Pertanika 7(3), 101–113 (1984)

Phytoplankton Composition and Productivity of a Shallow Tropical Lake

M.Y. FATIMAH, A.K. MOHAMMAD MOHSIN and A.S. MUSTAFA KAMAL
Faculty of Fisheries and Marine Science,
Universiti Pertanian Malaysia,
Serdang, Selangor, Malaysia.

Key words: Swamp lake; tropical; phytoplankton; composition; productivity.

RINGKASAN

Komposisi dan pengeluaran fitoplankton di paya Bungor, Pahang, masing-masing telah dikaji dari Oktober 1981 hingga September 1982 dan dari Januari hingga Disember 1982. Pelbagaian fitoplankton adalah dalam susunan (klorofita Basilariofiseae Sinofita Krisofiseae; tetapi susunan mengikut kelimpahan ialah Sinofita Krisofiseae Klorofita Basilariofiseae. Sistem air coklat di Paya Bungor mengandungi pengeluaran fitoplankton yang lebih tinggi daripada sistem air putih. Pengeluaran maksimum amnya berlaku di lapisan permukaan, tetapi semasa hari panas, pengeluaran maksimum berlaku di subpermukaan kerana perencatan-foto di lapisan permukaan. Amnya, nutrien dan tenaga cahaya adalah dua faktor yang penting di dalam pengawalan daya pengeluaran fitoplankton di Paya Bungor.

SUMMARY

Phytoplankton composition and production in Paya Bungor, Pahang, were studied from October 1981 to September 1982 and from January to December 1982 respectively. Phytoplankton diversity is in the order of Chlorophyta > Bacillariophyceae > Cyanophyta > Chrysophyceae > Euglenophyta > Phyrrhophyta; but the order in terms or abundance is Cyanophyta > Chrysophyceae > Chlorophyceae > Bacillariophyceae. The brown water system of Paya Bungor seems to contain a higher phytoplankton production than the white water system. Maximum production generally occurs at the top layer of the water, but shifts to the subsurface layers on hot days due to photo-inhibition at the surface. Generally, nutrient and light energy are the two most important factors controlling phytoplankton production in Paya Bungor.

INTRODUCTION

Phytoplankton constitute the base of the ecological pyramid providing food energy for the higher trophic levels of the aquatic ecosystems. In view of this relationship, attempts have been made to correlate primary productivity and fish yields (e.g. Sreenivasan 1964, 1968; Melack, 1979). In addition, phytoplankton is also important as an index of the trophic status of a water body. Thunmark and Nygaard (in Wetzel, 1975) have developed a number of phytoplankton indices to quantify algal species as indicators of aquatic enrichment. Relationship between algal associations and lake fertility is also discussed in detail by Hutchinson (1967).

In view of the importance of phytoplanktonic communities, a study has been undertaken on a swamp lake, Paya Bungor to elucidate the successional periodicity of phytoplankton productivity and composition. According to Wetzel (1975), seasonal variations of phytoplankton are insignificant in unperturbed systems. However, with increasing development in Malaysia involving aquatic systems, it is likely that most water bodies will experience additional nutrients and thus eutrophication, which will bring about changes in phytoplanktonic productivity and composition.

Study Area

The study area is located in Paya Bungor Lake, Pahang (3° 47′ N; 102° 55′ E) which covers an area of approximately 2.84 km sq. A brief description of the lake has been given by Fatimah *et al.* (1982). Physical and chemical characteristics of the lake water are described by Fatimah *et al.* (1983). Based on the physical and chemical characteristics, the lake can be divided into having a brown water system in the south and a white water system in the north. Five stations were chosen (Stations I, II, III in the white water system and Stations IV and V in the brown water system) for the determination of phytoplankton abundance and composition. For primary productivity study, Station II which is located in the deepest part (3.0 m) of the white water system and Station V (in the deepest part of the brown water system) were selected *(Fig. 1).*

MATERIALS AND METHODS

Phytoplankton samples were collected twice a month at the surface and mid depth using a water sampler at Stations I, II, III, IV and V from October 1981 to September 1982, and were preserved in Lugol's solution. Identification and enumeration were carried out using an inverted microscope. The data from stations I, II and III were averaged to represent the white water system and from Stations IV and V to represent the brown water systems.

The primary productivity study was carried out from January to December 1982. Stations II and IV in the open-water zone were chosen to represent the white and brown water systems respectively. Productivity measurements were obtained at monthly inververvals using the light and dark bottles technique (Vollenweider, 1974). The paired light and dark bottles were filled with lake water collected from the surface, 1.5 m and 3.0 m depths, and exposed for 4 hours at the

