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Supplementary material

Effects of autotrophic biomass and composition on photosynthesis, respiration and light utilisation efficiency for a tropical savanna river

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Comparison of measured dissolved oxygen concentrations and modelled concentrations for the Daly River, November 2008

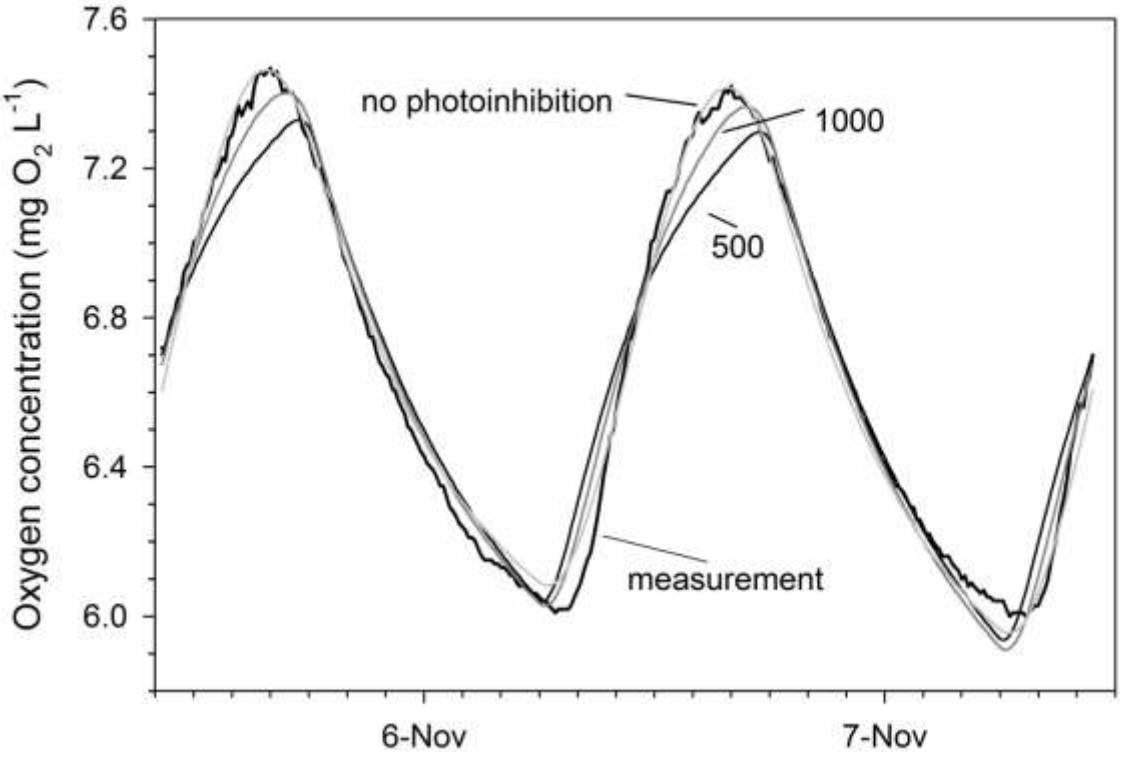

Fig. S1. Time series of oxygen concentration measured (heavy line) and for modelled fits to these data obtained using three values of I_k (µmol photons m^{-2} s^{-1}) in the representation of photosynthesis rate. No photo inhibition is the case $I_k = \infty$.

Benthic chamber trial to determine photosynthetic parameters for periphyton

For the each chamber, the oxygen balance can be expressed using a similar expression to that used for the diurnal oxygen method for river metabolism. Without connection to the atmosphere, the reaeration term is neglected although the dissolution of oxygen as bubbles was observed within the domes when the concentrations became supersaturated and loss of the bubbles when concentrations reduced below saturation.

