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LIMNOLOGY AND FISH PRODUCTION POTENTIAL OF SOME RESERVOIRS IN ANURADHAPURA DISTRICT, SRI LANKA

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In the past, several large and small reservoirs have been constructed in Sri Lanka, mainly for irrigational and hydroelectric purposes. Subsequently they have also been used to develop inland fisheries. Not much research has been done relative to hydrobiological conditions and fish production of these reservoirs and as a result, our knowledge about their biological productivity is very limited. So far a few accounts on the hydrobiology of some inland waters of Sri Lanka have been reported, (Holsinger, 1955; Mendis, 1964; Costa and de Silva, 1969; 1978 a, b, c). Scanty information however is available on connected aspects such as fish production (Mendis, 1965; Costa and Liyanage, 1978). Recently, attempts have been made to derive new methods for the estimation of potential fish production in inland water bodies with a view to improve the existing fishery resources (Welcomme, 1976; Wijeyaratne and Costa, 1981; Wijeyaratne and Amarasinghe in preparation).

Limnological conditions existing in water bodies are not uniform and tend to vary from one reservoir to the other and area to area. Hence it is necessary to carry out detailed limnological studies for as many reservoirs as possible, in order to obtain a general idea of the biological productivity of the reservoirs. The present study was undertaken to record the hydrobiological features and determine the fishery potential of seven man-made reservoirs in the north central province of Sri Lanka. A similar study has been carried out on the reservoirs of Hambantota district (Daniel, Costa and Wijeyaratne, in preparation). These studies will provide base-line information for future studies regarding the development of inland fishery resources in Sri Lanka. The seven reservoirs studied were Hurulu wewa, Kala wewa, Mahakandarawa wewa, Mahawilachchiya wewa, Nachchaduwa wewa, Nuwara wewa and Rajanganaya wewa. These are perennial tanks and except for Mahakandarawa wewa. They also receive diverted water from the river Mahaweli. Except Nuwara wewa, in all the other reservoirs, there are decaying tree stumps. Among these tanks, the largest is Kala wewa and the smallest is Mahawilachchiya wewa. Table I gives the morphometric features of these reservoirs.

Materials and Methods :

Sampling was carried out once a month, for a period of 12 months, commencing from June 1980. Measurements for September 1980 were not taken due to unavoidable circumstances. Temperature was measured with a thermometer, accurate to 0.1 °C, between 10.00 a.m. and 3.00 p.m. Light penetration was determined with a standard Sechchi disc (diameter, 20 cm.) A "HACH" portable conductivity meter was used to measure conductivity, while a "Karl Kolb" portable pH meter was used to measure pH. Samples for the determination of dissolved Oxygen, total alkalinity and phytoplankton were taken with a Nansen's water sampler. For the determination of dissolved Oxygen, samples were taken both from the surface and the bottom, between 10.00 a.m. and 3.00 p.m. Dissolved Oxygen was measured by the Winkler method as described by Mackereth *et. al.*, (1978). Total alkalinity was determined by titrating the water samples with 0.01 N HCl (Golterman *et. al.*, 1978) and expressed as Calcium carbonate. Temperature, pH, dissolved Oxygen and total alkalinity were measured 3 times a day at 2 hour intervals and the mean values of the three measurements are given in Fig. 1 to 7. Primary production was estimated by the light and dark bottle method as described by Vollenweider (1974). Primary

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production at the surface and at the bottom were measured and the results are expressed as g C m^{-2} day^{-1}

Phytoplankton were identified (Abeywickrama, 1979) and the cell counts were carried out as described by Vollenweider (1974). A single cell was considered as a unit for unicellular and filamentous algae, while a single colony was considered as a unit for colonial algae. Countings were done in triplicate and the average numbers for each genus were calculated. The results are expressed as number of cells/colonies per litre. The maximum sustainable fish yields (MSY) were calculated using morphoedaphic indices (MEI) and the regression equation calculated by Wijeyaratne and Amarasinghe (in preparation) which is as follows.

$$\log_e \text{MSY} = 0.9005 \log_e \text{MEI} + 1.9220$$

Results :

(a) Physico-chemical Factors :

Seasonal variation of physico-chemical factors for different reservoirs are graphically represented in figures 1 to 7.

1. Hurulu wewa (Fig. 1)

Temperature : Air and water temperatures varied from 20.4 °C to 31.8 °C and from 27.2 °C to 31.9 °C respectively during the period of investigation. Maximum air temperature was noted in April and the minimum in January. Maximum water temperature was observed in April and the minimum in August.

pH : The pH varied from 7.22 to 8.52 attaining a maximum in August and minimum in November.

Secchi disc visibility : This value ranged from 40 cm. to 111 cm. with a maximum in January and minimum in June and August.

Total alkalinity : This value ranged between 59.3 and 164.7 ppm., with a maximum in January and a minimum in February.

Dissolved Oxygen : The dissolved Oxygen concentrations of surface layers registered its peak value (10.5 mg/l) in July and the minimum 6.33 mg/l in November. Dissolved Oxygen concentrations of bottom layers ranged between 6.53 mg/l in November and 9.47 mg/l in July during the period of study.

Conductivity : Conductivity fluctuated between 140μ mhos per cm. in December and 300μ mhos/cm in November.

2. **Kala wewa (Fig. 2) :**

Temperature : Maximum air temperature (32.5° C) and water temperature (30.9° C) were noted during April and May respectively while the minimum air temperature was noted in December (28.8° C) and the minimum water temperature in October (27.2° C)

pH : This value fluctuated between 7.47 and 8.43 attaining a maximum in March and a minimum in October.

Secchi disc visibility : This value varied from 41 cm. to 94 cm.

Total alkalinity : The highest value (119.3 ppm.) was noted in March and the lowest (50.0 ppm.) in October.

Dissolved Oxygen : Dissolved Oxygen in the surface water layers varied from 9.4 mg/l to 7.87 mg/l, with maximum in July and March and minimum in December.

Dissolved Oxygen concentration of bottom layers ranged from 7.53 mg/l in December to 9.67 mg/l in July.

Conductivity : Maximum value (400μ mhos/cm) was noted in January and May and the minimum (82μ mhos/cm) was observed in August.

