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Phytoplankton Production in Ogelube Lake Opi, Enugu State, Nigeria

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Abstract

The rate of phytoplankton production in Ogelube lake, Opi was investigated for one year using oxygen light and dark bottle technique. Water samples were collected from a mid-lake location at three depths and incubated *in situ* for four hours around midday. The phytoplankton population in the acidified samples was estimated using sedimentation technique. Primary productivity increased with increase in phytoplankton population. Mean rate of gross production for the period of investigation was 204.18 mg Carbon/m^3/hr. Mean rate of net production was 71.22 mg C/m^3/hr. Mean daily gross production rate for the lake was 1582.17 mg Carbon/m^3/day and mean net production was 569.75mg C/m^3/day. Gross production was highest in December and lowest in May, the latter having a negative value. Primary production decreased with depth. Based on the low net production obtained, the lake can be said to be oligotrophic.

Key Words: Phytoplankton, Ogelube lake, Nigeria

Introduction

The Ogelube lake, Opi, is a tropical lake, at an elevation of about 244 m above sea level on the Nsukka-Okigwe cuesta of Anambra basin (Ofomata, 1975). The lake is one of a series of small natural lakes, which lie in the valley of River Uhere, a branch of River Ora. The Ora river empties into the Cross River and finally into the Gulf of Guinea at Calabar (Fig. 1).

The estimated area of the lake is about 3 256 m^2, volume 5505m^3 and mean depth 1.69 metres. Maximum depth recorded during 1979 and 1980 was 4 m (Hare, 1986) and 3.5 m in 1981 (Evurunobi, 1984).

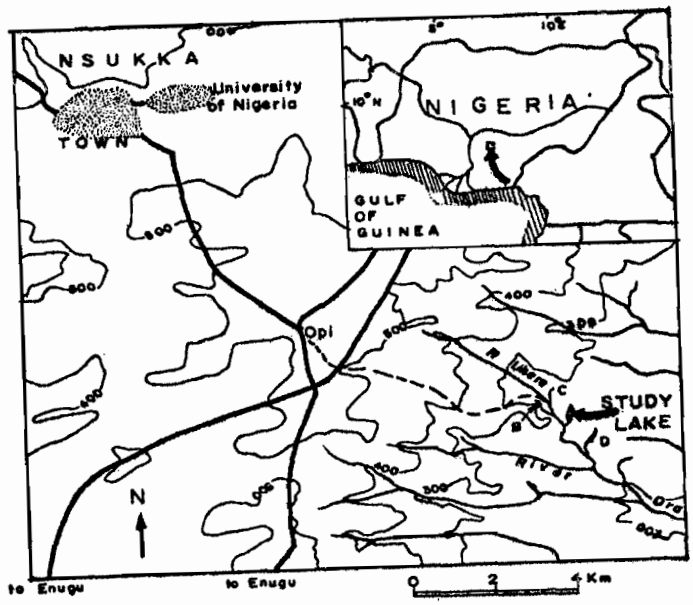

Fig.1: Location in Nigeria of study area (inset) and a portion of the Enugu escarpment with Opi lakes A- D indicated (redrawn from Federal Surveys Nigeria Map Sheet 287: 1967, after Hare, 1986).

Primary productivity of natural West African lakes has not been studied as has been done for the East African lakes and reservoirs in Nigeria. Earlier reports on natural Nigerian lakes are those of Compere and Iltis (1983) on Lake Chad; Nwadiaro and Oji (1986) on Oguta lake among others.

Primary production has been observed to be affected by phytoplankton population density (Beadle, 1974; Talling 1975; Bayne et al, 1983), in addition to abiotic factors such as resuspension by wind that tend to cause attenuation of light thereby reducing algal production (Hellstrom ,1991) or in contrast induce resuspension of sediment loving algae (meroplankton), (Carrick et al, 1993).

