HYDROLOGICAL FACTORS AND THE PRIMARY PRODUCTION IN MARINE FISH PONDS

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In the earlier papers dealing with the ecological characteristics of the salt water lagoon near Mandapam and the results of experimental fish culture in such areas, Tampi (1959 and 1960) indicated that certain intrinsic factors are responsible for restricting biological productivity of these environments. Since then some experiments in this field have been conducted to assess the basic productivity of the area. A few preliminary trials in the use of artificial manures have also been tried to test the response in any possible increase in biological production. The results, in conjunction with the hydrological factors, are broadly presented in this paper which may be significant while the problem of utilising saline coastal lagoons is receiving increased attention in our country. In this context, a reference to the pioneering work of Gross, Marshall and their collaborators in the United Kingdom during the years from 1944 to 1949 is of utmost significance. A good amount of subsequent work, although mainly done in fresh water ponds, have bearing on the present problem. These are indicated in the review by Mortimer (1954) and Maciolek (1954).

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EXPERIMENTAL PROCEDURE

Routine analysis of water samples collected for eleven months, beginning from April 1961, were carried out for determining the salinity, dissolved oxygen, hydrogen-ion-concentration, inorganic and total phosphorus and nitrite-nitrogen. The methods employed were those given by Barnes (1959). Samples were analysed for interstitial, adsorbed and total phosphorus contents. The organic matter was also determined using the methods given by Rochford (1951). Experiments on primary production were conducted following the dark and light bottle technique.

Superphosphate (16·5%) was used to study the effect of artificial fertilisation on the primary production. In the first series of fertilisation experiments Pond I was kept as a control and Pond II was fertilised at the rate of 25 kg. of Superphosphate per 1,000 cubic metre of water. The fertiliser was suspended in mosquito net bags at 4 different points in the pond so that equal dissolution and distribution is effected. In the second series of experiments only 10 kg. of fertiliser were used for every 1,000 cubic metre of water. The manner of application was the same as before.

Parallel to the primary production studies, the growth of phytoplankton in the water was also being closely studied. 1 litre of surface water was collected at 5·30 a. m. preserved with ceutral formalin. The samples were centrifuged after settling and the volume reduced to 20 ml. The Phytoplanktons in 1 c.c. aliquot were counted from which the total number of cells was computed for the original sample.

RESULTS

The results of analysis of the hydrological data relating to three of the experimental ponds are given in Table I.

For the major part of the period of investigation the salinity remained well above 36‰. During the summer season the values went up as high as 51‰ in one pond. Even though the general trend was kept up in all the ponds, there were slight variations from pond to pond. The summer months of July through September recorded the highest salinity values while the minimum level was seen in the post monsoon period.

There was no set pattern of changes in the hydrogen-ion-concentration of the water and the values remained on the alkaline side varying between 8·00 and 8·90.

The dissolved oxygen concentration fluctuated between 2 and 4 cc/L. In general the maximum values were observed in the months of July and December. Only in one instance in Pond VI (data not included in the table) the value went below 2 cc/L. This low value corresponded to the high value of nitrite-nitrogen recorded from that pond. So it seems possible that the oxygen has been used up for the oxidation of ammonia to nitrite.

The nutrient salts were found in very low concentrations during most part of the year. Even complete depletion was observed in certain months. Stray cases of nitrite maximum (in Pond VI) raising the values even up to 1·28 μg-at/L has been observed. However, this is not a general phenomenon. After the regeneration the concentration remained fairly high for 3 to 4 weeks.

The concentration of inorganic phosphate in individual cases has been recorded as 0·55 μg-at/L. But during almost all seasons the concentration was very low and the variations do not conform to any definite pattern.

Total phosphate concentration varied between 0·07 to 2·00 μg-at/L. In the ponds I, II and III the maximum values were observed in April-May and again in October. But in the ponds V, VI & VII (data not included in the Table) the second maximum occurred as late as in December.

The interstitial phosphorus varied between 0·542 to 1·610 μg/g of mud. The maximum and minimum values of adsorbed phosphorus were 24·00 and 5·85 μg/g of silt, respectively. The total phosphorus content was found to be generally high and varied between 131·6 and 436·0 μg/g of silt.

