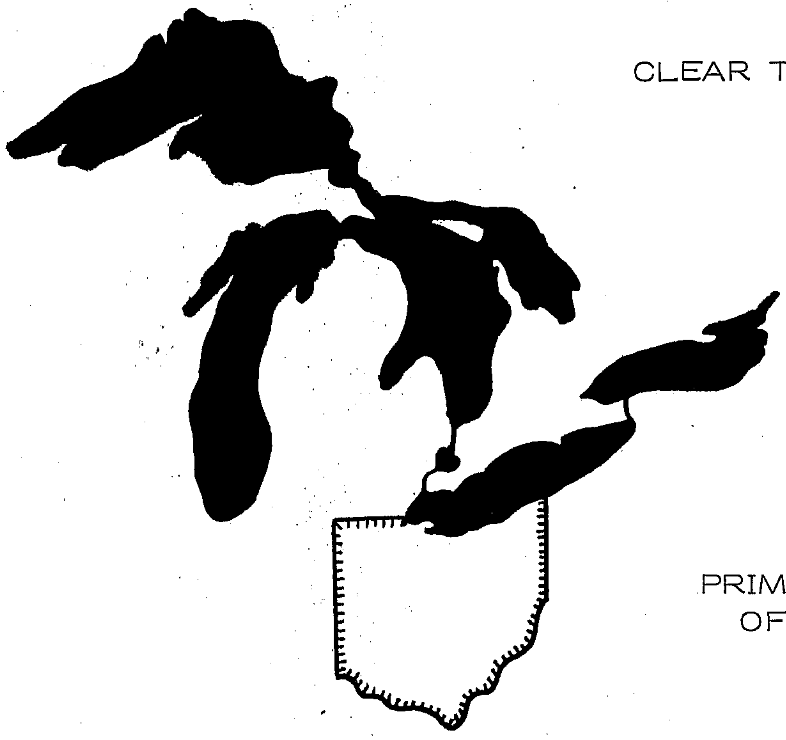

CLEAR TECHNICAL REPORT NO. 42

PRIMARY PRODUCTIVITY SURVEY OF CENTRAL AND WESTERN LAKE ERIE

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INTRODUCTION

Lake Erie is the fourth in the series of five interconnected Great Lakes located in mid-North America that drain to the Atlantic Ocean via the St. Lawrence River. It has the fourth largest surface area (25,400 km^2) and the smallest volume (540 km^3) of the Great Lakes (Dobson, Gilbertson, and Sly 1974). Verber divided the lake into three basins (Davis 1966). A line between the tip of Point Pelee, Ontario and Cedar Point, Sandusky, Ohio divides the western and central basins, and a line between the base of Long Point, Ontario and the base of Presque Isle, Pennsylvania divides the central and eastern basins. The western, central and eastern basins have mean depths of 24 feet [7.3 m] (Beeton 1969), 18.5 m (Beeton 1965), and 24.4m (Beeton 1965), respectively. Approximately 12 million people inhabit the drainage basin of Lake Erie (Beeton and Edmondson 1972).

Within the last twenty years biologists have observed that man has increased the nutrient input of Lake Erie, causing significant changes in its flora and fauna (Beeton and Edmondson 1972). From 1938-1964 total phytoplankton concentration in the island area increased by 3.5 times, and the dominant phytoplankton changed from diatoms to blue-green algae. From 1920-1962 in central Lake Erie phytoplankton numbers increased several fold during spring and autumn pulses. Copepods and cladocerans increased in numbers from 1939-1958 (Beeton 1969). Increased oxygen demand in the sediments has resulted in changes in benthic organisms. In western Lake Erie the once dominant Hexagenia has been replaced by oligochaetes and midges (Beeton and Edmondson 1972).

Depletion of oxygen in the hypolimnion of the central basin has been noted since 1929 (Center for Lake Erie Area Research 1974). The action of nitrifying bacteria on sedimented algae and the oxidation of metallic sulfides has reduced the oxygen concentration (Burns and Ross 1971). The anoxic zone nearly doubled in area from 5870 km^2 in 1964 to 11,270 km^2 in 1973 (Center for Lake Erie Area Research 1974).

Primary productivity measures the rate of buildup of organic compounds, the energy of which is transferred to successive trophic levels. The photosynthetic process is responsible for the greater part of this buildup in most environments (Goldman 1963). Estimates of primary productivity for Lake Erie first appear in 1949, when Verduin (1951) measured the rates of CO_2 removal per unit of phytoplankton volume per hour in western Lake Erie. Verduin concentrated phytoplankton by passing lake water through bolting cloth and placed these samples in bottles under an optimal light intensity of 400 foot candles. However, he estimated that about two thirds of the photosynthetic organisms escaped concentration (Verduin 1956). Consequently, since 1957 he has used natural phytoplankton densities and has estimated rates of CO_2 removal in open lake conditions. He found that under these conditions photosynthetic rates exceed those rates obtained from bottle experiments by two times (Verduin 1960 and 1962). For these reasons his more recently published rates of 256 mmol CO_2 [3070 mg C] absorbed per m^2 per day for net photosynthesis and 513 mmol CO_2 [6160 mg C] absorbed per m^2 per day for gross photosynthesis are used for comparison to the results of subsequent studies.

Saunders (1964) reported that the first estimate of primary productivity in Lake Erie with ^{14}C was made at a single station in the western basin in 1957 where estimates of 68.3 mg C/m^3 per day for net and 142.9 mg C/m^3 per day for gross photosynthesis were obtained. He converted these estimates to 97.6 and 371.5 mg C/m^2 per day, respectively, for net and gross daily integral photosynthesis by using a formula derived by Rodhe, Vollenweider, and Nauwerck (Saunders 1964).

Further primary productivity work was not done on Lake Erie until 1968 when Parkos, Olson, and Odlaug (1969) made a one-day cruise along the entire lake. They reported primary productivity estimates for central Lake Erie for the first time. Using the ^{14}C technique and a shipboard incubator (light intensity = 1000 foot candles, temperature = 60°F), Parkos, Olson, and Odlaug (1969) found surface rates of 127.7 mg C/m^3 per hour at one station in the western basin and 42.4-54.7 mg C/m^3 per hour at two stations in the central basin. In 1969 and 1970 Cody (1972), using ^{14}C, found extremely variable rates from 11-5470 mg-atoms C [132-65,640 mg C] per m^2 per day in western Lake Erie during in situ studies at ten stations. Glooschenko et al. (1974) made intensive measurements in Lake Ontario and all three basins of Lake Erie (25 stations) by calibrating a shipboard incubator (light intensity = 8000 lux, temperature = surface water temperature) with simultaneous in situ experiments. Surface water productivity obtained from the incubator for each station was converted to an in situ estimate for the entire water column. Mean values for ten cruises in 1970 were 30-4760 mg C/m^2 per day and 120-1690 mg C/m^2 per day for the western and central basins respectively.

This report includes data for the central and western basins of Lake Erie during July-October 1974. The objectives of the study were to investigate by means of the ^{14}C method and shipboard incubation of samples the vertical, horizontal, and temporal distribution of primary productivity in central and western Lake Erie and to compare data obtained in 1974 with data from previous investigations. Sampling areas were selected from a cruise list prepared by the Center for Lake Erie Area Research at The Ohio State

University. This study was part of the Lake Erie Nutrient Control Program sponsored by the U. S. Environmental Protection Agency (USEPA Grant No. R-802543-02). Five western basin stations and eleven central basin stations were sampled during 26 July - 6 August (Cruise 6), 12 August - 19 August (Cruise 7), 26 August - 7 September (Cruise 8), and 21 October - 1 November (Cruise 10) aboard the R/V Hydra (Figure 1).

Between cruises a location approximately 250 m offshore, south of The Rattles of Rattlesnake Island in western Lake Erie was chosen for *in situ* experiments. Cody (1972) reported ranges of 16.7- 185.4 mg-atoms C [200-2225 mg C] per m^3 per hour, 36.1- 654.9 mg-atoms C [433-7859 mg C] per m^2 per hour, and 240-5470 mg-atoms C [2880-65,640 mg C] per m^2 per day for optimal, integral, and daily integral primary productivity, respectively, at Rattlesnake Island in 1970.

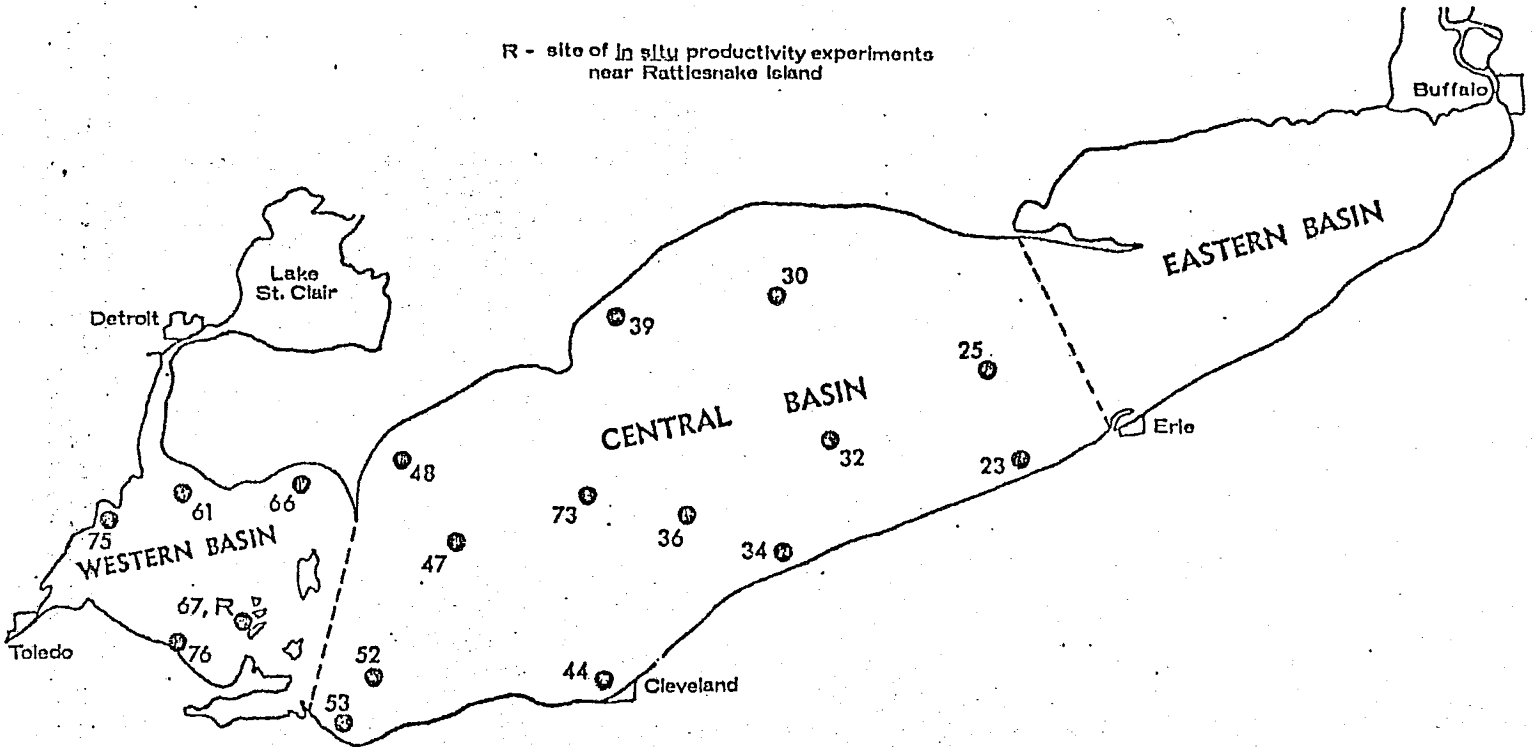

Figure 1. Map of Lake Erie showing station locations in the central and western basins.

METHODS

Physical and Chemical Parameters

At selected stations submarine photometer (G. M. Manufacturing and Instrument Corp. No. 268WA300) readings were taken at one-meter intervals from lake surface to bottom, or until the light meter (microamperes) read zero. The reading made when the photometer was suspended just above the water represented surface light intensity. Samples of lake water were collected from one meter and from a depth of about one percent of the surface light intensity, which represented the lower limit of the euphotic zone. Samples were also collected from intermediate levels (commonly three meters and five meters), depending upon the thickness of the euphotic zone.

Water temperature and pH readings were made at one-meter intervals with a Martek Mark II Model A monitoring system. Total alkalinity was determined with a 100-ml sample and a mixed indicator of bromcresol green and methyl red (APHA 1971). Total alkalinity in thermally stratified areas was determined in samples collected from one meter below the lake surface, one meter above the metalimnion, one meter below the metalimnion, and one meter above lake bottom. Total alkalinity in non-stratified areas was determined in samples collected from one meter below the lake surface, an intermediate depth, and one meter above lake bottom. Total alkalinity for depths sampled for productivity estimates was interpolated where necessary, as frequently productivity sampling depths did not coincide with total alkalinity depths other than at the one-meter level. Secchi disc depth was determined from the shaded side of the research vessel by lowering a 30-cm diameter Secchi disc with alternating black and white quadrants until it just disappeared from sight. The distance from the lake surface to the point of disappearance was taken as the Secchi disc depth.

Sample Preparation

Sample preparation follows the method of Goldman (1963). A sample of lake water, taken with a five-liter Niskin sampling bottle (General Oceanics Inc.), was transferred to 300-ml BOD bottles, two light and one dark for each depth. The dark bottles were wrapped with a double layer of black plastic electrical tape. A layer of aluminum foil covered the tape to prevent heat buildup. Two layers of foil covered the stopper to keep out light. Between cruises both dark and light bottles were washed with concentrated HNO_3 and thoroughly rinsed with tap water with a final rinse of distilled water. The bottles were inverted and air dried.

A fresh stock solution of ^{14}C was prepared daily by combining the contents of ampules of sodium bicarbonate-^{14}C ($NaH^{14}CO_3$) in sterile aqueous solution with pH = 9.5, which was supplied in the amount of 5.0 µCi/5.0 ml per ampule by New England Nuclear Corp. Approximately 1.0 ml of the stock solution was added to each BOD bottle by means of a 2-ml hypodermic syringe (accuracy = ± 5%) with a 15-cm 18-guage needle. The stock solution was added to the bottom of the bottle, and the syringe was rinsed gently with water from the top of the bottle. The activity of the $NaH^{14}CO_3$ added via the syringe was taken to be 1.0 microcurie (2.22×10^6 ± 10% disintegrations per minute) as determined by New England Nuclear Corp.

After innoculation the bottle contents were thoroughly mixed, and the bottles were placed in a shipboard incubator for three to five hours. Light intensity of approximately 9000 lux was provided by a bank of six daytime fluorescent lamps. Surface water was continuously circulated through the incubator. After incubation the bottle contents were mixed, 10 ml of material was removed with a repipet, and 10 ml merthiolate solution (Eli Lilly Solution No. 45) was added to stop further ^{14}C uptake. The bottle contents were thoroughly mixed.

Since the relative activity of the plankton was unknown when experiments were begun, the investigator concentrated as much material as possible from a bottle onto a membrane filter. As more material is added, sample counting time decreases linearly unless the additional material decreases detection of the β-particles emitted from ^{14}C. In areas with high concentrations of suspended particles filter pores clogged within approximately ten minutes. In some areas (e.g., Stations 30, 47, and 73) the entire bottle content was passed through the filter within ten minutes; in other areas (notably Stations 61, 75, and 76) an aliquot was used since the filtration time for the entire content would have exceeded ten minutes. Material from each BOD bottle was vacuum-filtered onto a 25-mm diameter Gelman GA-6 Metricel membrane filter (pore size 0.45 μ). The filtration apparatus aboard the R/V Hydra consisted of a vacuum manifold that held four filter funnels so that the contents of as many as four BOD bottles could be filtered simultaneously. Vacuum pressure did not exceed 300 mm Hg. Since the membrane filters differ in rates of water absorption, all filters were presoaked in distilled water. Presoaking filters decreased filtration time. Once the material had been concentrated on the membrane filter, the filter was rinsed with approximately 25 ml of 0.003 N HCl to remove any ^{14}C that may have accumulated on the surface of the filtered material; a rinse of 25 ml filtered lake water (if available) or distilled water followed. The membrane filter was then attached with household glue to a 32-mm diameter stainless steel planchet. Water retained by the filtered material absorbs the β-particles emitted from ^{14}C, so filters were stored in pillboxes and assayed several weeks later.

Radioassay

Filters were assayed with a thin end-window gas-flow detector (Nuclear Chicago Corp. Model No. D-47); gas composition was approximately 0.9% isobutane in 99.1% helium. Planchets were loaded onto a Nuclear Chicago Corp. Model No. C-110B automatic sample changer. A Nuclear Chicago Corp. Model No. 181A scaler recorded the counts per measurement, and a Nuclear Chicago Corp. Model No. C-111B printing timer recorded the time required for the measurement. A 0.0875 μCi ^{14}C standard source (Radioactive Materials Corp.) was used to calculate counter yield by the formula of Arena (1971, p. 119):

$$Y = cpm/dpm,$$

where Y is counter yield, cpm is observed count rate of the standard (counts per minute), and dpm is the calibrated activity of the standard (disintegrations per minute). Counter yield was 16-17%. Light bottles were counted a minimum of 10,000 counts (± 2.1% probable error at $P = 0.05$) and dark bottles a minimum of 1000 counts (± 6.4% probable error at $P = 0.05$). One thousand counts per measurement for dark bottles was chosen to reduce sample counting time to about ten minutes. The discrepancy between light and dark bottle counting statistics is discussed later.

Primary Productivity Calculation

Incubator productivity was calculated by an expanded formula of Saunders, Trama, and Bachmann (1962) in Appendix I. Dark bottle incubator productivity was subtracted from light bottle incubator productivity to correct for non-photosynthetic uptake of ^{14}C. The corrected incubator productivity (mg $C/m^3 \cdot h$) was converted to integral productivity (mg $C/m^2 \cdot h$) by the relationship reported by Glooschenko et al. (1974):

$$\frac{\text{mg } C/m^2 \cdot h}{\text{mg } C/m^3 \cdot h} = 1.85x,$$

where mg $C/m^2 \cdot h$ is integral productivity, mg $C/m^3 \cdot h$ is incubator productivity, and x is Secchi disc depth in meters; the relationship is solved for mg $C/m^2 \cdot h$. Since the incubator productivity of Glooschenko et al. (1974) is based on a composite sample from one-meter and five-meter depths, incubator productivity from one-meter and five-meter depths in this report were averaged, and the mean value was inserted into the above relationship. Integral productivity was converted to daily integral productivity (mg $C/m^2 \cdot$day) by the method of Glooschenko et al. (1974).

In situ Productivity

Procedure for *in situ* productivity experiments near Rattlesnake Island was similar to the shipboard method except incubation. Photometer readings and Secchi disc depth were determined as previously described. Temperature was measured by means of a YSI Model 51A dissolved oxygen meter equipped with a YSI 5450 probe. Lake water was collected with a three-liter non-metallic Kemmerer water sampling bottle. For the one-meter depth, one intermediate depth, and the bottom sampling depth, pH was measured in the laboratory on South Bass Island within two hours of collection, and total alkalinity was determined within four hours of collection. Upon innoculation with one microcurie of $NaH^{14}CO_3$, one light and one dark bottle were suspended in the lake at the depth from which the water was taken. The incubation apparatus consisted of an anchored nylon line with an attached float on the lake surface. Aluminum strips were tied to the line at the proper depths. The BOD bottles were attached to the strips by shower curtain hooks that fastened to hose clamps at the necks of the bottles. If possible, the samples were fixed when the bottles were retrieved from the line; when the weather was rough, they were fixed at the laboratory approximately half an hour after retrieval. Samples were filtered at the South Bass Island laboratory or aboard the R/V Hydra, and the membrane filters were prepared for gas-flow counting.

In situ primary productivity (mg $C/m^3 \cdot h$) at each sample depth was calculated by the formula in Appendix I. These estimates were then plotted against depth on graph paper. Integral in situ productivity (mg $C/m^2 \cdot h$) was calculated by determining the area beneath the productivity-depth curve with a planimeter.

Correction Factors

The filtered material absorbs energy from the β-particles emitted from ^{14}C and prevents the escape and subsequent detection of some of the particles by counting equipment. Lower sample count rate and, therefore, lower productivity result. An experiment was performed to determine whether this self-absorption of β-particles occurred in filtered material during the 1974 season. Lake water from a depth of one meter in Put-in-Bay Harbor was collected with a Kemmerer water sampling bottle on 5 October. The water was transferred to six clear BOD bottles, and approximately one microcurie of $NaH^{14}CO_3$ was added to each bottle. After the contents were thoroughly mixed, the bottles were incubated approximately four hours in the shipboard incubator. After incubation the contents were fixed as previously described. Aliquots of 25, 50, 75, and 100 ml from each bottle were filtered onto membrane filters as described. Because filtration of the 100-ml aliquots required approximately ten minutes, these volumes were assumed to represent the denser concentrations of material collected over the season. Filters were rinsed and processed for gas-flow counting as in the productivity experiments. Filters were counted 10,000 counts minimum. Sample count rate was corrected to actual ^{14}C uptake (Appendix I, symbol a). Carbon-fourteen uptake (dpm) was divided by aliquot volume (ml) and duration of incubation (h), and the result (dpm/ml per hour) was plotted against aliquot volume.

