5

PRIMARY PRODUCTIVITY IN AJWA RESERVOIR

(I) Primary production by Phytoplankton at Station A.

Open water.

(a) Rate of photosynthesis and diurnal rhythum.

The rate of photosynthesis by phytoplankton at Station A was measured *in situ* on non isolated natural communities at four-hourly intervals round the clock once a month from March 1969 to March 1970. The results are shown in Table 44. Readings were taken at about the same time every day. The difference between two successive readings gave a four hourly production during the day houre and the respiratory values during the night hours.

An attempt is made to compare the production rates in the morning, noon and afternoon in the Table-44.

44 Table - 44

Production rates in the morning, noon and after at Station-A

1969				
Hours		0.800	1200	1600
March	- 24	0.271	0.129	0.029
April	- 21	0.200	0.067	0.025
May	- 25	0.283	0.054	0.017
June	- 13	0.233	0.075	0.025
July	- 14	0.092	0.065	0.028
August	- 15	0.120	0.057	0.020
September	- 15	0.095	0.077	0.012
October	- 26	0.072	0.062	0.020
November	- 6	0.185	0.142	0.055
November	- 26	0.120	0.062	0.015
December	- 27	0.145	0.117	0.020
1970				
January	- 7	0.160	0.095	0.042
January	- 27	0.190	0.085	0.045
February	- 19	0.120	0.070	0.025
March	- 23	0.107	0.125	0.045

45 From the study of the above table it willbe evident that in all the cases the morning production values were greater than the corresponding noon and afternoon values.

Anna Mani et al. (cf. Ganapati,1970) have measured the total radiation from the sun and sky in India during the International Geographical Year at four respective Stations viz., Poona, Delhi, Calcutta and Madras and have found that the forenoon values are slightly higher than the corresponding values in the afternoon except in case of Madras, where the afternoon values are predominently higher. Qasim et al.(1969) have found that at Cochin the values for the rate of photosynthesis as measured by dark and clear bottle experiments progressively increased upto 14 hours and then declined sharply. Maximum values of photosynthesis between 12 and 14 hours corresponded to peak illumination which under normal weather conditions invariably occurs during the early hours of afternoon.This corresponds to the maximum solar radiation between 12 and 14 hours for Poona (Anna Mani et al, 1962). But the production values at Baroda show a slight deviation where the

16 production rate is highest between 0600-1000 hours that is mid-morning and not between 1200 to 1400 hours. (Figure 9) (See discussion).

Verduin (1957), Yentsch and Ryther (1957), Doty and Oguri (1957), Ohle (1958), Vollenweider and Nauwerck (1961), Copeland, Butler and Shelton (1961), Copeland and Dorris (1962) and Wetzel (1965,1970) have all found photosynthetic maxima under natural light conditions to occur in the mid morning. Beyers (1965) concludes that the lack of uniformity in the rate of photosynthesis should be kept in mind by those who wish to extrapolate the diurnal or annual primary productivity measurement from light and dark bottle or C^{14} experiments of six hour or less in length.

Large differences between early morning and late afternoon rates have been reported by Ohle (1958), Doty (1959) and Vollenweider and Nauwerck (1961). Results in the present work show that values from 6 to 10 hours are greater than those from 10 to 14 hours. There is thus need for more detailed study of the course of photosynthesis during early morning (just before and after sunrise), forenoon, afternoon and at dark.