Various methods have been used to determine primary productivity viz: chlorophyll a content, rate of carbon fixation and dissolved oxygen *in situ* in lake using oxygen light and dark bottle technique (Beadle, 1974; Imevbore and Bozormenyi, 1975; Wetzel and Likens, 1979; Melack, 1982; Rieman and Ernst, 1982). Counting and weighing of algal cells/ biomass have been applied and a correlation between population density (cells per unit volume) and net productivity observed (Beadle, 1974). Biswas (1978) noted that *in situ* measurement of productivity is a better way than other methods.

Studies have shown that in productivity measurements the flux of oxygen and carbon will be balanced at a steady state such that photosynthetic quotient will be approximately 1.2 (Harris, 1978, 1986; Wetzel and Likens, 1979).

This study was set up to investigate the rate of primary production by phytoplankton and the trophic state of the Ogelube lake in 1986.

Materials and Methods

Samples were collected from a mid-lake location at bi-weekly intervals. The investigation was carried out between November 1985 and November 1986. During the first 5 months of sampling, samples were collected by means of a 2-litre Kemmerer water sampler, which later developed mechanical fault. Subsequent samples were collected by means of Irwin's sampler designed after the description of Welch (1948).

Samples were collected from three depths viz. sub-surface, 1- metre and 2- metre. For each sampling depth 3 oxygen bottles labeled "initial" "light" and "dark" were filled with the lake water. The "dark" bottle was shielded with black polythene material and held in position with rubber bands. Sub-surface samples were collected by dipping the bottle 5 centimetres below the water surface. Samples from 1 metre and 2 metre depths were collected by means of Kemmerer/Irwin's sampler.

The oxygen in the "initial" oxygen bottle was fixed immediately with Winkler's reagent after Welch (1948). The "light" and "dark" oxygen bottles meant for productivity measurements were suspended in the lake at their depths of collection. They were left in the water for 4 hours at the end of which they were brought out and the oxygen fixed immediately with Winkler's reagents. The oxygen in all the bottles was determined titrimetrically within 3 hours of fixation.

Samples were collected between 10.00 a.m. and 12 noon. *In situ* incubation of samples collected was done around mid-day because highest efficiency of utilization of irradiance in photosynthesis is known to occur during periods of low irradiance such as between mid morning and early afternoon as noted by Melack (1979, 1982).

At the end of the incubation period (4 hours) water samples were collected from the depth sampled and fixed with Lugol's iodine for population studies.

Changes in dissolved oxygen concentration in the "light" and "dark" bottles during the 4 hours experimental period were used for the determination of productivity (Viner, 1970 b; Beadle, 1974) as follows: -

(1) The difference between final oxygen concentration in "light" bottle and "dark" bottle gave the Gross Photosynthesis;
(2) The difference between the initial and final oxygen concentration in the "light" bottle gave the net photosynthesis; and
(3) The difference between the initial and final oxygen concentration in the "dark" bottle gave the Respiratory activities.

These values - the gross oxygen produced, the net oxygen produced and the respired oxygen were used in computing the Gross production, net production and respiration in $mgC/m^3/hr$ following Wetzel and Likens (1979).

Daily rates of production were calculated by plotting the data on daily irradiance and working out a factor from the area of the graph during which the incubation was carried out. This was obtained as the ratio of total irradiance per day to irradiance during exposure time (Vollenweider, 1974; Beadle, 1974). Mean production per day for the lake was calculated from the daily rates.

Phytoplankton population studies were carried out on the acidified samples (sample in the oxygen bottles) after Biswas (1978), and fixed final water samples using sedimentation technique (Lund, Kipling and Le Cren, 1958). One millilitre of sample was sedimented in a one millilitre sedimentation chamber for one hour and the population counted under an inverted microscope, Wild Heerburg, Model M40 with X 600 magnification.

When population was high samples were diluted and appropriate corrections made (Lund, Kipling and Le Cren, 1958). For low population at least half of the sedimentation area was counted and estimates were expressed as the number of individuals/ml of sample.

Mean values for the investigated parameters (production and population density) for each sampling date were calculated and also were the monthly and yearly means.

Computerized Pearson correlation was used for correlation analysis between the parameters investigated. All tests of significance were at 11 degrees of freedom at 95% and 99% values of probability. The ANOVA and LSD for month and depth were calculated for the parameters investigated and tests of significance were at .001, .01 and .05 levels.