Strickland and Parsons (1968) stated that the fixative formaldehyde at a concentration of 0.3% by volume may influence the excretion or loss of fixed ^{14}C from the more delicate marine algae. The effect of merthiolate upon sample activity was studied, as merthiolate may also cause ^{14}C loss from phytoplankton. Lake water collected on 16 September from one meter below the surface of Put-in-Bay Harbor was added to six clear 300-ml BOD bottles. About one microcurie $NaH^{14}CO_3$ was added, and the bottles were incubated approximately four hours in the shipboard incubator. Samples were fixed as in the productivity experiments. At intervals of 1, 2, 4, 8, 16, and 24 hours after fixation 50-ml aliquots from each BOD bottle were filtered onto membrane filters. The filters were prepared for gas-flow counting. The experiment was run again on 19 October, and aliquots were filtered at intervals of 0, 1, 2, 4, 8, and 16 hours after fixation. During both experiments bottles were refrigerated after the eight-hour aliquots were removed in order to simulate field conditions when bottles were stored overnight and filtered the next day. Filters were counted 10,000 counts minimum. Graphs of dpm/ml per hour vs. time after fixation were drawn for the twelve bottles.

Relative light intensity in the incubator was measured while the research vessel was docked at Put-in-Bay on 19 September. The incubator was divided into nine horizontal zones, and several photometer readings were taken at each zone to represent light intensity at clear water, mid-lake central basin stations, as the water had been standing for several days. Photometer readings were repeated after the water had been circulated for two hours, which approximated turbid stations. Whether relative light intensity was reduced by use of a clear plexiglass top when the lake was rough was also determined. A mean relative light intensity value for any position in the incubator during each set of conditions was determined by averaging individual measurements at each location in the incubator.

RESULTS AND DISCUSSION

Incubator, integral, and daily integral productivity in 1974 were, respectively, 4.1-124 mg C/m^3 per hour, 16-364 mg C/m^2 per hour, and 140-4370 mg C/m^2 per day for western Lake Erie and 5.1-51.2 mg C/m^3 per hour, 44-242 mg C/m^2 per hour, and 530-2180 mg C/m^2 per day for central Lake Erie (Table 1). Complete results for each depth sampled at the stations are in Appendix II. Results of calculations using Glooschenko's relationship are presented in Table 2.

Maximum incubator productivity in 1974 agrees to within 3% of that reported by Parkos, Olson, and Odlaug (1969) and 16% of the maximum mean productivity per cruise reported by Vollenweider, Munawar, and Stadelmann (1974) for western Lake Erie (Table 1). Maximum central basin incubator productivity in 1974 is 2.4 times greater than the mean productivity per cruise reported by Vollenweider, but the difference may be in the comparison of mean values per cruise to a range of values for the entire season of 1974. Parkos, Olson, and Odlaug (1969) report productivity 7% greater than the maximum incubator productivity found during this study.

Daily integral productivity reported by Saunders (1964) is relatively low when compared with other western basin

Table 1. Comparison of primary productivity measurements in central and western Lake Erie from 1957 - 1974.

Date	Method	Incubation	mg $C/m^3 \cdot h$	mg $C/m^2 . h$	mg $C/m^2 . day$	Source
			Western basin			
1957 - 1962	$pH-CO_2$	natural conditions			net 3,070 gross 6,160	Verduin (1962)
1957 Oct	^{14}C	*in situ*			net 96.7 gross 371.5	Saunders (1964)
1968 July	^{14}C	shipboard	127.7			Parkos, Olson, & Odlaug (1969)
1969 - 1970	^{14}C	*in situ*	13.2 - 2225	18.0 - 7859	132 - 65,640 mean 10,000	Cody (1972)
1970 Apr - Dec	^{14}C	*in situ*, shipboard	4.8 - 146.9^a	5.0 - 397^a	30 - 4,760^a	Vollenweider, Munawar, & Stadelmann (1974)
1974 July - Oct	^{14}C	*in situ*	3.6 - 152	95 - 342		Sheffield (1975)
	^{14}C	shipboard	4.1 - 124^b	16 - 364	140 - 4,370	
			Central basin			
1968 July	^{14}C	shipboard	42.4 - 54.7			Parkos, Olson, & Odlaug (1969)
1970 Apr - Dec	^{14}C	*in situ*, shipboard	5.5 - 21.4^a	17 - 141^a	120 - 1,690^a	Vollenweider, Munawar, & Stadelmann (1974)
1974 July - Oct	^{14}C	shipboard	5.1 - 51.2^b	44 - 242	530 - 2,180	Sheffield (1975)

[a] range of mean values per cruise

[b] range of station means for productivity within euphotic zone

Table 2. Carbon assimilation rates by station and cruise for central and western Lake Erie in 1974.

Date	Station	Mean Incubator Rate[a] (mg $C/m^3 \cdot h$ ± SE)	Integral Rate[b] (mg $C/m^2 \cdot h$)	Daily Integral Rate (mg $C/m^2 \cdot day$)
		Cruise 6		
1 Aug	30	19.8 ± 1.5	130	1560
30 July	47	16.4 ± 1.6	180	2160
4 Aug	48	11.1 ± 1.2	83	1000
27 July	52	20.8 ± 3.3	109	1310
26 July	61	12.4 ± 1.3	37	440
28 July	66	33.0 ± 3.1	194	2330
27 July	67	33.5 ± 1.4	157	1880
30 July	73	17.3 ± 2.2	133	1600
26 July	75	124 ± 6	364	4370
26 July	76	98 ± 2	166	1990
		Cruise 7		
13 Aug	23	8.3 ± 0.9	94	1130
13 Aug	25[c]	5.1 ± 0.4	84	1010
14 Aug	30[d]	8.1 ± 0.9	84	1010
15 Aug	34	10.1 ± 1.0	82	980
15 Aug	36[c]	7.2 ± 1.3	73	880
17 Aug	44	13.6 ± 0.8	124	1490
12 Aug	47	14.0 ± 0.7	154	1850
16 Aug	48	15.7 ± 0.9	135	1620

Table 2. Continued.

Date	Station	Mean Incubator Rate[a] (mg C/m^3·h ± SE)	Integral Rate[b] (mg C/m^2·h)	Daily Integral Rate (mg C/m^2·day)
		Cruise 8		
6 Sept	53	33.3 ± 2.2	44	530
7 Sept	61	30.4 ± 1.1	87	1040
6 Sept	67	31.0 ± 1.6	75	900
7 Sept	75	32.3 ± 2.3	57	680
7 Sept	76	76.8 ± 2.6	85	1020
		Cruise 10		
23 Oct	23	23.1 ± 0.9	87	780
23 Oct	25	14.5 ± 0.5	82	740
26 Oct	30	18.4 ± 1.1	80	720
26 Oct	32	10.9 ± 0.6	69	620
27 Oct	36	18.6 ± 1.0	160	1440
27 Oct	39	17.0 ± 1.2	60	540
29 Oct	44	51.2 ± 1.2	242	2180
21 Oct	47	29.9 ± 1.6	216	1940
28 Oct	48	23.2 ± 0.9	172	1550
30 Oct	53	34.8 ± 0.9	123	1110
1 Nov	61	4.1 ± 0.1	16	140
29 Oct	66	28.1 ± 1.0	136	1220
30 Oct	67	46.0 ± 1.4	141	1270
21 Oct	73	30.3 ± 1.7	223	2010
1 Nov	75	77.6 ± 2.4	171	1540
31 Oct	76	26.4 ± 1.2	73	660

Table 2. Continued

a average of all sample depths

b incubator rates from 1 m and 5 m depths were averaged and the mean value inserted into the relationship found in Glooschenko et al. (1974).

c includes sample from metalimnion

d includes 2 samples from hypolimnion

estimates in Table 1, but this probably is explained by his sampling one site late in the year. The lower limit of Verduin's estimates fall within the daily integral productivity range calculated in 1974. Cody's (1972) mean estimate of 10,000 mg C/m^2 per day is 2.3 times greater than the maximum daily integral productivity in the western basin in 1974.

Central Lake Erie incubator productivity for late July averaged 1.7 times mid-August values and 0.7 times late October values (Table 3). Nutrient release upon fall overturn (Gächter, Vollenweider, and Glooschenko 1974) probably resulted in the October maximum. Mean incubator productivity for western Lake Erie decreased from late July to late October with the July value being 1.4 and 1.6 times greater than September and October values, respectively. Integral productivity for central Lake Erie followed the trend of incubator productivity with the late July value being 1.2 times the August value and 0.9 times the October value. Western Lake Erie integral productivity in July was 2.4 and 1.7 times September and October integral productivity, respectively.

Horizontal distribution of incubator productivity follows that of previous investigators. Parkos, Olson, and Odlaug (1969) and Glooschenko et al. (1974) report a west to east gradient in Lake Erie with the highest productivity in the western end. A north to south gradient in both basins

Table 3. Mean productivity by basin from July - October 1974.

No. of Stations	Basin	Incubator Productivity (mg C/m^3·h ± SE)	Integral Productivity (mg C/m^2.h)	Daily Integral Productivity (mg C/m^2·day)
		Cruise 6		
5	central	17.1 ± 1.7	127	1530
5	western	60 ± 22	184	2200
		Cruise 7		
8	central	10.2 ± 1.3	104	1250
		Cruise 8		
4	western	42.6 ± 11.4	76	910
		Cruise 10		
11	central	24.7 ± 3.4	138	1240
5	western	36.4 ± 12.3	107	960

during 1970 (Glooschenko et al. 1974) is not quite as evident during 1974. The maximum productivity in mid-summer in western Lake Erie reported by Glooschenko occurred in 1974. However, upon examination of his monthly distribution maps (Glooschenko et al. 1974, Fig. 6), one finds that the estimates of 124 mg $C/m^3 \cdot h$ and 98 mg $C/m^3 \cdot h$ reported in July 1974 for Stations 75 and 76 are nearly double those reported for the summer 1970.

Results of three in situ experiments near Rattlesnake Island show that when productivity (mg $C/m^3 \cdot h$) is plotted against relative light intensity (microamperes), three distinct curves result (Figure 2). Primary productivity on 10 September remained linear through a relative light intensity at least 2.5 times greater than that for 21 July and 6 October. In October, when surface light intensity and water temperature are lower, phytoplankton survive at lower light intensities than in July and September. Primary productivity in October leveled off more rapidly than in July and September.

For each of the three in situ experiments the primary productivity vs. depth curve has a slope similar to its corresponding light transmission curve (Figure 3). Maximum productivity occurred at approximately one meter. Cody (1972) reported maximal productivity in western Lake Erie from one to three meters and rarely at depths shallower than one meter.

For a series of increasing volumes of filtered phyto-

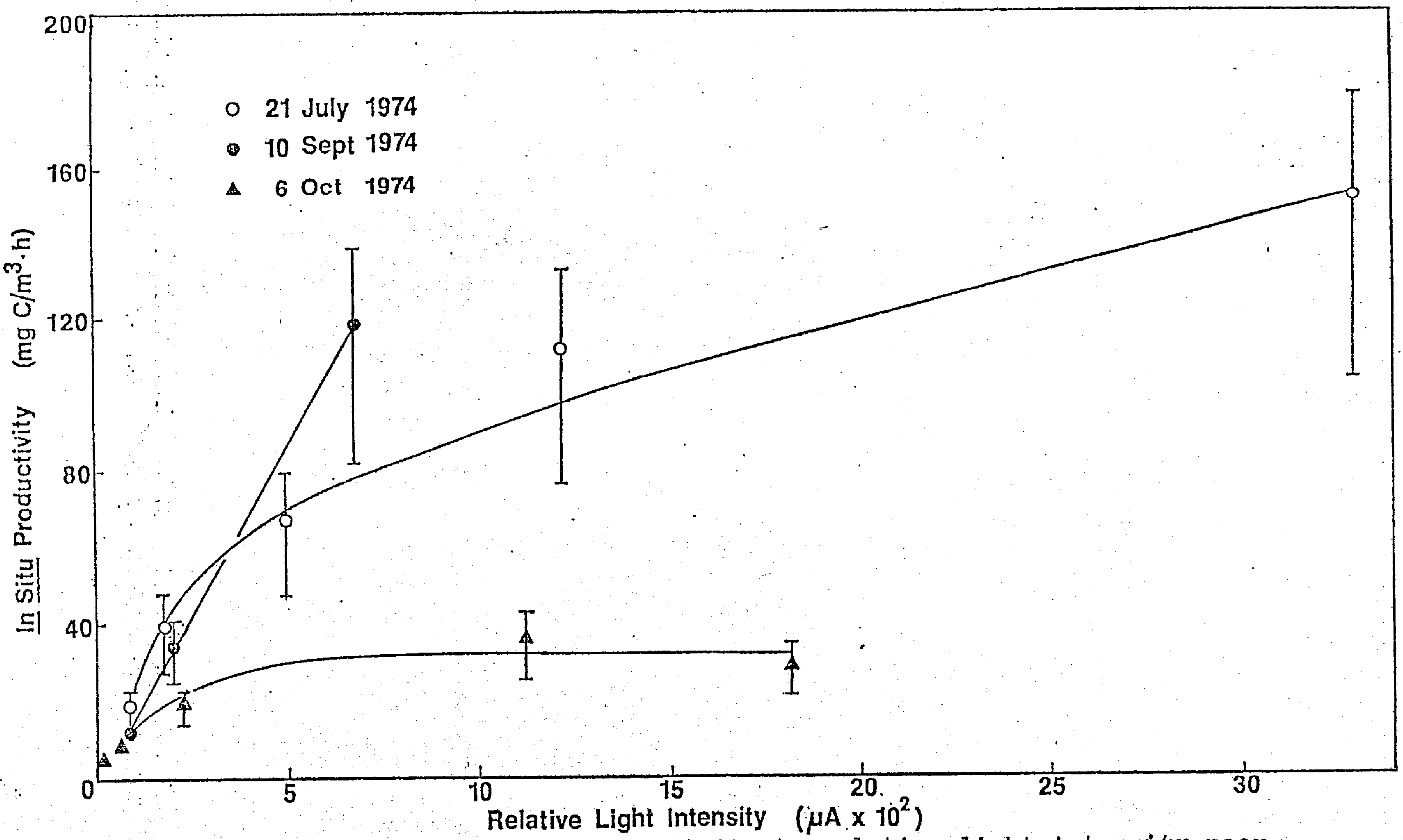

Figure 2. Relationship of <u>in situ</u> productivity to relative light intensity near Rattlesnake Island.

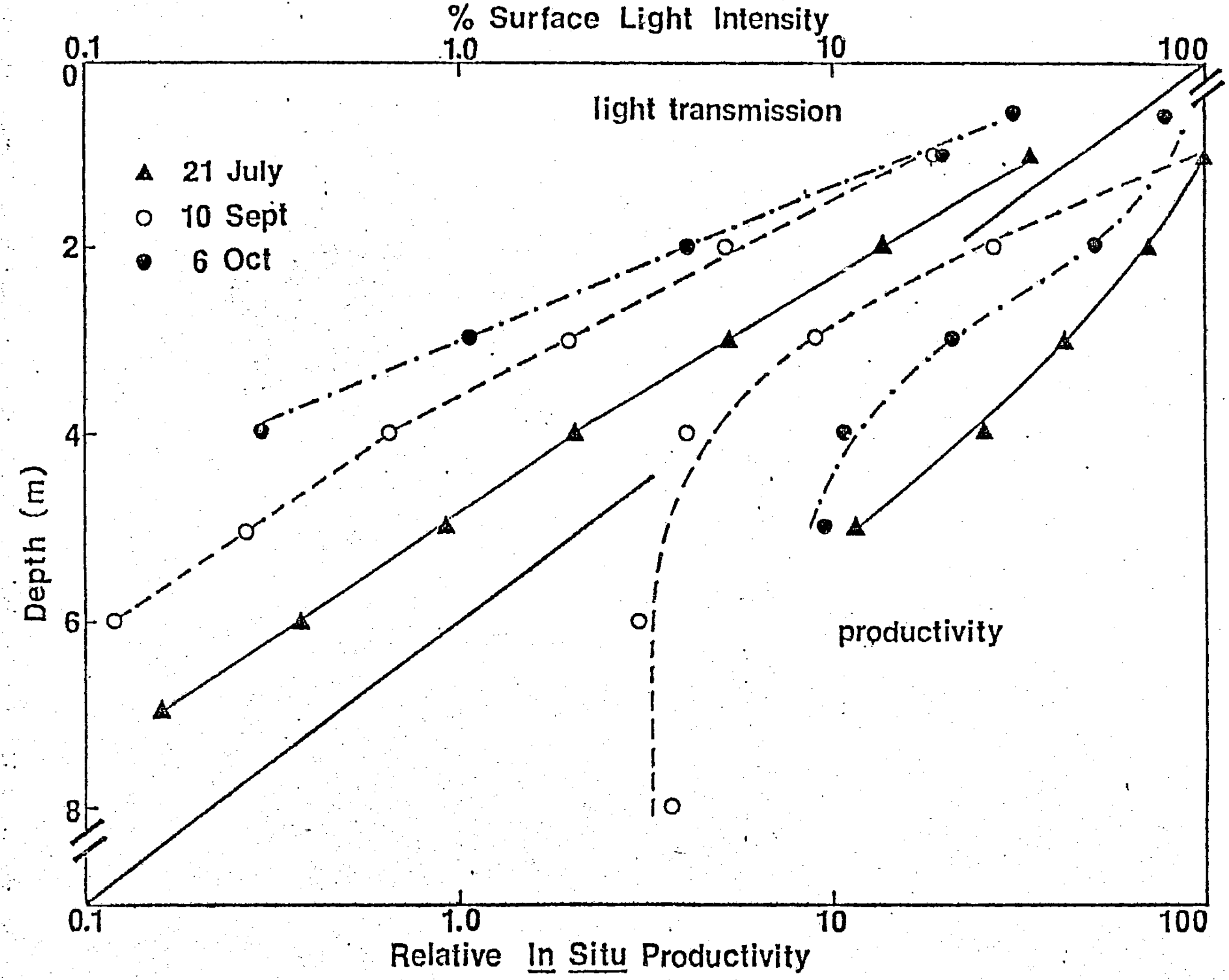

Figure 3. Relationship of relative *in situ* productivity and light transmission to depth near Rattlesnake Island.

plankton, self-absorption of β-particles from ^{14}C exists if a decrease in dpm/ml per hour occurs. Results of the self-absorption experiment (Figure 4) indicate that there was no decrease in dpm/ml per hour, although results from individual bottles varied. No correction of sample count rate was made on the basis of this evidence.

Effect of merthiolate fixation on sample activity experiments indicate that loss of activity occurs non-linearly for approximately the first eight hours (Figure 5). Approximately 14% loss occurs during the first four hours, another five to seven percent during the next four hours, and about four percent during eight additional hours. On the average, approximately 21% of the original activity is lost per sample within eight hours after fixation. Again individual bottles vary in loss rates. Hourly loss rates become similar after eight hours.

Relative incubator light intensity in clear water averaged 900 μA (range of 775-1075 μA) and 775 μA (range of 675-975 μA) in turbid water. When the clear plexiglass top covered the top of the incubator during rough weather, relative light intensity in clear water was reduced from 900 to 825 μA (range of 725-925 μA), a reduction of 9%. Since no records were kept of the horizontal position of the bottles in the incubator, no correction was applied to the carbon assimilation rates.

