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Research Letter

The Diatom *Anorthoneis dulcis* Hein from Southern Brazil: Morphology and Ecology

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A new geographic locality for *Anorthoneis dulcis* is reported. The paper describes the distribution and relative abundance of *A. dulcis* in Lagoa dos Patos lagoon (a lagoon in Rio Grande do Sul state, Brazil) from samples collected between 2004 and 2005, and shows that this rare species is present all year round. This study extends the species distribution to South America indicating that the species can thrive on sand grains in lentic estuarine, and freshwater areas. It widens the range of tolerance to environmental parameters. The valve fine structure, morphology, and dimensions are in agreement with the original diagnosis.

1. INTRODUCTION

The South American diatom flora is poorly known, and the fine structure issue for South American diatoms has been rarely addressed. On the other hand, proper taxonomic identifications, biogeography, patterns of distribution, and frequency of plants are essential topics for conservation programs.

In the Lagoa dos Patos lagoon (30°23′30″ and 32°10′00″ S; 50°30′00″ and 52°15′00″ W), the benthic diatom flora has revealed several species described for Venezuela and/or Florida, but rarely recorded elsewhere, such as *Amphora tumida* Hustedt, *Desikaneis gessneri* (Hustedt) Prasad and *Desikaneis howellii* Prasad, *Fallacia teneroides* (Hustedt) D.G. Mann, *Fallacia tenera* (Hustedt) D.G. Mann, and *Staurosira obtusa* (Hustedt) Garcia ([1] and unpublished data).

The genus *Anorthoneis* so far includes nine species, *A. dulcis* Hein, *A. eurystoma* Cleve, *A. excentrica* (Donkin) Grunow, *A. hyalina* Hustedt, *A. hummii* Hustedt, *A. minima* Foged, *A. pulex* Sterrenburg, *A. tenuis* Hustedt, and *A. vortex* Sterrenburg. Eight out of these nine species, except *A. dulcis* Hein, are marine and benthic and have been recorded as rare or scarce for several coastal areas (see [2, 3]) except for Sterrenburg [4] who found abundant *Anorthoneis* populations in sediments and on beaches of the North Sea (The Netherlands).

Anorthoneis dulcis Hein was described in 1991 from some rivers in Northern Florida (29°N, USA) as a periphytic species (either adnate or attached to substrate by mucilage stalks) in subtropical waters in the autumn and winter.

Anorthoneis dulcis has also been found in the Kwang River (South Korea, 36°55′N- 129°25′E) by LEE *et al.* [5] on stones at a depth of 30 cm in areas with slightly brackish water and apparently free from major pollution sources (their stations 11 and 12) in spring and summer times. In the stations where *A. dulcis* occurred, the authors also found *Actinocyclus normanii* (Greville) Hustedt and *Rhaphoneis surirella* Ehrenberg, which are brackish/marine species. Their specimens of *A. dulcis* were larger in size and had coarser striae and puncta than specimens in the type material.

The present investigation describes the valve morphology and the fine structure of specimens studied from Southern Brazil. Data on the frequency, distribution in this estuarine area and alongside the Western margin of the Lagoa dos Patos lagoon, and environmental data are also presented.

1.1. Material and methods

The Lagoa dos Patos lagoon is the largest lagoon in Brazil and has a surface area of 9 910 Km^2. The lagoon coastline is essentially composed of unconsolidated Quaternary sediments forming extensive and continuous sandy beaches and sandy

