PRIMARY PRODUCTIVITY OF LAKE GEORGE, NEW YORK: ITS ESTIMATION AND REGULATION

A Final Technical Report for Union Carbide
Subcontract (in part) for the
Eastern Deciduous Forest Biome, IBP,
Lake George Site

From

THE RESEARCH FOUNDATION OF THE STATE UNIVERSITY
OF NEW YORK
Account 6074A

by

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Albany, New York

Deciduous Forest Biome
IBP Memo Report 73-84

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ABSTRACT

Primary Productivity of Lake George, New York: Its Estimation and Regulation

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Rates of production were estimated for phytoplankton and the attached macrophytes of the sublittoral zone in Lake George, N.Y. Water and plants were incubated in glass bottles with $NaHCO_3$ for three-hour intervals. Measurements of light saturation, temperature response, nutrient stimulation, and daily rhythm were carried out in addition to a standard seasonal evaluation of rates.

In the phytoplankton, photosynthetic capacities were measured for the fifth consecutive year at selected stations and depths.

The sublittoral ribbon of *Nitella flexilis* that exists in the depth zone of 7 and 13 meters is more productive in the southern basin. Density of plants range from 18.0 to 205.0 g (dry wt)/m^2 in the southern basin and from 12.0 to 102.0 g (dry wt)/m^2 in the northern basin.

Photosynthetic capacity is seasonal. Maximum mean rates of 5.5 to 6.5 mg C/g (dry wt) hr. were measured in the latter part of June. All rates were reduced to 1/6 of the previously reported rates that were erroneous owing to a systematic calculation error.

Photosynthetic capacity of *Nitella* is influenced by length of the plant. Separate regressions for plants at 7 and 12 meters show a decline of 0.1 and 0.05 mg, respectively with each cm increase in length.

Preliminary estimates of light saturation indicate that *Nitella* is light saturated somewhere in the range of 500 and 1500 ftc with no real

difference in the response of shallow (7 m) and deep (12 m) plants.

A temperature of 18°C gave maximum photosynthetic rates of approximately 6.0 mg C/g/hr. Rates were only 3.5 mg C/g/hr. at 13°. There was probably no difference in the response of shallow and deep plants.

Nutrient limitation of photosynthetic capacity was expressed with the addition of phosphate but not nitrate. Maximum rates were achieved with additions of 1.0 uM PO_4/liter in 1973 and 2.0 uM in 1972. In both instances the stimulated rate was doubled.

A daily rhythm in photosynthetic capacity of Nitella was apparent at 2,000 ftc, but not in plants incubated at 100 ftc. The peak rate was in the afternoon (1600) and the minimum in early morning (0600). The maximum was nearly twice the minimum rate.

INTRODUCTION

The goal of the primary productivity effort on Lake George has had to be restricted because of limited funds. Intuitively the optimal strategy appears to be to follow up the suggestion that emerged from the analysis in 1972 (Stross, IBP-EDFB Memo Rept. 72-72). A significant interaction between the macrophytes and the phytoplankton of Lake George was apparent in the trends of daily photosynthetic rates. A large decline in photosynthetic capacity of phytoplankton in June corresponded with the timing of maximum photosynthetic activity of Nitella flexilis, the demonstrably major component of the macrophyte assemblage.

Appropriately, the major effort in 1973 was devoted to work with Nitella productivity and the environmental factors that influence photosynthetic capacity. Light intensity, temperature, and nutrient concentration are likely to modify short term growth rates sufficiently to make modelling of them necessary as is demonstrated in most of the so called ecological process models. Likewise the condition of the plant as related to depth, time of day, day of year, and length is likely to influence responsiveness of the plant whose daily cycle and life span are easily programmable features of real live organisms.

ACKNOWLEDGEMENTS

I wish to thank Dr. Krishna Chakrabarty for a truly splendid performance with the project. Her acceptance and modification of the carbon oxidizer was an essential feature in reducing variance and even bias in the estimates of macrophyte photosynthesis. Secondly, Mr. Richard Keyel was outstanding with his capacity for coordinating field activities, assisting Dr. Chakrabarty and preparing the data for graphic presentation. Others not specifically mentioned are also acknowledged for their selfless assistance.

METHODS

Much of the methodology for estimates of biomass and photosynthetic capacity is standard and has been described in previous memo reports. Nitella flexilis is sampled with a stainless steel Ekman dredge. A series of dredge hauls at each depth are averaged to get a mean estimate which is presented as a dry wt. (105°C) estimate with standard errors.

Specimens collected with the dredge were also employed for measurements of photosynthetic capacity. They were transported from collection site in the Tea Island area of the lake to the laboratory from the lake in lake water maintained at lake temperature ± 2.0°C. All measurements were performed immediately on return of the plants, although it was shown that storage under appropriate conditions did not affect performance.

Single plants were incubated with ^{14}C in milk dilution bottles. Incubation for a standard interval of 3.0 hrs were performed in a rotating drum incubator to satisfy the turbulence requirement while light and at a temperature of the lake.