The estimated average range of total error of a single productivity measurement determined by the methodology pre-

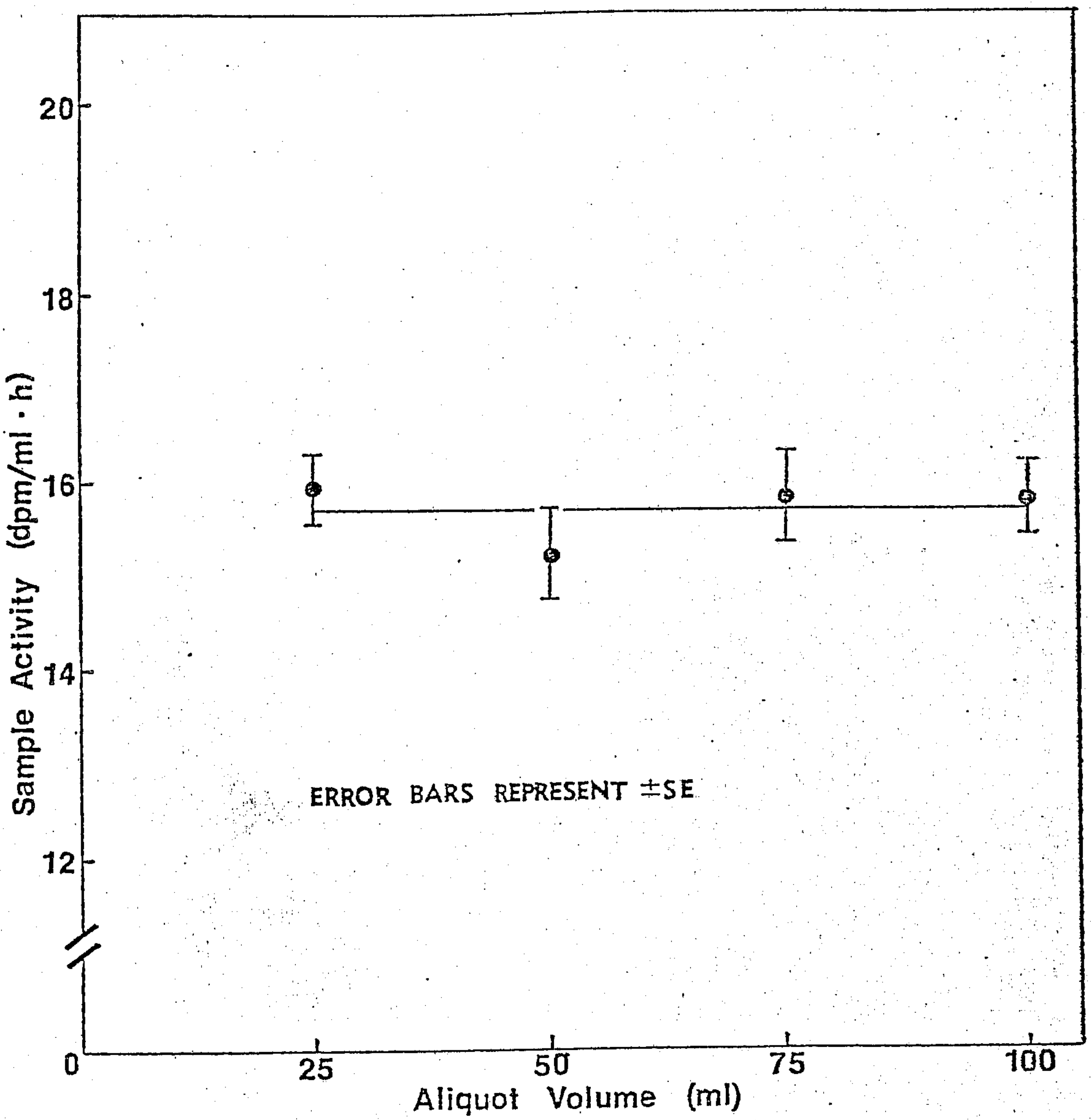

Figure 4. Relationship of sample activity to aliquot volume.

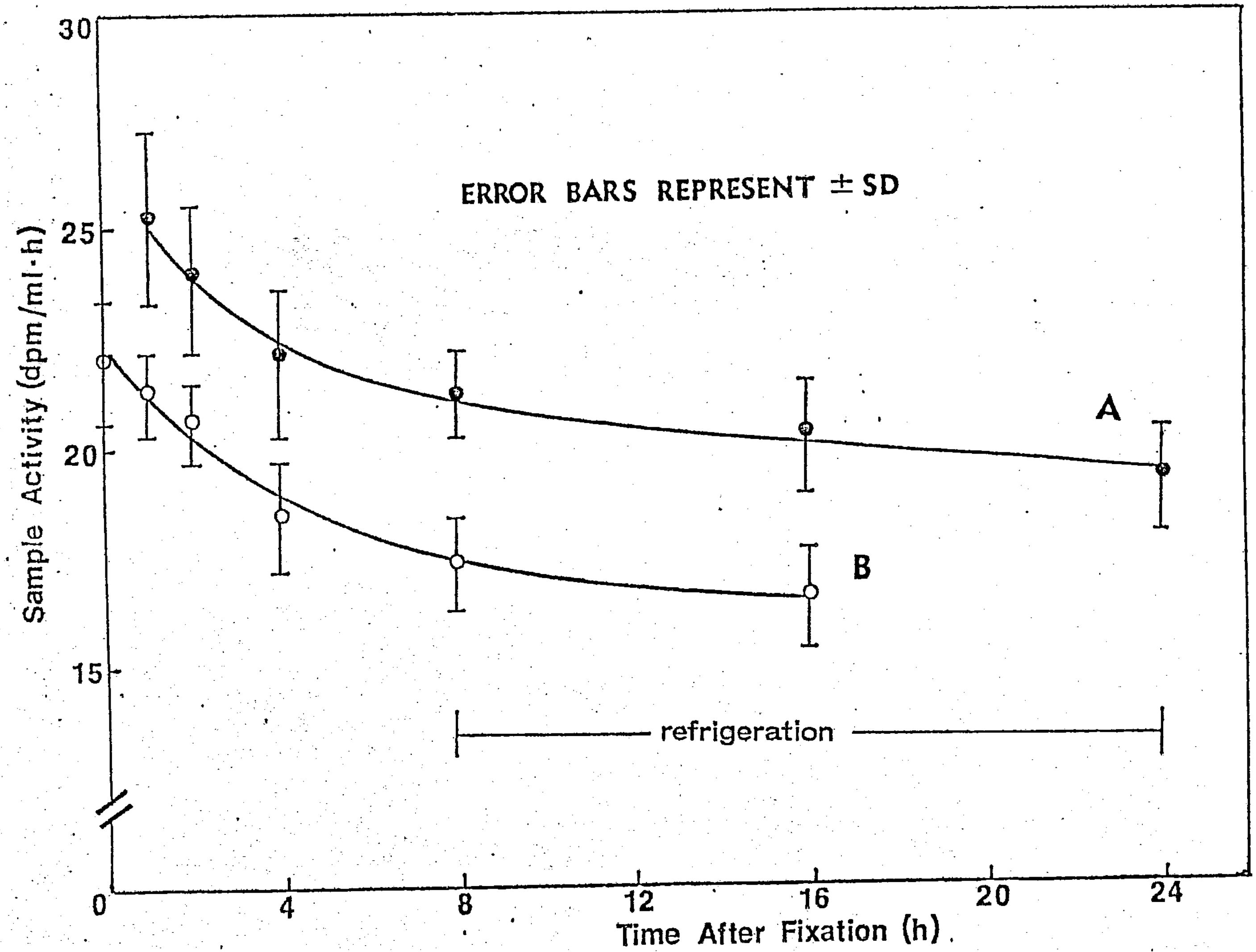

Figure 5. Relationship of sample activity to time after fixation.

sented in this report is +18% to -32%. Counting statistics, syringe calibration, ampule activity calibration, and fixation effects were factors considered. Dark bottle ^{14}C uptake and light bottle ^{14}C uptake can both be expressed in relative units in which light bottle uptake equals 100 and dark bottle uptake its corresponding percentage. From such consideration the relative dark uptake (49%) that yields the greatest uncertainty to the net sample count rate contributes a total probable error in counting statistics of 10% ($P = 0.05$). Mean relative dark bottle uptake of 14% ($n = 182$) yields a probable error of 3% ($P = 0.05$), and thus the mean probable error caused by counting statistics alone is ±3%. Syringe accuracy contributes ±5% error. Accuracy of ampule calibration by New England Nuclear Corp. as determined by ampule lables and technical information is assumed to be ±10% of the stated value of 5.0 µCi per 5.0 ml [1.0 µCi/1.0 ml] aqueous solution. Samples were assumed to have been filtered within four hours after fixation. Therefore, samples lost 14% of their original activity (Figure 5, curve B). This estimate is probably conservative since filtration of some samples was not completed for at least 24 hours. No accurate records were kept of the time between sample fixation and filtration, as the fixation effect was not discovered until about two-thirds through the sampling season. For this reason primary productivity measurements remain uncorrected for sample activity loss. The fixation effect contributes the greatest uncertainty to the methodology used during this study.

Agreement between duplicate light bottles (n=183 pairs) averaged 21% ± 2% (SE)for all samples over the entire season. This measured valued falls within the predicted range of +18% to -32%. Saunders, Trama, and Bachmann (1962) reported that ±20% is the normally accepted error for estimates of photosynthesis. The positive side of the estimated error for 1974 is 10% less than Saunders' figure, while the negative side is 60% greater, since sample fixation causes loss in addition to the three other sources of error considered. The amount of error introduced by the relationship of Glooschenko et al. (1974) is unknown. Error bars in figures accompanying the text represent the estimated error of +18% to -32% unless otherwise indicated.

Graphs of the vertical distribution of incubator productivity within the euphotic zone reveal that the wide range of error may reduce productivity maxima and minima of raw data. For example, the graph of incubator productivity vs. depth for Station 47 on 30 July (Figure 6) shows that peaks at 1 m, 5 m, and 14 m reduce to a small increase (approximately 20%) from 1 m to a plateau at about 7 m. Superficially, a doubling of incubator productivity is observed from 2 m to 5 m and from 7 m to 14 m. Vertical profiles where maximum productivity was ≥ 1.32 times the minimum productivity were compared. Maximum to minimum productivity ratios ≥ 1.32 were considered significant, since -32% was the average maximum

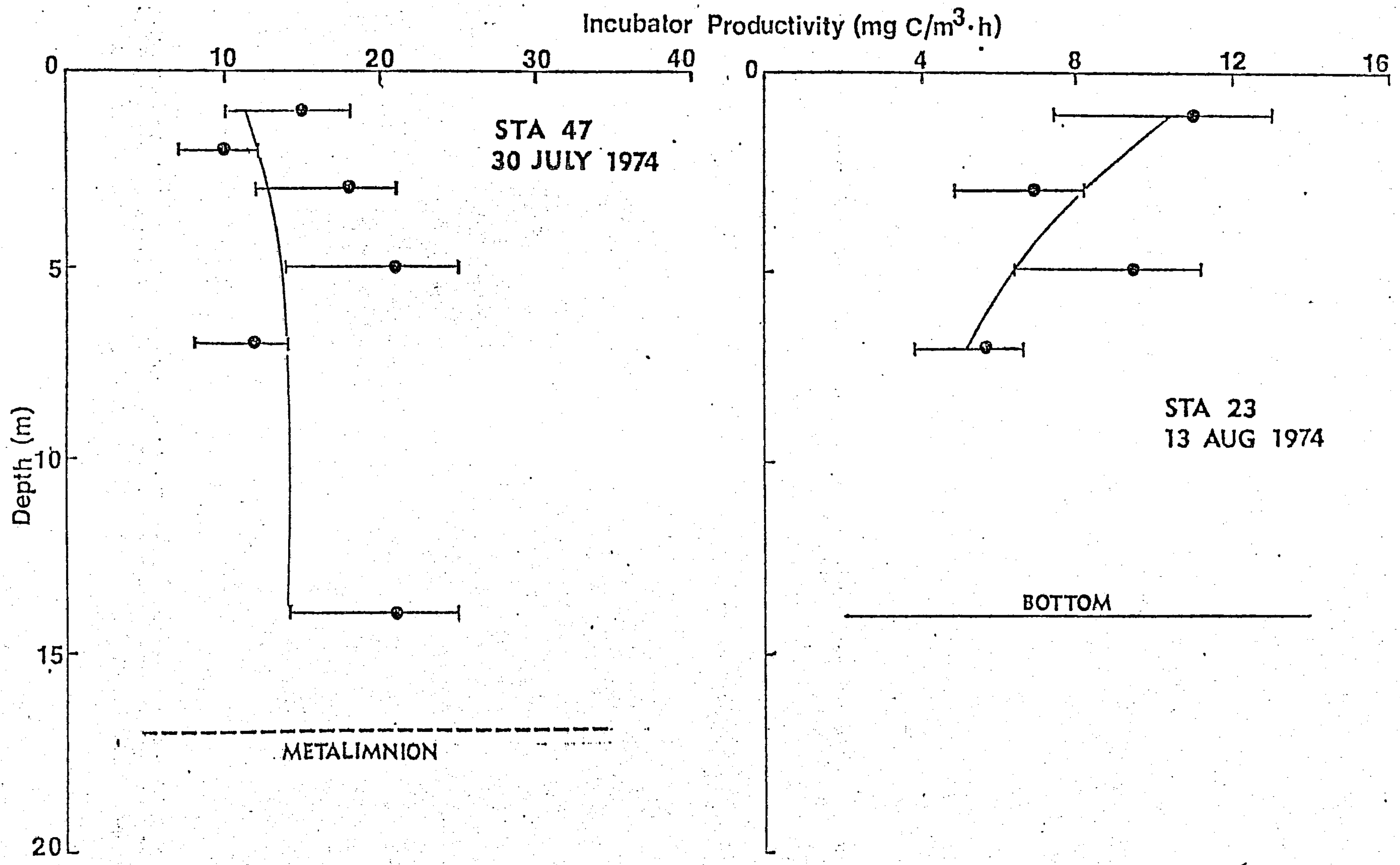

Figure 6. Vertical profile of incubator productivity at Station 47 on 30 July 1974 and Station 23 on 13 August 1974.

error involved in making the productivity estimates. The number of significant productivity profiles was 15 of 39 or 38% of the total incubator productivity experiments.

Central Lake Erie incubator productivity profiles had a wider range of carbon fixation rates than western Lake Erie profiles. Maximum productivity to minimum productivity ratios for central Lake Erie averaged 1.80, 1.83, and 1.17 for early August, mid-August, and late October, respectively. Western Lake Erie ratios averaged 1.33, 1.16, and 1.07 for late July, early September, and late October, respectively. For central Lake Erie at Station 23 during both mid-August and late October maximum productivity at 1 m decreased with depth (Figure 6). The profile at Station 25 in mid-August showed increasing productivity from about 5 m to a plateau at 15 m to the bottom of the euphotic zone at 18 m (Figure 7). For Station 30 in early August incubator productivity increased linearly from 1 m to 11.5 m (Figure 7); in mid-August productivity remained the same from 1 m to 4 m, where it increased and reached a plateau at 15 m in the metalimnion (Figure 8). Station 34 in mid-August had a profile similar to Station 30 in Figure 8, although the euphotic zone extended to only 11 m. Station 36 in mid-August had a nearly linear profile similar to Station 30 (Figure 7) except it started at 3m. Station 39 in late October had minimum productivity at 5 m which increased at 7 m to nearly the level at 1 m (Figure 8). Productivity at Station 48 in

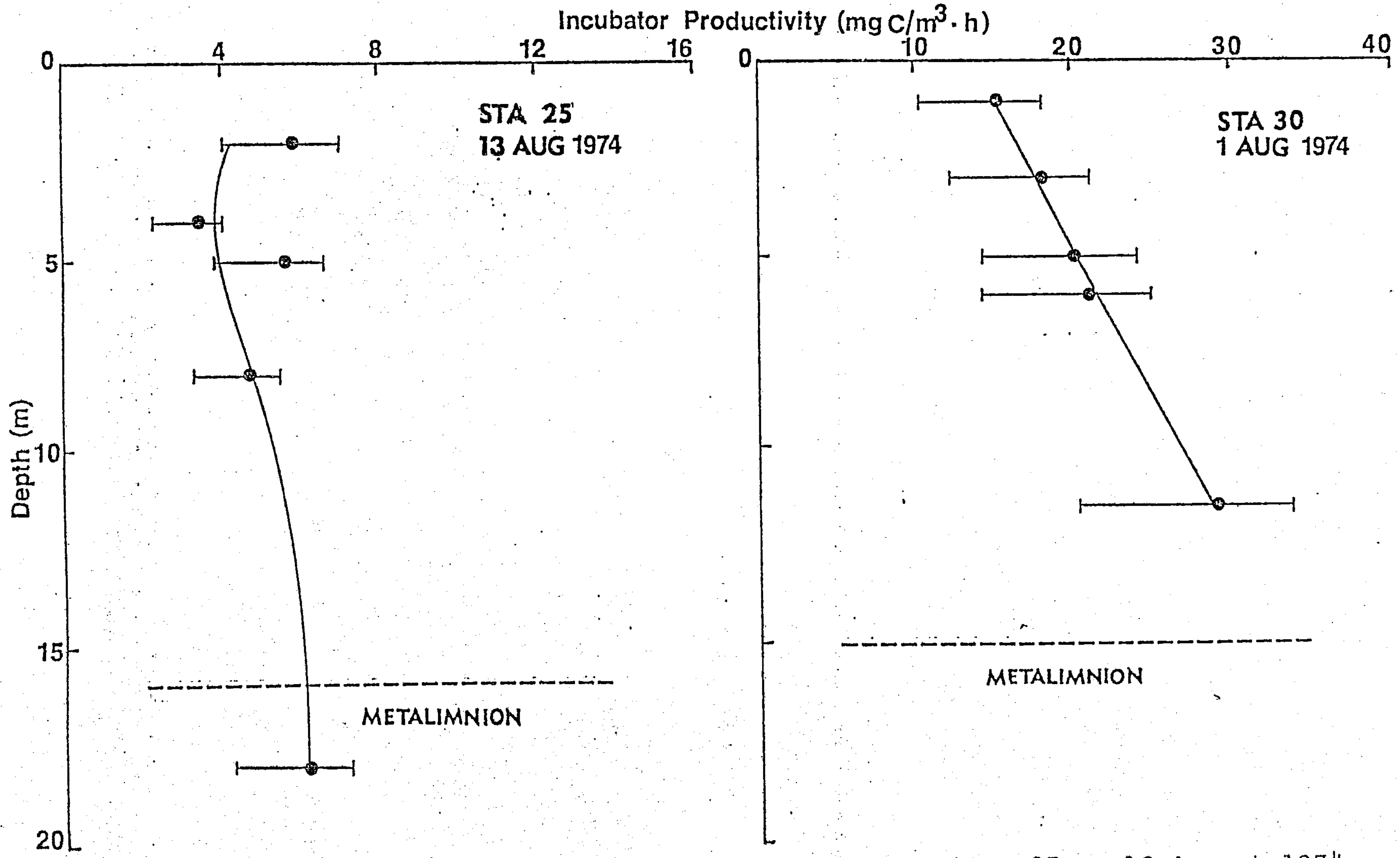

Figure 7. Vertical profile of incubator productivity at Station 25 on 13 August 1974 and Station 30 on 1 August 1974.

