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# Light Availability for Phytoplankton Production in Turbid Tropical Fish Ponds

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## ABSTRAK

*Produktiviti primer bagi air hijau telah ditentukan di lapisan yang berbeza dalam kolam ikan yang keruh semasa musim hujan (bulan Mei, November dan Disember 1986), dengan menggunakan teknik botol terang-gelap. Zon 1% cahaya didapati kurang daripada 0.75 m dalam, apabila nilai pekali pemupusan cahaya melebihi 5. Produktiviti pada tiap-tiap kedalaman berbeza -beza secara bererti iaitu pada jarak kedalaman 0.25 m apabila nilai pekali pemupusan berjulat daripada 5.09 ke 8.39, dan berbeza dengan bererti pada jarak 0.05 m kedalaman iaitu pekali pemupusan berjulat daripada 3.74 ke 4.47. Produktiviti tidak berbeza dengan bererti apabila nilai pekali pemupusan 1.67.*

## ABSTRACT

*Primary productivity of green water was determined at different depths using light-dark bottle technique in turbid fish ponds during raining season (May, November and December 1986). The 1% light zone was less than 0.75 m when attenuation coefficients were more than 5. Productivity at various depths was significantly different at intervals of 0.25 m when light attenuation coefficients ranged between 5.09 to 8.39, and at depth intervals of 0.50 m when attenuation coefficients ranged between 3.74 to 4.47. Productivity did not differ significantly when attenuation coefficient was 1.67.*

## INTRODUCTION

The productivity of pond water is a function of light energy, temperature, and supply of nutrients. In the wet tropics, water from well-weathered drainage basins usually contains very low nutrients necessary for phytoplanktonic carbon fixation. However, their shortage in fish ponds can be overcome by adding inorganic or organic fertilizers.

Like most countries in the tropics, Peninsular Malaysia experiences high rainfall ranging from 2000-3500 mm/yr. Improper land used practices coupled with heavy rainfall have contributed to highly turbid streams and rivers in Malaysia. From the air, rivers can be easily mistaken for winding laterite roads. This turbid silt-laden water forms the water source for most fish ponds in the country. It is not uncommon to observe fish ponds in Malaysia with turbidity ranging from 200 to over 2000 mg/L.

Adverse effects of high turbidity on fish population are well known (Ellis 1936, Cordone and Kelly 1961, Chutter 1969). Turbidity also decreases light penetration and thereby reduces the rate of photosynthesis. Thus, availability of light can exert a major control on the phytoplankton activity in turbid fish ponds. This experiment demonstrates the effects of light availability on the phytoplanktonic productivity in turbid fish ponds.

## MATERIALS AND METHODS

Green water was prepared in a 500 liter transparent fibre-glass tank by adding Conway's nutrient medium and vitamins (B1 and B12) at the rate of 1 ml and 0.1 ml per liter water respectively. The algae culture (90% *Chlorella* sp.) was then added at the rate of about 1 liter per 15 liters of water. After 7 days, the green water was used for the determination of productivity at different water depths in fish ponds. Light and dark bottles were filled with well mixed green water using a Van Dorn water sampler. The bottles were immediately stored in light proof wooden boxes. In the ponds, each pair of light and dark bottles were incubated at the centre of each pond at 10 cm, 25 cm, 50 cm and 75 cm depths for about two hours (between 1100 hrs to 1300 hrs). Three fish ponds located in the Agriculture University of Malaysia were used in this experiment.

Light availability for photosynthesis in the waveband 400-700 nm in the ponds was measured using a light meter. A LICOR model LI-888 integrating quantum meter was connected through a LICOR sensor-selector to a LICOR quantum sensor (LI-190 SB) and a spherical underwater quantum sensor (LI-193 SB). Under water light was measured at 10 cm, 25 cm, 50 cm and 75 cm depths at the centre of each pond. Data from the LICOR sensor in air and the LICOR sensor underwater were used to obtain percentages of total surface 400-700 nm photon flux density (PFD) which remained at each depth. The attenuation coefficient (b), which represents a composite for all wavelengths, was calculated following the equation of McNabb *et al.* (1988):

$$\ln y = a + bz$$

where y is the percentages of surface light at depth, z is depth, b is the attenuation coefficient and a is the y intercept.