Results

Phytoplankton: A total of 163 taxa were encountered. The species composition of the different divisions encountered is presented in Table 1.

Table 1: Composition of Phytoplankton species in Ogelube lake.

Phylum	No of species	% Composition
Chlorophyta	95	58.28
Cyanophyta	21	12.88
Euglenophyta	16	9.82
Bacillariophyta	15	9.20
Dinophyta	6	3.68
Xanthophyta	4	2.45
Chrysophyta	3	1.84
Cryptophyta	3	1.84
Total	**163**	**100**

Chlorophyta had the largest species composition followed by Cyanophyta (Cyanobacteria), Euglenophyta, Bacillariophyta, Dinophyta, Xanthophyta, Chrysophyta, and Cryptophyta in decreasing order.

Significant variations were observed in the phytoplankton population densities with depth (Table 2a). The populations decreased consistently with depth. The number of the phytoplankton did not however differ at the subsurface and I metre depths. Significant differences existed between these depths and the 2 – metre depth. High population was observed at the various depths investigated. Values ranged from 24,509 to 42,448 individuals/ml. Results from calculated LSD showed the population was more in the first 1 metre depth. Also, results from ANOVA showed that the total population in the various bottles ('initial', 'light' and 'dark') varied with the months and depths sampled. The values for months for the various bottles being significant at 0.01 in 'initial' and 'light bottles' but at 0.05 in the 'dark bottle' (Table 2b).

Table 2a: Variations of mean Phytoplankton Population Density in the "initial" "light" and "dark" bottles with depth.

	Sub-Surface	1- metre	2-metre	$\bar{x} \pm SE$	$LSD_{0.05}$
Initial bottle	35,195 [a] ±10,914	30,870 [a] ±9,450	15,700 [b] ±5,090	27,255 ±5,026	12,463
Final "light"	42,448[a] ±13,398	36,416[a] ±11,218	16,190[b] ±5,185	31,685 ±6,045	15,988
Final "dark" bottle	33,670[a] ±11,182	27,148[a] ±9,690	12,713[b] ± 4,467	24,509 ±8,701	14,906

Table 2b: ANOVA of Phytoplankton Density

Items	Df	Initial bottle		Final Light Bottle		Dark Bottle	
		MS		MS		MS	
Total Month	38						
Depth	12	0.233×10^{10}	***	3.21×10^{10}	***	0.219×10^{10}	***
Error	2	0.136×10^{10}	**	0.246×10^{10}	**	0.136×10^{10}	*
	24	0.024×10^{10}		0.390×10^{9}		0.034×10^{10}	

*** Significant at 0.001 ** Significant at 0.01 *Significant at 0.05

The mean monthly phytoplankton population densities in the "initial", "light" and 'dark'

bottles are presented in Fig. 2. Populations in the different bottles were low at various depths from November to February, increased rapidly thereafter and attained a peak in August. This was followed by a sharp decline from September to October at the sub-surface and at 1-metre depths (Fig 2a, b, and c). The peak at 2 - metre depth was reached in April, thereafter there was a decrease to the September minimum. An abrupt drop was observed at 2 metre depth in June.

There was no significant difference between the populations in the "initial" "light" and "dark" bottles from each depth from March to May but differences were observed between November to February and July to September (Fig. 2d; Table 2a).

Productivity: Variations in monthly mean gross, net and respired carbon per day are presented in Table 3. The mean daily gross production for the lake was 1,582.17 mgC/m^3/day. Mean net carbon production was 569.75 mgC/m^3/day. Mean respiration was 1,266.58 mgC/m^3/day. Gross production was highest in December and lowest in October. Net production was lowest in May when it had a negative value and high in December, January and April. Respiration was high in May, July, September and November but low in October

Table 3: Monthly Means of Gross, Net, and Respired Carbon Per Day (mg.C/cm^3/day) from November 1985 to November 1986.