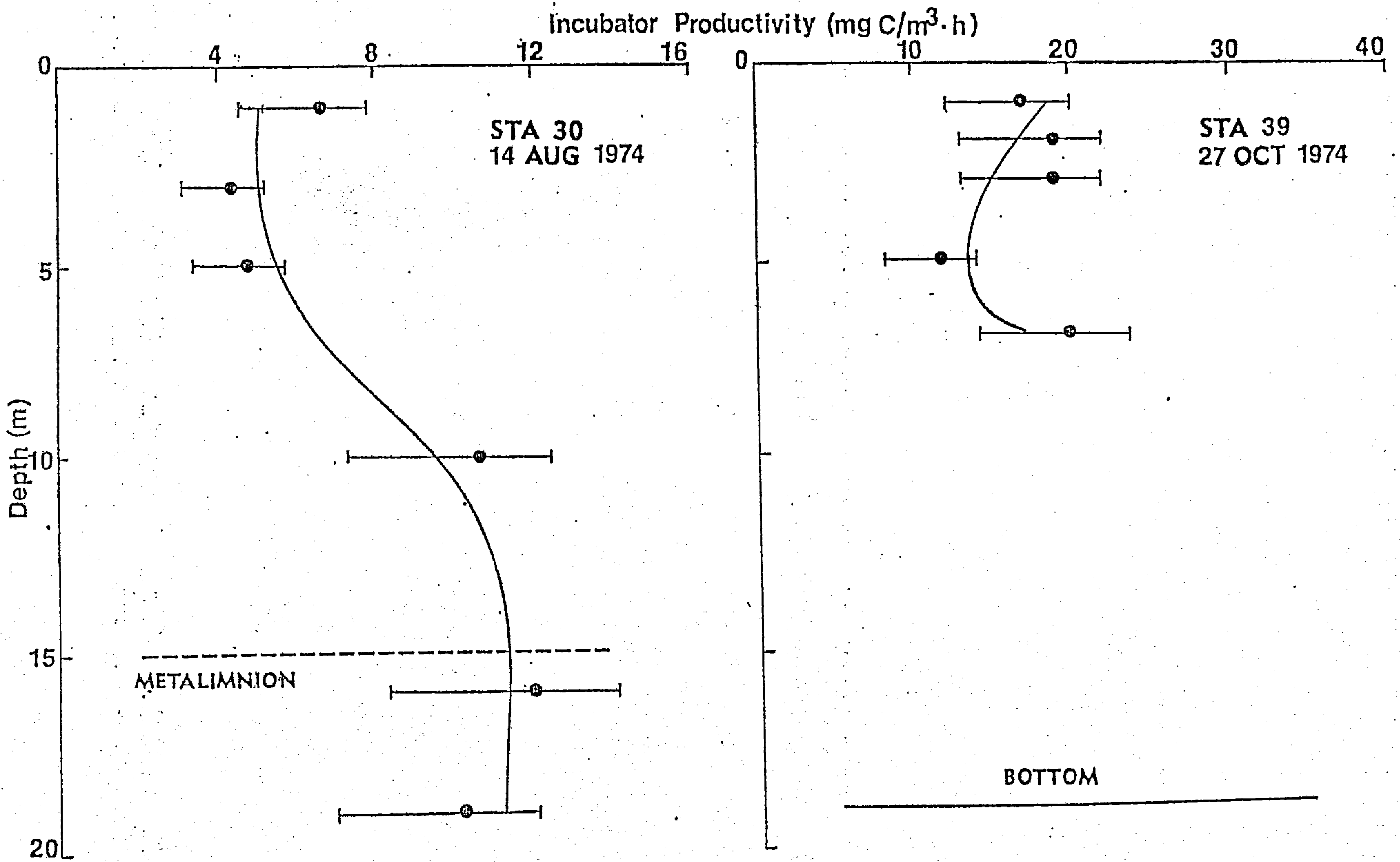

Figure 8. Vertical profile of incubator productivity at Station 30 on 14 August 1974 and Station 39 on 27 October 1974.

early August had a maximum at 4 m and decreased to nearly the same level as at 1 m (Figure 9); in mid-August productivity remained nearly the same for the first five meters, increased slightly at 9 m, and it decreased to a minimum level at 13 m (Figure 9). Productivity at Station 52 in late July had a sharply defined maximum at 3 m (Figure 10). Station 73 in early August showed minimum productivity at 1 m (Figure 10). In mid-lake areas phytoplankton accumulated in the lower epilimnion and metalimnion. Station 30 (Figures 7 and 8) showed this trend in incubator productivity profiles. The profile for 14 August is supported by chlorophyll _a_ (uncorrected) data (Table 4). Productivity at Station 36 on 15 August showed a marked increase toward the metalimnion (see text p. 33). However, chlorophyll _a_ concentration and productivity do not agree.

Table 4. Vertical distribution of uncorrected chlorophyll _a_ concentration at Stations 30 and 36 in August 1974.

Station 30 Depth (m)	14 August Concentration (mg/m^3)	Station 36 Depth (m)	15 August Concentration (mg/m^3)
1	2.7	1	3.9
14	3.9	16	3.9
16	3.8	19	3.6
20	3.5	23	5.5

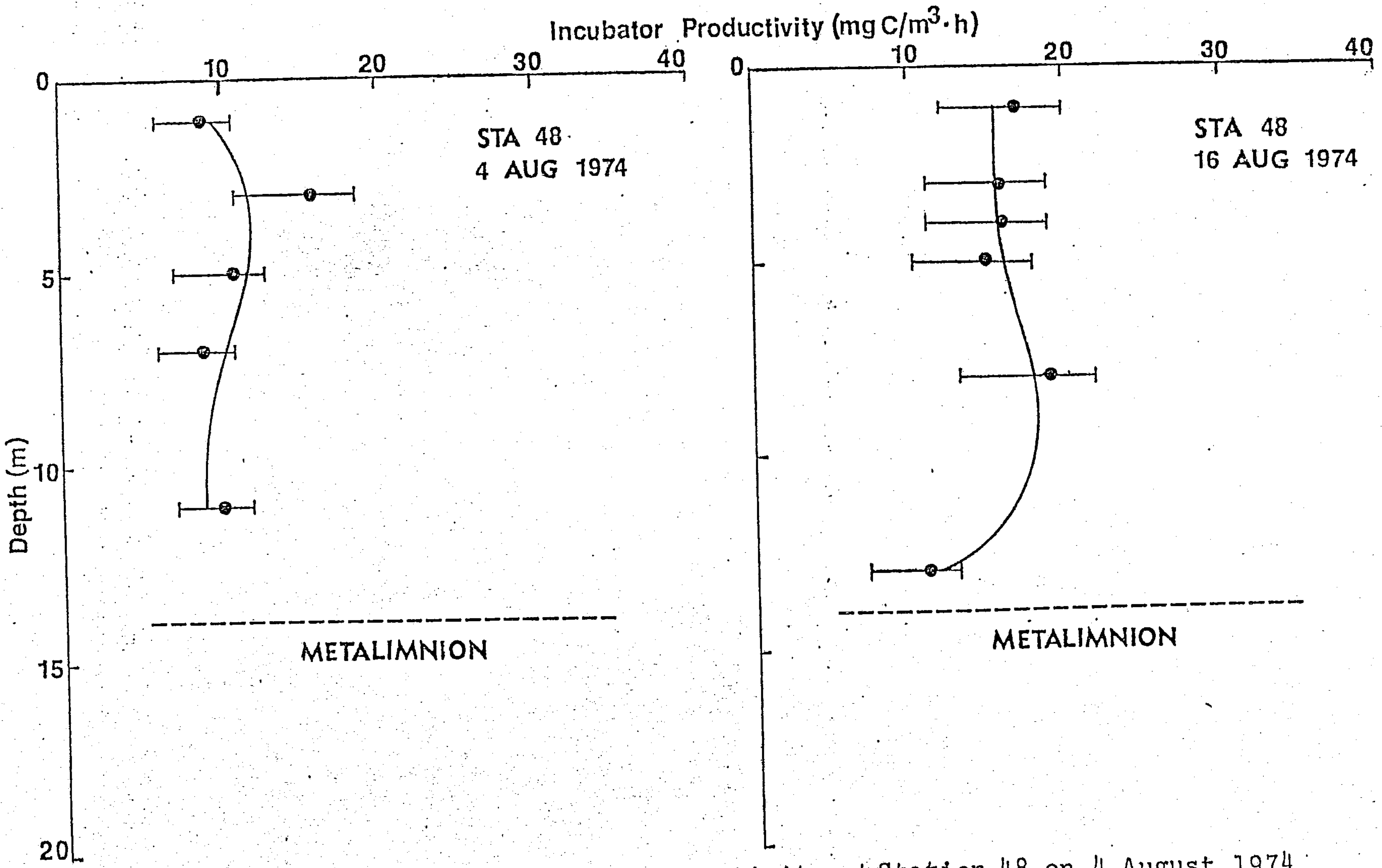

Figure 9. Vertical profile of incubator productivity at Station 48 on 4 August 1974 and 16 August 1974.

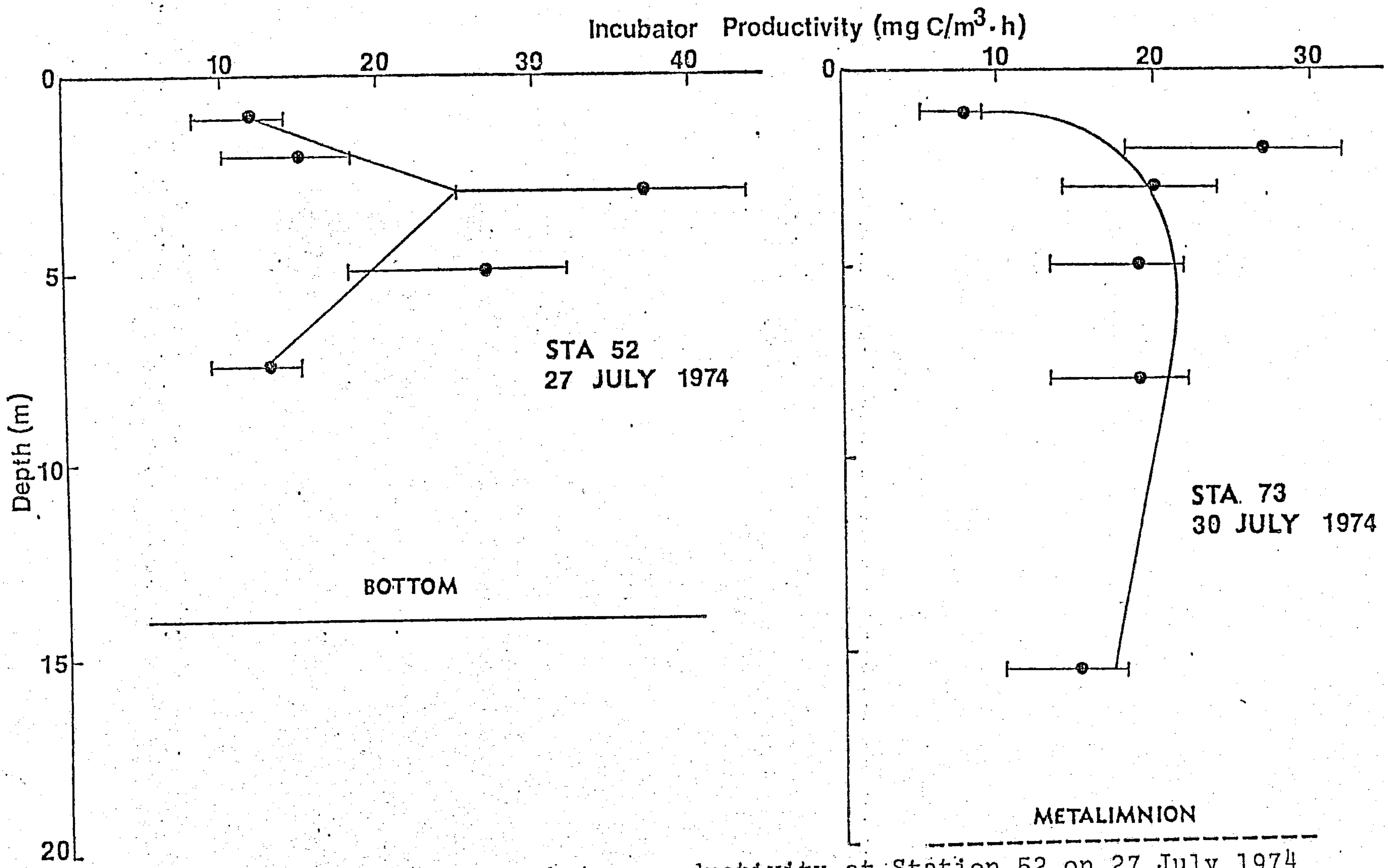

Figure 10. Vertical profile of incubator productivity at Station 52 on 27 July 1974 and Station 73 on 30 July 1974.

In western Lake Erie productivity increased linearly with depth at Station 61 in late July similar to Station 30 in Figure 7. Productivity at Station 66 in late July had a profile similar to Station 52 (Figure 10) with a maximum at 5 m, but the maximum was not quite as sharply defined. Productivity at Station 75 in early September resembled Station 30 (Figure 7) although the increase was not quite linear.

Central Lake Erie showed higher relative dark bottle ^{14}C uptake (dark bottle activity expressed as percent of the corresponding light bottle activity) than western Lake Erie. Central basin mean dark uptake increased during thermal stratification from 18% in early August to 24% in mid-August and decreased after fall overturn to 12% in late October. Relative dark uptake ranged from 3-34% and 3-58% for early and mid-August, respectively. Relative dark uptake of 560% and 630% at Station 23 on 13 August and 77% at Station 73 on 30 July is considered aberrant and unexplainable. Western Lake Erie relative dark uptake remained at the same levels throughout the season, as mean rates were 6%, 8%, and 7% (excluding Station 61) for late July, early September, and late October, respectively. The mean relative dark uptake for all samples during the season was 14%. For incubator studies in the eastern tropical Pacific Ocean, Jones, Thomas, and Haxo (1958) reported relative dark ^{14}C uptake of 16-22% for productivity experiments lasting four to eight hours. Larson (1972) reported relative dark uptake from 4-70% during in situ productivity studies in Crater Lake. Relative dark ^{14}C uptake of 6% has been obtained in western Lake Erie (J. Verduin, personal communication); the western basin values found in 1974 agree with this estimate. Obviously, higher relative dark uptake drastically reduces light bottle uptake when corrected by subtraction.

Primary productivity at one meter in central and western Lake Erie during 1974 showed high correlation (r = 0.92) with uncorrected chlorophyll a concentration, which is a phytoplankton biomass indicator (Figure 11). The correlation exceeds by three-fourths one reported by Glooschenko et al. (1974) for mean values per cruise of chlorophyll a and incubator productivity in surface water in all three basins. Glooschenko et al. called the slope of the graph the assimilation number, the units of which are mg C/mg chlorophyll a·h. Glooschenko's mean assimilation number of 1.93 mg C/mg chlorophyll a·h agreed to within 10% of that for 1974.

The relationship between incubator primary productivity and nutrient concentration in central and western Lake Erie during 1974 is not clear. From the concentrations of total and soluble reactive phosphorus and total inorganic, ammonia, and nitrate-nitrite nitrogen in the two basins (Center for Lake Erie Area Research, unpublished) only total phosphorus correlated with incubator productivity (r = 0.68) for lake water samples from the one meter depth (Figure 12). Brydges

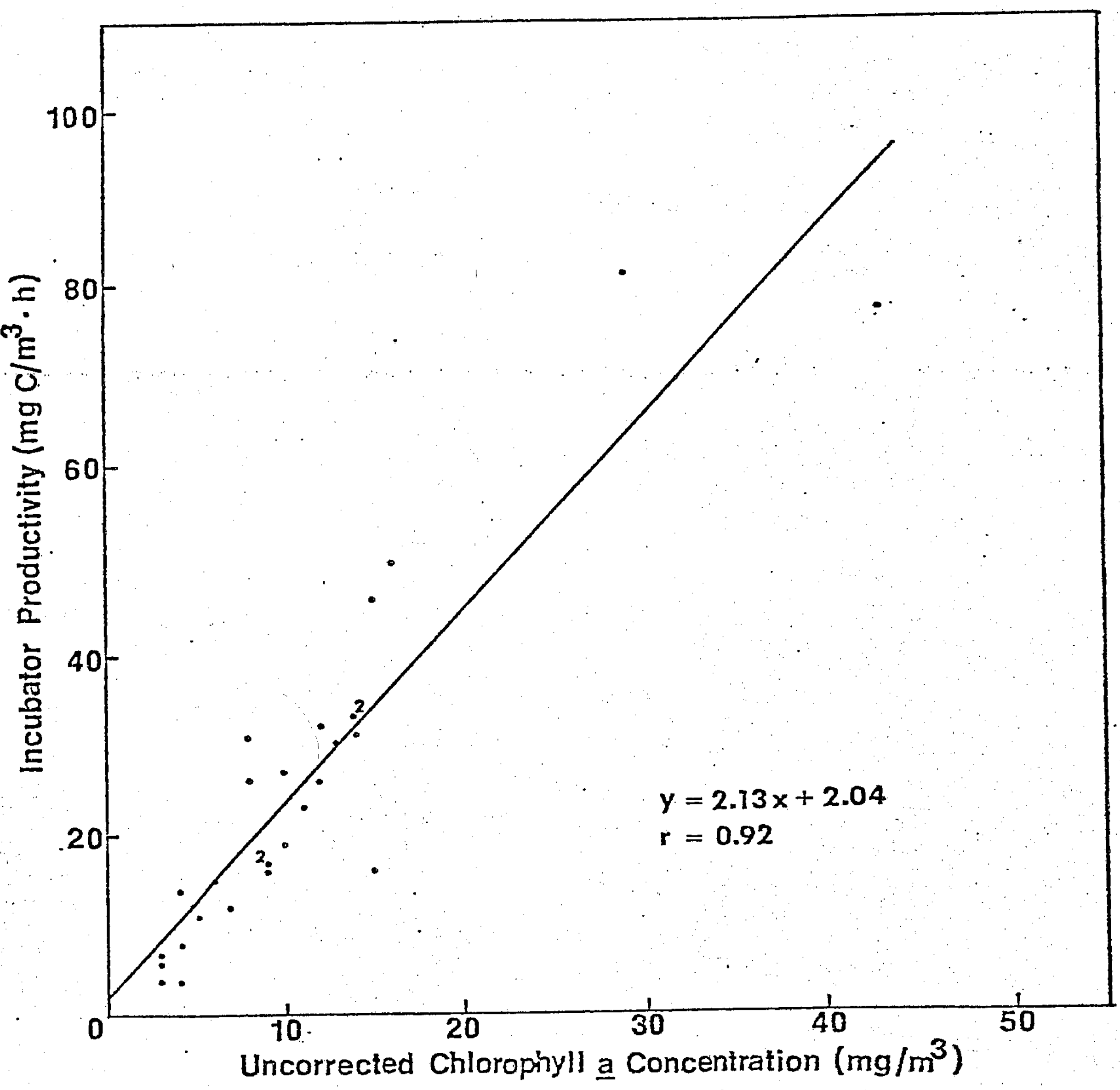

Figure 11. Relationship of incubator productivity to uncorrected chlorophyll a concentration at 1 m depth.

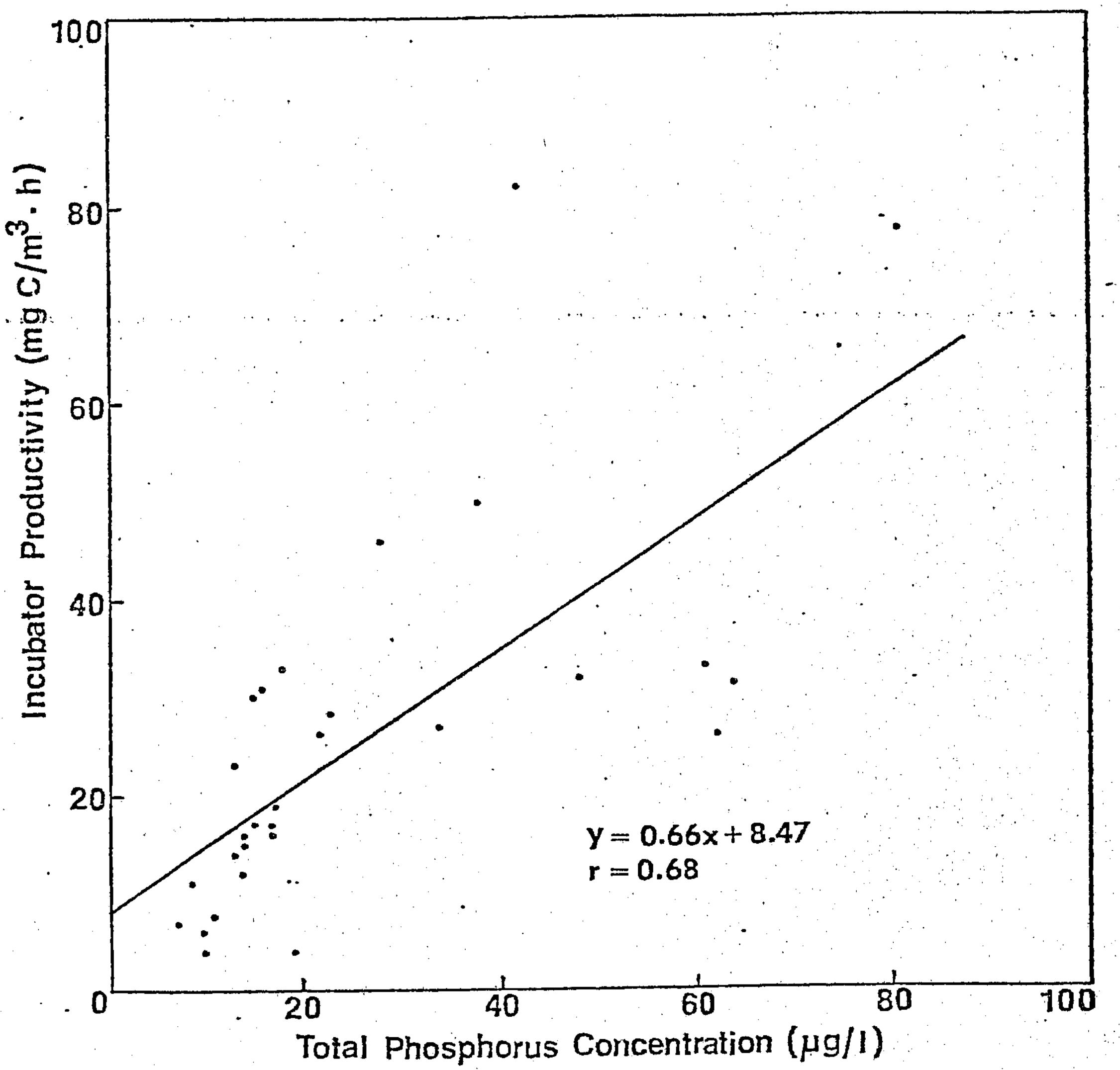

Figure 12. Relationship of incubator productivity to total phosphorus concentration at 1 m depth.