After incubation each plant was measured for length and dried. It was pelletized and combusted in a sealed chamber from which the carbon dioxide product was driven with purge gas (N_2). Collected in ethanolamine, the CO_2 sample was measured for uptake of radioactive label in a scintillation system.

RESULTS AND DISUCSSION

Photosynthetic capacity of Nitella flexilis responded positively to most of the variables tested. A strong seasonal trend in rates first noted in 1972 (see memo report) was again present (Fig. 1). In 1973 the rates appeared to increase to maximum of 5.5 or 6.5 mg C/g (dry wt)/hr. in late June. Earlier and later estimates were lower. The decline was less spectacular in 1973 owing perhaps to a deliberate selection for healthier plants within the sample. No easily detectable difference existed between depths when the plants were incubated at 1500 ftc. and at lake temperature.

Larger plants are less active and plants are longer in the deeper water (Fig. 2). In the summer of 1973 the mean length at 12 meters was 48.0 cm and at 7.0 meter depth only 24.4 cm, a factor-of-two relationship observed also in 1972. The taller plants declined at the rate of 0.06 mg/cm of plant length with an r of -0.79. The shorter plants at shallow (7 m) depth show a sharper decline in rate of 0.10 mg/cm of length. Coefficient of correlation was -0.68. Both plants intercepted at 5.5 to 5.75 mg C/g tissue (dry wt)/hr.

The ubiquity of daily rhythms in biological activity was also apparent in measurements of photosynthetic capacity. Nitella fixed carbon at the fastest rate in the afternoon and at the slowest rate in early morning (Fig. 3). The mean rates oscillated from 1.8 to 3.0 mg C/g/hr. Unfortunately, the photosynthetic activity of the population was on the decline when the estimates were made in mid-August.

An attempt to measure the intensity of light saturation was successful although a better technique is now necessary to measure precisely the light intensity and to correct measurements made with an exposure meter. Preliminary estimates indicate saturation somewhere in the range of 500 and 1500 ftc. There appears to be no significant increase in shade adaptation of plants from 12 meters as compared to plants from 7.0 meters.

Nutrient limitation was again expressed by Nitella. Phosphate stimulated at low concentration (1.0 uM/liter), increasing the rate of photosynthesis from 3.0 to 5.0 mg $C/m^2/hr$. (Fig. 4). Larger concentrations were ineffective, or suppressive since the rate returned to the base level at 2.0 uM/liter. A similar pattern was observed in 1972 with maximum stimulation at modest concentration (2.0 uM/liter) and a sharp decline in rate with further enrichment. Nitrate enrichment resulted in no stimulation of photosynthesis, at least within the 3-hour incubation interval (Fig. 5).

A temperature optimum for photosynthesis was suggested from measurements at 13, 18, and 32°C. Rates were largest at 18°C and approximately double rates at 13°C (Fig. 6). The highest temperature, 32°C, suppressed photosynthesis of plants from 12 meters. Since the plants were from the southern basin where a depth of 12 meters is within the thermocline, it is possible that a gradient in thermal optimum exists across the depth stratum occupied by the Nitella population.

MACROPHYTE PRODUCTIVITY

Standing crops of Nitella were estimated in August 1973 with a mean of three or four dredge hauls from each reported depth. Five transects were selected in each basin. In the southern basin the mean density at 7.0 meter for all transects was 92.0 g (dry tissue)/m^2. In the northern basin the same mean was only 12.1 g/m^2. The northern basin although generally less productive contained beds nearly as dense as those in the southern basin, especially at the deeper end of the zone (Table 3). Sample comparisons are given in Tables 1 and 2 along with standard errors.

Annual production estimated for the zone 7 to 13 meters for Lake George show the south basin to be three times more productive. In 1973 it produced an estimated 2,484 metric tons, of nearly all Nitella, compared with a production of 796.0 metric tons in the north basin (Table 4). The indication is that 1973 was a more productive year for Nitella than 1972. Only 2/3 as much Nitella was produced in the south basin, and estimated Nitella production in 1973 was equivalent to total macrophyte productivity in 1972.

CONCLUSIONS

A series of measurements have been performed on Nitella flexilis, the species of attached macroscopic plant in Lake George, New York. It was earlier found to be virtually the only species in the depth zone of 7 and 12 meters. In the northern basin of the lake the plant extends to a depth of 13 meters.

The measurements presented in naked form have an intrinsic value that awaits an appropriate process model that accepts them as parameters.

TABLE 1. Standing Crop of *Nitella flexilis* for Southern Basin of Lake George - August 1973.

(Measurements in g dry tissue/m^2 $\pm$ S.E.$_{\bar{x}}$)

LOCATION	7m	8m	9m	10m	11m	12m	TOTAL
Tea Island Bay	146.0 ± 19.7	127.3 ± 26.8	96.5 ± 14.2	55.6 ± 11.2	90.2 ± 26.9	28.4 ± 22.9	544.0
Dunham Bay	86.5 ± 17.6	233.1 ± 84.8	152.6 ± 32.6	.26 ± .25	0	0	472.5
Katskill Bay	217.7 ± 74.1	582.3 ± 253.9	258.6 ± 37.7	302.0 ± 58.3	340.1 ± 73.3	97.6 ± 15.0	1,798.3
Dome Island	10.7 ± 2.2	110.7 ± 32.3	104.8 ± 17.5	5.1 ± 1.6	11.9 ± 1.4	6.6 ± 2.1	249.8
Northwest Bay	0	0	0	0	38.6 ± 15.5	21.0 ± 9.5	59.6
MEAN	91.9 ± 23.4	204.8 ± 33.4	122.5 ± 10.8	72.6 ± 14.4	101.2 ± 32.5	17.9 ± 3.4	

TABLE 2. Standing Crop for *Nitella flexilis* for Northern Basin of Lake George - August 1973.