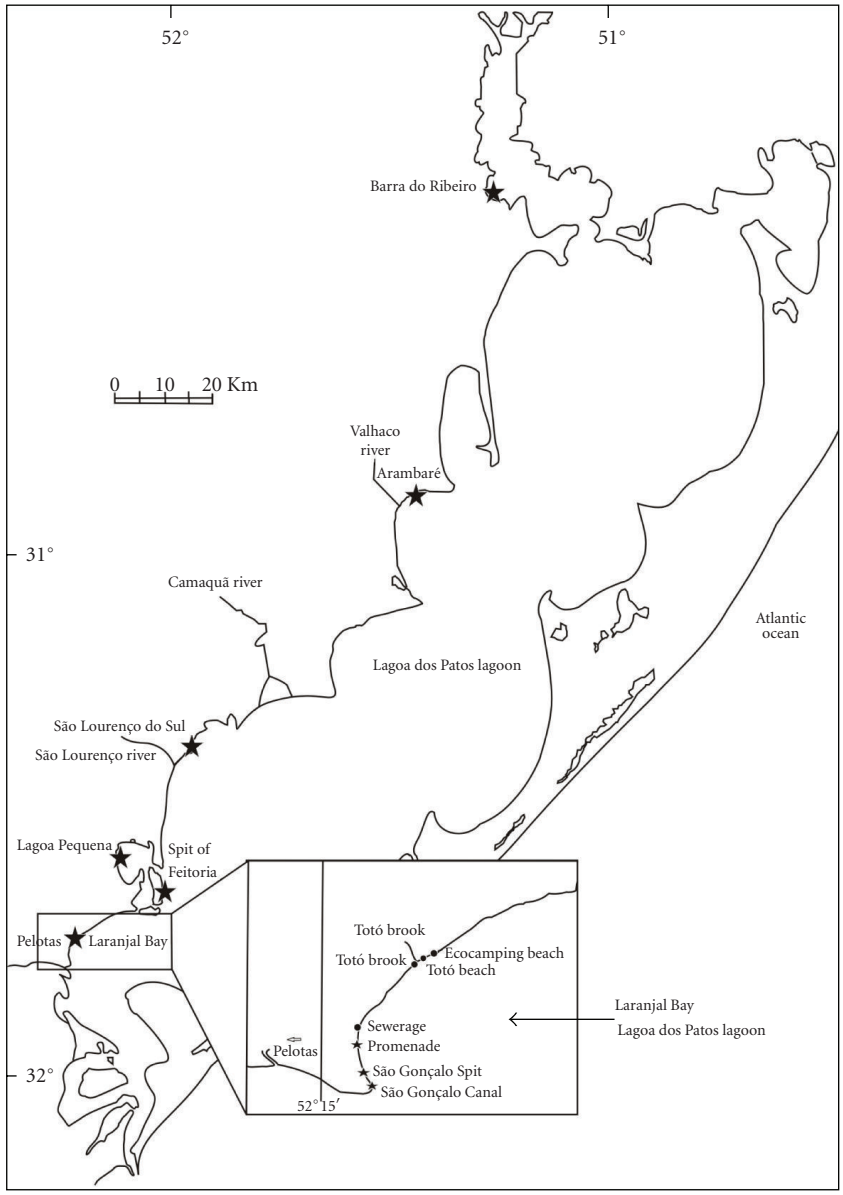

Figure 1: Sampling sites at Lagoa dos Patos lagoon.

spits. Sands along the Western side of the lagoon are poorly sorted, with fine-to-coarse sand grains [6].

Sediment samples were collected from the Lagoa dos Patos lagoon between 2004 and 2005 in several sampling sites: Barra do Ribeiro (three sites), Arambaré (three sites), São Lourenço do Sul (three sites), Feitoria Spit (one site), Lagoa Pequena mouth (one site), and Laranjal Bay (seven sites). In all these sites, the two first millimeters of sand or muddy/sandy surface were collected from the wet areas next to the splash zone (Figure 1). The samples were fixed with Lugol's solution at 0.3%. Fixed material was deposited in the Herbarium of the Department of Botany, Federal University of Pelotas (Rio Grande do Sul, Brazil) with access number ranging from 22858 to 24073. In total, 163 samples were studied.

The sand and mud (only at Lagoa Pequena mouth) samples were cleaned by the method described in Simonsen [7]. Aliquots were dried onto on-cover slips and mounted in Hyrax for permanent slides. For each sample, at least two slides were mounted. Slides were examined with an Olympus BX 40 light microscope with phase contrast. For scanning electron microscopy (SEM), cleaned frustules were dried on a stub, coated with gold at 1 kV for 4 minutes, and examined with Jeol 6060 at an accelerating voltage of 15 or 20 kV.