The values of primary production experiments conducted during March are given in Table II. In both cases the dark-bottle value had gone down considerably form the initial concentration. In pond I the light-bottle value at the end of the experiment was also less than the initial value. However, in Pond II the light-bottle value was always greater than the initial value which evidences a slight amount of carbon fixation.

TABLE I

Hydrological data from fish Ponds I, II & III

Pond	Month	Salinity ‰	pH	Dissolved O2 cc/l	Inorg. Phosphate µg-at/l	Org. Phosphate µg/at/l	Nitrite-Nitrogen µg-at/l	Interstitial Phosphate µg/g of md	Adsorbed Phosphate µg/g of silt	Total Phosphate µg/g of silt	Organic matter %
I	April 1961	36·60	8·65	2·36	0·240	1·583	0·173				
	May	37·55	8·70	2·49	0·550	1·120	0·100				
	June	—	—	—	—	—	—				
	July	48·34	8·70	3·15	0·320	1·280	0·135				
	August	47·16	8·60	2·93	0·180	0·987	0·056	1·32	19·55	309·22	22·17
	September	48·80	8·68	2·89	0·230	1·250	0·075	0·99	13·71	297·00	22·43
	October	40·94	8·60	2·67	0·209	2·050	0·086	1·03	6·85	131·80	19·28
	November	—	—	—	—	—	—	—	—	—	—
	December	31·16	8·60	3·78	Nil	1·270	Nil	1·533	9·30	213·00	16·71
	January 1962	37·03	8·57	3·28	0·140	0·940	0·210	1·423	8·65	307·80	22·00
	February	38·04	8·60	2·37	0·150	1·250	Nil	0·931	8·63	162·50	16·66
II	April 1961	39·16	8·60	2·75	0·420	1·203	0·180				
	May	37·55	8·70	2·67	0·430	1·350	0·270				
	June	—	—	—	—	—	—	—	—	—	—
	July	46·46	8·50	2·85	0·320	1·210	0·280				
	August	44·75	8·56	2·93	0·130	0·880	0·150	0·980	17·73	262·07	14·31
	September	46·18	8·52	2·61	0·170	1·120	0·140	0·740	13·81	283·00	14·56
	October	39·58	8·55	2·54	0·230	1·949	0·050	0·703	7·50	270·00	12·78
	November	—	—	—	—	—	—	—	—	—	—
	December	30·14	8·70	3·55	Nil	1·160	Nil	0·589	7·35	309·20	11·56
	January 1962	37·09	8·58	3·12	0·134	0·820	0·012	0·836	9·20	267·80	14·56
	February	37·59	8·53	2·51	0·075	1·450	Nil	0·527	8·62	206·30	11·90
III	April 1961	39·16	8·50	2·01	0·380	1·780	0·280				
	May	37·55	8·70	2·64	0·320	1·530	0·250				
	June	—	—	—	—	—	—	—	—	—	—
	July	44·36	8·56	3·14	0·380	1·160	0·155				
	August	44·96	8·58	3·05	0·170	0·920	0·070	1·610	24·20	288·00	16·52
	September	43·59	8·52	3·05	0·220	0·960	0·100	1·090	16·81	436·60	16·49
	October	38·37	8·55	2·82	0·250	2·490	0·032	1·125	5·85	131·60	15·71
	November	—	—	—	—	—	—	—	—	—	—
	December	30·79	8·55	3·91	Nil	0·995	Nil	1·010	9·92	307·60	12·09
	January 1962	36·08	8·56	3·11	0·167	0·850	0·012	1·342	10·62	283·50	13·21
	February	36·34	8·67	2·53	0·210	1·310	Nil	0·929	16·42	268·60	12·00

A dash indicates that the particular value is not available.

The results of the first series of fertilisation production experiments are given in Tables III A & B. It was found that in pond II where artificial fertilisation was done the values of inorganic and total phosphorus reached as high as 34·00 µg-at/L and 44·00 µg-at/L respectively.

