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PREIMPOUNDMENT AND IMMEDIATE POST IMPOUNDMENT ADENOSINE TRIPHOSPHATE CONCENTRATIONS IN SOUTHERN INDIAN LAKE: 1975, 1976

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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ABSTRACT

Guildford, S. 1977. Preimpoundment and immediate post impoundment adenosine triphosphate concentrations in Southern Indian Lake: 1975, 1976. Can. Fish. Mar. Serv. Tech. Rep. 749: v + 15 p.

Southern Indian Lake and some nearby Lakes and reservoirs in northern Manitoba are being studied to determine the environmental effects of impoundment of Southern Indian Lake and diversion of the Churchill River. Adenosine triphosphate (ATP) is being used as an indicator of planktonic biomass. The distribution of mean total ATP values through the lake revealed a strong influence by the flow of the Churchill River through the lake. A comparison of values for 1975 and 1976 showed ATP concentrations more than doubled at two stations in South Bay after diversion of the Churchill River through South Bay. Size fractionation of ATP revealed a shift in size distribution of planktonic biomass from 1975-1976. A detailed study of ATP concentrations in Long Bay (7 km^2), a small bay on Southern Indian Lake (2,530 km^2) revealed that spatial variability of ATP was low in Long Bay.

Key words: ATP, annual variations, biomass, limnology, planktonology, variations, reservoirs, seasonal variations, size distribution.

RÉSUMÉ

Guildford, S. 1977. Preimpoundment and immediate post impoundment adenosine triphosphate concentrations in Southern Indian Lake: 1975, 1976. Can. Fish. Mar. Serv. Tech. Rep. 749: v + 15 p.

Nous étudions le Southern Indian Lake et les lacs et réservoirs voisins, dans le nord du Manitoba, afin d'y déterminer les incidences environnementales de l'endiguement de ce lac et de la dérivation de la Churchill River. L'adénosine triphosphate (ATP) est utilisé comme indicateur de la biomasse planctonique. La distribution dans le lac des valeurs totales moyennes d'ATP a démontré la profunde influence qu'exerce la Churchill River en traversant le lac. Une comparaison des valeurs de 1975 et de 1976 a démontré que les concentrations d'ATP ont plus que doublé, aux deux stations de la South Bay, depuis la dérivation de la Churchill river par cette baie. La séparation de la biomasse a révelé un changement dans la répartition des tailles chez le plancton, de 1975 à 1976. Une étude détaillée des concentrations d'ATP dans la Long Bay (7 km^2), petite baie du Southern Indian Lake (2530 km^2), y a révélé la faible variabilité spatiale de l'ATP.

Mots-clés: ATP, variations annuelles, biomasse, limnologie, planctonologie, variations, réservoirs, variations saisonnières, répartition des tailles.

INTRODUCTION

To augment installed hydro-electric capacity on the Nelson River, Manitoba Hydro has raised the water level of Southern Indian Lake and diverted the flow of the Churchill River out of Southern Indian Lake via a man-made channel into the Nelson River drainage system (Hecky and Ayles 1974). The environmental consequences of this development were predicted in the Canada-Manitoba Lake Winnipeg, Churchill and Nelson Rivers Study (Hecky and Ayles 1974) and are presently being studied by a research team from the Freshwater Institute in order to assess and improve the predictive capability of the Department of Fisheries and Environment in relation to major hydroelectric developments across Canada.

This report summarizes adenosine triphosphate (ATP) concentrations measured in Southern Indian Lake and some nearby lakes and reservoirs during 1975 and 1976. The intent of this report is to present ATP concentration as an indicator of plankton biomass before and immediately after impoundment of Southern Indian Lake and to facilitate future comparisons with post impoundment ATP concentrations.

Adenosine triphosphate was chosen to monitor changes in planktonic biomass because it is a rapid and reasonably reliable method for estimating biomass (Holm-Hansen and Booth 1966; Paerl et al. 1976). Rudd and Hamilton (1973) demonstrated how the size distribution of planktonic organisms can be obtained by separating suspended material into size classes prior to analysis. This approach to size fractionation was used to gain more information on the composition of the planktonic community.

STUDY AREA

Figure 1 shows the study area. Most of the sampling stations are on Southern Indian Lake which is located in northern Manitoba, Canada (latitude 56°45' to 57°40' N and longitude 98°10' to 99°30' W). It has an area of approximately 2,530 km^2 and a mean depth of 12 m after impoundment (Cleugh et al. 1974). Because of the lake's vast size, stations sampled must necessarily be assumed to represent large regions. In 1976 there was an average of one station for every 280 km^2 of water surface on Southern Indian Lake. In order to study the effects of impoundment on a smaller scale scientists at the Freshwater Institute began in May, 1976 to monitor intensively biological, chemical and hydrological parameters at Long Bay, a relatively isolated bay on Southern Indian Lake (see Fig. 1). In Long Bay (during 1976) there was one station for every 1.2 km^2 of water surface and stations were sampled once a week while the other stations in the study area were sampled every two weeks. The sampling program in Long Bay provides detailed information regarding spatial and temporal variation in ATP concentrations on a relatively fine scale.

DIVERSION AND IMPOUNDMENT

Prior to diversion the Churchill River contributed over 90% of all water entering Southern Indian Lake (Hecky and Ayles 1974). Figure 1 is a schematic representation of the pre-diversion and post-diversion flow pattern of the Churchill River through Southern Indian Lake. The pre-diversion flow pattern is based on zooplankton distribution studies (Patalas 1975) and primary productivity studies (Hecky 1975). These studies show that the biological characteristics of different water masses within the lake are strongly influenced by their proximity to the main plume of the Churchill River (Fig. 1).

The following is a brief summary of the sequence of impoundment and diversion. Figure 1 (after diversion) gives the location of dam and channel sites.

1. 1973. A coffer dam was constructed south of Notigi Lake cutting off the flow of the Rat River which flows out of the western basin of Notigi Lake. By 1976 the water level at Notigi Lake had been raised 18 m. During 1973-1975 a control structure was built behind the coffer dam at Notigi.

2. 1974-1975. A coffer dam on the south channel outflow at Missi Falls allowed construction of a control dam behind it. The coffer dam was removed upon completion of the control dam and the North channel was then blocked off by a coffer dam. Thus the outflow of the Churchill River from Southern Indian Lake was regulated. During this construction (1974, 1975) water levels on Southern Indian Lake were higher than they would have been without construction activity and exceeded the historical maximum levels by 0.2 m and 0.4 m respectively for 6 month periods.

3. June 1976. The man-made channel connecting South Bay of Southern Indian Lake to Isset Lake, designed to carry a flow of 850 m^3/s, was completed. The control dam at Notigi began allowing the Rat River to flow through Notigi Lake for the first time since 1973.

4. July - August 1976. The control dam at Missi Falls began decreasing the outflow of the Churchill River and water began to flow out the diversion channel.

5. August - September 1976. The water level in Southern Indian Lake exceeded historic maximum levels and outflow at the South Bay Channel increased to 280 m^3/s. Outflow at South Bay remained at 280 m^3/s to 340 m^3/s during the winter of 1976/77.

On the long term, an average of 85% of the Churchill River flow will be diverted from Southern Indian Lake via South Bay. As of October 1976, a flow of about 280 m^3/s of the Churchill River was passing through the South Bay - Isset Lake Channel while the remaining discharge was flowing out of Southern Indian Lake at Missi Falls. Figure 1 (after diversion) is intended to show the probable water mass distribution when the flow through the South Bay - Isset Lake channel reaches 850 m^3/s.

The influence of the Churchill River on those areas west of the point of diversion (that point where the Churchill River flow is diverted from the main part of Southern Indian Lake into South Bay) will probably be approximately the same before and after diversion. This area includes Long Bay. It is expected that the influence of the Churchill River in the part of the Lake north and east of the point of diversion will be much reduced as the flow of the Churchill River to this part of the Lake will be approximately 10% of its pre-diversion flow.

MATERIALS AND METHODS

Samples were usually taken in the morning. During June and July 1975 water samples were taken at 2 m depth with a Van Dorn sampler and siphoned into two-litre brown polypropylene bottles which had been previously washed with dilute HCl. From August 1975 until October 1976 integrated samples were taken from the surface to the depth of 1% light penetration using an integrating sampler similar to that described by Fee (1976).

The change in samplers was made when blue-green algae appeared in the surface water at some stations. Prior to this the Van Dorn was adequate for sampling the well mixed water column.

The samples were maintained in the dark as close as possible to sampling temperature until analysis. During 1975 samples were extracted within eight hours. In 1976 extraction took place within twenty-four hours of sampling.