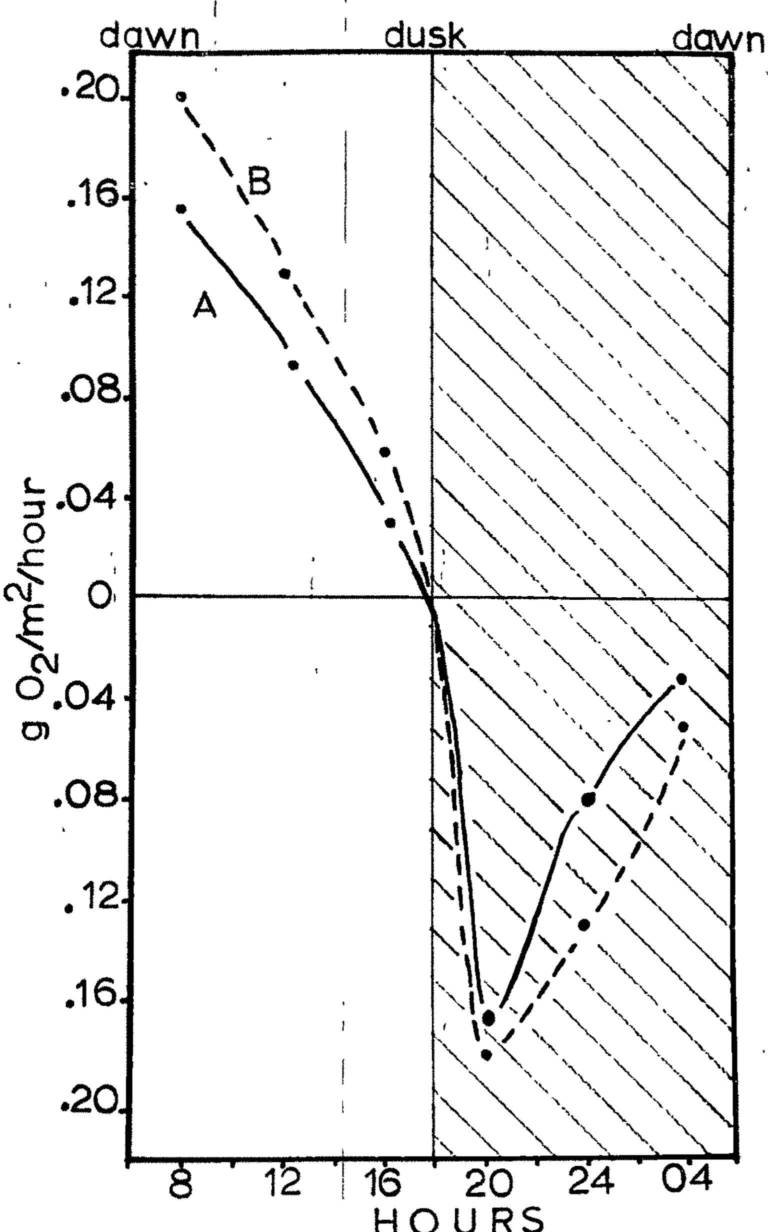

Figure 9 Diurnal rates of production and night time respiraton (Sta. A & B).

17 (b) <u>Gross production, net production and respiration.</u>

Two opposite processes are at work. They are total respiration and gross photosynthesis. Total respiration is the respiration of all organisms, both macro and micro animals and plants in the ecosystem; while gross photosynthesis is the entire photosynthetic production of all primary producers in the ecosystem. Neither of these quantities is measureable in light because they involve chemical changes proceeding simultaneously in both directions. During the day only the excess of gross photosynthesis over day time respiration can be measured; in dark only respiration takes place; and it is possible to measure it. The respiration which takes place during the light period is masked by photosynthesis. Hence we get two measurable quantities, photosynthesis during day and respiration as measured in dark. These values for Ajwa reservoir are shown in Figure 10 and Tables F in the Appendix.

(i) <u>The rate of respiratory uptake of oxygen in free water</u> :

This can be estimated from the natural rate of decline of oxygen corrected for atmospheric exchange. The possibilities and difficulties, in assessing the latter have been stated previously. Under favourable conditions, it may be avoided (cf. Winberg 1960, 1963) by considering period during which the saturation level of oxygen in the surface water is close to 100%. This point is often passed at some time during the night period and during the latter as a whole. Considering the effects of conditions promoting oxygen loss to and gain from the atmosphere the average rate of oxygen decline at night should approximate the average rate of oxygen consumption in respiratory activity in the water column (e.g. Talling 1957c). This formulation implies a constancy of the consumption rate over the 24 hour period, a much used assumption which can be quite unjustified in some situations of periodic stratification or low oxygen tension. Some examples of these are given by Winberg (1955, 1960, 1962).

49 Brown (1953) using isotopically enriched oxygen (O^{18}) has shown that the respiration is the same in light as that in dark. But Qasim et al (1969) have shown that the respiration loss is variable from month to month and therefore as pointed by Ryther (1956) cannot be corrected by common factor. If the respiratory process is considered quite independent of photosynthesis and also that it occurs at the same rate throughout the day and night and the values for the respiratory loss occuring during the night are substracted from the day net production, an estimate of 24 hours' net primary production called here as 'adjusted net production' can be calculated (shown in Table- 45).

The assumption that the rate of respiration during the night is the same as during the day does not seem unrealistic though the respiratory losses during day or night do not preclude the respiration contributed by zooplankton and bacteria; and therefore, may not strictly conform to the phytoplankton respiration alone.

0 The figures for gross and net production and respiration and adjusted net production are given in Table 45.

These figures are helpful in estimating the potential source of organic matter which is transferred to next tropic level.

(c) Seasonal changes in production rates :

(i) Monthly changes in production rates.

The monthly values of net and gross production at various depth 0-5 m, shown in Fig. reveal that there is a seasonal cycle in biological production. Increasing values are recorded in March to June and lower values in July, through September and February. The difference between gross and net production is greatest at 0.0 m and it gradually diminishes till it falls off steeply at 4.0m and 5.0 m depths.

The production rates (both gross and net) of the optimum period is at the most two to three times the rates of the season of lowest production. This