By analogy with Eqn 1 (see Methods), we model the oxygen concentration within the dome as:

$$\frac{dO}{dt} = P - R + K_B(O_{sat} - O) \quad \text{(S1)}$$

where $K_B$is an exchange coefficient with the bubble phase. We shall assume that the concentration of oxygen in the bubble phase (mass of bubbles/volume of chamber) is *B*. Thus, we have:

$$\frac{\mathrm{d}B}{\mathrm{d}t} = -K_B(O_{sat} - O) \quad \text{(S2)}$$

The mass of bubbles can't fall below zero, so if $B \leq 0$, then we set $K_D = 0$; otherwise, K_D has a fixed value which will be assumed to be the same across all the dome deployments. With the magnitude of K_D specified, the problem of determining photosynthesis and respiration rates for the domes becomes exactly equivalent to the problem of determining photosynthesis and respiration in the river and is solved as a two-parameter fit rather than as a three-parameter fit as is undertaken for the river. Photosynthesis rate is assumed to be linearly proportional to irradiance.

For each selected K_B, we calculate the average root mean square difference between modelled and measured oxygen concentration across all 18 dome deployments (Fig. S1). This difference is minimised with $K_B = 0.12$ day^{-1} for which $\bar{\sigma}_{RMS} = 0.33$ mg O_2 L^{-1}. With $K_B = 0$, $\bar{\sigma}_{RMS} = 0.34$ mg O_2 L^{-1}; that is, it is only marginally larger. For $I_k \geq 900$ µmol photons m^{-2} s^{-1}, $\bar{\sigma}_{RMS}$ is only a very weak function of I_k. This analysis demonstrates that if photoinhibition occurs for periphyton this would only be for a high value of I_k. The results are also consistent with no photoinhibition. Fig. S2 shows an example of modelled oxygen time series in the domes compared with measurements for $K_B = 0$ and no photoinhibition (i.e. $I_k = \infty$). The results are shown for chamber which had a paver chlorophyll *a* biomass of 3.8 mg m^{-2} which was close to the median biomass for all the pavers.

By fitting Eqn 3 to the time series of oxygen concentrations within each dome we derive the rate of photosynthesis of the primary producers within it. The photosynthetic coefficient is calculated as the rate of photosynthesis per unit of photosynthesising chlorophyll per unit of irradiance. In estimating the chlorophyll contributing to photosynthesis within each dome, we consider both the chlorophyll recovered from the paver surface and a small contribution from phytoplankton trapped within the dome when it was installed. The latter is calculated as the product of the dome volume (7.5 L) and the

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measured chlorophyll concentration in the water column (0.5 μg L^{-1}).The contribution of phytoplankton chlorophyll mass to the total is small in virtually all cases so that the derived α mostly reflect the presence of periphyton. Fig. 7 of the paper shows that α calculated from the chamber trial tends to decline with increasing chlorophyll concentration over the range of periphyton biomasses measured in the Daly River.

