B. NIDLE

Limnological Surveys of Babine Lake, British Columbia: Results of the Monitoring Program, 1974-1978

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November 1978

Fisheries and Marine Service Manuscript Report No. 1494

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Fisheries and Marine Service — Service des pêches et de la mer

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Fisheries and Marine Services

Manuscript Report 1494

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LIMNOLOGICAL SURVEYS OF BABINE LAKE, BRITISH COLUMBIA: RESULTS OF THE MONITORING PROGRAM, 1974-1978.

by

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Cat. no. Fs 97-4/1494 ISSN 0701-7618

ABSTRACT

Stockner, J.G., and K.R.S. Shortreed. 1979. Limnological surveys of Babine Lake, British Columbia: results of the monitoring program, 1974-1978. Fish. Mar. Serv. MS Rep. 1494: 35 p.

Results of the Babine Lake monitoring program, using a standard OECD format, are discussed in relation to known watershed and lake changes. Physical, chemical and biological data were gathered from spring and autumn surveys conducted from 1974 to 1978, and from a winter-early spring survey carried out under ice conditions in 1977. The two copper mines on the lake shore have thus far not seriously affected water quality and copper concentrations at stations contiguous to the operations remain at low levels. The lake has remained oligotrophic despite intensive logging and copper mining in the watershed and the operation of 3 bubble lines for ice-free winter crossings.

Key words: lake survey, copper, phytoplankton, nutrient chemistry, primary production, chlorophyll.

RESUME

Stockner, J.G., and K.R.S. Shortreed. 1979. Limnological surveys of Babine Lake, British Columbia: results of the monitoring program, 1974-1978. Fish. Mar. Serv. MS Rep. 1494: 35 p.

Le résultant de la campagne limnologique au lac Babine, pour laquelle on a employé une méthode normalisee de l'O.C.D.E., sont interprétés à la lumiere des modifications connues de la ligne de partage des eaux et du lac. Les données physiques, chimiques et biologiques ont été recueillies le printemps et l'automne, de 1974 à 1978, et dans l'hiver et au début du printemps de 1977, pendant que la glace était prise. Ainsi, les deux mines de cuivre situées sur la rive du lac n'ont donc pas trop altéré la qualité de ses eaux et la teneur en cuivre des eaux à proximité y est restée basse. Le lac est demeuré oligrotrophe en dépit de l'intensité de l'exploitation forestière et de l'extraction de cuivre à proximité de la ligne de partage des eaux, et du fontionnement de trois rideaux de bulles qui maintiennent des passages libres de glace.

Mots cléfs: étude limnologique; cuivre; phytoplancton; chimie des éléments nutritifs; production primaire; chlorophylle.

INTRODUCTION

In 1973 the Steering Committee of the Babine Lake Watershed Change Program (BLWCP) expressed concern over potential environmental change resulting from anticipated increases in logging and mining in the watershed and the impact any changes in water quality may have on the lake's capacity to rear juvenile sockeye salmon (*Oncorhynchus nerka*) (Smith MS 1975). A monitoring program was developed in 1973, using the format of monitoring proposed by the Environment Directorate of the Organization for Economic Co-operation and Development (OECD) in Paris in 1973.[1]

This report presents results from the 1974-1978 Babine Lake spring and fall monitoring program and compares data with the intensive limnological study done in 1973 (Stockner and Shortreed 1974, 1975). To facilitate analysis, and for ease in reporting, some limnological data from the previous monitoring report (Stockner and Shortreed 1976) are included in this report. Also, the BLWCP Steering Committee was concerned over the growing use of bubble lines to maintain ice-free channels across the lake during the winter months. A brief experiment in April, 1977 studied this problem and results are presented and discussed in this report.

LOCATION OF STATIONS

There were 13 lake sampling stations in the monitoring program (Figs. 1 and 2). From 1974 to 1976 samples for chemical analyses were collected from all stations except Station O. At the river and mine stations, samples for chemical analyses only were obtained.

A description of lake morphometry, watershed physiography, and resource utilization is presented in Stockner and Shortreed (1975) and Smith (MS 1975). In the bubble line experiment, samples were taken at five stations: one directly over the bubble line in open water and the others under ice up to one kilometer away (Fig. 3). The Northwood Pulp Ltd. bubble line was used in the experiment and is located one kilometer north of Fulton River (Fig. 1).

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[1]Summary Report of the agreed monitoring project on Eutrophication of Waters (OECD), 21 p.

METHODS

Detailed descriptions of field techniques and analytical procedures are given in Stockner and Shortreed (1975). Primary production was estimated using a modified ^{14}C method (Steeman-Nielsen 1952) and volumetric and integral carbon uptake were calculated on a Hewlett Packard 9820 computer. Samples for determination of chlorophyll *a* concentration and for phytoplankton enumeration and biomass estimates were taken at all main lake stations. Water transparency was determined using a standard 22-cm Secchi disc, and light extinction with depth was measured using a Montedoro Whitney Illuminance meter (Model LMT-8A). Daily solar radiation was measured with a Belfort recording pyrheliometer. At each station a bathythermograph (BT) was lowered to obtain a temperature-depth profile, and surface temperature for BT calibration was measured with a bucket thermometer.

All chemical analyses, with the exception of the October, 1975 series, were conducted at the Provincial Government's Water Resources Service Environmental Laboratory in Vancouver, B.C., using methods described in McQuaker (1973). The October, 1975, series was analyzed at the Environmental Protection Service (E.P.S.) - Fisheries Service chemistry laboratory at the Pacific Environment Institute in West Vancouver, B.C. Methods used are described in the joint Fisheries/E.P.S. Laboratory Manual (1975).

RESULTS AND DISCUSSION

Temperature-depth profiles in all years were similar to those at comparable stations and dates in 1973 (Stockner and Shortreed 1975). At the time of the spring surveys (late May - early June), the main lake (Stations 2-5) was either weakly stratified or isothermal, while both Nilkitkwa Lake and the North Arm of Babine Lake (Stations 0 and 1) were well stratified. In the autumn, well stratified conditions occurred; the shape of the temperature-depth profile was similar throughout the lake and typical of autumnal profiles of north temperate lakes (Hutchinson 1957), although the depth of the epilimnion in the main lake was much greater (>12 m) than that in the north arm (>8 m). Secchi disc values in early June were significantly higher in the main lake in the North Arm, while fall values tended to be lower in the main lake but not significantly different from those in the North Arm (Table 4, Fig. 4).

No increasing nor decreasing trends in nutrient or heavy metal concentration were observed in the three years of sample collection (Tables 1-3). Although copper toxicity was of some concern in Babine Lake owing to the presence of two copper mines on its shores, indications are that the chelating capacity of the lake's humic waters at present greatly exceeds the influx of copper ions (Chau and Wong MS 1975). In addition, chemical observations in 1963 and 1969 on Babine Lake (Stephens et al. 1969) were very similar to 1976 values.

As expected in a survey encompassing such a wide range of dates and locations, considerable variation was evident in all biological data. Primary production ranged from a low of 43 $mg \cdot C \cdot m^{-2} \cdot d^{-1}$ at Station 2 in spring, 1976 to a high of 511 in spring, 1975 at Station 1 (Table 5). The lowest chlorophyll *a* concentration (0.18 $mg \cdot m^{-3}$) was recorded at Station 4 in June, 1975, and the highest (2.99) in Nilkitkwa Lake (Station 0) in June, 1975 (Table 5). As was the case in the 1973 study (Stockner and Shortreed 1975), significant regional disparities in primary production and chlorophyll *a* concentration were evident, although the differences among years were not significant (Table 4). In the spring, biomass (volume) of phytoplankton was always higher in the North Arm of Babine and in Nilkitkwa Lake than in the main lake basin, but in the fall the opposite trend was observed (Fig. 5A-E).

Studies on the bubble line in April, 1977, showed chlorophyll *a* and phytoplankton concentrations to be lower in the open water of the bubble line than in water beneath the ice (Fig. 3). These differences were due chiefly to the rapid upwelling of lake water, causing extreme vertical instability in the bubble line contrasted with the relatively stable conditions under ice cover. Primary production bottles held stationary and incubated in the open water of the bubble line were exposed to abnormally high light intensities as opposed to those incubated at very low light levels under ice (Table 4), and this led to the higher rate of carbon uptake. Actual production values in the bubble line were probably much lower than those under ice owing to the very rapid water circulation leading to vertical instability.

