Light Availability for Phytoplankton Production in Turbid Tropical Fish Ponds

FATIMAH MD. YUSOFF
Department of Fisheries Biology and Aquaculture, Faculty of Fisheries and Marine Sciences, Universiti Pertanian Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.

Key words: Light, phytoplankton production, turbid, tropical fish ponds.

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-watered 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% Chlorrella 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):

\[ \text{In } y = a + bz \]

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/mVhr)
\[ = \frac{(LB - DB \times 1000 \times 0.375)}{PQ \times t} \]

Net productivity (mg C/mVhr)
\[ = \frac{LB - IB \times 1000 \times 0.375}{PQ \times t} \]

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 \( P < 0.05 \).

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 herbivo-rous/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.

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
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 small 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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Preliminary Study on Mortality of Catfish (Clarias macrocephalus)
Fry Transported in Plastic Bags.

*AHYAUDIN B. ALI, *TG. MOHAMAD IZHAM TG. KAMALDEN AND **ADNAN ABAS

*School of Biological Sciences
**School of Medical Sciences
Universiti Sains Malaysia
11800 Penangy Malaysia.

Key words: Catfish, Clarias macrocephalus, mortality, transportation, plastic bag.

ABSTRACT
Catfish (Clarias macrocephalus) fry were transported in plastic bags using clean water and pure oxygen at a ratio of 1:3. The rise in temperature and total ammonia during transportation was related to transportation time and packing density. Though dissolved oxygen increased when pure oxygen began to dissolve in the water during transportation it did not pose a problem. Low mortalities were observed among the less densely packed fish but post-transporatation mortalities were fairly high. Mortalities, however, could be reduced with the addition of salt (NaCl) to the water.

INTRODUCTION
In Southeast Asia, fish are widely transported in sealed plastic bags with air replaced by pure oxygen (Sampson 1987). The convenience and associated low cost has resulted in its widespread use. Even though the plastic bag method of transporting fish is easy and economical (Frose, 1986), the hauling stress experienced usually results in poor fry survival (Sampson 1987). The senior author has experienced a 98% mortality of catfish (Clarias macrocephalus) fry transported in plastic bags. The fry died within 1 to 2 days after arrival and a post-mortem indicated transportation stress as the most probable mortality cause. This major problem slows down catfish farming in Perlis, Kedah, Penang, and Northern Perak where the low fry production from local hatcheries is further aggravated by high losses during transportation.

The plastic bag method generally involves packing a certain number or weight of fish in a plastic bag filled with clean water and pure oxygen at the ratio of 1:3 by volume (Sampson, 1987). Salt (NaCl) may be added to the water to reduce mortalities (Piper et al. 1982; Nikinmaa et al. 1983). However, there does not appear to be rules and it appears to be trial and error based rather than scientifically determined (Sampson 1987). This study investigates the effects of different packing densities, transportation time, and salt concentrations on mortality of catfish fry during and after transportation.

MATERIALS AND METHODS
The experiments were conducted using plastic bags (71 cm x 56 cm), dechlorinated water and catfish fry with mean size of 146 mg ±12 mg.
and 20 mm ± 1 mm long (total length), the size sold by most hatcheries. The plastic bags were thoroughly washed to remove any trace of chemicals present, and prior to the experiments, the fry were acclimatised for one week and starved for 12 h to clear their guts.

In experiment A, fry at four different packing densities (5, 10, 20, and 30 ind./l - each density replicated 5 times), were subjected to four different transportation times (0.25, 4, 8, and 12 h). Dissolved oxygen (D.O.) and water temperature were measured at specified time intervals using a Yellow Spring Instrument (Model 57) D.O. meter with a thermistor. Final total ammonia concentrations in the 8 and 12 h treatments for the 10, 20, and 30 ind./l densities were measured using the indophenol method (Boyd 1979), while the initial and final pH values were also recorded using a Hanna (HI 8314) pH meter. After the experiments, the fish were kept in aquaria (18 cm x 32 cm x 22 cm) filled with 3 l dechlorinated water and reared for one week to determine post-transformation mortality. During rearing, the water was fully aerated and changed every 2 days, and the fish were fed to satiety with Tubifex worms at 5% body weight 3 times daily. All mortalities were recorded.