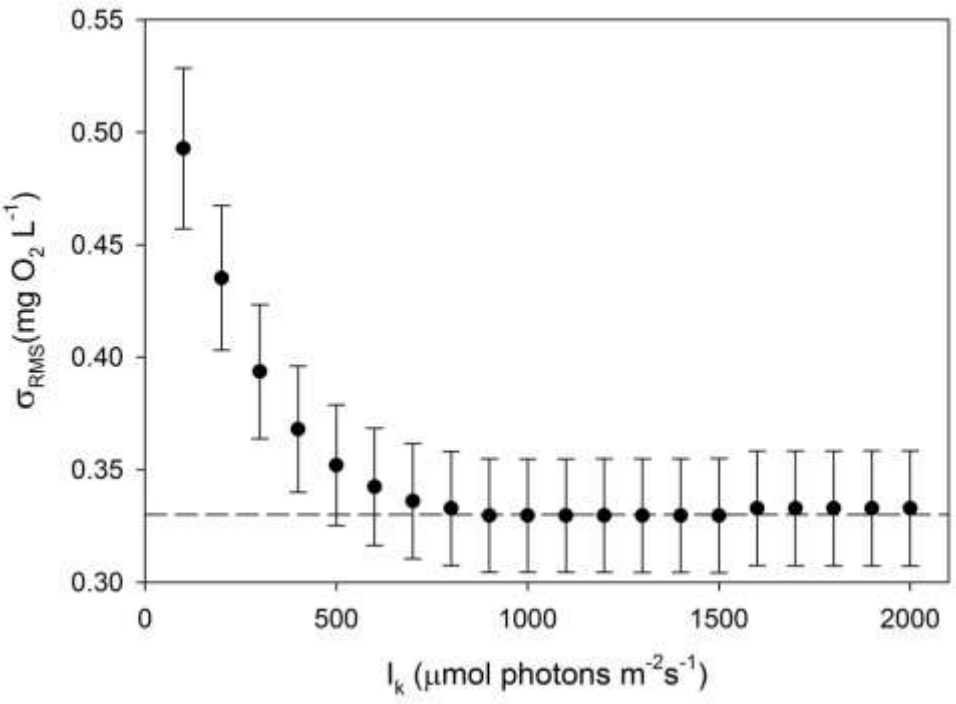

Fig. S2. Average RMS error ($\bar{\sigma}_{RMS}$) in model fit to measurements with $K_B = 0$. The error bars are the expected error in the mean based on the variation in the RMS error for each dome deployment. The dashed line shows the minimum value of $\bar{\sigma}_{RMS}$.

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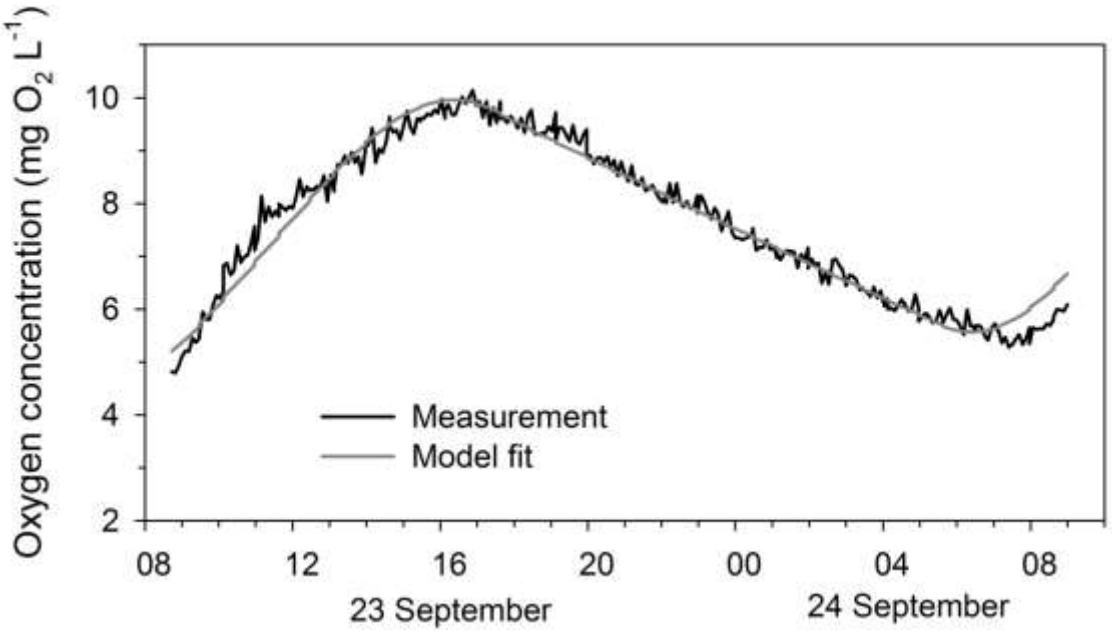

Fig. S3. Example comparison of measured time series of oxygen concentration within a dome with the fit obtained with $K_B = 0$ and $I_k = \infty$.