Temperature profiles taken at the time of the experiment indicate that the effect of the bubbler was very localized. On the basis of temperature the upwelling cannot be detected at a distance of 70 m from the open water (Farmer and Spearing, unpublished data).

The five years of data collection since the year of intensive studies (1973) indicate that Babine Lake is at present in a steady state condition, and that as yet cultural eutrophication from increased settlement or increasing copper concentrations due to mining activities are not seriously affecting the water quality of the lake. Since Babine Lake is a highly important rearing area for juvenile sockeye (largest on the Skeena River watershed), and because cultural, mining and logging activities along its shores are steadily increasing, the limnological monitoring program will continue for the foreseeable future, so that any changes in trophic state may be detected before they are of sufficient magnitude to be detrimental to the lake's water quality.

ACKNOWLEDGEMENTS

Thanks are extended to Dr. Ron Buchanan for providing funding for chemical analyses at Provincial Laboratories and to Mr. Rick Kussat for providing personnel to carry out sample collection in the field from 1974-76. Their permission to publish the chemical results is most gratefully acknowledged. Messrs. E. MacIsaac and K. Simpson assisted in field surveys and E. MacIsaac with Mr. B. Cochlan assisted in data collation and drafting of figures. We are grateful for the assistance and accommodation provided by the supervisors and staff at Pinkut Creek, Fulton River and Babine River Fisheries Service camps. Finally, without the financial support of the Pacific Biological Station, the authors' input to the monitoring would not have been possible. We thank Drs. D. Alderdice and H. Mundie for review of this manuscript.

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Table 1a. Babine Lake Monitor Program - chemical data, Lake stations

Date: May 15-16, 1976

TYPE OF ANALYSIS	STATION 1	2	3	4	5
pH	7.2	7.3	7.5	7.3	7.2
Spect. Cond. ($\mu mho \cdot cm^{-2}$)	76.0	79.0	80.0	80.0	81.0
Turbidity (F.T.U.)	0.8	0.2	0.4	0.3	0.8
Colour	20.0	10.0	10.0	10.0	15.0
Nutrients ($mg \cdot L^{-1}$)					
Total Org. C	9.0	8.0	10.0	7.0	7.0
Diss. P	<0.003	<0.003	<0.003	<0.003	<0.003
Total P	0.005	0.004	0.006	0.004	0.006
Diss. N(NO_3+NO_2)	0.09	0.10	0.10	0.10	0.11
Total Kjeldahl N	0.17	0.15	0.18	0.16	0.44
Total N	0.26	0.25	0.28	0.26	0.55
React. SiO_2	4.4	4.4	4.4	4.5	4.8
Diss. Na	2.0	2.0	2.0	2.0	2.2
Diss. K	0.5	0.5	0.6	0.6	0.7
Diss. Cl	0.6	0.5	0.5	0.7	<0.5
Diss. SO_4	<5.0	<5.0	<5.0	<5.0	<5.0
Total Res. (105C)	64.0	66.0	62.0	64.0	70.0
Filt. Res. (105C)	60.0	64.0	60.0	62.0	66.0
Total Alkal.$CaCO_3$($mg \cdot L^{-1}$)	33.6	35.5	36.5	35.5	36.0
Heavy Metals[a] ($mg \cdot L^{-1}$)					
Cd	<0.0005	<0.0005	<0.0005	<0.0005	0.0039
Cu	0.002	0.004	0.003	0.003	0.023
Fe	0.2	<0.1	<0.1	0.1	0.1
Pb	<0.001	<0.001	<0.001	<0.001	0.01
Mo	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zn	<0.005	<0.005	<0.005	<0.005	0.05
Mg	2.3	2.5	2.4	1.9	2.6
Ca	10.4	10.8	10.6	10.6	11.1

[a]unfiltered samples

Table 1b. Babine Lake Monitor Program - chemical data, Lake stations

Date: July 18-20, 1976

TYPE OF ANALYSIS	STATION 1	2	3	4	5
pH	7.8	7.8	7.9	7.9	7.8
Spect. Cond. (μmho·cm^{-2})	74.0	77.0	76.0	77.0	77.0
Turbidity (F.T.U.)	8.0	0.5	0.5	0.5	0.4
Colour	25.0	20.0	20.0	20.0	20.0
Nutrients (mg·L^{-1})					
Total Org. C	8.0	8.0	7.0	8.0	7.0
Diss. P	<0.003	<0.003	<0.003	0.004	<0.003
Total P	0.005	0.006	0.006	0.007	0.007
Diss. N(NO_3+NO_2)	0.07	0.07	0.07	0.08	0.06
Total Kjeldahl N	0.20	0.18	0.21	0.19	0.18
Total N	0.27	0.25	0.28	0.27	0.23
React. SiO_2	4.2	4.2	4.3	4.5	4.7
Diss. Na	2.1	2.1	2.0	2.1	2.0
Diss. K	0.6	0.6	0.6	0.6	0.6
Diss. Cl	0.5	<0.5	0.5	0.5	<0.5
Diss. SO_4	<5.0	<5.0	<5.0	<5.0	<5.0
Total Res. (105C)	61.0	64.0	63.0	62.0	64.0
Filt. Res. (105C)	58.0	62.0	61.0	60.0	62.0
Total Alkal.$CaCO_3$(mg·L^{-1})	35.8	36.7	36.4	37.0	37.4
Heavy Metals[a] (mg·L^{-1})					
Cd	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cu	0.007	0.006	0.006	0.005	0.005
Fe	0.1	0.1	<0.1	0.1	0.1
Pb	0.002	<0.001	0.002	0.002	<0.001
Mo	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zn	0.011	<0.005	0.007	0.006	0.006
Mg	2.5	2.5	2.6	2.6	2.7
Ca	10.3	10.5	10.6	10.5	10.5

[a] unfiltered samples

Table 1c. Babine Lake Monitor Program - chemical data, Lake stations

Date: Oct. 3-4, 1976

TYPE OF ANALYSIS	STATION 1	2	3	4	5
pH	7.9	7.8	7.7	7.8	7.9
Spect. Cond. (μmho$\cdot$cm^{-2})	78.0	78.0	77.0	78.0	78.0
Turbidity (F.T.U.)	0.4	0.4	0.4	0.4	0.5
Colour	15	20	15	15	20
Nutrients (mg$\cdot$L^{-1})					
Total Org. C	7.0	7.0	8.0	6.0	6.0
Diss. P	<0.003	<0.003	<0.003	<0.003	<0.003
Total P	0.005	0.004	0.004	0.005	0.006
Diss. N(NO_3+NO_2)	0.05	0.06	0.06	0.06	0.06
Total Kjeldahl N	0.19	0.17	0.13	0.14	0.17
Total N	0.24	0.23	0.19	0.20	0.23
React. SiO_2	4.0	4.1	4.1	4.2	4.4
Diss. Na	1.9	2.0	2.0	2.0	2.0
Diss. K	0.5	0.6	0.6	0.6	0.6
Diss. Cl	<0.5	<0.5	<0.5	<0.5	<0.5
Diss. SO_4	<5.0	<5.0	<5.0	<5.0	<5.0
Total Res. (105C)	64	66	62	62	64
Filt. Res. (105C)	62	64	60	60	62
Total Alkal.$CaCO_3$(mg$\cdot$L^{-1})	36.5	36.2	36.4	36.0	37.5
Heavy Metals[a] (mg$\cdot$L^{-1})					
Cd	<0.005	<0.005	<0.0005	0.0007	<0.0005
Cu	0.002	0.002	0.002	0.003	<0.001
Fe	<0.1	0.1	<0.1	0.1	<0.1
Pb	0.002	<0.001	0.005	<0.001	<0.001
Mo	<0.0005	<0.0005	0.0005	0.0006	0.0005
Zn	<0.005	<0.005	0.020	0.008	<0.005
Mg	2.6	2.6	2.6	2.6	2.7
Ca	10.1	9.8	9.8	9.6	9.9

[a] unfiltered samples

Table 2a. Babine Lake Monitor Program - chemical data for river stations
Date: May 15-16, 1976