(Measurements in g dry tissue/m^2 $\pm$ $S.E._{\bar{x}}$)

LOCATION	7m	8m	9m	10m	11m	12m	13m	14m
Gull Bay	28.3 ± 3.2	18.9 ± 5.1	33.8 ± 7.9	43.7 ± 7.1	30.8 ± 4.4	38.6 ± 7.5	-	-
Heart's Bay	0	0	0	0	0	164.2 ± 32.2	29.5 ± 29.5	0
Hulett's Landing	0	62.7 ± 23.9	164.2 ± 21.3	150.7 ± 18.9	131.1 ± 10.6	102.0 ± 21.5	16.1 ± 6.0	0
Bloomer Mt.	-	.60 ± .60	-	23.1 ± 22.9	-	-	-	-
Rattlesnake Bay	-	-	1.4 ± 1.3	-	100.2 ± 11.8	-	-	-
MEAN	12.1 ± 4.1	20.2 ± 7.6	58.0 ± 17.7	60.3 ± 14.7	61.9 ± 12.7	101.5 ± 18.9	21.9 ± 11.9	0

- indicates samples not taken.

TABLE 3. Annual Production of *Nitella* and other species in Lake George for the year 1973.

SOUTH BASIN (measurements g dry weight/m^2 $\pm$ $S.E._{\bar{x}}$)

depth (m)	*Nitella**	Other[⊕] Species	Annual Production
7	183.8 ± 46.8	0	183.8 ± 46.8
8	409.6 ± 66.8	X	409.6 ± 66.8
9	245.0 ± 21.6	0	245.0 ± 21.6
10	145.2 ± 28.8	0	145.2 ± 28.8
11	202.4 ± 65.0	0	202.4 ± 65.0
12	35.8 ± 6.8	0	35.8 ± 6.8

NORTH BASIN

depth (m)	*Nitella**	Other[⊕] Species	Annual Production
7	24.2 ± 8.2	0	24.2 ± 8.2
8	40.4 ± 15.2	11.7 ± 11.7	52.4 ± 26.9
9	116.0 ± 35.4	0	116.0 ± 35.4
10	120.6 ± 29.4	0	120.6 ± 29.4
11	123.8 ± 25.4	4.9 ± 2.5	128.7 ± 27.9
12	203.0 ± 37.8	0	203.0 ± 37.8
13	43.8 ± 23.8	0	43.8 ± 23.8
14	0	0	0

*Two crops of *Nitella* were assumed, so the August figures were doubled to give this value.

⊕Only one crop was assumed.

XA single plant of *Chara* (*globularis*) was found at Dome Island, weight not available.