(1971) found that in western Lake Erie station averages of chlorophyll a from a composite sample of 1.5 m and 7.5 m water were positively correlated with total phosphorus at 1.5 m for the years 1967-1969. Megard (1972) reported that for eutrophic Lake Minnetonka, Minnesota total phosphorus in the range of 0-170 mg/m^3 (µg/l) was linearly correlated with daily maximum photosynthesis per unit volume of water during the months of July, August, September. Brydges (1971) also found that soluble phosphorus, nitrate-nitrite nitrogen, and ammonia nitrogen did not correlate with chlorophyll a.

Light energy penetrating the surface waters in central Lake Erie was transmitted more readily than in western Lake Erie during thermal stratification in August (Table 5). The mean euphotic zone in central Lake Erie was 2.4 times deeper than in western Lake Erie. In mid-August light transmission improved slightly. Upon lake overturn the euphotic zone in central Lake Erie was only 30% deeper than in western Lake Erie. Verduin (1954) reported that dissolved pigments have not been observed in western Lake Erie, and that differences in light transmission were attributable to suspended particles. The same is assumed for central Lake Erie.

Incubator productivity represents maximal carbon assimilation rates that result from optimal light intensities. A rough approximation of incubator light intensity assumes that full light intensity measured by the photometer (10.5 mA)

Table 5. Mean Secchi disc and euphotic zone depths for central and western Lake Erie from July - October 1974.

No. of Stations	Basin	Secchi disc (m)	Euphotic Zone (m)
		Cruise 6	
5	central	4.5	12.0
5	western	2.0	5.0
		Cruise 7	
8	central	6.0	14.5
		Cruise 8	
4	western	1.0	3.5
		Cruise 10	
11	central	3.0	8.0
5	western	2.0	6.0

equals 10,000 foot candles (Saunders, Trama, and Bachmann 1962) during the brightest days. Therefore, since an average of 0.9 mA of relative light intensity reaches the tops of the bottles in the incubator under clear water conditions, approximate light intensity is 9000 lux. Talling (1966) stated that the light-saturating range of Asterionella communities in English lakes is 8000-10,000 lux. Talling (1966), using an incubator equipped with daylight fluorescent lamps, converted incubator light intensity to quantity of photosynthetically active radiant energy (400-700 nm) by the conversion factor of 4.1 kerg/cm^2 per sec per kilolux. Therefore, 37 kerg/cm^2 per sec (9 x 4.1) approximates the radiant energy received by phytoplankton samples in the incubator during the 1974 study. If the areal and time units are changed to m^2 and h, respectively, the resulting radiant energy of approximately 1 x 10^{12} erg/m^2 per hour falls near the maximum carbon uptake rates on the light-saturated portions of photosynthesis-light intensity curves published by Stadelmann, Moore, and Pickett (1974) for Lake Ontario phytoplankton communities.

Photosynthetic productivity per unit volume of water reflects phytoplankton densities in the water column at a particular depth, but the relationship is not a simple one to one correspondence. Talling (1966) for English lakes found a broad correlation from April to June between population density (cell number) and gross photosynthetic rate specific photosynthesis of *Asterionella* populations increased during periods of population decline, and higher specific photosynthesis was found at times of lower cell concentration and active cell division. Another complication is that net specific photosynthesis per unit volume of phytoplankton increases with decreasing phytoplankton volume per liter of water (Verduin 1960). Rodhe (1958), using ^{14}C, reported that nannoplankton contributed a greater share of the primary productivity per standing crop of phytoplankton than did net-plankton. Primary productivity per unit volume of water is the product of the specific photosynthetic rate $\frac{\text{mg C/m}^3\cdot\text{h}}{\text{mg chlor } \underline{a}\text{/m}^3}$ and the phytoplankton density [mg chlor *a*/m^3] (Megard 1972). For these reasons incubator productivity is a metabolic index of population density as Saunders, Trama, and Bachmann (1962) believed when they exposed samples from different depths to a light intensity of 500 foot candles. The strong correlation between incubator productivity and chlorophyll *a* concentration at the one meter depth in 1974 emphasizes their contention.

Both incubator and *in situ* productivity data for 1974 remain uncorrected for excretion of organic matter, respiration losses, and grazing because they were not quantified by experiment. Excretion of organic compounds may cause significant underestimation of productivity. Fogg, Nalewajko, and Watt (1965) found that during a four-hour experiment approximately 34% of the initially assimilated ^{14}C was excreted by diatom dominated communities in English lakes. With the ^{14}C technique no way exists to measure loss of $^{14}CO_2$ during breakdown of organic compounds in respiration (Kiefer et al. 1972). The reaction involved is:

$$*CH_2O + O_2 \longrightarrow *CO_2 + H_2O.$$

Signficiant grazing of phytoplankton standing crop may reduce productivity. Parkos, Olson, and Odlaug (1969) felt that grazing may be important in localized areas of lakes but should not cause the large variations in productivity they observed in each of the four Great Lakes they investigated. Verduin (1952) felt that grazing was insignificant in western Lake Erie. Glooschenko, Moore, and Vollenweider (1974) felt that the zooplankton in Lake Erie, which are characterized by protozoans, rotifers, and cladocerans, consume detritus and bacteria more than phytoplankton.

For the 1974 incubator studies ^{14}C uptake was assumed to be linear at constant light intensities. The literature gives varying results. Barnett and Hirota (1967) found that at constant light intensity the rate of ^{14}C uptake was constant during a two-hour incubation. In a second experiment of four hours' duration, Barnett and Hirota used phytoplankton concentrations ten times greater, and light intensity was half of the first experiment. They found that ^{14}C uptake rate decreased to 62% of the rate at one hour. Fogg, Nalewajko, and Watt (1965) found that photosynthesis was proportional to incubation time under constant light intensity *in situ* and in the laboratory, but organic matter was excreted at an almost constant percentage of the photosynthetic uptake.

Extracellular ^{14}C adsorbed to phytoplankton leads to overestimates of productivity. McMahon (1973) showed that rinsing filters with 100 ml of distilled or filtered lake water removed extracellular ^{14}C, which had led to erroneous conclusions concerning self-absorption. The investigator assumed that the acid and filtered lake water rinses used in 1974 adequately removed extracellular ^{14}C.

Estimation of phytoplankton productivity at several stations during different times of the day may exaggerate productivity relative to each other. Vollenweider and Nauwerck (1961) found during *in situ* studies on Lake Erken, Sweden the interval of 0530-0930 yielded productivity per unit area of water one third of the daily total of a series of five four-hour time blocks. Holmes and Haxo (1958) demonstrated changes in photosynthesis throughout the day in incubator studies at a station in the tropical eastern Pacific Ocean. Maximum photosynthesis occurred at 0800-1000. Verduin (1957) found that the period 0700-1000 EST in western Lake Erie yielded maximal net photosynthetic rate per unit volume of water two-thirds greater than during the intervals 1000-1300 and 1300-1600.

Whether the ^{14}C method estimates net or gross productivity remains unsolved. Saunders (1964) felt that because the sum of a series of short experiments over a day exceeded the estimate of a single full day exposure, the series estimated gross productivity and the single exposure net. Vollenweider and Nauwerck (1961) suggested that productivity measured by ^{14}C lies between net and gross.

Both incubator and *in situ* productivity estimates made by the ^{14}C method include combined contributions by phytoplankton and bacteria. Cody (1972) states that the measurement of carbon assimilation is complicated by autotrophic bacteria, both chemosynthetic (aerobic) and photosynthetic (nonsulfur which are aerobic and sulfur which are anaerobic). The relative amount of bacterial assimilation is unknown.

Phytoplankton, zooplankton, and bacteria all play a role in dark ^{14}C uptake (Gerletti 1968). Sorokin (1965) described three groups of bacteria involved in dark CO_2 uptake. Heterotrophic bacteria involved in aerobic decomposition of organic matter account for the major part of dark CO_2 assimilation in surface layers of eutrophic and meso-eutrophic lakes. Another group of bacteria intermediate between heterotrophic and chemosynthetic oxidizes simple organic products of anaerobic decomposition. A third group are chemoautotrophs that utilize CO_2 in the syntheses of all their organic compounds.

During *in situ* studies on Lake Maggiore, Italy, Gerletti (1968) found that below the optimal level of illumination (where maximum photosynthesis is expected to occur) relative dark uptake of $^{14}CO_2$ (dark bottle activity expressed as percent of the corresponding light bottle activity) increased. In situ experiments at Rattlesnake Island during 1974 support Gerletti. Relative dark ^{14}C uptake on 21 July was 2% at one meter, increasing to 14% at five meters; for 10 September, 2% at one meter, increasing to 33% at six and eight meters; and on 6 October, 6% increasing to 35% at four meters. However, in the incubator studies at an optimal light intensity, relative dark bottle rates ranged from 1-58% and were especially high in the central basin during late July to mid-August. On the hottest summer days incubator temperature remained within 2°C of the lake surface temperature. Since the temperature from surface to lower epilimnion did not vary by more than 2°C on the average over the sampling season, the temperature differential between incubator and sample depth is negligible. Even though light intensity in the incubator is optimal, a significant increase in relative dark bottle activity occurs. The source of this uptake is not specifically known, although the bottle surface effect on bacteria may stimulate their growth (Gerletti 1968). Menon, Glooschenko, and Burns (1972) reported bacterial densities of $3.3\text{-}3700 \times 10^3$/ml and $3.4\text{-}790 \times 10^4$/ml for central and western Lake Erie, respectively. Vertical distribution was uniform until stratification, when hypolimnion bacterial densities increased more than epilimnion densities. Bacteria in late August utilized organic matter from excretion and degradation products of blue-green and green algal blooms to attain maximum densities.

Morris, Yentsch, and Yentsch (1971) found that with marine phytoplankton relative dark uptake of ^{14}C became greater with smaller population densities. Smaller phytoplankton densities in both central and western Lake Erie in 1974 yielded higher relative dark uptake, but the relationship is non-linear (Figure 13). Relative dark uptake increased with decreasing turbidity (Figure 14), which supports the previous relation.

No relationship was noted between dark ^{14}C uptake and temperature. For both relative and absolute values equally high and low rates were observed at temperature ranges of 10-13°C and 18-24°C.

In situ productivity vs. depth profiles show the effect of decreasing light intensities on carbon assimilation rates, whereas incubator productivity profiles at constant light intensity show relatively little change in carbon assimilation rates. The shipboard counterpart to Rattlesnake Island, Station 67, did not have significant changes in vertical distribution of productivity. *In situ* profiles show that productivity at one meter and deeper closely parallels light transmission in all three experiments down to a relative light intensity of approximately 10% of the surface light intensity. Such parallelism indicates that phytoplankton

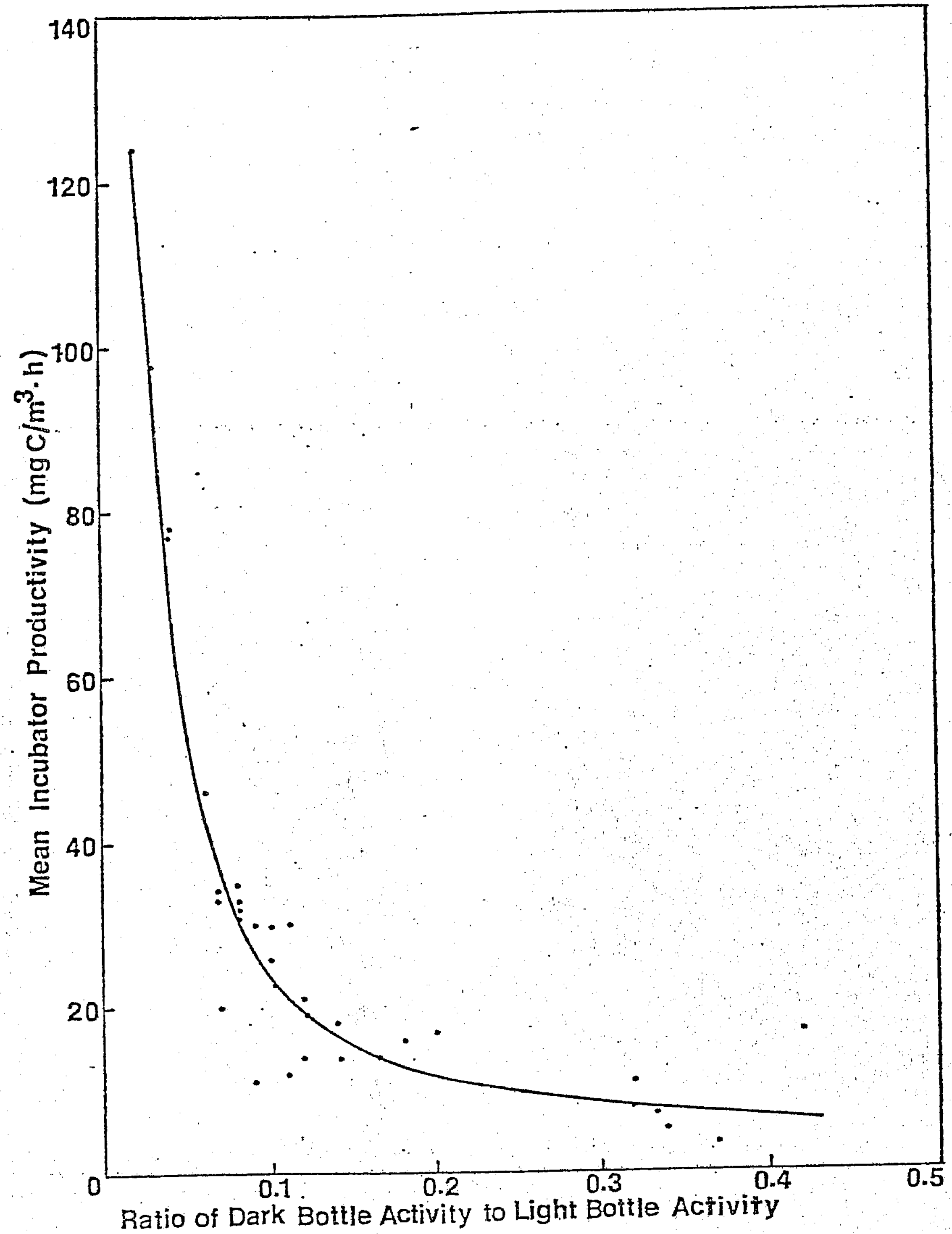

Figure 13. Relationship of mean relative dark ^{14}C uptake to mean incubator productivity at each station in central and western Lake Erie.

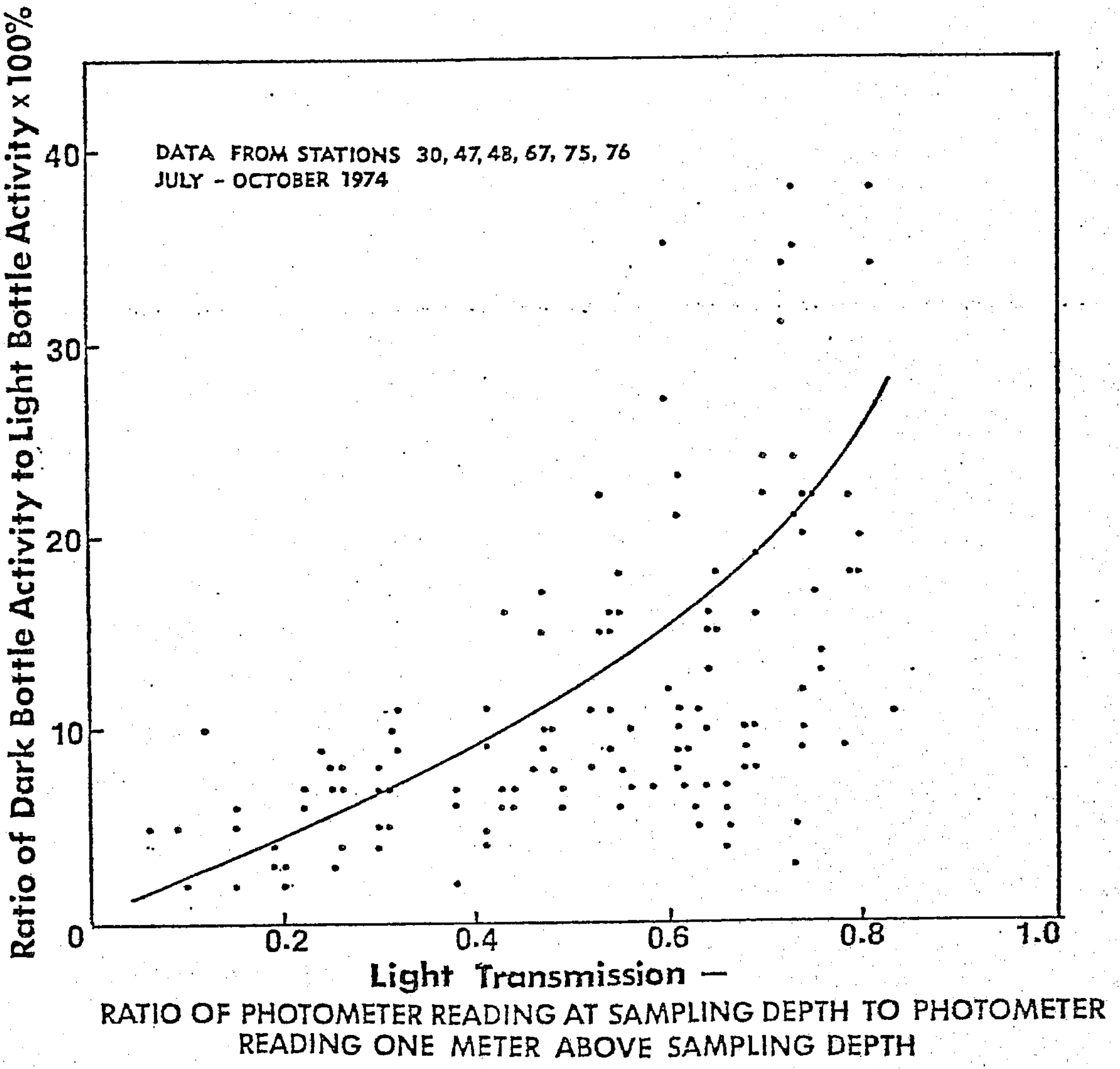

Figure 14. Relationship of relative dark ^{14}C uptake to light transmission.

populations are homogeneously distributed, at least down to the level of 10% of the surface light intensity. Rodhe (1965) found that the slopes of assimilation curves of nine lakes closely agreed with the slope of the most penetrating component (usually green) of subaquatic light at a level from 1-12.5% of the subsurface intensity of the component.

Incubator data showed that the phytoplankton in both basins survived the light intensity of the water bath. For example, a sample of lake water from four meters at Station 53 on 6 September from a relative light intensity of 0.1% of the incubator relative light intensity (775 μA) had a productivity potential nearly 20% greater than a sample from one meter, which received about a 370 times greater relative light intensity. The survival of the phytoplankton under incubator light intensity suggests that the water at Station 53 circulates completely down to four meters so that the cells at four meters do not remain in total darkness, otherwise they may have been injured by the incubator light intensity and would not have functioned photosynthetically, or if so, then at a reduced rate. Water temperature and oxygen concentration remain unchanged from one meter to four meters (Center for Lake Erie Area Research, unpublished), which supports this hypothesis. Kiefer et al. (1972) reported that phytoplankton from 100-400 m in Lake Tahoe survived light intensity increases of 10^7, as they had photosynthetic potentials per unit of chlorophyll <u>a</u> slightly less than phytoplankton at 75 m in the euphotic zone (85 m), when the samples were incubated at a light intensity 40% of the surface.

The incubator productivity-total phosphorus relationship may indicate that total phosphorus is an indicator of phytoplankton densities. Brydges (1971) suggested that if total phophorus concentrations were reduced, there would be less algae. The 1974 incubator data support Brydges' argument.

The parallelism in the _in situ_ productivity-light transmission curves in Figure 3 suggests that light is a controlling factor in primary productivity in western Lake Erie. Since total phosphorous concentration is linearly related to incubator productivity at the one meter depth, then both light and total phosphorus may together limit primary productivity. If the light-_in situ_ productivity relationship holds for central Lake Erie, then both factors may be limiting in central Lake Erie also.

SUMMARY

Western basin incubator productivity was 3.5 times greater than central basin incubator productivity in the summer and 1.5 times greater in the fall. Incubator productivity estimates were comparable to those in 1970. Central basin incubator productivity decreased in late summer and increased upon fall overturn. Western basin incubator productivity declined throughout the season.