The amount of carbon fixed per day in pond I varied from zero to 0·279 g/m³. The average rate of production was 0·106 g/m³. In pond II the primary production varied between 0·284 and 1·072 g/m³, with an average value of 0·609 g/m³. A comparison of the productive rate of the two ponds showed that the value in pond II was about six times greater than in pond I. In both the ponds the dissolved oxygen concentration of the water increased during day time from morning to evening. The increase was greater than the difference between dark and light bottle.

The results of the second series of experiments are given in Table IV A & B. In pond I the production rate varied between zero and 0·214 g/m³ from May 14th to 20th. The average value was 0·122 g/m³. After the fertilisation of the pond on the 20th at 8 a.m. with 10 Kg. of superphosphate the production rate was found to increase gradually and reached 1·238 g/m³. The average value for a period of 11 days was 0·955 g/m³. In pond II which was fertilised on the commencement of the series the rate was found to vary between 0·691 and 2·021 g/m³. Until May 21st the value remained higher than 1·5 g/m³. In this series also it was noticed that the dissolved oxygen concentration of the pond water increased from morning till evening. In the case of pond I this increase was always greater than the difference between the corresponding dark—and light-bottle values. However, in pond II till 23rd May this increase of dissolved oxygen in the open pond was less than the difference between that day's dark—and light-bottle values. After 23rd the increase of oxygen in the pond was higher.

The amount of phytoplankton has been uniformly poor in these ponds. The diatoms in the samples examined have been limited both in numbers and in species and mostly those that usually grow attached to some substrata. Species of *Pleurosigma*, *Amphora* and *Nitzschia*, besides which some peridinians, microflagellates, *Chroococcus* and filaments of *Phormidium* could be encountered. Very often a greenish scum was found to develop at the bottom which seemed to consist entirely of *Gloethoce* (identified through the kindness of Dr. R. P. Varma of this Institute) and a considerable amount of what appeared to be sulphur bacteria. During field observations perceptible changes in the colour of the water in the ponds have been taking place but these were by no means reflected in the phytoplankton counts, probably because all the microflagellates which are responsible for the colour changes in the water are destroyed during preservation of the samples.

DISCUSSION

The experimental part of these preliminary studies has been more of a qualitative nature and obviously not based on any statistical design. Nevertheless, the data when studied in conjuntion with earlier observations help to throw some light on the factors limiting biological productivity and to plan future work on this area.

Annual fluctuations in salinity is one of the major factors affecting the biological production. Oscillations from hypersaline conditions in summer to comparatively low salinity

TABLE II

Results of Primary Production Experiments

Date	Initial diss. Oxygen cc/1	Dissolved Oxygen cc/1		Differences cc/1	Production Rate gm/m
		Light Bottle	Dark Bottle		
		Pond I			
22-3-62	3·09	2·66	2·18	0·48	0·257
23-3-62	2·95	2·82	2·30	0·52	0·279
24-3-62	2·93	2·74	2·14	0·60	0·322
25-3-62	2·89	2·88	2·07	0·81	0·434
26-3-62	3·04	2·88	2·16	0·62	0·332
		Pond II			
22-3-62	2·77	3·09	1·93	1·14	0·611
23-3-62	2·58	3·14	1·72	1·42	0·761
24-3-62	2·74	3·10	2·03	1·07	0·574
25-3-62	2·67	2·95	1·84	1·11	0·595
26-3-62	2·72	2·74	2·20	0·54	0·289

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TABLE III (A)

