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Diversity and Distribution of Algae in Wetlands of the Rio Grande do Sul, Brazil

Diversidade e distribuição de algas em áreas úmidas do Rio Grande do Sul, Brasil

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Abstract

Surveys of algae diversity and distribution involving the Rio Grande do Sul State was completely unknown. The main goals of this study were to analyze the richness and distribution of the algae genera in wetlands of Rio Grande do Sul and to compare the algal composition among five geomorphologic provinces and between different wetland classes and types. A total of 146 wetlands were sampled within the five geomorphologic provinces of Rio Grande do Sul: Coastal Plain, Central Depression, Cristaline Shield, Highlands and Pampas. One single visit took place in each wetland from March to October 2002. A total of 107 genera of algae were found, distributed along five divisions: Cyanophyta, Heterokontophyta, Dinophyta, Euglenophyta, and Chlorophyta. The highest number of genera was found in Chlorophyta (52). Most of the observed genera presented a sporadic and occasional distribution in the wetlands of Rio Grande do Sul. The wetland algal composition of Cristaline Shield, Central Depression and Pampas was similar. While the planktonic algae were more associated with the aquatic bed vegetation (*Gymnodinium, Scenedesmus* and *Ankistrodemus*), and permanent wetlands (*Dictyosphaerium* and *Ankistrodesmus*), the periphytic algae were more associated with the emergent vegetation (*Oscillatoria* and *Encyonema*), and intermittent wetlands (*Nostoc*). The results showed a high richness and wide geographic distribution of the algae in wetlands of Rio Grande do Sul.

Key words: biodiversity, algae, wetlands, South of Brazil.

Resumo

Estudos sobre a diversidade e distribuição de algas em áreas úmidas do Estado do Rio Grande do Sul eram inexistentes. Os principais objetivos desse estudo foram analisar a riqueza e a distribuição geográfica de gêneros de algas em áreas úmidas do Rio Grande do Sul e comparar a composição entre as cinco províncias geomorfológicas do Estado e entre as diferentes classes e tipos de áreas úmidas. Um total de 146 áreas foi amostrado de março a outubro de 2002 ao longo das cinco províncias geomorfológicas do Rio Grande do Sul: Planície Costeira, Depressão Central, Escudo Cristalino, Planalto e Planalto da

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Campanha. Uma única coleta foi realizada em cada área úmida. Um total de 107 gêneros de algas foi encontrado, estando distribuídos em cinco divisões: Cyanophyta-Cyanobacteria, Heterokontophyta, Dinophyta, Euglenophyta e Chlorophyta. A divisão Chlorophyta apresentou o maior número de gêneros (52). A maioria dos gêneros apresentou distribuição esporádica e ocasional nas áreas úmidas do Estado. A composição de algas entre as áreas úmidas do Escudo Cristalino, Depressão Central e Planalto da Campanha foi similar. Enquanto as algas planctônicas estiveram mais associadas às áreas úmidas herbáceas (*Gymnodinium, Scenedesmus* e *Ankistrodesmus*), e permanentes (*Dictyosphaerium* e *Ankistrodesmus*), as algas perifíticas estiveram mais associadas às áreas úmidas emergentes (*Oscillatoria* e *Encyonema*) e intermitentes (*Nostoc*). Estes resultados mostraram uma alta riqueza e ampla distribuição de algas em áreas úmidas no Rio Grande do Sul.

Palavras-chave: biodiversidade, algas, áreas úmidas, sul do Brasil.