Initial oxygen content of the green water was determined using the Winkler method (American Public Health Association 1985). After the incubation period of 2 hours, the oxygen content of light and dark bottles was determined. Phytoplanktonic productivity was calculated according to the following equations (Wetzel and Likens 1979, Cole 1983):

Gross productivity (mg C/m$^3$/hr

$$= \frac{(LB - DB \times 1000 \times 0.375}{PQ \times t}$$

Net productivity (mg C/m$^3$/hr

$$= \frac{LB - IB \times 1000 \times 0.375}{PQ \times t}$$

where LB is concentration of oxygen in light bottle (mg/L), DB is concentration of oxygen in dark bottle, IB is concentration of oxygen in initial bottle, PQ is photosynthetic quotient (assumed to be 1.2), t is hours of incubation, and 0.375 is molecular weight ratio of carbon to oxygen gas.

The experiment was repeated six times during the rainy period (May, November and December 1986, *Figure 1*). Statistical analysis using ANOVA with Duncan's Multiple Range Test was performed on the algal productivity data to determine significant differences between different depths at $P < 0.05$.

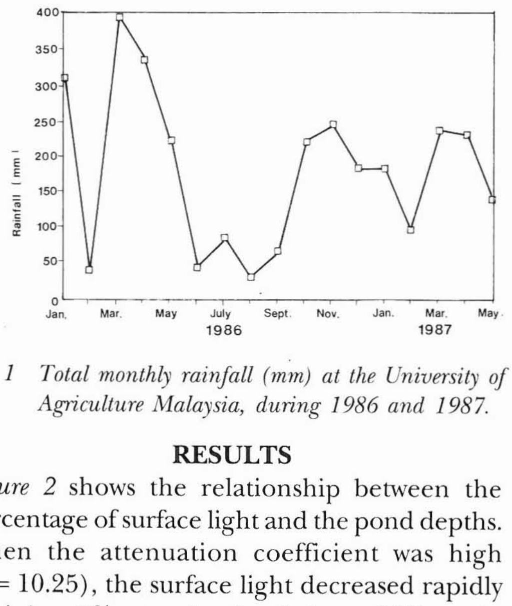


*Fig 1 Total monthly rainfall (mm) at the University of Agriculture Malaysia, during 1986 and 1987.*

## RESULTS

*Figure 2* shows the relationship between the percentage of surface light and the pond depths. When the attenuation coefficient was high (b = 10.25), the surface light decreased rapidly attaining 1% at a depth of about 0.35 m. As attenuation coefficient lessened, the 1% light zone extended deeper to 0.73 m and 1.90 m at b = 5.00 and b = 1.70 respectively.

Table 1 shows that when ponds were very turbid with mean attenuation coefficients ranging from 5.09 to 8.39, phytoplanktonic productivity at depth intervals of 0.25 m differed significantly. Gross productivity at 0.1 m was significantly higher than productivity at 0.25 m. At 0.25 m, it was higher than at 0.50 m, and at 0.5 m it was higher than at 0.75 m. When values of attenuation coefficients were between

3.74 to 4.47, productivity differed significantly at depth intervals of about 0.5 m (Table 1). When the extinction coefficient was 1.67, productivity did not differ throughout pond depth.