Results of Experiments on Artificial Fertilisation—First Series

Pond I. Without fertiliser as control

Date	Salinity	Inorganic Phosphate	Total Phosphate	Nitrite Nitrogen	Dissolved Oxygen Pond Initial	Dissolved Oxygen Pond Final	Difference	Diss. Oxygen Bottles L.B.	Diss. Oxygen Bottles D.B.	Difference	Production Rate
	‰	µg-at/l	µg-at/l	µg-at/l	cc/l		cc/l	cc/l		cc/l	gm/m³
April '62											
11	48·97	Nil	1·10	↑	3·04						
12	48·74	0·15	1·12		2·96						
13	48·74	Nil	1·18		3·15						
14	—	—	—		—						
15	41·60	0·15	1·20		3·34						
16	41·78	Nil	1·28		2·81						
17	39·92	0·20	1·10		3·37						
18	41·04	0·20	1·16		2·98						
19	40·86	0·16	1·10		2·60						
20	40·12	Nil	1·08		3·12						
21	39·20	0·15	1·20	Nil	2·82						
22	38·66	Nil	0·96		2·88						
23	38·19	Nil	1·00		3·06						
24	37·71	Nil	1·00		2·84	4·76	1·92	3·68	3·26	0·42	0·225
25	38·84	0·20	1·02		3·19	4·71	1·52	3·21	3·11	0.10	0·054
26	36·64	0·20	1·30		3·58	4·56	0·98	3·22	3·22	0·00	0·000
27	36·64	Nil	1·80		3·62	4·84	1·24	3·54	3·53	0·01	0·005
28	37·05	Nil	1·48		3·49	5·04	1·55	3·67	3·39	0·28	0·150
29	36·83	0·15	1·33		3·67	4·98	1·31	3·40	3·29	0·11	0·091
30	36·50	0·16	1·30		3·81	4·82	1·01	3·50	3·40	0·10	0·054
May											
1	36·40	Nil	1·20		3·52	4·80	1·28	3·32	3·17	0·15	0·080
2	36·42	Nil	1·28	↓	2·90	4·73	1·83	3·32	2·80	0·52	0·279

A dash indicates that the particular value is not available.

L.B.—Light Bottle. D.B.—Dark Bottle.

TABLE III (B)

Results of Experiments on Artificial Fertilisation—First Series

Pond II. Fertiliser added on April 10.

Date	Salinity	Inorganic Phosphate	Total Phosphate	Nitrite Nitrogen	Dissolved Oxygen Pond		Difference	Diss. Oxygen Bottles		Difference	Production Rate
					Initial	Final		L.B.	D.B.		
	‰	µg-at/l	µg-at/l	µg-at/l	cc/l		cc/l	cc/l		cc/l	gm/m²
April '62											
11	49·02	8·60	10·00	↑	2·58						
12	49·10	23·44	22·50		2·60						
13	47·63	34·04	36·02		1·98						
14	—	—	—		—						
15	44·87	32·69	36·00		2·53						
16	46·53	33·00	42·80		2·42						
17	46·14	25·60	28·80		2·67						
18	45·61	23·60	24·40		2·47						
19	44·87	18·00	22·20		2·02						
20	44·87	16·20	20·00		2·26						
21	44·33	14·00	15·00		2·45						
22	43·77	11·75	12·50	Nil	2·45						
23	43·14	9·00	11·10		2·42						
24	43·14	8·30	10·00		2·01	4·20	2·19	3·76	1·95	1·87	0·970
25	43·59	7·50	9·20		2·79	4·72	1·93	3·06	2·56	0·53	0·284
26	43·59	7·90	10·50		3·09	4·65	1·55	3·37	2·76	0·61	0·327
27	43·59	1·68	9·60		3·28	5·01	1·73	3·75	3·10	0·65	0·348
28	44·15	4·66	10·00		3·21	5·18	1·97	4·36	3·05	1·31	0·702
29	42·20	4·80	11·24		3·01	4·73	1·72	4·01	3·00	1·01	0·541
30	44·31	4·25	9·60		2·95	4·46	1·51	3·65	2·85	0·80	0·529
May											
1	44·35	4·50	10·00		2·64	4·87	2·23	4·03	2·51	1·52	0·815
2	44·62	4·25	5·62	↓	2·34	5·06	2·72	4·22	2·22	2·00	1·072

A dash indicates that the particular value is not available.
L.B.—Light Bottle. D.B.—Dark Bottle.