For samples collected in Laranjal Bay during 2005, 400 valves were counted in permanent slides at 1000× and the abundant species were determined by their frequency. At least two slides per station were observed. For all the slides studied, the whole cover-slip surface was observed under 400× in order to check the occurrence of *Anorthoneis*.

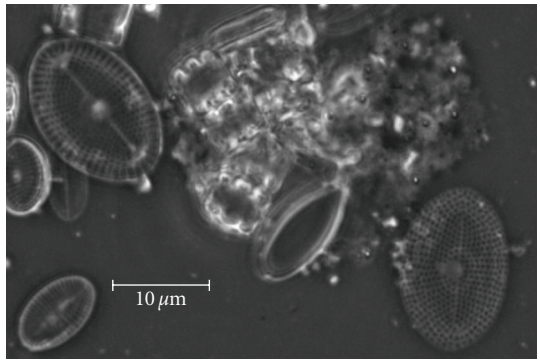

Figure 2: LM. Raphe and rapheless valve.

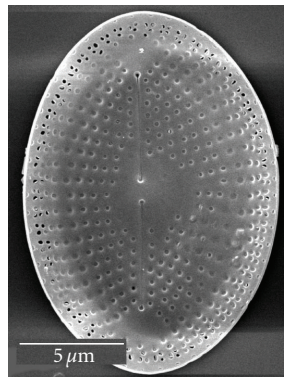

Figure 4: Another raphe valve in external view.

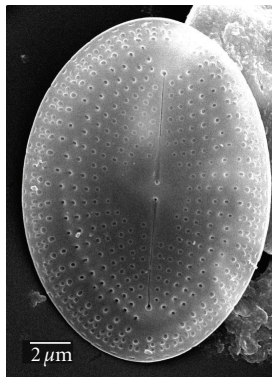

Figure 3: External general view of the raphe valve.

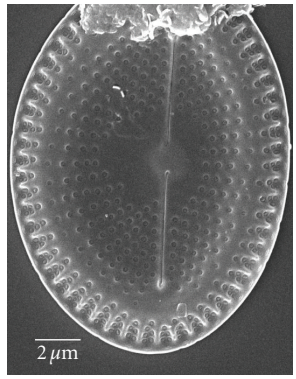

Figure 5: Internal general view of valve.

The conductivity was determined with a Korning CD-55 meter, which measures conductivity between 0 and 2000 μS/cm with 3% error. The pH was determined with na HI 8314 pH meter (Hanna Instruments, Mich, USA). Terminology follows [8, 9].

2. RESULTS

2.1. Observations on the morphology

Anorthoneis dulcis Hein (see [9, Figures 2–21, Figures 2–9])

Dimensions: lenght: 16–18 μm; width: 10–12 μm; striae in 10 μm: 18–20 (22); areolae in 10 μm: 20–23.

Observations in SEM. *Raphe valve*: in SEM, the undulation of the valve face is more noticeable than in LM (see Figure 2). The slightly radiate striae are formed by a single row of round areolae with almost the same size next to the raphe and valve margins. Around the margin, every single stria is composed of two areolae. These areolae vary in shape from circular to elliptical. Around the valve, there is a costa-like thickening at the angle between the valve face and the mantle. This thickening separates the biseriate striae from the small and elongated areolae present along the valve margin (see Figures 3 and 4). The raphe is short, straight, and filiform. The proximal and distal external raphe ends are small and are droplet shaped (see Figures 3 and 4). Internally, the proximal raphe ends in opposite directions and the distal raphe ends have helictoglossae (see Figures 4, 5, 6, and 7). *Rapheless valve*: the striae are radiate and composed of coarse and round areolae (Figure 9). Next to the valve margin, the areolae are variable in shape (see Figure 8) and occasionally biseriate striae are found.

2.2. Distribution and environmetal data

Anorthoneis dulcis was a rare species in Lagoa dos Patos lagoon occurring in a few sites (Table 1) and in very low number. In general, only one or two frustules/valves were observed in each permanent slide analyzed. It is interesting to notice that Barra do Ribeiro and Arambaré are located under strong freshwater water influence.

