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Phytoplankton Production in relation to Physico-chemical Conditions in Lake Kondakarla

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In lake Kondakarla of Visakapatnam the production values varied between 1·32 and 8·10 mg O_2/1/6 hr at surface layer and 0·84 and 4·92 mg O_2/1/6hr at bottom layer during 1979-'80. The depth integrated production figures ranged from 0·74 gC/m^2/day to 16·00 gC/m^2/day. The annual average for photosynthetic efficiency was below one percent at all the sites of the lake. On the basis of production figures and physico-chemical features, the lake could be considered eutrophic. The physical factors such as water depth, percentage light transmission, turbidity and few nutrient factors like chlorides, sulphates and magnesium showed significant relationship to plankton production. Basing on the real significant factors, different multiple regression equations were drawn at various sites of the lake. The difference in response to various environmental factors at different sites of the lake is attributed to variations in the plankton composition.

Key Wods: Phytoplankton, Photosynthetic efficiency, Nutrients, Productivity

Introduction

The phytoplankton play a major role as a primary producer component in deeper lakes. (Ganapati 1972, Ganapati & Pathak 1972, Hussainy 1967, Nasar & Munshi 1975, Nasar & Nasar 1978, Pande & Singh 1978, Sreenivasan 1972, 1976, Zafar 1966). However the real operative environmental factors influencing the plankton production are to be identified and quantified. Though a few investigations have attempted this kind of study (Bhatnagar 1972, Goldman 1960a & 1960b), yet mathematical quantification is absent in these reports. The present study attempts to relate significant physico-chemical factors with plankton production in a more quantitative way.

Study area and Sampling Sites

Lake Kondakarla stretches between latitudes 17° 35′ 30″ and 17° 36′ 02″ N, longitudes 82′ 59″ 27″ and 83° 01′ 0″ E and is situated

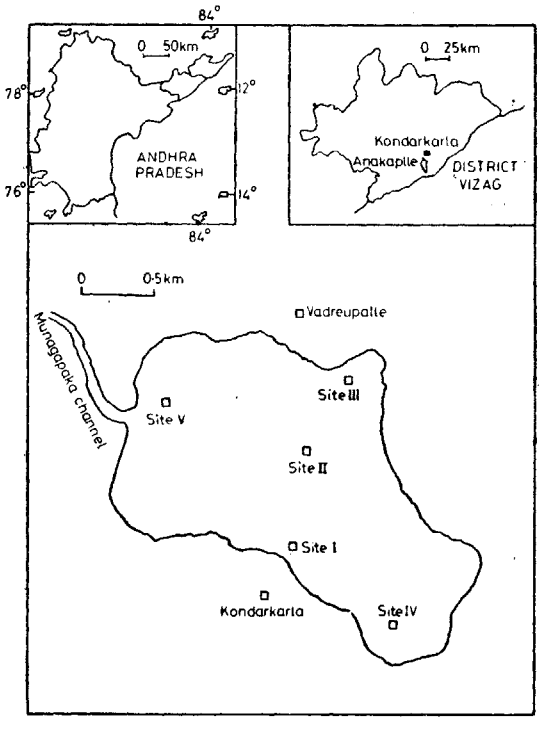

Figure 1 Map of lake Kondakarla with insets of state Andhra Pradesh and district Vizag

at about 50 kms South West of Visakhapatnam city. The maximum length of the lake is about 3 kms in N-S direction and 2.5 kms in the E-W direction. The lake with an area of 6.5 sq. kms, is surrounded by undulating plains of sandy to sandy loamy soils, except along the north west bank where it is bordered by river built plain of sandy silty loam of the Sarada river. The marginal areas are intensively cultivated and constitute 20 sq. kms. of the lake catchment area. In addition, the lake has an inlet known as Munagapaka channel joining it from Sarada river. Sampling sites were described in detail in our earlier paper (Seshavatharam & Venu 1984) (figure 1).