In experiment B, fry (from the same group as in experiment A) at 5 and 30 ind./l densities were packed in plastic bags containing water at four different salt concentrations (0, 10, 15, and 20 mg/1 - each concentration was replicated 5 times), and subjected to transportation times of 8 and 12 h, respectively. After the experiments, the fish were kept in aquaria filled with dechlorinated water and reared for one week to determine post-transformation mortality. The water management and feeding of fish were as in experiment A.

RESULTS

Experiment A
The temperature increased gradually during transportation (Figure 1A). However, for each packing density, the rise was small and the minimum and maximum values recorded were 26 and 32°C, respectively. There was also a gradual increase in D.O. (Figure 1A) and the minimum and maximum concentrations were 12.0 and 16.7 mg/1, respectively. For post-transformation rearing, the temperature was relatively constant but there were some fluctuations in D.O. especially for the 20 and 30 ind./l densities (Figure 1B). The final total ammonia-N concentrations for the 8 and 12 h transportation increased in relation to the packing densities (Figure 2). The concentrations for the 8 h transportation increased from 0.29 mg/1 for 10 and 20 ind./l densities to 0.48 mg/1 for 30 ind./l density, respectively. For the 12 h transportation the increase was from 0.20 mg/1 for the 10 ind./l to 0.29 and 0.36 mg/1 for the 20 and 30 ind./l densities, respectively. In all treatments the pH levels remained essentially circum-neutral, and declined slightly at the end of the study (Figure 2).

No mortalities were recorded during transportation for 5 and 10 ind./l densities but there were fairly low mortalities for 20 and 30 ind./l densities (Figure 3). Post transportation mortalities after one week of rearing were high for all the densities and all transportation times. For the 5 and 10 ind./l densities, the mortality rates increased with longer transportation times, whereas, the opposite occurred for the 20 and 30 ind./l densities (Figure 3).

Experiment B
The D.O. and temperature were stable during transportation as well as during post-transformation rearing. The average D.O. and temperature ranged from 11.6 to 15.3 mg/l and 29.8 to 33.3°C, respectively, during transportation. During post-transformation the average D.O. and temperature ranged from 2.0 to 6.6 mg/l and 25.5 to 28.6°C, respectively. There were no mortalities during transportation. The addition of salt, especially at 20 mg/l, during transportation reduced post-transformation rearing mortalities for both the 5 ind./l and 30 ind./l densities; however, lower salt concentrations were less effective (Table 1). During post-transformation rearing, mortalities occurred randomly whether in the first 3 or the last 4 days of rearing. If there were high mortalities in the first three days then the last 4 days would have lower mortalities and vice versa (Table 1).
MORTALITY OF CATFISH \( (C. \text{MACROCEPHALUS}) \) FRY TRANSPORTED IN PIASIC BAGS

Fig. 1 Temperature (line) and dissolved oxygen (bar) measured at different time intervals during transportation (A) and daily during post-transportation rearing (B).
Fig. 2 Final total ammonia-N concentrations (line) and pH levels (bar) for fry transported at two different time intervals and three different packing densities.

Fig. 3 Total mortality rates (%), during transportation (bar) and post-transportation rearing of seven days (line), for fry transported at four different time intervals and packing densities.
MORTALITY OF CATFISH (C. MACROCEPHALUS) FRY TRANSPORTED IN PLASTIC BAGS

TABLE 1
Effects of different salinities (NaCl) on post-transportation mortality (%) of catfish (Clarias macrocephalus) fry packed at 5 and 30 ind./l densities and transported at two different transport times.