TABLE IV (A)

Results of Artificial Fertilisation Experiments—Second Series

Pond. I Fertiliser added on May 20

Date	Salinity	Inorganic Phosphate	Total Phosphate	Nitrite Nitrogen	Dissolved Oxygen Pond		Difference	Diss. Oxygen Bottles		Difference	Production rate
					Initial	Final		L.B.	D.B.		
	‰	µg-at/l	µg-at/l	µg-at/l	cc/l		cc/l	cc/l		cc/l	gm/m^3
May '62											
14	30·75	0·170	0·90	0·165	3·57	5·22	1·65	3·44	3·44	0·00	0·000
15	30·75	0·15	0·74	0·140	3·48	4·80	1·32	3·41	3·27	0·14	0·075
16	27·36	0·26	0·90	0·200	4·09	4·37	0·64	3·66	3·60	0·06	0·032
17	28·37	0·12	0·74	0·236	3·51	4·69	1·18	3·80	3·39	0·41	0·220
18	29·65	0·20	0·72	0·286	4·11	4·69	0·58	3·93	3·60	0·33	0·177
19	30·39	0·16	0·72	0·153	3·86	5·06	1·20	4·10	3·84	0·26	0·139
20	31·11	Nil	0·82	0·178	3·83	4·98	1·15	4·12	3·72	0·40	0·214
21	31·47	17·00	18·00	0·200	3·51	5·18	1·67	4·14	3·43	0·71	0·381
22	31·83	20·00	23·40	0·270	3·54	5·17	1·63	4·97	3·50	1·47	0·788
23	32·79	14·20	22·70	0·260	3·16	5·04	1·88	4·49	2·98	1·51	0·808
24	33·44	10·00	10·00	Nil	2·51	5·06	2·55	4·21	2·41	1·80	0·965
25	33·12	6·40	7·90	Nil	2·83	5·11	2.28	4·70	2·81	1·89	1·013
26	33·66	5·60	8·00	Trace	2·68	4·86	2·18	4·40	2·52	1·88	1·008
27	—	—	—	—	—	—	—	—	—	—	—
28	34·94	3·65	4·50	Trace	2·45	5·11	2·66	4·29	2·66	2·03	1·088
29	34·87	2·70	3·00	0·152	2·40	4·78	2·38	4·16	2·16	2·00	1·072
30	35·41	1·70	2·85	Nil	2·73	4·80	2·07	4·39	2·63	1·76	0·943
31	35·32	1·14	1·60	0·100	2·50	5·05	2·55	4·46	2·20	2·26	1·211
June											
1	35·68	0·98	1·54	0·110	2·39	5·16	2·77	4·60	2·29	2·31	1·238

A dash indicates that the particular value is not available.

L.B.—Light Bottle. D.B.—Dark Bottle.

TABLE IV (B)

Results of Artificial Fertilisation Experiments—Second Series

Pond II. Fertiliser added on May 14.

Date	Salinity	Inorganic Phosphate	Total Phosphate	Nitrite Nitrogen	Dissolved Oxygen Pond Initial	Dissolved Oxygen Pond Final	Difference	Diss. Oxygen Bottles L. B.	Diss. Oxygen Bottles D. B.	Difference	Production rate
	‰	µg-at/l	µg-at/l	µg-at/l	cc/l	cc/l	cc/l	cc/l	cc/l	cc/l	gm/m²
May '62											
14	31·65	22·70	20·00	↑	3·50	5·86	2·36	6·30	3·18	3·12	1·672
15	31·65	19·60	25·00		3·15	5·08	1·93	5·44	2·57	2·87	1·538
16	28·46	15·00	19·40		4·00	6 28	2·28	7·32	3·55	3·77	2·021
17	29·11	16·00	19·00		3·30	5·49	2·19	6·71	3·15	3·56	1·908
18	30·19	10·60	13·80		3·37	5·42	2·05	6·53	3·20	3·30	1·769
19	30·57	11·00	12·50		3·62	5·54	1·92	6·53	3·37	3·16	1·694
20	31·29	8·50	9·60		3·58	5·56	1·96	6·34	3·26	3·08	1·651
21	31·47	7·00	7·90		3·18	5·56	2·38	5·84	2·95	2·89	1·549
22	31·91	6·42	7·20		3·38	5·52	2·14	5·79	3·26	2·53	1·356
23	32·42	5·60	6·20		2·91	5·33	2·42	5·25	2·65	2·60	1·394
24	33·15	5·60	5·70	Nil	2·62	5·44	2·82	5·18	2·32	2·86	1·533
25	32·42	4·55	4·55		2·66	5·46	2·80	4·77	2·38	2·39	1·281
26	33·31	4·05	5·40		2·42	5·19	2·77	3·54	2·55	0·89	0·691
27	—	—	—		—	—	—	—	—	—	—
28	34·58	4·60	4·65		2·25	5·93	3·68	3·62	2·09	1·53	0·820
29	34·40	3·80	4·40		2·04	5·55	3·51	3·34	1·74	1·60	0·858
30	33·86	4·20	5·32		2·06	5·62	3·56	3·37	1·84	1·53	0·820
31	35·05	4·00	5·68		1·89	5·49	3·60	3·22	1·62	1·60	0·850
June											
1	34·78	3·95	5·88	↓	2·00	4·75	2·75	3·55	1·88	1·67	0·895