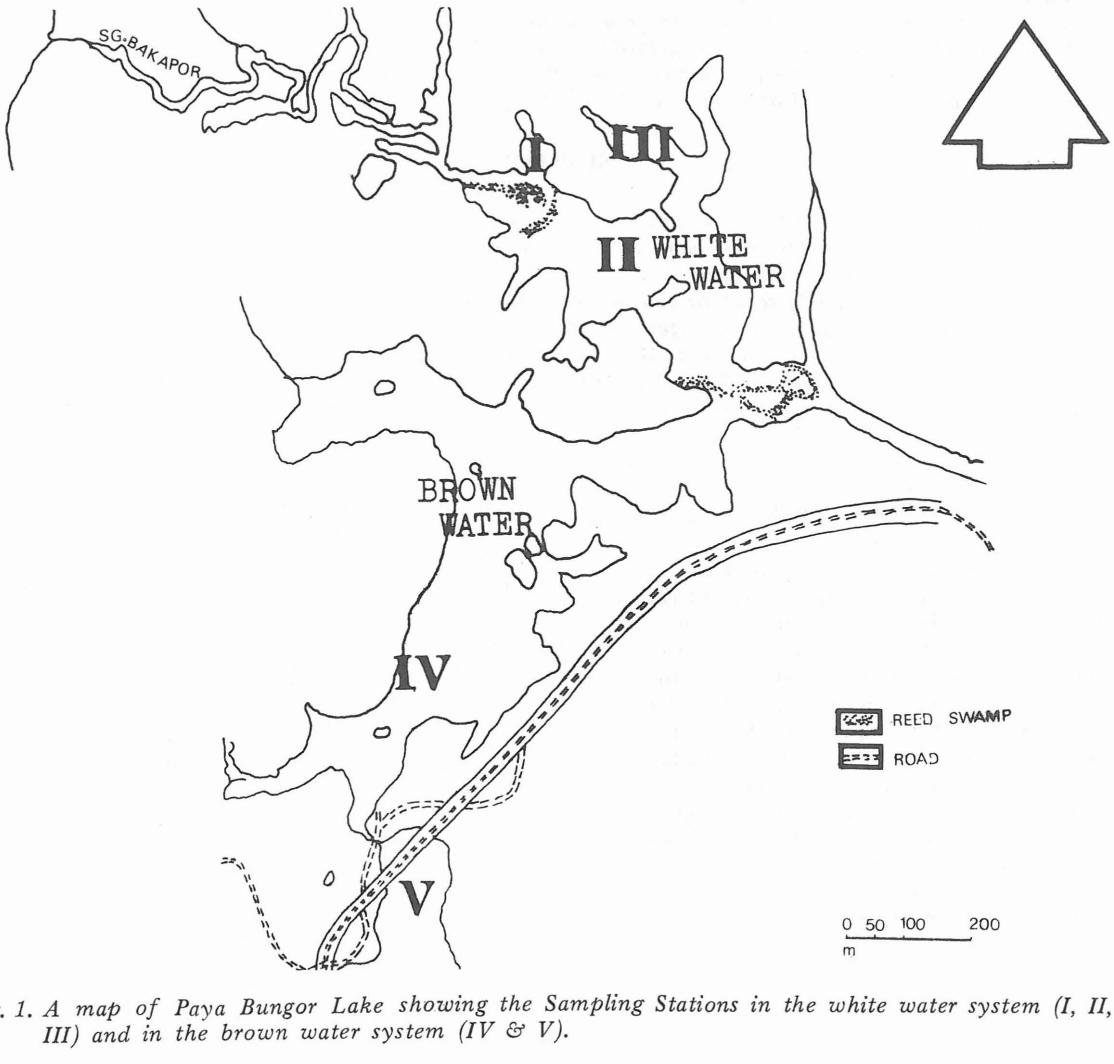

Fig. 1. A map of Paya Bungor Lake showing the Sampling Stations in the white water system (I, II, III) and in the brown water system (IV & V).

same depths from where the samples were obtained. The experiment was carried out twice a day, from morning to noon (0900 – 1300 hours) and from afternoon to early evening (1300 – 1700 hours) to obtain mean daily productivity. Dissolved oxygen concentrations were determined by Winkler's method (American Public Health Association, 1976). Photosynthetic values in O_2/l/day were multiplied by 0.375 to give values in mg C/l/day (Sreenivasan, 1964).

Water transparency was measured using a Secchi disk.

RESULTS

Phytoplankton communities of Paya Bungor Lake consist of 7 genera of Cyanophyta (blue green algae), 22 genera of Chlorophyta (green algae), 8 genera of Bacillariophyceae (diatoms) and 2 genera of Chrysophyceae, 3 genera of Euglenophyta and 1 genus of Pyrrhophyta (Table 1). Euglenophyta and Pyrrhophyta are found to be very few in number and were not considered in the calculation. Chlorophyta was the most diverse, but in terms of density, Cyanophyta was the most abundant (Table 2). Table 2 also shows that the brown water system supported a higher density of phytoplankton population than the white water system. The mean phytoplankton density of the brown water system was 19.7 cells/ml with a minimum of 0.1 cell/ml and a maximum of 397.9 cells/ml, whereas in the white water system, the mean density was 5.6 cells/ml with a minimum of 0.1 cell/ml and a maximum of 128.3 cells/ml (Table 2).

The seasonal fluctuations ofthe Cyanophyta in the white water system is shown in Fig. 2. The blue green algae population was low from October to June but increased soon after that until it reached a peak of 128.3 cells/ml in August. In the brown water system, the blue green population was low from October to May. The population then began to exhibit a high density from June to August with a peak of 397.9 cells/ml in June (Fig. 3). In both parts of the Lake, *Anabaena* was by far the most abundant species and was mainly responsible for the peak of the total blue greens.

In the white water system, the population of green algae was low with density generally less than 20 cells/ml (Fig. 2). The population fluctuated with no specific trend. In the brown water system, Chlorophyta exhibited two peaks with densities of 8.5 cells/ml in April and 10.1 cells/ml in July.

Dinobryon was the only member of the Chrysophycene in Paya Bungor. Its periodicity in the white water system shown in Fig. 2 indicated that its appearance in the lake was sporadic and fluctuated with a density less than 2.2 cells/ml from October 1981 to June 1982. The population then increased from June to August when it attained a peak of 8.0 cells/ml. In the brown water system, however, *Dinobryon* exhibited a different pattern of fluctuations (Fig. 3). The population was generally low from October to January but increased and attained a peak in February with a density of 23.9 cells/ml; it experienced a sharp drop in March and April. The population increased again in May and reached a second peak in July with a density of 15.1 cells/ml.

The graph of diatoms in the white water system in Fig. 2 shows that the highest population density was about 4.0 cells/ml in October. This was followed by a gradual decline in January after which the diatoms maintained a low population of less than 0.5 cell/ml. Similar to the diatoms of the white water system, the diatoms in the brown water system were consistently low in numbers with a population density of less than 3 cells/ml (Fig. 3).

The gross phytoplankton production values ranged from 0.083 mg C/l/day to 0.76 mg C/l/day with a mean of 0.334 mg C/l/day in the white water system; and from 0.179 mg C/l/day to 1.310 mg C/l/day with a mean of 0.479 mg C/l/day in the brown water system. The mean, minimum and maximum values of net primary productivity of the white water system was 0.204 mg C/l/day, 0.043 mg C/l/day and 0.587 mg C/l/day respectively. In the brown water system, the mean net primary production value was 0.294 mg C/l/day with a minimum of 0.152 mg C/l/day and maximum of 0.713 mg C/l/day (Table 3).