The entire water sample was passed through a 200 μm aperture nitex mesh to remove larger zooplankton. For the 1975 field season replicate 250 ml subsamples were passed through 48 μm aperture nitex mesh discs (47 mm in diameter) replicate 250 ml subsamples were passed through 10 μm aperture nitex mesh discs (47 mm in diameter) and replicate 50 ml subsamples were passed through 47 mm diameter 0.22 μm pore size Millipore filters. From each fractionation plankton retained by the filter was extracted for ATP. The amounts of ATP in the 0.22-10 μm and 10-48 μm size fraction were obtained by subtraction. During 1976 the procedure was modified so that replicate 1,000 ml subsamples were passed through 48 μm aperture nytex mesh filters, and the filtrates were passed through replicate 10 μm aperture nytex mesh filters. Fifty ml subsamples of the 10 μm filtrates were passed through 0.22 μm Millipore filters. By this procedure the amounts of ATP in each size fraction could be estimated directly, and the total ATP in the water sample was assumed to be the sum of the amounts on the various sized filters. A vacuum of about 80 mm Hg was applied when filtering through the 0.22 μm Millipore filters. The 10 and 48 μm nytex mesh filters did not usually require a vacuum and the flow rate was determined by controlling the escape of air from the filtration flask.

ATP was extracted and measured as in Rudd and Hamilton (1973). Briefly, ATP was extracted from the filters, immediately after filtering, by boiling in Tris buffer (0.05 M) for 5 minutes. The extract volume was measured and frozen for up to 4 months at which time the extracts were thawed and analyzed. ATP was estimated by measuring the amount of light produced by the luciferin-luciferase reaction in the presence of ATP. A Packard model 2425 scintillation counter was used to monitor the light reaction. Standards ranging in concentration from 1.2×10^{-4} μg ATP/0.2 ml Tris to 4.8×10^{-3} μg ATP/0.2 ml Tris were made by diluting a stock solution of 12 mg ATP/L Tris. Luciferin-Luciferase firefly enzyme extract and ATP for standards were obtained from Sigma Chemical Co.

RESULTS AND DISCUSSION

TOTAL ATP CONCENTRATIONS

The replication of samples was poorer than reported from the literature (Paerl and Williams 1976). The relative standard deviation between replicates was as high as 25%.

Individual ATP concentrations and mean ATP concentrations for 1975 and 1976 are given in Fig. 2 and Table I, respectively. Patterns of mean total ATP (concentration) during 1975 and 1976 are shown in Fig. 3. The pattern in 1975 is similar to the pre-diversion water mass distribution shown in Fig. 1. The lowest mean total ATP concentration was at station 6G in South Bay which was isolated from the pre-diversion Churchill River plume and was also the most turbid station in 1975 (Hecky, personal communication). Stations 6E, 6C, 1C and 2G had the next lowest ATP concentrations and in 1975 they too were isolated from the Churchill River influence. Cousins Lake, east of Southern Indian Lake, had low ATP concentrations similar to the isolated bay stations on Southern Indian Lake.

Stations located directly in the plume of the Churchill River (1A, 2E and 4B) and Sandhill Bay (2H) had ATP concentrations greater than observed at the isolated bay stations. Also in this mid range category was Wood Lake. Wood Lake is east of Missi Falls and drains into the Churchill River. The highest ATP concentrations observed on Southern Indian Lake in 1975 were at stations 2A, 4D, and 5B. Figure 1 shows these areas to be moderately influenced by the Churchill River. All three stations are more transparent to light relative to other Southern Indian Lake stations influenced by the Churchill River (Hecky, personal communication) and this may account in part for the high levels of ATP. Partridge Breast Lake is immediately below the outflow of the Churchill River at Missi Falls. ATP concentrations were as high as stations 4D and 5B on Southern Indian Lake.

Stations at Notigi Reservoir 100 km south of Southern Indian Lake had the highest ATP concentrations observed in the study area in 1975. Increasing water levels in both basins since closing off the Rat River below Notigi in 1973 probably caused increased nutrient loading from flooded shorelines. The west basin had mean total ATP slightly higher than 5B in the north end of Southern Indian Lake while the east basin at Notigi had mean total ATP almost 2 times as high as the highest values observed on Southern Indian Lake.

ATP concentrations observed in 1975 in Southern Indian Lake are apparently related to the Churchill River plume. If this relationship is true, then diversion of the Churchill River should effect the pattern of ATP concentrations directly. By the end of 1976 only partial diversion was occurring. Figure 3 (1976) shows mean total ATP concentration patterns for 1976. It should be noted that fewer stations were sampled in 1976 than 1975, and stations were sampled more frequently in 1976 (Fig. 2). However in Fig. 3 (1976) and Table 2 only those values obtained from samples taken at corresponding times of year in 1975 were used in calculating the mean total ATP concentrations. For the purpose of comparing mean total ATP in 1976 to that in 1975 a "significant" change is considered to be an increase or decrease greater than 20% of the 1975 mean ATP value.

Figure 3 (1976) shows that once again the pattern of the Churchill River plume dominates the lake with the only significant change occurring in South Bay where the mean total ATP at stations 6C and 6G increased by 84 and 113 % respectively from 1975 to 1976 (see Table 2). These increases probably reflect the 280 m^3/s of Churchill River water and accompanying nutrients, being diverted through South Bay commencing August 1976. There were no significant changes in mean total ATP at other Southern Indian Lake stations monitored in 1976. This is not surprising as the diversion did not reach 280 m^3/s until September 1976 and even then the discharge at Missi Falls was still 620 m^3/s.

The only other significant change in mean total ATP concentration occurred at the Notigi east and west stations. Notigi west went ip 47% and Notigi east went down by 30% over the whole summer. From 1973 to 1975 the water level at Notigi Lake was continually rising. In 1975 ATP concentrations as well as chlorophyll concentrations and primary productivity rates were higher at Notigi Lake than at any other stations in the study area (Hecky, personal communication). These high values might be attributed to high nutrient loading from the flooded shorelines, a phenomenon which has been observed in other reservoirs (Lowe-McConnell, 1973). In 1976 the full supply level for the Notigi reservoir was achieved and the water level was stabilized. Newly flooded shorelines are no longer being added to Notigi, and nutrient loading from this source may be in decline. The 30% decrease in mean total ATP concentration observed at Notigi East Basin is a possible result of decreased nutrient supply. At Notigi west there was a 47% increase in mean total ATP concentration. Although water level stabilization occurred in both basins, the west basin began receiving nutrient rich diversion waters from newly flooded Southern Indian Lake and Upper Notigi reservoir when the control dam below Notigi was opened.

It was not until August and September of 1976 that water levels in Southern Indian Lake exceeded historical maximum levels and the outflow at South Bay Channel reached 280 m^3/s. Therefore one might not expect to see any major effects of impoundment and/or diversion until then. The preceding discussion has compared 1975-1976 mean total ATP concentrations calculated from full seasonal (June-September) values. A comparison of only August-September values from each year should demonstrate more clearly changes in ATP concentration which might be attributable to impoundment and diversion. Table 2 is a comparison of mean total ATP concentrations calculated using June-September values and mean total ATP concentration calculated using August-September values only. The values for Wood Lake, which is uninfluenced by impoundment and diversion are essentially unchanged from 1975 to 1976 during the August-September months. The increase in mean total ATP at station 6C, which lies directly on the South Bay plume of the Churchill River after diversion, is emphasized by looking at only post diversion values. The increase observed at station 6G in South Bay when comparing August-September values only is not as great, however the increase in total ATP from 1975 to 1976 is still large (79%).

August-September values for stations 1A and 2E indicate significant increases in mean total ATP which were not apparent in June-September comparisons. Both 1A and 2E are located on the flow of the Churchill River plume before and after diversion. The 36% increase in mean total ATP during August-September 1976 may have been a result of the increased water levels. However, similar increases were not observed at 4B, 5B and 6E where water levels were simultaneously affected. When comparing 1975-1976 August-September ATP concentrations the only decrease (16%) occurred in the north end of the lake at stations 4B and 5B and in Notigi East.

SIZE FRACTIONATION

Figure 2 shows complete seasonal size distribution data for each station. The mean ATP concentration for each size fraction for each station was calculated and is listed in Table 1. The mean ATP in each size fraction was expressed as a percent of the mean total ATP calculated for that station.

In order to compare ATP size distribution data from 1975-1976 it was necessary to recalculate mean ATP for each size fraction using data from corresponding times in the year. These values are expressed as a percent of mean total ATP for that station in Table 2.

In 1975 the 10-200 μm size fraction was an important part of the total ATP measured. The 10-200 μm size class contributed at least 40% of total ATP at all stations (except Wood Lake where it contributed 36%) and up to as much as 81% at Station 6G in South Bay. In 1976 the 1975 ATP size distribution was maintained only at Wood Lake, which is uninfluenced by impoundment and diversion. At all other stations in the study area there was a decrease in the proportion of total ATP in the 10-200 μm size fraction. By far the most dramatic example of this shift in size fractions was observed at the two Notigi stations. In 1975 the ATP consisted of 59% and 73% large size fraction (10-200 μm) at Notigi west and east, respectively. By 1976 the 10-200 μm size class made up 19% of total ATP at Notigi west and 28% of total ATP at Notigi east. The plots of seasonal ATP concentrations in Fig. 2 show this shift in size distribution most clearly.

