25	25	25	0	25	1	12
	Momich River	75	200	NR	75	25	25	25	25	0	20
	Salmon River	1,250	1,500	750	1,500	2,000	400	1,500	750	900	1,580
	Scotch Creek	25	0	200	25	25	25	25	25	5	0
	Seymour River	0	NR	NR	NR	NR	NR	NR	2	1	25
	Lower Shuswap R.	400	750	400	75	300	250	100	200	40	100
	Middle Shuswap R.	400	750	400	400	400	500	500	200	60	594
	Sinmax River	400	200	200	213	104	165	200	75	25	40

P - Present
NR - None Recorded

APPENDIX II

SUMMARY TABLES OF PHYSICAL AND CHEMICAL DATA FROM ZONES A, B, AND C

(a) Temperature Readings
(b) Secchi Readings/Photic Zones
(c) Turbidity Readings
(d) Conductivity Readings
(e) Total Phosphorus Concentrations
(f) Total Dissolved Phosphorus Concentrations
(g) Nitrate/Nitrite Concentrations
(h) Ammonia Concentrations
(i) Total Dissolved Nitrogen Concentrations
(j) Particulate Nitrogen Concentrations
(k) Total Nitrogen Concentrations
(l) Particulate Carbon Concentrations
(m) Silicon Dioxide Concentrations

APPENDIX II(a) TEMPERATURE (°C) READINGS FROM SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE			SEPTEMBER			STATION		NOVEMBER		
			Range	Mean	S. Dev.**	Range	Mean	S. Dev.			Range	Mean	S. Dev.
A	1-11	EPI*	10.0-18.0	14.86	3.38	16.7-17.5	17.04	0.39					
		HYP	3.9-11.0	6.31	2.34	4.0-9.3	5.31	1.40					
									1-11	ISO	3.0-6.4	5.52	0.70
B	12-17,												
	21-30	EPI	9.3-17.5	14.29	2.48	15.0-18.2	16.46	0.73					
		HYP	3.6-8.2	4.34	0.88	3.5-5.3	4.24	0.44					
									13,16	ISO	4.8-5.5	5.13	0.27
C	31-33	EPI	13.5-15.0	14.57	0.68	15.9-16.2	16.10	0.14			-	-	-
		HYP	4.0-4.6	4.31	0.26	3.7-4.4	4.05	0.31					

1979

ZONE & STATION			APRIL			STATION		JUNE			AUGUST			OCTOBER		
			Range	Mean	S. Dev.			Range	Mean	S. Dev.	Range	Mean	S. Dev.	Range	Mean	S. Dev.
A	1-3	EPI	3.7-6.0	4.78	0.88	1-11	EP	7.0-20.0	14.91	3.78	18.6-25.5	22.51	2.21	11.9-13.0	12.58	0.31
		HYP	3.0-4.2	3.47	0.46		HYP	3.5-12.5	5.41	1.82	4.4-14.2	6.76	2.14	3.9-7.0	5.17	0.77
	4-11	ISO	3.0-4.5	3.93	0.44											
B						16	EPI	9.8-20.5	15.15	7.57	21.5-24.5	23.0	2.12	12.3-12.5	12.4	0.14
							HYP	5.5-5.6	5.55	0.07	4.1-4.3	4.2	0.14	3.5-3.7	3.6	0.14
	16	ISO	4.2-4.5	4.4	0.14											

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal
**S. Dev. = standard deviation

APPENDIX II(b) SECCHI READINGS/PHOTIC ZONES (metres) FOR SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				NOVEMBER			
			n	Range	Mean	S.Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-11	secchi	11	1.5-2.5	2.33	0.33	11	2.3-4.0	3.34	0.42	11	32.5-5.25	4.61	0.76
		photic	11	3.75-6.25	5.57	0.82	11	6.25-10.00	8.35	1.04	11	8.13-13.13	11.52	1.90
B	12-17,													
	21-30	secchi	16	2.5-5.0	3.69	0.84	16	3.75-8.25	5.20	1.36	2	5.75-8.0	6.88	1.12
		photic	16	6.25-12.5	9.22	2.11	16	9.38-20.63	13.09	3.4	2	14.8-20.0	17.19	2.81
C	31-33	secchi	3	5.0-5.5	5.33	0.24	3	7.0-7.5	7.28	0.21				
		photic	3	12.5-13.75	13.33	0.59	3	17.5-18.75	17.21	0.52				

1979

ZONE & STATION			APRIL				STATION	JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.		n	Range	Mean	S.Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	secchi	3	2.25-3.75	3.25	0.71	1-11	7	2.0-3.5	2.78	0.59	10	2.5-3.5	3.05	0.42	11	4.0-6.0	4.73	0.62
	4-11	"	8	4.75-6.25	5.44	0.56													
	1-3	photic	3	5.63-9.38	8.13	1.77	1-11	7	5.0-8.75	6.96	1.47	10	6.25-8.75	7.63	1.04	11	10.0-15.0	11.82	1.54
	4-11	"	8	11.88-15.03	13.59	1.39													
B	16	secchi		-	9.75		16	1	-	4.0	-	1	-	4.0	-	1	-	7.0	-
	16	photic		-	24.38		16	1	-	10.0	-	1	-	10.0	-	1	-	17.5	-

S. Dev. = standard deviation
photic = 2.5 x secchi

APPENDIX II(c) TURBIDITY READINGS (Formazin Turbidity Units) FOR SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION		NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.
A	1-11	EPI*	13	1-2.3	1.45	0.32	22	0.48-1.8	1.00	0.30						
		HYP	13	0.46-2.3	1.20	0.43	18	0.40-1.1	0.83	0.21						
											1-11	ISO	44	-	0.96	0.36
B	12-17,															
	21-30	EPI	32	0.4-3.0	1.05	0.48	32	0.36-1.0	0.66	0.19						
		HYP	32	0.18-3.3	0.75	0.66	32	0.34-1.0	0.54	0.19						
											13,16	ISO	8	0.44-0.84	0.74	0.17
C	31-33	EPI	6	0.21-1.0	0.62	0.29	6	0.48-0.78	0.59	0.10						
		HYP	6	0.25-0.65	0.36	0.16	6	0.36-0.65	0.52	0.11						

1979

ZONE & STATION			APRIL				STATION		JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S.Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	< 1.0-1.5	1.15	0.17	1-11	EPI	22	< 1.0-2.8	1.4	0.54	22	< 1.0-1.8	1.37	0.33	22	0.5-1.0	0.6	0.2
	1-3	HYP	6	1.2-4.5	2.2	1.17	1-11	HYP	22	0.5-< 1.0	0.88	0.2	22	< 1.0-3.0	1.19	0.43	19	0.5-3.0	0.9	0.6
	4-44	ISO	32	< 1.0-3.6	1.27	0.49														
B							16	EPI	2	< 1.0-1.2	1.1	0.1	2	< 1.0-1.3	1.15	0.15	2	0.5	0.5	0
							16	HYP	2	< 1.0	1.0	0	2	< 1.0	1.0	0	2	0.5	0.5	0
	16	ISO	4	< 1.0	< 1.0	0														

*EPI = epilimnion ISO = isothermal
HYP = hypolimnion **S. Dev. = standard deviation

NOTE: If a value was recorded as being less than the detection limit (1.0 FTU), half the detection limit (0.5 FTU) was used for that value when calculating means

APPENDIX II(d) CONDUCTIVITY READINGS (umhos/cm) FOR SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE n	JUNE Range	JUNE Mean	JUNE S.Dev.**	SEPTEMBER n	SEPTEMBER Range	SEPTEMBER Mean	SEPTEMBER S. Dev.	STATION		NOVEMBER n	NOVEMBER Range	NOVEMBER Mean	NOVEMBER S. Dev.
A	1-11	EPI*	19	109-121	118.3	4.3	22	101-114	110.7	3.4						
		HYP	19	108-132	115.0	6.3	18	107-115	108.9	2.5						
											1-11	ISO	44	98.2-109	104.5	4.2
B	12-17,															
	21-30	EPI	32	83.1-125	98.6	10.4	32	83.3-108	92.6	8.7						
		HYP	32	80.5-112	108.4	7.1	32	87.4-112	101.2	4.7						
											13,16	ISO	8	101-103	101.9	0.6
C	31-33	EPI	6	56.4-83	75.7	10.3	6	68.3-70.1	69.4	0.7						
		HYP	6	70.1-86.3	82.8	6.6	6	69.6-86.3	81.4	6.3						