Figures 4 and 5 represent seasonal fluctuations of primary production of the white and brown water systems respectively. The white water system registered two peaks with the highest in July and a lower one in March. The brown water system exhibited the highest peak in February with a maximum value of 1.310 mg C/l/day. Net primary productivity showed similar patterns of fluctuation as the gross primary productivity. In both systems, the Secchi disk transparency was deepest when the production was highest (Figs., 4 and 5).

TABLE 1
List of Phytoplankton in Paya Bungor
during 1981-82.

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA
Chrococcales	Chlorococcales	Bacillariophyceae	Euglenophyceae
Chroococcaceae	Coelastraceae	Centrales	*Euglena* spp.
Merismopodia spp	*Coelastrum* sp.	*Melosira* sp.	*Phacus* sp.
Microcystis sp.	Hydrodictyaceae	Pennales	
Oscillatoriales	*Pediastrum* sp.	*Diatoma* sp.	
Oscillatoriaceae	Oocystaceae	*Tabellaria* sp.	
Lyngbya sp.	*Ankistrodesmus* spp.	*Asterionella* sp.	
Oscillatoria spp.	*Closteriopsis* sp.	*Fragilaria* sp.	
Spirulina sp.	*Selenastrum* sp.	*Eunotia* spp.	
Nostochaceae	Scenedesmaceae	*Navicula* spp.	
Anabaena sp.	*Actinastrum* sp.	*Nitzschia* sp.	
Aphanizonmenon sp.	*Crucigenia* sp.	Chyrophyceae	
	Scenedesmus sp.	Dinobryonaceae	
	Ulotrichales	*Dinobryon* spp.	
	Ulotrichasceae	*Mallomonas* sp.	
	Ulothrix sp.		
	Volvocales		
	Chlamydomonaceae		
	Chlamydomonas sp.		
	Volvocaceae		
	Volvox sp.		
	Zygnematales		
	Desmidiaceae		
	Closterium spp.		
	Cosmarium spp.		
	Desmidium spp.		
	Euastrum spp.		
	Spondylosium spp.		
	Staurastrum spp.		
	Triploceras spp.		
	Mesotaeniaceae		
	Micrasterias spp.		
	Pleurotaenium spp.		
	Zygnemataceae		
	Mougeotia soo.		
	Zygnema spp.		

TABLE 2
The mean, minimum and maximum population densities of various phytoplankton in white water and brown water systems of Paya Bungor Lake (1981 – 1982).

Location	Taxa	Density (No of cells/ml) Mean	Minimum	Maximum
White water	Chlorophyta	0.9	0.2	2.2
	Bacillariophyceae	0.8	0.1	4.0
	Cyanophyta	18.8	0.1	128.3
	Chrysophyceae	1.7	0.1	8.0
Overall		5.6	0.1	128.3
Brown water	Chlorophyta	3.3	0.7	10.1
	Bacillariophyceae	0.9	0.2	3.0
	Cyanophyta	69.4	0.2	397.9
	Chrysophyceae	5.5	0.1	23.9
Overall		19.7	0.1	397 9

In the white water system, with the exception of April, the production – depth profiles conform to a curve having a maximum production at the surface from February to May and November to December. In June to October, however, maximum production occurred at sub-surface layers. Occasionally, when the Secchi disk transparency was deep, bottom layers of the lake showed high primary production, as was observed in July (Fig. 6).

In the brown water system, maximum production occurred at the surface from February to May and October to November. For the rest of the year, production was highest at mid-depths (Fig. 7).

DISCUSSION

Various groups of phytoplankton in Paya Bungor Lake can be ranked in decreasing species diversity : Chlorophyta > Bacillariophyceae > Cyanophyta > Euglenophyta > Chrysophyceae > Pyrrhophyta; and in decreasing numerical abundance : Cyanophyta > Chrysophyceae > Chlorophyta > Bacillariophyceae > Euglenophyta > Pyrrhophyta. High phytoplankton densities more or less coincide with the high values of primary productivity indicating some correlation between the two factors.

From the results, it seems that the brown water system supports a higher phytoplankton population and has higher phytoplankton productivity than the white water system. This could be due to the high concentration of suspended solids in the white water system.

Although both the white and brown water systems consist of the same species of phytoplankton, their patterns of fluctuation and abundance are different. Chlorophyta and Bacillariophyceae of the white water system are very small in densities and contribute little to the total fluctuation of phytoplankton population in this system. Cynophyta and Chrysophyceae however, exhibited a peak in July – August (Fig. 2). Similar to the blue green population of the white water system, the blue greens of the brown water system shows high densities during June – August period. Chlorophyta and Chrysophyceae, however, exhibit bimodal fluctuations with small peaks in April and July; February and July respectively (Fig. 3).

In Paya Bungor, the data shows that when the phytoplankton density is high, the nutrients such as phosphates and nitrates are low, indicating rapid utilization of these compounds by the algae growth (Figs. 8 and 9). However, it is observed that the nutrient concentrations are high just before and after the phytoplankton peaks. This is in agreement with the findings of Rzoska and