Method of Study and Calculation

Sampling for water analysis was done between 9.00 A.M. and 10.00 A.M. at all the sites. Temperature, *p*H, water depth and light transmission were measured in the field itself. Temperature was measured with a thermister thermometer and *p*H with a Lovibond Comparator. Light transmission was measured with a Bio-chem light meter and depth of the lake by lowering a graduated tape with a weight from the boat. Water samples were collected in 5 litre plastic cans for the routine analysis of other chemical features. Bottom waters were collected using a modified Dussart's sampler. The methods given in IBP Hand book No. 8 were followed in the estimation of the nutrients (Golterman & Clymo 1969).

Plankton productivity of the lake water was estimated using the Gaarder and Gran's (1927) light and dark bottle technique. 500 ml corning bottles were used for the conduct of the experiments. The lake being shallow, production experiments were conducted at the surface and botom layers. Depth integrated productivity values were calculated by integrating the data obtained from surface and bottom layers. The photosynthetic rate was calculated on the basis of total oxygen produced. The oxygen values were multiplied by 0.937 to convert them into carbohydrates (Ganapati & Sreenivasan 1970). Taking the average value of combustion of carbohydrate as 4,100 cals g^{-1}, the values for carbohydrate produced were converted into energy values (calories). Based on the photosynthetic available radiation (P.A.R.) (40% of the total solar radiation) and the estimated total energy that is locked up by the plankton in the form of carbohydrate, photosynthetic efficiency was calculated (Morowitz 1968). Simple correlation coefficients were calculated between production values and physico-chemical parameters. Basing on the real significant factors, multiple regression equations were drawn to quantify the influence of various parameters on phytoplankton production.

Results and Discussion

The fluctuation in the air temperature was 25.5 to 35.5°C while the temperature of surface water was 22.0 to 32.5°C and for bottom layers 20.5 to 32.0°C. Water was slightly alkaline with *p*H ranging from 7.8 to 8.6 and percentage transmission varying from 10 to 60% of the subsurface light. Water was moderately rich in nutrients and had oxygen fluctuating from 0.7 to 11.4 mgl^{-1}. Lower levels of oxygen at bottom layers could be attributed to minimum growth of submerged weeds in Sites II and IV (table 1).

Regarding primary productivity, surface layers showed a range from 1.32 to 8.10 mg O_2/1/6h at various sites of the lake. While at bottom layers the values were in the range from 0.84 to 4.92 mg O_2/1/6h (figure 2). Respiratory consumptions at surface layer fluctuated from 12.7 to 68.6% of the gross production. Values for bottom layers were in the range from 14.2 to 80.0%. No definite seasonal trend was noticed in the respiratory consumptions (table 2). Depth integrated productivity figures varied from 0.74 to 16.00 gc/m^2/day at different sites of the lake. Productivity trend showed a biomodal fluctuation, one peak occurring in September at all the sites and the other during March at Sites II and IV, February at Site I and during December at Site III (table 3). Values for photosynthetic efficiencies showed great variation and fluctuated between 0.098 and 2.595 % and annual averages for photosynthetic efficiencies were below one at all five sites of the lake (table 4).

The productivity of phytoplankton has been studied extensively in a number of water bodies. In the present study the average production, of the entire lake, based on the study of five sites during different seasons is

Table 1 *Physico-chemical characters of lake Kondakarla (ranges observed in the annual cycle)*