1979

ZONE & STATION			APRIL n	APRIL Range	APRIL Mean	APRIL S. Dev.	STATION		JUNE n	JUNE Range	JUNE Mean	JUNE S. Dev.	AUGUST n	AUGUST Range	AUGUST Mean	AUGUST S. Dev.	OCTOBER n	OCTOBER Range	OCTOBER Mean	OCTOBER S. Dev.
A	1-3	EPI	6	114-127	117.3	4.5	1-11	EPI	22	100-124	112.7	5.8	22	107-110	108.3	0.9	22	106-110	108	1.8
	1-3	HYP	6	192-204	196.5	4.3		HYP	22	98-132	113.8	7.8	22	98-120	108.9	4.8	19	108-116	109.9	2.8
	4-44	ISO	32	108-134	115.5	6.8														
B							16	EPI	2	105-106	105.5	0.7	2	104-106	105	1.4	2	101	101	0
							16	HYP	2	103-108	105.5	3.5	2	104-106	105	1.4	2	105	101	0
	16	ISO	4	108-112	109.5	1.7														

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal

**S. Dev. = standard deviation

APPENDIX II(e) TOTAL PHOSPHORUS CONCENTRATIONS (ug/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION	NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.		n	Range	Mean	S. Dev.
A	1-11	EPI*	18	4-46	16	9	22	9-15	11	1					
		HYP	19	4-25	12	5	18	5-18	9	4					
											1-11	43	5-17	10	2
B	12-17,														
	21-30	EPI	32	5-14	8	2	30	4-15	8	2					
		HYP	32	3-10	5	2	32	3-43	7	7					
											13,16	8	3-6	5	1
C	31-33	EPI	6	4-6	5	1	6	3-7	5	1					
		HYP	6	2-3	3	0.4	6	3-8	4	2					

1979

ZONE & STATION			APRIL				STATION		JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	7.8-21.3	11.3	4.6	1-11	EPI	22	3.5-56.5	14.0	11.0	22	5.0-14.0	11	12	22	5.5-8.9	7	1
	1-3	HYP	6	20.8-40.3	30.1	7.1		HYP	22	2.0-21.1	8.0	5.0	22	5.0-20.9	9	4	19	3.3-28.6	10	7
	4-44	ISO	32	5.0-19.8	8.4	2.8														
B							16	EPI	2	3.5-5.0	4.0	1.0	2	8.5-11.0	10	2	2	4.8-5.5	5	0
							16	HYP	2	2.0-3.0	3.0	1.0	2	5.0	5	0	2	3.3-4.0	4	0
	16	ISO	4	3.1-7.8	5.0	2.0														

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal

**S. Dev. = standard deviation

APPENDIX II(f) TOTAL DISSOLVED PHOSPHORUS CONCENTRATIONS (ug/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE n	JUNE Range	JUNE Mean	JUNE S.Dev.**	SEPTEMBER n	SEPTEMBER Range	SEPTEMBER Mean	SEPTEMBER S. Dev.	STATION	NOVEMBER n	NOVEMBER Range	NOVEMBER Mean	NOVEMBER S. Dev.
A	1-11	EPI*	19	4-8	5.7	1.2	22	3-8	4.4	1.0					
		HYP	19	4-14	6.9	2.8	17	3-16	6.2	3.4					
											1-11	44	2-85	5.1	1.6
B	12-17,														
	21-30	EPI	32	2-7.5	3.3	1.0	32	2-5	3.5	0.8					
		HYP	32	2-4	3.0	0.7	30	2-15	3.3	2.5					
											13,16	7	< 2-7	2.3	0.7
C	31-33	EPI	6	2-3	2.4	0.5	6	< 2-4	2.5	0.8					
		HYP	6	1-2	1.7	0.5	5	< 2-4.5	2.1	1.6					

1979

ZONE & STATION			APRIL n	APRIL Range	APRIL Mean	APRIL S. Dev.	STATION		JUNE n	JUNE Range	JUNE Mean	JUNE S. Dev.	AUGUST n	AUGUST Range	AUGUST Mean	AUGUST S. Dev.	OCTOBER n	OCTOBER Range	OCTOBER Mean	OCTOBER S. Dev.
A	1-3	EPI	6	5.0-12.5	6.3	2.8	1-11	EPI	22	< 2-16.8	5.3	4.5	22	2.5-6.5	3.8	1.1	22	2.0-6.7	3.6	1.5
		HYP	6	5.0-18.0	13.4	4.5		HYP	21	< 2-14.0	5.0	3.4	22	2.0-12.5	4.6	2.5	19	2.0-17.8	6.3	4.1
	4-11	ISO	32	2.0-8.0	2.9	1.6														
B							16	EPI	1	-	< 2	-	2	3.5-4.0	3.8	0.4	2	2.0-4.8	3.4	2.0
							16	HYP	2	-	< 2	-	2	3.5-4.0	3.8	0.4	1	0	2.0	0
	16	ISO	4	< 2.0-2.0	1.3	0.5														

*EPI = epilimnion ISO = isothermal
HYP = hypolimnion **S. Dev. = standard deviation

Note: If a value was recorded as being less than the detection limit (< 2.0 ug/l) half the detection limit (1.0 ug/l) was used for that value when calculating means.

APPENDIX II(g) NITRATE/NITRITE CONCENTRATIONS (ug/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION	NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.		n	Range	Mean	S. Dev.
A	1-11	EPI*	19	< 2-71	7.7	17.8	22	< 2-5	1.4	1.1					
		HYP	19	2-130	58.5	40.2	18	< 2-180	107.8	35.8					
											1-11	44	54-92	72.1	11.6
B	12-17, 21-30	EPI	32	< 2-68	19.9	16.4	32	< 2-12	2.2	2.3					
		HYP	32	7-95	70.7	26.7	32	21-130	96.8	18.4					
											13,16	8	62-98	74.4	13.9
C	31-33	EPI	6	29-45	37.0	6.2	5	3-110	22.0	43.0					
		HYP	6	83-85	84.0	0.6	6	9-95.5	78.5	34.1					

1979

ZONE & STATION			APRIL				STATION		JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	21-57	42.6	12.2	1-11	EPI	22	< 2-69	12.5	21.9	22	< 2	< 2	0	22	2.5-6	3.7	0.9
		HYP	6	57-166	142.8	38.5		HYP	22	32.5-129	94.0	23.4	22	< 2-157	102.1	42.5	19	3.6-192	124.5	37.7
	4-11	ISO	32	50.5-121	68.2	15.8														
B							16	EPI	2	< 2-55.9	28.5	38.8	2	< 2	< 2	0	2	3.2-110	56.6	75.5
							16	HYP	2	94-101	97.5	4.9	2	106-110	108.0	2.8	2	3.2-110	56.6	75.5
	16	ISO	4	74-76.3	74.8	1.1														

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal
**S. Dev. = standard deviation

Note: Half the detection limit (1.0 ug/l) was used for values less than the detection limit (2.0 ug/l) when calculating means.