3. **Mahakanadarawa wewa (Fig. 3) :**

Temperature : Air temperature ranged from 29.3° C to 32.2° C and the water temperature ranged from 28.0 °C to 31.5 °C. The maximum air and water temperatures were recorded in August and in March respectively. Minimum air temperature was noted in November and the minimum water temperature was observed in July.

pH : It fluctuated between 7.90 and 8.45, with a maximum in August and a minimum in November.

Secchi disc visibility : The highest value (95 cm) was observed in January and the lowest (40 cm) in July.

Total alkalinity : This value varied from 107.0 ppm. in December to 189.0 ppm. in October.

Dissolved Oxygen : Dissolved Oxygen of surface water layers varied from 7.13 mg/l to 10.40 mg/l, with a maximum in July and a minimum in May. The maximum Oxygen concentration of bottom water layers (9.47 mg/l) was recorded in July and the minimum (7.27 mg/l) in February.

Conductivity : It showed an erratic fluctuation with a maximum of 910μ mhos/cm in February and a minimum of 420μ mhos/cm in August.

4. **Mahawilachchiya wewa (Fig. 4) :**

Temperature : Air temperature varied from 28.4° C to 33.8° C, attaining a maximum in June. The lowest value was recorded in January. The maximum water temperature (33.0 °C) was in June and the minimum (28.8 °C) was in January.

pH : The highest pH value (8.48) was noted in August and the lowest (7.50) in November.

Secchi disc visibility : This fluctuated between 42 cm and 78 cm.

Total alkalinity : It ranged from 81.0 ppm to 174.7 ppm. The maximum value was observed in July and the minimum in January.

Dissolved Oxygen : In the surface waters, maximum Oxygen concentration was 9.53 mg/l in June and the minimum was 7.33 mg/l in April. The Oxygen concentration of bottom water layers varied from 7.60 mg/l in February to 9.33 mg/l in July.

Conductivity : Conductivity ranged from 400μ mhos/cm to 800μ mhos/cm, with maximum in October and May and a minimum in June.

5. **Nachchaduwa wewa (Fig. 5) :**

Temperature : Air temperature varied from 28.6 °C to 32.9 °C. Water temperature recorded its maximum value (33.1°C) in November and the minimum (27.5°C) in July.

pH : Its highest value (8.50) was noted in January and the lowest (7.53) was observed in October.

Secchi disc visibility : It ranged between 40 cm and 90 cm.

Total alkalinity : These values varied from 45.3 pp. to 140.0 ppm.

Dissolved Oxygen : The peak value of dissolved Oxygen concentration in surface water (9.47 mg/l) was observed in June and the lowest value (7.07 mg/l) was noted in May. The maximum Oxygen concentration of bottom water layers was 8.60 mg/l in May.

Conductivity : Conductivity was maximum (570μ mhos/cm) in August and minimum (350μ mhos/cm) in November.

6. **Nuwara wewa (Fig. 6) :**

Temperature : The maximum air temperature (31.3°C) was noted in April and the minimum (28.8°C) was in June. Water temperature ranged between 27.3 °C and 31.3°C with a maximum in November and a minimum in July.

pH : It ranged between 8.20 and 8.60, attaining its maximum in July and its minimum in November.

Sechchi disc visibility : It ranged between 22 cm and 54 cm, the lowest recorded for all the reservoirs studied.

Total alkalinity : Total alkalinity varied between 74.7 ppm and 133.3 ppm.

Dissolved Oxygen : Dissolved Oxygen concentration fluctuated between 6.47 mg/l and 10.13 mg/l in the surface water, attaining its maximum in June and the minimum in January. The maximum dissolved Oxygen concentration of bottom water layers was 9.6 mg/l in June and the minimum was 6.27 mg/l in January.

Conductivity : Its peak value (840μ mhos/cm) was recorded in April and the lowest value (300μmhos/cm) was noted in July.

7. Rajanganaya wewa (Fig. 7) :

Temperature : The maximum air temperature (32.4°C) was noted in May and the minimum (26.5°C) was in December. The water temperature varied from 27.2°C to 30.5°C with a maximum in May and a minimum in December.

pH : pH ranged between 7.47 and 8.57.

Sechchi disc visibility : This value ranged between 65 cm and 151 cm.

Total alkalinity : The peak value (191.7 ppm) was recorded in August and its minimum, (124.7 ppm) was noted in November.

Dissolved Oxygen : Dissolved Oxygen of surface layers of the water body ranged between 4.80 mg/l in December and 9.60 mg/l in July. In the bottom layers, this value varied from 4.80 mg/l to 8.80 mg/l with a maximum in July and a minimum in December.

Conductivity : This ranged between 455μ mhos/cm and 650μ mhos/cm.

(B) BIOLOGICAL FACTORS :

Phytoplankton :

The main phytoplankton groups and their monthly fluctuations are shown in Figures 1 to 7.

Hurulu wewa :

Phytoplankton population in Hurulu wewa showed two pulses, one in July/August and the other in October. The dominant group of phytoplankton during the period was Bacillariophyceae.

Kala wewa :

Phytoplankton population in Kala wewa also recorded two pulses, one during August and the other during March/April. During August the most abundant group was Bacillariophyceae. It was also noted that the dominant group during March/April was Myxophyceae.

Mahakanadarawa wewa :

Phytoplankton density in this reservoir was comparatively low. A peak was recorded in April. During this time, diatoms predominated.

Mahawilachchiya wewa :

Phytoplankton density showed 2 peaks during the study period. Bacillariophyceae was the dominant group during August while Myxophyceae dominated in May.

Nachchaduwa wewa :

Phytoplankton was mainly made up of blue-green algae in July. Diatoms occur in large numbers in May.

Nuwara wewa :

Phytoplankton densities were relatively high and two pulses of Myxophyceae

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during January and March were noted. Two peaks of Chlorophyceae occurred in October and April.

Rajanganaya wewa :

Number of phytoplankton increased rapidly from June until August, followed by a decline. Myxophyceae and Chlorophyceae were the dominant groups during this period.

Primary Production :

Fluctuations of gross primary production (GPP) and net primary production (NPP) in the seven reservoirs studied are graphically represented in Figures I to 7.