Parameter	Site I	Site II	Site III	Site IV	Site V
Air temp. °C	26·5–34·0	25·5–34·5	28·0–35·0	27·0–33·0	28·0–35·5
Water temp. °C surface	22·0–32·5	23·5–31·5	24·5–32·0	22·5–32·0	23·0–32·5
Water temp. °C bottom	20·5–31·5	23·5–31·5	21·0–32·0	20·5–32·0	21·5–31·0
Water depth (in meters)	0·3 3·0	0·5 3·3	0·3 2·6	0·3 2·6	0·3 2·5
% Light transmission	10–45	10–40	10–45	10–60	10–50
Turbidity (SiO_2 ppm)	2·1–7·0	2·9–7·0	3·7–8·0	0·9–6·3	2·1–7·8
*p*H (Surface)	8·0–8·4	8·0–8·6	8·0–8·6	8·0–8·4	7·8–8·6
*p*H (Bottom)	7·8–8·2	7·8–8·4	7·8–8·2	7·8–8·4	7·8–8·2
Total alkalinity (ppm)	128–186	118–186	106–199	110–224	110–216
Chlorides (mg l^{-1})	53–191	51–174	42–189	31–210	76–188
Sulphates (mg l^{-1})	115–200	95–210	110–196	115–160	90–188
Total hardness (ppm)	41–125	30–110	37–107	73–195	52–140
Calcium (mg l^{-1})	15·4–33·8	16·0–36·0	13·6–35·2	17·2–31·2	16·4–38·4
Magnesium (mg l^{-1})	1·7–24·4	3·1–19·7	2·1–28·8	1·4–15·5	1·2–12·4
Dssolved oxygen Surface layers (mg l^{-1})	5·1–10·5	5·9–10·4	5·5–9·2	4·1–11·4	5·8–9·9
Dissolved oxygen Bottom layers (mg l^{-1})	3·1–10·1	0·5–5·1	1·3–10·4	0·7–6·3	2·4–6·1
Total nitrogen (mg l^{-1})	1·1–5·6	2·4–6·6	0·7–6·2	2·8–6·7	1·9–6·2

Table 2 *Percentage respiratory consumptions at surface* and bottom waters of lake Kondakarla*

Site	March 1979	April	May	June	July	August	September	October	November	December	January 1980	February
I	*47·7	47·5	28·8	31·0	32·4	40·1	42·8	34·0	41·2	57·1	52·4	27·2
	58·3	43·6	59·0	31·0	41·6	60·9	61·3	61·3	60·0	35·4	49·2	30·7
II	36·4	37·3	48·8	43·6	28·4	32·3	39·1	46.8	36·3	27·5	45·5	21·6
	63·8	66·8	43·8	29·0	16·5	41·0	29·4	70·1	31·8	47·5	34·8	45·1
III	33·0	46·0	45·0	49·7	45·6	52·6	37·0	35·0	—	45·4	42·4	—
	19·4	54·8	19·0	36·2	50·0	35·7	68·9	14·2	—	57·1	24·2	—
IV	34·2	58·3	37·6	26·9	—	19·3	—	30·9	48·0	12·7	—	40·7
	63·8	65·2	48·9	35·8	—	80·0	—	29·5	57·2	75·3	—	39·8
V	—	64·5	29·3	50·4	22·4	39·0	62·7	24·0	23·0	62·7	26·2	68·6
	—	64·0	59·6	55·2	27·3	56·9	52·7	41·3	38·1	31·3	41·2	26·3

Table 3 *Seasonal variation in depth integrated gross primary production of lake Kondakarla* ($gC/m^2/day$)

Site	March 1979	April	May	June	July	August	September	October	November	December	January 1980	February
I	4·36	3·64	2·26	1·18	0·74	2·51	9·39	4·81	6·30	2·41	5·47	6·40
II	9·77	2·61	3·88	0·96	1·65	3·76	16·00	5·75	6·01	7·27	5·10	8·05
III	6·60	2·44	2·17	0·98	1·98	2·33	11·15	5.55	6·40	7·84	5·42	4·80
IV	6·75	4·20	2·78	0·97	—	1·96	12·00	6·43	6·71	3·32	5·30	2·70
V	—	2·80	2·70	1·20	1·40	2·70	9·80	6·20	6·21	4·80	5·10	4·90
Average for the five sites	6·59	3·10	2·70	1·06	1·41	2·55	11·66	5·74	6·26	5·12	5·20	5·30

Table 4 *Seasonal variation of photosynthetic efficiency at different sites of lake Kondakarla*
(Toal radiation (T.R.), Photosynthetically available radiation (P.A.R.) and Gross Production are given in cals/m^2/day)