Phytoplankton photosynthetic efficiency

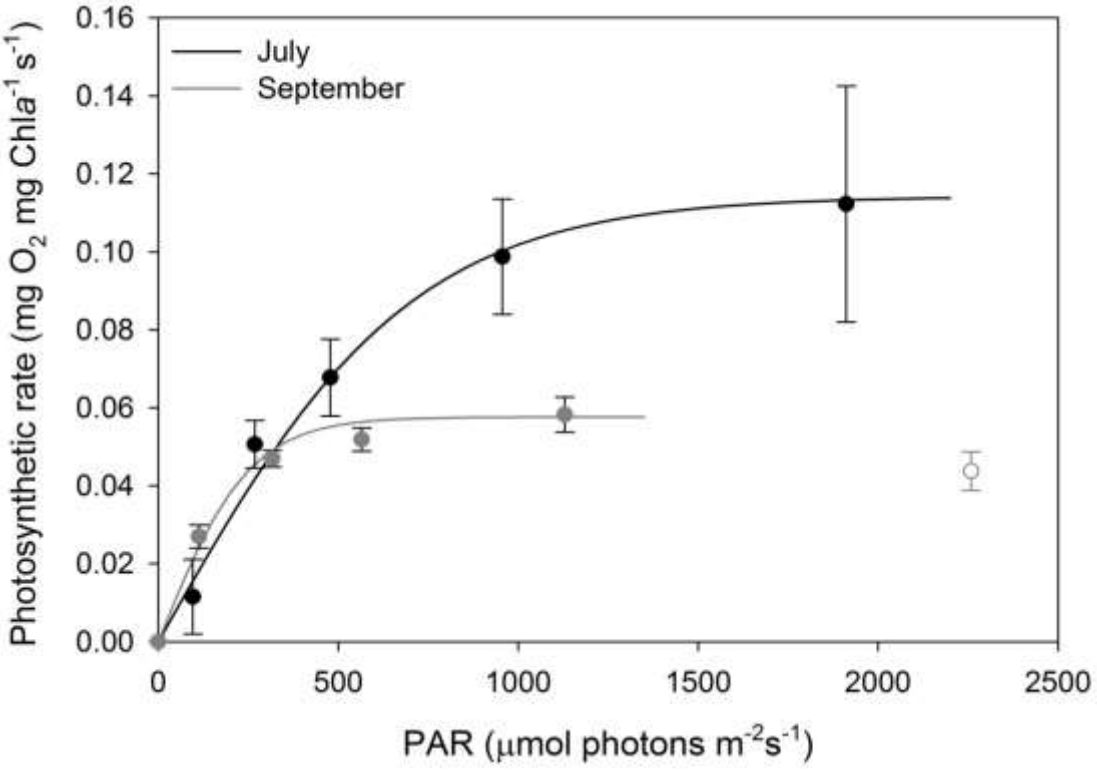

Fig. S4. Comparison between measured photosynthesis rate and rates modelled using Eqn 2 (see Methods). Points represent measurements and lines are the optimal model fits (Eqn 2). The solid points are used in the fitting procedure, whereas the open point was not.

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Model to explain the periphyton photosynthetic efficiency

Here, we propose a simple model to explain this behaviour. Suppose a paver surface is divided into N partitions such that each partition has the same area as is covered by a single algal cell. Further suppose that algal cells are distributed across the paver surface in a completely random way. Then, the probability that a particular cell will occur within a specified partition is $1/N$ so the probability that this cell will not occur within the partition is $1 - 1/N$. If a total of M cells is spread across the paver the probability that a specified partition will remain clear of cells is $P_{clear} = (1 - 1/N)^M$. Thus, the probability that the partition will be covered by at least one cell is $P_{cover} = 1 - P_{clear}$. If N is a large number, then $(1 - 1/N)^M \sim e^{-M/N}$ and so $P_{cover} = (1 - e^{-M/N})$ and the total light flux intercepted by cells over an area A of paver will be $F' = IAP_{cover}$. Conversely, if the cells are spread uniformly across the paver and provided $M \leq N$, the light flux intercepted by cells will be $F = IAMN^{-1}$. So, if cells are allowed to stack on top of one another, the relative reduction in light intercepted by cells on the paver compared to a single layer of cells will be $R = F'/F = N(1 - e^{-M/N})/m$. Now, the ratio M/N is proportional to the areal concentration of cells or equivalently of chlorophyll assuming each cell has a fixed amount of chlorophyll. Thus, if we specify $M/N = \lambda$Chl-a where λ is a proportionality factor and Chl-a is the areal concentration of chlorophyll, then $R = (1 - e^{-\lambda\text{Chl-}a})(\lambda\text{Chl-}a)^{-1}$. We expect the photosynthetic efficiency to be reduced by this factor if cells are stacked so that if α' is the effective photosynthetic efficiency with stacked cells and α_0 is the efficiency of a uni-layer then,

$$\alpha' = \frac{\alpha_0(1-e^{-\lambda\text{Chl-}a})}{\lambda\text{Chl-}a} \quad \text{(S3)}$$

Fig. 7 of the paper shows Eqn S3 with the coefficients α_0 and λ determined through least-squares fitting. In this case, α_0 = 10.3 mg C mg^{-1} Chl-a mol^{-1} photons m^{-2} and λ = 0.64 m^2 mg^{-1} Chl-a.