In Laranjal Bay, from the seven sites studied, *A. dulcis* was observed only in São Gonçalo Spit during 2004 (Table 2), but in 2005 it was found in São Gonçalo Canal, São Gonçalo Spit, and Promenade. The quantitative study of *A. dulcis* at Laranjal Bay revealed that the highest values of the relative frequency observed were between 1.3–1.5% (see Figure 10), although it is a rare species in this Bay.

No seasonal pattern for *A. dulcis* was observed (Table 3). Therefore, it was present throughout the year.

At Lagoa dos Patos lagoon, *A. dulcis* was found at electric conductivity values varying from 100 to 2000 μS/cm areas

Table 1: Samples where *A. dulcis* was recorded alongside Lagoa dos Patos lagoon Western margin with its respective collecting date, electric conductivity, and pH.

Location name	Date	Conductivity (μS/cm)	pH
Barra do Ribeiro (30°18′11′′S–51°17′07′′W)	August 2004	600	6.7
Arambaré (30°55′52′′S–51°30′14′′W)	August 2004	220	6.5
São Lourenço do Sul (31°21′48′′S–51°57′40′′W)	March 2004	1500	8.0
São Lourenço do Sul (31°21′48′′S–51°57′40′′W)	August 2004	220	6.5
Spit of Feitoria/Lagoa Pequena mouth (31°40′36′′S–52°01′52′′W)	April 2004	—	—
São Lourenço do Sul (31°21′48′′S–51°57′40′′W)	March 2005	1090	6.2

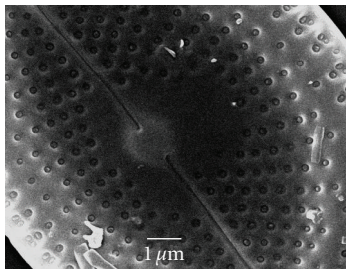

Figure 6: Detail of a valve in internal view showing the proximal raphe endings in opposite directions.

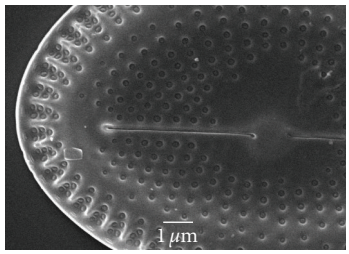

Figure 7: Detail of Figure 5, showing the distal raphe end in helictoglossa.

Table 2: Electric conductivity (μS/cm), pH, and air temperature (°C) of samples collected in 2004 at São Gonçalo Spit.

Month	Conductivity (μS/cm)	pH	Air temperature (°C)
January	179	7.1	27
May	>2000	7.4	17
July	>2000	6.3	21.4
August	>2000	6.7	—
September	1815	6.8	21.5

with freshwater and brackish water influence. The pH during the study period ranged from 6.0 to 8.0 and the temperature ranged from 14ºC to 31ºC.

3. DISCUSSION

Regarding the occurrence, no noticeably seasonality was detected but the previous authors found *A. dulcis* in fall and winter times in Northern Florida. In South Korea, it was present in spring and summer.

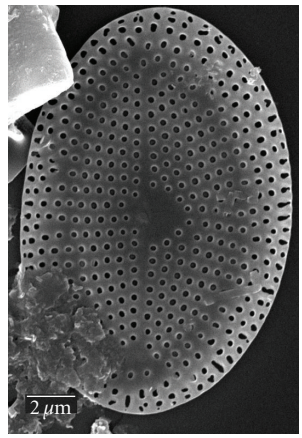

Figure 8: External view of the rapheless valve.

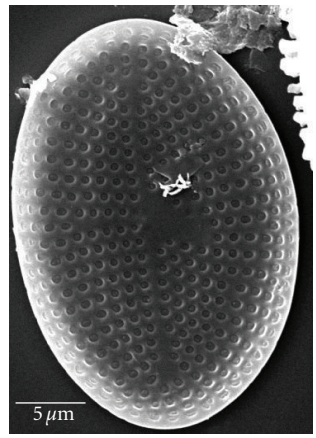

Figure 9: Internal view of the rapheless valve.