Daily rates of gross primary production for Hurulu wewa, Kala wewa, Mahakanadarawa wewa, Mahawilachchiya wewa, Nachchaduwa wewa, Nuwara wewa and Rajanganaya wewa ranged between 1.20 - 5.40, 1.42 - 4.16, 1.42 - 4.16, 1.98 - 4.20, 1.73 - 3.67, 2.25 - 5.63 and 1.35 - 4.36 g Cm^{-2} day^{-1} respectively.

(C) Potential Fish Production :

Morpho — edaphic indices (MEI) and the maximum sustainable fish yields (MSY) were calculated and are presented in Table IV. Table V shows the present fish catches in the same reservoirs.

Disscussion :

Present study was undertaken mainly to acquire an idea about the prevailing limnological conditions and to assess the potential fish production of the major reservoirs of the north central province of Sri Lanka. Morphometrically, the seven reservoirs studied differ much from each other (Table I).

Mahawilachchiya wewa is fairly shallow while Rajanganaya wewa is relatively deep for its area. Degree of wind exposure and maximum depth influences the variation of water temperature (Hutchinson, 1957). Higher values were noted to occur in the shallow tanks such as Mahawilachchiya where the water temperature ranged from 28.7°C to 33.0°C. All the waters are slightly alkaline with most waters having pH values greater than 8.0. These reservoirs have high proportions of CO_3 and HCO_3 ions and it is apparent that the increasing total alkalinity influences the pH fluctuations. In the tanks which have high values for total alkalinity, pH fluctuates very little as the waters are considerably buffered. In all the reservoirs, total alkalinity values increase during dry seasons and during the months of low water levels, since evaporation exceeds inflow.

Sechchi disc visibilities were higher in deeper reservoirs, as for example, in Rajanganaya wewa this value ranged between 65 cm and 151 cm while it was often low in shallow tanks; in Nuwara wewa, it ranged between 22 cm and 54 cm. The lower values encountered in shallow tanks may be due to the turbulence caused by suspended particles and perhaps even due to the presence of large number of phytoplankton. These conditions were more pronounced in smaller reservoirs and were more commonly observed after heavy precipitation. Myxophyceae were the dominant phytoplankton in all reservoirs. Sreenivasan (1970 b) and Uhlmann *et.al.*,(1982) have stated that the dominance of blue green algae among the phytoplankton seem to be a feature of tropical reservoirs. The population densities of phytoplankton were directly correlated with the amounts of dissolved Oxygen which were rather high for both the surface and bottom layers in all the months except during the rainy season. This slight decline in rainy months may be due to, among other reasons, the decomposition of organic matter which gets drained into the water bodies with rain water. During dry seasons, phytoplankton increases rapidly in numbers so that increase in the amount of dissolved Oxygen during this time is mainly due to phytoplankton photosynthesis. In most reservoirs, however, except Mahakanadarawa wewa, the water levels do not markedly recede during the dry season because of the diverted Mahaweli water into these reservoirs. This diversion may tend to decrease the residence time of the water, making the nutrients in water bodies to get diluted as is reflected by the lower values for conductivity in certain reservoirs. In Mahakanadarawa wewa which receives only rain water on the other hand, there is a close relationship between total dissolved solids and rain fall.

Results showed that the production was moderately high throughout the year with little fluctuations in the rates of primary production. It was observed that higher primary production rates are related to high phytoplankton densities (Fig. 1 to 7). Various authors (Sreenivasan, 1964, 1965, 1966, 1970a 1974, Vijayaraghavan, 1971, Costa and de Silva, 1978 c) have shown that primary production in tropical waters is moderately high throughout the year with little fluctuations. Productivity values of waters in major reservoirs in Anuradhapura district (5.63 — 1.20 g C m $^{-2}$ day $^{-1}$) are similar to those of that of Indian and other Sri Lankan water bodies. When considered seasonally, the values for production decline during the rainly seasons and increased during the dry seasons. These results also indicate that the community respiration resulting in low primary production was high during the rainy seasons.

Potential fish yields were calculated and they indicated that under optimum conditions, a potential fish yield of 5,881,384 kg/yr of fish could be harvested from these reservoirs if proper management measures are taken. According to the present catch statistics maintained by the ministry of fisheries, the present total fish catch from all these reservoirs is 2,854,002 kg/yr. It appears that the potential fish yield for Rajanganaya wewa (409 kg ha $^{-1}$ yr $^{-1}$) and Mahawilachchiya wewa (630 kg ha $^{-1}$ yr $^{-1}$) are almost similar to the present fish catches (442 kg ha $^{-1}$ yr $^{-1}$ and 583 kg ha $^{-1}$ yr $^{-1}$ respectively), so that it could be hypothesized that the fish stocks in these two reservoirs are being intensively exploited. Assuming the efficiency of all the crafts and fishermen in all the reservoirs were the same, values for catch per unit effort (CPUE) were estimated to compare the stock abundance (Table V). The CPUE values for Hurulu wewa and Kala wewa which have the same range of MEI values as Rajanganaya wewa, are a little lower than the CPUE for Rajanganaya wewa. When compared with Mahawilachchiya wewa the fish yields appear to be very low in Mahakandarawa wewa, Nachchaduwa wewa and Nuwara wewa although they have high MEI values. Correct management measures should be taken to increase the fish stock sizes of the reservoirs, namely, Hurulu wewa, Kala wewa, Mahakandarawa wewa, Nachchaduwa wewa and Nuwara wewa. This should be done by taking steps to stock more fish fingerlings in these reservoirs and by increasing the fishing effort.

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TABLE I. Morphometric data of the reservolrs studied

(From Register of Irrigation Projects in Sri Lanka.)