A few 1975 and 1976 Notigi East and West samples have been analyzed for phytoplankton. These results show: (1) On equivalent dates the biomass in 1976 is lower than the biomass in 1975. In order to substantiate this trend more phytoplankton samples need to be counted. (2) The dominant algae both years at Notigi was *Aphanizomenon flos-aquae*. In 1975 the *Aphanizomenon* occurred in clumps and in 1976 it occurred in strands. The change in size distribution occurring in the 1975-1976 Notigi ATP samples may have been related to the change from clumps to strands in the *Aphanizomenon* aggregations. It is also possible that the algae were in a poorer physiological state in 1976 than 1975 and that holding the Notigi ATP samples for 24 hours before extraction caused the large algae to die and bacteria to grow. However, an experiment conducted in 1975 using a Notigi sample showed no change in total ATP after holding for 24 hours.

LONG BAY

It is hoped that the Long Bay study will reveal details about impoundment on a much finer scale than the much larger and more complex Southern Indian Lake Study. It is not expected that Long Bay will reflect diversion of the Churchill River because the point of diversion is located well down stream from Long Bay (see Fig. 3). Figure 3 shows the location of the six stations in Long Bay and Fig. 2 gives full seasonal and size fraction data for 1976. The mean ATP concentrations for each station are listed in Table 1.

The pattern of ATP concentration in Long Bay during June-October 1976 is shown in Fig. 3 and is based on the mean seasonal total ATP concentration for each station. The ATP concentrations are low to moderate relative to the ATP concentrations observed at the other stations in the Southern Indian Lake Study. The areas of highest ATP concentration in Long Bay (Long Bay south and Long Bay Small Bay) are also the shallowest stations in Long Bay and are more transparent to light than the other Long Bay stations (Hecky, personal communication).

Because 1976 is the first full season when data was collected in Long Bay it is not possible to determine whether there are any immediate effects of impoundment. The seasonal plots in Fig. 2 do not show any obvious differences in ATP concentrations during August and September (when impoundment and diversion came into effect) compared to the June and July ATP concentrations.

The 1976 Long Bay data is useful in determining the importance of spatial and temporal variations in ATP concentration within areas similar to Long Bay. From Fig. 3 and means in Table 1 it can be seen that spatial variation in Long Bay is not great. If Long Bay Centre represented the entire bay the mean total ATP concentration would be 0.5 mg m^{-3} a value 13% lower than the average of the mean total ATP concentrations for all six stations which is 0.40 mg ATP m^{-3}. Long Bay north and south were sampled weekly. The mean of biweekly total ATP concentrations for these two stations is essentially the same as the mean of weekly ATP concentrations. It would appear that the number of stations sampled in Long Bay could be decreased and the length of time between sampling periods increased without significantly under- or overestimating the mean total ATP concentrations.

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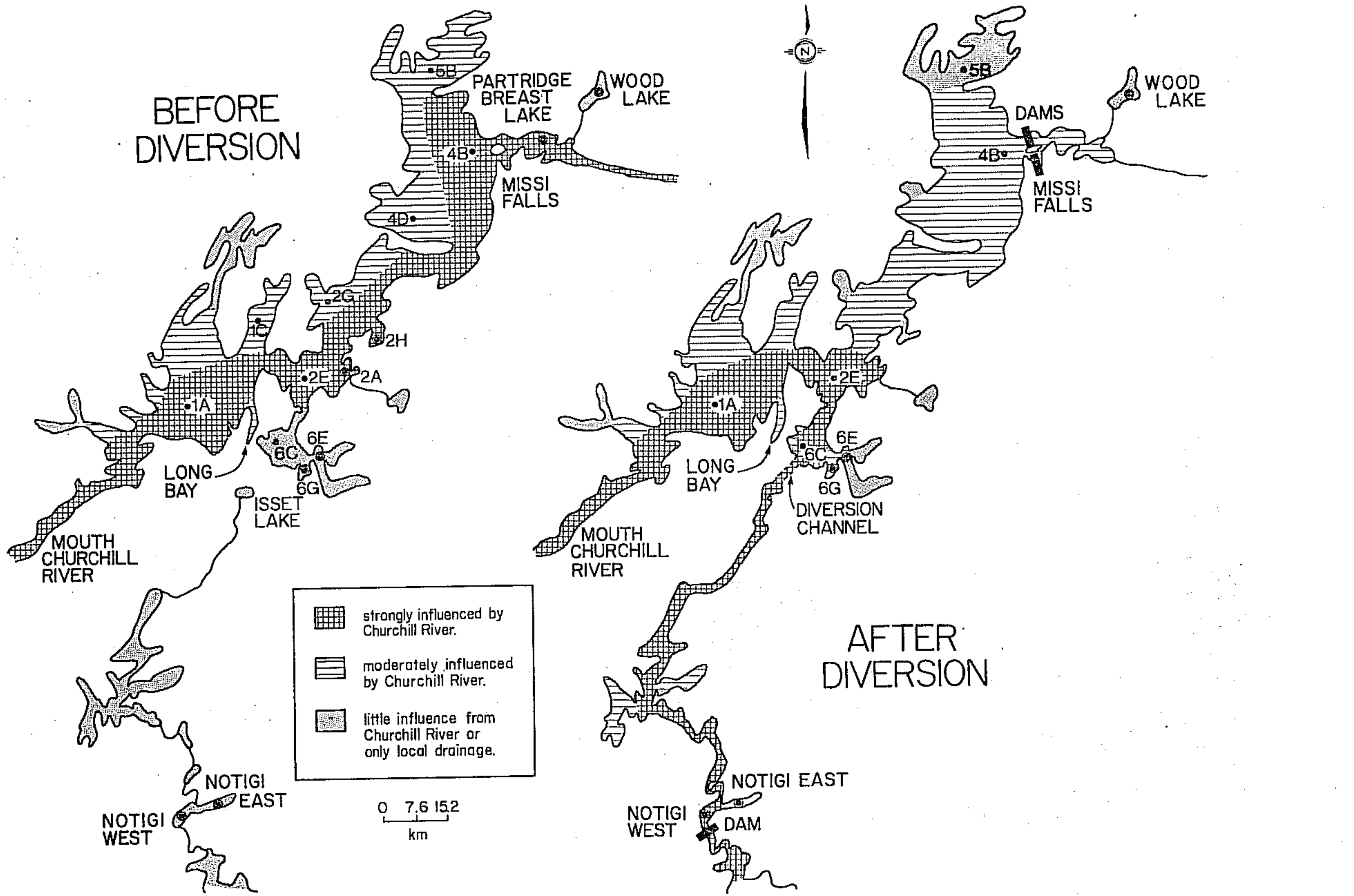
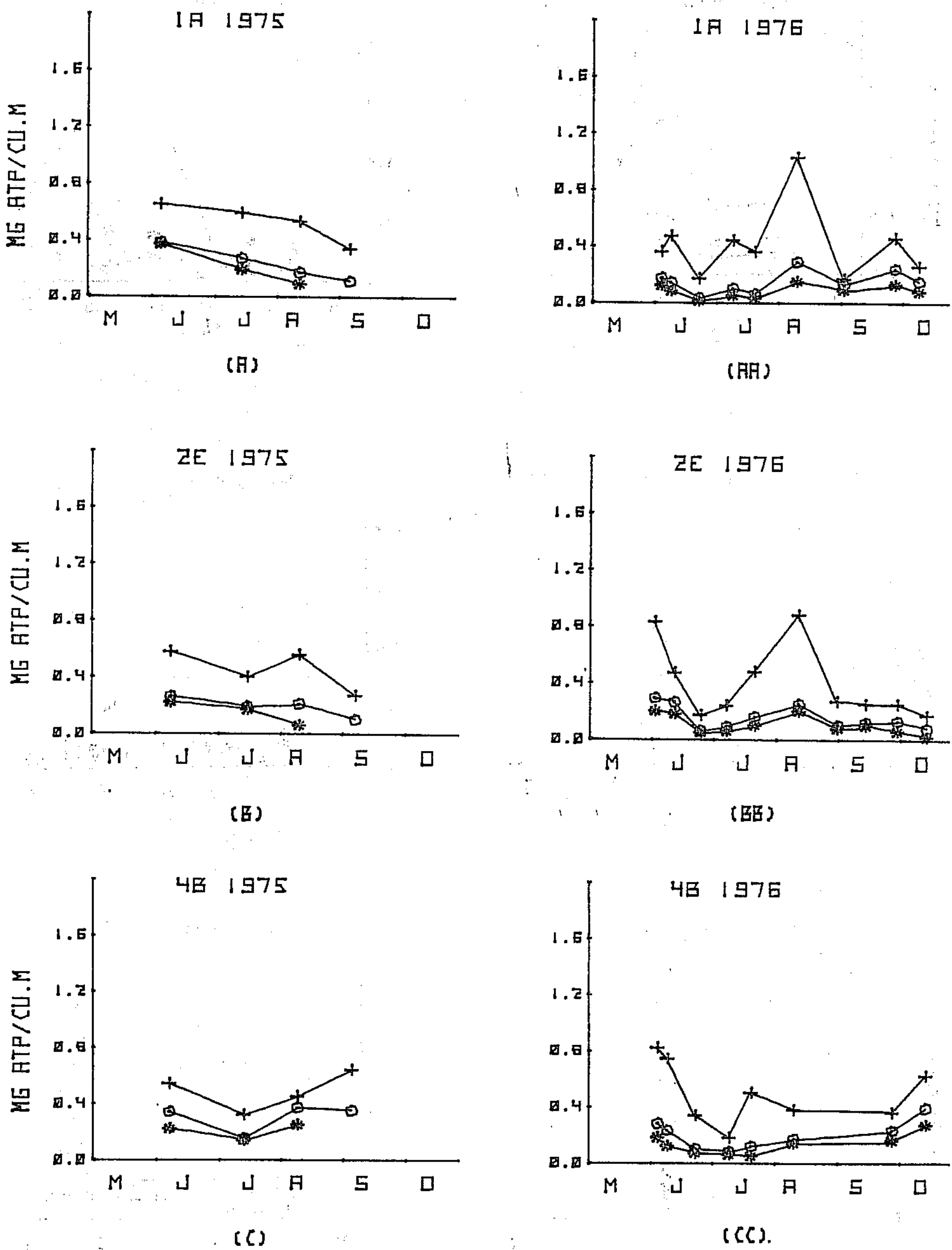
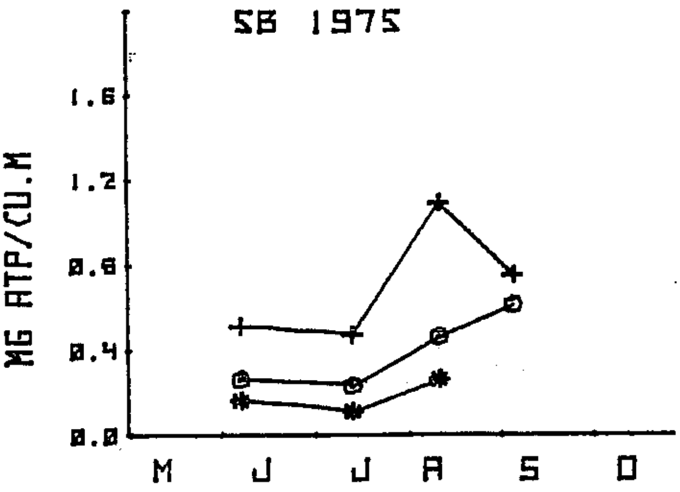