APPENDIX II(h) AMMONIA (ug/l) CONCENTRATIONS IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION		NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.
A	1-11	EPI*	19	< 2-32	11.4	8.5	22	16-27	21.2	3.1						
		HYP	19	< 2-18	4.9	5.4	18	< 2-28	2.9	6.3						
											1-11	ISO	44	< 2-14	2.6	2.7
B	12-17,															
	21-30	EPI	32	6-16	11.6	3.5	32	2-62	13.8	10.2						
		HYP	32	< 2-32	11.3	8.1	32	< 2-13	2.3	2.9						
											13,16	ISO	8	< 2-4	1.6	1.1
C	31-33	EPI	6	6-17	10.8	4.0	5	< 2-13	5.8	4.4						
		HYP	6	5-12	8.5	2.4	6	< 2-5	1.7	1.6						

1979

ZONE & STATION			APRIL				STATION		JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	2-3.5	2.6	0.6	1-11	EPI	22	< 2-27.4	6.3	5.5	22	2-7	3.7	1.9	22	4.3-14.5	7.6	2.6
		HYP	6	2-22.2	7.6	7.0		HYP	22	< 2-20.8	3.8	4.5	22	2-5.2	2.1	1.2	19	2-15.6	6.0	3.4
	4-11	ISO	32	2.5-13	5.8	2.5														
B							16	EPI	2	7.6-8.4	8.0	0.6	2	3-5.6	4.3	1.8	2	4.3-8.5	6.4	3.0
							16	HYP	2	-	< 2.0	0	2	2.2-3.1	2.7	0.6	2	-	3.0	0
	16	ISO	4	2.5-3.8	2.8	0.7														

*EPI = epilimnion
HYP = hypolimnion

ISO = isothermal
**S. Dev. = standard deviation

Note: Half the detection limit (2.5 ug/l) was used for values less than the detection limit (5.0 ug/l) when calculating means.

APPENDIX II(i) TOTAL DISSOLVED NITROGEN CONCENTRATIONS (ug/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE n	Range	Mean	S.Dev.**	SEPTEMBER n	Range	Mean	S. Dev.	STATION		NOVEMBER n	Range	Mean	S. Dev.
A	1-11	EPI*	19	110-200	156.6	25.5	22	87-140	106.0	11.8						
		HYP	19	130-220	158.9	25.6	18	100-240	166.4	32.8						
B	12-17,										1-11	ISO	44	110-150	125.3	9.7
	21-30	EPI	32	82-130	109.4	14.3	32	10-180	88.6	34.8						
		HYP	32	96-170	137.2	20.2	32	100-190	145.8	16.8						
C	31-33	EPI	6	100-120	108.3	9.8	6	60-89	72.5	12.5	13,16	ISO	8	120-140	123.8	7.4
		HYP	6	130-140	138.3	4.1	6	70-140	118.3	24.8						

1979

ZONE & STATION			APRIL n	Range	Mean	S. Dev.	STATION		JUNE n	Range	Mean	S. Dev.	AUGUST n	Range	Mean	S. Dev.	OCTOBER n	Range	Mean	S. Dev.
A	1-3	EPI	6	120-170	136.7	16.0	1-11	EPI	22	95-220	131.9	32.6	22	135-205	156.6	19.7	22	100-182.5	116.6	19.8
		HYP	6	20-28	261.7	27.9		HYP	22	105-240	151.8	28.4	22	90-225	166.1	28.4	19	170-750	230.5	129.3
	4-11	ISO	32	13-21	145.9	19.5														
B							16	EPI	2	-	130.0	0	2	-	145.0	0	2	95-105	100.0	7.1
							16	HYP	2	140-145	142.5	3.5	2	-	155.0	0	2	-	175.0	0
	16	ISO	4	-	140.0	0														

*EPI = epilimnion
HYP = hypolimnion

ISO = isothermal
**S. Dev. = standard deviation

Note: Total dissolved nitrogen values may be slight overestimates of the actual lake levels because the samples were allowed to settle and then the decant was used for the analysis.

APPENDIX II(j) PARTICULATE NITROGEN CONCENTRATIONS (ug/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION		NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.
A	1-11	EPI*	19	9-950	59.4	21.8	22	27-58	41.6	8.0						
		HYP	19	< 5-560	19.5	14.1	18	< 5-28	8.9	5.7						
											1-11	ISO	44	10-52	20.8	6.9
B	12-17, 21-30	EPI	32	13-61	30.6	13.8	32	< 17-42	26.9	9.8						
		HYP	32	< 2-51	10.9	12.6	32	10-32	7.4	5.3						
											13,16	ISO	8	< 10-17	12.3	4.7
C	31-33	EPI	6	15-24	19.3	3.6	6	< 10-43	12.8	15.2						
		HYP	6	< 2-< 5	< 2.3	0.6	6	< 10-14	6.5	3.7						

1979

ZONE & STATION			APRIL				STATION		JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	31-106	54.3	25.6	1-11	EPI	22	< 5-125	47.0	32.8	22	< 5-101	56.2	28.5	22	25-39	32.7	3.7
		HYP	6	15-67	30.2	17.3		HYP	22	< 5-35	4.0	6.9	22	< 5-93	16.2	27.5	19	< 5-30	8.7	8.6
	4-11	ISO	32	12-56	35.9	10.9														
B							16	EPI	2	11-67	39.0	39.6	2	55-64	59.5	6.4	2	28-31	29.5	2.1
							16	HYP	2	< 5	< 5	0	2	< 5	< 5.0	0	2	< 5	< 5.0	0
	16	ISO	4	13-18	15.5	2.1														

*EPI = epilimnion ISO = isothermal
HYP = hypolimnion **S. Dev. = standard deviation

Note: Half the detection limit (2.5 ug/l) was used for values less thatn the detection limit (2.0 ug/l) when calculating means.

APPENDIX II(k) TOTAL NITROGEN CONCENTRATIONS (ug/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION		NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.
A	1-11	EPI*	19	138-295	216	42.5	22	123-187	148	16.5						
		HYP	19	149-234	178	25.7	19	128-250	175	29.5						
											1-11	ISO	44	127-197	146	12.6
B	12-17, 21-30	EPI	32	111-186	140	17.4	32	47-222	116	39.2						
		HYP	32	93-177	148	15.7	32	125-200	153	14.7						
											13,16	ISO	8	133-150	137	5.3
C	31-33	EPI	6	116-139	128	7.7	5	70-129	87	21.5						
		HYP	6	133-143	141	3.7	6	84-145	125	19.5						

1979

ZONE & STATION			APRIL				STATION		JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	161-276	191	39.5	1-11	EPI	22	116-315	179	56.5	22	163-296	217	31.1	22	131-218	142	18.7
		HYP	6	267-313	292	14.1		HYP	22	108-275	157	33.5	22	118-283	186	37.9	19	175-305	209	35.7
	4-11	ISO	32	157-246	182	18.1														
B							16	EPI	2	141-197	169	28.0	2	200-209	205	4.5	2	126-133	130	3.5
							16	HYP	2	145-150	148	2.5	2	158	158	0	2	178	178	0
	16	ISO	4	153-158	156	1.8														

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal

**S. Dev. = standard deviation

APPENDIX II(1) PARTICULATE CARBON CONCENTRATIONS (ug/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION		NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.
A	1-11	EPI*	19	150-606	449.1	128.6	22	240-650	345.0	92.0						
		HYP	19	100-410	207.7	85.0	18	39-210	124.3	54.3						
											1-11	ISO	44	120-250	181.8	34.5
B	12-17,	EPI	32	170-440	277.8	78.3	32	95-350	217.7	66.7						
	21-30	HYP	32	39-400	150.3	90.1	32	< 10-210	77.4	40.8						
											13,16	ISO	8	110-200	145.0	27.8
C	31-33	EPI	6	210-260	235.0	17.6	6	95-140	110.6	15.6						
		HYP	6	82-110	92.2	10.2	6	40-140	64.0	37.5						