In situ productivity-light intensity curves for western Lake Erie showed that phytoplankton are photosynthetically active at lower light intensities in October as opposed to July and September, and that maximal productivity is reached within a narrower range of light intensities. Maximum productivity was located at approximately one meter. In all three *in situ* experiments relative productivity curves lay parallel to light transmission curves down to a level of approximately ten percent of the surface light intensity.

Estimated errors for the 1974 methodology showed that a slightly greater total error existed than was normally accepted in the literature. Each sample lost an average of 14% of its initially assimilated ^{14}C when merthiolate fixative was used. This fixation effect had the greatest uncertainty in the estimate of total error.

Incubator productivity profiles showed several forms. Maxima were located at one meter, slightly below one meter, and some mid-lake central basin profiles increased toward the metalimnion. Lower maximum to minimum incubator productivity ratios indicate that western Lake Erie waters are mixed more thoroughly than central Lake Erie waters.

Central basin relative dark ^{14}C uptake averaged three times greater than western basin relative dark uptake. Central basin relative dark uptake increased during thermal stratification, yet western basin relative dark uptake remained rather constant. Higher relative dark uptake occurred in areas of less turbidity and phytoplankton densities. The effect of temperature on relative dark uptake was not evidenced.

Incubator productivity correlated with uncorrected chlorophyll a concentration and total phosphorous concentration at the one meter depth. The incubator productivity - total phosphorus and relative *in situ* productivity - light transmission relationships suggest that light and phosphorus together operate as limiting factors in central and western Lake Erie.

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APPENDIX I

Primary Productivity Calculation

$$P = \frac{a}{b \cdot c} \cdot d \cdot e \cdot f \cdot g \cdot h \cdot i$$

Symbol	Definition	Physical Significance	Unit	Numerical Value
P	primary productivity	rate of inorganic C assimilation	$mg\ C/m^3 \cdot h$	to be calculated
a	sample count rate divided by counter yield	actual ^{14}C assimilation, correcting for counter yield	$cpm \cdot \frac{dpm}{cpm}$	measured
b	activity added to BOD bottle	amount ^{14}C added to BOD bottle	dpm	2.22×10^6
c	time BOD bottle incubated	time in which "a" amount ^{14}C assimilated	h	measured
d	capacity BOD bottle (300 ml)/ volume of material filtered	volume correction factor, to account for entire bottle content	ml/ml	measured
e	capacity BOD bottle/capacity BOD bottle - 10 ml	fixative factor, to correct for removal of 10 ml sample in order to add 10 ml fixative	$\frac{300\ ml}{290\ ml}$	1.03
f*	total alkalinity as determined by equation below	amount dissolved inorganic C in water expressed in terms of $CaCO_3$	$\frac{mg\ CaCO_3}{l}$	calculated
g	factor from Table 2, in Saunders, Trama, and Bachmann (1962), which incorporates temperature and pH	converts TA to mg C/l, the amount of dissolved inorganic C in the water	$\frac{mg\ C}{mg\ CaCO_3}$	read from Table 2
h	converts ^{14}C uptake to ^{12}C uptake	isotope factor, accounts for ^{14}C uptake slower than ^{12}C uptake	none	1.06
i	conversion of l to m^3	converts C assimilation in bottle to C assimilation in lake	$\frac{1}{10^3 cm^3} \times \frac{10^6 cm^3}{m^3}$	1000

$$^{*}TA = \frac{ml_{tit} \times N \times 50{,}000}{ml_S} \quad \text{which expands to:}$$

$$= \frac{ml_{tit} \times eq/l \times \frac{100\ g\ CaCO_3/mole}{2eq/mole} \times \frac{10^3\ mg}{g}}{ml_S} = mg\ CaCO_3/l$$

TA = total alkalinity

ml_{tit} = ml acid titrated

eq = equivalent = weight in grams that accepts one mole H^+

eq/l = normality of acid = N

100g = molecular weight of $CaCO_3$

∴ equivalent weight $CaCO_3$ = 100g $CaCO_3$/mole x $(2eq/mole)^{-1}$ = 50g/eq

10^3mg/g = converts g $CaCO_3$/l to mg $CaCO_3$/l

ml_S = ml sample used

APPENDIX II

Light Bottle and Dark Bottle Data

Abbreviations and Symbols

Sta	Station number
Net C. R.	Net count rate (sample count rate - background)
Vol	Volume of material filtered
Alky	Total alkalinity
Rel Dark Uptake (%)	$\frac{\text{Dark bottle activity}}{\text{Light bottle activity}} \times 100\%$
Rat. Is.	*In situ* site near Rattlesnake Island
lb	Light bottle
db	Dark bottle
A, B	Aliquots from same bottle
a	Questionable value
b	Bottle stored overnight in refrigerator and filtered next day
c	Station mean of dark bottle ^{14}C assimilation
d	Bottle stored 24-48 hours in refrigerator until filtration

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m3.h)
23	13 Aug	1	lb 1	1070	0.171	4.32	300	91	0.24	20	15.6
			lb 2	823	0.171	4.23	295	91	0.24	25	12.5
			db	209	0.171	4.28	300	91	0.24		3.1
		3	lb 1	559	0.171	4.20	300	91	0.24	29	8.3
			lb 2	735	0.171	4.47	300	91	0.24	23	10.4
			db	170	0.171	4.55	300	91	0.24		2.4
		5	lb 1	904	0.171	4.33	300	92	0.24	22	13.3
			lb 2	830	0.171	4.57	300	92	0.24	25	11.5
			db	199	0.171	4.45	300	92	0.24		2.9
		7	lb 1	958	0.171	4.52	300	92	0.24	54	13.4
			lb 2	871	0.171	4.37	300	92	0.24	58	12.6
			db	482	0.171	4.27	295	92	0.24		7.3
		13	lb 1	728	0.171	4.38	300	90	0.24	630[a]	10.3
			lb 2	833	0.171	4.50	300	90	0.24	560[a]	11.5
			db	4180	0.156	4.42	300	90	0.24		64.6[a]
23	23 Oct	1	lb 1	1630	0.156	5.27	250	96	0.24	7.5	26.8
			lb 2	1900	0.156	5.50	250	96	0.24	6.6	30.2
			db	127	0.156	5.42	250	96	0.24		2.0
		2	lb 1	1590	0.156	5.53	250	96	0.24	10	25.1
			lb 2	1760	0.156	5.45	250	96	0.24	8.9	28.2
			db	146	0.156	5.15	250	96	0.24		2.5
		3	lb 1	1730	0.156	5.32	250	95	0.24	9.6	28.1
			lb 2	1500	0.156	5.38	250	95	0.24	11	24.0
			db	156	0.156	5.57	250	95	0.24		2.7
		5	lb 1	1030	0.156	5.18	200	95	0.24	11	21.4
			lb 2	1170	0.156	5.22	200	95	0.24	9.9	24.2
			db	114	0.156	5.07	200	95	0.24		2.4
		6.5	lb 1	1110	0.156	5.12	200	94	0.24	11	23.2
			lb 2	1160	0.156	5.23	200	94	0.24	11	23.7
			db	125	0.156	5.35	200	94	0.24		2.5

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
25	13 Aug	2	lb 1	586	0.171	4.38	300	90	0.24	26	8.3
			lb 2	576	0.171	4.55	300	90	0.24	28	7.9
			db	155	0.171	4.43	300	90	0.24		2.2
		4	lb 1	431	0.171	4.13	300	91	0.24	44	6.6
			lb 2	398	0.171	4.22	300	91	0.24	49	5.9
			db	187	0.171	4.07	300	91	0.24		2.9
		5	lb 1	596	0.171	4.32	300	91	0.24	32	8.7
			lb 2	519	0.171	4.03	300	91	0.24	35	8.1
			db	185	0.171	4.17	300	91	0.24		2.8
		8	lb 1	486	0.171	4.35	300	91	0.24	34	7.0
			lb 2	518	0.171	4.52	300	91	0.24	33	7.2
			db	170	0.171	4.48	300	91	0.24		2.4
		18	lb 1	532	0.171	4.25	300	95	0.251	31	8.6
			lb 2	543	0.171	4.10	300	95	0.251	30	9.1
			db	170	0.171	4.28	300	95	0.251		2.7
25	23 Oct	1	lb 1	789	0.156	3.45	250	92	0.24	17	19.1
			lb 2	694	0.156	3.45	250	92	0.24	20	16.8^b
			db	151	0.156	3.83	250	92	0.24		3.3
		3	lb 1	643	0.156	3.45	250	93	0.24	17	15.8^b
			lb 2	738	0.156	3.45	250	93	0.24	15	18.1
			db	125	0.156	3.88	250	93	0.24		2.7^b
		5	lb 1	672	0.156	3.45	250	93	0.24	15	16.4
			lb 2	750	0.156	3.45	250	93	0.24	13	18.4^b
			db	122	0.156	4.20	250	93	0.24		2.4^b
		7.5	lb 1	589	0.156	3.45	250	94	0.24	16	14.6^b
			lb 2	751	0.156	3.45	250	94	0.24	13	18.6
			db	123	0.156	4.32	250	94	0.24		2.4^b
		9	lb 1	587	0.156	3.45	250	94	0.24	17	14.5
			lb 2	581	0.156	3.45	250	94	0.24	17	14.4^b
			db	118	0.156	4.17	250	94	0.24		2.4^b

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel.Dark Uptake (%)	Productivity (mg C/m^3·h)
30	1 Aug	1	lb 1	1070	0.171	4.43	300	95	0.24	16	15.8[b]
			lb 2	1430	0.171	4.77	300	95	0.24	13	19.7[b]
			db	169	0.171	4.42	300	95	0.24		2.5[b]
		3	lb 1	1300	0.171	4.47	300	95	0.24	5.3	19.0[b]
			lb 2	1350	0.171	4.50	295	95	0.24	5.0	20.0[b]
			db	72.3	0.171	4.58	300	95	0.24		1.0[b]
		5	lb 1	1330	0.171	4.67	300	94	0.24	5.4	18.5[b]
			lb 2	1670	0.171	4.63	300	94	0.24	4.3	23.4[b]
			db	66.5	0.171	4.52	300	94	0.24		1.0[b]
		6	lb 1	1380	0.171	4.55	300	94	0.24	7.1	19.7[b]
			lb 2	1870	0.171	4.80	300	94	0.24	5.6	25.2[b]
			db	99.6	0.171	4.62	300	94	0.24		1.4[b]
		11.5	lb 1	3660	0.171	4.72	300	94	0.24	3.2	50.3[a,b]
			lb 2	2230	0.171	4.70	300	94	0.24	5.2	30.7[b]
			db	120	0.171	4.75	300	94	0.24		1.6[b]
30	14 Aug	1	lb 1	722	0.171	4.18	300	90	0.24	27	10.7
			lb 2	560	0.171	4.22	300	90	0.24	35	8.2
			db	193	0.171	4.15	300	90	0.24		2.9
		3	lb 1	408	0.171	3.88	300	90	0.24	38	6.6
			lb 2	472	0.171	4.08	300	90	0.24	35	7.2
			db	172	0.171	4.30	300	90	0.24		2.5
		5	lb 1	463	0.171	3.92	300	90	0.24	38	7.4
			lb 2	510	0.171	3.93	300	90	0.24	35	8.0
			db	176	0.171	3.97	300	90	0.24		2.8
		10	lb 1	862	0.171	4.35	300	90	0.24	20	12.3
			lb 2	948	0.171	4.28	300	90	0.24	18	13.8
			db	160	0.171	4.05	300	90	0.24		2.5
		16	lb 1	834	0.171	4.13	300	97	0.279	20	15.7
			lb 2	802	0.171	4.25	300	97	0.279	22	14.7
			db	169	0.171	4.10	300	97	0.279		3.2

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
30	14 Aug	19	lb 1	723	0.171	4.03	300	97	0.279	21	14.0
			lb 2	633	0.171	3.98	300	97	0.279	24	12.4
			db	153	0.171	4.02	300	97	0.279		3.0
30	26 Oct	1	lb 1	822	0.156	3.72	250	94	0.24	16	18.8
			lb 2	1040	0.156	3.87	300	94	0.24	16	19.1
			db	149	0.156	4.10	250	94	0.24		3.1
		3	lb 1	1060	0.156	4.18	250	94	0.24	17	21.6
			lb 2	1350	0.156	3.97	300	94	0.24	15	24.2
			db	160	0.156	3.80	250	94	0.24		3.6
		5	lb 1	1050	0.156	4.07	300	94	0.24	16	18.3
			lb 2	951	0.156	4.13	250	94	0.24	15	19.7
			db	136	0.156	4.03	250	94	0.24		2.9
		7	lb 1	1060	0.156	3.75	250	95	0.24	11	24.4
			lb 2	1130	0.156	3.77	250	95	0.24	10	25.8
			db	123	0.156	3.90	250	95	0.24		2.7
		9	lb 1	1040	0.156	3.83	250	95	0.24	12	23.4
			lb 2	1020	0.156	3.93	250	95	0.24	12	22.4
			db	129	0.156	4.00	250	95	0.24		2.8
32	26 Oct	1	lb 1	1000	0.156	4.58	300	92	0.24	15	15.2
			lb 2	840	0.156	4.38	300	92	0.24	17	13.3[b]
			db	154	0.156	4.65	300	92	0.24		2.3
		3	lb 1	978	0.156	4.18	300	92	0.24	14	16.3
			lb 2	806	0.156	4.35	300	92	0.24	18	12.9[b]
			db	148	0.156	4.42	300	92	0.24		2.3
		5	lb 1	842	0.156	4.52	300	91	0.24	18	12.8
			lb 2	638	0.156	4.22	300	91	0.24	22	10.4[b]
			db	140	0.156	4.28	300	91	0.24		2.3[b]
		7	lb 1	796	0.156	4.45	300	91	0.24	20	12.3[b]
			lb 2	941	0.156	4.62	300	91	0.24	18	14.0
			db	164	0.156	4.55	300	91	0.24		2.5[b]

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
32	26 Oct	10	lb 1	955	0.156	4.48	300	90	0.24	16	14.5
			lb 2	686	0.156	4.25	300	90	0.24	21	11.0[b]
			db	149	0.156	4.32	300	90	0.24		2.3[b]
34	15 Aug	1	lb 1	674	0.171	4.25	300	92	0.24	23	10.0
			lb 2	679	0.171	4.37	300	92	0.24	23	9.9
			db	153	0.171	4.17	300	92	0.24		2.3
		3	lb 1	635	0.171	4.08	300	92	0.24	24	9.9
			lb 2	567	0.171	4.12	300	92	0.24	27	8.8
			db	164	0.171	4.32	300	92	0.24		2.4
		4	lb 1	1250	0.171	4.07	300	92	0.24	15	19.5
			lb 2	872	0.171	4.40	300	92	0.24	23	12.6
			db	186	0.171	4.13	300	92	0.24		2.9
		5	lb 1	985	0.171	4.35	300	92	0.24	28	14.4
			lb 2	972	0.171	4.22	300	92	0.24	28	14.6
			db	261	0.171	4.03	300	92	0.24		4.1
		11	lb 1	934	0.171	4.27	300	93	0.24	19	14.0
			lb 2	1050	0.171	4.18	300	93	0.24	16	16.2
			db	171	0.171	4.30	300	93	0.24		2.6
36	15 Aug	1	lb 1	369	0.171	4.17	300	93	0.24	44	5.7[b]
			lb 2	492	0.171	4.08	310	93	0.24	33	7.5
			db	150	0.171	3.87	300	93	0.24		2.5
		3	lb 1	376	0.171	3.92	300	93	0.24	39	6.2[b]
			lb 2	456	0.171	4.03	290	93	0.24	32	7.5
			db	151	0.171	4.00	300	93	0.24		2.4
		5	lb 1	512	0.171	3.90	300	93	0.24	31	8.4[b]
			lb 2	528	0.171	4.13	300	93	0.24	32	8.2
			db	152	0.171	3.82	300	93	0.24		2.6

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
36	15 Aug	9	lb 1	662	0.171	3.97	300	92	0.24	20	10.6[b]
			lb 2	4080	0.156	4.05	300	92	0.24	3.0	70.3[a]
			db	133	0.171	3.95	300	92	0.24		2.1
		18.5	lb 1	771	0.171	3.77	300	95	0.266	-	14.9[b]
			lb 2	911	0.171	3.83	300	95	0.266	-	17.3
			db	-	-	-	-	-	-		2.4[c]
36	27 Oct	1	lb 1	1250	0.156	4.10	300	93	0.24	13	21.5
			lb 2	1570	0.156	4.82	300	93	0.24	12	23.0
			db	161	0.156	4.07	300	93	0.24		2.8
		3	lb 1	1590	0.156	4.67	300	92	0.24	8.9	23.7
			lb 2	1080	0.156	3.98	300	92	0.24	11	18.9
			db	147	0.156	4.78	300	92	0.24		2.1
		5	lb 1	1430	0.156	4.75	300	92	0.24	12	21.0
			lb 2	1110	0.156	4.17	300	92	0.24	13	18.6
			db	167	0.156	4.60	300	92	0.24		2.5
		7	lb 1	1100	0.156	4.13	300	91	0.24	14	18.4
			lb 2	1660	0.156	4.20	300	91	0.24	9.2	27.1
			db	149	0.156	4.03	300	91	0.24		2.5
		10	lb 1	943	0.156	3.95	300	90	0.24	13	16.2
			lb 2	1450	0.156	4.63	300	90	0.24	9.9	21.3
			db	146	0.156	4.70	300	90	0.24		2.1
39	27 Oct	1	lb 1	913	0.156	4.02	250	90	0.24	19	18.6[b]
			lb 2	1170	0.156	4.32	250	90	0.24	16	22.1
			db	175	0.156	4.05	250	90	0.24		3.5
		2	lb 1	978	0.156	4.28	250	90	0.24	13	18.6[b]
			lb 2	1250	0.156	4.22	250	90	0.24	10	24.2
			db	136	0.156	4.38	250	90	0.24		2.5

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
39	27 Oct	3	lb 1	1120	0.156	4.35	250	90	0.24	11	21.0[b]
			lb 2	2230	0.156	4.08	250	90	0.24	5.1	44.7[a]
			db	112	0.156	3.98	250	90	0.24		2.3
		5	lb 1	1180	0.156	3.92	250	90	0.24	51	24.5
			lb 2	1220	0.156	4.15	250	90	0.24	52	24.0[b]
			db	658	0.156	4.25	250	90	0.24		12.6
		7	lb 1	1180	0.156	4.42	250	91	0.24	12	22.0
			lb 2	1120	0.156	4.12	250	91	0.24	12	22.4[b]
			db	129	0.156	4.17	250	91	0.24		2.6[b]
44	17 Aug	1	lb 1	1310	0.171	4.40	300	92	0.24	11	18.9
			lb 2	1210	0.171	4.43	300	92	0.24	12	17.4
			db	157	0.171	4.72	300	92	0.24		2.1
		2	lb 1	1040	0.171	4.33	300	92	0.24	16	15.3
			lb 2	1190	0.171	4.68	300	92	0.24	15	16.2
			db	166	0.171	4.27	300	92	0.24		2.5
		3	lb 1	836	0.171	4.18	300	92	0.24	17	12.7
			lb 2	1240	0.171	4.60	300	92	0.24	13	17.1
			db	154	0.171	4.47	300	92	0.24		2.2
		5	lb 1	931	0.171	4.57	300	93	0.24	18	13.1
			lb 2	1380	0.171	4.63	300	93	0.24	12	19.2
			db	171	0.171	4.53	300	93	0.24		2.4
		10	lb 1	713	0.171	4.30	250	94	0.24	16	12.9
			lb 2	929	0.171	4.50	250	94	0.24	13	16.1
			db	116	0.171	4.23	250	94	0.24		2.1
44	29 Oct	1	lb 1	2210	0.156	4.38	200	94	0.24	5.0	54.0
			lb 2	3360	0.156	4.67	300	94	0.24	5.3	51.1
			db	113	0.156	4.53	200	94	0.24		2.7