A dash indicates that the particular value is not available.

L.B.—Light Bottle. D.B.—Dark Bottle.

during the monsoon are detrimental to the growth of biota in an enviornment. The shallowness of the lagoon and the excessive evaporation tend to maintain the salinity high during a major part of the year, when the lagoon remains completely out off from the sea.

The concentration of nutrient salts, especially phosphate, is found to be very low in the pond waters. The analysis of the mud samples from the ponds shows that the bottom mud contains an appreciable amount of phosphate without noticeable regeneration. In general the phosphate fluctuated between zero and 0·55 μg-at/L. Jayaraman (1954) has observed similar values in the adjacent Palk Bay, but in this case the value always ranged between 0·12 to 0·25 μg-at/L. The hypothesis that phosphates could permanently be lost from the water by the presence of ferric-organic complex (Mortimer 1941 & '42, 1949) or calcium carbonate (Zicker and Berger, 1956), may well be applicable for the saline lagoon areas. Calcium in the form of calcium carbonate is plentiful in the mud (1·2% to 3·4%) while the extent of iron present was only 0·02 to 0·06 mg/g of mud.

The concentration of nitrite-nitrogen is very low most of the times with slight regeneration in some ponds, which shows that there is a possibility of the nitrogen cycle.

Thus it is seen that the concentration of the major nutrient salts is very poor for the major part of the year with lack of systematic regeneration to compensate the deficiency. The replenishment from the surrounding run off water is also negligible because of the leached soil all round.

The dark and light-bottle experiments conducted during March with a view to assess the basic productivity of the ponds do not reveal any significant information. This was because the results were much affected by prolonging the experiments for 24 hours, since this caused a greater depletion of oxygen in the dark bottles, suspected to be due to the presence of bacterial community.

The fertilisation experiments show that it is possible to raise the productivity by artificial manuring. The effect of fertilisation is visible only after a week to fourteen days. The production rate in Pond I which was 0·106 gm/m^3 in the month of April and 0·122 gm/m^3 till May 20th could be increased to 0·955 gm/m^3 after fertilisation of the ponds on 20th May. Similarly in Pond II also a marked increase in production rate is found from April to May. However, the productivity of the ponds does not depend entirely on the nutrient salts. Intensity of light and salinity may influence the productivity to a large extent. The effect of light intensity has been observed in our experiments. The production rate of Pond II which was 0·609 gm/m^3 in the month of April, when the sun was bright, has risen to the average value of 1·725 gm/m^3 during the first eight days in May, when the sky was cloudy.

Even though attempts to increase the basic production rate by the application of inorganic fertilisers have been found partially successful, it has not been possible to sustain a high degree of productivity for a period beyond a fortnight. However, repeated fertilisation has not been tried in these experiments. The total production of the pond per day is far lower than the value that could be obtained from the open sea where the same rate of production is found. The only available data from the area with which the present values could be compared are those of Prasad and Nair (1960), but these relate to the Gulf of Mannar, Assuming that in Palk Bay also the rate of production is of the same magnitude, the total production of an area in the sea corresponding to that of all the ponds put together will be many hundred times greater than that of the ponds.