Name of the reservolr	Area ha.	Capacity $m^3 \times 10^4$	FSL m MSL	FSD m
1. Hurulu wewa	2125·5	6796·6	132·4	8·4
2. Kala wewa	2583·3	8981·2	128·2	9·2
3. Mahakandarawa wewa	1457·6	4479·6	94·9	5·8
4. Mahawilachchiya wewa	971·8	4016·2	53·8	6·7
5. Nachchaduwa wewa	1784·8	5579·1	101·8	7·6
6. Nuwara wewa	1196·9	4454·8	87·5	7·0
7. Rajanganaya wewa	1599·4	10083·8	68·4	10·7

FSL — Full Supply Level

MSL — Mean Sea Level

FSD — Full Supply Depth

TABLE II. Morpho- edaphic indices (MEI) and maximum sustainable yields (MSY) of the reservoirs :

Reservoir	Mean depth m	Conductivity µmhos per cm.	MEI	MSY kg yr^{-1} ha^{-1}	MSY kg yr^{-1} whole tank
Hurulu wewa	3·1	197	61·73	280	594970
Kala wewa	3·4	318	91·57	399	1031434
Mahakanadarawa wewa	3·0	651	211·95	850	1239149
Mahawilachchiya wewa	4·1	628	151·99	630	612383
Nachchaduwa wewa	3·1	461	147·59	613	1095350
Nuwara wewa	3·7	483	129·69	546	653831
Rajanganaya wewa	6·3	593	94·07	409	654267

TABLE III. Fish catch statistics for some major reservoirs in Anurad district. (1980—1981)

Reservoir	Catch* kg yr^{-1}	Catch ha^{-1} yr^{-1} kg	Mean No. of crafts	Catch craft^{-1} day^{-1}kg	Catch ha^{-1} craft^{-1} day^{-1} kg
Hurulu wewa	1,47,449	69	28	14·43	2·28
Kala wewa	4,83,476	187	66	20·07	2·84
Mahakanadarawa wewa	1,48,897	102	30	13·60	3·41
Mahawilachchiya wewa	5,72,073	588	59	26·49	9·9[illegible]
Nachchaduwa wewa	6,14,139	344	78	21·61	4·4[illegible]
Nuwara wewa	1,80,840	151	38	13·15	4·1[illegible]
Rajanganaya wewa	7,07,128	422	126	15·35	3·5[illegible]

* From the Statistical Division, Ministry of Fisheries.

ustainable

MSY
kg yr-1
ole tank

594970
1031434
239149
12383
095350
653831
654267

Anuradh

Catch
ha-1
craft-1
day-1 kg

2·28
2·84
3·41
9·95
4·42
4·10
3·56

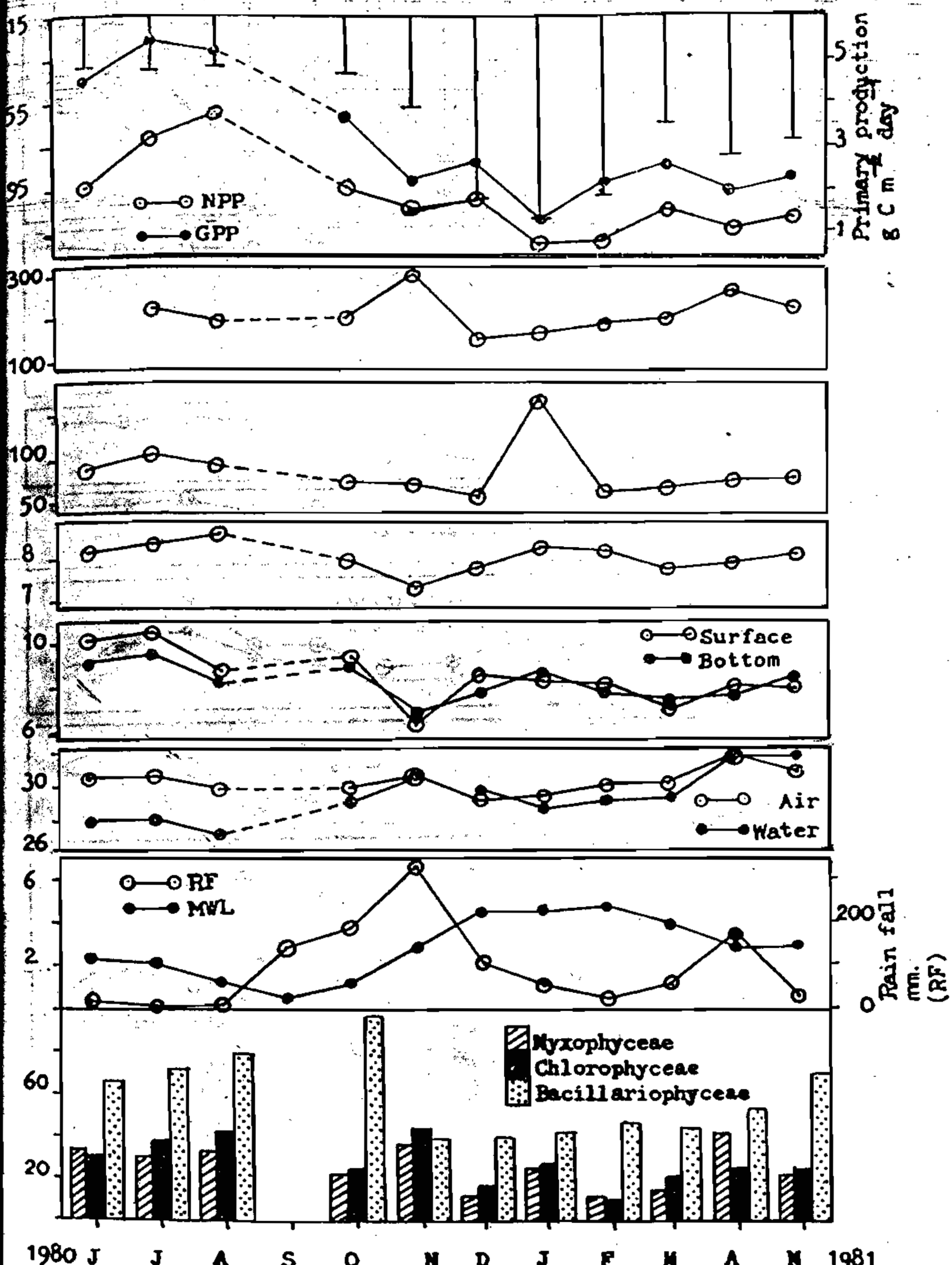

Fig. 1 Seasonal variations of hydrobiological conditions in Hurulu Wewa.