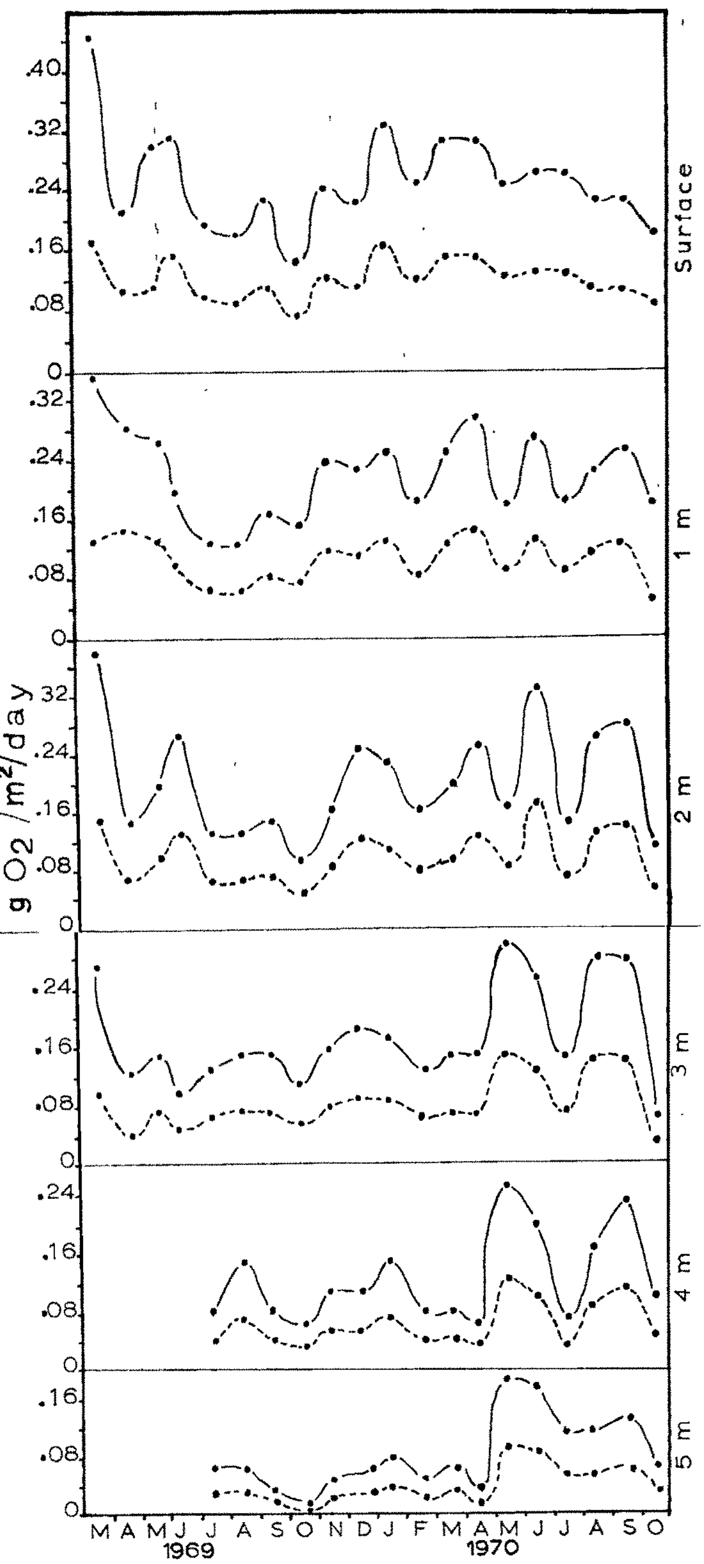

Figure 10 Gross and net primary production in Ajwa Reservoir (Station A)

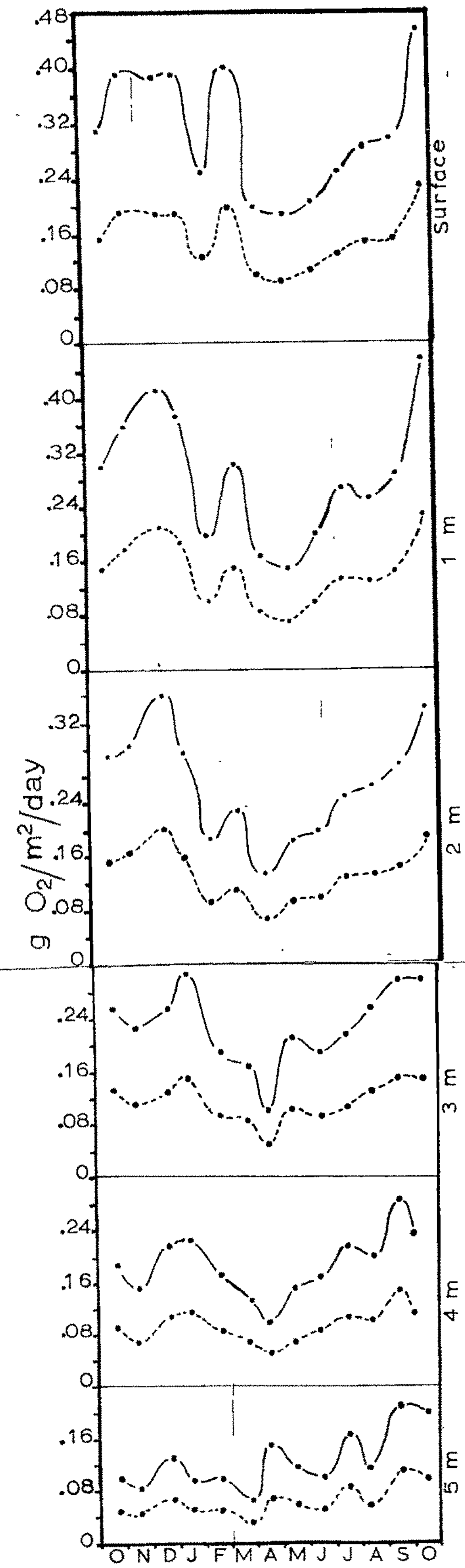

Figure 11 Gross and net primary production in Ajwa Reservoir (Station B)

Table - 45

Gross production, net production, adjusted net production and respiration in the Ajwa Reservoir at Baroda during 1969-70

STATION-A

Date		O_2 Production (g/m^2/day)					24 hrs. respi-ration	-g/m^2/day adjusted net pro-duction
		Net produc-tion	Respi-ration	Gross produc-tion	net produc-tion/gross production	Respiration expressed as % of gross production		
1969								
March	- 23	1.716	1.884	3.600	0.5	50.2	3.768	- 0.168
April	- 21	1.272	1.272	2.546	0.5	50.0	2.228	+ 0.318
May	- 25	1.494	1.494	2.988	0.5	50.0	2.822	+ 0.166
June	- 13	1.471	1.471	2.942	0.5	50.0	2.664	+ 0.278
July	- 14	0.828	0.828	1.656	0.5	50.0	1.536	+ 0.120
August	- 15	0.842	0.842	1.684	0.5	50.0	1.584	+ 0.100
September	- 15	0.741	0.741	1.482	0.5	50.0	1.464	+ 0.018
October	- 23	0.599	0.599	1.198	0.5	50.0	1.224	- 0.026
November	- 6	1.378	1.378	2.758	0.5	50.0	3.048	- 0.290
November	- 26	0.679	0.679	1.358	0.5	50.0	1.584	- 0.226
December	- 27	1.034	1.034	2.068	0.5	50.0	2.256	- 0.188
Average		1.14	1.14	2.28	0.5	50.0	2.184	+ 0.096

