

On the occurrence of *Spirogyra maxima* (Zygnematophyceae) in the Upper Paraná River floodplain

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ABSTRACT – Massive growth of *Spirogyra* Link was observed in multispecific banks of aquatic macrophytes in the Baía River, Upper Paraná River floodplain, in August 2019. In the laboratory and under optical microscopy, reproductive stages (conjugation) were observed in the collected specimens, which made it possible to determine the species taxonomically as *Spirogyra maxima* (Hassall) Wittrock. This species is characterized by the wide variation in the size of vegetative cells, spiral plastids arranged in up to nine ribbons and with small pyrenoids. Zygospores have lenticular morphology of the reticulated wall. The occurrence of this species represents a new citation for the Upper Paraná River floodplain.

Keywords: Baía River, conjugation, green algae, taxonomy

RESUMO – Ocorrência de *Spirogyra maxima* (Zygnematophyceae) na planície de inundação do Alto Rio Paraná. Crescimento em massa de *Spirogyra* Link foi observado em bancos multiespecíficos de macrófitas aquáticas no Rio Baía, Planície de inundação do Alto Rio Paraná, em agosto de 2019. Em laboratório e sob microscopia óptica foi possível observar estágios reprodutivos (conjugação) dos espécimes coletados, o que possibilitou determinar taxonomicamente a espécie como *Spirogyra maxima* (Hassall) Wittrock. Essa espécie é caracterizada pela ampla variação de tamanho de suas células vegetativas, plastos espiralados dispostos em até nove fitas e com pequenos pirenóides. Os zigósporos possuem morfologia lenticular de parede reticulada. A ocorrência desta espécie representa uma nova citação para a planície de inundação do Alto Rio Paraná.

Palavras-chave: Alga verde, Conjugação, Rio Baía, taxonomia

INTRODUCTION

The genus *Spirogyra* Link (Zygnematophyceae, Zygnemataceae) groups filamentous and unbranched macroscopic algae that occur in different freshwater environments (Bicudo & Menezes 2017). The genus, which has a high diversity of species, is easily distinguished from other filamentous algae by the morphology and arrangement of their plastids in the form of a spiral ribbon (Schagerl & Zwirn 2015). The traditional delimitation of species within *Spirogyra* is based on morphology, considering the asexual and sexual stages of the life cycle, including cell size, plastid number and orientation in the cell and type of conjugation of the filaments, in addition to the size, shape, color and ornamentation of the zygospore wall (Transeau 1951, Hoshaw *et al.* 1987). However, reproductive stages are not easily recorded, and the scant knowledge of individuals at the species level has limited a better understand of their distribution and ecology (McCourt *et al.* 1986, Takano *et al.* 2019).

Spirogyra species can grow alone or together with other filamentous green algae forming floating macroscopic masses in the coastal regions of low-flow lentic and/or lotic environments, generally rich in nutrients and in different seasonal periods (Timoshkin *et al.* 2015, Santos & Krupek 2016, Sherwood 2016). They provide ecological responses to the concentration of pollutants in water, and they are therefore used as bioindicator organisms in biomonitoring research (Schneider & Lindstrøm 2009), or for inhibiting cyanobacterial blooms due to their allelopathic potential (Mohamed 2002). Thus, the knowledge of individuals of this genus at the species level is important, since the lack of observation of the reproductive stages makes taxonomic characterization impossible. This means that the real ecology of the species cannot be shown and induces ecological generalizations in data interpretation (Schneider & Lindstrøm 2009).

The objective of the present research is to carry out the morphological characterization of vegetative and reproductive stages of a *Spirogyra* population occurring

in the Upper Paraná River floodplain. It comprises an ecosystem of great ecological importance and, although there has been mainly ecological research with algae in this plain (Dunck *et al.* 2018), individuals from *Spirogyra* have not been reported at the specific level. As it is the last stretch of the Paraná River not yet dammed in Brazilian territory, the floodplain of the upper Paraná River deserves special attention regarding the conservation of biodiversity.

MATERIAL AND METHODS

Sampling was carried out in the Baía River, which is a tributary of the right bank of the Paraná River (22°43' S and 53°17' W). This river is rich in nutrients, especially nitrogen and phosphorus, and shows strong interaction with a large number of lakes connected along its course, in which nutritional exchange takes place (Roberto *et al.* 2009). In addition, due to the low current and small slope of its bed, this river is characterized as semilotic (Souza-Filho & Stevaux 1997).

Spirogyra filaments were collected manually in the water along the river banks, intermingled in multispecific banks of aquatic macrophytes (e.g. *Eichhornia azurea* Kunth, *Nymphaea amazonum* Mart. & Zucc., *Egeria najas* Planch.), in which this alga showed massive growth on 01 September 2019 (Fig. 1). The sample was preserved with Transeau's solution (Bicudo & Menezes 2017).

