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be in terms of primary production is difficult to evaluate. It has been shown, however, that diatoms make up the bulk of the food of some insect larvae (5) and of several species of minnows in the Des Moines River (6). The colonies provide a suitable habitat for many types of protozooans, rotifers, and aquatic worms. Many other diatom taxa are also found thriving among the stalks of *G. olivaceum.*

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A Study of Photosynthesis in Clear Lake, Iowa[1]

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Abstract. The oxygen and carbon-14 methods were used to measure photosynthesis in Clear Lake, Iowa during 1958 and 1959. Differences in the rates of photosynthesis at widely separated stations were generally small. Daily variations in the rate of photosynthesis were not greater than two-fold. The correlation between the rate of photosynthesis and the incident illumination was 0.81, and the efficiency of utilization of incident light energy was 0.72 per cent. The net gain of organic matter at the phytoplankton level during the period May 1 to November 1 was equivalent to 3480 pounds of glucose per acre.

Despite the basic position of planktonic algae in the food chain of aquatic environments there have been few extensive studies of food production by phytoplankton in well-defined ecosystems, and little has been done to follow quantitatively the flow of organic matter from one level in the food chain to the next. A knowledge of the total food budget available at the primary level would contribute much to an understanding of fish population dynamics even though the food relationships between fish and phytoplankton are complex and generally obscure. This study of photosynthesis was undertaken to supplement studies of fish population dynamics that have been carried on in Clear Lake since 1941.

Clear Lake has an area of approximately 1500 hectares and a

[1] This study was conducted in the Department of Botany and Plant Pathology as a part of Project 11 of the Atomic Energy Commission under contract AT(11-1)59, administere dthrough the Institute for Atomic Research, Iowa State University, Ames, Iowa.

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mean depth of 4 meters during years of average rainfall. Because the lake lies in a shallow basin, exposed to the slightest wind action, it undegoes complete and nearly constant circulation. The limnological features of the lake have been studied extensively and are described by Pearcy (1). At the time of this study the mean depth of the lake had been reduced to 2.3 meters because of a prolonged period of below-average rainfall. Due to the low transparency of the water (the average Secchi disk reading was 0.6 meter) submergent vegetation was restricted to the very shallow water near shore. An extensive retreat of the shoreline prior to, and during this study greatly reduced the amount of submergent and emergent vegetation, and their contribution to the total food budget of the lake was considered inconsequential. The effect of the lower water level on the total surface area of the lake was not determined.

Methods

Water samples were taken with a three-liter Kemmerer sampler and placed in 300 ml B.O.D. bottles. Replicate samples were taken for determination of dissolved oxygen, inorganic carbon, and ash-free weight of seston, and for *in situ* photosynthesis measurements. Three replicate bottles to be used for measurement of photosynthesis were suspended in wire racks in the lake at each depth interval. The bottles were positioned at 0.1, 0.5, or 1.0 meter intervals in 1958, and at 0.1 or 0.3 meter intervals in 1959, and they remained in the lake from sunrise until noon.

Carbon-14 labeled sodium carbonate, with a specific activity of 4 microcuries per milliliter, was prepared from labeled barium carbonate according to the method of Aronoff (2) and Steemann Nielsen (3), and stored in sealed, one-milliliter glass ampoules. The contents of one ampoule were added to each 300 ml bottle of lake water used for photosynthesis measurement. At the end of the exposure period an aliquot volume of 5-25 ml (depending upon the amount of seston in the water) was taken from each bottle by pipette, filtered through a 1.2 micron Millipore filter, dried, and counted with a D-34 thin-window tube using a Nuclear-Chicago 151A scaler (the counting efficiency was 3%). The algal residue on the filters showed no self-absorption of radiation over a wide range of residue thickness. Three replicate dark bottles were used on each occasion to correct for non-photosynthetic carbon fixation. The total amount of dissolved inorganic carbon in the water was determined by methyl orange titration. The amount of carbon fixed by the samples was calculated by using the relationship:

$$\text{Carbon Fixed} = \frac{(\text{Net sample activity}) \times (\text{Total inorg. Carbon})}{\text{Activity added to sample}}$$

A factor of 1.11 was used to correct for isotope discrimination.