Table - 45
(continued)

Date	O_2 production ($g/m^2/day$) net production	Respiration	Gross production	Net production/gross production	Respiration expressed as % of gross production	24 hrs. respiration	$-g/m^2/day$ adjusted net production
1970							
January - 7	1.089	1.089	2.178	0.5	50.0	2.376	- 0.198
January - 27	1.187	1.187	2.374	0.5	50.0	2.568	- 0.224
February - 19	0.813	0.813	1.626	0.5	50.0	1.708	- 0.082
March - 23	0.864	0.864	1.728	0.5	50.0	2.208	-0.180
April - 16	1.274	1.274	2.544	0.5	50.0	2.304	0.240
May - 15	1.976	1.976	3.954	0.5	50.0	3.648	0.306
June - 14	1.670	1.670	3.340	0.5	50.0	3.024	0.316
July - 15	0.980	0.980	1.960	0.5	50.0	1.776	0.184
August - 9	1.440	1.440	2.880	0.5	50.0	2.712	0.168
September - 15	1.507	1.507	3.014	0.5	50.0	2.952	- 0.062
October - 15	1.650	1.650	3.300	0.5	50.0	3.388	- 0.088
Average	1.31	1.31	2.62	0.5	50.0	2.568	+ 0.034

53 indicates that seasonal fluctuations in the production rates in the tropics are not marked. (Hulbert et al.,1960; Menzel and Ryther, 1961a; Prasad and Nair,1963; and Qasim et al.,1969). This feature is in contrast to higher latitudes where the seasonal amplitude of production during spring and summer may be fifty times or more of the autumn or winter (Raymont, 1966).

(ii) Vertical distribution of biological production.

Throughout the year, except in June (early monsoon) the rate of production (gross as well as net) diminishes with increasing depth. In June the maximum rate is observed at 3 m depth which can probably be accounted for by the insolation effect at the upper layers and surface.

(d) Annual production.

The estimated annual production in the Ajwa reservoir during the two year period is given in Table-46. The annual average gross production is 365 x 2.28 g O_2/m^2 in 1969 and 365 x 2.62 g O_2/m^2 in 1970. Similarly