Fig. 1. Schematic maps indicating the influence of the Churchill River in the Southern Indian Lake study area. The observed water mass distribution before diversion and the inferred distribution after diversion are represented. Flooded areas after diversion are not depicted.

Fig. 2 (A-X). ATP (mg m^{-3}) concentrations are plotted for the sampling season May to October. + denotes total ATP or the 0.22-200 μm size fraction, O: 10-200 μm, *: 48-200 μm.

A	1A 1975
AA	1A 1976
B	2E 1975
BB	2E 1976
C	4B 1975
CC	4B 1976
D	5B 1975
DD	5B 1976
E	6C 1975
EE	6C 1976
F	6E 1975
FF	6E 1976
G	6G 1975
GG	6G 1976
H	NOTIGI EAST 1975
HH	NOTIGI EAST 1976
I	NOTIGI WEST 1975
II	NOTIGI WEST 1976
J	WOOD LAKE 1975
JJ	WOOD LAKE 1976
K	PARTRIDGE BREAST LAKE 1975
L	COUSIN'S LAKE 1975
M	1C 1975
N	2A 1975
O	2B 1975
P	2G 1975
Q	2H 1975
R	4D 1975
S	LONG BAY SOUTH 1976
T	LONG BAY CENTRE 1976
U	LONG BAY SMALLBAY 1976
V	LONG BAY NORTH 1976
W	LONG BAY CHANNEL 1976
X	LONG BAY OUTSIDE 1976


1A 1975
1A 1976
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O
(A)
(AA)
2E 1975
2E 1976
MG ATP/CU.M
(B)
(BB)
4B 1975
4B 1976
MG ATP/CU.M
(C)
(CC).


5B 1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
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M
J
J
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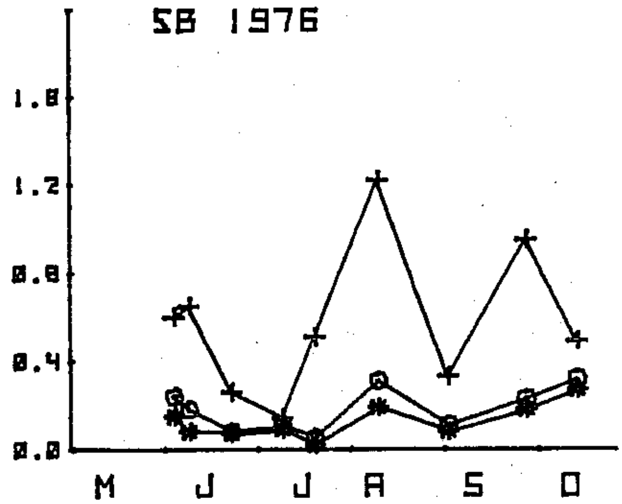
(D)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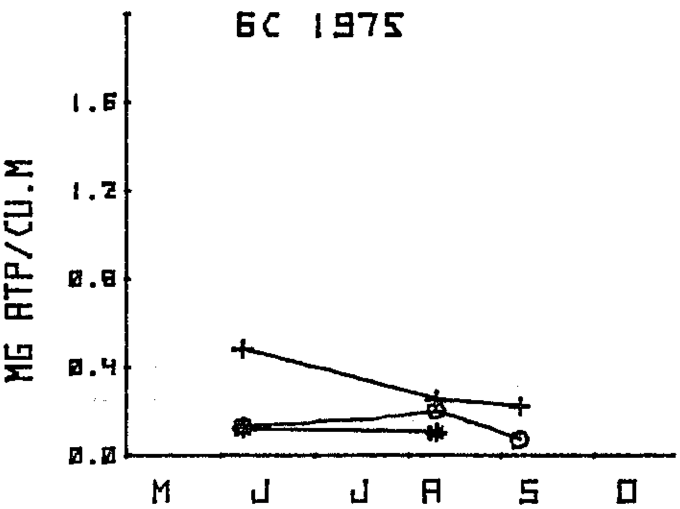
6C 1975
MG ATP/CU.M
1.6
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0.8
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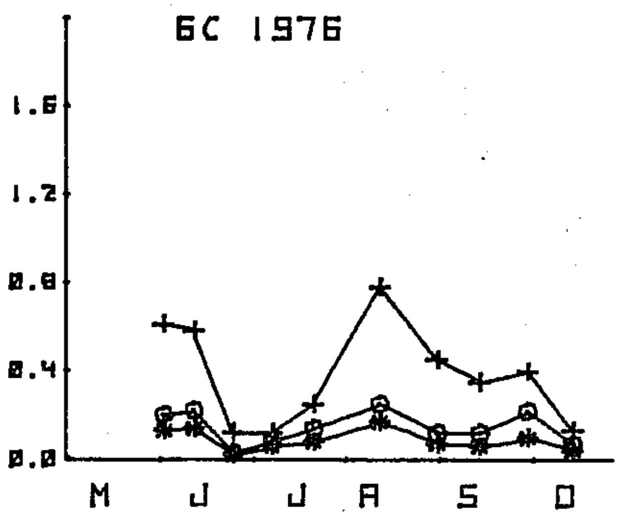
(E)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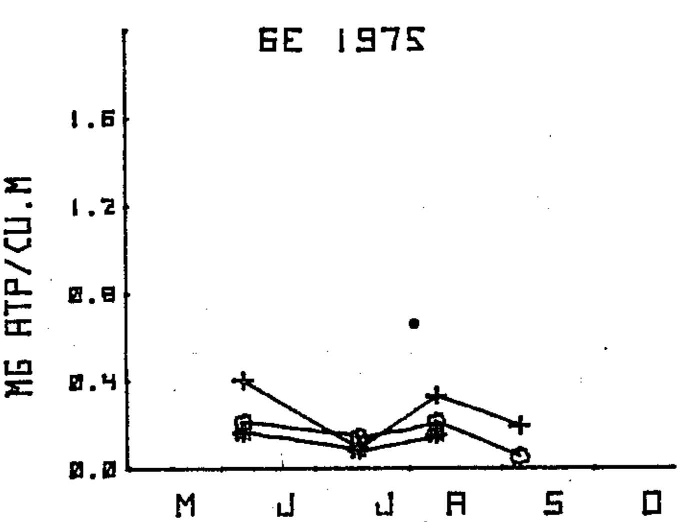
6E 1975
MG ATP/CU.M
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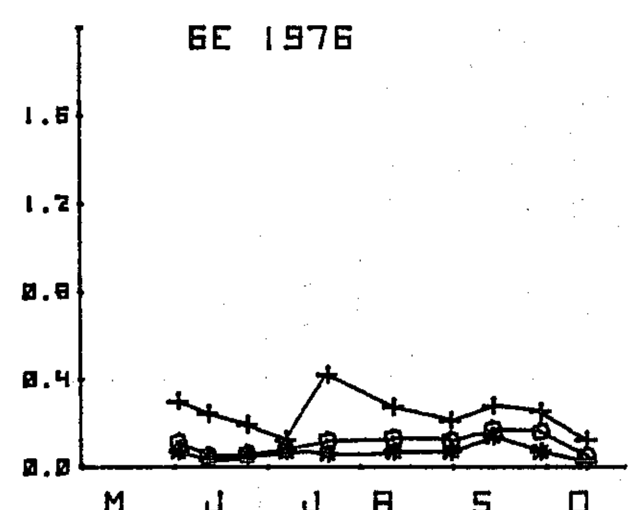
(F)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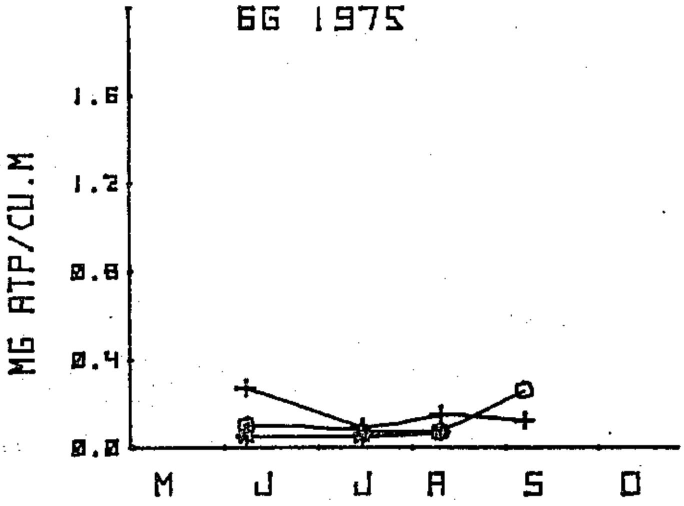
GG 1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
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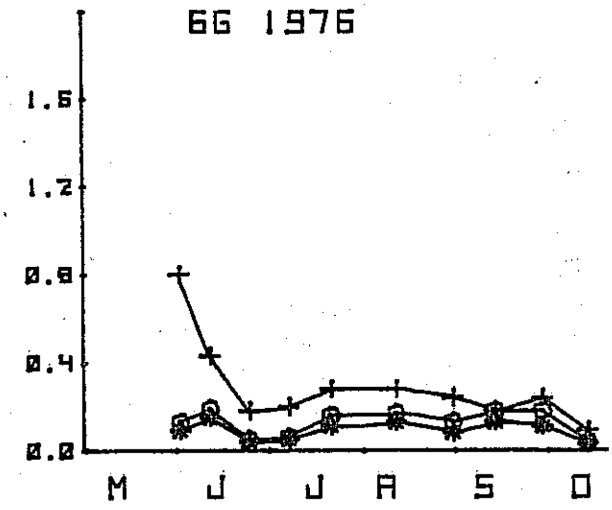
M J J A S O