Dissolved oxygen determinations were made according to Welch (4). All samples were given immediate field treatment and titrations were completed within four hours of collection. Three control dark bottles were used on each occasion to determine respiration rates, permitting the determination of gross and net photosynthesis rates. A photosynthetic quotient of one was used to convert data to carbon values. The net photosynthesis of a sample bottle was determined by subtracting the oxygen concentration of the lake water at dawn from the oxygen concentration of the sample bottle at the end of the exposure period (at noon). Gross photosynthesis was determined by adding the net photosynthesis and respiration rates. The respiration rate was determined by measuring the oxygen uptake in the dark bottles.

The values of net photosynthesis obtained by the oxygen method represent the amount of organic material produced in excess of the total plankton respiration, whereas the values of photosynthesis obtained by the carbon-14 method represent the amount of organic material produced in excess of phytoplankton respiration. One would expect the net oxygen values to be lower than the carbon-14 values (Table 1).

Table 1. A comparison of photosynthesis data from the oxygen and carbon-14 methods
(mg. carbon/m²/photoperiod), 1958

	Method		
Date	Oxygen (net)	Carbon-14	Oxygen (gross)
June 23	0.89	1.07	1.85
June 26	1.12	1.52	1.89
July 3	1.42	1.63	2.21
July 9	0.97	1.26	1.92
July 23	0.77	1.26	1.81

The ash-free weight of seston was determined by centrifuging four replicate 200 ml volumes of lake water 20 minutes at 1500 × G. The seston was dried at 50°C for 24 hours and ashed at 500°C. for 30 minutes. Water temperature was measured with a Whitney Resistor thermometer.

Measurements of surface and submarine illumination were made with a Whitney Submarine photometer. Readings of surface illumination were taken at hour intervals (or more often during varying sky conditions) beginning at sunrise, and were graphically integrated to obtain foot-candle-hours of illumination. The transparency of the water was also measured freuently with a Secchi disk.

Results and Discussion

The oxygen and carbon-14 methods were used concurrently at Station I (Figure 1) on five dates in 1958. The photosynthesis values obtained were in close agreement and gave credence to the relationship discussed above.

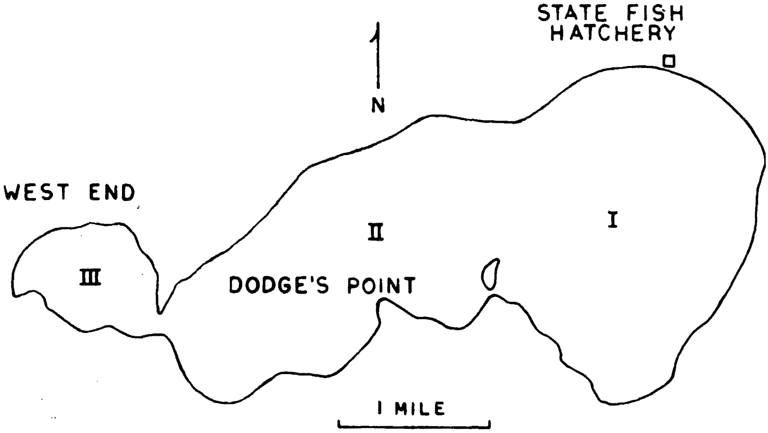

Figure 1. Map of Clear Lake showing location of stations

The productivity in different regions of the lake were studied by making carbon-14 measurements concurrently at Station I and II on June 26, July 31, August 7, August 27, September 19, and October 18, 1958. Concurrent measurements at Station I, II, and III were made on August 27 and September 19, 1958 (Figure 2). On June 26, August 27, September 19, and October 18 replicate bottles were suspended at the same depth intervals at Station I and II. This permitted an analysis of variance of the data, and a significant difference (0.05 level) among stations was found on August 27 only. This was in agreement with a report by Small (5), who took plankton samples at widely scattered stations in the lake on July 7, July 24, and August 25. His data indicated a significant variation in plankton counts among stations only on August 25. This was approximately the time at which the difference in station productivity was observed.