In the laboratory, morphological and morphometric characteristics of the vegetative and reproductive stages were observed under optical microscopy, using an *Opticam O400S* microscope. Digital images were taken using a *14.0 MPLOPT14003* camera and the software *Image-Pro Premier 9.1.4* for image processing and measurement. Measurements of a total of 50 filaments and 20 zygospores were obtained, and the mean (*M*), median (*Mdn*) and standard deviation (*SD*) calculated.

The identification of the species was based on specialized literature for the genus: Transeau (1951), Brook & Johnson (2002), Ferrer & Cáceres (2017). The current status of the species and the classification system were verified in Algaebase (Guiry & Guiry 2020).



Figure 1. Partial view of collection site where the *Spirogyra* filaments were sampled intermingled in banks of aquatic macrophytes in the Rio Baía, Upper Paraná River floodplain, Brazil. **A.** General view of the habitat; **B.** Close view of *Spirogyra* massive growth; **C.** *Spirogyra* filaments collected from the bank.

RESULTS

Diagnosis

Division Charophyta
 Class Zygnematophyceae
 Order Zygnematales
 Family Zygnemataceae
 Genus *Spirogyra* Link
Spirogyra maxima (Hassall) Wittrock

Figs.2 and 3

Unbranched filaments, vegetative cells varying in size, which can be as long as wide or wider than long, flat end walls. Chloroplasts arranged in spiral ribbon comprising from 6 to 9 per cell and with small pyrenoids. Conjugation scalariform. Conjugation tubes formed by both gametangia. Fertile cells uninflated. Zygospores lenticular with reticulated wall, orange when mature.

Measurements: Vegetative cells 53-145 μm long ($M = 131.5 \mu\text{m}$; $Mdn = 135.5 \mu\text{m}$; $SD = 13 \mu\text{m}$) and 105-152 μm wide ($M = 101.5 \mu\text{m}$; $Mdn = 99 \mu\text{m}$; $SD = 31 \mu\text{m}$).

Zygospores 97-115 μm long ($M = 105 \mu\text{m}$; $Mdn = 103 \mu\text{m}$; $SD = 7 \mu\text{m}$) and 119-145 μm wide ($M = 126 \mu\text{m}$; $Mdn = 125 \mu\text{m}$; $SD = 8 \mu\text{m}$).

Material examined: BRAZIL, PARANÁ AND MATO GROSSO DO SUL, Rio Baía, 09.i.2019, *U.L. Fernandes* (HNUP-17332).

Related taxa: *S. crassiuscula* (Wittrock & Nordstedt) Transeau, *S. heeriana* Nägeli ex Kützing, *S. megaspore* Transeau and *S. submaxima* Transeau.

Distribution: Cosmopolitan, occurring on several continents. In South America it has been registered in Brazil (state of Mato Grosso) (Dias & Bicudo 2006, Freitas & Loverde-Oliveira 2013) and Argentina (Ferrer & Cáceres 2017). North America (Prescott 1962, Drummond *et al.* 2005). Asia (Jao 1988, Barinova & Niyatbekov 2018). Oceania (Day *et al.* 1995). Europe (Brook & Johnson 2002).