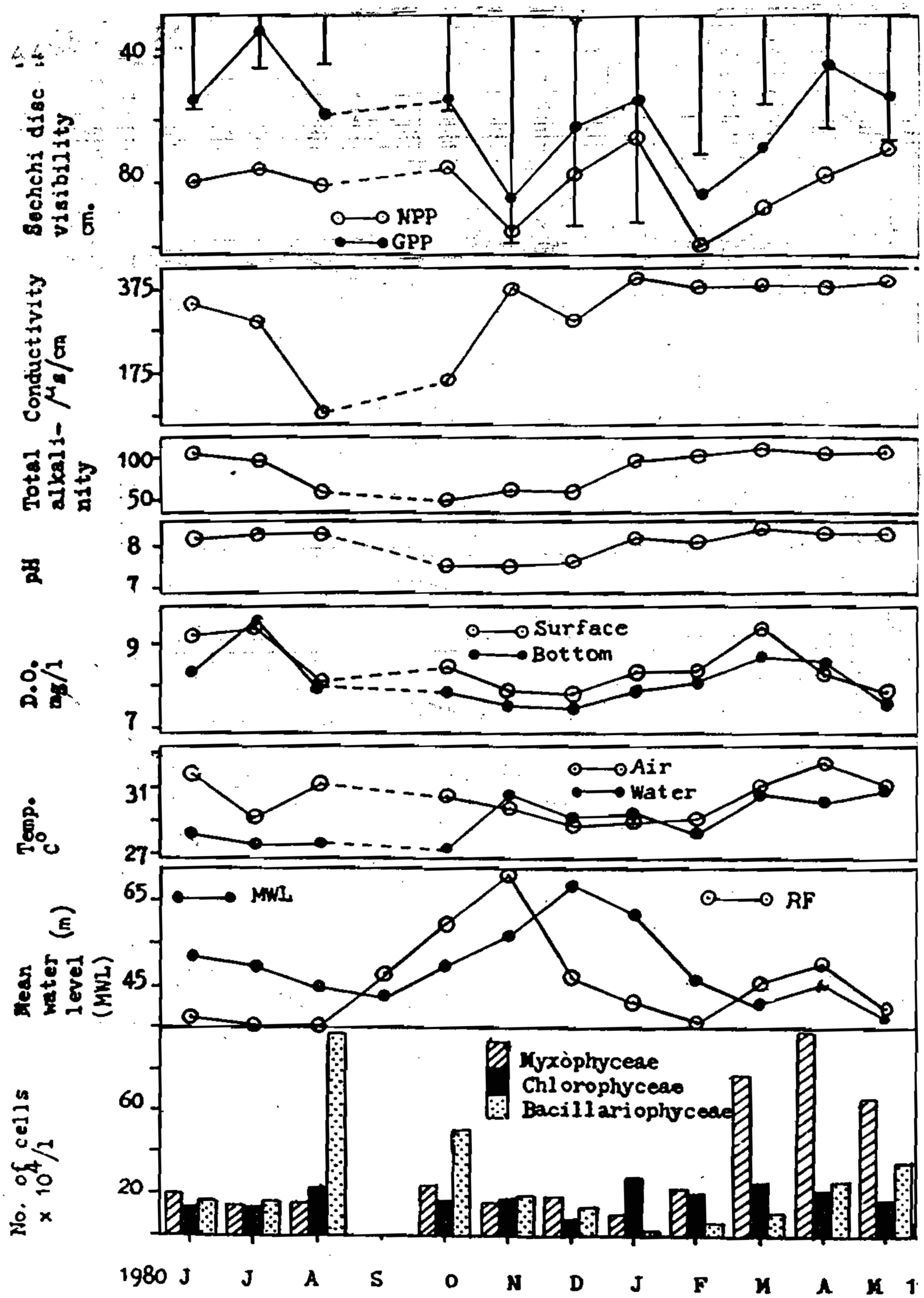

Fig. 2 Seasonal variations of hydrobiological conditions in Kala Wewa

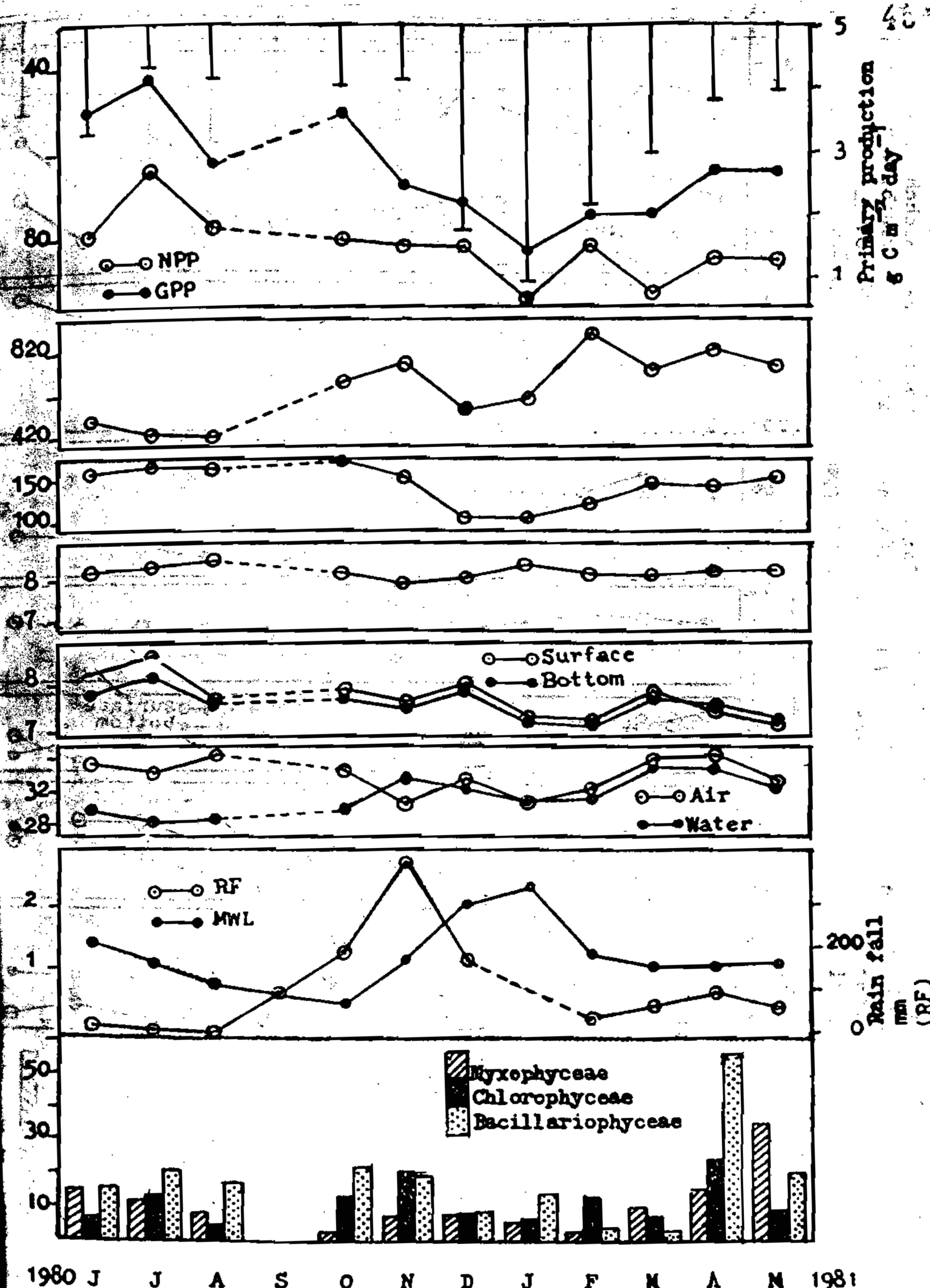