Differences in mean ash-free weight seston at Station I and II on June 6, July 31, August 27, September 19, and October 18, 1958, were tested using "Students *t*". Differences, though significant on two dates, were small (Table 2.). A high correlation was found between the optical density of the lake water and the ash-free weight of seston ($r = 0.92$). The transparency of the water at Station I and II was compared by analysis of covariance of the regression of $\log_{10}$ illumination on depth. Differences between regression coefficients were not significant at the 0.05 level. Temperature differences between the two stations were generally less than 1°C. and never exceeded 2°C.

The close agreement of photosynthesis, transparency, seston,

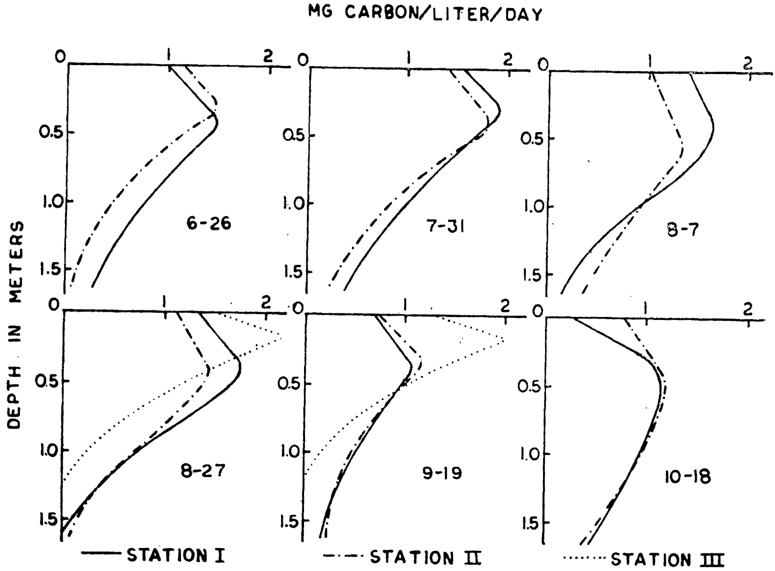

Figure 2. Concurrent measurements of photosynthesis at Station I, II, and III, 1958

and temperature data from Station I and II led to the assumption that the main part of the lake could be treated as a uniform body.

Conditions in the West End of the lake were much different, however. The optical density of the water and the ash-free weight of seston were twice as great as in the main body of the lake, and the mean water depth was only 0.6 meter. Despite the dissimilarity of conditions the gross photosynthesis at Station III was nearly the same as that of the main part of the lake (Figure 3).

The similarity in photosynthesis rates suggested that the efficiency of utilization of incident light energy was essentially the same in all parts of the lake. During the period June 23-July 23, 1958, the average gross photosynthesis was 1.94 grams of carbon per square meter per photoperiod. This is equivalent to 4.85 grams of glucose. The incident light energy averaged 2500 kilocalories per square meter per day. The average efficiency for the conversion of light energy to chemical energy was 0.72 per cent. An efficiency of 0.8 per cent was reported by Riley (6) for waters of the Northwestern Atlantic, and Rabinowitch (7) estimated a similar efficiency for land plants.

In 1959 the study was confined to Station I, the measurement intervals were reduced to 0.1 meter, and attention was focused on daily variations in photosynthesis and their relationship to environmental conditions.