1979

ZONE & STATION			APRIL				STATION		JUNE				ZONE	DEPTH	AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	236-646	374.7	141.4	1-11	EPI	22	42-844	466.6	174.6	A	EP	22	220-732	540.0	125.6	22	237-388	289.3	35.1
		HYP	6	192-710	309.8	199.4		HYP	22	100-1910	266.8	378.0		HYP	22	116-699	274.8	174.3	19	105-312	161.8	52.2
	4-11	ISO	32	135-1360	289.9	196.9																
B							16	EPI	2	167.0	167.0	0	B	EP	2	528-554	541.0	18.4	2	261-273	267.0	8.5
							16	HYP	2	78-136	107.0	41.0		HYP	2	123-137	130.0	9.9	2	114-125	119.5	7.8
	16	ISO	4	135-163	150.0	13.6																
													C	EP								
														HYP								

APPENDIX II(m) SILICON DIOXIDE CONCENTRATIONS (mg/l) IN SHUSWAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION			JUNE				SEPTEMBER				STATION		NOVEMBER			
			n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.
A	1-11	EPI*	19	6.3-8.5	7.0	0.6	22	5.6-6.3	5.8	0.2						
		HYP	19	6.6-8.5	7.4	0.5	18	5.6-8.3	7.1	0.6						
											1-11	ISO	44	6.4-7.5	6.6	0.3
B	12-17,															
	21-30	EPI	32	6.0-7.6	6.3	0.4	32	5.1-5.9	5.4	0.2						
		HYP	32	6.2-7.1	6.5	0.2	32	5.4-7.9	6.5	0.5						
											13,16	ISO	8	6.4-6.7	6.5	0.1
C	31-33	EPI	6	5.4-5.9	5.7	0.2	6	4.5-5.8	5.1	0.6						
		HYP	6	5.8-6.0	5.9	0.1	6	5.7-5.9	5.8	0.1						

1979

ZONE & STATION			APRIL				STATION		JUNE				AUGUST				OCTOBER			
			n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3	EPI	6	6.57-6.95	6.73	0.11	1-11	EPI	22	4.30-6.97	5.69	0.66	22	4.04-4.54	4.24	0.15	22	4.7107.70	5.24	0.54
		HYP	6	10.40-11.66	11.08	0.39		HYP	22	5.93-8.19	6.95	0.51	22	4.09-7.92	6.82	0.77	19	6.42-8.30	7.04	0.29
	4-11	ISO	32	6.50-8.28	6.59	1.22														
B							16	EPI	2	4.60-6.33	5.48	1.22	2	2.97-4.06	3.53	0.77	2	4.71	4.71	0
							16	HYP	2	6.50-6.85	6.67	0.24	2	6.31-6.72	6.52	0.28	2	6.42-6.74	6.58	0.11
	16	ISO	4	6.72-6.85	6.77	0.05														

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal

**S. Dev. = standard deviation

APPENDIX III

PHYSICAL AND CHEMICAL DATA FROM SHALLOW WATER STATIONS

(a) Surface Temperatures
(b) Turbidity
(c) pH
(d) Conductivity
(e) Phosphorus
(f) Nitrogen
(g) Silicon Dioxide

APPENDIX III(a) SURFACE TEMPERATURES AT SHALLOW WATER STATIONS (°C) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	16.0	19.0	19.0	-	25.0	21.0	15.5	12.0
SA-S2	10.5	12.0	16.0	19.0	19.0	-	25.0	20.5	17.0	13.0
SA-S3	11.0	11.0	16.0	19.0	19.0	-	25.0	20.5	16.5	13.0
SA-S4	4.5	8.0	11.5	19.0	20.5	-	24.0	19.0	17.0	13.0

APPENDIX III(b) TURBIDITY OF SHALLOW WATER STATIONS (Formazin Turbidity Units) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	3.2	2.8	3.8	5.3	3.1	2.2	1.4	1.7
SA-S2	1.2	2.5	1.7	3.3	1.3	2.6	1.6	1.5	1.4	1.2
SA-S3	1.3	3.4	2.0	2.2	1.8	2.9	2.0	1.2	1.3	1.2
SA-S4	< 1.0	1.3	< 1.0	1.6	1.8	1.3	1.1	< 1.0	1.0	< 1.0

APPENDIX III(c) pH OF SHALLOW WATER STAITONS 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	8.0	8.0	7.6	7.9	8.2	8.0	7.9	7.8
SA-S2	8.0	8.1	8.0	8.1	7.9	8.0	8.3	7.9	7.9	7.9
SA-S3	8.0	8.1	8.1	8.0	7.6	8.0	8.3	8.0	7.9	7.9
SA-S4	8.0	8.0	7.9	8.1	7.8	7.8	7.9	7.8	7.9	7.8

APPENDIX III(d) CONDUCTIVITY OF SHALLOW WATER STAITONS (umhos/cm) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	131	125	143	149	120	110	114	118
SA-S2	118	119	121	124	111	115	110	110	111	112
SA-S3	118	117	123	125	113	114	109	108	109	112
SA-S4	110	108	111	115	109	108	104	102	98	104

APPENDIX III(e) PHOSPHORUS FOR SHALLOW WATER STATIONS (ug/l) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
					Total Phosphorus					
SA-S1	--	--	21.0	26.0	33.9	52.7	30.9	14.9	8.2	10.5
SA-S2	12.7	143.0	27.3	26.0	14.0	14.8	13.5	13.4	7.5	8.2
SA-S3	19.1	--	15.0	23.0	11.5	15.0	14.0	10.3	6.5	8.3
SA-S4	4.3	6.0	7.3	14.3	12.0	94.0	9.9	8.6	3.0	5.8
					Total Dissolved Phosphorus					
SA-S1	--	--	8.0	10.5	13.2	13.7	5.5	4.1	< 2	15.0*
SA-S2	3.3	< 2	3.4	11.0	6.0	7.4	4.0	5.2	< 2	6.0
SA-S3	2.5	< 2	4.3	18.0	10.8	5.8	5.0	4.5	< 2	4.4
SA-S4	2.5	< 2	3.3	7.0	3.5	5.5	4.0	3.8	< 2	3.7
					Total Particulate Phosphorus					
SA-S1	--	--	13.0	15.5	20.7	39.0	25.4	10.8	< 8.2	--
SA-S2	9.4	141.0	23.9	15.0	8.0	7.4	9.5	8.2	< 7.5	2.2
SA-S3	16.6	--	10.7	5.0	0.7	9.2	9.0	5.8	< 6.5	3.9
SA-S4	1.8	< 4	4.0	7.3	8.5	88.5	5.9	4.8	< 3.0	2.1

*Dissolved higher than total

APPENDIX III(f) NITROGEN FOR SHALLOW WATER STATIONS (ug/l) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
					Nitrate/Nitrite					
SA-S1	--	--	2.8	< 2.0	< 5.0	< 2.0	< 2.0	< 2.0	< 2.0	2.9
SA-S2	30.0	226.0	< 2.0	< 2.0	< 5.0	< 2.0	< 2.0	< 2.0	< 2.0	2.5
SA-S3	32.5	< 10.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	2.0
SA-S4	73.8	42.0	25.9	< 2.0	< 5.0	< 2.0	< 2.0	< 2.0	< 2.0	2.0
					Ammonia					
SA-S1	--	--	3.5	< 2.0	2.5	< 2.0	< 2.0	2.0	4.5	10.0
SA-S2	< 2.0	3.8	8.0	< 2.0	2.0	< 2.0	< 2.0	2.0	4.7	5.5
SA-S3	2.5	< 2.0	2.0	< 2.0	2.7	< 2.0	2.2	2.5	3.8	4.4
SA-S4	< 2.0	2.0	7.5	< 2.0	2.0	5.5	4.5	< 2.0	5.2	2.0
					Total Dissolved Nitrogen					
SA-S1	--	--	175	193	160	205	210	150	175	120
SA-S2	120	120	145	155	130	200	180	145	170	105
SA-S3	130	120	145	148	135	205	175	145	165	125
SA-S4	140	130	150	150	125	175	130	130	150	100