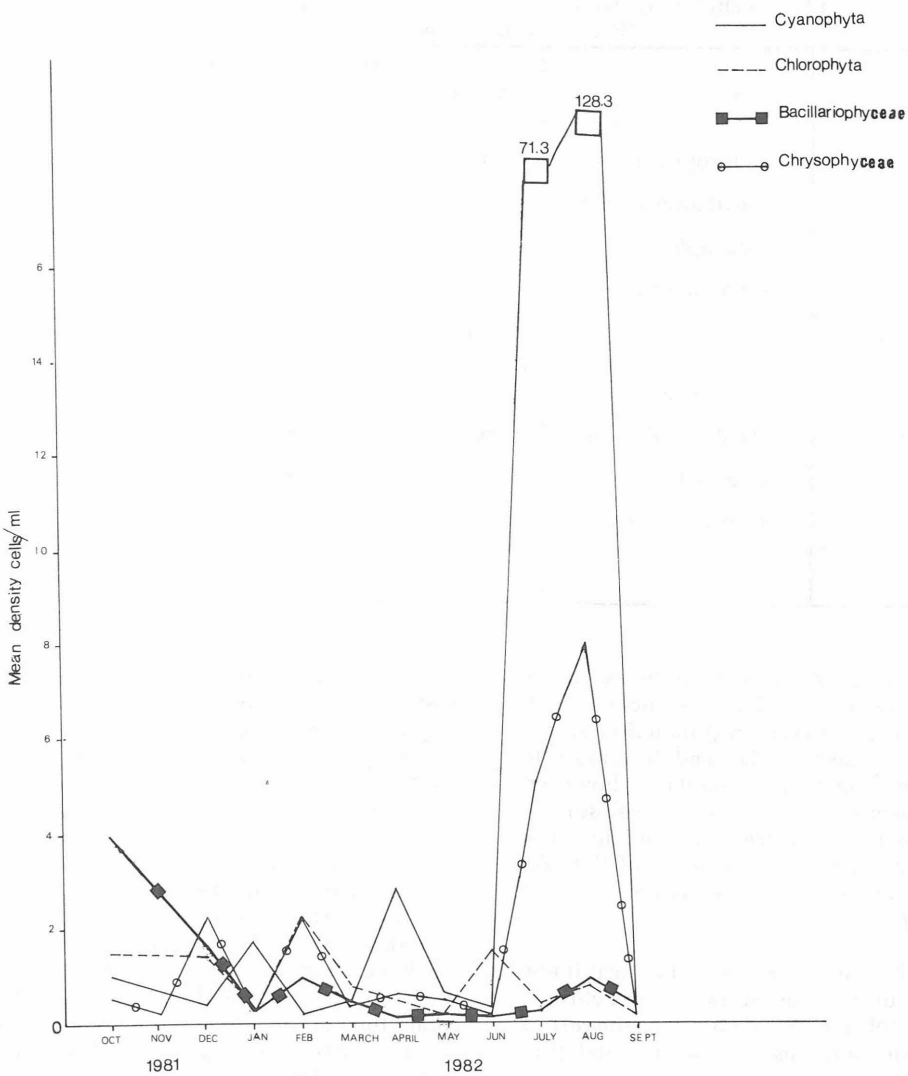

Fig. 2. The fluctuations of phytoplankton density (cells/ml) in the white water system of Paya Bungor from October 1981 to September 1982.

Talling (1966) that the nitrate content is very low during the maximum growth of diatoms. Prowse and Talling (1958) also reported occurrence of nitrate accumulation at the beginning and end of phytoplankton growth. In Plover Cove Reservoir, Hong Kong, Hodgkiss (1974) found a decrease in phospate as a result of the increased growth of blue green algae.

Generally, the phytoplankton population assumes higher densities during the dry season (January to September with scattered rainfall in April) and low densities in the wet season (October to December). The declining rate of primary production and population densities during the wet season could be attributed to the dilution of planktonic organisms following the increase in the volume of water. Some of the plankton could also be flushed off from the lake into the effluent river during high water levels The seasonal decline in solar radiation and hence the intensity of light during the wet season is likely to be a major factor in depressing primary production at this time.

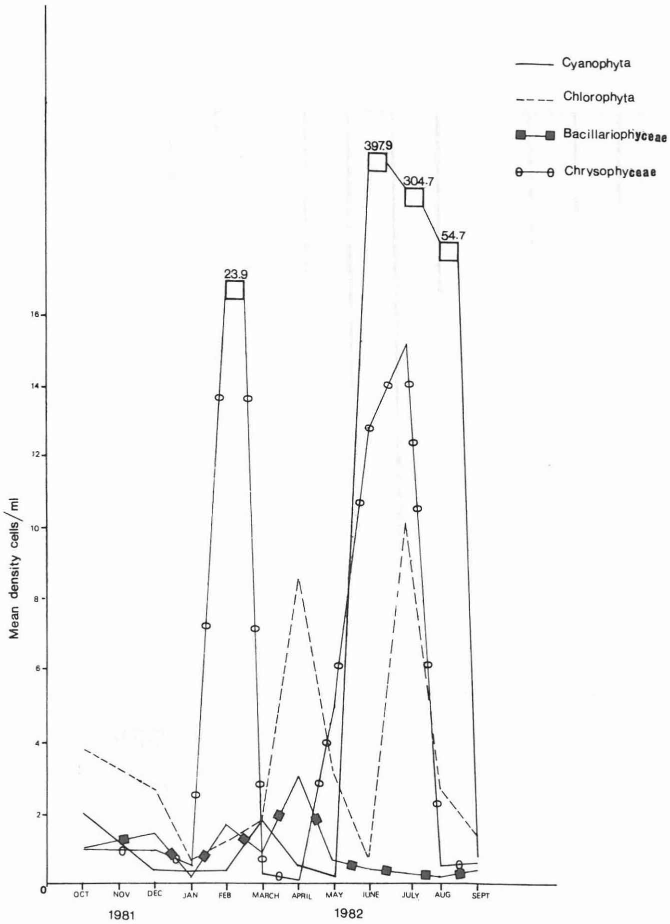

Fig. 3. The fluctuations of phytoplankton density (cells/ml) in the brown water system of Paya Bungor from October 1981 to September 1982.

TABLE 3
Mean gross primary productivity (GPP) and net primary productivity (NPP) in mg C/1/day at 2 stations in Paya Bungor, Pahang.