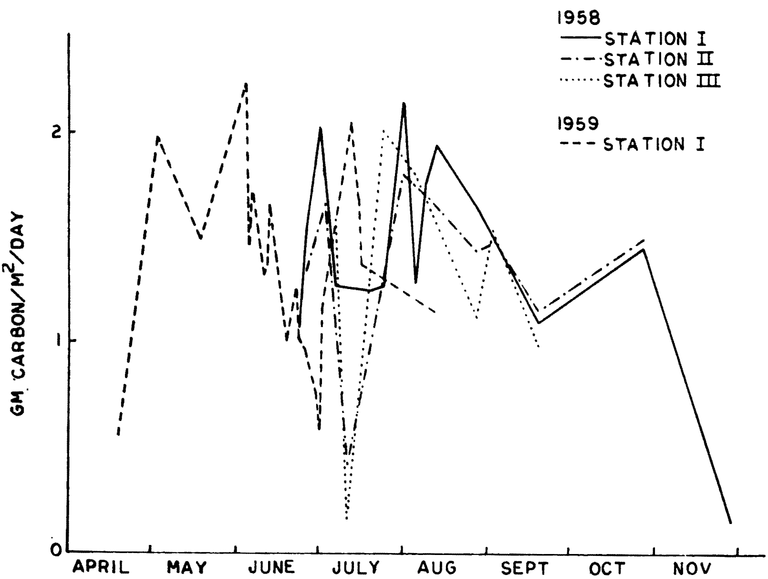

Figure 3. Summary graph of carbon-14 data from 1958 and 1959

Table 2. Ash-free weight of seston at Station I and II, 1958
Ash-free weight (mg/1)

Date	Station I	Station II	Student's "t"*
June 26	11.625	11.875	0.562
July 31	15.675	15.250	0.859
Aug. 27	17.700	16.825	2.346
Sept. 19	15.150	13.400	5.418**
Oct. 18	16.250	15.125	4.364**

* With 6 degrees of freedom
** Significant at the 0.05 level

The depth of maximum photosynthesis shifted gradually from 0.7 meter on April 18 (one week after the ice went out) to 0.2 meter on June 3 (Figure 4a). By this time the photosynthesis zone was shallower than it was in 1958. Measurements of photosynthesis were made on consecutive days during five periods: June 3-5, June 0-12, June 22, 23, 25, June 29- July 1, and July 13-17. Analysis of variance of the photosynthesis data indicated significant differences among days in all periods but the first. Daily variations in photosynthesis as large as three-fold have been roported for some lakes (8), but in this study they did not exceed two-fold. Daily productivity was rather highly correlated with total incident illumination (r = 0.81) and it was interesting to note the vertical shift of the photosynthesis maxima with changes in surface illumination from day to day. The typical photosynthesis curve consisted of two components—an upper linear region in which light was inhibitory and the rate of photosynthesis was inversely proportional to the logarithm of the light intensity; and a lower exponential region in which light was limiting and the photosynthesis rate was directly proportional to the light intensity. The relationship between incident light intensity and the depth of the photosynthesis maximu mwas well demonstrated by the data from the period June 29—July 1 (Figure 4e). On June 30 the incident light intensity permitted a maximum rate of photosynthesis at the surface of the lake, the only time this condition was obtained during the entire study.

Table 3. Relationship between photosynthesis and total incident light energy

	Gm carbon/m²/day	Incident light 10^3 ft. c. hrs/day
June 3	2.10	78.9
" 4	1.50	77.2
" 5	1.80	77.0
" 10	1.32	48.2
" 11	1.40	33.9
" 12	1.70	79.5
" 18	1.04	21.9
" 22	1.27	75.8
" 23	1.02	38.9
" 25	0.95	57.4
" 29	0.75	17.1
" 30	0.58	12.9
July 1	1.16	29.7
" 13	1.59	71.5
" 14	1.72	70.4
" 15	1.92	69.3
" 16	1.44	78.9
" 17	1.18	38.0

The change in the magnitude of the photosynthesis maxima and the shape of the photosynthesis curves from the June 10-12 period to the June 22-25 period can be explained by using the seston and chlorophyll data collected during these periods (Figure 4c and 4d). The ash-free weight of seston dropped from 27.1 milligrams per liter on June 11 to 19.8 milligrams per liter on June 25, and a corresponding decrease occurred in the optical density of the water. As a result the depth of the photosynthetic zone increased. A 30 per cent decrease in the chlorophyll content of the plankton was also noted (9). Since the incident illumination on June 25 was higher than it was on June 11 the lesser rate of photosynthesis was undoubtedly due to a decrease in the photosynthetic capacity of the phytoplankton.