*Dissolved higher than total

APPENDIX III(g) SILICON DIOXIDE FOR SHALLOW WATER STATIONS (mg/l) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	9.3	6.4	5.8	5.9	4.7	4.4	4.6	5.0
SA-S2	6.5	6.2	6.5	6.4	3.8	4.3	4.2	4.4	4.5	4.7
SA-S3	6.5	6.2	6.9	6.5	3.8	4.3	4.1	4.4	4.4	4.7
SA-S4	6.7	6.5	5.9	5.4	3.6	4.3	4.2	4.4	4.4	4.6

APPENDIX IV

PHYTOPLANKTON DATA - DOMINANT ALGAE IN ZONE A, B AND C

APPENDIX IV(a)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) JUNE 1978

	STATIONS												
	1	2	3	4	5	6	7	8	9	10	11	SUM	MEAN
Fragilaria crotonensis	2114.59	1991.46	1498.95	1359.76	1426.68	2355.50	1084.06	1929.90	990.38	824.42	1905.81	17481.51	1589.23
Ceratium sp.	1610.85	--	--	805.42	--	--	--	--	--	805.42	--	3221.69	292.88
Anabaena spiroides	1421.67	458.09	379.11	600.25	521.28	663.45	631.85	252.74	537.07	1942.94	552.87	7961.32	723.76
Tabellaria fenestrata	438.26	287.50	140.24	220.88	427.74	217.38	213.87	269.97	108.69	77.13	140.24	2541.90	231.08
Melosira granulata var augustissima	409.35	312.76	335.76	296.66	170.18	248.37	257.57	114.98	170.18	232.97	96.59	2665.37	242.31
Cryptomonas borealis	171.01	142.51	99.75	178.13	156.76	142.51	142.51	149.63	142.51	114.00	135.38	1574.70	143.15
Synedra ulna	152.69	61.07	30.54	--	--	--	30.54	--	--	--	--	274.84	24.99
Stephanodiscus niagare	106.47	--	--	106.47	--	--	--	--	--	106.47	--	319.41	29.04
Fragilaria capucina	--	3847.66	--	--	--	--	--	--	--	--	--	3847.66	349.79
Gomphonema herculeanum	--	139.04	--	--	--	139.04	--	--	--	--	--	278.08	25.28
Mallamonas sp.	--	--	30.91	--	129.84	197.85	--	--	--	--	--	358.60	32.60
Navicula sp.	--	--	26.99	--	--	--	--	--	--	--	--	26.99	2.45
Anabaena sp3	--	--	--	128.48	--	--	--	--	--	--	--	128.48	11.68
Rhizosolenia eriensis	--	--	--	--	49.54	--	--	--	--	--	--	49.54	4.50
Chroomonas acuta	--	--	--	--	38.00	--	--	--	--	--	25.11	63.11	5.74
Cymbella ventricosa	--	--	--	--	--	150.95	--	--	--	--	--	150.95	13.72
Anabaena sp2	--	--	--	--	--	--	37.93	--	37.93	75.85	--	151.71	13.79
Achnanthes minutissima	--	--	--	--	--	--	35.59	--	--	--	38.00	73.59	6.69
Synedra radians	--	--	--	--	--	--	--	101.19	128.78	--	--	229.97	20.91
Closterium sp.	--	--	--	--	--	--	--	61.60	--	--	--	61.60	5.60
Asterionella formosa	--	--	--	--	--	--	--	45.24	--	--	--	45.24	4.11
Melosira granulata	--	--	--	--	--	--	--	--	507.14	--	--	507.14	46.10
Synedra delicatissima	--	--	--	--	--	--	--	--	--	--	83.92	83.92	7.63
													3827.03

APPENDIX IV(b)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) JUNE 1978

	12	13	14	15	16	17	21	22	23	24	25	26	27	28	29	30	SUM	MEAN
Fragilaria crotonensis	1370.47	1788.04	1043.91	1159.01	993.06	749.48	350.65	164.62	372.06	447.01	301.13	607.61	338.60	559.43	307.82	351.99	10904.89	681.56
Gymnodinium sp.	1330.96	—	—	665.48	—	665.48	—	—	—	—	—	—	—	—	—	—	2661.92	166.37
Anabaena spiroides	394.91	426.50	142.17	94.78	94.78	142.17	63.19	39.49	189.56	—	63.19	31.59	47.39	—	—	55.29	1785.01	111.56
Anabaena sp2	265.48	—	151.71	—	—	—	—	—	—	—	—	—	—	—	—	—	417.19	26.07
Melosira granulata var augustissima	133.38	78.19	78.19	—	85.09	27.60	—	—	—	—	—	—	—	—	—	—	402.45	25.15
Cryptomonas borealis	121.13	220.88	78.38	92.63	178.13	192.38	42.75	35.63	163.88	78.38	106.88	57.00	53.44	156.76	121.13	106.88	1806.26	112.89
Tabellaria fenestrata	80.64	175.31	175.30	105.18	133.23	129.73	68.37	28.05	87.65	—	71.88	66.62	82.39	105.18	77.13	136.74	1523.40	95.21
Synedra radians	64.39	27.60	—	55.19	—	—	—	—	—	—	—	—	—	—	—	—	147.18	9.20
Closterium sp.	—	61.60	—	—	—	—	—	—	—	—	—	—	—	—	—	—	61.60	3.85
Chroomonas acuta	—	43.43	40.72	56.32	—	—	23.58	—	43.09	—	—	—	—	—	—	—	207.14	12.95
Dinobryan sertularia	—	—	31.89	—	—	—	—	15.95	—	53.16	—	21.26	—	—	63.79	—	186.05	11.63
Spirogyra sp.	—	—	—	1055.60	—	—	—	—	—	—	—	—	—	—	—	—	1055.60	65.98
Synedra ulna	—	—	—	—	763.42	—	—	—	—	—	30.54	30.54	—	—	—	—	824.50	51.53
Stephanodiscus niagare	—	—	—	—	212.93	—	106.47	—	106.47	159.70	133.08	106.47	—	106.47	—	—	931.59	58.22
Asterionella formosa	—	—	—	—	40.72	26.24	—	—	—	—	—	—	—	—	—	—	66.96	4.19
Cyclotella ocellata	—	—	—	—	—	25.33	—	21.38	—	45.92	37.21	—	30.08	77.59	114.00	63.34	414.83	25.93
Chroomonas sp.	—	—	—	—	—	—	65.15	23.41	48.18	128.93	—	—	—	—	—	—	265.67	16.60
Cyclotella comta	—	—	—	—	—	—	29.59	20.72	35.51	59.19	142.05	—	29.60	53.27	65.11	63.11	500.15	31.26
Stephanodiscus astrea var minulate	—	—	—	—	—	—	—	—	—	91.84	32.80	32.80	—	72.16	75.44	37.72	309.96	19.37
Oocystis sp.	—	—	—	—	—	—	—	—	—	—	—	—	43.73	—	—	—	43.73	2.73
Cyclotella bodanica	—	—	—	—	—	—	—	—	—	—	—	—	21.83	—	43.66	—	65.49	4.09
Cyclotella stelligera	—	—	—	—	—	—	—	—	—	—	—	—	—	39.74	—	—	39.74	2.48
Synedra delicatissima	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	55.95	55.95	3.50
																		542.32

APPENDIX IV(c)

ZONE C DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) JUNE 1978

	STATIONS				
	31	32	33	SUM	MEAN
Cyclotella comta	254.51	331.46	298.62	884.59	294.86
Fragilaria crotonensis	226.18			226.18	75.39
Dinobryan sertularia	148.84	186.05	206.49	541.38	180.46
Cyclotella ocellata	83.92	50.67	36.38	170.97	56.99
Cyclotella bodanica	65.48	87.31		152.79	50.93
Cryptomonas borealis	57.00	24.94	24.91	106.85	35.62
Cyclotella stelligera	38.57	16.36	14.02	68.95	22.98
Dinobryan sp.	34.00		28.91	62.91	20.97
Dinobryan bavaricum		16.10		16.10	5.37
Stephanediscus astrea var minulata		14.76		14.76	4.92
Synedra ulna			22.84	22.84	7.61
Synedra radians			13.76	13.76	4.59
					760.69