TYPE OF ANALYSIS	STATION Babine	Pinkut	Fulton	Morrison
pH	7.9	7.3	7.3	7.0
Spect. Cond. (μmho·cm^{-2})	74	76	68	64
Turbidity (F.T.U.)	1.0	17.0	6.6	2.6
Colour	15	40	60	60
Nutrients (mg·L^{-1})				
Total Org. C	10.0	8.0	14.0	12.0
Diss. P	<0.003	0.003	<0.003	<0.003
Total P	0.005	0.063	0.005	0.011
Diss. N(NO_3+NO_2)	0.09	0.05	0.04	0.08
Total Kjeldahl N	0.19	0.17	0.31	0.26
Total N	0.28	0.22	0.35	0.34
React. SiO_2	4.3	7.5	5.0	5.0
Diss. Na	2.0	2.3	1.5	1.8
Diss. K	0.5	0.7	0.3	0.3
Diss. Cl	0.6	0.5	0.8	0.6
Diss. SO_4	<5.0	<5.0	<5.0	<5.0
Total Res. (105C)	64	110.0	74	64
Filt. Res. (105C)	60	66	60	56
Total Alkal.$CaCO_3$(mg·L^{-1})	34.4	35.0	31.1	27.0
Heavy Metals[a] (mg·L^{-1})				
Cd	<0.0005	<0.0005	<0.0005	<0.0005
Cu	0.003	0.002	<0.001	<0.001
Fe	0.1	1.8	0.6	0.2
Pb	<0.001	<0.001	<0.001	<0.001
Mo	<0.0005	<0.0005	<0.0005	<0.0005
Zn	<0.005	<0.005	0.010	<0.005
Mg	2.3	2.9	2.0	2.3
Ca	9.7	10.6	10.4	9.7

[a]unfiltered samples

Table 2b. Babine Lake Monitor Program - chemical data for river stations

Date: July 18-20, 1976

TYPE OF ANALYSIS	STATION			
	Babine	Pinkut	Fulton	Morrison
pH	7.8	8.0	7.7	7.6
Spect. Cond. ($\mu mho \cdot cm^{-2}$)	72	74	61	60
Turbidity (F.T.U.)	0.5	1.8	0.6	0.7
Colour	20	40	40	50
Nutrients ($mg \cdot L^{-1}$)				
Total Org. C	8.0	11.0	10.0	10.0
Diss. P	<0.003	<0.003	0.012	<0.003
Total P	0.003	0.014	0.025	0.010
Diss. N(NO_3+NO_2)	0.04	<0.02	<0.02	<0.02
Total Kjeldahl N	0.22	0.23	0.35	0.64
Total N	0.26	0.23	0.35	0.64
React. SiO_2	3.9	7.4	4.4	4.3
Diss. Na	2.0	2.3	1.5	1.8
Diss. K	0.6	0.6	0.2	0.4
Diss. Cl	0.5	0.6	0.6	0.5
Diss. SO_4	<5.0	<5.0	<5.0	<5.0
Total Res. (105C)	62	70	58	62
Filt. Res. (105C)	60	66	56	60
Total Alkal. $CaCO_3$ ($mg \cdot L^{-1}$)	34.6	37.5	29.3	28.0
Heavy Metals[a] ($mg \cdot L^{-1}$)				
Cd	<0.0005	<0.0005	<0.0005	<0.0005
Cu	0.003	0.003	0.002	0.002
Fe	0.1	0.2	0.3	0.2
Pb	0.002	<0.001	0.004	0.006
Mo	<0.0005	0.0005	<0.0005	<0.0005
Zn	0.005	0.007	0.010	<0.005
Mg	2.4	2.5	1.9	1.9
Ca	10.0	10.5	9.1	8.7

[a]unfiltered samples

Table 2c. Babine Lake Monitor Program - chemical data for river stations
Date: Oct. 3-4, 1976

TYPE OF ANALYSIS	STATION			
	Babine	Pinkut	Fulton	Morrison
pH	7.9	7.9	7.5	7.6
Spect. Cond. ($\mu mho \cdot cm^{-2}$)	81	80	73	59
Turbidity (F.T.U.)	0.8	1.3	1.0	0.6
Colour	20	30	30	40
Nutrients ($mg \cdot L^{-1}$)				
Total Org. C	6.0	10.0	9.0	9.0
Diss. P	0.005	0.005	0.050	<0.003
Total P	0.017	0.018	0.069	0.005
Diss. N(NO_3+NO_2)	0.04	0.02	0.08	<0.02
Total Kjeldahl N	0.24	0.29	0.43	0.25
Total N	0.28	0.31	0.51	0.25
React. SiO_2	4.4	7.0	4.3	4.6
Diss. Na	2.0	2.2	1.3	1.7
Diss. K	0.5	0.6	0.4	0.3
Diss. Cl	<0.5	<0.5	0.5	0.5
Diss. SO_4	<5.0	<5.0	<5.0	<5.0
Total Res. (105C)	68	76	64	60
Filt. Res. (105C)	66	72	60	58
Total Alkal.$CaCO_3$($mg \cdot L^{-1}$)	37.5	39.6	34.2	26.5
Heavy Metals[a] ($mg \cdot L^{-1}$)				
Cd	<0.0005	<0.0005	<0.0005	<0.0028
Cu	0.003	0.006	0.004	<0.001
Fe	0.1	0.1	0.1	<0.1
Pb	0.002	0.004	0.016	0.005
Mo	0.0006	0.0008	<0.0005	<0.0005
Zn	<0.005	0.005	<0.005	0.006
Mg	2.4	2.7	2.2	1.7
Ca	10.8	10.4	9.6	7.7

[a]unfiltered samples

Table 3a. Babine Lake Monitor Program - chemical data, mine sites

Date: May 15-16, 1976

TYPE OF ANALYSIS	STATION		
	Noranda	Granisle A	Granisle B
pH	7.5	7.5	7.4
Spect. Cond. ($\mu mho \cdot cm^{-2}$)	80	85	82
Turbidity (F.T.U.)	0.3	0.3	0.6
Colour	-	-	-
Nutrients ($mg \cdot L^{-1}$)			
Total Org. C	6.5	8.0	7.5
Diss. P	<0.003	<0.003	<0.003
Total P	0.003	0.003	0.004
Diss. N(NO_3+NO_2)	0.09	0.10	0.08
Total Kjeldahl N	0.13	0.15	0.12
Total N	0.22	0.25	0.20
React. SiO_2	4.4	4.4	4.4
Diss. Na	2.0	2.2	2.1
Diss. K	0.6	0.6	0.6
Diss. Cl	0.5	0.5	0.5
Diss. SO_4	5.0	5.0	5.0
Total Res. (105C)	61	72	70
Filt. Res. (105C)	59	70	68
Total Alkal.$CaCO_3$($mg \cdot L^{-1}$)	36.8	37.2	36.6
Heavy Metals[a] ($mg \cdot L^{-1}$)			
Cd	<0.0005	<0.0005	<0.0005
Cu	0.005	0.004	0.005
Fe	0.2	<0.1	0.1
Pb	<0.001	<0.001	<0.001
Mo	0.0005	0.0005	0.0005
Zn	0.006	<0.005	<0.005
Mg	2.6	2.7	2.7
Ca	10.6	11.0	10.7

[a]unfiltered samples

Table 3b. Babine Lake Monitor Program - chemical data, mine sites

Date: July 18-20, 1976

TYPE OF ANALYSIS	STATION		
	Noranda	Granisle A	Granisle B
pH	7.7	7.8	7.8
Spect. Cond. ($\mu mho \cdot cm^{-2}$)	76	84	80
Turbidity (F.T.U.)	0.4	0.5	0.9
Colour	10	10	10
Nutrients ($mg \cdot L^{-1}$)			
Total Org. C	10.0	10.0	9.0
Diss. P	<0.003	<0.003	<0.003
Total P	0.005	0.007	0.006
Diss. N(NO_3+NO_2)	0.07	0.09	0.07
Total Kjeldahl N	0.23	0.17	0.09
Total N	0.30	0.25	0.16
React. SiO_2	4.3	4.2	4.3
Diss. Na	2.0	2.3	2.0
Diss. K	0.6	0.7	0.6
Diss. Cl	<0.5	<0.5	<0.5
Diss. SO_4	<5.0	5.0	<5.0
Total Res. (105C)	64	66	61
Filt. Res. (105C)	61	66	61
Total Alkal. $CaCO_3$ ($mg \cdot L^{-1}$)	36.9	37.9	37.3
Heavy Metals[a] ($mg \cdot L^{-1}$)			
Cd	<0.0005	<0.0005	<0.0005
Cu	0.002	0.004	0.004
Fe	<0.1	<0.1	<0.1
Pb	<0.001	<0.001	<0.001
Mo	0.0007	0.0007	0.0007
Zn	<0.005	<0.005	<0.005
Mg	2.8	2.7	2.6
Ca	10.7	10.9	10.8