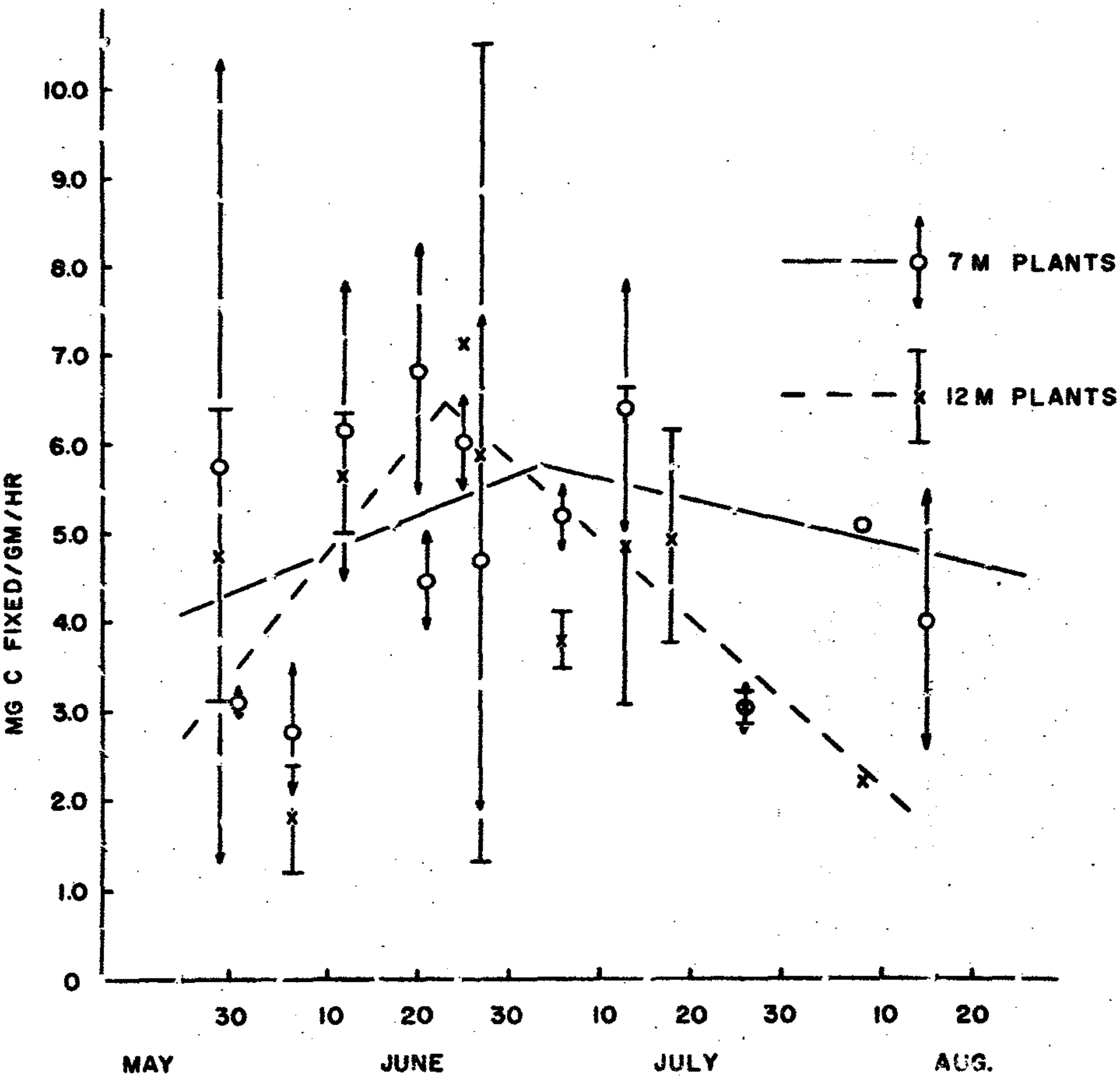
TABLE 4. Annual Production of Macrophytes within the 7-14 m Contour Limits (rates expressed as g (dry weight)/m^2/yr. ± $S.E._{\bar{x}}$).

	SOUTH BASIN		1973		NORTH BASIN		
depth m	Annual rate/m^2	Surface area (mi^2)	Production (g x 10^6/contour)	Annual rate/m^2	Surface area (mi^2)	Production (g x 10^6/contour)	Total Producti (g x 1(/conto
7	183.8 ± 46.8	.75	357.0	24.2 ± 8.2	0.45	28.0	385.0
8	409.6 ± 66.8	.80	848.7	52.4 ± 26.9	0.45	60.5	909.2
9	245.0 ± 21.6	.80	507.6	116.0 ± 35.4	0.45	134.0	641.6
10	145.2 ± 28.8	.75	282.1	120.6 ± 29.4	0.45	139.3	421.4
11	202.4 ± 65.0	.80	419.4	128.7 ± 27.9	0.45	148.7	568.1
12	35.8 ± 6.8	.75	69.5	203.0 ± 37.8	0.45	234.5	304.0
13	-	-	-	43.8 ± 23.8	0.45	50.6	50.6
14	-	-	-	0	-	0	0
TOTAL			2,484.3			795.6	3,279.9
	SOUTH BASIN 1972*						
7	103.0 ± 40.2	.75	200.2				
8	107.6 ± 42.9	.80	222.9				
9	120.9 ± 21.6	.80	250.7				
10	190.7 ± 43.3	.75	370.4				
11	111.2 ± 39.5	.80	230.4				
12	163.9 ± 43.1	.75	318.4				
13							
TOTAL			1,593.0				

*These values are slightly different from the report figures because a different conversion factor (2.59) was used to change mi^2 to km^2.