Station		Productivity (mg C/1/day) Mean	Minimum	Maximum
Station II (White Water	GPP	0.334	0.083 (December)	0.761 (July)
	NPP	0.204	0.43 (December)	0.587 (July)
Station IV (Brown water)	GPP	0.479	0.179 (November)	1.310 (February)
	NPP	0.294	0.152 (November)	0.713 (February)

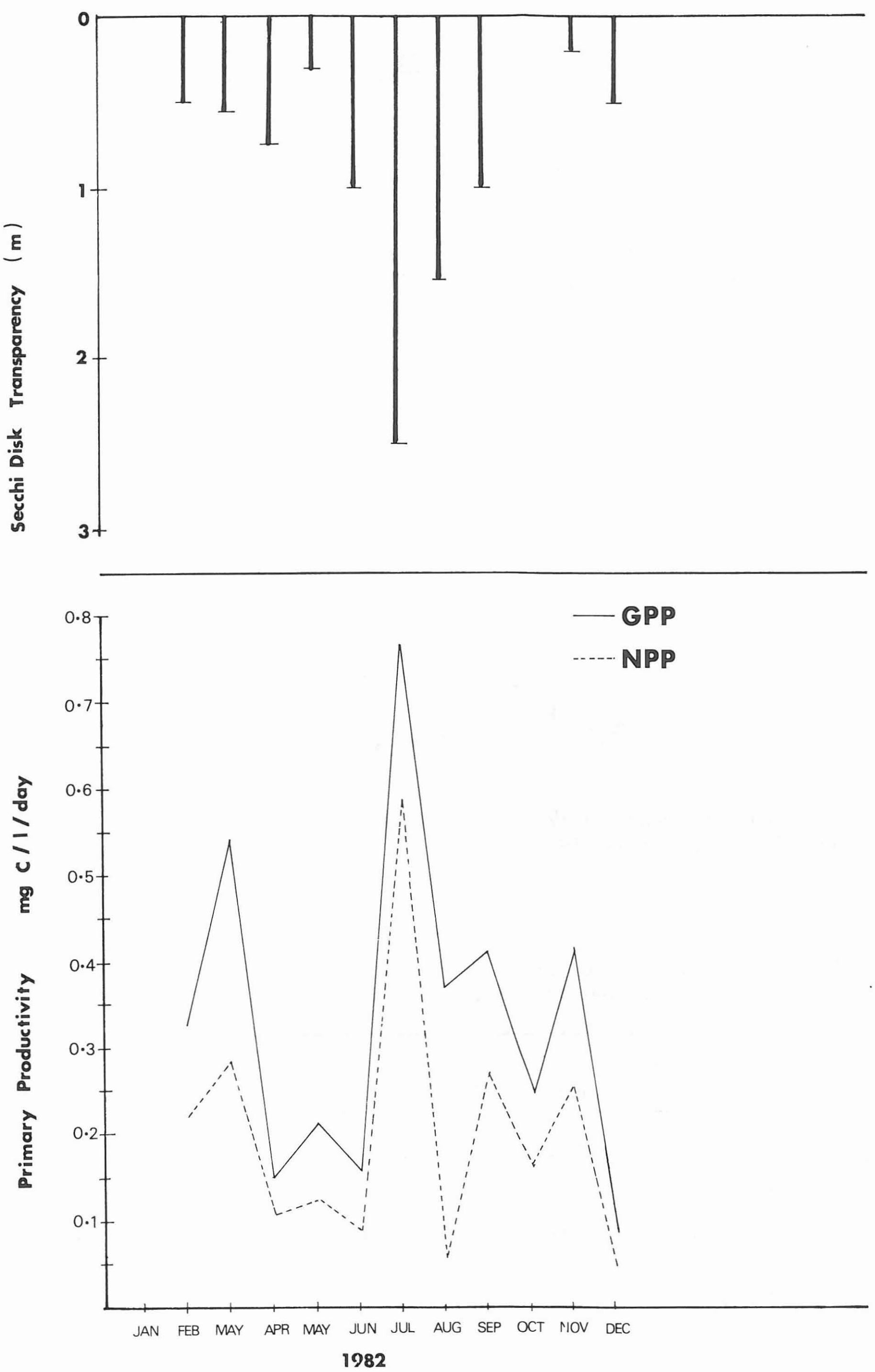

Fig. 4. The seasonal variations of gross primary productivity (GPP) and net primary productivity (NPP) in Secchi disk transparency in the white water system during 1982.

