Photosynthetic parameters for phytoplankton in Amazon floodplain lakes, April – May 1987

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Introduction

The central floodplain of the Amazon River contains thousands of lakes ranging in size from <1 ha to >600 km² (Wetzel 1979, Mielke 1984). Primary productivity in these systems is thought to be high due to the input of nutrient rich river water during seasonal floods (Schneider 1973, Fromme & Parsley 1979). However, the spatial and temporal variability of phytoplankton production over most of the floodplain is still largely unknown. This is due, in part, to the difficulty of sampling these remote lakes spread out over 60,000 km² of floodplain (Mielke 1984) and to the small number of limnologists working in the region (<1 per 10,000 km²).

The estimation of primary production rates from remotely sensed (by satellite or aircraft) chlorophyll a and extinction data may offer a unique technological solution to this problem. Good correlations have already been obtained between remotely sensed chlorophyll data and direct estimates of plankton production in the sea (Epifan et al. 1985). Precise estimates of production, though, will require the use of numerical models of photosynthesis which incorporate the chlorophyll specific parameters Pm and Pm*, the light saturated rate of photosynthesis, mg O₂ mg Chl⁻¹ h⁻¹, and the initial slope, mg O₂ m² mg Chl⁻¹ h⁻¹, from the photosynthesis-light curve. Since these two parameters cannot be derived from the satellite data, average values must be assumed. The accuracy of production estimates, then, will depend on the real spatial and temporal variability of these coefficients.

We present here an analysis of the variability of phytoplanktonic photosynthetic parameters among Amazon floodplain lakes during the rising water period (April – May) of 1987.

Study area and methods

Fifteen lakes were sampled along the central floodplain of the Amazon River between Santo Antonio do Iça and Obedos, a distance of approximately 1,500 km (Fig. 1). A 20 liter polyethylene carboy was filled at a depth of 0.5 m near the center of each lake. The depth profile of temperature was also determined at this point with a YSI (Yellow Springs Instruments) model 80 thermostor. The carboy was transported to the laboratory of the 19 m research vessel, L.M. Arens, and subsampled within 1-2 hours. During this period the sample was kept in the dark to avoid light shock. After thorough mixing, samples were taken for the determination of chlorophyll a and for measurements of photosynthesis and respiration. Rates of gross photosynthesis and community respiration were estimated from changes in the oxygen concentrations in replicate transparent and dark BOD bottles (70 ml capacity) exposed to a range of light intensities (0-800 µE m⁻² s⁻¹) in an incubator similar to that described by Fyfe (1973). Oxygen concentrations were measured photoelectronically with a YSI (Yellow Springs Instruments) model 80 oxygen meter using a probe with a high sensitivity membrane. The light source in the incubator consisted of four 500 W mercury vapor lamps. Incubation times ranged from 1-2 hours. The temperature was maintained at 29 ± 2°C during all incubations. This corresponded to the average mixed layer temperature of the fifteen lakes. Light levels in the incubator were measured with a Li-COR (Lambda Inst. Corp.) model LI-188B integrating quantum meter equipped with an LI-192SB underwater cosine quantum sensor. Values of Pm and Pm* for each lake were determined by fitting the photosynthesis and light data to the mathematical model of Smith (1936) using the statistical procedure described by Jasen & Platt (1976). Chlorophyll samples were collected on pre-Combusted Gelman A/E glass-fiber filters and stored in a vacuum desicator in the dark for one month before analysis. Chlorophyll a concentrations were determined spectrophotometrically, following maceration and extraction in 90% acetone, using the trichrome equations of Strickland & Parsons (1972).

Table 1. Summary statistics for photosynthetic parameters (see text for definitions).