(G)


GG 1976
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1.2
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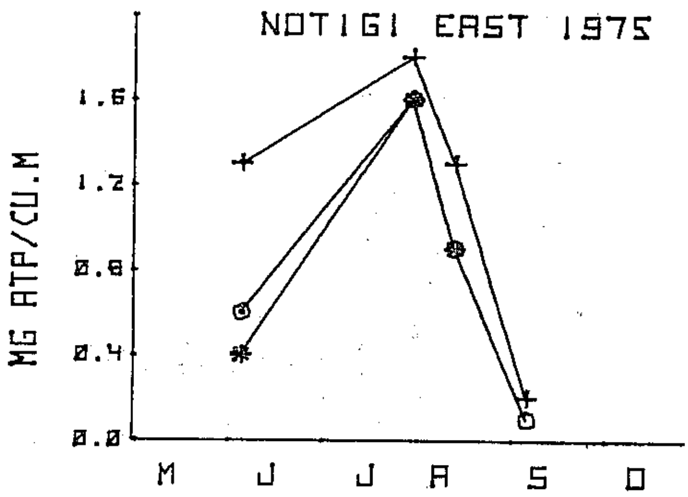
M J J A S O

(GG)


NOTIGI EAST 1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
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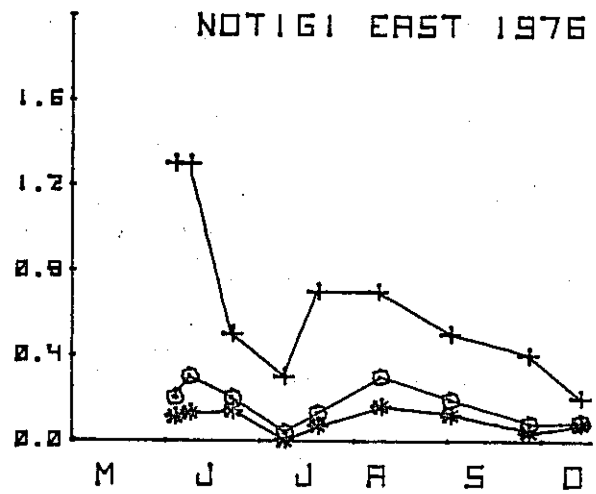
M J J A S O

(H)


NOTIGI EAST 1976
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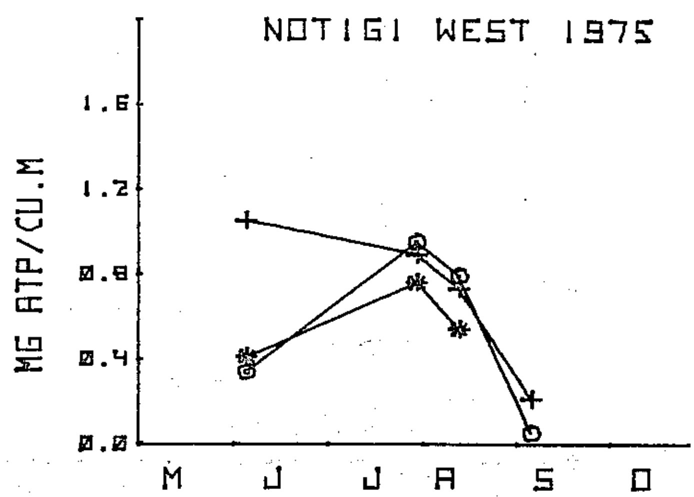
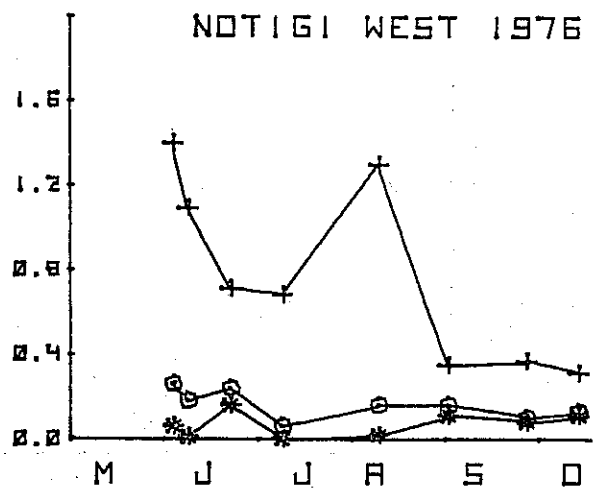
0.4
0.0
M J J A S O

(HH)


NOTIGI WEST 1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

(I)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1.6
1.2
0.8
0.4
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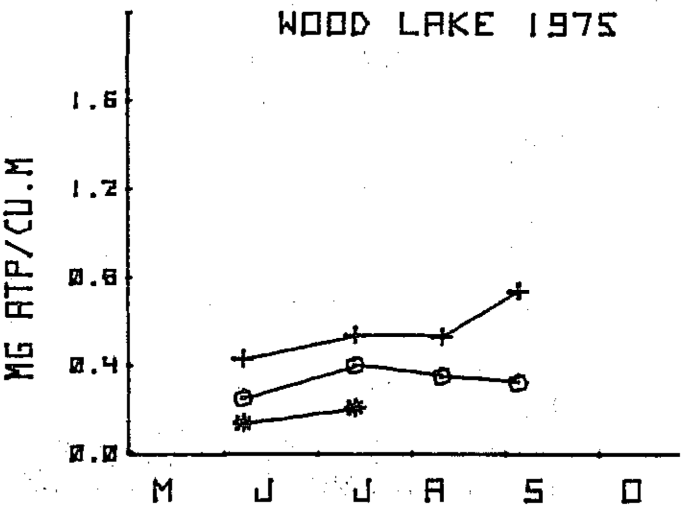
M J J A S O

