Phytoplankton dynamics in different aquatic systems of the central Amazonas River: spectral group distribution and primary productivity

Luis Felipe Artigas¹, Sonia Brugel¹, Fabrice Lizon², Jessica Chicheportiche¹, Elizabeth Cristina Arantes de Oliveira³, Beatriz Lamback³, Marie-Paule Bonnet⁴, Gwenaël Abril ⁴,⁵,⁶,⁷

Felipe.Artigas@univ-littoral.fr
Institutions

- 1 Laboratoire d’Océanologie et Géosciences (LOG), CNRS UMR 8187, MREN, Université du Littoral Côte d’Opale, Wimereux, France
- 2 Laboratoire d’Océanologie et Géosciences (LOG), CNRS UMR 8187, SMW, Université des Sciences et Technologies de Lille, Wimereux, France
- 3 Laboratório de Géoquimica (LAGEQ), Instituto de Geociencias, Brasilia, Brazil
- 4 Laboratoire des Mécanismes et Transferts en Géologie, IRD, CNRS, Université Paul Sabatier, Toulouse, France
- 5 Laboratoire EPOC, Environnements et Paléoenvironnements Océaniques, CNRS UMR 5805, Université Bordeaux 1, France
- 6 Centro de Estudos Superiores do Trópico Úmido, Universidade do Estado do Amazonas, Manaus - Brasil.
- 7 Laboratório de Potamologia Amazônica – LAPA, Universidade Federal do Amazonas, Manaus - Brasil
Workpackage 2: microbial activities and floodplain net production

Carbon Budget of the Amazon River

WP2 20% microbial activities

EPOC LOG LMTG LGE

Limitation of CO₂ outgassing by phytoplankton* and aquatic vegetation in floodplains

Benthic and planktonic primary production and respiration
Dynamics of phyto- and bacterio-plankton*. Light and nutrient controls
Floodplain vs channel

Phytoplankton and aquatic vegetation as source of organic matter

Remote sensing of phytoplankton blooms

Large Box Modelling of net metabolism
Considerations

**Thomas R. Fisher** (1978)

The 10 m annual change in water level of the Amazon River provides and drains most of the water in lakes along the river. During storage of river water in the lakes the particulates settle and the dissolved inorganic nutrients are converted to organic forms by intense phytoplankton growth (in Lago Janauca, large phytoplankton populations produced up to 3.5 g C/m² per day; average = 2.2). These lakes may be a major source of organic matter for the river ecosystem.

**Philips, Edward J.; Havens, Karl E.; Lopes, Maria Rosélia Marques** (2008)

Once the lake is isolated from the river and turbidity declines, density increases an order of magnitude and the assemblage becomes dominated by filamentous N-fixing *Aphanizomenon tropicalis*. Coincidentally concentrations of dissolved oxygen increase and levels of TN decline, similar to changes during autogenic succession in temperate shallow lakes.
Approaches in microbiology and biogeochemistry

WP2: net ecosystem production of Amazonian varzeas

• To estimate Net Ecosystem Productivity in different individual and contrasting floodplains, by combining experimental determination of photosynthetic parameters of primary producers, respiration rates in the field and biogeochemical modelling.

• Photoadaptation of phytoplankton has never been studied using PhytoPAM techniques in Amazonian waters. In addition, the use of these techniques in combination with biogeochemical modelling is still very seldom, but very powerful.
Workpackage 2: microbial activities and floodplain net production

• Characterisation of phytoplankton and bacterial communities
• Measurements of primary production, photosynthetic efficiency, and respiration in the waters and sediments
• Integration at the ecosystem level, including information on microbial communities and dynamics and using a coupled hydrological/biogeochemical model.
Phytoplankton spectral groups detected by Fluorescence

**Sampling**: continuous recording in sub-surface waters pumped on board.

**Device**: new multi-wavelength submersible probe (FluoroProbe, bbe-Moldaenke®; Beutler et al. 2002).

**Principle**: Spectral groups of algae (green group, Chlorophyta; blue, Cyanobacteria; brown, Heterokontophyta, Haptophyta, Dinophyta; mixed, Cryptophyta) are each characterised by a specific composition of photosynthetic antenna pigments and, consequently, by a specific excitation spectrum of the Chl fluorescence.