The peculiar double maximum in the photosynthesis curves for the July 13-17 period occurred during a bloom of dinoflagellates. The lower maximum of each curve was probably due to the light sensitivity of the dinoflagellates. This aspect was not further investigated, however.

The mean daily gross productivity of the lake (1.95 grams of carbon per square meter per day) was similar to that of East

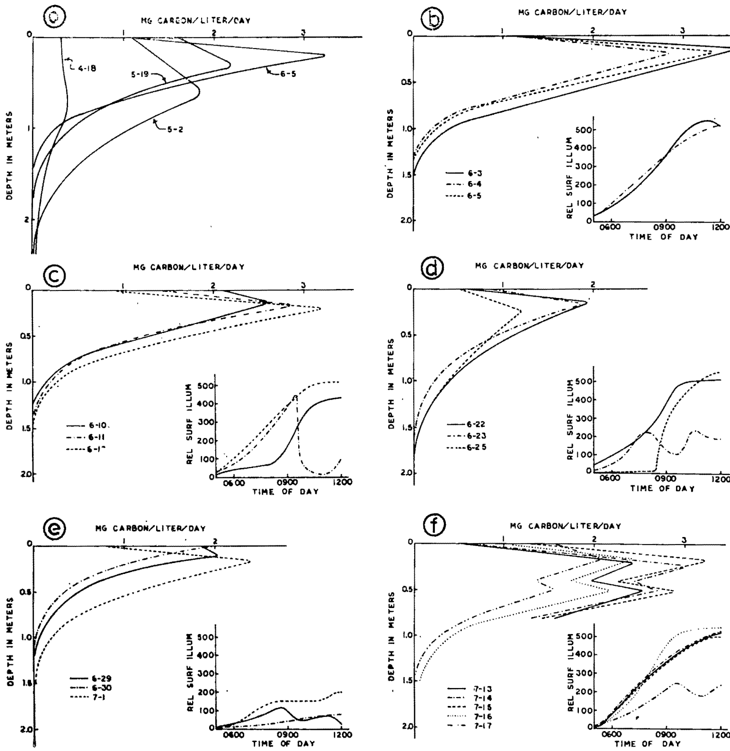

Figure 4. Daily photosynthesis curves at station I, 1959

Okoboji Lake (10), and indicated that the lake was well within the range given for eutrophic lakes by Gessner (11). The annual net gain of organic matter at the phytoplankton level, which should be of interest to the fisheries biologist, was estimated for the period May 1 to November 1 by using the carbon-14 data from 52 station measurements of photosynthesis made during 1958 and 1959. Because the carbon-14 measurements were limited to the photoperiod, the relationship between the carbon-14 and oxygen data (Table 4) was employed to determine the rate of phytoplankton respiration.

Table 4. Average gross and net measurements of photosynthesis, 1958 and 1959

Measurement	Method	Gm carbon/m²/day*
Gross photosynthesis	Oxygen	1.95
Net photosynthesis	Carbon-14	1.40
Net photosynthesis	Oxygen	1.01

* Photoperiod only

The mean net gain in organic matter was found to be 0.85 grams of carbon per square meter per day. For the entire period mentioned above this would amount to 156 grams of carbon per square meter, or the equivalent of 5,400 metric tons of glucose for the lake as a whole (3480 lbs. of glucose per acre).

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Notes on Fleshy Fungi in Iowa[1]

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Abstract. Eighty-two sporocarps of fleshy fungi were collected during the summer of 1962. In the collections were seven species. *Peziza sylvestris* (Bond.) Sacc. & Trott., *Cortinarius uraceus* Fr., *Clitopilus subvilis* Pk., *Inocybe radiata* Pk., *Inocybe geophylla* Fr., *Lactarius hysginus* Fr., *Mycena subcaerulea* (Pk.) Sacc., and one genus, *Nolanea* Fr., not previously reported for the state of Iowa.

A number of notes, reports, and lists of fleshy fungi in Iowa have appeared in the past. Gardner (1) published an annotated checklist of the Homobasidiomycetes of Iowa which summarized

[1] Journal Paper No. J-4597 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1251. In cooperation with the Central States Forest Experiment Station, United States Forest Service.

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