(II)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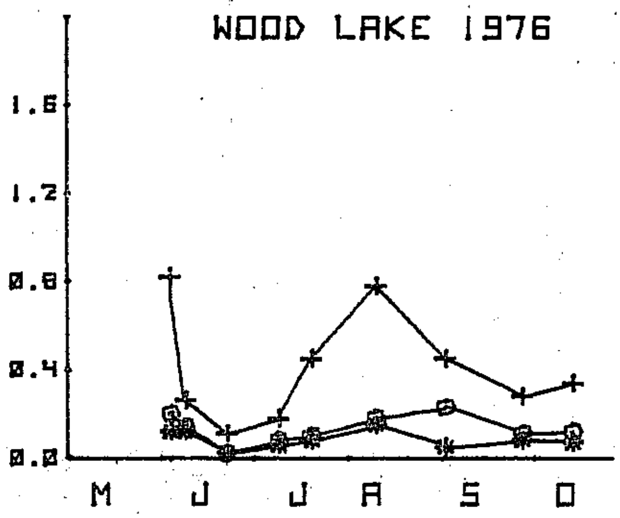
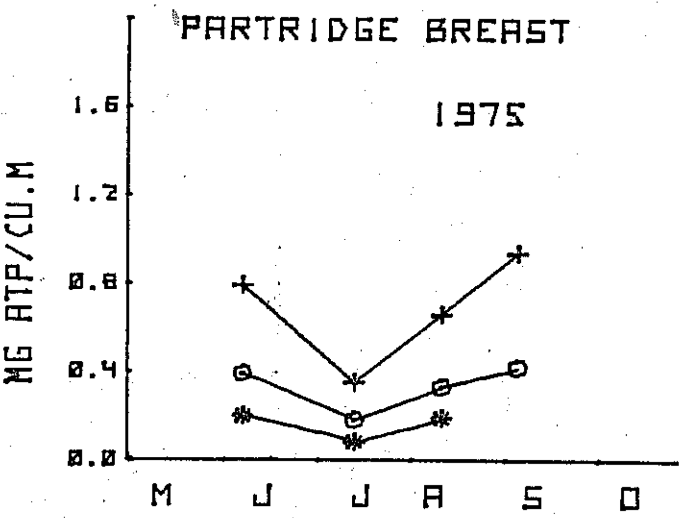
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

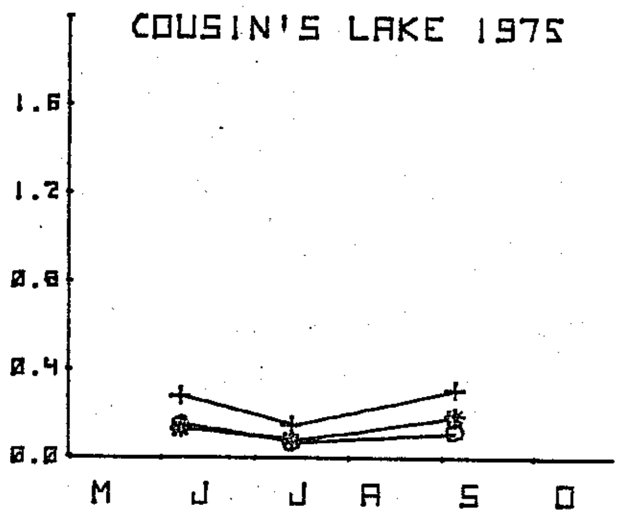
(J)


WOOD LAKE 1976
1.6
1.2
0.8
0.4
0.0
M J J A S O

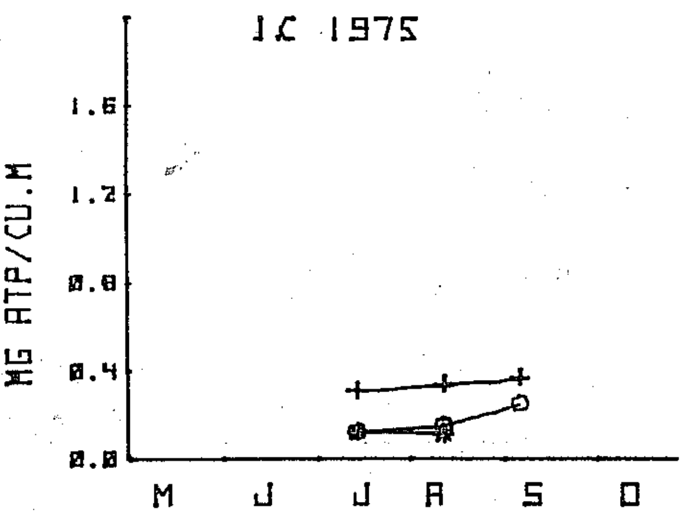
(JJ)


PARTRIDGE BREAST
1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

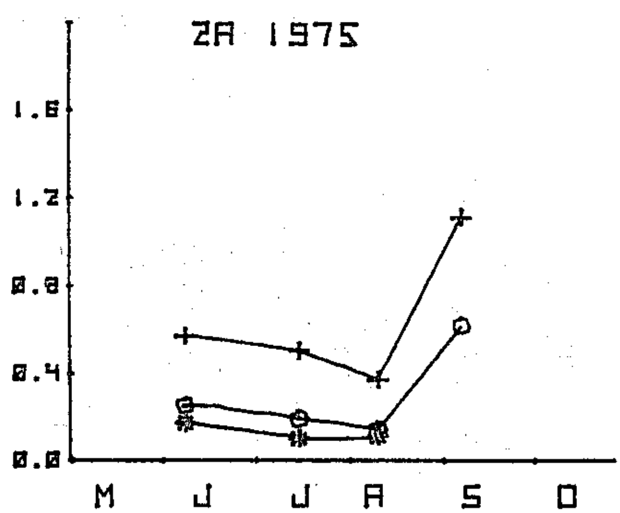
(K)


COUSIN'S LAKE 1975
1.6
1.2
0.8
0.4
0.0
M J J A S O

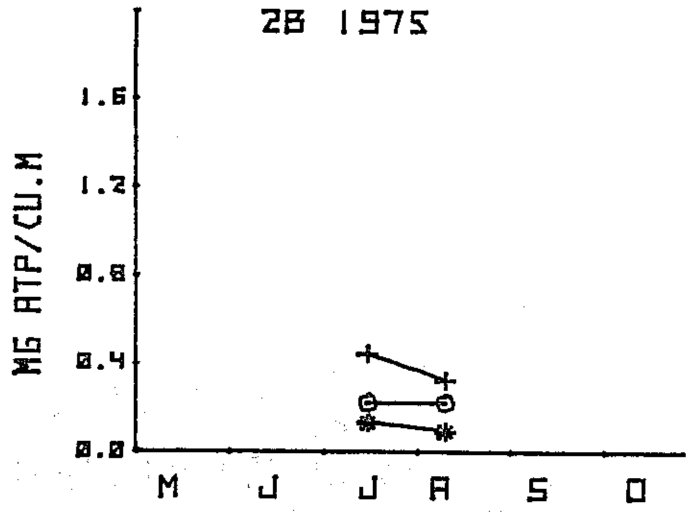
(L)


1C 1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

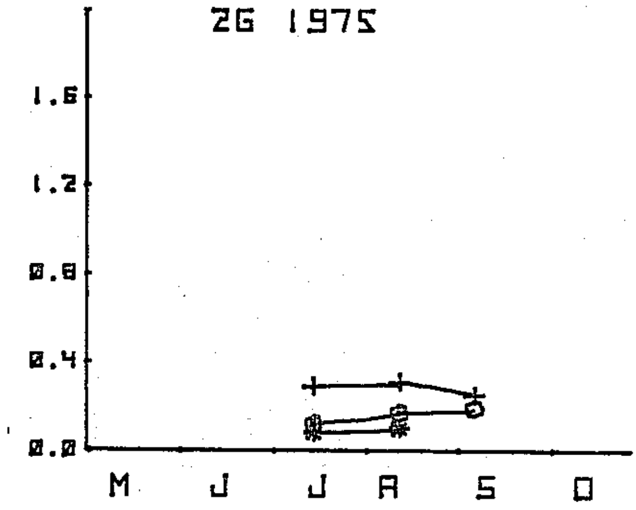
(M)


2A 1975
1.6
1.2
0.8
0.4
0.0
M J J A S O

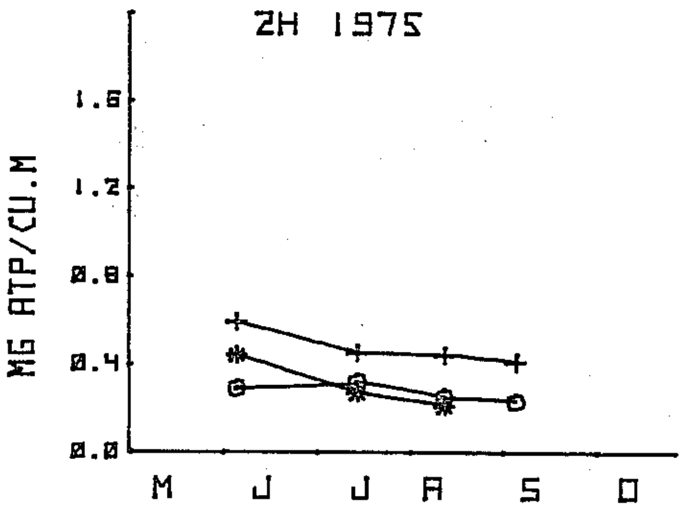
(N)