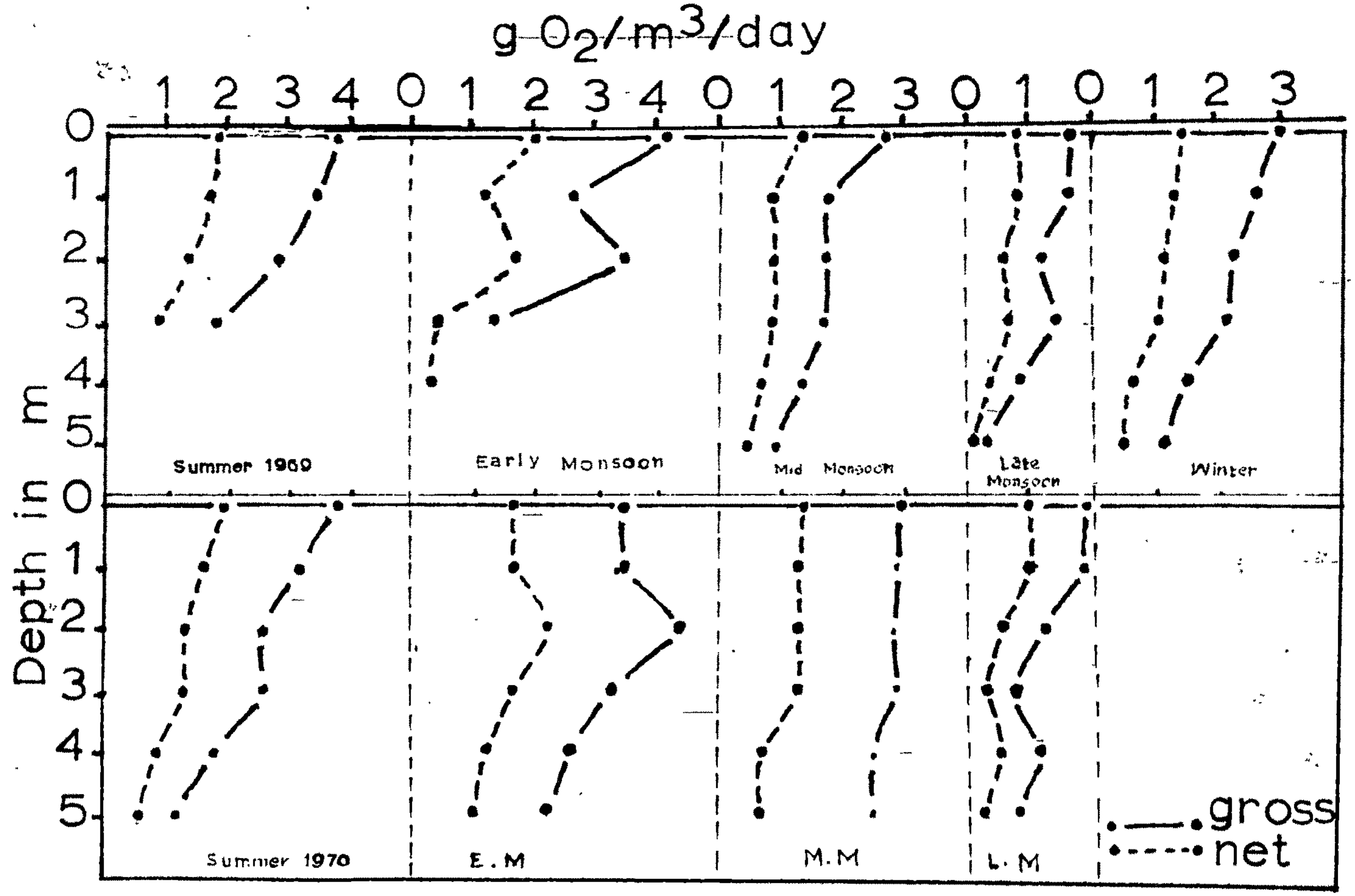

Figure 12 Seasonal changes in gross & net production (Sta. A).

54 the net production for days averaged 365 x 1.14 g O_2/m^2 in 1969 and 365 x 1.31 g O_2/m^2 in 1970. The estimatea net 24 hour production shows the potential source of organic matter which is available for the next trophic level.

Table - 46

Annual estimates of gross and net primary production in 1969 and 1970

Year	Annual production	
	Gross	Net
1969 (9 months)	365 x 2.28	365 x 1.14
1970 (10 months)	365 x 2.62	365 x 1.31

In the case of lake Victoria about 2500 g O_2(or 950 g using a photosynthetic quotient of 1)/year is reported from the average daily estimate of about 7 g O_2/m^2 (Talling,1965).

(e) Phytosynthetic efficiency :

The efficiency of the ecosystem to convert solar energy into organic matter was determined from the

55 monthly readings of the visible solar radiation and the gross production values according to Ganapati and Sreenivasan (1970) and the results are given in Table-47.

The calculated efficiencies in the several months of the two years period are shown in Table 47 and Figure 14 along with the monthly average visible radiation values. The efficiencies range from 0.23 to 0.69 % in 1969 and from 0.27 to 0.80 % in 1970, the yearly average being 0.48 %. Ryther (1962) has shown that the coastal and inshore waters have an average value of 0.5 %; and has discussed the several factors affecting photosynthetic efficiency of different marine environments. Ganapati and Sreenivasan (1970) have shown that the magnitude of photosynthetic efficiencies in South Indian reservoirs range from 0.41 to 2.62 %. Ganapati and Pathak (1970) found the figure to be 0.31 % for the two year period of 1963 and 1964.

Table - 47

Photosynthetic Efficiency (column 5) in different months of 1969 and 1970

Date	Average daily visible radiation Cal/m²/day x 10^3	Gross production g O_2/m^2/day	Energy for gross production @ 3.68 Calories per mg of O_2	Ratio of columns 4/2 in percentage
1	2	3	4	5
1969				
March - 24	2173	3.60	13248.0	0.69
April - 21	2526	2.55	9384.0	0.37
May - 25	2673	2.99	11003.2	0.41
June - 13	2607	2.94	10819.2	0.42
July - 14	2631	1.66	6108.8	0.23
August - 15	1912	1.68	6182.4	0.32
September-15	1796	1.48	5446.4	0.30
October - 23	1504	1.20	4416.0	0.29
November - 6	1632	2.76	10156.8	0.62
November -26	1632	1.36	5004.8	0.31
December -27	1575	2.07	7617.6	0.48
Average	2060	2.21	8126.9	0.40
1970				
January - 7	1552	2.18	8022.4	0.52
January - 17	1552	2.37	8721.6	0.56
February- 19	1920	1.63	5998.4	0.31
March - 23	2173	1.73	6366.4	0.29
April - 16	2526	2.54	9347.2	0.37
May - 15	2673	3.95	14536.0	0.54
June - 14	2607	3.34	12291.2	0.47
July - 15	2631	1.96	7212.8	0.27
August - 9	1921	2.88	10598.4	0.55
September-15	1796	3.01	11076.8	0.61
October - 15	1504	3.30	12144.0	0.80
Average	2077.7	2.63	9574.1	0.48

Table - 48

Gross production, net production, adjusted net production and respiration in the Ajwa Reservoir at Baroda during 1969-70

STATION-B

Date		O_2 Production ($g/m^2/day$)					24 hrs. respi- ration	$-g/m^2/day$ adjusted net pro- duction
		Net produc- tion	Respi- ration	Gross produc- tion	Net produc- tion/gross production	Respiration expressed as % of gross production		
1969								
October	- 23	1.48	1.48	2.96	0.5	50.0	3.024	- 0.94
November	- 6	1.40	1.40	2.40	0.5	50.0	3.000	- 0.600
November	- 26	1.43	1.43	2.80	0.5	50.0	3.072	- 0.212
December	- 27	1.76	1.76	3.52	0.5	50.0	3.840	- 0.320
Average		1.52	1.52	3.00	0.5	50.0		
1970								
January	- 7	1.91	1.91	2.82	0.5	50.0	4.176	- 0.356
January	- 27	1.42	1.42	2.84	0.5	50.0	3.072	- 0.232
February	- 19	1.04	1.04	2.08	0.5	50.0	2.184	- 0.104
March	- 23	1.26	1.26	2.52	0.5	50.0	2.520	+ 0.000
April	- 16	0.89	0.89	1.78	0.5	50.0	1.608	+ 0.172
May	- 15	1.11	1.11	2.22	0.5	50.0	2.040	+ 0.180
June	- 14	1.21	1.21	2.48	0.5	50.0	2.184	+ 0.300
July	- 15	1.39	1.39	2.78	0.5	50.0	2.544	+ 0.236
August	- 9	1.46	1.46	2.92	0.5	50.0	2.760	+ 0.160
September	- 15	1.96	1.96	3.92	0.5	50.0	3.840	+ 0.080
October	- 15	2.00	2.00	4.00	0.5	50.0	4.080	- 0.080
Average		1.42	1.42	2.84	0.5	50.0		

II **Primary Production by hydrophytes** (and periphyton) **at Station B.**

(a) Rates of photosynthesis and diurnal rhythum.

