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Phytoplankton and periphyton production and its relation to temperature in a humic lagoon

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ABSTRACT

To analyse the existence of interactive competition between phytoplankton and periphyton, we studied their photosynthesis–irradiance (P–E) response during one year in a humic lagoon. Lake production was dominated by phytoplankton, which followed seasonal changes in temperature. Periphyton primary production and algae biomass increased in winter, when phytoplankton biomass and production were lower. In this study we show that even in conditions of phytoplankton dominance, the habitat coupling between phytoplankton and periphyton can still be noticed.

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Phytoplankton and periphytic algae are among the major producers in aquatic ecosystems. The relative importance of each community to lake primary production depends mainly on environmental conditions (e.g., light and nutrients), which in turn influence the net outcome of the interactive competition among them (Jäger and Diehl, 2014). Phytoplankton intercepts light before it reach periphyton, which recycles nutrients within their own matrix preventing thus their flux towards the water column (Hansson, 1988; Wetzel, 2005). Hence, when periphyton dominate primary production a clear-water state is established and phytoplankton dominance determine a turbid state (Moss, 1990; Genkai-Kato et al., 2012). In this study, we explored the contribution of phytoplankton and periphyton to whole-lake primary production on a seasonal basis in a turbid, humic shallow lake from the temperate zone in Argentina.

Grande Lake is a lagoon from the floodplain of the Paraná river (34°14′S, 58°52′W), which has been previously studied with special emphasis in algal community structure, trophic interactions and primary production (e.g., Rodríguez et al., 2011, 2012; Izaguirre





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et al., 2012). It is shallow with an area of 156 ha, mean depth ca. 0.7 m and maximum depth rarely exceeding 1 m. The lagoon has high concentrations of dissolved organic carbon, generally exceeding 15 mg L^{-1} (Aguilar Zurita, Unpubl. data).

The survey was carried out from April 2006 to March 2007 and samplings performed on a monthly basis, ca. 50 m away from the shoreline. The zone was free of aquatic plants during the study period. Water temperature, pH, dissolved oxygen and conductivity were measured with portable metres. Photosynthetic available radiation (PAR, 400-700 nm) was recorded with a submersible spherical quantum sensor LI-193SA (Li-Cor, Lincoln, USA) every 5 cm in the water column to calculate the vertical attenuation coefficient (k_d) and the mean irradiance integrated in the water column (*E*_{mean}) (Neale et al., 1991; Kirk, 2011). Water samples for chemical analysis were obtained with a tube sampler integrating water from the first centimetres and stored in plastic flasks in cold and dark conditions until processing within 24 h. Water samples were treated as described in Rodríguez et al. (2012) for absorbance and nutrient analyses. The absorption coefficient (g440) was calculated from absorbance measurements at 440 nm (Kirk. 2011). Dissolved inorganic nitrogen (DIN) represents the addition of the concentration of ammonia, nitrate and nitrite ions. Phytoplankton chlorophyll-a (Chl-a) was extracted with ethanol and determined spectrophotometrically (Jespersen and Christoffersen,

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1987). Depth integrated samples were taken, preserved with acid lugol iodine solution (1%) and counted in the laboratory under an inverted microscope (Utermöhl, 1958).

Periphton analyses were performed on artificial substrata (polycarbonate strips, $1 \text{ mm} \times 1.6 \text{ cm} \times 7.5 \text{ cm}$) that were allowed to colonize at 10 cm depth for one month as described in Rodríguez et al. (2012). For quantitative analyses of algal classes, Chl-*a*, and mass determinations, substrata were collected and transported to the laboratory in plastic zip-lock bags. Quantitative and Chl-*a* analyses were performed as described for phytoplankton, with the previous step of scraping 3 substrata. Dry weight (DW) and ash free dry weight (AFDW) determinations were performed in triplicate following standard protocols (APHA, 2005). The autotrophic index (AI) was estimated as the ratio AFDW/Chl-*a*. The P-E curves were performed by an in situ simulated deployment using the ¹⁴C assimilation technique as described in Holm-Hansen and Helbling (1995) and full details of the methodology are given in Rodríguez et al. (2012).

The parameters of the P–E curves were fitted by iteration following Eilers and Peeters (1988):

$$P = E(aE^2 + bE + c)^{-1} \tag{1}$$

where *P* is Chl-*a* specific primary productivity (μ gC (μ gChl a)⁻¹ h⁻¹), *E* is irradiance (μ mol photon m⁻² s⁻¹), and *a*, *b* and *c* are adjustment parameters. The initial slope or photosynthetic efficiency (α) and the maximum Chl-*a* specific photosynthetic rate (P_{max}) can be obtained from *a*, *b* and *c* as follows:

$$\alpha = \frac{1}{c} \tag{2}$$

$$P_{\max} = \frac{1}{b + 2(ac)^{1/2}}$$
(3)

The irradiance corresponding to the onset of saturation (E_k) was calculated as $E_k = P_{\text{max}}/\alpha$ (Kirk, 2011). Hourly production rates were extrapolated to daily values employing a sinusoidal formula (McBride, 1992).

Spearman correlations were applied to pairs of physical, chemical and biological variables. Multiple regressions were conducted to explain phytoplankton and periphyton production with environmental variables with forward stepwise selection of variables. For phytoplankton, depth, pH, temperature, E_{mean} , DIN and soluble reactive phosphorus (SRP) were considered as independent variables. For periphyton, conductivity, temperature, $E_{10 \text{ cm}}$, DIN, SRP and phytoplankton Chl-*a* were included. The dependent variable was Log₁₀ transformed to fulfil normality assumption when needed. Mann–Whitney *U* (M–W) testing was applied to look for differences among samples.