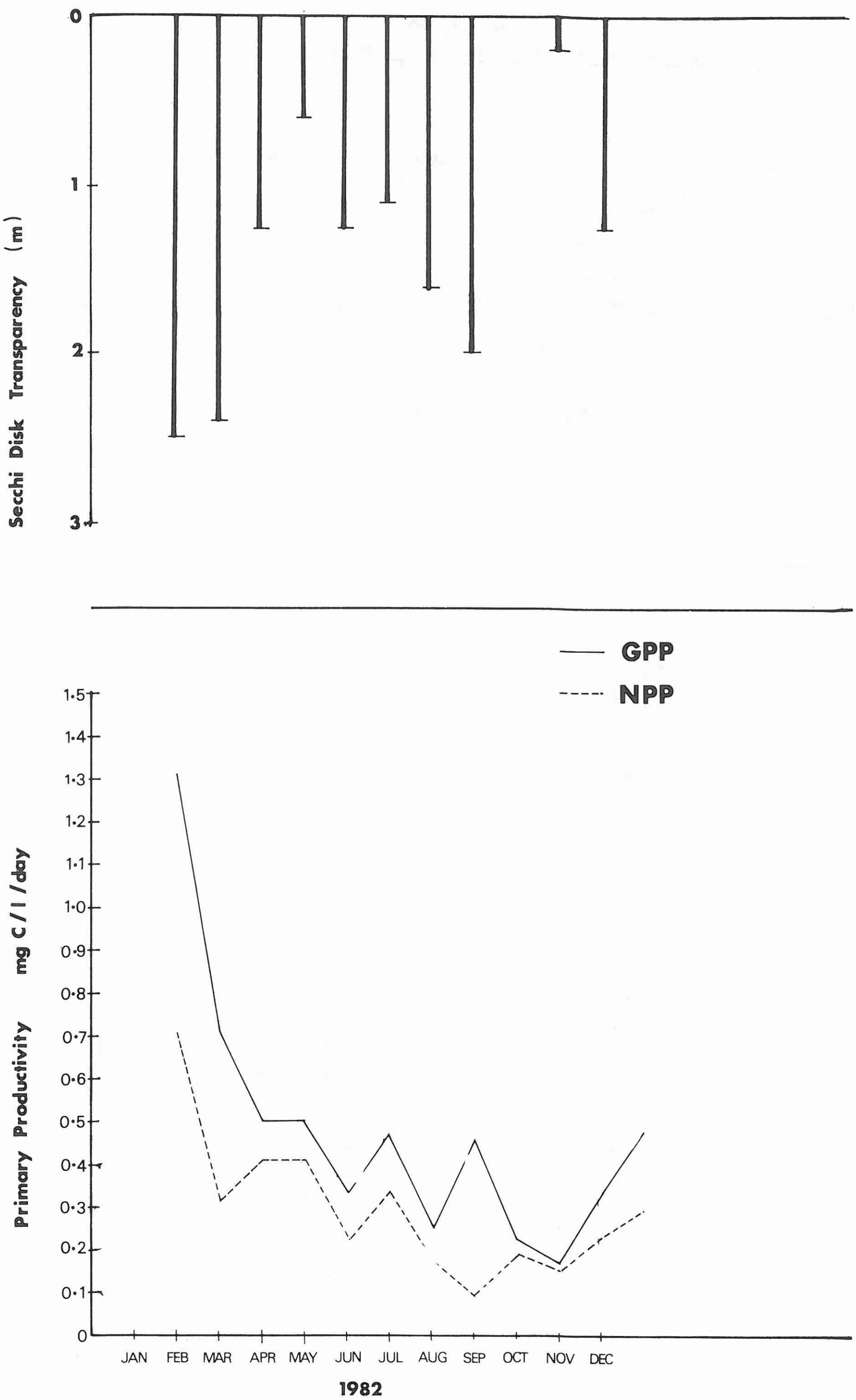

Fig. 5. The seasonal variations of gross primary productivity (GPP) and net primary productivity (NPP) in mg C/1/day with Secchi disk transparency in the brown water systems during 1983.

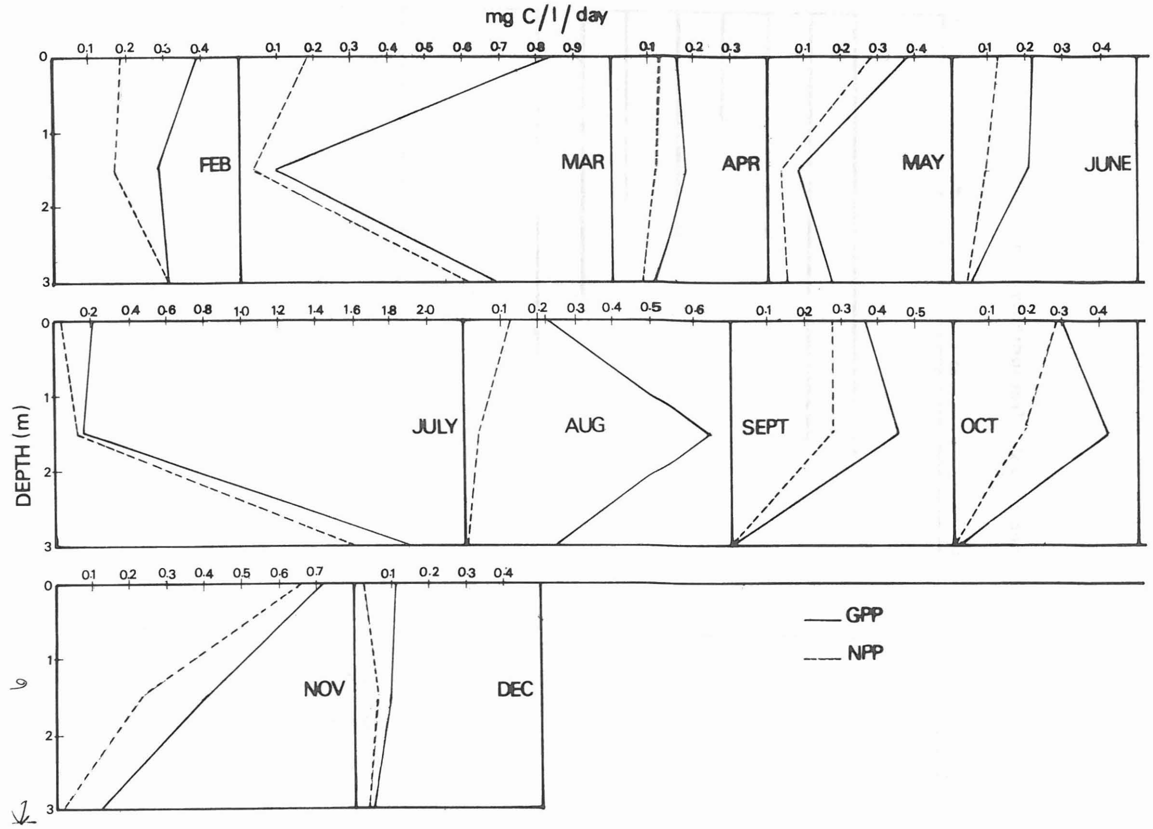

Fig. 6. The depth profiles of gross primary production (GPP) and net primary production (NPP) in mg/C/1/ day in the white water system, Paya Bungor, during 1982.

High turbidity values and hence low transparency values caused by the land run-off during the wet season reduces the amount of light intensity in the water. This is enhanced by the shallow nature of the lake and its susceptibility to wind actions. The decline of primary production in the wet season may be caused by the dilution of essential ions. This is probably because the run-off water has low nutrient content. Odum (1971) reported that the soils in the catchment area in the tropics, although rich in aluminium and iron, are, however poor in biologically essential elements such as phosphorus and nitrogen. The dilution of lake waters by run-off from ion deficient,uproductive catchment areas has been reported elsewhere in the tropics (Talling and Talling 1965, Imevbore 1967, Sreenivasan 1970).