FIG. 1

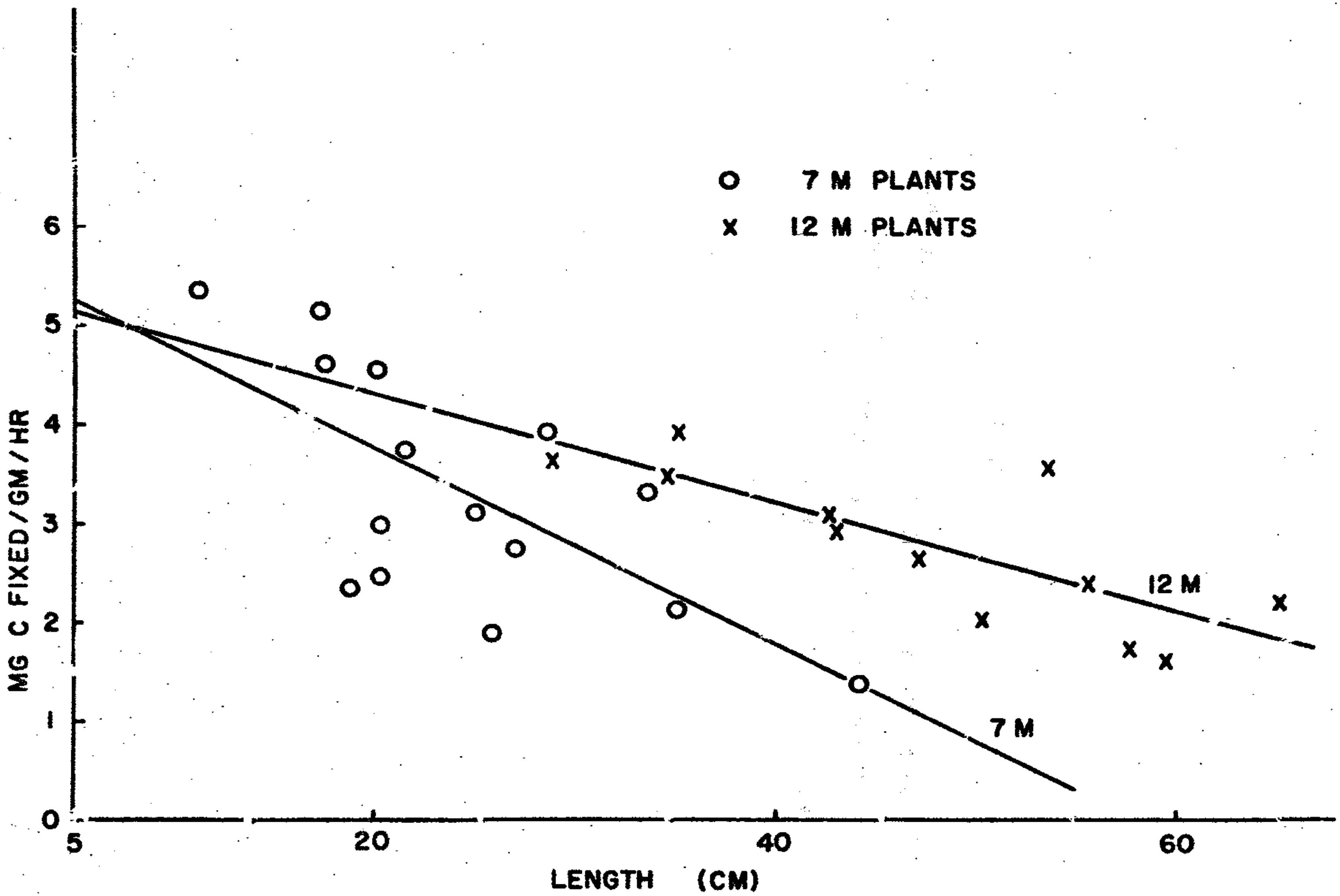
Seasonal trend in hourly rate of carbon fixation by whole plants of *Nitella flexilis* from Lake George, N.Y. Incubation was at standard light intensity and temperature as described in "Methods". The rate for each plant was corrected so that at a standard length with the regression shown in Figure 2. 95% confidence limits are included with each estimate.



MG C FIXED/GM/HR
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
30
10
20
30
10
20
30
10
20
MAY
JUNE
JULY
AUG.
7 M PLANTS
12 M PLANTS

FIG. 2

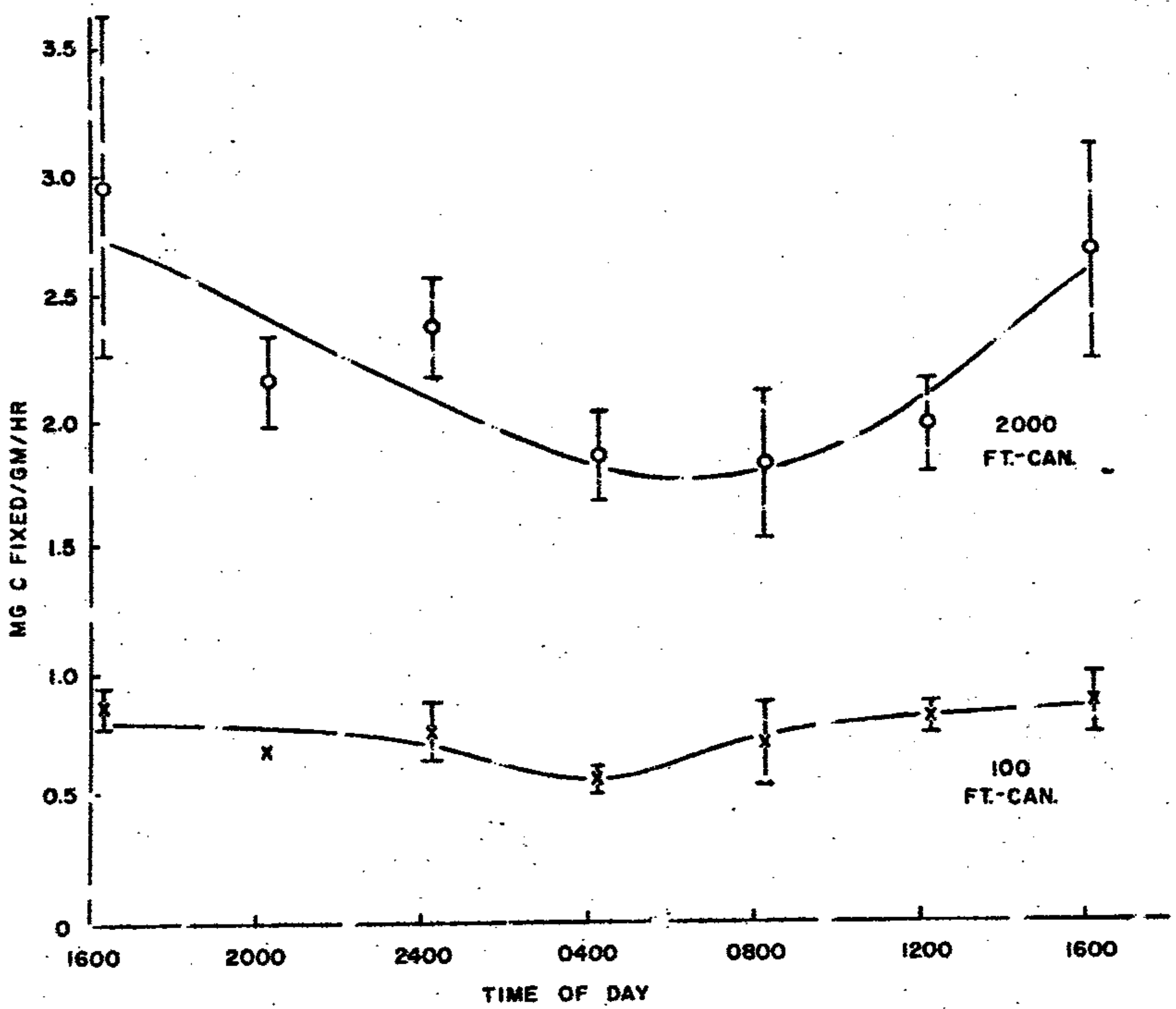
Regression of photosynthetic capacity on length of the Nitella plant. Measurements were made over a wide range of dates from May to mid-August, 1973.