	March 1979	April	May	June	July	August	September	October	Novemer	Decembe	January 1980	February
T.R	16209	15950	11596	13420	17990	17337	14784	16963	11672	14913	15235	16502
P.A.R.	6483	6380	4638	5378	7196	6934	5913	6785	5068	5965	6094	6500
Site-I												
G.P.	41·83	34·94	21·69	11·32	7·10	24·08	90·14	46·15	60·48	23·13	52·48	61·41
Efficiency	0·565	0·547	0·467	0·210	0·098	0·347	1·524	0·680	1·193	0·387	0·861	0·930
Site-II												
G.P.	84·16	25·05	37·22	9·21	15·84	31·28	153·5	55·18	57·67	69·76	48·96	77·25
Efficiency	1·298	0·347	0·834	0·194	0·228	0·402	2·595	0·887	1·137	1·267	0·803	1·170
Sie-III												
G.P.	63·36	23·04	20·82	9·39	19·00	22·35	107·0	53·28	61·41	75·24	52·02	46·08
Efficiency	0·826	0·298	0·402	0·156	0·283	0·309	1·659	0·856	1·158	1·426	0·891	0·756
Site-IV												
G.P.	64·80	40·32	26·68	9·30	—	18·81	115·2	61·70	64·40	31·86	50·86	25·92
Efficiency	0·845	0·451	0·623	0·145	—	0·282	1·948	0.949	1.27	0·555	0.834	0·425
Site-V												
G.P.	—	26·85	25·92	11·52	13·42	25·92	94·06	59·50	59·61	46·08	46·96	47·01
Efficiency	—	0·333	0·484	0·192	0·193	0·406	1·45	0·956	1·12	0·913	0·803	0·740

Table 5 *Significant correlation coefficients between plankton production and various environmental factors ('———' indicates values not significant)*

Site	Phytoplankton Production (PPP*) versus									
	Water depth (WDH)	%Light transmission (PLT)	Turbidity (TUR)	Sp H (SPH)	Chlorides (CHL)	Sulphates (SUL)	Magne-sium (MAG)	Surface O_2 (SOX)	Bottom O_2 (BOX)	Nitrogen (NIT)
I	0·726	—0·704	—	—	—0·494	—	—	—	—0·586	—
	$P<0·01$	$P<0·01$			$P<0·02$				$P<0·05$	
II	0·731	—0·429	0·428	0·655	—	—	—	0·495	—	0·557
	$P<0·01$	$P<0·2$	$P<0·2$	$P<0·02$				$P<0·1$		$P<0·05$
III	0·849	—0·713	0·505	0·467	—0694	—0·601	—0·459	—	—	—
	$P<0·01$	$P<0·01$	$P<0·1$	$P<0·1$	$P<0·01$	$P<0·05$	$P<0·2$			
IV	0·684	—0·531	—	—	—	—	—	—	—	—
	$P<0·01$	$P<0·1$								
V	0·835	—0694	0·508	—	—0·446	—0·555	—	—	—	0·46
	$P<0·001$	$P<0·01$	$P<0·1$		$P<0·2$	$P<0·05$				$P<0·02$