The values for gross primary production in Paya Bungor are low compared to the values of eutrophic lakes in this region. Saravanamuthu and Lim (1982) reported mean values for gross primary production and net primary production in Taman Jaya lake to be 5.16 mg C/1/day and 2.88 mg C/1/day respectively. However, primary production values of Paya Bungor are higher than that found in other swamp lakes such as Tasik Bera. Okino and Lim (in Furtado and Mori, 1982) reported gross primary productivity of Tasik Bera to be from 0.07 – 0.25 mg C/1/day. Productivity depth profiles indicate that maximum production generally occurs at the top layer of the water. From June to October, however, maximum production occurs at the subsurface layers which may be due to the surface photoinhibition caused by high solar radiation on hot days. In July, when the transparency was deepest, maximum production occurred at the bottom layer (Fig. 6). In general, the depth at which maximum rate of plankton production occurs varies with the transparency of the water, which is in turn governed by the concentration of dissolved and particulate matter and abiotic turbidity (Wetzel, 1975).

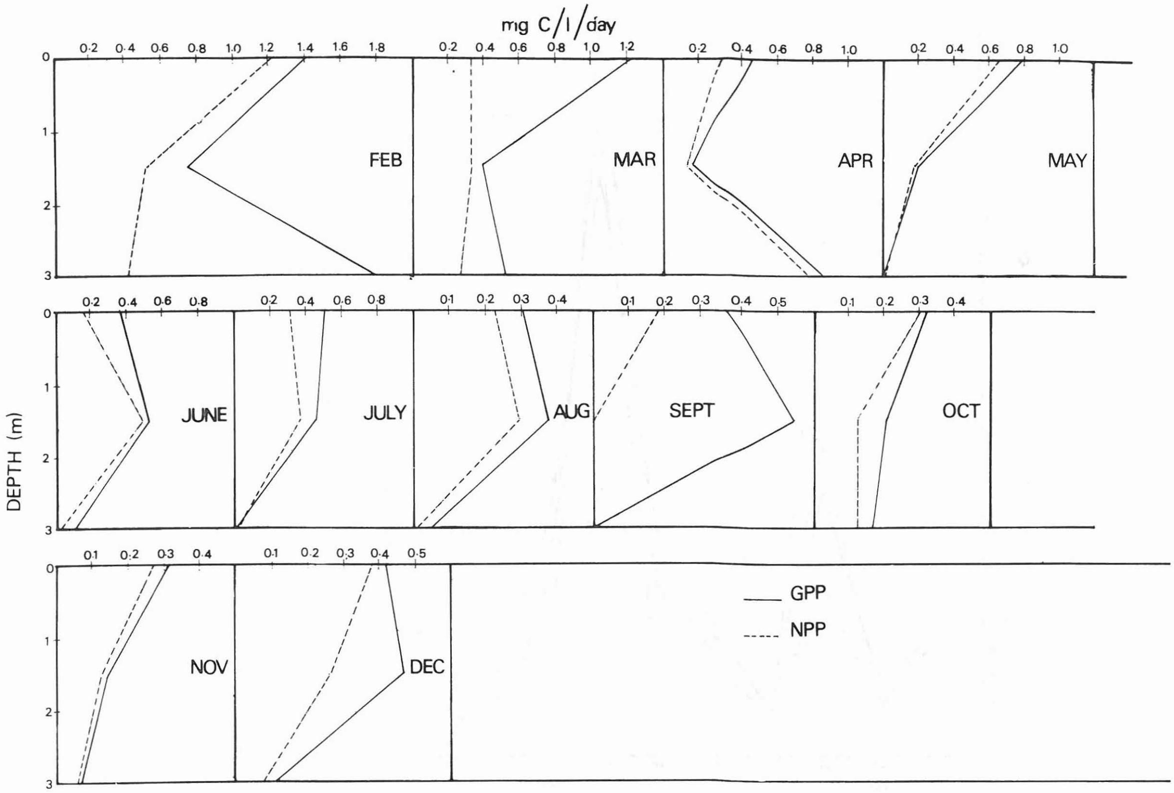

Fig. 7. The depth profiles of gross primary production (GPP) and net primary production (NPP) in mg C/1/ day in the brown water system, Paya Bungor during 1982.

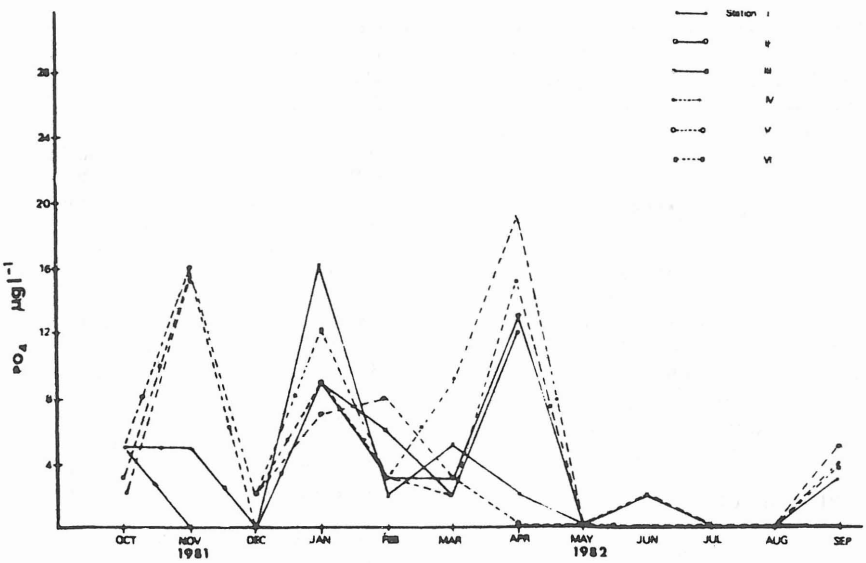

Fig. 8. Annual Variations of PO_4 ($\mu g l^{-1}$) at Different Stations in Paya Bungor, Pahang, During 1981 – 1982.