Month	Gross Carbon	Net Carbon	Respired Carbon
November	2527.76	611.12	2298.72
December	2659.57	1319.52	1416.72
January	1483.05	1013.92	883.36
February	1263.60	430.56	800.00
March	1661.71	930.56	1116.64
April	2095.92	1250.00	1016.72
May	861.12	-597.12	1750.00
June	1048.00	472.24	700.00
July	2480.24	906.80	1883.36
August	1070.56	152.49	1533.36
September	1972.24	333.36	1966.72
October	500.00	333.36	266.64
November	944.48	250.00	833.36
Mean	**1582.17**	**569.75**	**1266.58**
$\bar{x}$ SE	**204.80**	**150.14**	**171.22**

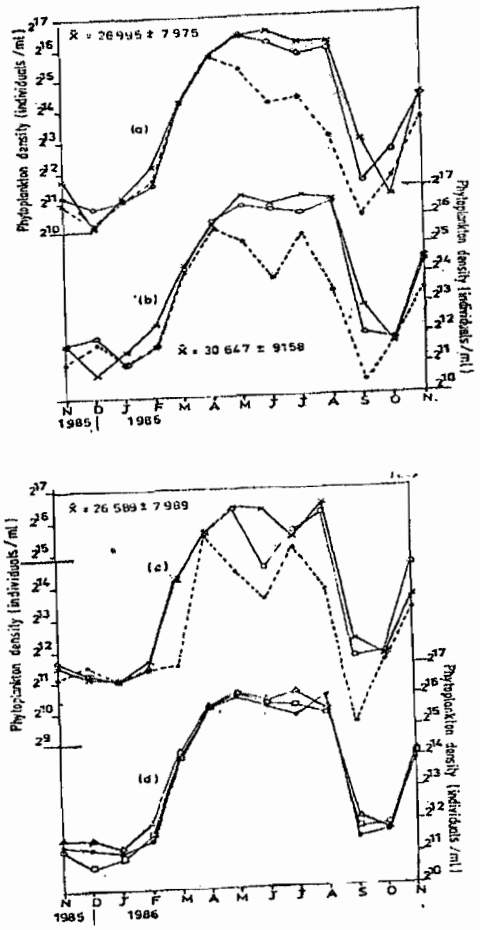

Fig. 2. Monthly variations in phytoplankton population density in:
(a) initial bottles at the surface (X---X), 1 metre (⊙---⊙) and 2 metre (O—O);
(b) light bottles at the surface (X---X), 1 metre (⊙--⊙) and 2 metre (O –O);
(c) dark bottles at the surface (X---X), 1 metre (⊙---⊙) and 2 metre (O –O) and
(d) mean initial (⊙---⊙), light (Δ...Δ) and dark (O—O) bottles

Table 4a shows mean rates of gross and net production and respiration at the surface 1 metre and 2 metre depths while Table 4b is the ANOVA for the gross production, net production and respiratory rates. Mean rate of gross production was 204.18 mgC/m^3/hr while the mean rate of net production was 71.22mgC/m^3/hr. Gross and net production decreased

with depth. Respiration was high at all depths investigated (Table 4a).

Mean gross and net production for the period of investigation varied with depth. Results from ANOVA showed that at 99% level of confidence, gross and net production were significant, while there were no statistically significant differences in respiration for months and the depths (Table 4b).

Table 4 a: Mean Gross and Net Production and Respiration Rates (mg. C/m³/hr) at the various depths

	Sub-Surface	1- metre	2 - metre	$\bar{x}$ ± SE	LSD
Gross production	335.75[a]	192.28[b]	84.53[c]	204.18	83.69
	±46.78	±34.75	±13.46	±25.08	
Net Production	191.11[a]	49.48[b]	24.88[c]	71.22	94.81
	±50.19	±18.72	±21.32	±18.77	
Respiration	171.65	175.98	127.42	158.32	
	±37.09	±45.68	±29.04	±21.40	