[a]unfiltered samples

Table 3c. Babine Lake Monitor Program - chemical data, mine sites

Date: Oct. 3-4, 1976

TYPE OF ANALYSIS	STATION Noranda	Granisle A	Granisle B
pH	7.8	7.7	7.8
Spect. Cond. ($\mu mho \cdot cm^{-2}$)	79	81	80
Turbidity (F.T.U.)	0.8	0.5	0.6
Colour	25	20	25
Nutrients ($mg \cdot L^{-1}$)			
Total Org. C	6.5	8.0	8.5
Diss. P	<0.003	<0.003	<0.003
Total P	0.005	0.007	0.005
Diss. N(NO_3+NO_2)	0.06	0.07	0.07
Total Kjeldahl N	0.21	0.17	0.23
Total N	0.27	0.24	0.30
React. SiO_2	4.2	4.1	2.1
Diss. Na	1.9	2.0	1.9
Diss. K	0.6	0.6	0.6
Diss. Cl	0.6	0.6	0.6
Diss. SO_4	<5.0	5.0	5.0
Total Res. (105C)	63	64	63
Filt. Res. (105C)	61	62	61
Total Alkal.$CaCO_3$($mg \cdot L^{-1}$)	36.8	37.3	37.5
Heavy Metals[a] ($mg \cdot L^{-1}$)			
Cd	<0.0005	<0.0005	<0.0005
Cu	0.004	0.006	0.005
Fe	<0.1	<0.1	<0.1
Pb	<0.001	<0.001	<0.001
Mo	<0.0005	0.0008	0.0006
Zn	<0.005	<0.005	<0.005
Mg	2.4	2.5	2.5
Ca	9.9	10.6	10.5

[a]unfiltered samples

Table 4. Statistical comparison of north (Station 1) and south (Stations 4 and 5) and 1973 and 1978 values.

	Degrees of Freedom	Student's "t" value	Significant at 0.05 level (*) north>south	south>north
SPRING				
Primary Production	4	2.13	*	
Chlorophyll *a*	3	7.25	*	
Secchi Depth	4	6.52		*
FALL				
Primary Production	1	2.11	N.S.[1]	N.S.
Chlorophyll *a*	2	9.49		*
Secchi Depth	2	0.07	N.S.	N.S.
			1973>1978	1978>1973
SPRING				
Primary Production	4	0.31	N.S.	N.S.
Chlorophyll *a*	4	0.04	N.S.	N.S.
Secchi Depth	4	0.97	N.S.	N.S.
FALL				
Primary Production	2	0.34	N.S.	N.S.
Chlorophyll *a*	4	0.50	N.S.	N.S.
Secchi Depth	4	2.43		*

[1]N.S. - not significant.

Table 5. Biological and physical data from Babine Lake monitoring program, 1974-1978.

STN.	PRIM. PROD. ($mgC \cdot m^{-2} \cdot d^{-1}$)	CHL. *a* ($mg \cdot m^{-3}$)	ASSIM. NO.	ALGAL NO. ($x10^8 \cdot m^{-3}$)	ALGAL VOL. ($mm^3 \cdot m^{-3}$)	EXTINCT. COEFF. "k"	COMP. DEPTH (m)
	SPRING 1974 - JUNE 7-12						
0	179	0.93	2.2	8.7	220	1.10	4.0
1	390	1.37	2.9	8.4	568	1.31	3.2
2	213	0.67	3.6	7.7	357	0.64	6.3
3	138	0.59	2.6	5.7	83	0.67	6.6
4	343	1.22	3.5	9.2	159	0.65	6.7
5	207	0.32	5.9	2.3	55	0.64	6.7
	FALL 1974 - OCTOBER 23-24						
1	200	1.97	1.1	8.3	228	0.78	5.6
2	371	1.89	1.9	4.6	196	0.80	5.4
3	435	2.21	2.6	3.5	429	0.94	4.6
4	463	2.74	2.7	2.9	387	1.07	4.2
	SPRING 1975 - MAY 29-JUNE 3						
0	226	-	-	4.2	191	1.34	3.3
1	511	0.76	4.2	2.8	111	0.80	5.4
2	438	0.78	2.4	10.3	192	0.64	6.2
3	162	0.19	5.6	6.5	39	0.63	6.8
4	230	0.18	8.8	3.1	102	0.57	7.6
5	202	0.25	7.8	2.7	100	0.57	-
	SPRING 1976 - MAY 29-JUNE 2						
0	42	0.39	1.0	5.0	70	-	-
1	73	0.37	1.6	2.9	66	-	-
2	43	0.38	1.2	7.0	67	-	-
3	84	-	-	3.8	61	-	-
4	75	-	-	3.2	89	-	-
5	79	-	-	3.2	45	-	-
	FALL 1976 - OCTOBER 5-7						
1	92	1.37	1.5	6.1	143	-	-
2	127	1.80	1.3	8.2	382	-	-
3	159	1.63	1.6	7.8	235	-	-
5	186	2.32	1.5	11.3	450	-	-

Table 5 contd. Biological and physical data from Babine Lake monitoring program, 1974-1978.

STN.	PRIM. PROD. ($mgC \cdot m^{-2} \cdot d^{-1}$)	CHL. *a* ($mg \cdot m^{-3}$)	ASSIM. NO.	ALGAL NO. ($x10^8 \cdot m^{-3}$)	ALGAL VOL. ($mm^3 \cdot m^{-3}$)	EXTINCT. COEFF. "k"	COMP. DEPTH (m)
	SPRING 1977 - MAY 25-28						
0	188	2.99	1.1	14.2	699	0.88	4.9
1	237	2.23	1.6	21.5	670	0.95	4.8
2	204	1.62	2.0	16.9	335	0.88	5.0
3	72	0.87	1.7	9.8	218	0.65	6.3
4	215	1.62	0.8	36.7	292	0.67	6.8
5	62	0.86	0.7	14.1	189	0.49	8.7
	FALL 1977 - SEPT. 15-16						
2	260	1.94	1.3	10.7	201	0.60	7.1
3	399	1.52	2.3	8.6	154	0.56	7.6
4	429	1.46	2.7	9.0	174	0.73	6.0
5	333	1.79	1.9	9.8	232	0.69	6.3
	SPRING 1978 - MAY 26-30						
0	-	2.58	-	10.8	193	0.83	5.2
1	134	1.30	1.5	6.5	240	0.72	6.3
2	185	0.73	4.0	6.0	200	-	-
3	150	1.08	1.3	5.7	96	0.56	7.8
4	90	0.42	2.5	3.3	97	0.62	7.1
5	98	0.66	1.2	3.1	48	0.54	8.3
	FALL 1978 - SEPT. 8-9						
1	197	1.37	2.7	5.2	134	0.62	7.4
2	228	2.16	2.1	7.4	281	0.73	6.2
3	176	2.11	2.1	9.3	217	0.66	6.7
4	-	2.77	-	9.2	496	0.59	7.5
5	-	2.20	-	5.4	147	0.55	8.2