<table>
<thead>
<tr>
<th>Salinity (mg/l)</th>
<th>5 individuals/l</th>
<th>30 individuals/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 h</td>
<td>12 h</td>
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<tr>
<td></td>
<td>day 3</td>
<td>day 7</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>32.0</td>
<td>8.0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>44.0</td>
</tr>
<tr>
<td>15</td>
<td>16.0</td>
<td>80.0</td>
</tr>
<tr>
<td>20</td>
<td>4.0</td>
<td>32.0</td>
</tr>
</tbody>
</table>

DISCUSSION
A rise in temperature during transportation is unavoidable. Even though catfish can tolerate temperature extremes in their natural environment (Ali and Ahmad 1988), the water temperature in the plastic bag must be allowed to equilibrate slowly with the water temperature of the place to be stocked to avoid shock that might kill the fry (Sampson 1987). Dissolved oxygen is not a problem since the pure oxygen used would dissolve with longer transportation time and lead to an increase in D.O. towards the end of transportation. If pure oxygen is not available, hydrogen peroxide may be used as an oxygen source (Taylor and Ross 1988) or atmospheric air can be used if the transportation time does not exceed 20 h (Frose 1986).

The main problem faced during transportation is the change in water quality, primarily of pH and ammonia (Sampson 1987). The increase in carbon dioxide during transportation would increase carbonic acid and result in lower pH (Boyd 1979). The severity of the drop is related to packing density (Sampson 1987). Concurrently, an increase in total ammonia concentrations as a result of excretion also occurred. The increase is also related to packing density (Siraj et al 1985) but can be minimised by properly starving the fish prior to transportation. Properly starved fish would not regurgitate food, thus, lessening water fouling problem (Sampson 1987), while, ammonia toxicity during transportation can be reduced by the low pH and low water temperature (Colt and Tchobanoglous 1976; Robinette 1983; Sampson 1987). In this study, the fairly high total ammonia-N detected is probably due to the short starvation period of 12 h, and ammonia at these levels can affect fish stamina (Robinette 1983) possibly leading to higher post-transportation mortality. Stress is an important factor affecting fish mortalities. Thus, different levels of stress could also be responsible for the higher ammonia-N levels for fish transported at 8 h compared to those transported at 12 h. During transportation, no mortalities occurred in the less densely packed bags but occurred in the 20 and 30 ind./l bags indicating the greater stress of higher packing densities. However, the transportation stress for the 5 and 10 ind./l densities finally manifested itself during post-transportation rearing with high fry mortalities, although, for the 20 and 30 ind./l densities, the mortalities were lower because most of the stressed fish had already died during transportation.

Nikinmaa et al (1983) and Frose (1986) suggested adding salt to water during transportation to reduce post-transportation mortalities. The role of salt is primarily to reduce physiological stress by reducing the osmotic work needed to maintain stable ion levels (Nikinmaa et al 1983). Depending on species, the suggested concentrations range from 1 to 10 g/l (Frose 1986). Adult catfish have been successfully transported in water containing 3 g/l salt. However, no suggested concentration for fry is available. This study indicated that adding 20 mg/l salt to water during transportation...
could lower post-transportation mortalities among catfish fry packed at both 5 ind./l and 30 ind./l densities. However, lower salt concentrations have less noticeable effects.

CONCLUSION
The use of plastic bags to transport fish should be encouraged. However, further research should be done to "fine tune" the technique to make it more reliable. Since it is difficult to maintain optimum water quality condition during transportation, fish should be treated with care prior to, during and after transportation in order to reduce losses. Adding salt to water during transportation can reduce mortalities, but rough handling of fish should be avoided at all times (Frose 1986). Proper conditioning before transportation would help to identify weaker fish for removal, thus, reducing mortality during and after transportation (Sampson 1987). Adequate starvation before transportation also helps to reduce the problem of water fouling and ammonia toxicity (Sampson 1987). Packing procedure suggested by Frose (1986) is recommended.

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