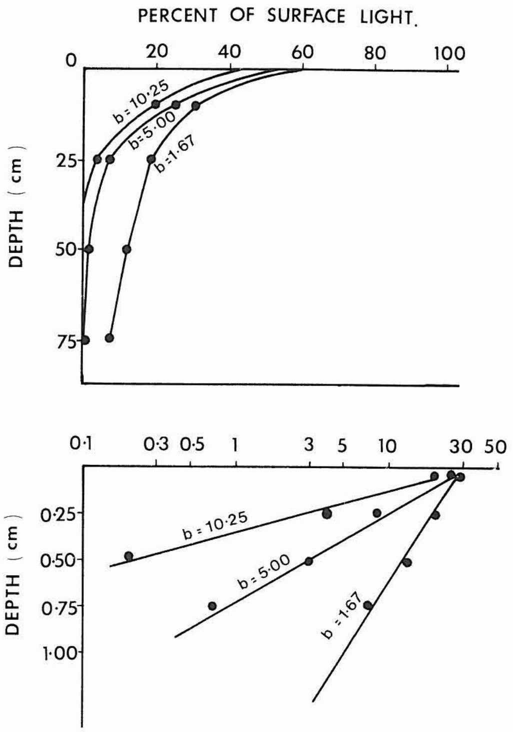


*Fig 2* *Percentage of incident light that would remain after passing through depths of water expressed on linear (upper) and a logarithmic (lower) scale.*

*Figure 3* shows the relationship between attenuation coefficients and the relative gross primary productivity (relative productivity value was proportion of the algal productivity at a specific depth compared to the productivity near the surface, i.e 10 cm depth). At high attenuation coefficient values, changes in light availability produced little change in relative productivity. At low light attenuation coefficients, a little increase in turbidity would greatly decrease gross productivity (*Figure 3*).

## DISCUSSION

Phytoplankton in fish pond is important because it forms a very important source of food for zooplankton, aquatic insects and herbivorous/omnivorous fishes. Zooplankton and aquatic insects, in turn, serve as food for omnivorous/carnivorous fishes. One of the main factors governing phytoplankton production in pond water is subsurface light. Underwater light availability for photosynthesis is mainly controlled by suspended particles and dissolved coloured compounds (Wetzel 1983). The higher the concentrations of suspended particles or dissolved compounds, the lower is the light transmitted and thus available to the photosynthetic organisms at lower depths.

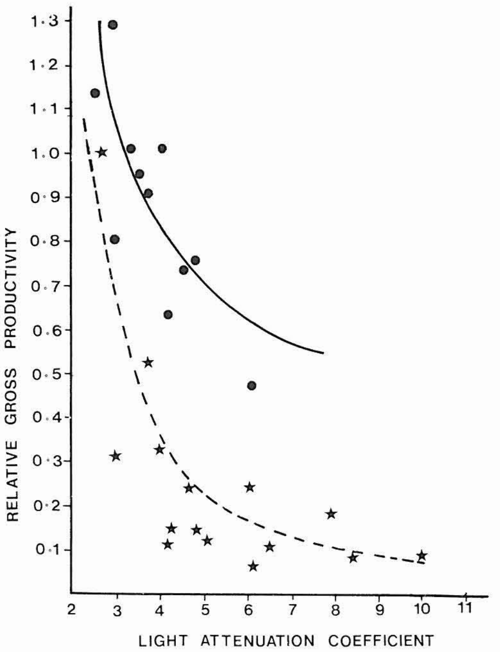


*Fig 3* *Relationship between light attenuation coefficient and relative gross productivity at 0.25 m* (•) and at 0.75 m depths (★).

Turbidity caused by soil particles does not only affect underwater light penetration, but also causes an erroneous relationship between Secchi disk transparency and chlorophyll concentrations. Several workers have proposed the use of empirical relationships between Secchi disk depth and chlorophyll a to predict chlorophyll levels from changes in transparency (Carlson 1977). However, the Secchi disk transparency provides little information about

TABLE 1
Mean light attenuation coefficients, and gross and net productivity at different depths, on different days in turbid fish ponds (n = 3). GPP is gross primary productivity and NPP is net primary productivity.