APPENDIX IV(d)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) SEPTEMBER 1978

	STATIONS												
	1	2	3	4	5	6	7	8	9	10	11	SUM	MEAN
Surirella ovata	1044.82	--	--	--	--	--	--	--	--	--	--	1044.82	94.98
Synedra delicatissima	237.77	83.92	90.91	55.95	34.97	90.91	97.91	62.94	83.92	83.92	97.91	1021.03	92.82
Navicula gastrum	77.81	--	--	--	--	25.94	--	--	--	25.94	--	129.69	11.79
Melosira granulata	58.02	32.23	36.53	32.23	--	--	--	116.04	36.53	--	--	311.58	28.33
Anabaena sp2	56.89	66.37	94.82	85.33	104.30	85.33	85.33	132.74	104.30	66.37	66.37	948.15	86.20
Melosira granulata var augustissima	52.89	102.34	83.94	66.69	112.69	45.99	44.84	80.49	86.24	51.74	64.39	792.24	72.02
Aphanizomenon sp.	51.69	--	--	68.92	25.84	--	--	51.69	--	--	34.46	232.60	21.15
Tobellaria fenestrata	43.83	--	--	--	--	--	--	--	--	--	--	43.83	3.98
Anabaena sp.	--	43.54	31.67	--	--	23.75	--	--	--	--	--	98.96	9.00
Cryptomonas borealis	--	42.75	32.06	71.25	64.13	60.57	49.88	67.69	49.88	64.13	53.44	555.78	50.53
Fragilaria capucina	--	28.50	--	28.50	--	--	--	--	--	--	--	57.00	5.18
Fragilaria crotonensis	--	28.10	45.50	--	--	--	--	--	41.49	--	--	115.09	10.46
Cyclotella comta	--	--	47.35	--	20.58	--	17.76	29.59	35.51	29.60	26.64	207.03	18.82
Closterium sp.	--	--	--	30.80	--	30.80	--	--	--	30.80	--	92.40	8.40
Chroomonas acuta	--	--	--	--	25.62	31.56	39.53	36.64	29.52	39.70	36.81	239.38	21.76
Anabaena spiroides	--	--	--	--	23.69	--	--	--	--	--	--	23.69	2.15
Cymbella sp A	--	--	--	--	--	--	111.14	--	--	--	--	111.14	10.10
Anabaena sp3	--	--	--	--	--	--	21.41	--	--	--	21.41	42.82	3.89
													551.56

APPENDIX IV(e)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($cm^3/m^3 \times 0.001$) SEPTEMBER 1978

	STATIONS																	
	12	13	14	15	16	17	21	22	23	24	25	26	27	28	29	30	SUM	MEAN
Synedra delicatissima	69.93	41.96	41.96	76.93	83.92	62.94	62.94	45.58	84.01	42.07	54.28	--	55.95	31.50	40.88	79.47	874.32	54.65
Cryptomonas borealis	60.57	67.69	114.00	128.26	85.50	81.94	85.50	41.08	110.57	85.73	67.81	74.82	74.82	84.40	73.72	41.64	1278.05	79.88
Anabaena sp2	56.89	66.37	47.41	47.41	37.93	56.89	28.44	28.52	28.47	33.27	35.61	28.44	--	--	--	--	495.65	30.98
Melosira granulata	38.68	--	--	58.02	--	30.08	--	--	--	--	--	--	--	--	--	--	126.78	7.92
Aphanizomenon sp.	34.46	34.45	25.84	34.46	34.46	17.23	--	--	34.50	38.87	30.18	25.84	43.07	34.49	28.74	21.57	438.16	27.39
Cyclotella ocellata	28.50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	28.50	1.78
Chroomonas acuta	27.65	52.93	33.08	34.27	30.54	31.22	33.08	20.16	24.55	19.22	26.21	30.20	34.44	25.23	27.74	23.24	473.76	29.61
Melosira granulata var augustissima	24.15	27.60	--	49.44	18.40	31.05	--	--	23.00	--	--	--	--	--	--	--	173.64	10.85
Cyclotella comta	--	53.27	29.60	73.99	47.35	50.31	73.99	23.74	32.60	14.84	71.88	82.86	73.99	55.28	47.90	48.07	779.67	48.73
Anabaena spiroides	--	23.69	--	--	15.80	--	--	--	--	--	--	--	--	--	--	--	39.49	2.47
Synedra radians	--	--	23.00	--	--	--	--	--	--	--	--	--	--	--	--	--	23.00	1.44
Anabaena sp3	--	--	21.41	--	--	--	--	--	--	--	--	--	--	--	--	--	21.41	1.34
Gymnodinium sp.	--	--	--	--	--	--	665.48	--	--	--	--	--	--	--	--	--	665.48	41.59
Ceratium sp.	--	--	--	--	--	--	402.71	--	--	--	--	--	--	--	--	--	402.71	25.17
Closterium sp.	--	--	--	--	--	--	30.80	15.44	--	--	--	--	--	--	--	--	46.24	2.89
Fragilaria crotonesis	--	--	--	--	--	--	--	17.45	--	23.48	--	37.47	--	--	16.75	42.83	137.98	8.62
Dinobryan sertularia	--	--	--	--	--	--	--	17.32	--	14.66	--	--	82.39	20.38	--	--	134.75	8.42
Arthrodesmus sp.	--	--	--	--	--	--	--	--	22.02	--	--	--	--	--	--	--	22.02	1.38
Staurastrum sp.	--	--	--	--	--	--	--	--	--	--	23.47	--	--	--	--	--	23.47	1.47
Anabaena sp.	--	--	--	--	--	--	--	--	--	--	20.82	--	--	--	--	--	20.82	1.30
Chlamydomonas sp.	--	--	--	--	--	--	--	--	--	--	--	24.50	--	--	--	13.58	38.08	2.38
Aphanothece sp.	--	--	--	--	--	--	--	--	--	--	--	20.36	38.45	39.99	26.79	18.12	143.71	8.98
Stephanodiscus niagare	--	--	--	--	--	--	--	--	--	--	--	--	33.23	--	--	--	53.23	3.33
Tabellaria fenestrata	--	--	--	--	--	--	--	--	--	--	--	--	--	25.44	--	--	25.44	1.59
Oedogonium sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	121.41	--	121.41	7.59
																		411.75

APPENDIX IV(f)

ZONE C DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) SEPTEMBER 1978

	STATIONS				
	31	32	33	SUM	MEAN
Cryptomonas borealis	52.92	39.29	82.90	175.11	58.37
Cyclotella comta	48.91	72.53	164.40	285.84	95.28
Arthrodesmus sp.	35.68	--	--	35.68	11.89
Rhopalodia gibba	23.87	--	--	23.87	7.96
Chlamydomonas sp.	13.02	9.99	15.45	38.47	9.49
Chroomonas acuta	12.88	13.51	24.71	51.10	17.03
Synedra delicatissima	11.67	10.52	42.00	64.19	21.40
Aphanizomenon sp.	11.50	25.91	12.93	50.34	16.78
Fragilaria crotonensis	--	30.86	--	30.86	10.29
Aphanothece sp.	--	10.21	--	10.21	3.40
Dinobryan sertularia	--	--	15.96	15.96	5.32
Cyclotella glomerata	--	--	8.87	8.87	2.96
					260.17

APPENDIX IV(g)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) NOVEMBER 1978