*Abbreviations used for various parameters in table 6

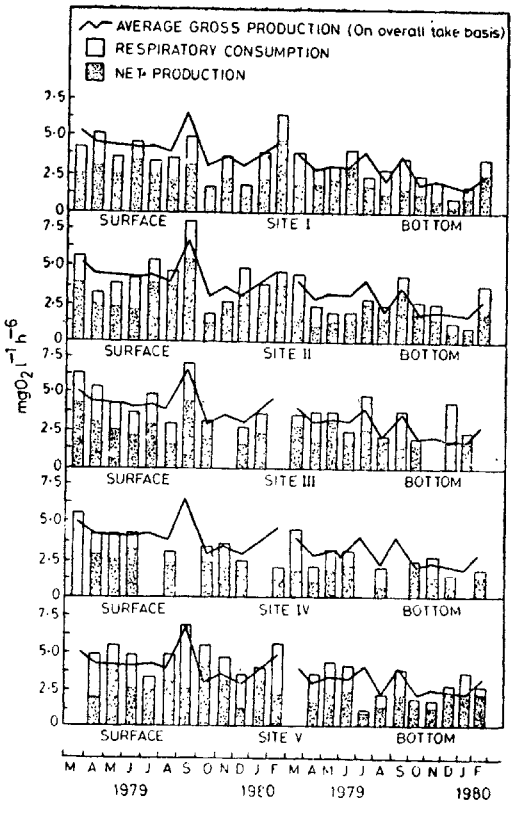

Figure 2 Primary production (mg O_2/l/hr) level in surface and bottom layers of lake Kondakarla

4.72 gC/m²/day. This value is very high when compared with those for some North Indian lakes (Chilwa, Ramgarh, and Vihar lakes) which showed production figures between 0.037 and 0.0450 gC/m²/day (Gopal et al. 1978). The upland lakes of South India (Sreenivasan 1963) showed considerable variations in their production potential, the highest figure being 3.802 gC/m²/day shown by Ooty lake is nearer to the average value of lake Kondakarla. Higher values, 23.60 and 26.56 gC/m²/day were reported by Nasar and Nasar (1976) and Sreenivasan (1964) respectively for few fish ponds. These are highest figures so far recorded from India. Productivity trend which showed a biomodal fluctuation in lake Kondakarla was also noticed earlier by Nasar and Munshi (1975), Nasar and Nasar (1978) and Vijaya Raghavan (1971) in various other situations. Ecological efficiencies exhibited wider amplitude of variation, ranging between 6.6 and 13.8% (Jayanagoudar et al. 1970) and 0.06 and 4.03% (Sreenivasan 1972, 1976) for few ponds and reservoirs of South India.

An examination of the correlation coefficients between physico-chemical factors and primary production indicated that five parameters were significantly related with plankton production at Site I, six at Site II, seven at Site III, two at Site IV and five at Site V (tables 5 & 6). As the lake is shallow and turbid water depth was significantly related to primary production at all the sites. Both turbidity and percentage light transmission were also found to influence plankton production significantly. Hillbert et al. (1960), Menzel and Ryther (1961) and Prasad and

Table 6 *Multiple regression Equations of phytoplankton production on physico-chemical features*

Site		Multiple Regression Equation
I	PPP	= 0·1648 WDH—0·0411 PLT—0·0061 CHL—0·1499 Box+5·7967
II	PPP	= 0·1571 WDH—0·0283 PLT+0·2175 TUR—0·0075 SUL+0·2148 SOX+0·2684 NIT+2·6753
III	PPP	= 0·1323 WDH—0·0190 PLT+0·1730 TUR+1·0303 SPH—0·0058 CHL—0·0010 MAG—0·0095 SUL+5·1499
IV	PPP	= 0·3989 WDH—0·0443 PLT+3·9815
V	PPP	= 0·1702 WDH—0·0251 PLT+0·1075 TUR+0·0067 CHL—0·0092 SUL+5·6011

Nair (1963) made similar observations in some tropical waters.

The role of nutrients in the plankton production was well emphasized by Goldman (1960a,b) and Lund (1965). Goldman reported that in Brooks lake, Alaska, magnesium was limiting factor in the spring, nitrogen in summer and phosphorus in the fall while in Castle lake, potassium, sulphur and molybdenum were reported to be limiting factors.

In the present analysis, among the various nutrient factors examined, chlorides showed significant relationship with primary production at three sites while magnesim and oxygen levels were limited in their influence to only at one site of the lake. Other factors of the lake did not exhibit significant relation with plankton production. The difference in response to various environmental factors at different sites of the lake may be attributed to variation in the plankton composition which respond diversely to various chemical features of the lake.

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