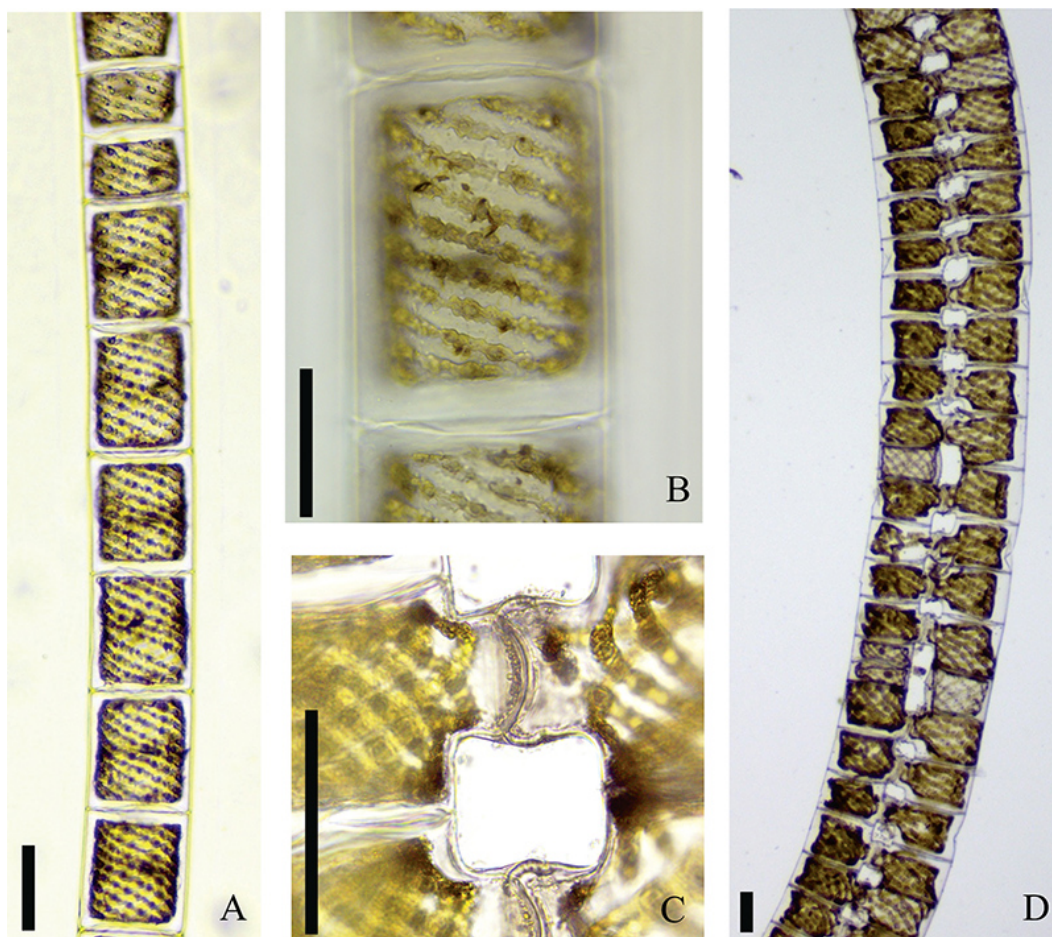


Figure 2. *Spirogyra maxima* (Hassall) Wittrock. **A.** Vegetative filament; **B.** Vegetative cell with detail for the terminal walls; **C.** Detail showing the conjugation tube formed by both gametangia; **D.** Filaments with scalariform conjugation. Bars = 50 μm .