	STATIONS												
	1	2	3	4	5	6	7	8	9	10	11	SUM	MEAN
Anabaena sp2	163.70	113.88	180.15	170.67	75.88	132.74	142.35	87.75	42.70	121.00	113.78	1344.60	122.24
Surirella ovata	130.72	--	--	--	--	--	--	--	--	--	--	130.72	11.88
Tabellaria fenestrata	71.06	148.70	203.35	47.33	153.01	234.91	94.75	120.56	77.64	197.39	140.24	1488.94	135.36
Stephanodiscus niagare	59.94	--	--	--	--	--	39.96	79.92	--	39.96	--	219.78	19.98
Synedra delicatissima	52.50	21.00	34.97	20.98	42.00	41.96	31.50	64.74	42.00	21.00	20.98	393.63	35.78
Fragilaria crotonensis	44.20	68.32	175.32	70.93	106.11	18.74	131.61	104.48	97.45	121.56	155.25	1093.97	99.45
Cryptomonas borealis	40.12	29.42	10.69	85.50	104.24	114.00	80.23	81.97	69.53	77.56	128.26	821.52	74.68
Closterium sp.	23.12	23.12	--	61.60	30.80	30.80	46.24	--	23.12	--	30.80	269.60	24.51
Melisira granulata var augustissima	--	23.31	37.94	28.75	--	--	--	--	--	--	--	90.00	8.18
Fragilaria vaucheriae	--	22.58	--	--	--	--	--	--	--	--	--	22.58	2.05
Asterionella formosa	--	--	24.88	--	--	--	--	--	18.34	--	--	43.22	3.93
Gyrosigma sciotense	--	--	21.41	--	--	--	--	--	--	--	--	21.41	1.95
Melosira granulata	--	--	--	21.49	--	--	--	77.36	--	--	--	98.85	8.99
Dinobryan sertularia	--	--	--	17.95	--	26.58	21.95	49.19	17.96	--	15.95	149.58	13.60
Aphanizomenon sp.	--	--	--	17.23	--	17.23	--	--	--	--	--	34.46	3.13
Mullamonas sp.	--	--	--	--	--	--	--	--	12.76	--	--	12.76	1.16
Cymbella caespitosa	--	--	--	--	--	--	--	--	12.51	--	15.44	27.95	2.54
													643.41

APPENDIX IV(h)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0,001) NOVEMBER 1978

	STATIONS							
	*12	13	*14	*15	16	*17 - 20	SUM	MEAN
Tabellaria fenestrata		89.48			186.87		276.35	138.18
Fragilaria crotonensis		74.34			134.62		208.96	104.48
Closterium sp		69.36			23.12		92.48	46.24
Anabaena sp2		64.06			113.88		177.94	88.97
Cryptomonas borealis		58.84			34.77		93.61	46.81
Synedra delicatissima		36.75			31.50		68.25	34.13
Melosira granulata		22.58			--		22.58	11.29
Melosira granulata var augustissima		17.26			--		17.26	8.63
Asterionella formosa		--			18.68		18.68	9.34
Dinobryan sertularia		--			13.97		13.97	6.99
								495.06

* - not sampled

APPENDIX IV(i)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) APRIL 1979

	STATIONS														
	1	2	3	SUM	MEAN	4	5	6	7	8	9	*10	11	SUM	MEAN
Cryptomonas borealis	1923.83	555.77	1482.06	3961.65	1320.55	976.17	783.78	573.59	760.95	997.88	1140.05		598.53	5830.95	832.99
Asterionella formosa	702.12	532.02	546.50	1780.64	593.55	462.35	316.68	254.25	180.83	174.01	633.36		218.66	2240.14	320.02
Chlamydomonas	233.29	98.02	133.31	464.62	154.87	94.10	57.83	42.15	76.49	101.97	72.54		42.48	487.56	69.65
Mallomonas	228.76	--	49.46	278.22	92.74	46.37	27.82	--	42.53	25.51	55.65		20.09	217.97	31.14
Dinobryan sertularia	148.84	--	--	148.84	49.61	--	--	--	--	--	--		--	--	--
Fragilaria crotonensis	112.42	91.01	69.59	273.02	91.01	--	152.57	266.33	--	144.54	133.84		--	697.28	99.61
Dinobryon sp.	111.29	--	49.46	111.29	37.10	--	27.82	--	--	15.46	--		30.91	74.19	4.42
Navicula gastrum	103.75	--	--	103.75	34.58	--	--	--	--	--	--		--	--	--
Cyclotella comta	--	189.41	--	355.14	118.38	--	--	--	--	--	--		--	--	--
Oscillatoria	--	108.80	69.59	108.80	36.27	--	--	72.54	54.54	--	--		--	126.99	18.14
Rhopalodia gibba	--	95.22	--	95.22	31.74	--	--	--	--	--	--		--	--	--
Cyclotella ocellata	--	71.25	--	71.22	23.75	30.08	--	29.29	51.88	67.33	79.17		54.89	312.64	44.66
Synedra delicatissima	--	--	111.89	111.89	37.30	55.95	--	27.97	--	--	--		27.97	111.89	15.98
Cyclotella stelligera	--	--	37.40	37.40	12.47	--	--	--	--	--	--		--	--	--
Fragilaria capucina	--	--	--	--	--	38.00	19.00	--	--	--	--		--	57.00	8.14
Arthrodesmus sp.	--	--	--	--	--	22.02	66.05	--	--	30.28	44.03		--	162.38	23.20
Tabellaria fenestrata	--	--	--	--	--	--	--	49.09	--	--	--		--	49.09	7.01
Stephanodiscus niagare	--	--	--	--	--	--	--	--	106.47	--	--		--	106.47	15.21
Cymbella prostrata	--	--	--	--	--	--	--	--	89.35	--	--		--	89.35	12.76
Melosira granulata var augustissima	--	--	--	--	--	--	--	--	--	--	36.80		--	36.80	5.26
Gymnodinium sp.	--	--	--	--	--	--	--	--	--	--	--		665.48	665.48	95.07
					2633.92										1603.26

* - Station 10 was not sampled in April 1979

APPENDIX IV(j)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) APRIL 1979

	STATION *16
Cryptomonas borealis	206.09
Gymnodinium sp.	165.93
Asterionella formosa	41.36
Arthrodesmus sp.	38.43
Melosira granulatea	19.29
Cyclotella ocellata	17.11
Closterium sp.	15.36
Chlamydomonas sp.	11.73
	515.3

* Station 16 was the control site in April 1979

APPENDIX IV(k)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) JUNE 1979

STATIONS	1	2	3	4	5	6	7	8	9	10	11	SUM	MEAN
Stephanodiscus niagare	678.11	479.19	199.59	656.53	1135.72	2102.40	212.98	851.72	1630.20	709.62	638.60	9314.66	846.79
Fragilaria crotonensis	328.94	554.08	355.85	412.21	1026.39	1552.71	341.79	347.97	1357.98	752.31	347.02	7377.25	670.66
Anabaena spiroides	142.04	120.46	130.31	921.45	221.15	460.69	65.18	94.78	339.62	273.68	394.70	3164.06	287.64
Melosira granulata var. augustissima	129.24	115.59	118.35	128.78	51.56	--	--	--	77.42	134.10	--	755.04	68.64
Cryptomonas borealis	117.46	103.92	124.66	285.01	239.90	298.90	100.95	377.64	220.88	195.05	278.95	2343.65	213.06
Synedra delicatissima	52.40	55.95	55.95	--	--	--	--	--	--	--	--	164.30	14.94
Chlamynomonas sp	48.48	--	--	--	--	--	33.90	--	41.17	--	--	123.55	11.23
Asterionella formosa	48.14	57.08	39.79	--	--	--	--	--	--	--	--	145.01	13.18
Fragilaria construens varventer	--	121.18	--	--	--	--	--	--	--	--	--	121.18	11.02
Stephanodiscus astrea var minutula	--	--	38.53	--	113.44	179.14	45.65	72.16	95.12	49.73	51.37	645.14	58.65
Anabaena sp3	--	--	--	428.27	--	--	--	--	--	160.46	--	588.73	53.52
Tabellaria fenestrata	--	--	--	161.28	511.65	388.26	69.84	185.82	--	180.08	178.18	1675.11	152.28
Dinobryan sertularia	--	--	--	67.33	46.08	--	103.68	127.58	--	--	73.53	418.20	38.02
Ceratium sp	--	--	--	--	--	1610.85	--	--	--	--	704.48	2315.33	210.48
Melosira granulata	--	--	--	--	--	361.02	--	--	--	--	--	361.02	32.82
Cymbella prostrata	--	--	--	--	--	--	--	89.35	--	--	--	89.35	8.12
													2691.05