Table 4 b: ANOVA of Gross production, Net Production and Respiratory Rates

		Gross Production		Net Production	Respiration
Items	**Df**	**MS**		**MS**	**MS**
Total	38				
Month	12	21542.683		12441.591	16499.050
Depth	22	206488.475		156511.523	17525.200
Error	4	10687.408	***	13715.350	

*** significant at 0.001 ** significant at 0.1 * significant at 0.05

Details of the monthly values show the following exceptions:

i.) gross production was higher at 1 meter than at the other depths in May and August (Fig. 3a);

ii) negative net production was observed at the surface during the months of May and August and at I metre in November, May and June (Fig. 3b); and

(iii) respiratory activity was higher at the surface in August and September and at 1 metre

in September. It increased with depth during April to July and decreased with depth during August to November 1986 (Fig. 3c). It was higher than net photosynthesis most of the time (Fig. 3d.).

Phytoplankton and Productivity: The correlation matrix for total phytoplankton at the various depths investigated is presented in Table 5. The total phytoplankton at the various depths showed significant positive correlation with one another. Also, they showed significant positive correlation with respiration at 2 metre depth (surface, r = 0.63; 1 metre, r = 0.68; 2 metre, r = 0.81)

There were no significant relationships between mean gross and net production and the population density but net carbon produced at 2 metre showed significant negative correlation with final phytoplankton population in the open water (r = - 0.88).

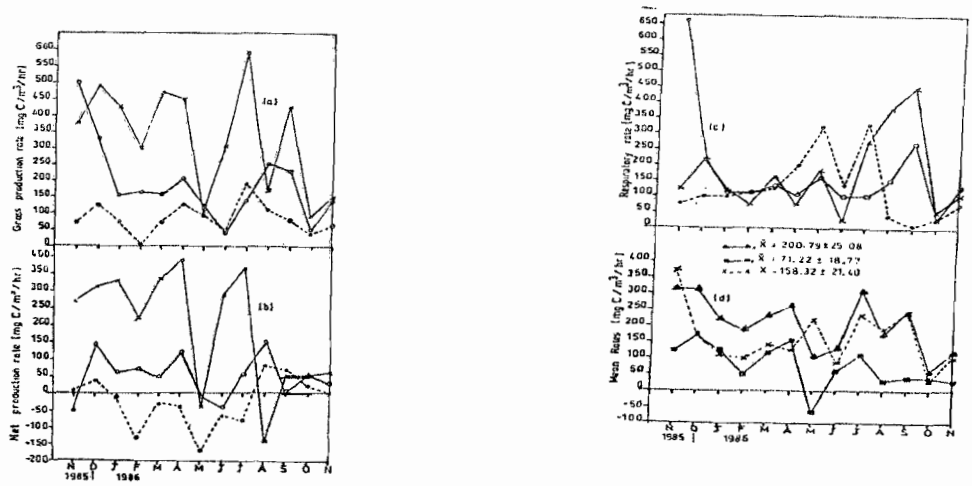

Fig. 3: Monthly variations in:

(a) gross production rates at the surface (X_X), 1 metre (⊙---⊙) and 2 metre (0- --0);

(b) mean net production rates at the surface (X_X), 1 metre (⊙---⊙) and 2 metre (0- --0);

(c) mean respiratory rates at the surface (X_X), 1 metre (⊙---⊙) and 2 metre (0- --0); and

(d) mean rates of gross production (Δ....Δ), net production (□ ....□) and respiration (x-x) in the water column.

Table 5. **Correlation matrix for Total Phytoplankton at the various depths investigated.**

Depths	Sub-Surface	1 - metre	2 - metre	Mean
Surface	1	0.98**	0.68**	0.97**
1 meter		1	0.75**	0.99**
2 meter			1	0.82**
Mean				1

* Significant at 95% probability at 11 d.f; ** Significant at 99 % probability at 11 d.f

Discussion

Chlorophyta were the most abundant group in Ogelube lake. This contradicts the observations of Howard-Williams and Ganf (1981), Egborge (1973) and Biswas (1982) on other shallow tropical lakes that Cyanophyta (Cyanobacteria) are dominant over other divisions in terms of species composition, but conforms with earlier observations on the lake (Biswas and Nweze, 1990). This indicates that there was no significant change in dominance within the three years interval between this and the last investigation on the lake. When compared with the species composition published (Biswas and Nweze, 1990) fewer number was observed in this investigation. This may be as a result of the sampling location being at the lake centre and as such only strictly phytoplankton species were encountered, eliminating tychoplanktonic species found when the ends of the lake were sampled during the earlier investigations. Moreover, because the bottom was not sampled, bottom-loving species may not have been encountered.