O 7 M PLANTS
X 12 M PLANTS
MG C FIXED / GM / HR
0
1
2
3
4
5
6
5
20
40
60
LENGTH (CM)
12 M
7 M

FIG. 3

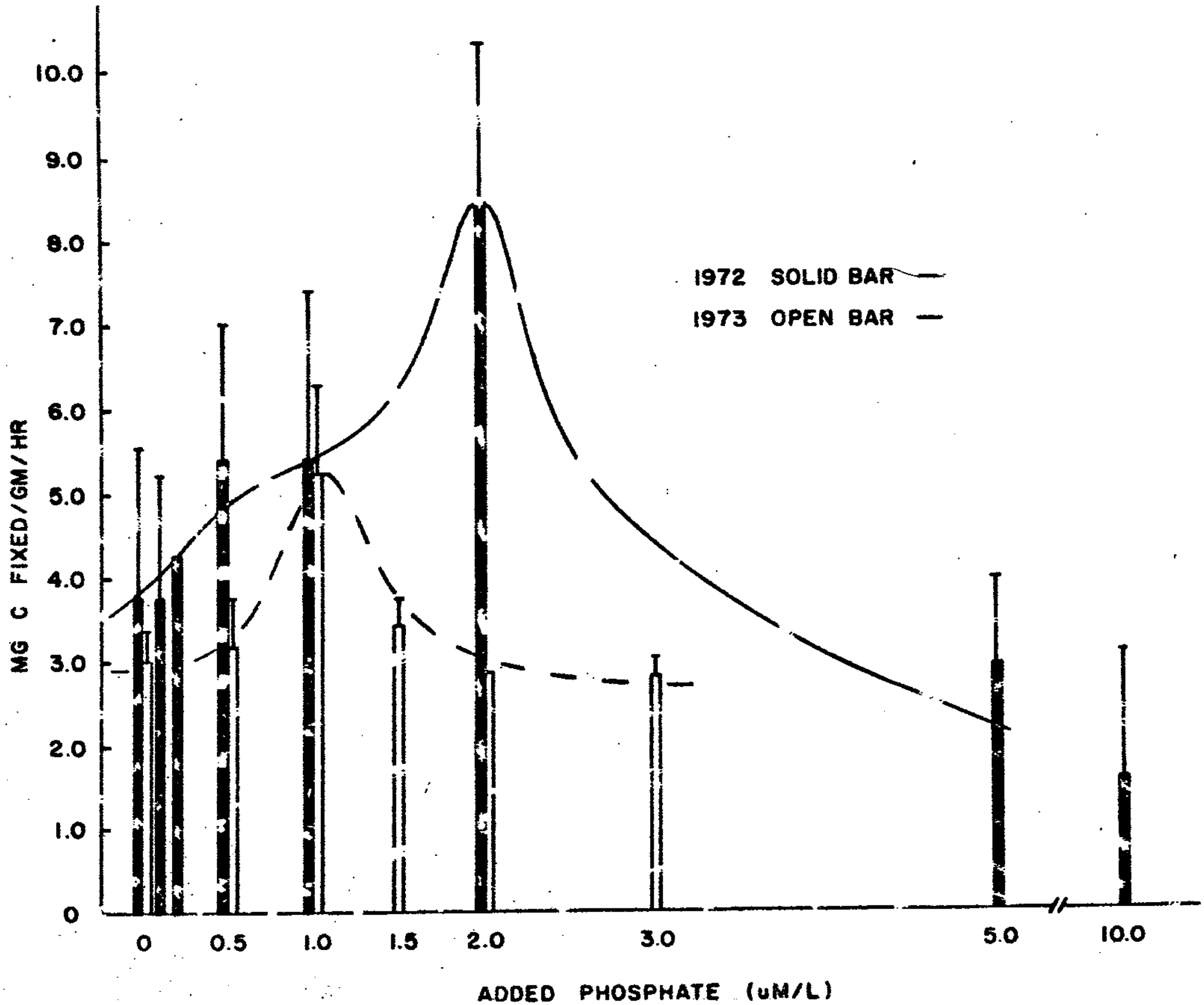
Daily rhythm in photosynthetic capacity in _Nitella_ as measured at 100 and 2000 ftc. on August 15-16, 1973. Measurements corrected for length variation.