APPENDIX IV(1)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) JUNE 1979

	*16
Ceratium sp.	1610.85
Stephanodiscus niagare	931.50
Fragilaria crotonensis	765.78
Anabaena spiroides	710.83
Tabellaria fenestrata	254.59
Cryptomonas borealis	187.89
Dinobryan sertularia	114.27
Stephanodiscus astrea var minulata	60.67
	4636.38

* Station 16 was the control site in June 1979

APPENDIX IV(m)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($cm^3/m^3 \times 0.001$) AUGUST 1979

	STATIONS												
	1	2	3	4	5	6	7	8	9	10	11	SUM	MEAN
Gymnodinium sp	1996.44	1996.44	5656.58	1330.96	665.48	--	--	--	--	--	--	11645.90	1058.72
Anabaena spiroides	473.89	789.82	315.93	315.93	--	78.98	157.96	102.68	236.94	375.16	118.47	2965.76	269.61
Anabaena sp3	428.27	1391.88	1070.68	428.27	428.27	374.74	428.27	--	--	642.41	--	5192.79	472.07
Melosira granulata	409.72	345.97	532.93	285.38	103.15	110.31	94.55	161.17	445.54	338.45	81.66	2908.83	264.44
Aphanothece sp.	289.54	193.40	244.30	222.77	153.82	141.75	99.53	74.65	108.58	109.71	74.65	1712.70	155.70
Oscillatoria sp.	199.47	--	--	--	--	--	--	--	--	--	--	199.47	18.13
Cryptomonas borealis	149.63	--	--	--	--	--	--	--	--	--	--	149.63	13.60
Fragilaria capucina	123.51	--	--	--	--	--	--	--	--	--	--	123.51	11.23
Anabaena sp2	--	379.26	948.15	379.26	284.45	284.45	284.45	284.45	537.29	663.71	474.08	4519.55	410.87
Stephanodiscus niagare	--	133.08	--	716.73	638.79	319.39	585.56	106.47	--	79.85	53.23	2633.1	239.37
Cyclotella comta	--	112.46	328.86	--	56.23	61.16	106.54	--	--	--	38.47	374.86	34.08
Melosira granulata var augustissima	--	--	--	--	--	--	--	--	--	--	--	328.86	29.90
Synedra delicatissima	--	--	209.80	--	69.93	65.27	--	--	--	--	--	345.00	31.36
Gomphonema parvulum	--	--	--	359.02	--	--	--	--	--	--	--	359.02	32.64
Spirogyra sp.	--	--	--	--	--	--	791.70	1319.50	2639.00	2639.00	--	7389.20	671.75
Diatoma vulgare	--	--	--	--	--	--	--	110.08	82.56	--	--	192.64	17.51
Closterium sp.	--	--	--	--	--	--	--	61.60	--	--	--	61.60	5.60
Aphanizomenon sp.	--	--	--	--	--	--	--	--	91.89	172.29	86.14	350.32	31.85
Microcystis sp.	--	--	--	--	--	--	--	--	85.77	--	--	85.77	7.80
Staurastrum sp.	--	--	--	--	--	--	--	--	--	--	54.63	54.63	4.97
													3781.2

APPENDIX IV(n)

ZONE B   DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) AUGUST 1979

	*16
Stephanodiscus niagare	372.63
Anabaena sp2	284.45
Melosira granulata	146.13
Aphanothece sp.	108.58
Anabaena spiroides	94.78
Aphanizomenon sp.	86.14
Tabellaria fenestrata	73.63
Cryptomonas borealis	45.13
	1211.47

* - Station 16 was the control site in August 1979

APPENDIX IV(o)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) OCTOBER 1979

	STATIONS												
	1	2	3	4	5	6	7	8	9	10	11	SUM	MEAN
Aphanizomenon sp.	86.14	--	--	--	--	--	--	86.14	--	--	--	172.28	15.66
Stephanodiscus niagare	53.23	--	--	--	79.64	--	53.23	--	26.55	39.82	--	252.47	22.93
Melosira granulata	36.53	--	--	--	22.50	22.50	23.64	40.11	16.07	--	--	161.35	14.67
Ankistrodesmus sp.	29.03	24.88	32.35	24.05	30.40	30.40	38.15	24.88	26.06	23.74	43.96	297.50	27.05
Oscillatoria sp.	27.20	--	--	36.27	--	54.26	36.27	36.27	54.26	40.77	72.54	357.84	44.73
Chroomonas acuta	27.14	31.39	32.74	32.40	23.10	28.55	31.39	--	19.20	30.20	33.76	289.87	26.35
Cryptomonas borealis	24.94	57.00	39.19	42.75	39.97	58.63	35.63	54.63	37.31	29.08	24.94	444.07	40.37
Aphanothece sp.	24.88	36.19	--	--	--	--	--	--	--	--	--	61.07	5.55
Anabaena sp3	--	107.07	107.07	--	--	--	--	--	--	--	--	214.14	19.47
Anabaena sp.	--	79.17	98.96	98.96	74.03	74.03	138.55	98.96	69.09	79.07	79.17	889.99	80.91
Fragilaria crotonensis	--	64.24	--	--	--	--	24.09	--	--	--	--	88.33	8.03
Chlamydomonas sp.	--	23.03	21.07	--	19.43	23.46	--	--	--	--	--	86.99	7.91
Closterium sp.	--	--	30.80	--	--	--	--	--	--	--	--	30.80	2.80
Synedra radians	--	--	20.70	--	--	--	--	--	--	--	--	20.70	1.88
Anabaena spiroides	--	--	--	157.96	59.08	59.08	--	--	--	--	--	276.12	25.10
Microcystis sp.	--	--	--	36.29	--	--	--	--	--	24.73	16.49	77.51	7.05
Cyclotella comta	--	--	--	23.68	--	--	--	23.68	--	--	--	47.36	4.31
Tabellaria fenestrata	--	--	--	--	--	--	--	28.05	--	--	--	28.05	2.55
Diatoma vulgare	--	--	--	--	--	--	--	--	20.59	--	--	20.59	1.87
Synedra delicatissima	--	--	--	--	--	--	--	--	--	27.96	55.95	83.91	7.63
Gomphonema herculeanum	--	--	--	--	--	--	--	--	--	--	69.52	69.52	6.32
													373.16

APPENDIX IV(p)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm^3/m^3 x 0.001) OCTOBER 1979

	*16
Oscillatoria sp.	99.59
Anabaena sp.	84.00
Microcystis sp.	72.57
Cryptomonas borealis	67.63
Stephanodiscus niagare	46.53
Ankistrodesmus sp.	36.24
Chroomonas acuta	26.98
Chlamydomonas sp.	21.91
	455.45

* Station 16 was the control site in October 1979

APPENDIX V

PERIPHYTON ASH-FREE WEIGHT
AT SHALLOW WATER STATIONS
IN SHUSWAP LAKE
DURING 1979

APPENDIX V(a) PERIPHYTON ASH-FREE WEIGHT ($mg/m^2/day$) AT SHALLOW WATER STATIONS IN SHUSWAP LAKE DURING 1979

STATIONS	END OF APPROXIMATE THREE-WEEK PERIODS									
	May 8	May 29	June 19	July 12	July 31	Aug. 21	Sept. 11	Oct. 2	Oct. 23	Mean
SA-S1	--	--	215.0	83.3	363.2	361.9	90.5	71.4	20.0	172.2
SA-S2	50.0	19.0	15.0	54.2	31.6	276.2	38.1	--	15.0	62.4
SA-S3	56.3	19.0	30.0	54.2	36.8	57.1	52.4	28.1	20.0	40.4
SA-S4	31.3	90.5	110.0	20.8	42.1	33.3	76.2	47.6	15.0	51.9