2B 1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

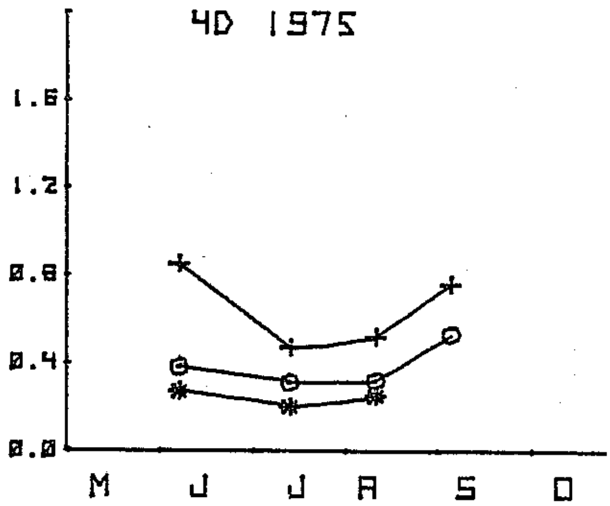
(O)


2G 1975
1.6
1.2
0.8
0.4
0.0
M J J A S O

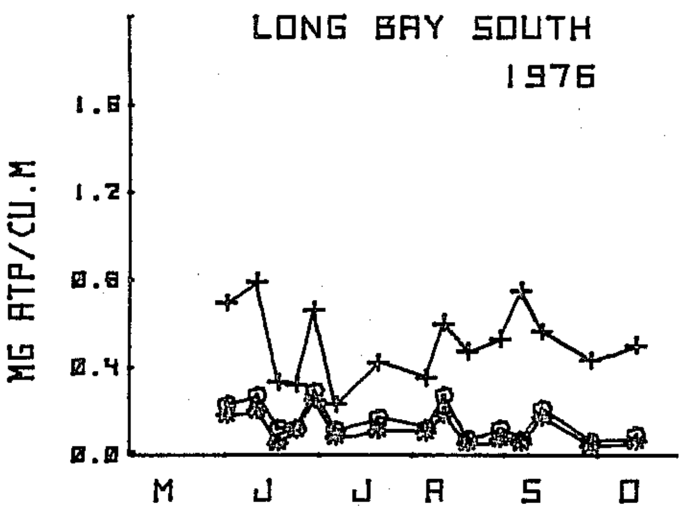
(P)


2H 1975
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

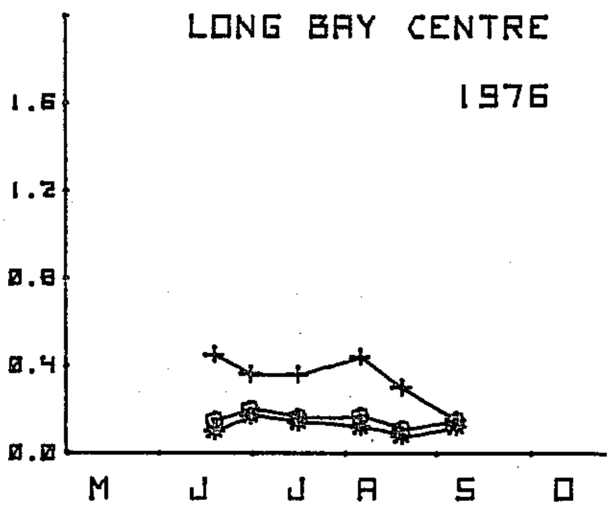
(Q)


4D 1975
1.6
1.2
0.8
0.4
0.0
M J J A S O

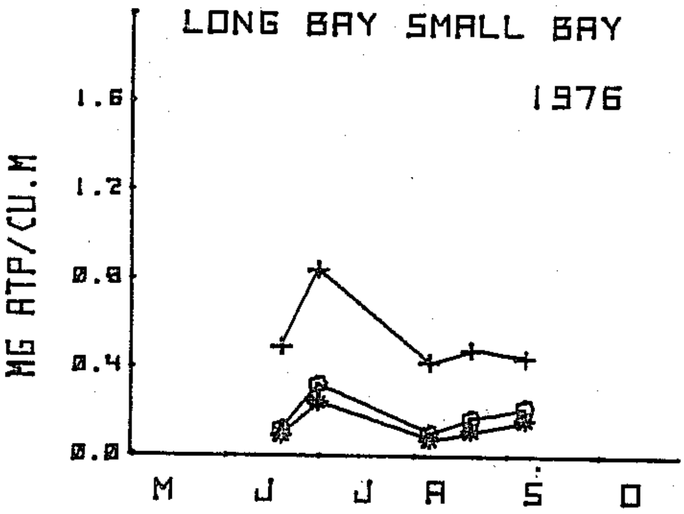
(R).


LONG BAY SOUTH
1976
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

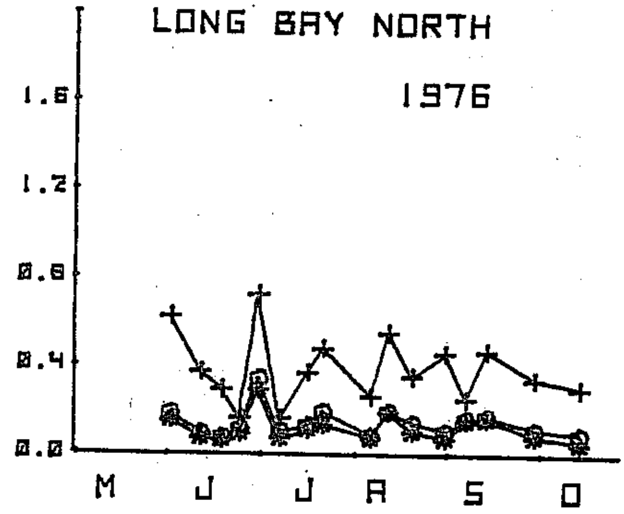
(S)


LONG BAY CENTRE
1976
1.6
1.2
0.8
0.4
0.0
M J J A S O

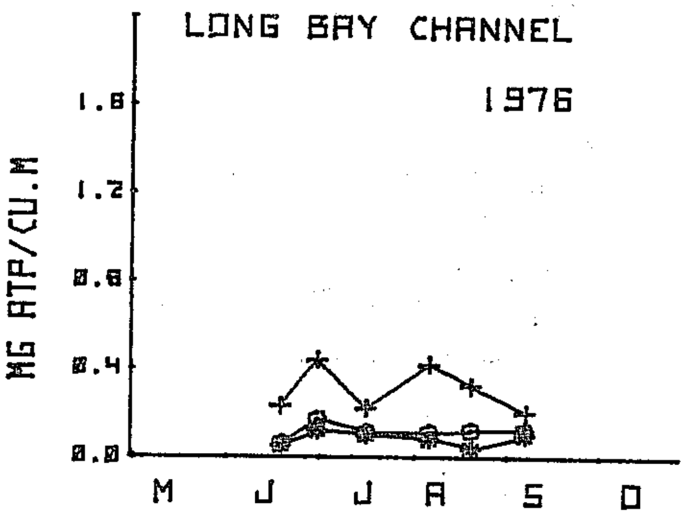
(T)


LONG BAY SMALL BAY
1976
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

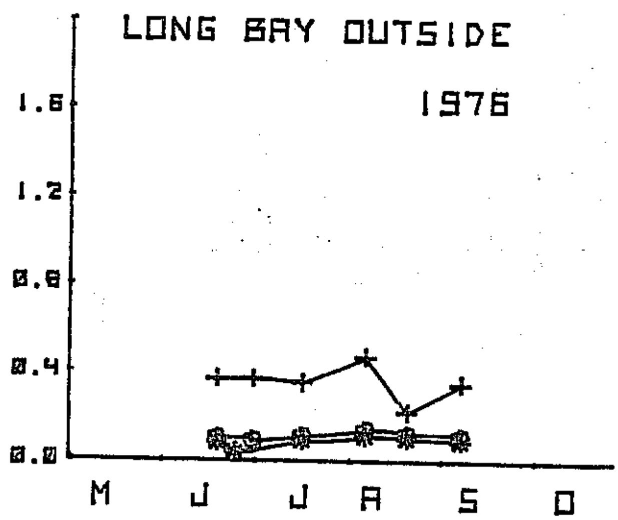
(U)


LONG BAY NORTH
1976
1.6
1.2
0.8
0.4
0.0
M J J A S O

(V).