Fig. 3 Seasonal variations of hydrobiological conditions in Mahakanadarawa Wewa.

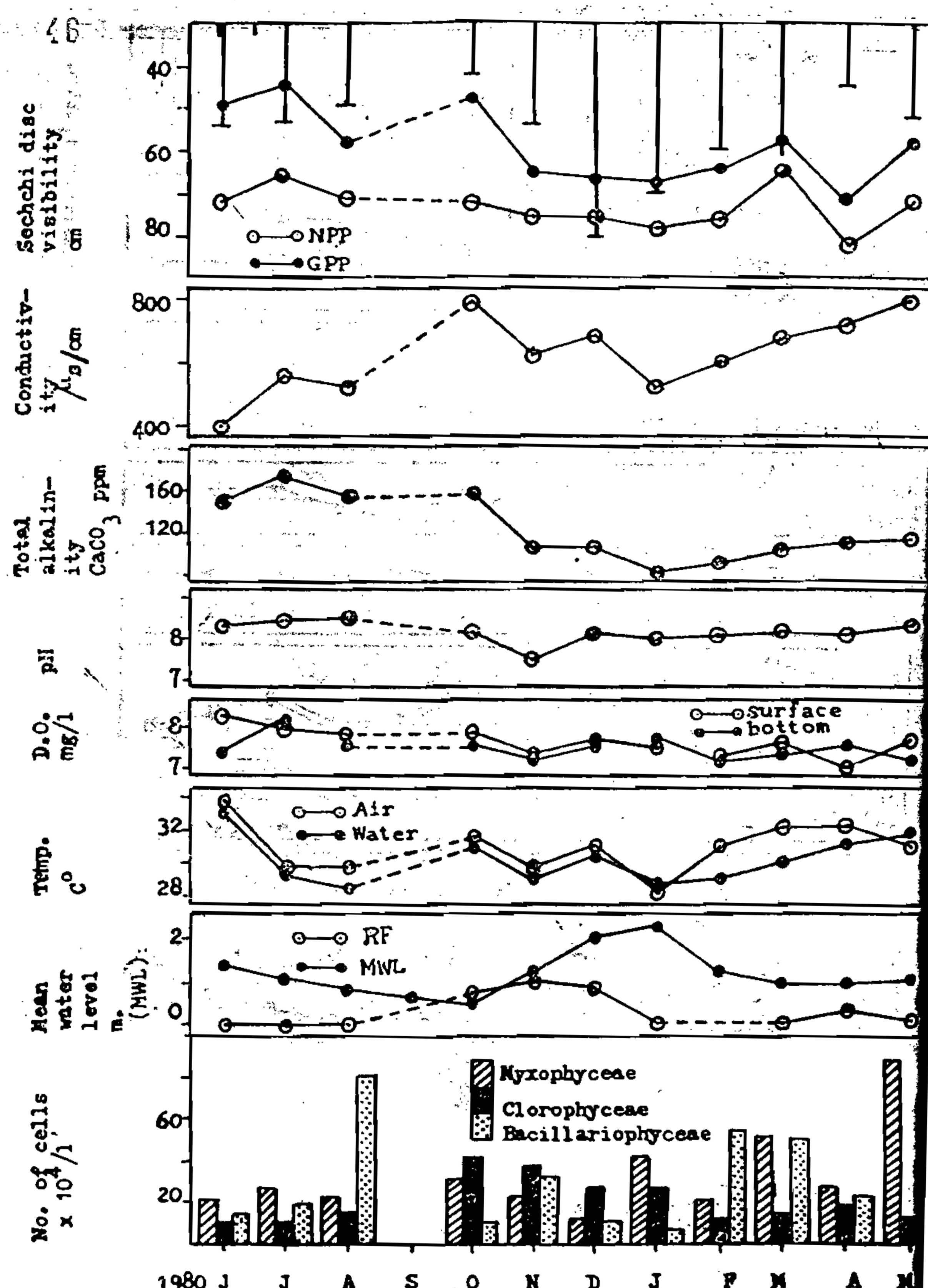

Fig. 4 Seasonal variations of hydrobiological conditions in Malawilachchiya Wewa.