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
44	29 Oct	2	lb 1	2230	0.156	4.32	200	94	0.24	4.7	55.1
			lb 2	3160	0.156	4.50	300	94	0.24	5.2	50.0
			db	109	0.156	4.42	200	94	0.24		2.6
		3	lb 1	1900	0.156	4.22	200	94	0.24	7.1	48.2
			lb 2A	1090	0.156	4.25	100	94	0.24	6.2	54.8
			lb 2B	1490	0.156	4.25	150	94	0.24	6.8	49.8
			db	138	0.156	4.35	200	94	0.24		3.4
		5	lb 1	2950	0.156	4.47	250	94	0.24	4.6	56.3
			lb 2	2440	0.156	4.43	200	94	0.24	4.4	58.6
			db	103	0.156	4.28	200	94	0.24		2.6
		7	lb 1	2340	0.156	4.57	200	94	0.24	3.7	54.7
			lb 2	2510	0.156	4.60	200	94	0.24	3.4	58.2
			db	87.7	0.156	4.63	200	94	0.24		2.0
47	30 July	1	lb 1	1140	0.171	4.25	300	93	0.24	18	17.2
			lb 2	1360	0.171	4.43	300	93	0.24	16	19.7
			db	197	0.171	4.05	300	93	0.24		3.1
		2	lb 1	965	0.171	4.28	300	93	0.24	34	14.5
			lb 2	997	0.171	4.02	300	93	0.24	31	15.9
			db	315	0.171	4.12	300	93	0.24		4.9
		3	lb 1	1630	0.171	4.53	300	93	0.24	24	23.1
			lb 2	1690	0.171	4.37	300	93	0.24	23	24.8
			db	368	0.171	4.22	300	93	0.24		5.6
		5	lb 1	1140	0.171	4.13	300	93	0.24	7.3	17.7
			lb 2	1730	0.171	4.20	300	93	0.24	4.9	26.4
			db	86.6	0.171	4.32	300	93	0.24		1.3
		7	lb 1	878	0.171	4.08	300	93	0.24	22	13.8
			lb 2	1180	0.171	4.47	300	93	0.24	18	17.0
			db	207	0.171	4.48	300	93	0.24		3.0
		14	lb 1	2080	0.171	4.52	300	92	0.24	4.4	29.3
			lb 2	1040	0.171	4.33	300	92	0.24	8.5	15.3
			db	91.3	0.171	4.40	300	92	0.24		1.3

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
47	12 Aug	1	lb 1	972	0.171	4.47	300	91	0.24	11	13.7
			lb 2	1350	0.171	4.72	300	91	0.24	8.4	17.9
			db	109	0.171	4.58	297	91	0.24		1.5
		3	lb 1	972	0.171	4.52	300	91	0.24	22	13.5
			lb 2	1080	0.171	4.75	300	91	0.24	21	14.3
			db	232	0.171	4.80	300	91	0.24		3.0
		5	lb 1	1450	0.171	4.67	300	91	0.24	9.7	19.5
			lb 2	1140	0.171	4.48	300	91	0.24	12	16.0
			db	129	0.171	4.38	300	91	0.24		1.8
		10	lb 1	1110	0.171	4.43	297	91	0.24	9.4	15.9
			lb 2	1180	0.171	4.62	300	91	0.24	9.4	16.0
			db	105	0.171	4.40	300	91	0.24		1.5
		13.5	lb 1	1160	0.171	4.78	300	91	0.24	-	15.2
			lb 2	1160	0.171	4.33	300	91	0.24	-	16.8
			db	-	0.171	-	-	-	-		1.7[c]
		15	lb 1	1150	0.171	4.57	300	91	0.24	11	15.8
			lb 2	1250	0.171	4.63	300	91	0.24	11	16.9
			db	133	0.171	4.68	300	91	0.24		1.8
47	21 Oct	1	lb 1	2460	0.156	4.60	300	95	0.24	7.5	38.5
			lb 2	2000	0.156	4.32	300	95	0.24	8.7	33.2
			db	175	0.156	4.35	300	95	0.24		2.9
		3	lb 1	2360	0.156	4.50	300	95	0.24	8.2	37.6
			lb 2	2010	0.156	4.42	300	95	0.24	9.5	32.7
			db	184	0.156	4.25	300	95	0.24		3.1
		5	lb 1	1780	0.156	4.15	300	94	0.24	9.8	30.5
			lb 2	1680	0.156	4.53	300	94	0.24	11	26.4
			db	178	0.156	4.28	300	94	0.24		3.0
		7	lb 1	2330	0.156	4.48	300	94	0.24	7.0	36.9
			lb 2	1800	0.156	4.67	300	94	0.24	9.5	27.3
			db	171	0.156	4.63	300	94	0.24		2.6

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
47	21 Oct	9.5	lb 1	1670	0.156	4.45	300	93	0.24	9.8	26.4
			lb 2	2300	0.156	4.22	300	93	0.24	6.8	38.2
			db	172	0.156	4.57	300	93	0.24		2.6
48	4 Aug	1	lb 1	335	0.171	5.47	200	93	0.24	19	5.9^b
			lb 2	810	0.171	5.42	200	93	0.24	7.6	14.4
			db	56.9	0.171	5.07	200	93	0.24		1.1
		3	lb 1	889	0.171	5.53	200	94	0.24	5.8	15.6^b
			lb 2	1080	0.171	5.50	200	94	0.24	4.7	19.1
			db	51.0	0.171	5.57	200	94	0.24		0.9
		5	lb 1	743	0.171	5.37	200	94	0.24	10	13.4
			lb 2	588	0.171	5.08	200	94	0.24	12	11.3^b
			db	52.7	0.171	5.05	150	94	0.24		1.4
		7	lb 1	730	0.171	5.23	250	94	0.24	8.3	10.8
			lb 2	525	0.171	5.30	200	94	0.24	9.4	9.6^b
			db	46.4	0.171	5.12	200	94	0.24		0.9
		11	lb 1	550	0.171	5.18	200	95	0.24	7.6	10.5
			lb 2	578	0.171	5.58	200	95	0.24	7.8	10.2^b
			db	41.8	0.171	5.33	200	95	0.24		0.8
48	16 Aug	1	lb 1	928	0.171	3.45	300	91	0.24	21	16.9^b
			lb 2	1400	0.171	3.65	300	91	0.24	15	24.1
			db	195	0.171	3.37	300	91	0.24		3.6
		3	lb 1	1050	0.171	3.52	300	92	0.24	15	19.0
			lb 2	1050	0.171	3.62	300	92	0.24	15	18.4^b
			db	153	0.171	3.42	300	92	0.24		2.8
		4	lb 1	1070	0.171	3.80	300	92	0.24	18	17.9^b
			lb 2	1120	0.171	3.40	300	92	0.24	15	20.9
			db	182	0.171	3.60	300	92	0.24		3.2

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
48	16 Aug	5	lb 1	994	0.171	3.75	300	92	0.24	20	16.8
			lb 2	951	0.171	3.55	250	92	0.24	16	20.4
			db	178	0.171	3.47	300	92	0.24		3.2
		8	lb 1	991	0.171	3.67	250	93	0.24	14	20.8
			lb 2	1300	0.171	3.72	300	93	0.24	13	22.4
			db	170	0.171	3.78	300	93	0.24		2.9
		13	lb 1	726	0.171	3.83	300	95	0.24	22	12.4
			lb 2	804	0.171	3.57	300	95	0.24	18	14.8
			db	154	0.171	3.70	300	95	0.24		2.7
48	28 Oct	1	lb 1	1790	0.156	4.73	300	96	0.24	9.4	27.6
			lb 2	1580	0.156	4.67	300	96	0.24	11	24.5
			db	175	0.156	4.92	300	96	0.24		2.6
		3	lb 1	1750	0.156	4.88	300	95	0.24	11	25.7
			lb 2	1790	0.156	5.00	300	95	0.24	11	25.8
			db	191	0.156	4.70	300	95	0.24		2.9
		5	lb 1	2180	0.156	4.77	300	93	0.24	7.1	32.2
			lb 2	1710	0.156	4.55	300	93	0.24	8.7	26.5
			db	156	0.156	4.83	300	93	0.24		2.3
		7	lb 1	1760	0.156	4.95	300	92	0.24	10	24.8
			lb 2	1680	0.156	4.85	300	92	0.24	10	24.2
			db	164	0.156	4.58	300	92	0.24		2.5
		9	lb 1	1400	0.156	4.62	300	91	0.24	10	20.9
			lb 2	1750	0.156	4.80	300	91	0.24	8.4	25.0
			db	141	0.156	4.63	300	91	0.24		2.1
52	27 July	1	lb 1	390	0.171	4.07	150	95	0.24	17	12.6[b]
			lb 2	479	0.171	4.00	150	95	0.24	14	15.7[b]
			db	65.4	0.171	3.95	150	95	0.24		2.2[b]

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
52	27 July	2	lb 1	483	0.171	3.73	150	95	0.235	15	16.6^b
			lb 2	552	0.171	4.05	150	95	0.235	14	17.5^b
			db	79.4	0.171	4.03	150	95	0.235		2.5^b
		3	lb 1	1220	0.171	3.77	150	95	0.24	5.9	42.4^b
			lb 2	1060	0.171	3.78	150	95	0.24	6.8	36.8^b
			db	71.2	0.171	3.70	150	95	0.24		2.5^b
		5	lb 1	889	0.171	3.85	150	95	0.24	8.9	30.3^b
			lb 2	906	0.171	3.97	150	95	0.24	9.0	30.0^b
			db	95.2	0.171	3.90	175	95	0.24		2.7^b
		7.5	lb 1	430	0.171	3.92	150	95	0.24	18	14.4^b
			lb 2	624	0.171	3.67	200	95	0.24	16	16.7^b
			db	101	0.171	3.82	200	95	0.24		2.6^b
53	6 Sept	1	lb 1	737	0.171	4.47	100	90	0.24	9.8	30.7
			lb 2	668	0.171	4.38	75.0	90	0.24	7.9	37.9
			db	53.2	0.171	4.42	75.0	90	0.24		3.0
		2	lb 1	745	0.171	4.52	75.0	91	0.24	7.5	41.4
			lb 2	646	0.171	4.58	75.0	91	0.24	8.8	35.4
			db	56.8	0.171	4.60	75.0	91	0.24		3.1
		3	lb 1	703	0.171	4.63	75.0	92	0.24	9.1	38.5
			lb 2	748	0.171	4.55	75.0	92	0.24	8.4	41.7
			db	62.5	0.171	4.50	75.0	92	0.24		3.5
		4	lb 1	693	0.171	4.32	75.0	92	0.24	7.9	40.6
			lb 2	670	0.171	4.35	75.0	92	0.24	8.2	39.2
			db	55.8	0.171	4.45	75.0	92	0.24		3.2
53	30 Oct	1	lb 1	1520	0.156	4.33	200	94	0.24	9.1	37.5^b
			lb 2	1350	0.156	4.17	200	94	0.24	9.8	34.6^b
			db	132	0.156	4.10	200	94	0.24		3.4^b

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
53	30 Oct	2	lb 1	1570	0.156	4.13	200	94	0.24	6.6	40.7^b
			lb 2	1610	0.156	4.27	200	94	0.24	6.7	40.2^b
			db	110	0.156	4.42	200	94	0.24		2.7^b
		3	lb 1	1700	0.156	4.23	200	94	0.24	8.2	42.9^b
			lb 2	1480	0.156	4.48	200	94	0.24	10	35.2^b
			db	134	0.156	4.05	200	94	0.24		3.5^b
		4	lb 1	1430	0.156	4.35	200	94	0.24	7.4	35.1^b
			lb 2	1530	0.156	4.08	200	94	0.24	6.5	40.0^b
			db	105	0.156	4.30	200	94	0.24		2.6^b
		6	lb 1	1400	0.156	4.20	200	94	0.24	8.2	35.5^b
			lb 2	1530	0.156	4.53	200	94	0.24	8.0	36.1^b
			db	119	0.156	4.38	200	94	0.24		2.9^b
61	26 July	1	lb 1	163	0.171	3.72	75.0	88	0.24	15	10.6
			lb 2	180	0.171	3.95	75.0	88	0.24	15	11.0
			db	24.4	0.171	3.75	75.0	88	0.24		1.6
		2	lb 1	153	0.171	3.98	75.0	88	0.24	11	9.3
			lb 2	157	0.171	3.77	75.0	88	0.24	10	10.1
			db	17.2	0.171	4.03	75.0	88	0.24		1.0
		3	lb 1	277	0.171	4.00	75.0	89	0.24	8.8	17.0
			lb 2	298	0.171	3.93	75.0	89	0.24	8.1	18.6
			db	23.7	0.171	3.80	75.0	89	0.24		1.5
		5	lb 1	258	0.171	3.88	75.0	90	0.24	11	16.5
			lb 2	282	0.171	3.82	75.0	90	0.24	9.8	18.3
			db	28.0	0.171	3.85	75.0	90	0.24		1.8
61	7 Sept		lb 1	1020	0.171	3.98	150	86	0.24	9.9	30.4^b
			lb 2	1080	0.171	3.97	150	86	0.24	9.3	32.4$_b$
			db	96.3	0.171	3.85	150	86	0.24		3.0^b

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity ($mg\ C/m^3 \cdot h$)
61	7 Sept	2	lb 1	795	0.171	3.82	125	85	0.24	12	29.2^b
			lb 2	948	0.171	3.90	125	85	0.24	10	34.3
			db	91.9	0.171	3.72	125	85	0.24		3.5^b
		3	lb 1	886	0.171	3.67	125	84	0.24	9.6	33.5
			lb 2	1120	0.171	3.88	150	84	0.24	9.6	33.5^b
			db	91.0	0.171	3.93	125	84	0.24		3.2^b
		5	lb 1	1050	0.171	3.73	125	83	0.24	7.0	38.8
			lb 2	981	0.171	3.77	125	83	0.24	7.5	35.9^b
			db	89.0	0.171	3.80	150	83	0.24		2.7^b
61	1 Nov	1	lb 1	318	0.156	4.32	200	78	0.24	40	6.5^b
			lb 2	318	0.156	4.22	200	78	0.24	39	6.7^b
			db A	91.4	0.156	4.07	150	78	0.24		2.6^b
			db B	59.3	0.156	4.07	100	78	0.24		2.6^b
		2	lb 1	270	0.156	4.02	200	77	0.24	34	5.9^b
			lb 2	295	0.156	4.25	200	77	0.24	33	6.1^b
			db	96.9	0.156	4.17	200	77	0.24		2.0^b
		3	lb 1	295	0.156	4.12	200	77	0.24	38	6.3^b
			lb 2	330	0.156	4.13	200	77	0.24	34	7.0^b
			db	107	0.156	3.98	200	77	0.24		2.4^b
		5	lb 1	322	0.156	4.27	200	77	0.24	35	6.6^b
			lb 2	314	0.156	4.05	200	77	0.24	34	6.8^b
			db	107	0.156	4.10	200	77	0.24		2.3^b
		7	lb 1	358	0.156	3.97	250	79	0.24	34	6.4^b
			lb 2	358	0.156	4.33	250	79	0.24	37	5.9^b
			db	104	0.156	4.28	200	79	0.24		2.2^b
66	28 July	1	lb 1	1240	0.171	4.10	200	90	0.24	5.0	28.2^b
			lb 2	1190	0.171	3.77	200	90	0.24	4.7	29.5
			db	63.1	0.171	4.05	200	90	0.24		1.4

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/mg^3·h)
66	7 July	2	lb 1	1160	0.171	3.73	200	90	0.238	7.3	28.7^b
			lb 2	1490	0.171	3.90	200	90	0.238	5.9	35.3
			db	91.2	0.171	4.00	200	90	0.238		2.1^b
		3	lb 1	1200	0.171	4.02	150	90	0.24	9.4	37.1
			lb 2	856	0.171	3.70	150	90	0.24	12	28.8^b
			db	108	0.171	3.80	150	90	0.24		3.5^b
		5	lb 1	1720	0.171	3.97	150	90	0.24	4.4	54.1
			lb 2	1710	0.171	4.12	150	90	0.24	4.7	51.5
			db	77.1	0.171	3.92	150	90	0.24		2.4^b
		9	lb 1	831	0.171	4.07	150	91	0.24	8.2	25.7^b
			lb 2	1070	0.171	3.95	150	91	0.24	8.2	34.1
			db	63.4	0.171	3.85	150	91	0.24		2.1^b
66	29 Oct	1	lb 1	1340	0.156	4.32	200	84	0.235	6.9	29.0^b
			lb 2	1770	0.156	4.55	200	84	0.235	5.5	36.2
			db	96.0	0.156	4.58	200	84	0.235		2.0
		2	lb 1	1350	0.156	4.27	200	84	0.236	7.1	29.7^b
			lb 2	1400	0.156	4.35	200	84	0.236	7.0	30.2
			db	98.9	0.156	4.45	200	84	0.236		2.1^b
		3	lb 1	1570	0.156	4.60	200	84	0.237	7.4	32.3
			lb 2	1320	0.156	4.48	200	84	0.237	8.7	27.7^b
			db	105	0.156	4.18	200	84	0.237		2.4^b
		5	lb 1	1570	0.156	4.52	200	84	0.24	7.5	33.2
			lb 2	1360	0.156	4.65	200	84	0.24	9.0	27.9^b
			db A	66.2	0.156	4.38	100	84	0.24		2.9^b
			db B	72.9	0.156	4.38	150	84	0.24		2.1^b
		8	lb 1	1490	0.156	4.42	200	84	0.24	7.2	32.1
			lb 2	1110	0.156	4.23	200	84	0.24	9.2	25.1^b
			db	103	0.156	4.28	200	84	0.24		2.3^b

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
67	27 July	1	lb 1	1390	0.171	4.07	150	91	0.24	5.6	42.9
			lb 2	1170	0.171	4.13	150	91	0.24	6.7	35.6[b]
			db	81.8	0.171	4.22	150	91	0.24		2.4
		2	lb 1	1190	0.171	4.40	125	91	0.24	6.1	40.8
			lb 2	968	0.171	4.30	125	91	0.24	7.4	33.9
			db	55.5	0.171	4.17	100	91	0.24		2.5[b]
		3	lb 1	1130	0.171	4.25	150	91	0.24	7.2	33.4
			lb 2	1030	0.171	4.08	150	91	0.24	7.6	31.7[b]
			db	66.7	0.171	4.12	125	91	0.24		2.4
		6.5	lb 1	895	0.171	4.20	125	92	0.24	6.8	32.5
			lb 2	1020	0.171	4.27	125	92	0.24	6.1	36.3
			db	61.8	0.171	4.32	125	92	0.24		2.2
67	6 Sept	1	lb 1	1350	0.171	5.07	125	84	0.24	8.6	37.0
			lb 2	1170	0.171	4.98	125	84	0.24	9.8	32.7
			db	115	0.171	4.95	125	84	0.24		3.2
		2	lb 1	844	0.171	4.88	100	85	0.24	8.6	30.4
			lb 2	1120	0.171	5.03	100	85	0.24	6.6	39.2
			db	76.2	0.171	5.20	100	85	0.24		2.6
		3	lb 1	693	0.171	4.82	100	86	0.24	11	25.5
			lb 2	1120	0.171	5.10	100	86	0.24	6.9	39.1
			db	74.2	0.171	4.92	100	86	0.24		2.7
		4	lb 1	824	0.171	4.77	100	88	0.24	7.9	31.5
			lb 2	972	0.171	5.15	100	88	0.24	7.3	34.4
			db	67.8	0.171	4.85	100	88	0.24		2.5
67	30 Oct	1	lb 1	1690	0.156	4.22	150	86	0.24	6.0	51.9
			lb 2	1820	0.156	3.92	200	86	0.24	6.8	45.4
			db	100	0.156	4.18	150	86	0.24		3.1

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
67	30 Oct	2	lb 1	1660	0.156	4.08	150	86	0.24	5.1	52.7
			lb 2	1650	0.156	4.05	150	86	0.24	5.1	53.1
			db	88.4	0.156	4.27	150	86	0.24		2.7
		3	lb 1	1680	0.156	4.02	150	86	0.24	6.4	54.5
			lb 2	1560	0.156	3.85	150	86	0.24	6.6	52.7^b
			db	106	0.156	3.98	150	86	0.24		3.5
		4	lb 1	1230	0.156	3.95	150	86	0.24	6.9	40.5
			lb 2	1450	0.156	4.15	150	86	0.24	6.2	45.4^b
			db	83.1	0.156	3.88	150	86	0.24		2.8
		5	lb 1	1480	0.156	4.12	150	86	0.24	6.9	46.7^b
			lb 2	1400	0.156	3.82	150	86	0.24	6.7	47.7
			db	92.2	0.156	3.78	150	86	0.24		3.2
Rat. Is.	21 July	1	lb	4000	0.171	4.77	100	90	0.24	2.4	156^b
			db	100	0.171	4.87	100	90	0.24		3.8
		2	lb	2960	0.171	4.82	100	90	0.24	2.4	114^b
			db	68.9	0.171	4.70	100	90	0.24		2.7^b
		3	lb	1820	0.171	4.90	100	90	0.24	3.3	68.9
			db	60.1	0.171	4.95	100	90	0.24		2.3^b
		4	lb	542	0.171	4.92	50.0	90	0.24	4.4	41.1
			db	47.6	0.171	4.83	100	90	0.24		1.8^b
		5	lb	568	0.171	4.73	100	90	0.24	14	22.4^b
			db	58.8	0.171	4.68	75.0	90	0.24		3.1^b
Rat. Is.	10 Sept	1	lb	3250	0.171	4.75	100	84	0.24	1.8	119^b
			db	73.2	0.171	4.78	125	84	0.24		2.1^b
		2	lb	977	0.171	4.72	100	84	0.24	5.8	35.9^b
			db	69.9	0.171	4.68	125	84	0.24		2.1^b