Consecutive collections at Station B were made *in situ* on non-isolated natural communities at four hourly intervals. Figure 9 shows that there was a similar trend in the production rates though the values being higher than those at Station A.The morning rates were highest, the rates in the noon were lower while the rates in the afternoon were lowest.

The values at Stations A and B indicate that there is a common factor governing these rhythms.

(b) Gross and net production.

The values for gross and net production and respiration and the adjested net production are given in Table-48.

(c) Seasonal changes in production rates.

(i) Monthly changes.

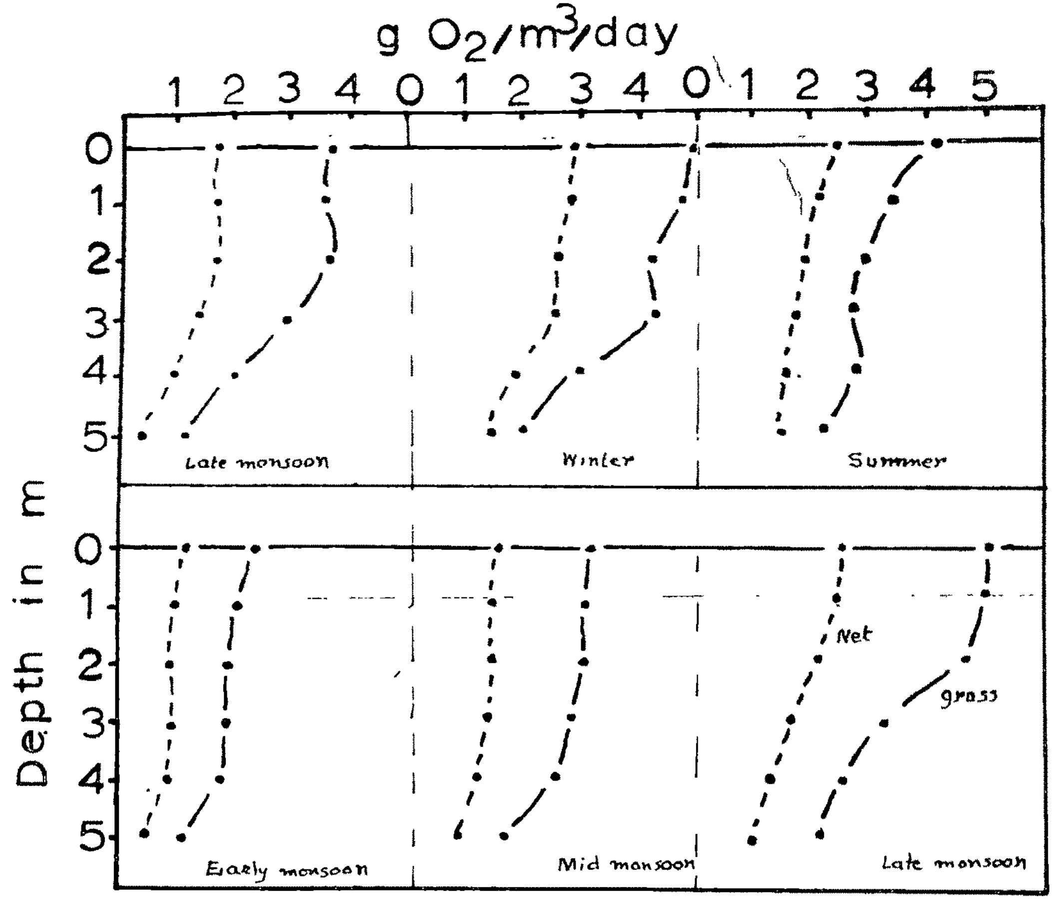

Figure 13 Seasonal changes in gross and net production (Sta. B)

The monthly changes in net and gross production at various depths from surface to 5m, shown in Figure 11 also reveal a similar seasonal cycle as Station A. The lowest rates were found in February and April, 1970. Station B showed mixed processes where both production due to macrophytes and periphyton were in progress (and phytoplankton production was also expected as it is not free from phytoplankton organisms. Station B showed the production rates throughout the year even when only the old stalks of dead macrophytes were observed; providing the evidence of the presence of phytoplankton). While from July onwards when the planktonic production reduced, there was an increase in values at Station B which was mainly due to macrophytic production.

(ii) Vertical destribution

Figure 11 and Table K (Appendix) show the vertical distribution of production at various depth. It will be seen the production at Station B is higher than at Station A, (Figure 10) nearly at all the depths.The bulk of the production was, ofcourse, at a nerrow zone of 0-3 m. Maximum production was in the surface layers of water in late monsoon (October). Even though the production decreased progressively from surface to the bottom, the lowest depth studied (i.e. 5 m) always showed some production.

(d) Annual Production.