<table>
<thead>
<tr>
<th></th>
<th>Pm</th>
<th>Pm*</th>
<th>α</th>
<th>R</th>
<th>c</th>
<th>Pm/R</th>
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<tr>
<td>Units</td>
<td>mg O₂ mg Chl⁻¹ h⁻¹</td>
<td>mg O₂ mg Chl⁻¹ h⁻¹</td>
<td>mg Chl⁻¹</td>
<td>mg O₂·m² mg Chl⁻¹ h⁻¹</td>
<td>mg Chl</td>
<td>-</td>
</tr>
<tr>
<td>n</td>
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<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
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</tr>
<tr>
<td>min</td>
<td>10</td>
<td>26</td>
<td>12.2</td>
<td>0.15</td>
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<tr>
<td>max</td>
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<td>555</td>
<td>33.5</td>
<td>1.93</td>
<td>100.0</td>
<td>44.0</td>
</tr>
<tr>
<td>g</td>
<td>16.4</td>
<td>176</td>
<td>21.9</td>
<td>0.79</td>
<td>38.1</td>
<td>11.5</td>
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<tr>
<td>S.D.</td>
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<td>126</td>
<td>5.8</td>
<td>0.43</td>
<td>23.7</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Results and discussion

A typical photosynthesis-light curve resulting from one of the incubations is shown in Fig. 2. Saturation light levels were obtained in all cases. Inhibition was often observed at the highest light intensities and these data points were always excluded from the statistical analysis.

Summary statistics for the photosynthetic parameters determined for the 15 lakes are listed in Table 1. Both the chlorophyll specific light saturated rate of photosynthesis, Pm a, and the initial slope of the P vs I curve, α, varied considerably. Their coefficients of variation (C.V.) were 28% and 27%, respectively.

There was a strong positive correlation (r = 0.88, p < 5%) between these two parameters (Fig. 3). This is not an autocorrelation resulting from both coefficients being normalized to chlorophyll, since the non-normalized coefficients were also highly correlated (r = 0.97, p < 5%), but appears to indicate a direct functional relationship between the parameters. Similar correlations have been observed in studies of the diel and seasonal
variability of these parameters (Côté & Platt 1983, Platt & Jasby 1976, Prezelnin & Sweders 1973). While the physiological significance of the relationship is unclear (Platt & Jasby 1976, Côté & Platt 1983) it could be of considerable practical value since it allows one parameter to be calculated directly from the other.

Chlorophyll concentrations, \( c (\text{mg Chl} \cdot \text{m}^{-2}) \), also vary considerably between lakes as did community respiration rates, \( R (\text{mg O}_2 \cdot \text{m}^{-2} \cdot \text{h}^{-1}) \), and the non-normalized photosynthetic parameters, \( P_{\text{max}} \), (the light saturated rate of photosynthesis, \( \text{mg O}_2 \cdot \text{m}^{-2} \cdot \text{h}^{-1} \)) and \( \alpha \) (initial slope of the non-normalized curve, \( \text{mg O}_2 \cdot \text{s}^{-1} \cdot \text{m}^{-2} \cdot \text{h}^{-1} \)). Their coefficients of variation were 82%, 62%, 72%, and 54%, respectively. R, \( P_{\text{max}} \), and \( \alpha \) were highly correlated with chlorophyll (r = 0.82, 0.94 and 0.90, respectively, p < 5%) and thus could conceivably be estimated from chlorophyll data during this period.

The \( P_{\text{max}} : R \) ratio ranged between 2.0 - 12.2 with an average value of 5.2. This average is lower than most values reported in the literature for natural phytoplankton communities (summarized by Gang 1980). This might indicate that the algae were under physiological stress. However the high levels of \( P_{\text{max}} \) encountered (Table 1) suggest that this was not the case. It is more likely that this low ratio reflects the dominance of heterotrophic activity in these systems (Richer et al. 1988).

The high variability of \( P_{\text{max}} \) and \( \alpha \) found here and in other regions (Côté & Platt 1983, Fisk et al. 1987) will make it difficult to apply numerical photosynthesis models to estimate integral production rates from remotely sensed chlorophyll and extinction data. It is clear that only the rough estimates can be made if these parameters are assumed to be constant.

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References