Table 4 lists some water characteristics from Florida by Hein [9], from South Korea by Lee *et al.* [5], and this study in Laranjal Bay. These measurements show that *A. dulcis* can thrive over a wider range than originally described. The range of pH in the sampling area in Lagoa dos Patos lagoon is slightly more acid than in Northern Florida and South Korea.

Regarding the dimensions measured, Lee *et al.* [5] found larger specimens than Hein [9], which allows us to extend the dimensions of *A. dulcis* to 21.5 μm (apical apex) and to 16.5 μm (transapical apex).

Table 3: Conductivity (μS/cm), **(pH)** and air temperature (°C) of samples collected in 2005 when *A. dulcis* was present at Laranjal Bay.

	São Gonçalo Spit (31°46′50″S–52°13′18″W)	São Gonçalo Canal (31°47′10″S–52°13′23″W)	Promenade (31°46′28″S–52°13′35″W)
January	>2000 (**6.4**) 31	Not observed	Not observed
March	—(**7.5**)-	Not observed	Not observed
July	128 (**6.5**) 14	Not observed	Not observed
August	134 (**7.0**) 15	105 (**7.7**) 15	774 (**7.0**) 16
September	>2000 (**6.0**) 18.5	1246 (**7.0**) 18.5	Not observed
October	466 (**6.4**) 20	Not observed	466 (**6.4**) 19
November	100 (**7.2**) 23.5	Not observed	Not observed
December	>2000 (**6.7**) 22	Not observed	Not observed

Table 4: Range of water characteristics in some rivers in Northern Florida and Laranjal Bay.

Water characteristics	Florida (EUA)	South Korea	Laranjal Bay
Temperature (°C)	15–27(water)	21.2–23.8(water)	14–31(air)
pH	7.5–8.1	7.8–8.1	6.0–8.0
Electric conductivity (μs/cm)	318–497	432–480	100–2000

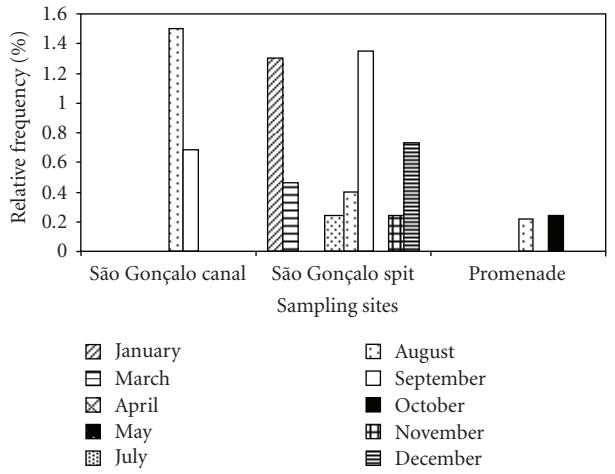

Figure 10: Relative frequency of *A. dulcis* at Laranjal Bay in 2005.

In the estuary of the Lagoa dos Patos lagoon, *A. dulcis* seems to present the pattern of occurrence of most other *Anorthoneis* species, that is, it is being observed in low density, is being registered as scarce and/or seldom, and it lives attached or next to sand grains in marine/estuarine habitats. This pattern was described by Sterrenburg [4], with the notable exception that in his study abundant populations of *Anorthoneis* (*A. vortex* and *A. pulex*) were recorded.

The analysis of more than 55 valves during the period of 2 years of sampling revealed that more than 99% of the valves were not broken or eroded, a phenomenon characteristic of allochthonous diatoms. In addition to this, whole frustules were found in the permanent slides.

In conclusion, *A. dulcis* has a wide global distribution in world occurring in North and South Americas as well as in Asia. It occurs in freshwater (lentic and lotic) habitats as a periphytic diatom in Florida and in Southern Brazil as an epipsammic diatom. On the other hand, in estuarine areas, it occurs in lentic (Brazil) and lotic (South Korea) habitats as an epipsammic and epilithic diatom, respectively.

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