The annual average gross production is 365 x 3.00 in 1969 and 365 x 2.75 in 1970. Similarly the net production is 365 x 1.52 in the year 1969 and 365 x 1.42 in year 1970.

(e) Photosynthetic efficiency.

Table 49 shows the photosynthetic efficiencies at Station B in several months of the year 1969 and 1970. The minimum of 0.26% was found in April 1970 and maximum was 0.98 in October 1970. The average photosynthetic efficiency was 0.54 at Station B.

TABLE - 49

Photosynthetic Efficiency in different months of 1969 and 1970

Date	Average daily visible radiation $Cal/m^2/day$ $x10^3$	Gross production $g\ O_2/m^2/day$	Energy for gross production @ 3.68 calories per mg of O_2	Ratio of items 4/2 in percentage
1969				
October - 23	1504	2.96	10892.8	0.72
November - 6	1632	2.80	10304.0	0.63
November - 26	1632	2.86	10524.8	0.65
December - 27	1575	3.52	12953.6	0.82
Average	1585.75	3.036	11171.3	0.68
1970				
January - 7	1552	3.82	14057.6	0.91
January - 27	1552	2.84	10451.2	0.67
February - 19	1920	2.08	7654.4	0.39
March - 23	2173	2.58	9273.6	0.43
April - 16	2526	1.78	6550.4	0.26
May - 15	2673	2.22	8169.6	0.30
June - 14	2607	2.42	8905.6	0.34
July - 15	2631	2.78	10230.4	0.38
August - 9	1912	2.92	10745.6	0.56
September - 15	1796	3.92	14425.6	0.75
October - 16	1504	4.00	14720.0	0.98
Average	2076.9	2.84	10471.0	0.54

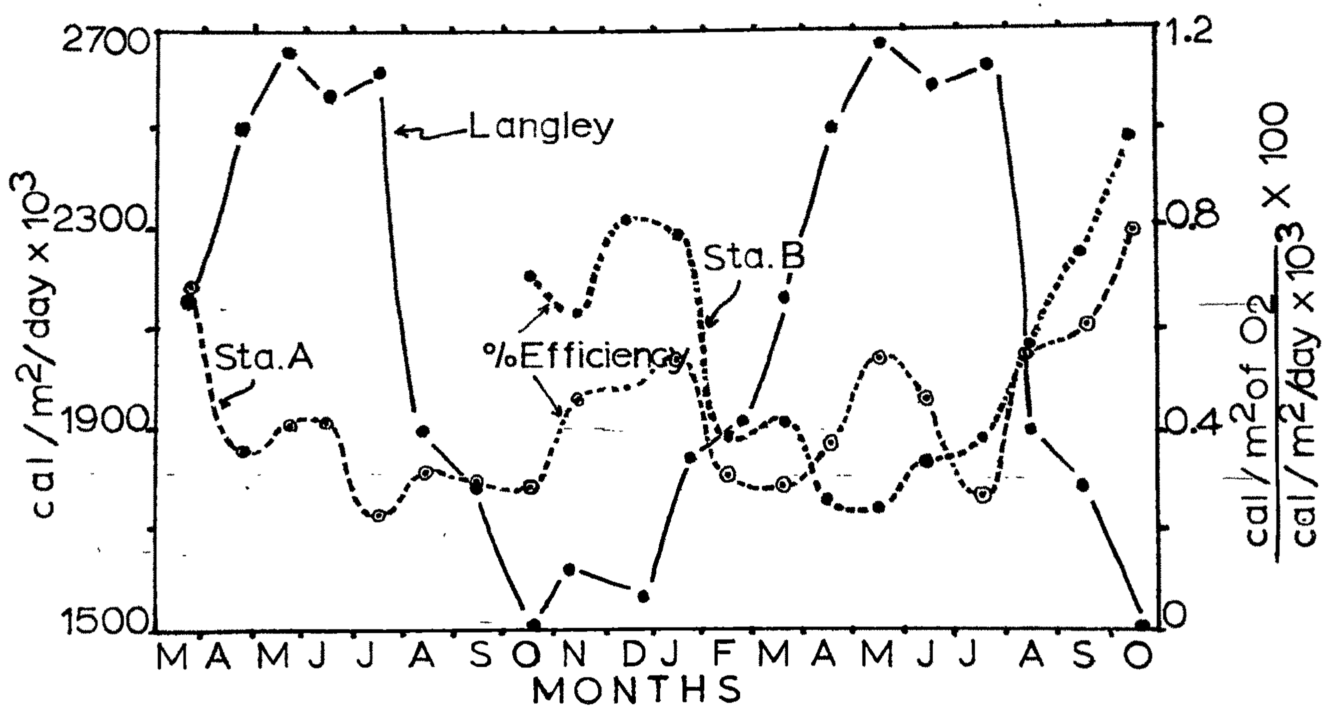

Figure 14 Average solar visible radiation and utilization (% Photosynthetic efficiency)

Table - 50

Average production rates of phytoplankton, macrophytes and periphyton in gC/m²/day

Date		Photo-plankton	Macrophytes	Periphyton
1969				
March	- 24	0.515	-	-
April	- 21	0.382	-	-
May	- 25	0.448	-	-
June	- 13	0.441	-	-
July	- 14	0.248	-	-
August	- 15	0.253	-	-
September	- 15	0.222	-	-
October	- 26	0.180	0.444	0.000
November	- 6	0.413	0.420	0.213
November	- 26	0.204	0.429	0.307
December	- 27	0.309	0.528	0.000
1970				
January	- 7	0.327	0.573	0.265
January	- 27	0.356	0.426	-
February	- 19	0.244	0.312	0.132
March	- 23	0.259	0.378	0.180
April	- 16	0.382	0.267	0.296
May	- 15	0.573	0.333	0.443
June	- 14	0.501	0.363	0.492
July	- 15	0.294	0.417	0.784
August	- 9	0.432	0.438	0.500
September	- 15	0.452	0.588	0.316
October	-16	0.495	0.600	0.360

41 (b) Periphyton productivity.