**Measurement**: discrimination of spectral groups in mixed populations, on the basis of the relative fluorescence intensity of chl a at 680 nm (due to the Photosystem II core pigments), following sequential light excitation by 5 light-emitting diodes (LEDs) emitting at 450, 525, 570, 590 and 610 nm.
Chlorophyll a & phaeopigments
(total and 4 size-classes)

**Sampling** : 300 ml of sub-surface water sample

**Filtration** : 40µm nylon mesh, 10µm & 3µm Polycarbonate Millipore® membrane filters and 0,7µ GF/F Whatman® filters

**Preservation** : - 22°C

**Extraction** : Aceton 90%

**Analysis** : Fluorimeter 10-AU Turner Desings® before and after acidification (Yentsch & Menzel 1963, Holm-Hansen et al., 1965)

Total Chlorophyll a, > 40µ, [40-10µ], [10-3µ], < 3µ
Photosynthetic parameters: Pulse Amplitude Modulated (PAM) fluorescence

PhytoPAM (Walz):
- 4-Wavelengths Chlorophyll Fluorometer:
  - to assess the photosynthetic activity and light-adaptational state of the 3 groups of phytoplankton

⇒ Fluorescence is excited alternatingly at high repetition rates by µsec pulses of 470, 520, 645 and 665 nm (LED).
PAM fluorimetry

- Variable fluorescence: minimal fluorescence (all PSII open) and maximum fluorescence (all PSII closed)
- Quantum yield of PSII (Fv/Fm)
Photosynthetic activity:

- Light curves: variable fluorescence measured after exposition to increasing light steps (*light response curves as* RLC *(in ± 4 mn)* or LC *(in ± 1 h)*)

- $\Rightarrow$ ETR$_{\text{max}}$  
- $\Rightarrow$ alpha  

(light-adaptational state)
PAM fluorimetry

- Conversion of fluorescence ratios into electron transfer rate (ETRmax)

  Slope = alpha

- Alpha: photosynthetical efficiency
- ETRmax: maximum photosynthetical activity
- Ek: saturation light intensity
Primary production

- Incubations in situ (moored line) and on-deck for 24h

- Samples incubated in light and dark conditions: correction for particles, bacteria

- C incorporation for the whole sample and on filters: total phytoplankton production and particulate phytoplankton production
CARBAMA Sampling stations (2009-2011)
Spatial distribution of phytoplankton groups

June 09 – High Water Period

Chlorophyll eq. FLP (µg l⁻¹)

Stations

Varzea Negro
Rio Solimões
Manacapuru
Janauaca
Rio Negro
Rio Madeira
Miríuba
Camaçari
Amazonas
Trombetas
Curuai
Rio Tapajós

Dates
6/19
6/20
6/21
6/22
6/23
6/25
6/26
6/27
6/28
6/29
6/30
7/1
7/2
7/3
7/4
7/5
7/6
7/7

South channel
North
North (Rio Urubu)

Green algae
Blue green algae
Brown algae
Chrytophyta

Dates
6/19
6/20
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South channel
North
North (Rio Urubu)

Green algae
Blue green algae
Brown algae
Chrytophyta
Spatial distribution of phytoplankton groups

August 10 – Falling waters period

Chlorophyll eq. FLP (µg l⁻¹)

Stations

Negro Cabalina Janauaca Madeira Mirinuba Canacari Curuai

24h Janauaca

24h Curuai

Note: The diagram shows the spatial distribution of phytoplankton groups across different stations from August 25 to September 10.
Spatial distribution of phytoplankton groups

October 09 – Low Water Period

Chlorophyll eq. FLP (µg l⁻¹)

Dates

Green algae
Blue green algae
Brown algae
Chryptophyta

Stations
Rio Solimões
Negro
Manacapuru
Janauaca
Rio Madeira
Mirimuta
Camaçari
Rio Amazonas
Curuai
Rio Tapajos

Dates
10/3
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11
10/12
10/13
10/14
10/15
10/16
10/17
10/18
10/19
10/20
Spatial distribution of phytoplankton groups

January 11 – Rising waters period

- Green algae
- Blue green algae
- Brown algae
- Chryptophyta

Chlorophyll eq. FLP (µg l⁻¹)

Dates

Stations

- Solimões
- Cabalina
- Solimões
- Januá
- Amazonas
- Madeira
- Mirante
- Canaçari
- Amazonas
- Curuai
- Tapajós
Phytoplankton spectral groups per water types

- Rivers
- Floodplain Lakes

Black waters
White waters
Clear waters
White waters

Chlorophyll eq. FLP (µg l⁻¹)

Negro  Manacapuru  Urubu  Solimões  Amazonas  Madeira  Tapajós  Cabaliara  Januacá  Miriúba  Canaçari  Curuá
Phytoplankton size-classes per water types

June 09 – High Water Period

Chlorophyll a (µg l⁻¹)

Percentage of chlorophyll a (%)

Stations

- North
- South
- Urubu
- Piracuara

[Color coding for size-classes: > 40µm, [40 – 10]µm, [10 – 3]µm, < 3µm, % chloro a]
Phytoplankton size-classes per water types

October 09 – Low Water Period

Chlorophyll a (µg l⁻¹)

Percentage of chlorophyll a (%)
Phytoplankton distribution from Varzeas to the Amazonas estuary

- The 5 flood plain systems sampled (Manacapurú-Cabaliana, Janaucá, Mirituba, Camaçarí, Curuái) showed maximum phytoplankton stocks compared to river channels, in the four periods considered.