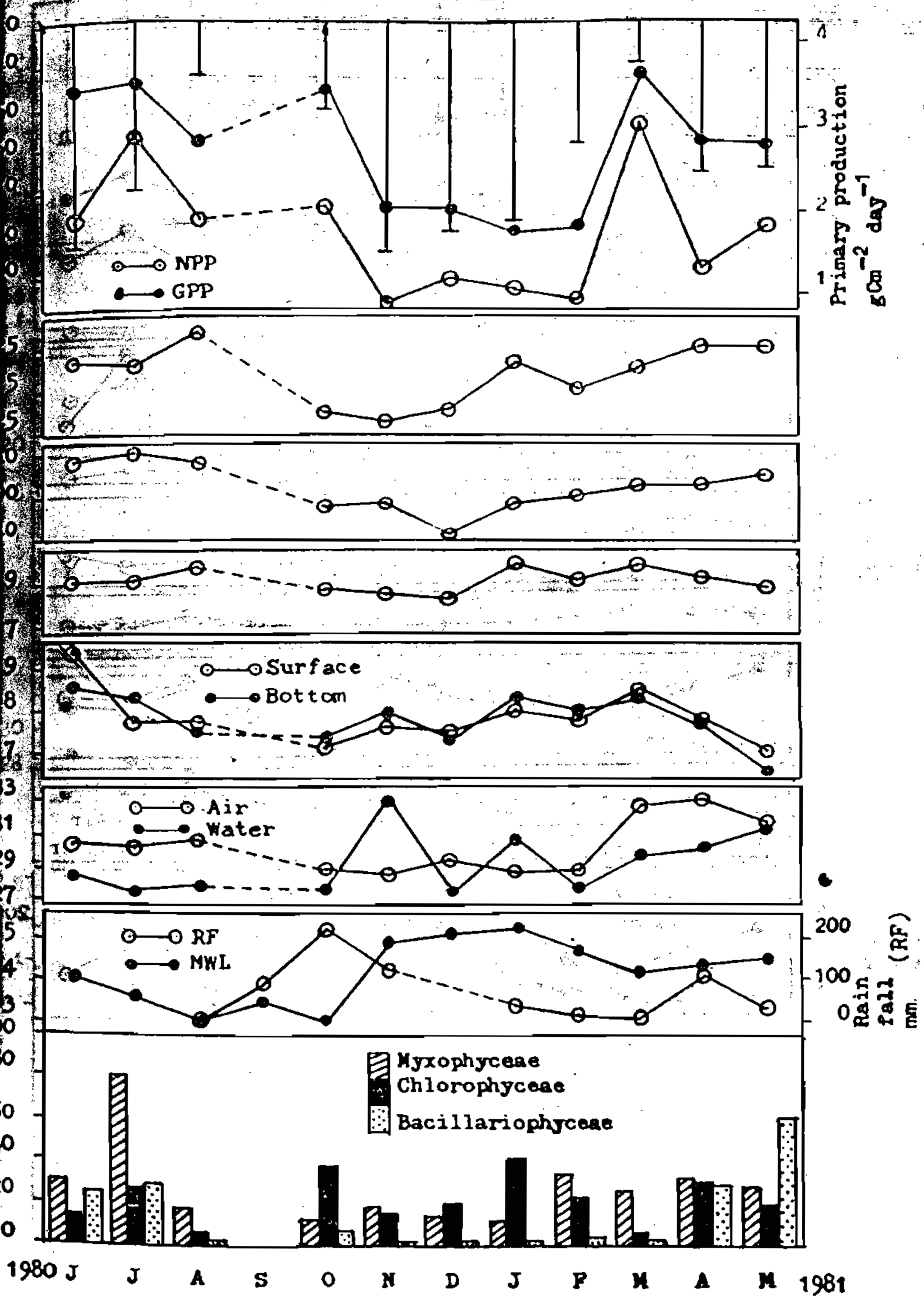

Fig. 5 Seasonal variations of hydrobiological conditions in Nachchaduwa Wewa.