| Dates | Light attenuation coefficients | | Depth (cm) | GPP (mgC/m3/hr) | NPP (mg C/m3/hr) |
|---|---|---|---|---|---|
| | Range | Mean | | | |
| 5/5/86 | 6.52-10.25 | 8.39 | 10 | 608.4[a] | 525.6[a] |
| | | | 25 | 413.5[b] | 344.5[b] |
| | | | 50 | 90.8[c] | 26.6[c] |
| | | | 75 | 31.5[d] | 0.0[d] |
| 11/23/86 | 2.96-7.75 | 5.16 | 10 | 738.3[a] | 613.8[a] |
| | | | 25 | – | – |
| | | | 50 | 575.1[b] | 469.2[b] |
| | | | 75 | 155.3[c] | 48.4[c] |
| 11/30/86 | 4.23-6.05 | 5.09 | 10 | 999.8[a] | 895.0[a] |
| | | | 25 | – | – |
| | | | 50 | 487.8[b] | 395.4[b] |
| | | | 25 | 85.5[c] | 20.0[c] |
| 12/7/86 | 3.37-5.95 | 4.47 | 10 | 957.7[a] | 655.8[a] |
| | | | 25 | 989.1[a] | 677.4[a] |
| | | | 50 | 521.8[b] | 142.0[b] |
| | | | 75 | 306.9[b] | 80.4[b] |
| 12/14/86 | 3.00-4.59 | 3.74 | 10 | 814.1[a] | 526.6[a] |
| | | | 25 | 668.8[ab] | 432.3[ab] |
| | | | 50 | 479.2[bc] | 249.1[bc] |
| | | | 75 | 312.9[c] | 121.2[c] |
| 12/21/86 | 1.20-2.50 | 1.67 | 10 | 929.0[a] | 768.5[a] |
| | | | 25 | 988.3[a] | 798.1[a] |
| | | | 50 | – | – |
| | | | 75 | 988.3[a] | 853.0[a] |

Mean productivity values for the same date within the same column followed by a different letter are significantly different at $P < 0.05$.

algal biomass in turbid ponds if the relationship disregards the effects of substances other than algae which attenuate subsurface light. This is because transparency does not simply depend on vertical attenuation of light due to chlorophyll, but also on absorption and scattering of light by suspended particles.

In this study, in turbid ponds with attenuation coefficients of more than 5, particulate suspensoids drastically reduced the light transmission to less than 1% of total surface light in less than 0.75 m depth (*Figure 2*). Other studies have shown that the sunlight zone for photosynthesis extends to the depth where 1% of surface light remains (Cole 1983). Thus, primary productivity was limited to less than 1 m depth when ponds in this study were very turbid. McNabb *et al.* (1988) reported that 1% of surface 400-700 nm photon flux density was present at 2.0 m depth when the attenuation coefficient was 2.06 in Wonogiri Reservoir in Java.

Since light penetration in turbid ponds is limited, the bottom layer of turbid ponds is likely to be heterotrophic, succumbing to accumulation of toxic decomposition products such as ammonia and under deoxygenated conditions, hydrogen sulphide. However, turbid periods usually occur during wet seasons when formation of stagnant deoxygenated bottom water does not develop due to complete mixing of water column in shallow ponds.

Besides giving rise to heterotrophic layers in ponds, particulate suspensoids also lessen the phytoplanktonic carbon fixation capacity in deeper layers. Phytoplankton populations in 0.75 m fixed less carbon than those at 0.5 m layer, and those at 0.5 m fixed less than at 0.25 m. Primary production differences between water layers were found to be significant (Table 1). This phenomenon occurred in extremely turbid conditions when attenuation coefficients were more than 5.0 (Table 1). Attenuation coefficients of more than 2.0 resulted in significant difference in phytoplanktonic production between bottom and surface layers (Table 1).

Phytoplanktonic production in subsurface layers decreased rapidly with increasing light attenuation coefficients until a saturation point was reached. At this point, increased coefficients resulted only in samll decreases in production (*Figure 3*). Once light is limited in an aquatic system, other means of increasing phytoplankton production, such as fertilizing ponds, proves futile. Therefore, 1 m deep fish ponds should not have attenuation coefficients of more than 2.0 in order for all layers of water to be photosynthetically productive.

This study showed that turbidity caused by silt and soil materials greatly influenced availability of light for photosynthesis at lower depths in ponds. Since subsurface light is a very important factor for production of algae used as food in ponds, turbidity should be controlled in water used for fish grow-out ponds. It is recommended that water for fish ponds should go through baffles which slow the water flow thus allowing solids to settle out. It would be even better for the water to go through limestones heaps, especially for soft water, because the limestone stack would not only filter the silt out, but would also increase the alkalinity of the water.

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