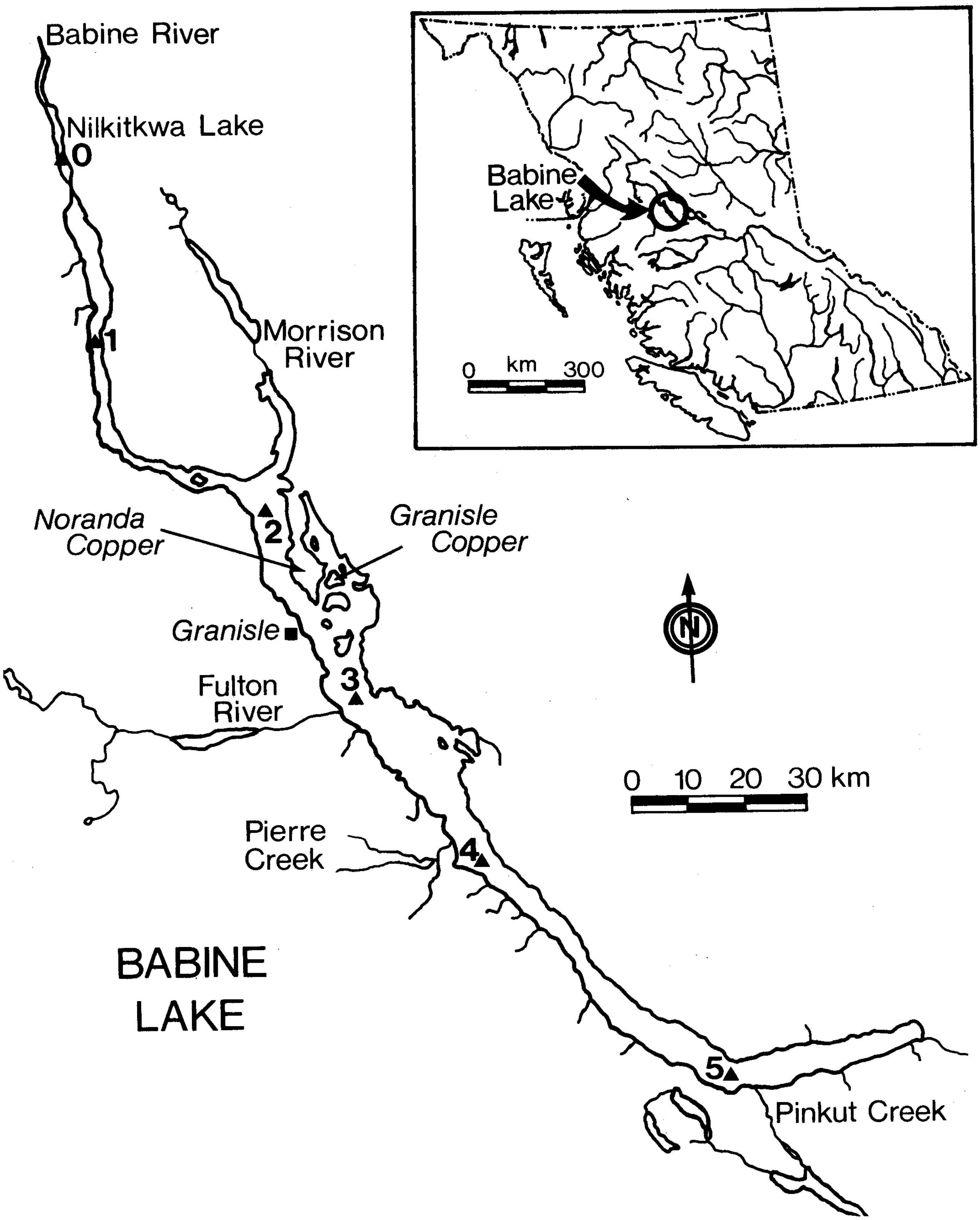

Fig. 1. Map of Babine Lake showing station locations, mine sites and major rivers.

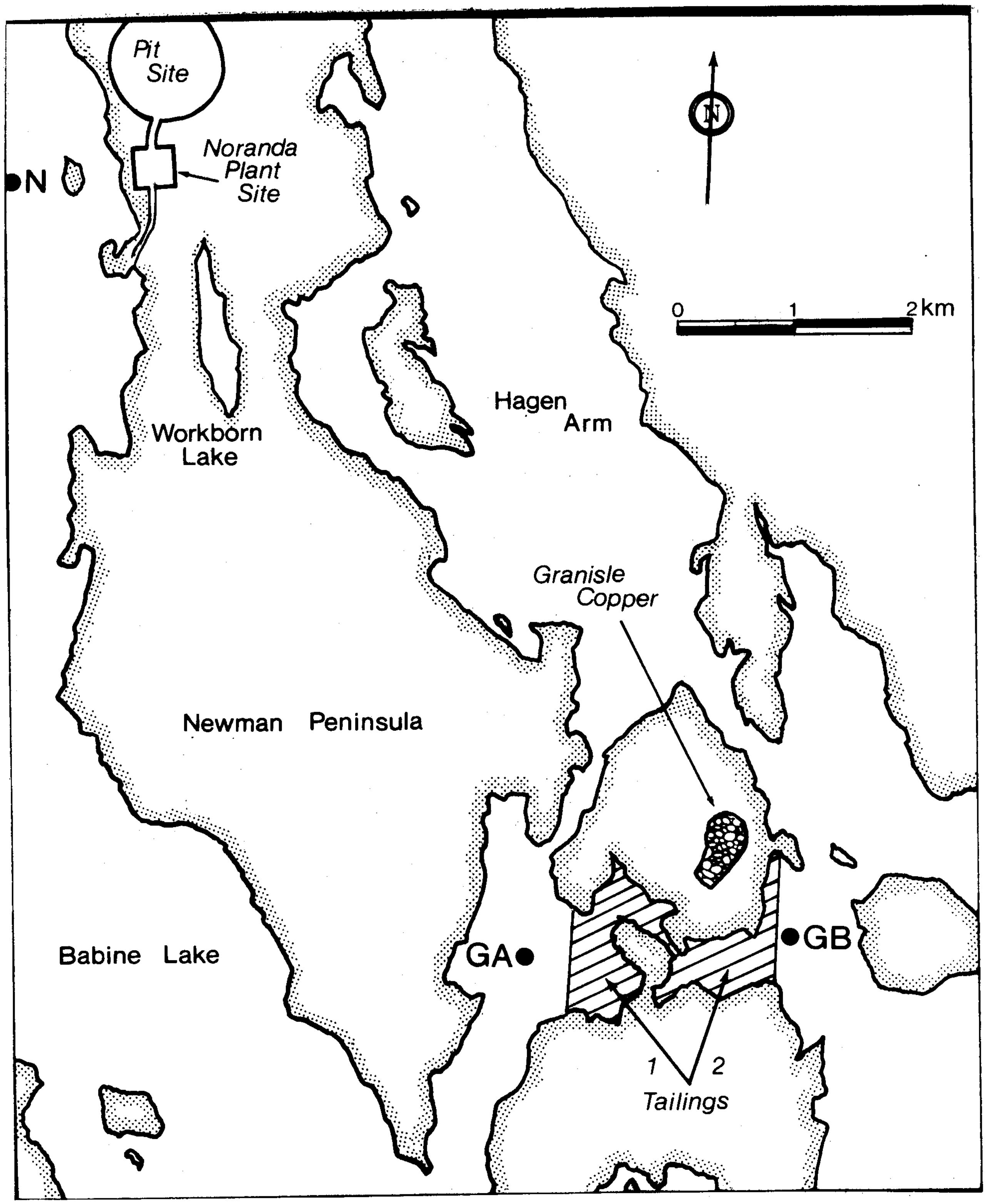

Fig. 2. Map of Hagen Arm, Babine Lake showing detail of mine sites and station locations.