LONG BAY CHANNEL
1976
MG ATP/CU.M
1.6
1.2
0.8
0.4
0.0
M J J A S O

(W)


LONG BAY OUTSIDE
1976
1.6
1.2
0.8
0.4
0.0
M J J A S O

(X)

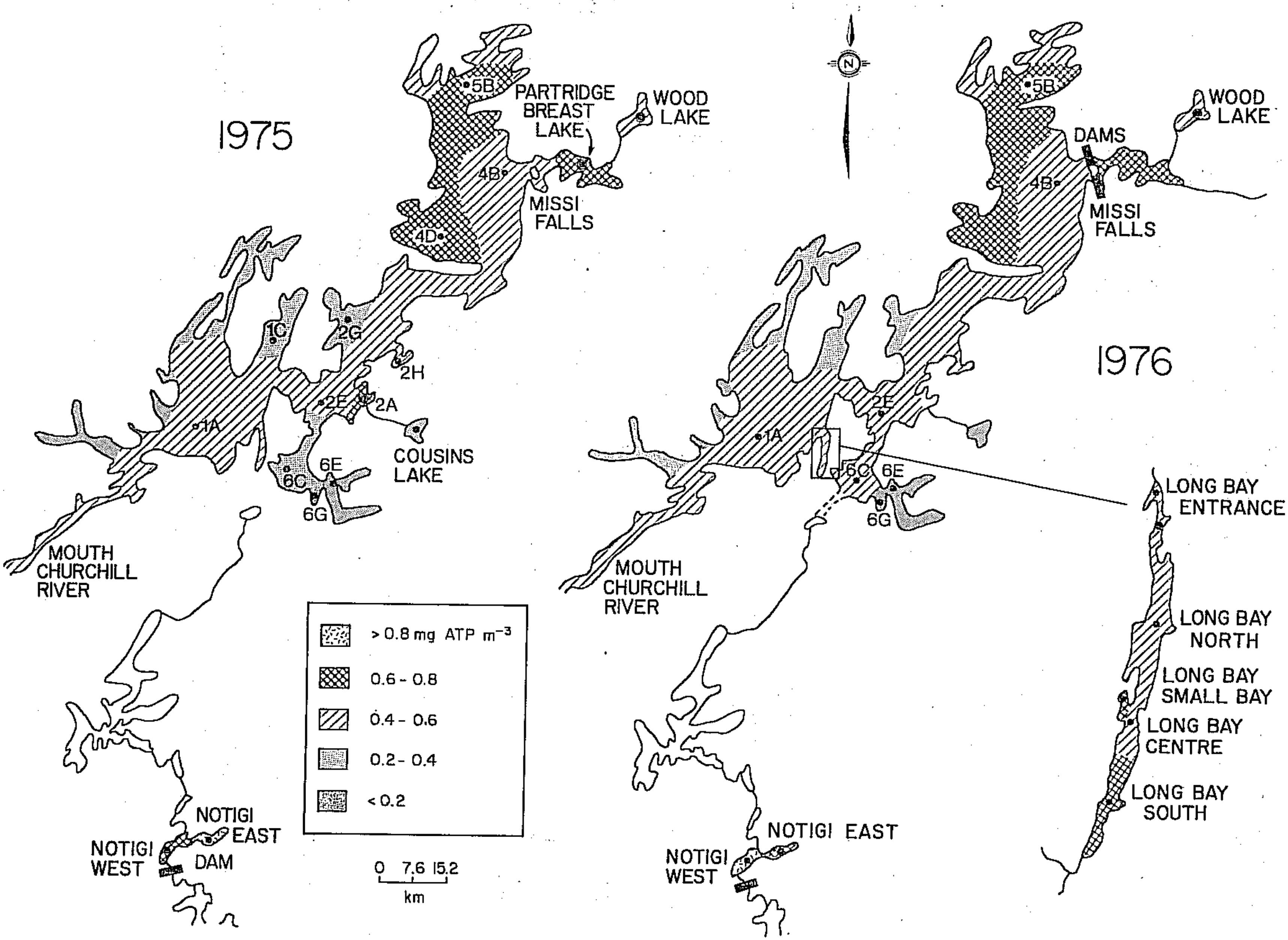


Fig. 3. Schematic maps indicating the levels of ATP in the Southern Indian Lake Study area 1975 and 1976. Inset enlarges Long Bay area.

Table 1. Means of ATP concentrations for full season for each station during 1975, 1976, in order of decreasing total ATP for each year except for Long Bay stations which are listed separately from other 1976 stations. All concentrations are in mg m^{-3}.

		0.22-200 μm		10-200 μm		48-200 μm		%	%[1]
Year	Station	mean	range	mean	range	mean	range	10-200 μm	48-200 μm
1975	Notigi East	1.13	0.16-1.80	0.82	0.09-1.64	0.98	0.42-1.61	73	87
	Notigi West	0.72	0.20-1.05	0.53	0.04-0.95	0.57	0.41-0.76	74	79
	5B	0.71	0.47-1.09	0.39	0.23-0.61	0.18	0.11-0.26	55	25
	Partridge Breast	0.68	0.35-0.94	0.33	0.18-0.42	0.16	0.08-0.20	49	24
	4D	0.65	0.47-0.85	0.39	0.31-0.53	0.24	0.20-0.27	60	37
	2A	0.64	0.37-1.12	0.30	0.14-0.25	0.12	0.10-0.17	47	19
	Wood Lake	0.56	0.43-0.74	0.33	0.25-0.40	0.16	0.14-0.21	59	29
	1A	0.53	0.34-0.65	0.23	0.11-0.38	0.21	0.08-0.37	43	40
	4B	0.49	0.32-0.64	0.30	0.15-0.37	0.20	0.14-0.25	61	41
	2H	0.46	0.41-0.59	0.32	0.23-0.32	0.30	0.21-0.44	70	65
	2E	0.45	0.27-0.58	0.19	0.10-0.26	0.15	0.06-0.22	42	33
	2B	0.44	0.32-0.55	0.21	0.21-0.22	0.11	0.09-0.13	48	25
	1C	0.34	0.31-0.37	0.17	0.12-0.25	0.12	0.11-0.12	50	35
	6C	0.32	0.22-0.48	0.14	0.07-0.20	0.11	0.10-0.12	44	34
	2G	0.28	0.25-0.31	0.16	0.12-0.19	0.09	0.08-0.10	57	32
	6E	0.25	0.09-0.40	0.15	0.05-0.21	0.13	0.08-0.16	60	52
	Cousin's Lake	0.24	0.15-0.31	0.11	0.07-0.15	0.07	0.02-0.11	46	29
	6G	0.16	0.09-0.27	0.13	0.07-0.26	0.05	0.05-0.07	81	31
1976	Notigi West	0.78	0.31-1.40	0.16	0.06-0.26	0.07	0.00-0.16	21	09
	Notigi East	0.65	0.22-1.32	0.14	0.04-0.30	0.08	0.00-0.16	22	12
	5B	0.57	0.14-1.22	0.18	0.05-0.32	0.11	0.01-0.27	32	19
	4B	0.49	0.18-0.82	0.20	0.08-0.39	0.13	0.05-0.27	41	27
	1A	0.41	0.17-1.03	0.14	0.03-0.29	0.08	0.01-0.15	34	20
	Wood Lake	0.41	0.11-0.82	0.13	0.02-0.23	0.08	0.02-0.15	32	20
	2E	0.40	0.17-0.88	0.15	0.06-0.29	0.11	0.02-0.20	38	28
	6C	0.38	0.12-0.78	0.14	0.03-0.25	0.09	0.02-0.17	37	24
	6G	0.29	0.09-0.80	0.13	0.04-0.18	0.09	0.02-0.15	45	31
	6E	0.25	0.12-0.42	0.11	0.05-0.17	0.07	0.02-0.14	44	28
Long Bay	Small Bay	0.53	0.42-0.84	0.18	0.10-0.32	0.13	0.07-0.24	34	25
"	South	0.51	0.23-0.79	0.15	0.06-0.29	0.11	0.04-0.25	29	22
"	North	0.38	0.16-0.72	0.14	0.07-0.34	0.12	0.05-0.29	37	32
"	Outside	0.35	0.22-0.47	0.11	0.09-0.14	0.09	0.04-0.11	31	26
"	Centre	0.35	0.15-0.45	0.16	0.11-0.20	0.12	0.08-0.17	46	34
"	Channel	0.30	0.20-0.44	0.12	0.06-0.17	0.09	0.04-0.12	40	30

[1]In 1975 the means for 10-200 μm size fraction were calculated from 4 ATP values while the 48-200 μm size fraction means were calculated from 3 values.

Table 2. Mean total ATP concentrations for 1975 and 1976 are compared in two ways (1) using means calculated from June to September data and (2) using means calculated from August-September data. The two largest size fractions (10-200 μm) and (48-200 μm) are expressed as a percent of total ATP.

	Mean Total ATP mg m^{-3}						Size Fractions As Percent of Total ATP			
	June-Sept			Aug-Sept			1975 June-Sept		1976 June-Sept	
Station	1975	1976	% change	1975	1976	% change	% 10-200 μm	% 48-200 μm	% 10-200 μm	% 48-200 μm
1A	0.53	0.51	- 4	0.44	0.60	+ 36	43	39	33	16
2E	0.45	0.54	+ 20	0.42	0.57	+ 36	42	29	35	25
4B*	0.44	0.50	+ 14	0.45	0.38	- 16	66	45	36	24
5B	0.71	0.63	- 11	0.92	0.78	- 15	55	26	29	16
6C*	0.32	0.59	+ 84	0.24	0.59	+146	41	30	32	23
6E	0.25	0.27	+ 8	0.26	0.26	0	60	48	41	22
6G	0.16	0.34	+113	0.14	0.25	+ 79	81	35	44	29
Notigi West*	0.66	0.97	+ 47	0.47	0.83	+ 77	59	54	19	5
Notigi East	1.13	0.79	- 30	0.72	0.58	- 19	73	68	28	14
Wood	0.56	0.52	- 7	0.64	0.62	- 3	36	37	33	23

*Note: If the data from one month was missing in one year the corresponding data in the other year was left out when calculating mean ATP values for the purpose of comparison.

4B - Sept values not included
6C - July " " "
Notigi West - July " " "