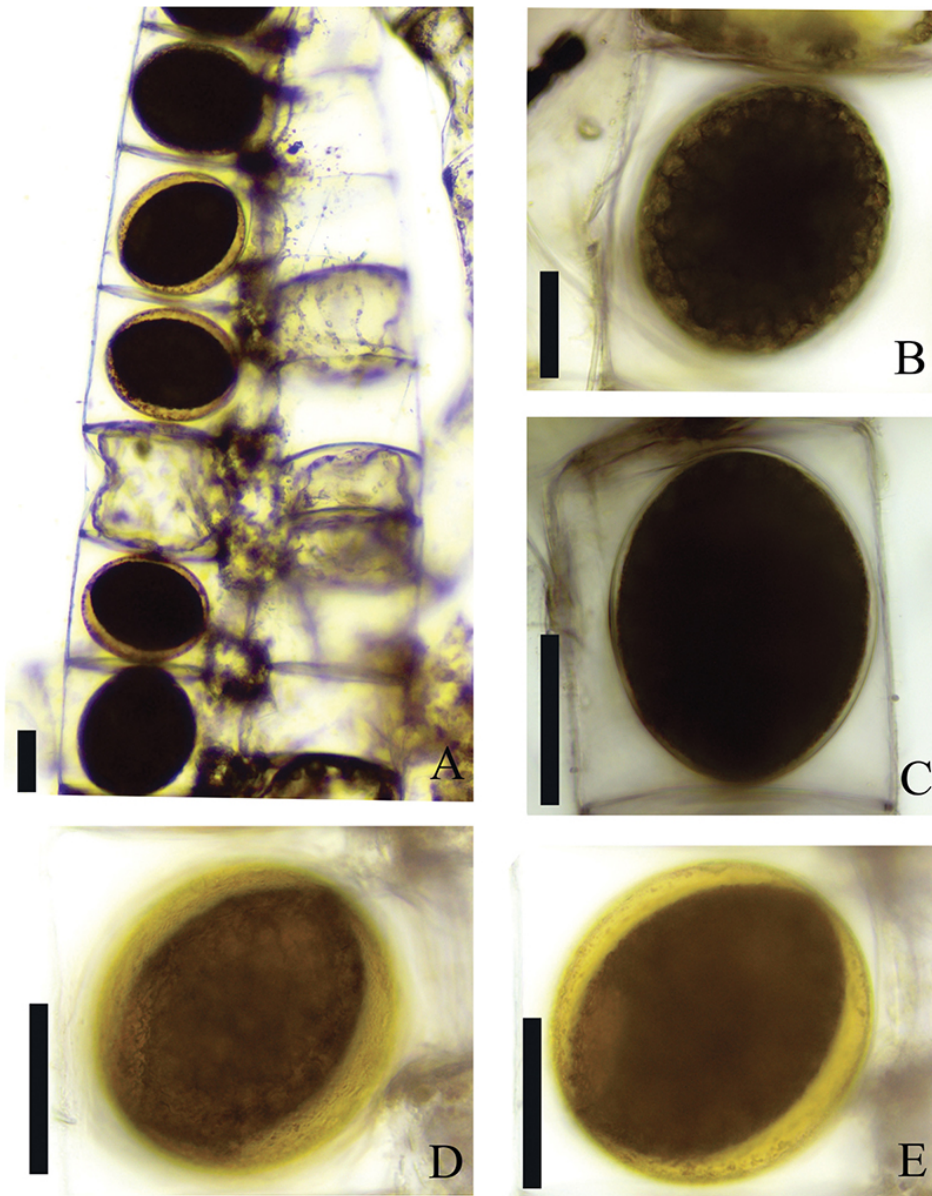


Figure 3. Reproductive stages of *Spirogyra maxima* (Hassall) Wittrock. **A.** Filaments with scalariform conjugation and mature zygospores; **B-C.** Detail of immature zygospores; **D-E.** Details of mature zygospores. Bars = 50 μ m.

DISCUSSION

This study contributes to the addition of a new taxon to the Upper Paraná River floodplain, since *Spirogyra* species are of great importance in this type of environment, usually reported as abundant or well represented in the periphyton (see Dunck *et al.* 2013, Adame *et al.* 2018). None of the specimens of the genus had previously been reported at a specific level for the ecosystems that comprise this floodplain (Dunck *et al.* 2018).

Regarding distribution elsewhere in Brazil, *Spirogyra maxima* has been recorded in the state of Mato Grosso in species lists (Dias & Bicudo 2006, Freitas & Loverde-Oliveira 2013). We believe that this alga possibly has a wider distribution in Brazilian territory, since this species

is considered cosmopolitan and has a record in the most varied ecosystems: lotic environments such as streams (Stancheva *et al.* 2013), lentic environments such as lakes (Simons 1987), puddles (Simons & van Beem 1990) and rice-growing areas (Devi & Panikkar 1994). In limnological terms, this species has been recorded in eutrophic and alkaline environments (Prescott 1962, Simons & van Beem 1990). Based on the ecological requirements listed in the aforementioned research for the occurrence of *S. maxima* and the nutrient availability characteristics that are known for the Baía River (see Roberto *et al.* 2009), this river is a favorable habitat for the mass growth of this alga.

More periodic monitoring to observe the massive growth of *Spirogyra* would certainly provide us with a better taxonomic understanding of this genus and ecology (*e.g.*

distribution and phenological aspects) in the floodplain of the upper Paraná River. It is well known in the literature that these algae show periodic growth: mass growth and observation of the common conjugation process were observed in the months of May and June, registered both for the Netherlands (in spring) (Simons & van Beem 1990) and for Argentina (in autumn) (Ferrer & Cáceres 2017). This species may have a wide niche breadth and the phenological characteristics that show mass growth and conjugation processes are not related only to the season of the year.

In relation to taxonomy, the features of the filament morphology observed here match the morphometric characteristics recorded by Ferrer & Cáceres (2017) for *S. maxima*, mainly the filaments that present cells with varied sizes. Variations in cell sizes have been observed for *S. maxima* in taxonomic studies of different populations around the world (Transeau 1951, Randhawa 1959, Brook & Johnson 2002, Ferrer & Cáceres 2017). Hoshaw *et al.* (1987) points out that this alga can present varied morphotypes, causing changes in conventional cell sizes, attributed to the capacity of this alga to present polyploidy.

Although there is variation in the size of its filaments, *S. maxima* is distinguished from its related taxa by presenting much smaller dimensions than *S. crassiuscula* and *S. megaspore*; or by the ornamentation of the zygospore mesospore wall, which has a smooth wall in *S. submaxima* and a verrucous wall in *S. heeriana* (Transeau 1951). In addition to cell sizes, our examined specimen exhibits the same numbers of plastid strands, which range from 6 to 9, as listed in other works (Transeau 1951, Prescott 1962, Ferrer & Cáceres 2017). The dimensions of the zygospores recorded here match the values recorded by Transeau (1951) and Prescott (1962) for this taxon.

In this study, we characterized the species *S. maxima* based on comparative taxonomic characters such as morphology and measurements in vegetative and reproductive stages, adding photomicrographs that had not previously been taken for this species in the Upper Paraná River floodplain. We conclude that the taxonomic characterization will provide new records of this alga in this floodplain, adding more information regarding its distribution in Brazilian territory.

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