Water temperature followed a seasonal pattern, with the minimum observed in July (winter) and the maximum in January (summer) (Fig. 1). Water depth was ca. 40 cm during most of the study and increased towards the summer; conductivity increased during spring-summer, with values above 1000 µS cm⁻¹during all the study period (Table 1). The higher concentration of dissolved oxygen (DO) was registered in November during a bloom of filamentous cyanobacteria. Light integrated in the water col $umn(E_{mean})$ did not show significant differences among seasons. Instead, k_d followed a seasonal trend with lower values during winter, as supported by a positive correlation with water temperature (Table 2). The k_d generally was around ca. 4 m^{-1} but in October and November, during the cyanobacteria bloom, it was ca. 20 and 17 m⁻¹, respectively (Table 1). Absorption coefficient at 440 nm (g440) followed a seasonal trend, with higher values during springsummer and was positively correlated with water temperature and k_d (Table 2).

Table 1

Mean, minimum and maximum (in parenthesis) values recorded at Grande Lake during the study period. DO=dissolved oxygen, E_{mean} =irradiance integrated in the water column, k_d =vertical attenuation coefficient of light, g440=absorption coefficient at 440 nm, SRP=soluble reactive phosphorus, TP=total phosphorus, DIN=dissolved inorganic nitrogen, TN = total nitrogen, nd = not detectable.

water temperature (°C) depth (m)	17.8 (5.8–27.5) 0.47 (0.37–0.68)
conductivity (μ S cm ⁻¹)	1854 (1005–2580)
$DO(mgL^{-1})$	8.3 (3.6-14.3)
pH	8.6 (7.8-9.5)
E_{mean} (µmol photon m ⁻² s ⁻¹)	425 (309-577)
$k_d (m^{-1})$	7.8 (3.8–20.3)
$g440 (\mathrm{m}^{-1})$	12.1 (3.7-27.9)
$SRP(mgL^{-1})$	0.24 (0.08-0.61)
$TP(mgL^{-1})$	0.69 (0.22-1.8)
$DIN(mgL^{-1})$	0.21 (nd-1.6)
$TN (mg L^{-1})$	1.8 (0.09-3.6)

The SRP concentrations were relatively high (Table 1) and did not show a seasonal pattern of variation; instead, TP showed a clear seasonal pattern with higher concentration during warmer months and was correlated to phytoplankton Chl-a (Table 2). DIN concentration tended to be lower towards the warmer months as supported by a negative correlation with water temperature (Table 2).

Phytoplankton abundances were higher in summer, with a maximum of 210,000 ind m L^{-1} in January, due to a bloom of the diatom Cyclotella meneghiniana. Lower abundances were observed in winter, with the minimum occurring in July $(3300 \text{ ind } \text{mL}^{-1})$ and the assemblage being dominated by cryptophyceans. In October and November abundances were high (ca. 70,000 ind mL^{-1}) due to the bloom of several filamentous genera of cyanobacteria. The rest of the year the community was a mixed assemblage composed of different groups (diatoms, cryptophyceans, cyanobacteria, euglenoids and chlorophyceans). Phytoplankton Chl-a concentration followed a seasonal pattern and was positively correlated to water temperature and phytoplankton abundance (Table 2). Concentrations were variable, ranging from 22 μ g L⁻¹ (July) to 507 μ g L⁻¹(November). Phytoplankton Chl-a was higher than periphyton chlorophyll-a (M-W test, p < 0.001); when expressed in area units, phytoplankton Chl-*a* ranged from 0.83 to 34 mg cm^{-2} .

Periphyton algae abundance were between 5750 ind cm⁻² (October) to 112,000 ind cm⁻² (March) without showing any seasonal pattern with diatoms the dominant group. Chlorophyll-a fluctuated between $0.5 \,\mu g \, \text{cm}^{-2}$ (September) and $4.5 \,\mu g \, \text{cm}^{-2}$ (April) and was correlated with periphyton abundance (Table 2). Dry weight (DW) and the ash free dry weight (AFDW) followed seasonal trends, with higher values during warmer months. DW values varied between 6.9 mg cm⁻² (January) and 0.25 mg cm⁻² (June). The highest AFDW value (5.2 mg cm^{-2}) was observed in January and the lowest (0.2 mg cm⁻²) in June. Significant multiple regression analysis showed that AFDW was mainly determined by water temperature (T) as follows: AFDW = $0.045 T - 0.77 (p = 0.005; R^2 = 0.6)$. The AI indicated a more autotrophic periphyton in winter (97), and more heterotrophic during summer (3330), when light attenuation was higher. This last observation is supported by direct correlations with temperature and k_d (Table 2).

Phytoplankton maximum photosynthetic rate (P_{max}) did not follow temperature seasonal variations (Fig. 1A). Photosynthetic efficiency (α) ranged from 0.005 to 0.04 mg C m² s (mg Chl $a \mu$ mol photon h)⁻¹ in January and March, respectively, and varied similarly to P_{max} . The irradiance at the onset of saturation (E_k) was higher than E_{mean} twice, during May and August (winter), when phytoplankton was potentially light-limited. On the other hand, phytoplankton production integrated in the water column (P_{ph}) followed a seasonal pattern (Fig. 1B), and water temperature (T) significantly explained its variation ($P_{ph} = 0.044 T$; p = 0.015; $R^2 = 0.7$). Download English Version:

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