The significance of microflora in ponds need hardly be emphasised. Copepods and such planktonic animals as well as filter feeding animals at the bottom make extensive use of them. Our experimental ponds are infested with a great number of lamellibranchs *Meritrix casta*) and it is quite likely that these clams take in a large crop of micro-flagellates. Marshall (1947) has pointed out that the zooplankton, the bottom fauna, and the growth of sea-weeds complicate the result of fertilisation experiments. Thus in judging the changes in the phytoplankton as a result of the added fertilisers etc., it has to be expressed in conjunction with the other dependent factors which have not been given consideration in these experiments.

SUMMARY

The chemical conditions existing in the experimental fish ponds near Palk Bay in Mandapam have revealed the lack of several factors conducive for a balanced growth of animal and plant community. Wide fluctuations in salinity, often reaching hypersaline conditions, combined with very low concentration of essential nutrient salts and their lack of regeneration or replenishment are some of the main reasons for the low level of biological productivity.

The basic production rate, calculated from light and dark—bottle experiments, is found to be very low compared to that of other economically working ponds or the open sea. Artificial fertilisation of the ponds with only superphosphate has helped to raise to some extent the primary production, but not to a sustained level.

REFERENCES

Barnes. H. 1959. *Apparatus and Methods of Oceanography Part I. Chemical.* George Allen and Unwin Ltd., London.

Gross. F. 1947. An experiment in marine fish cultivation I. Introduction. *Proc. Roy. Soc. Edinburgh* (B), **63** : 1—2.

Gross. F. 1949. Further observations on fish growth on a fertilised sea loch (Loch Graighn) *J. Mar. biol. Assoc. U.K.*, **28** : 1—8.

Gross. F. *et al.* 1944. A fish farming experiment in sea loch. *Nature.* **153** : 483—485.

Gross. F. *et al.* 1946. Application of fertilisers to an open sea loch. *Ibid.*, **158** : 187—189.

Jayaraman. R. 1954. Seasonal variations in salinity, dissolved oxygen and nutrient salts in the inshore waters of the Gulf of Mannar and Palk Bay. *Indian J. Fish.*, **1** : 345—364.

Maciolek. J. A. 1954. Artificial fertilisation of lakes and ponds. A review of literature. *U. S. Dept. Fish and Wildlif Service Spec. Sci. Rep.*, **No. 113.**

Marshall. S. M. 1947. An experiment in marine fish cultivation III. The plankton of a fertilised loch. *Proc. Roy. Soc. Edinburgh* (B), **63** : 21—33.

Mortimer. C. H. 1941/42. The exchange of dissolved substances between mud and water in lakes. *J. Ecol.*, **29** : 280—329; **30** : 147—201.

Mortimer. C. H. 1949. Seasonal changes in chemical conditions near the mud surface in the two lakes of the English Lake District. *Proc. Internat. Assoc. Limnol.* **10** : 353—356.

Mortimer. C. H. 1954. *Fertilisers in fish ponds.*—Colonial Office Fishery Publication **No. 5** : 1—155.

Prasad. R. R. & Nair. P.V.R. 1960. A preliminary account of primary production and its relation to fisheries of inshore waters of the Gulf of Mannar. *Indian J. Fish.*, **7** : 165—68.

Rochford. D. J. 1951. Studies in Australian estuarine hydrology. Introductory and comparative features. *Australian J. Mar. Fresh. Res.* (*B*), **2** (1) : 1—116.

Tampi. P. R. S. 1959. The ecological and fisheries characteristics of a salt water lagoon near Mandapam. *J. Mar. biol. Ass. India*, **2** (1) : 113—130.

Tampi. P.R.S. 1960. Utilisation of saline mud flats for fish culture—An experiment in marine fish farming. *Indian J. Fish.*, **7** (1) : 137—146.

Zicker. E. L. and Berger. K. C. 1956. Phosphorus release from bog lake muds. *Limnology and Oceanography*, **1** (4) : 296—303.