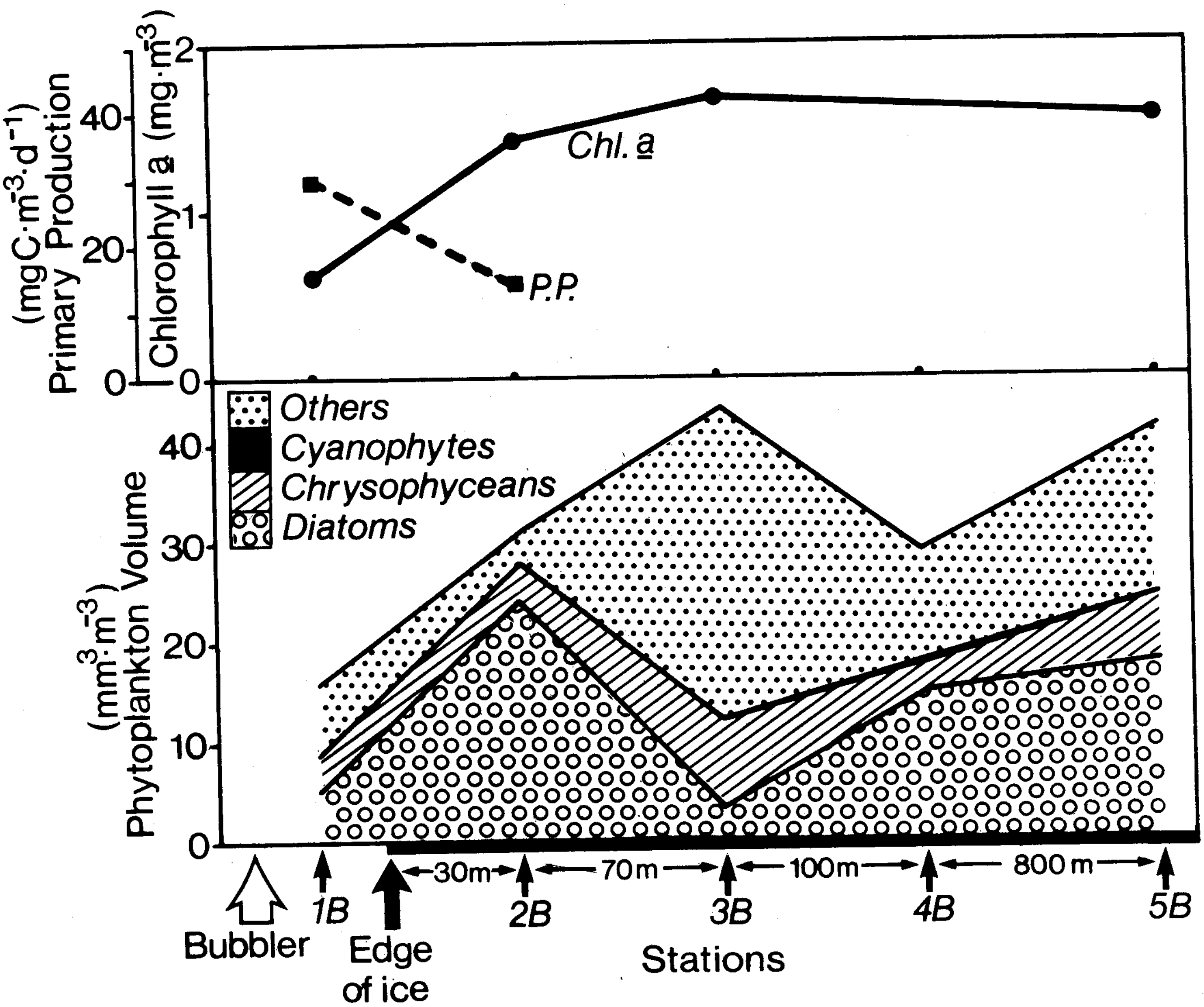

Fig. 3. Variation in chlorophyll, primary production and phytoplankton biomass as a function of distance from bubble line in April, 1977.

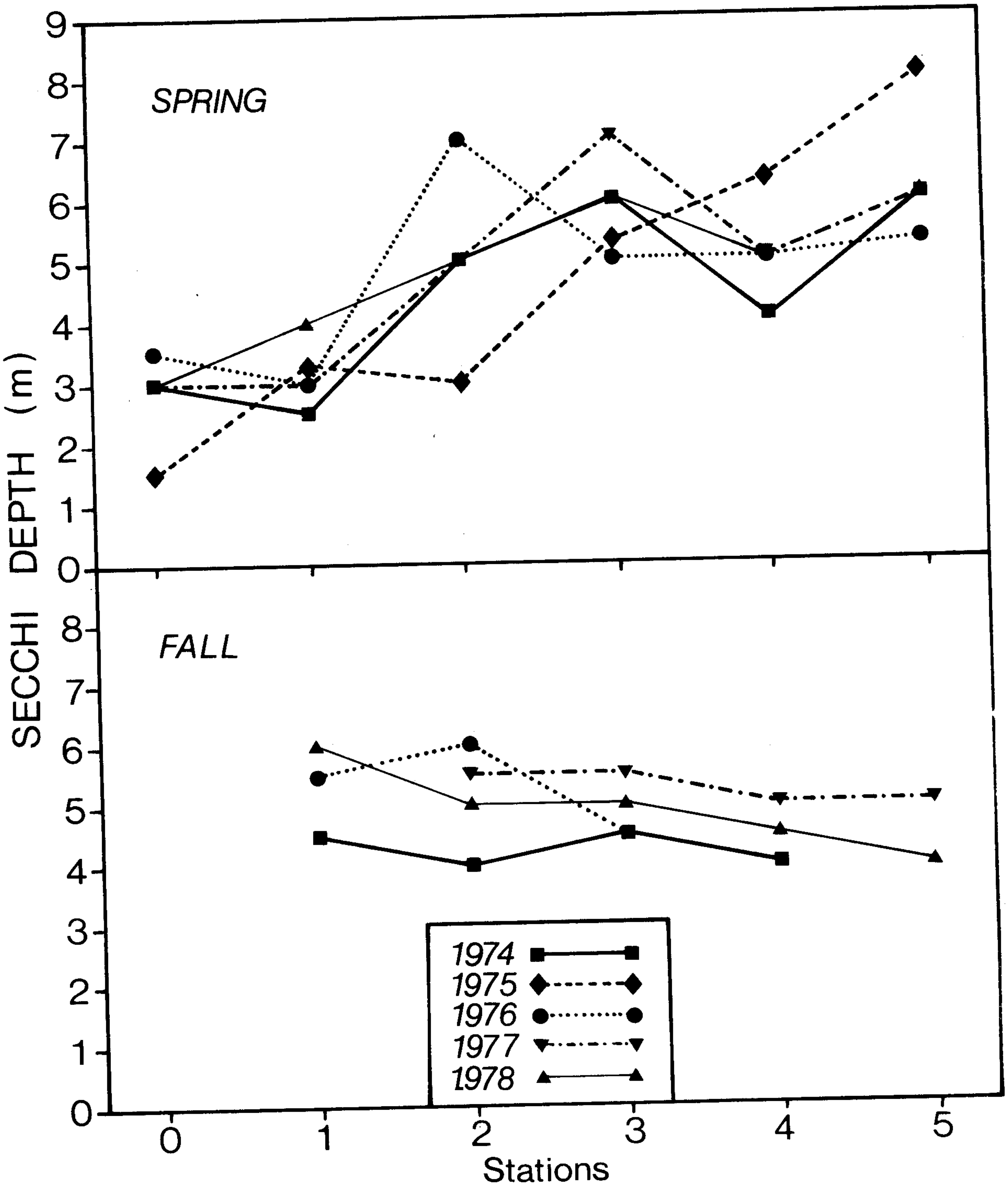

Fig. 4. Longitudinal variation in Secchi values in Babine Lake in spring and fall from 1974 to 1978.

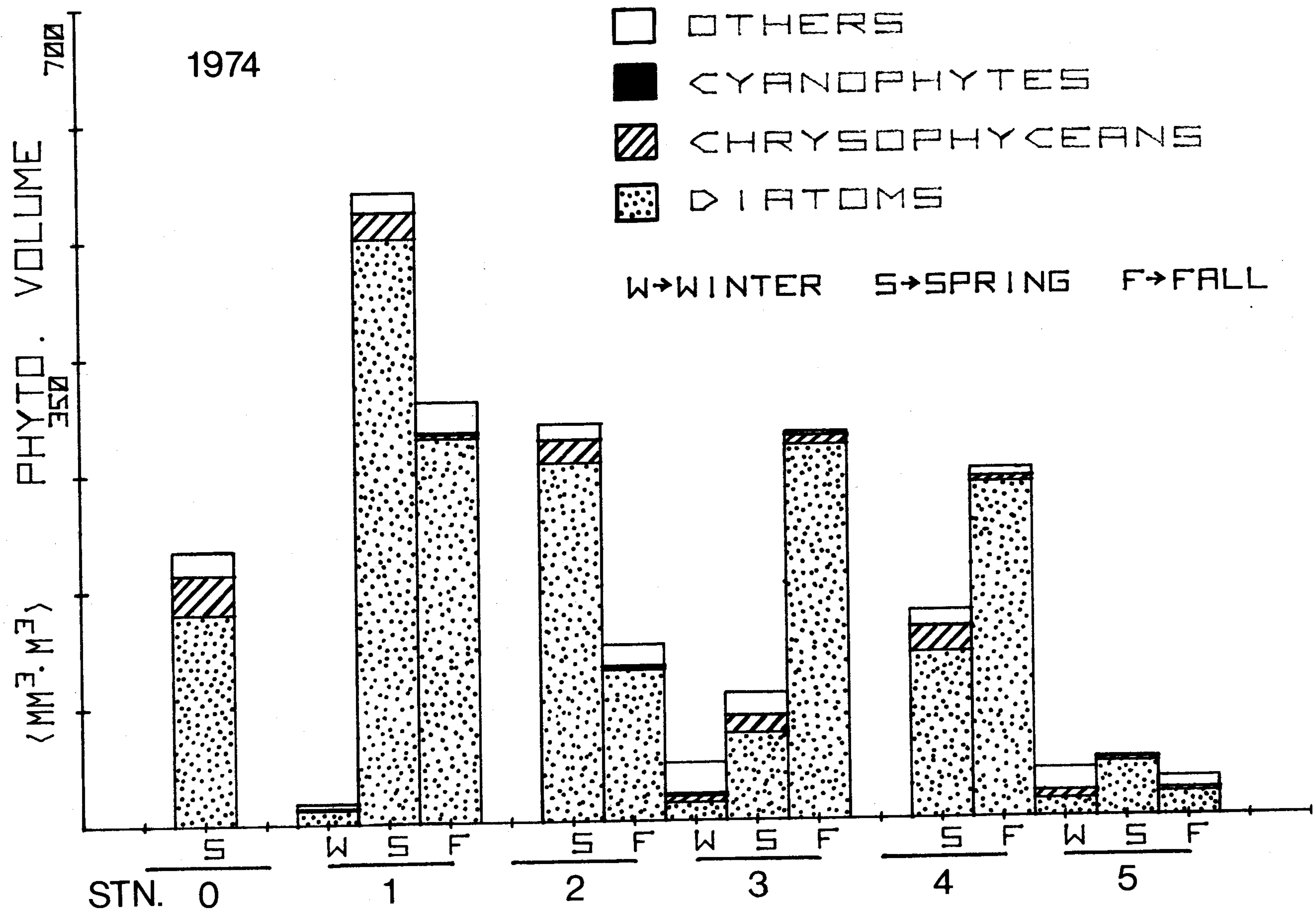

Fig. 5A. Phytoplankton biomass by season in Babine Lake from 1974 to 1978.