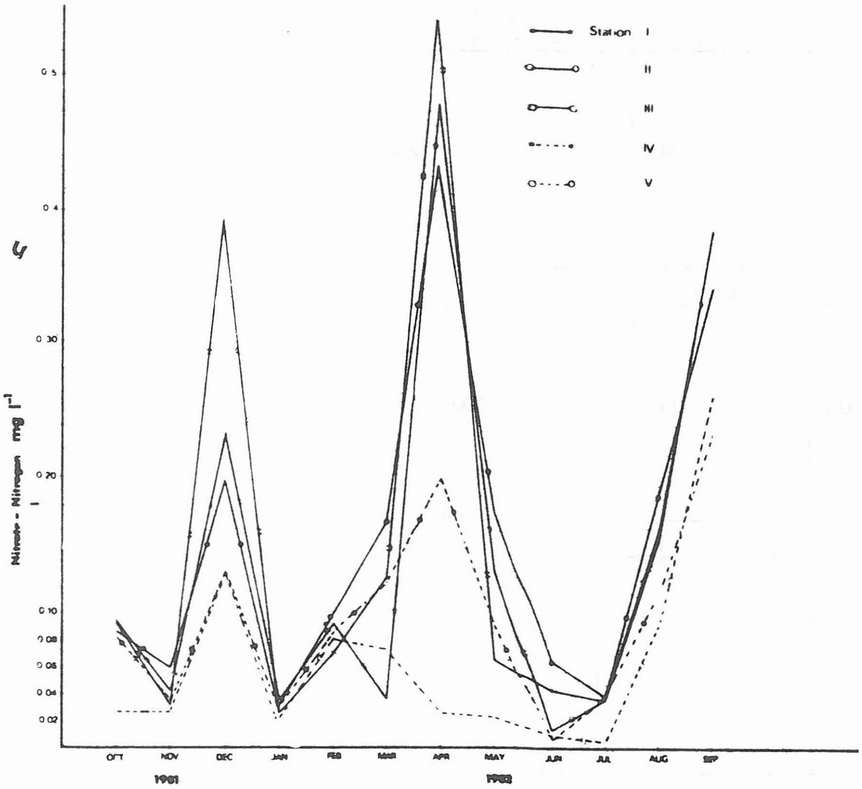

Fig. 9. Annual Variations of Nitrate-Nitrogen (mg l^{-1}) at Different Stations in Paya Bungor Pahang, During 1981 – 1982.

Therefore, the seasonal variations of phytoplankton growth and productivity in Paya Bungor is greatly influenced by the changes in the physicochemical properties of the water which themselves are determined mainly by the climatic changes of the region.

ACKNOWLEDGEMENTS

This research was supported by Universiti Pertanian Malaysia research grant 1713 – 1 – 316. The authors would like to extend their thanks to Perumal Kuppan, Jasni Md. Yusoff and Ramlan Meon for their technical assistance in the field and in the laboratory. Thanks are also due to Mohd. Azmi Ambak for reading the manuscript and Jamilah Abdol for typing it.

REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION (1976) : Standard Methods for the examination of Water, Sewage, and Wastewater. New York. APHA. 14th edition, 1193 pp.

FATIMAH, M.Y., AMBAK, M.A. and MOHSIN, A.K.M. (1982) : Diurnal fluctuations of some physicochemical parameters of a swamplake in Malaysia. *Malays. Appl. Biol.* **11(2)** : 72-83.

FATIMAH, M.Y.; KAMAL, M. and MOHSIN, A.K.M. : (1983) : Some aspects of limnological features of a swamp lake with observations on its suitability for fish culture. Research Project Report No. 1713-316 submitted to the Faculty of Fisheries and Marine Science, 1-112 pp.

FURTADO, J.I. and MORI,S. (eds.) 1982) : Tasik Bera, the ecology of a freshwater swamp. The Haque – Boston – London. Dr. W. Junk Publishers. 413 pp.

HODGKISS, I.J. (1974) : Studies on Plover Cove Reservoir, Hong Kong: Composition and distribution of phytoplankton and its relationship to environment tal factors. *Freshwat. Biol.* **4** : 111-126.

HUTCHINSON, G.E., (1967) : A Treatise on Limnology II. Introduction to Lake Biology and Limnoplankton. New York, John Wiley & Sons, Inc., 1115 pp.

IMEVBORE, A.M.A. (1967) : Hydrology and plankton of Eleiyele Reservoir, Ibadan, Nigeria. *Hydrobiologia,* **30** : 154-176.

MELACK, I.M. (1979) : Photosynthetic rates in four tropical fresh waters. *Freshwaters Biology.* **9** : 555-571.

ODUM, E.P. (1971) : *Fundamentals of Ecology* W.B. Saunders Co., Philadelphia. 574 pp.

PROWSE, G.A. & TALLING, F.J., (1958) : The seasonal growth and succession of plankton algae in the white Nile, *Limnol. Oceanogr.* **3** : 222-237.

RZOSKA, J.P. & TALLING, F.S. (1966) : The development of plankton in relation to hydrological regime in the Blue Nile. *J. Anim. Ecol* **55** : 637-662.

SARAVANAMUTHU, J., and R. P. LIM (1982) : A preliminary Limnological survey of an eutrophic pond, Taman Jaya Pond, Petaling Jaya. *Malay. Nat. J.* **35** : 83-97.

SREENIVASAN, A. (1964) ; The limnology, primary production, and fish production on a tropical pond. *Limnol. Oceanogr.,* **9(4)** : 391-396.

SREENIVASAN, A. (1968) : The Limnology and Fish production in Two ponds in Chinglepat (Madras). *Hydrobiologia,* **32** : 131-144.

SREENIVASAN, A. (1970) : Limnology of tropical impoundments : A comparative study of the major reservoirs in Madras State (INDIA) *Hydrobiologia,* **36** : 443-469.

TALLING, J.F. and TALLING, J.B. (1965) : The chemical composition of African lake waters. *Int. Revue. ges. Hydrobiol.* **50** : 1-32.

VOLLENWEIDER, R.A. (1974) : A manual on methods for measing primary production in Aquatic Environment, IBP Handbook no. 12. 2nd edition. London. Blackwell Scientific Publ. 225 pp.

WETZEL, R.G. (1975) : *Limnology.* Philadelphia. W.B. Saunders, Co. 743 pp.

(Received 13 June, 1984)