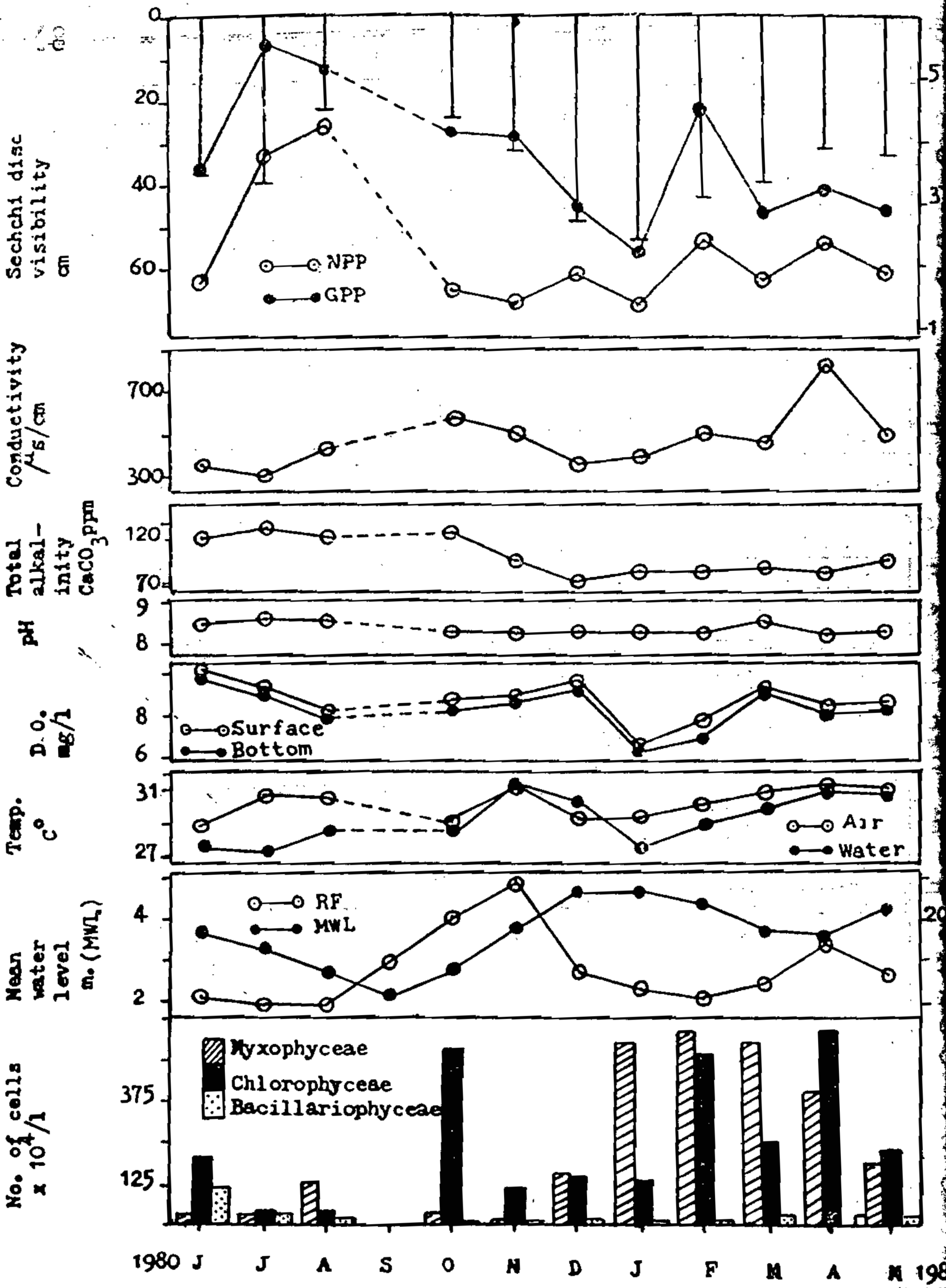

Fig. 6 Seasonal variations of hydrobiological conditions in Nuwara Wewa.

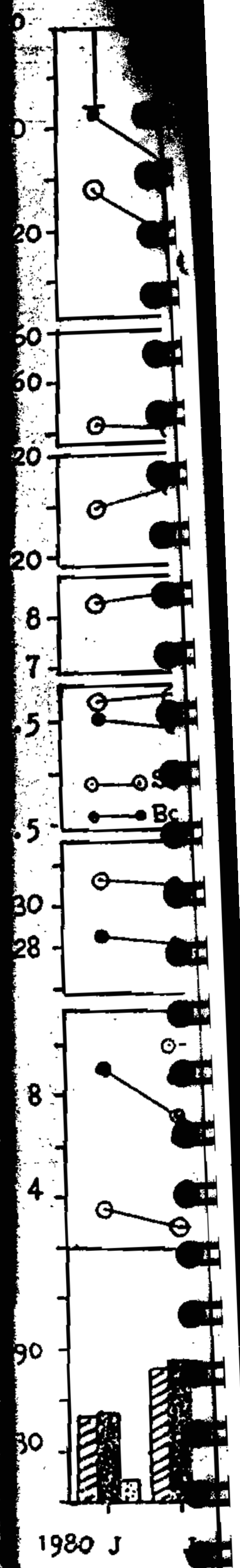

Fig. 7

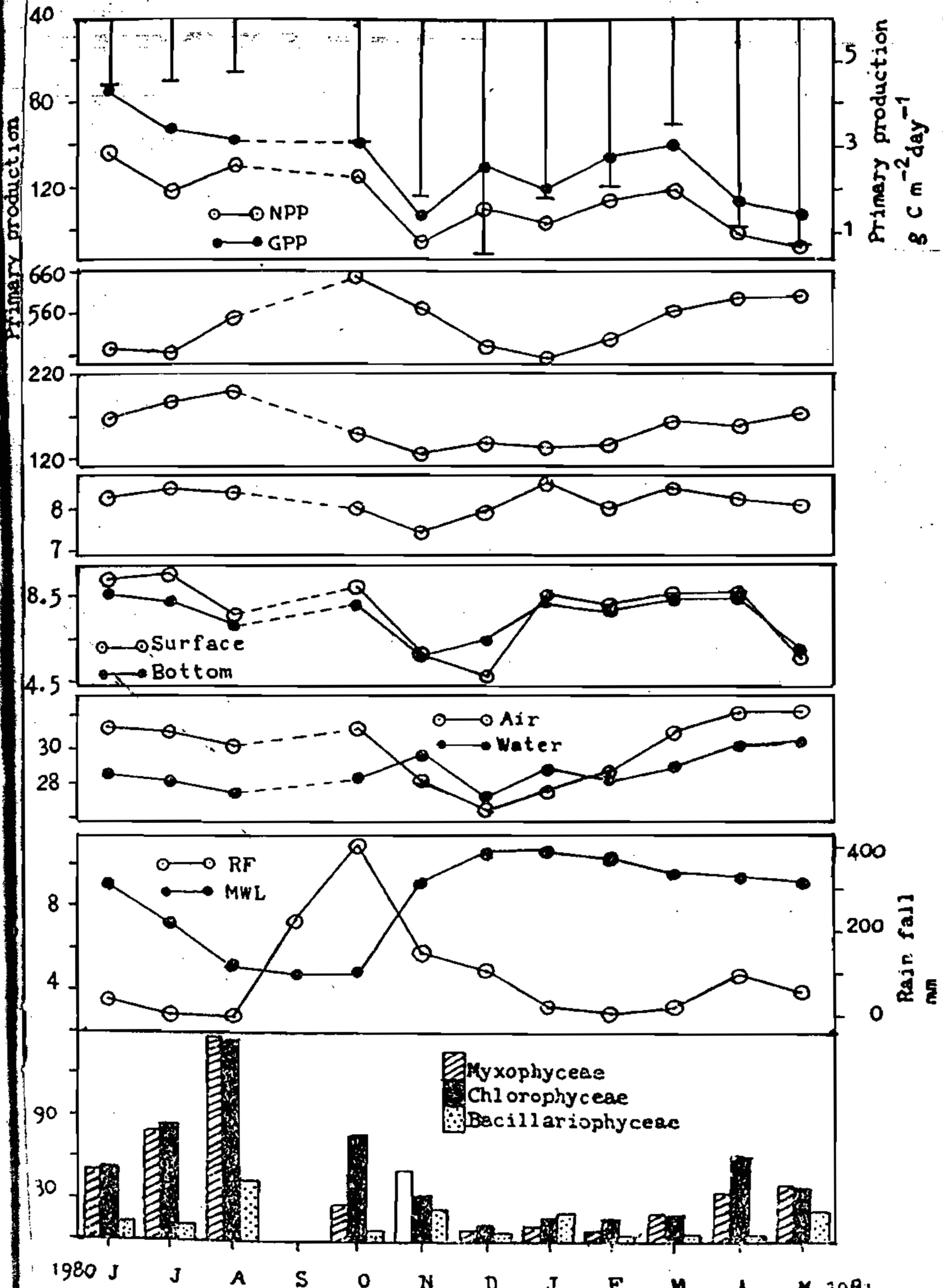

Fig. 7 Seasonal variations of hydrobiological conditions in Rajanganaya Wewa.