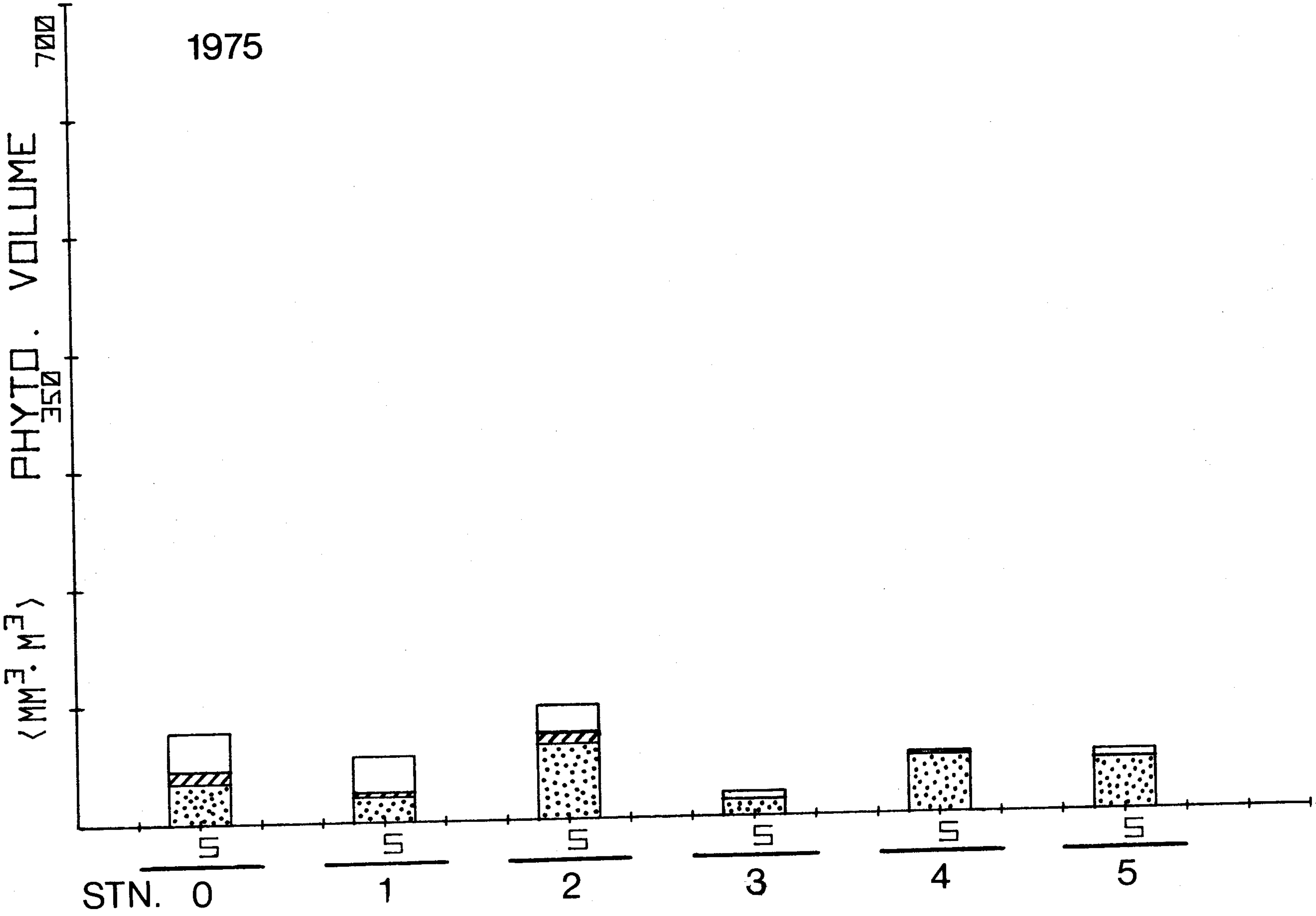

Fig. 5B. Phytoplankton biomass by season in Babine Lake from 1974 to 1978.

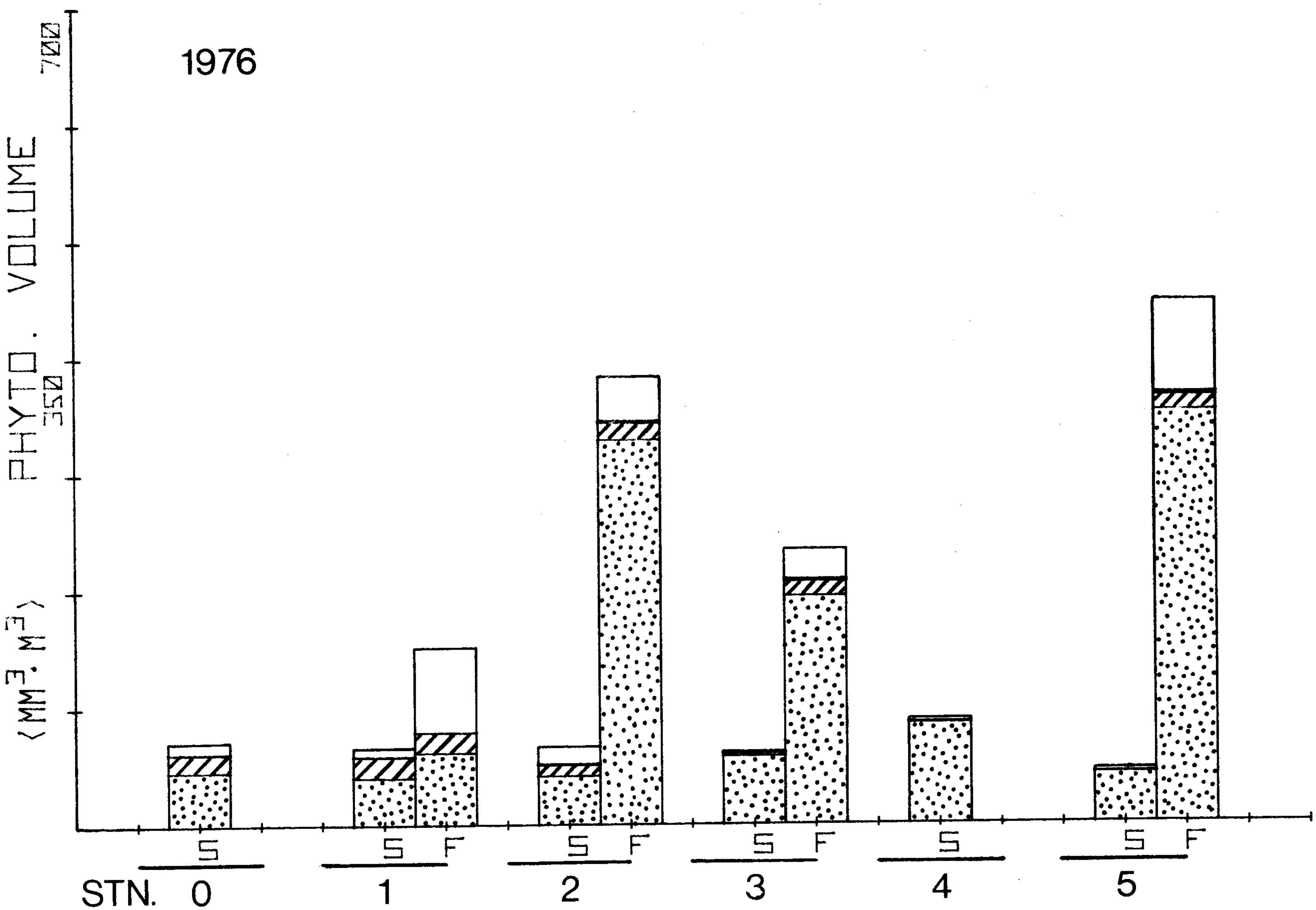

Fig. 5C. Phytoplankton biomass by season in Babine Lake from 1974 to 1978.