- A relatively homogeneous distribution of phytoplankton spectral groups was found in a determined period, even though a gradient was detected from Manacapurú to Curuái, concerning a slight raising % of Cyanobacteria over the whole phytoplankton biomass.

- Relatively low phytoplankton stocks were measured in black and white waters of the main channels of the Rio Negro, Madeira, Solimoes and Amazonas.

- A two- up to 10-fold increase was detected in phytoplankton biomass from high to falling waters and low water periods.

- The high water period was characterized mainly by small (< 10µm) nano- and/or picoplankton in most systems, whereas the low water period was characterized by big (> 10µm) nano- and microplankton. Shifts from “green-algae” and “brown algae” to Cyanobacteria were evidenced from high to low water periods, especially in the main floodplain systems sampled.
Phytoplankton photoacclimation - PAM fluorimetry

- Pulse Amplitude Modulated fluorimetry measures fluorescence of photosystem II
- Photoacclimation condition (quantum yield of PSII) and saturation light intensity for photosynthesis (Ek), for surface water samples

Photosynthetic yield and light intensity display an inverse relationship: decreasing values after mid-day reflect photoprotective mechanisms!

Saturation light intensity values follow solar radiations: increase in the morning and decrease in the afternoon

Diel variations of Ek were of 14%

No photoinhibition during this period
Phytoplankton photoacclimation

High waters (June 2009), Low waters (Oct. 2009) and Falling waters (Sept. 2010)

5 lakes from up to down stream: Cabaliana, Janauaca, Miratuba, Camaçari and Curuai

- High variations in phytoplankton biomass between the 3 seasons
- High yield values for the 3 seasons indicating good physiological conditions
- No significant variations between lakes or seasons for yield and Ek
  - Average $E_k = 370 \mu\text{mol photon.m}^{-2}\text{s}^{-1}$; a value close to the maximum irradiance available in sub-surface waters
- Variation of $E_k$ over all lakes and seasons = 20%; a greater value than diel variation (14%)

$\Rightarrow$ Phytoplankton was adapted to the similar light conditions prevailing at all seasons!
Phytoplankton production ($^{14}$C incubations)

- Surface daily PP:
  - High waters 0.05-1.5 mgC.m$^{-3}$.d$^{-1}$
  - Low waters 5-16 gC.m$^{-3}$.d$^{-1}$
  - Falling waters 0.5-6 gC.m$^{-3}$.d$^{-1}$

- Daily PP integrated over euphotic zone
  - High waters 0.8 mgC.m$^{-2}$.d$^{-1}$
  - Low waters 2-20 gC.m$^{-2}$.d$^{-1}$
  - Falling waters 0.5-3 gC.m$^{-2}$.d$^{-1}$

⇒ PP seems to be driven by hydrodynamism and nutrients availability. No correlation with photosynthetic parameters: problem to extrapolate PP rates
Conclusions

• Seasonal variations were pronounced for phytoplankton stocks (up to 10-fold) and primary production (up to 1000-fold) rates in flood plain lakes, which were greater during the dry season than during the flood period.

• An important change in the phytoplankton size-class distribution and composition was evidenced between high water and falling-low water periods.

• Photoprotective mechanisms were evidenced at short-term and prevented photoinhibition to occur at productive periods, what was also evidenced by remaining high apparent quantum PSII yields and relatively low saturation light intensity variability.
Prospectives

• To relate PP dynamics to hydrodynamism and nutrients availability.
• To explore and analyse the lack of correlation with photosynthetic parameters, as a problem to extrapolate PP rates from PAM measurements.
• To relate to other processes measured in order to integrate the data to a C fluxes model.
• To relate the high-frequency dynamics of phytoplankton groups to discrete and precise taxa determination.
MUCHAS GRACIAS POR SU ATENCION
MUITO OBRIGADO PELA ATENCAO
MERCI POUR VOTRE ATTENTION
THANK YOU