MG C FIXED/GM/HR
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
2000
FT.-CAN.
100
FT.-CAN.
1600
2000
2400
0400
0800
1200
1600
TIME OF DAY

FIG. 4

Photosynthetic response of Nitella flexilis to the addition of NaH_2PO_4 to lake water in the range of 0.1 and 10.0 micromoles/ liter. The 1972 response is shown for comparison.



MG C FIXED/GM/HR
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1972 SOLID BAR
1973 OPEN BAR
0
0.5
1.0
1.5
2.0
3.0
5.0
10.0
ADDED PHOSPHATE (uM/L)

FIG. 5

Photosynthetic rates of Nitella in response to the addition of $NaNO_3$ to lake water in the range of 0.1 and 10.0 micromoles/liter.

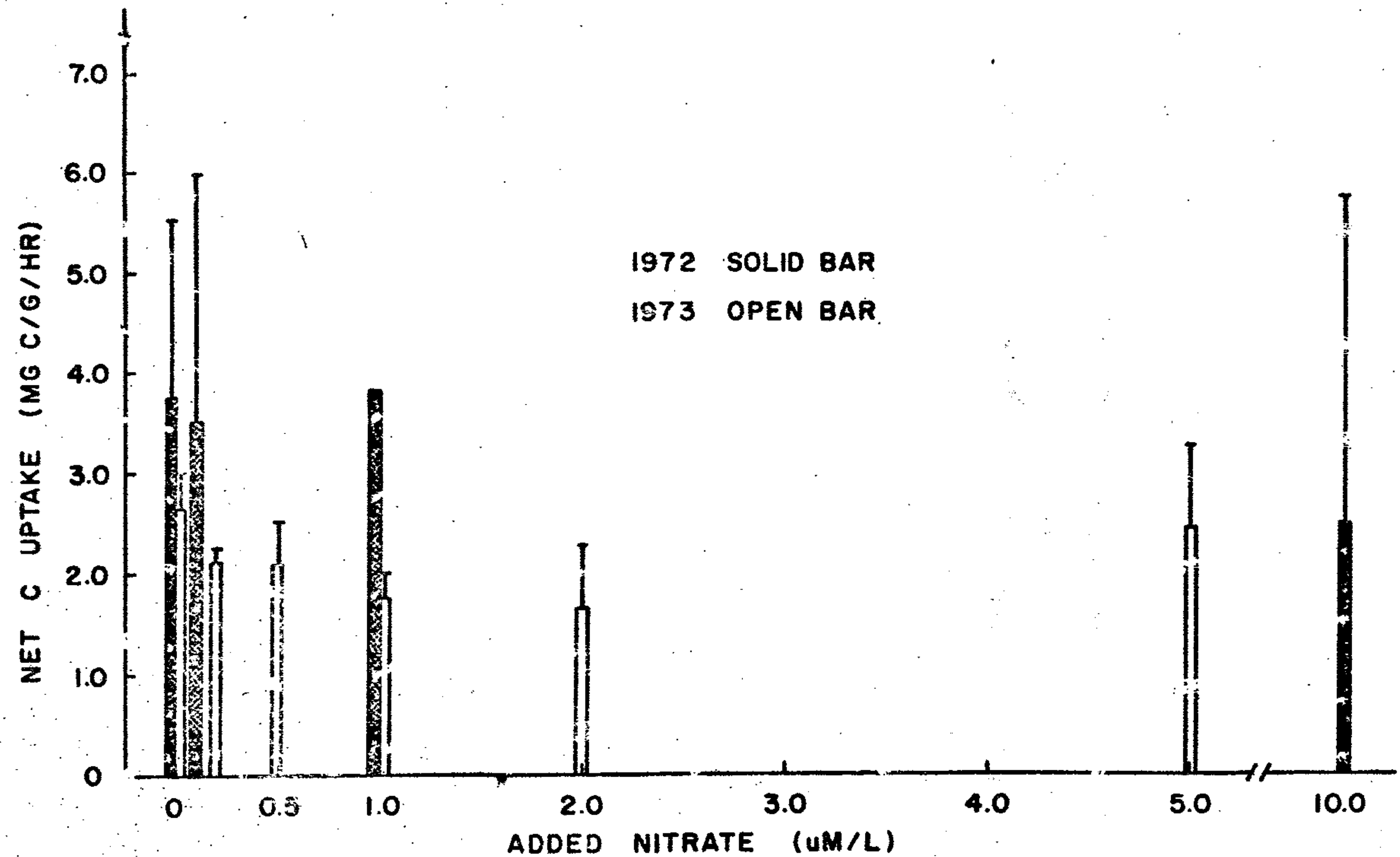
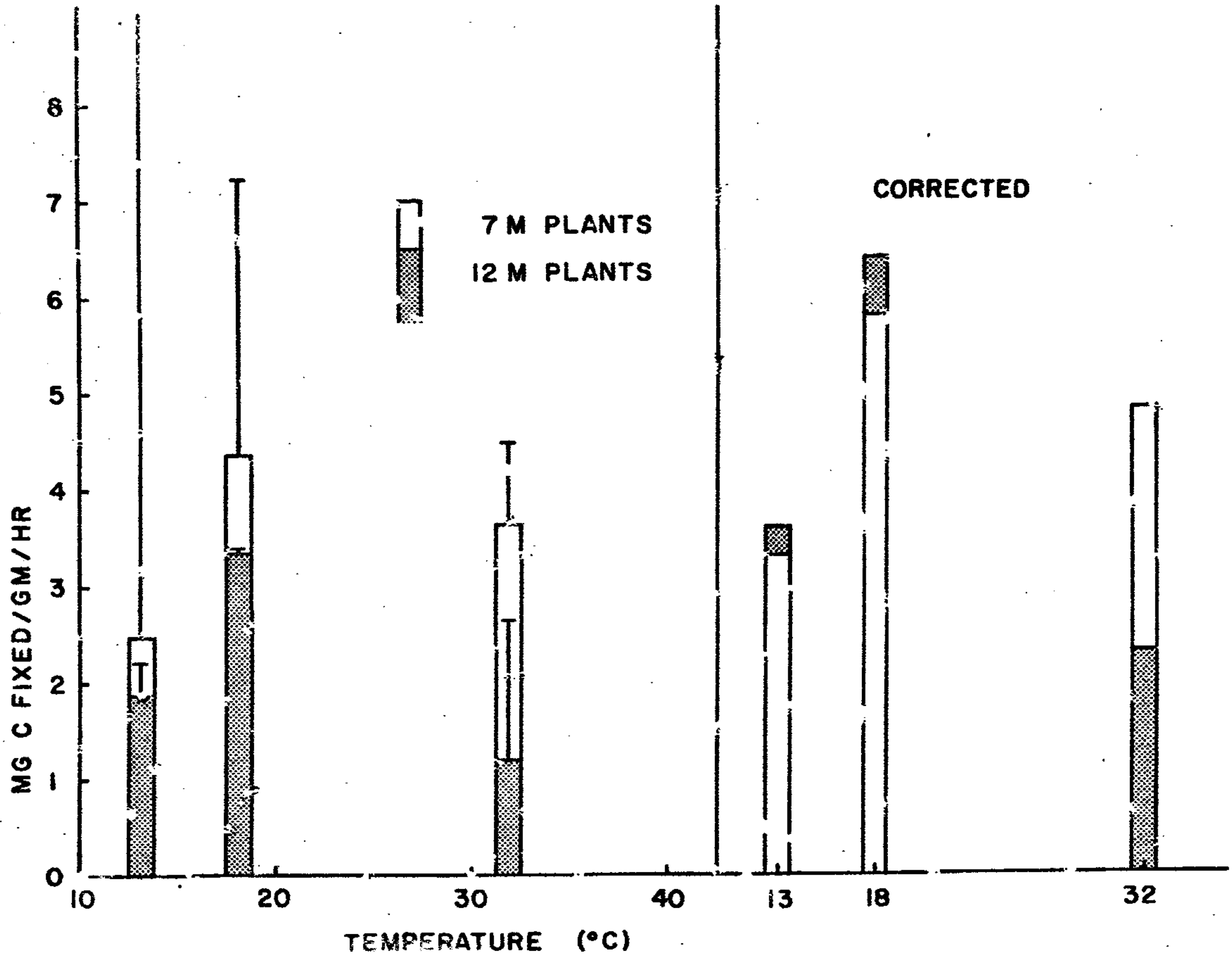

7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
NET C UPTAKE (MG C/G/HR)
1972 SOLID BAR
1973 OPEN BAR
0
0.5
1.0
2.0
3.0
4.0
5.0
10.0
ADDED NITRATE (uM/L)

FIG. 6

Photosynthetic capacity at three temperatures. Plants from 7 and 12 meters depth are compared with and without a correction for length of the plant. Plants collected from Lake George, N.Y. on separate occasions.



CORRECTED
7 M PLANTS
12 M PLANTS
MG C FIXED/GM/HR
0
1
2
3
4
5
6
7
8
10
20
30
40
13
18
32
TEMPERATURE (°C)