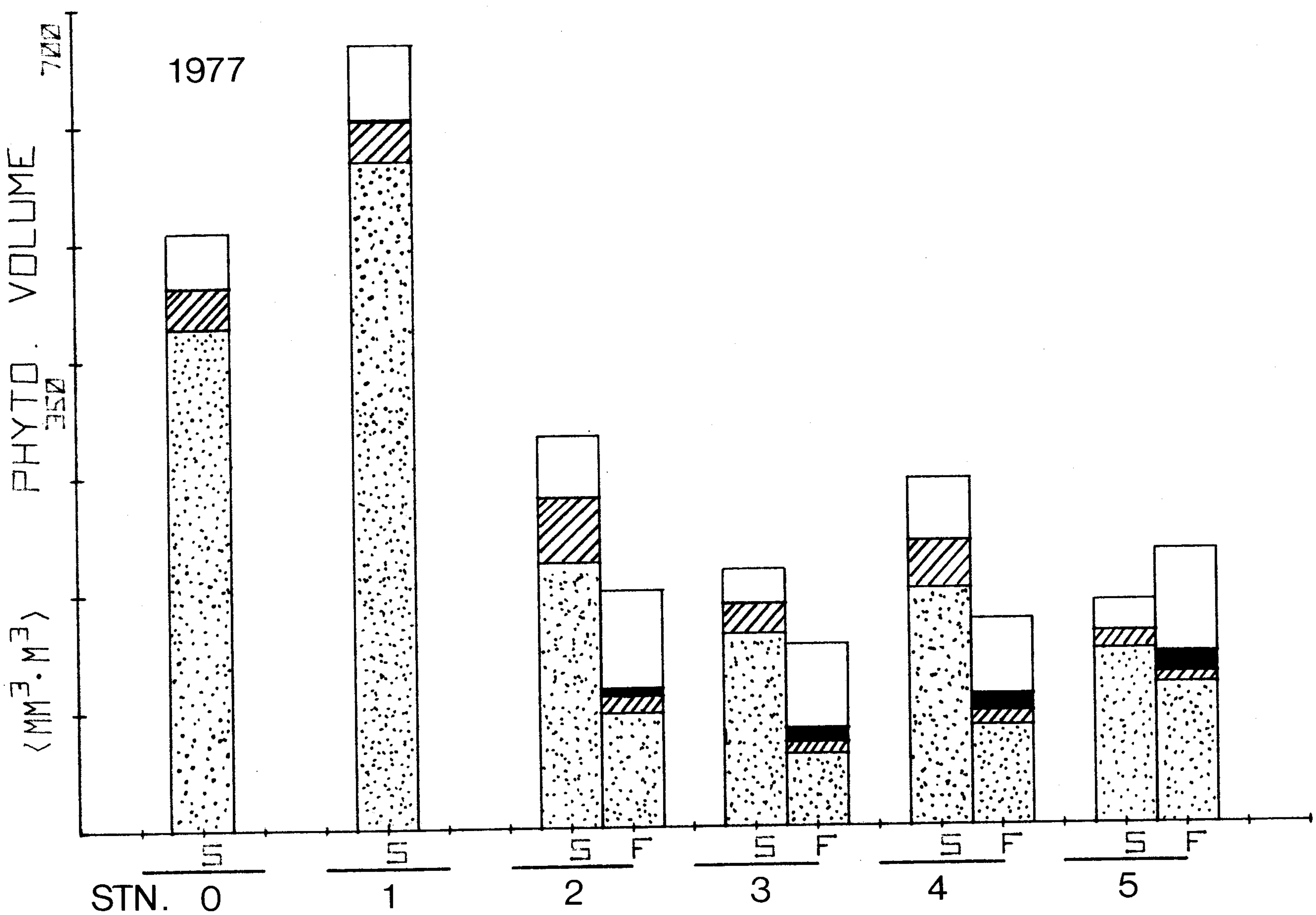

Fig. 5D. Phytoplankton biomass by season in Babine Lake from 1974 to 1978.

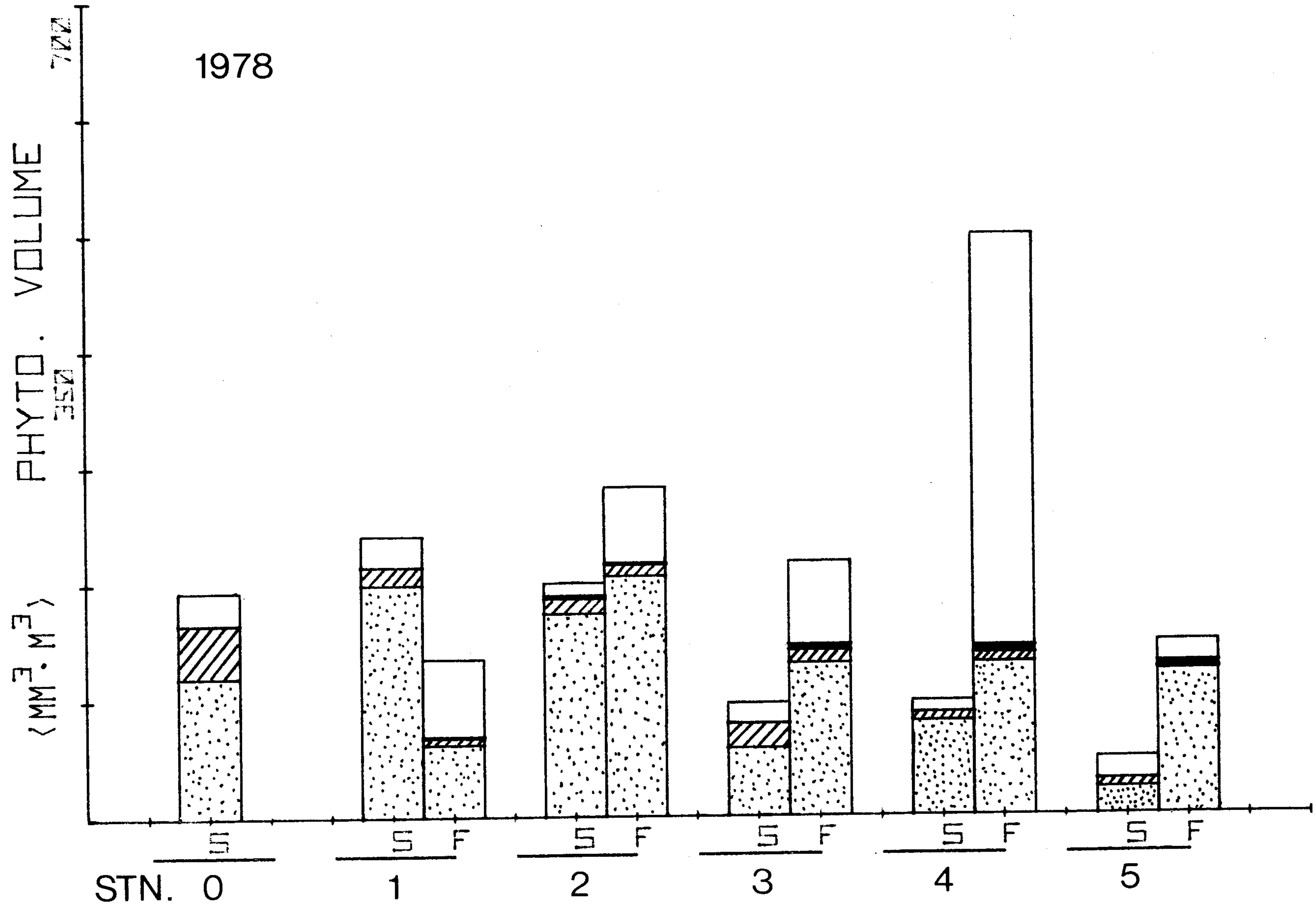

Fig. 5E. Phytoplankton biomass by season in Babine Lake from 1974 to 1978.