Periphyton productivity was estimated separately, by suspending the artificial substrates (glass slides) in the water at surface and at 2.5 m depth. The measurement of changes in oxygen content in dark and light bottles was not possible because of the crocodiles (see discussion). Instead the growth of periphyton on the slides was dried and the changes in the biomass (dry weight basis) were considered. As the mass on the slides is the total biomass less any removal, it gives the net growth. The biomass of the periphyton, expressed as fresh and dry weights is given in tables 42 and 43.

Second changes.

The biomass or the standing crop on the sampling dates is shown in figure 6 . The maximum growth at surface and at 2.5 m depth was found in July. The growth in November through March was gradual while from April there was an abrupt rise till it reached the maximum in July. In August there was very high removal at both the depths but at surface it was higher. The growth or

12 the removal were not constant in various months. Figures 7 and 8 show the observed changes (increments or the losses) in the biomass on slides on the dates shown. The removal was well evident in August and September. The cumulative productivity of periphyton is shown in Table- 51 and Figure 15.

Table - 51

Cumulative Periphyton Productivity in g/m^2/day of dry weight

Date	Surface	2.5 m depth
October - 23	0.000	0.000
November - 7	0.528	0.315
November - 27	0.607	0.756
December - 27	0.000	0.000
January - 27	0.348	0.387
February - 19	0.246	0.341
March - 24	0.284	0.504
April - 17	0.477	0.840
May - 25	1.050	0.918
June - 13	1.189	0.999
July - 15	1.256	2.230
August - 9	0.604	1.610
September - 19	0.101	1.304
October - 16	0.132	1.467
Average (1970 only)	0.479	0.963

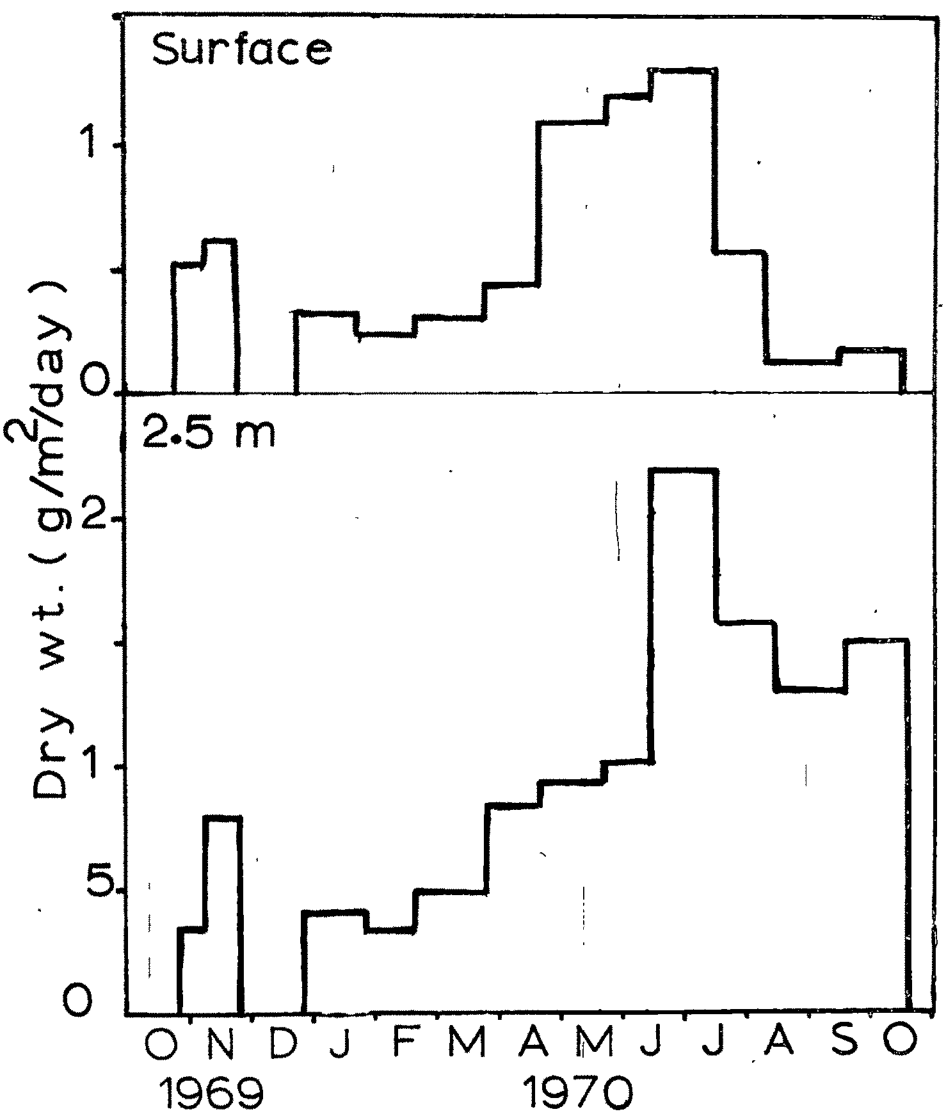

Figure 15
Cumulative periphyton production