The phytoplankton population was not restricted to any particular layer hence the significant positive relationships observed between total phytoplankton in the water column and at the various depths. The shallow depth favoured mixing and resuspension of sediment loving algae by wind as noted by Carrick *et al*, (1993). Despite this, the population was significantly higher in the first one metre depth of the water. The decrease in population with depth is expected due to the preference of phytoplankton for the euphotic zone (Harris, 1986).

High population at the various depths is expected for a shallow body of water of this nature, which is easily circulated by wind action. This may cause the population beyond the 2 metre depth that are mostly dying cells to come up to the euphotic zone.

The observed differences in population in the various bottles from November to

February and July to September are associated with high productivity, which favoured high population in the light bottles.

The negative net production values observed during the rainy months (May to June) were due to the decreased insolation as a result of cloud cover. Moreover, turbidity caused by runoffs and high phytoplankton population and resuspension of sediment by wind (Hellstrom 1991), must have resulted in decreased transparency and attenuation of light, which did not favour photosynthesis by phytoplankton. Hence during the rainy months, respiratory activity exceeded photosynthetic activity at the surface. For the same reason the increase in population in the open water later in the day led to attenuation of light, resulting in the observed decrease in net production at 2 metre depth. Hence the significant negative correlation observed between the net carbon produced at 2 metre depth and the final population in the open water and positive correlation between total phytoplankton at the various depths and respiration. This indicates that the population had a shielding effect on the lower layers in addition to the reduced light and respiration by dying algae, bacteria and other micro-organisms may have used up the oxygen in the lake bottom.

Negative net production values were also observed during periods when there was stratification - August and September. During stratification there was decreased cloud cover and very bright days leading to increased insolation. Also there was dilution and depletion of nutrients. These conditions favoured respiratory activity of the dying cells killed by starvation, which as noted by Pennak and Lavelle (1979) and Reiman, (1983) increased bacterial activity.

High net production in December to January and in April indicate high productivity induced by resuspension of nutrients by December and January harmattan winds and the early rains in April which brought in nutrients through runoffs.

The lack of difference in mean populations in the 'initial', 'light' and 'dark' bottles from March to May suggests that there was virtually uniform population growth in the three bottles within the incubation period in the months. The differences observed in the three bottles from November to February, and in July with the light bottles being higher indicated that growth was not uniform in these.

The poor photosynthetic activity was poorly correlated with phytoplankton biomass. This is in line with the studies in the lake Kainji (Imevbore and Borsormenyi, 1975). This may be attributed to high loss rates (Pollingher and Berman, 1977; Tilzer, 1984). The periods of very high production, (April) and low production (August) are similar to observations in the Kainji lake (Imevbore and Borzormenyi, 1975). On the other hand, the lake has low productivity (1,582.17 $mgC/m^3/day$) when compared to $2.7gC/m^2/day$, which was the maximum for Lake Kainji after impoundment (Imevbore and Borzomenyi, 1975).

Ogelube lake can be categorized as oligotrophic because it falls within the range stated by Wetzel (1975). The oligotrophy is due to the low net productivity observed, although the net productivity in this case involves the community metabolism as a result of both photosynthesis of algae, respiration of algae, bacteria, fungi, and macrozoans (Wetzel, 1975; Pennak and Lavelle, 1979).

The lake area is one of the highest suppliers of vegetables to the cities of Enugu and Nsukka. With time, the agronomic, domestic and other environmental influences will have far reaching consequences on the lakes in the Opi area. Consequently, comparative studies with time will help ascertain the level of influence of these activities on the trophic status of the lakes.

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