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
Rat. Is.	10 Sept	3	lb	346	0.171	4.62	100	85	0.24	16	13.2[b]
			db	71.2	0.171	4.82	125	85	0.24		2.1[b]
		4	lb	229	0.171	4.73	125	84	0.24	28	6.7[b]
			db	64.5	0.171	4.83	125	84	0.24		1.9[b]
		6	lb	184	0.171	4.63	125	83	0.24	33	5.5[b]
			db	59.3	0.171	4.65	125	83	0.24		1.8[b]
		8	lb	219	0.171	4.55	125	83	0.24	33	6.6[b]
			db	71.9	0.171	4.58	125	83	0.24		2.2[b]
Rat. Is.	6 Oct	0.5	lb	992	0.171	5.63	100	87	0.24	7.3	31.7
			db	70.8	0.171	5.60	100	87	0.24		2.3
		1	lb	1190	0.171	5.55	100	87	0.24	5.7	38.7
			db	68.5	0.171	5.50	100	87	0.24		2.2
		2	lb	664	0.171	5.45	100	87	0.24	10	22.0
			db	70.6	0.171	5.42	100	87	0.24		2.3
		3	lb	299	0.171	5.38	100	87	0.24	25	10.0
			db	73.5	0.171	5.35	100	87	0.24		2.5
		4	lb	186	0.171	5.32	100	87	0.24	35	6.3
			db	65.5	0.171	5.28	100	87	0.24		2.2
		5	lb A	165	0.171	5.25	100	87	0.24	-	5.7
			lb B	177	0.171	5.25	100	87	0.24	-	6.1
			db	-	0.171	-	-	-	-		2.3[c]
73	30 July	1	lb 1	1710	0.171	4.12	300	93	0.24	53	26.6[d]
			lb 2	1150	0.171	4.08	300	93	0.24	77[a]	18.1[d]
			db	800	0.156	4.02	300	93	0.24		14.0[d]
		2	lb	2080	0.171	4.53	300	93	0.24	7.8	29.6[d]
			db	148	0.156	4.47	300	93	0.24		2.3[d]

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
73	30 July	3	lb 1	2070	0.171	4.35	300	93	0.24	-	30.5^d
			lb 2	2080	0.171	4.25	300	93	0.24	-	31.5^d
			db	-	-	-	-	-	-		10.7^c
		5	lb 1	2540	0.171	4.38	300	93	0.24	25	37.3^d
			lb 2	1300	0.171	4.33	300	93	0.24	49	19.3^d
			db	556	0.156	4.13	300	93	0.24		9.4^d
		8	lb 1	2610	0.171	3.95	300	93	0.24	48	42.5^d
			lb 2	2200	0.171	3.98	300	93	0.24	58	35.6^d
			db	1180	0.156	4.05	300	93	0.24		20.5^d
		15.5	lb 1	1570	0.171	4.27	300	92	0.24	31	23.4^d
			lb 2	1490	0.171	4.33	300	92	0.24	33	21.8^d
			db	467	0.156	4.43	300	92	0.24		7.3^d
73	21 Oct	1	lb 1	2060	0.156	3.72	300	95	0.24	8.8	39.8
			lb 2	1580	0.156	4.13	300	95	0.24	13	27.4
			db	194	0.156	4.00	300	95	0.24		3.5
		3	lb 1	1740	0.156	3.97	300	95	0.24	14	31.6
			lb 2	2240	0.156	3.93	300	95	0.24	11	41.1
			db	235	0.156	3.75	300	95	0.24		4.5
		5	lb 1	2140	0.156	3.90	300	94	0.24	8.7	39.0
			lb 2	1510	0.156	3.78	300	94	0.24	12	28.4
			db	182	0.156	3.82	300	94	0.24		3.4
		7	lb 1	2270	0.156	4.05	300	94	0.24	7.5	40.0
			lb 2	1540	0.156	3.68	300	94	0.24	10	29.8
			db	173	0.156	4.08	300	94	0.24		3.0
		9.5	lb 1	1700	0.156	3.88	300	93	0.24	10	30.8
			lb 2	1640	0.156	3.85	300	93	0.24	10	29.9
			db	178	0.156	4.03	300	93	0.24		3.1

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
75	26 July	1	lb 1	1550	0.171	3.92	50.0	93	0.23	1.8	146
			lb 2	1590	0.171	4.12	50.0	93	0.23	1.8	143
			db	27.3	0.171	3.95	50.0	93	0.23		2.6
		2	lb 1	1160	0.171	4.00	50.0	93	0.23	2.6	107
			lb 2	1230	0.171	3.88	50.0	93	0.23	2.4	117
			db	30.2	0.171	3.98	50.0	93	0.23		2.8
		3	lb 1	1380	0.171	4.10	50.0	93	0.23	1.6	124
			lb 2	1320	0.171	4.05	50.0	93	0.23	1.7	120
			db	22.5	0.171	4.08	50.0	93	0.23		2.0
75	7 Sept	1	lb 1	1060	0.171	4.15	150	84	0.24	9.8	29.6
			lb 2	896	0.171	4.40	125	84	0.24	10	28.3
			db	92.8	0.171	4.43	125	84	0.24		2.9
		2	lb 1	1060	0.171	4.33	125	85	0.24	8.4	34.4
			lb 2	1290	0.171	4.23	125	85	0.24	6.7	43.0
			db	87.3	0.171	4.28	125	85	0.24		2.9
		3	lb 1	1090	0.171	4.27	125	86	0.24	7.7	36.3
			lb 2	926	0.171	4.17	100	86	0.24	7.1	39.6
			db	85.6	0.171	4.37	125	86	0.24		2.8
		4	lb 1	1100	0.171	4.32	125	86	0.24	6.1	36.3
			lb 2	1160	0.171	4.12	125	86	0.24	5.5	40.0
				50.9		4.20	100	86	0.24		2.2
75	1 Nov	1	lb 1	2120	0.156	4.05	125	90	0.234	4.2	83.5
			lb 2	2300	0.156	4.13	125	90	0.234	4.0	88.4
			db	91.7	0.156	4.17	125	90	0.234		3.5
		2	lb 1	1940	0.156	4.02	125	88	0.238	5.0	76.3
			lb 2	1970	0.156	4.20	125	88	0.238	5.1	74.2
			db	95.6	0.156	3.98	125	88	0.238		3.8

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
75	1 Nov	3	lb 1	2010	0.156	3.97	125	87	0.238	5.2	79.4
			lb 2	2410	0.156	4.32	125	87	0.238	4.7	87.2
			db	112	0.156	4.27	125	87	0.238		4.1
		4	lb 1	2460	0.156	4.30	125	86	0.239	3.5	89.2
			lb 2	1930	0.156	4.23	125	86	0.239	4.4	71.2
			db	86.1	0.156	4.35	125	86	0.239		3.1
		5	lb 1	1860	0.156	3.93	125	84	0.239	3.9	71.7
			lb 2	2110	0.156	4.12	125	84	0.239	3.6	77.6
			db	75.0	0.156	4.08	125	84	0.239		2.8
76	26 July	1	lb 1	1270	0.171	4.45	50.0	95	0.231	2.1	108
			lb 2	1230	0.171	4.42	50.0	95	0.231	2.2	105
			db	39.4	0.171	4.32	75.0	95	0.231		2.3
		2	lb 1	1650	0.171	4.28	75.0	95	0.235	3.3	99.1
			lb 2	1080	0.171	4.47	50.0	95	0.235	3.5	93.3
			db	37.4	0.171	4.38	50.0	95	0.235		3.3
		3	lb 1	1120	0.171	4.35	50.0	95	0.24	2.8	101
			lb 2	1110	0.171	4.57	50.0	95	0.24	2.9	95.4
			db	31.9	0.171	4.52	50.0	95	0.24		2.8
76	7 Sept	1	lb 1	1320	0.171	4.37	75.0	91	0.24	4.7	76.0
			lb 2	1560	0.171	4.47	75.0	91	0.24	4.1	87.7
			db	65.1	0.171	4.55	75.0	91	0.24		3.6
		2	lb 1	1450	0.171	4.50	75.0	90	0.24	4.5	80.1
			lb 2	1380	0.171	4.40	75.0	90	0.24	4.6	78.0
			db	63.2	0.171	4.32	75.0	90	0.24		3.6

Sta	Date	Depth (m)	Bottle	Net C.R. (cpm)	Counter Yield	Time (h)	Vol (ml)	Alky (ppm)	Alky Factor	Rel Dark Uptake (%)	Productivity (mg C/m^3·h)
76	31 Oct	1	lb 1	850	0.156	3.83	150	85	0.23	11	27.3
			lb 2	1020	0.156	3.87	150	85	0.23	9.2	32.5
			db	89.4	0.156	3.67	150	85	0.23		3.0
		2	lb 1	809	0.156	3.80	150	86	0.23	11	26.6
			lb 2	1020	0.156	3.93	150	86	0.23	8.9	32.4
			db	89.9	0.156	3.88	150	86	0.23		2.9
		3.5	lb 1	907	0.156	3.73	150	87	0.23	9.4	30.7
			lb 2	768	0.156	3.70	150	87	0.23	11	26.2
			db	86.0	0.156	3.77	150	87	0.23		2.9

APPENDIX III

Productivity and Related Parameters

Abbreviations and Explanations

Sta	Station number
Rel Sur Light Intensity (μA)	Relative surface light intensity
% Sur Light Intensity	% surface light intensity, ratio of photometer reading at sample depth to the relative surface light intensity x 100%
Temp	Water temperature at sampling depth
Productivity	Light bottle productivity - dark bottle productivity
Rat. Is	*In situ* site near Rattlesnake Island

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (μA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
23	13 Aug	0845	5.0	1450	1	55	22.00	8.49	11.0
					3	24	22.00	8.48	7.0
					5	10	22.00	8.48	9.5
					7	5.7	22.00	8.48	5.7
					13	0.98	22.00	8.48	-
23	23 Oct	1045	2.0	1150	1	37	11.00	8.62	26.5
					2	16	11.00	8.61	24.2
					3	8.5	11.00	8.61	23.4
					5	2.6	11.00	8.60	20.4
					6.5	0.91	11.00	8.59	21.0
25	13 Aug	1115	7.8	7000	2	47	22.00	8.53	5.9
					4	27	22.00	8.51	3.4
					5	21	21.75	8.50	5.6
					8	10	21.75	8.49	4.7
					18	1.0	14.25	7.66	6.2
25	23 Oct	1345	3.0	5300	1	43	12.00	8.48	14.6
					3	14	12.00	8.48	14.2
					5	3.8	12.00	8.46	15.0
					7.5	1.1	12.00	8.46	14.2
					9	0.47	12.00	8.45	12.0

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (μA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
30	1 Aug	1300	4.0	8400	1	64	21.50	8.61	15.2
					3	35	21.25	8.62	18.5
					5	14	21.00	8.64	20.0
					6	9.2	21.00	8.64	21.0
					11.5	1.0	21.00	8.54	29.1
30	14 Aug	1200	8.0	7700	1	60	22.00	8.48	6.6
					3	35	22.00	8.48	4.4
					5	20	22.00	8.48	4.8
					10	6.5	21.75	8.49	10.6
					16	1.5	10.50	7.21	12.0
					19	0.52	10.50	7.21	10.2
30	26 Oct	1000	2.7	2200	1	43	12.00	8.64	15.8
					3	10	12.00	8.64	19.3
					5	3.1	12.00	8.64	16.1
					7	1.0	12.00	8.64	22.4
					9	0.38	12.00	8.64	20.1
32	26 Oct	1530	3.5	4700	1	46	12.00	8.53	12.0
					3	16	12.00	8.53	12.3
					5	7.4	12.00	8.53	9.3
					7	3.0	12.00	8.53	10.6
					10	0.90	12.00	8.53	10.4

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (μA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
34	15 Aug	1200	4.9	8200	1	57	22.50	8.61	7.6
					3	22	22.50	8.61	7.0
					4	10	22.25	8.61	13.2
					5	7.6	22.25	8.60	10.4
					11	1.0	22.00	8.45	12.5
36	15 Aug	1545	8.0	7900	1	68	24.00	8.40	4.1
					3	43	23.00	8.40	4.4
					5	25	22.50	8.42	5.7
					9	10	22.00	8.41	8.5
					18.5	1.0	12.25	7.40	13.7
36	27 Oct	1100	4.7	4700	1	53	12.00	8.58	19.4
					3	19	12.00	8.58	19.2
					5	8.0	12.00	8.58	17.3
					7	3.1	12.00	8.57	20.2
					10	1.0	12.00	8.57	16.6
39	27 Oct	1445	2.3	4300	1	37	12.00	8.66	16.8
					2	20	12.00	8.67	18.9
					3	9.9	12.00	8.67	18.7
					5	3.0	11.50	8.62	11.6
					7	0.87	11.25	8.54	19.6

Sta	Date	Time	Secchi Disc (m)	Rel. Sur Light Intensity (μA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
44	14 Aug	1015	4.5	4300	1	15	22.75	8.51	16.0
					2	12	22.75	8.52	13.2
					3	8.7	22.75	8.52	12.7
					5	-	22.75	8.52	13.8
					10	-	22.75	8.42	12.4
44	29 Oct	0845	2.5	700	1	43	11.00	8.46	49.8
					2	16	11.00	8.46	50.0
					3	8.9	11.00	8.46	46.8
					5	2.7	11.00	8.46	54.8
					7	1.0	11.00	8.45	54.4
47	30 July	1100	5.4	8400	1	55	22.50	8.61	15.4
					2	39	22.50	8.61	10.3
					3	27	22.50	8.61	18.4
					5	13	22.50	8.60	20.8
					7	8.0	22.50	8.59	12.4
					14	1.0	21.50	8.36	21.0
47	12 Aug	1000	5.5	825	1	52	21.75	8.40	14.3
					3	20	21.75	8.40	10.9
					5	11	21.75	8.40	16.0
					10	2.2	21.50	8.40	14.4
					13.5	1.0	21.50	8.41	14.3
					15	0.76	21.50	8.42	14.6

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (μA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
47	21 Oct	1145	4.0	775	1	61	13.25	8.44	33.0
					3	18	13.25	8.44	32.0
					5	7.4	13.25	8.44	25.4
					7	2.5	13.25	8.44	29.5
					9.5	0.93	13.25	8.46	29.7
48	4 Aug	1130	4.5	7700	1	55	21.50	8.51	9.0
					3	22	21.50	8.49	16.4
					5	10	21.50	8.48	11.0
					7	4.2	21.50	8.48	9.3
					11	0.94	21.50	8.49	9.6
48	16 Aug	1330	4.5	8500	1	53	23.00	8.64	16.9
					3	22	23.00	8.64	15.9
					4	14	22.75	8.63	16.2
					5	9.7	22.75	8.60	15.4
					8	3.8	22.25	8.46	18.7
					13	1.0	22.00	8.54	10.9
48	28 Oct	1115	3.7	5300	1	47	12.00	8.68	23.4
					3	17	12.00	8.68	22.8
					5	6.1	12.00	8.67	27.0
					7	2.5	12.00	8.66	22.0
					9	1.1	12.00	8.65	20.8

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (μA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
52	27 July	1630	3.0	7200	1	43	24.00	8.55	12.0
					2	24	23.00	8.75	14.6
					3	12	22.75	8.58	37.1
					5	2.6	22.75	8.45	27.4
					7.5	0.90	22.50	8.37	13.0
53	6 Sept	1730	0.7	3400	1	8.1	20.75	-	31.3
					2	0.66	20.75	-	35.3
					3	0.11	20.75	-	36.6
					4	0.010	20.75	-	36.7
53	30 Oct	1600	2.0	825	1	42	11.00	8.61	32.6
					2	14	11.00	8.60	37.8
					3	7.0	11.00	8.60	35.6
					4	3.3	11.00	8.60	35.0
					6	1.0	11.00	8.58	32.9
61	26 July	1645	1.6	7400	1	27	22.50	8.37	9.2
					2	12	22.50	8.37	8.7
					3	5.1	22.50	8.36	16.3
					5	1.1	22.00	8.31	15.6

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (µA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
61	7 Sept	1745	1.5	3100					
					1	32	20.00	-	28.4
					2	15	20.00	-	28.2
					3	5.9	20.00	-	30.3
					5	0.97	18.75	-	34.6
61	1 Nov	1130	2.1	5100					
					1	42	10.25	8.36	4.0
					2	21	10.25	8.36	4.0
					3	14	10.25	8.36	4.2
					5	4.1	10.00	8.36	4.4
					7	1.7	10.00	8.34	4.0
66	28 July	1200	2.7	8000					
					1	61	23.75	8.68	27.4
					2	35	23.25	8.72	29.9
					3	18	23.25	8.69	29.4
					5	5.9	23.00	8.50	50.4
					9	0.94	22.50	8.05	27.8
66	29 Oct	1445	2.5	975					
					1	44	10.00	8.85	30.6
					2	18	10.00	8.84	27.8
					3	11	10.00	8.83	27.6
					5	3.8	10.00	8.78	28.0
					8	0.92	10.00	8.73	26.3

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (µA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3.h)
67	27 July	0900	2.5	2700	1	38	23.25	8.54	36.8
					2	19	23.25	8.54	34.8
					3	9.0	23.25	8.54	30.2
					6.5	1.1	23.00	8.45	32.2
67	6 Sept	1000	1.3	4700	1	24	20.00	-	31.6
					2	6.4	20.00	-	32.2
					3	2.0	20.00	-	29.6
					4	0.59	20.00	-	30.4
67	30 Oct	0845	1.7	925	1	22	10.00	8.66	45.6
					2	9.2	10.00	8.67	50.2
					3	4.1	10.00	8.66	50.1
					4	1.7	10.00	8.66	40.2
					5	1.0	10.00	8.66	44.0
Rat. Is.	21 July	1245	1.6	8800	1	38	23.50	8.7	152
					2	14	23.50	-	111
					3	5.7	23.50	8.6	66.6
					4	2.1	23.50	-	39.3
					5	0.88	23.25	8.5	19.3

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (μA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3·h)
Rat. Is.	10 Sept	1300	1.0	3600	1	19	21.00	8.45	117
					2	5.4	20.50	-	33.8
					3	2.1	20.50	8.45	11.1
					4	0.66	20.50	-	4.8
					6	0.12	20.50	8.35	3.7
					8	0.014	20.25	8.38	4.4
Rat. Is.	6 Oct	1145	0.8	5700	0.5	32	-	-	29.4
					1	20	13.50	8.38	36.5
					2	4.1	13.50	-	19.7
					3	1.1	13.50	-	7.5
					4	0.30	13.25	-	4.1
					5	0.088	13.25	8.38	3.6
73	30 July	1430	5.3	8600	1	51	22.25	8.58	8.4
					2	38	22.25	8.59	27.3
					3	28	22.25	8.58	20.3
					5	14	22.25	8.58	19.0
					8	6.1	22.25	8.57	18.6
					15.5	1.0	21.50	8.45	15.3
73	21 Oct	1445	4.0	5700	1	54	13.50	8.43	30.1
					3	16	13.25	8.43	31.8
					5	6.1	13.25	8.42	30.3
					7	2.3	13.25	8.42	31.9
					9.5	0.89	13.25	8.40	27.2

Sta	Date	Time	Secchi Disc (m)	Rel Sur Light Intensity (µA)	Depth (m)	% Sur Light Intensity	Temp (°C)	pH	Productivity (mg C/m^3.h)
75	26 July	1430	1.5	7500	1	10	23.75	9.00	142
					2	2.0	23.75	9.03	109
					3	0.77	23.50	9.03	120
75	7 Sept	1545	1.0	5000	1	12	19.75	-	26.0
					2	5.5	19.00	-	35.8
					3	1.4	19.00	-	35.2
					4	0.20	18.75	-	36.0
75	1 Nov	0930	1.2	1425	1	26	10.75	8.86	82.4
					2	7.9	10.75	8.82	71.4
					3	2.5	10.75	8.82	79.2
					4	1.0	10.75	8.81	77.1
					5	0.30	10.75	8.81	71.8
76	26 July	1100	0.9	1825	1	15	22.75	8.79	104
					2	2.9	22.75	8.75	92.9
					3	0.71	22.75	8.62	96
76	7 Sept	1200	0.6	6100	1	5.7	20.00	-	78.2
					2	0.53	19.50	-	75.4
76	31 Oct	1215	1.5	4100	1	32	12.00	8.96	26.9
					2	17	11.75	8.96	26.6
					3.5	6.1	11.50	8.95	25.6

APPENDIX IV

In situ Carbon Assimilation Near Rattlesnake Island

Date	Integral Rate (mg C/m^2.h)
21 July	342
10 Sept	114
6 Oct	95