Introduction

The wetlands are important conservation sites because of the extensive rich biodiversity, productivity and functions offered to humanity (Davis *et al.*, 1996; Engenlhardt and Ritchie, 2001; Getzner, 2002). The lack of information regarding biodiversity surveys is a great limitation for the policies oriented to the conservation programs in the Neotropical region. This region is a major contributor to global biodiversity which unfortunately, has been poorly assessed, mainly due to lack of experts able to identify the taxa down to species level (Maltchik and Callisto, 2004). In Brazil, studies of algae diversity in the wetland systems were developed mainly in floodplain systems of Amazonas River (Huszar and Reynolds, 1997), Pantanal Matogrossense (Espíndola *et al.*, 1996; Lima, 1996), Mogi-Guaçu River (Dias, 1991; Taniguchi *et al.*, 2005), Upper Paraná River (Train and Rodrigues, 1997, 1998; Rodrigues and Bicudo, 2001; Rodrigues *et al.*, 2004; Train *et al.*, 2004; Bovo-Scomparin *et al.*, 2005; Fonseca and Rodrigues, 2005), Sinos River (Matsubara *et al.*, 2002; Ávila *et al.*, 2002, 2004) and from several lakes of Coastal Plain in the Rio Grande do Sul (Lobo *et al.*, 1991, 1994). Surveys of algae diversity and distribution in wetland systems at large spatial scale are largely unstudied in Brazil.

The main goals of this study were to analyze the richness and distribution of the algae (genera) in wetlands of Rio Grande do Sul and to compare the algal composition among five geomorphologic provinces and between different wetland classes and types.

Material and methods

Study area

The State of the Rio Grande do Sul is located in southern Brazil and it has an area of 282,184 km^2. The Moist Subtropical Mid-Latitude Climate prevails in this region. The precipitation varies between 1,200 mm and 1,800 mm, and it is relatively well distributed along the year, without the existence of a dry period (Cf – Köppen's climate classification). The mean temperature varies between 15^{o}C and 18^{o}C. The minimum temperature is lower than 10^{o}C in the winter and the maximum temperature is higher than 32^{o}C in the summer (RADAMBRASIL, 1986).

The vegetation is represented by small fragments of forest, temperate and tropical grassland areas. The forest is represented by different major types: temperate summergreen deciduous forest, mixed evergreen-deciduous forest, and temperate mountainous coniferous forest. The grasslands are represented by savanna, steppe, and pioneering formations.

The Rio Grande do Sul State has approximately 3,441 wetlands with an area of flooding of about 30,332 km^2 (10.7% of the total area of the state). Around 72% of the wetlands in the State have an area smaller than 1 km^2 (100 ha) and this percentage rises to 92% when the wetlands with areas under 10 km^2 are included. The distribution of the wetlands in Rio Grande do Sul is heterogeneous and the Coastal Plain, Central Depression and Pampas are the areas with the highest concentration of wetlands (Maltchik *et al.*, 2003).

The State encompasses five geomorphologic provinces: Coastal Plain, Central Depression, Cristaline Shield, Highlands and Pampas. The Coastal Plain covers an extension of 600 km aside the Atlantic Ocean, and the main hydrologic characteristic of this province is the lack of large rivers and the presence of several lagoons distributed along its extension. The Central Depression is located in the central area of the State with altitudes between 250 and 300 m. The Jacuí and Ibicuí rivers are the largest rivers of the Central Depression. The Cristaline Shield is located in the southeastern of Rio Grande do Sul, with an altitude not higher than 600 m. The Highlands is a province located in the North region of Rio Grande do Sul, with altitudes between 1,800 m (E) and 50 m (W). The Pampas is the province located in the Western region of the State, with altitudes of about 300 m (Rambo, 2000).

Sampling methodology

This study was carried out using the Aqua-Rap (Chernoff *et al.*, 1996) as tool, an extension of Rapid Assessment Program for Biodiversity (Mittermeier and Forsyth, 1992) for aquatic ecosystems.

A total of 146 wetlands were sampled in the State of Rio Grande do Sul (Figure 1), distributed within the five geomorphologic provinces (26 in Coastal Plain, 22 in Central Depression, 23 in Cristaline Shield, 62 in Highlands, and 13 in Pampas). One single visit took place in each wetland from March to October 2002. The collection sites were selected according to the following characteristics: access, macrophytes occurrence, wetland type and size, altitude and distribution along the geomorphologic characteristics. The wetlands were aggregated following the classification proposed by Maltchik *et al.* (2004). The studied wetlands were divided into two hydrologic types - permanent (permanently flooded areas) and intermittent (flooded areas at least 4 months of the year) -, and two classes based on the presence and in the life form of the dominant plant species- aquatic bed and emergent. By convention, "dominance" is the coverage of more than 30% of the surface area of a wetland by a plant type (Dennison and Berry, 1993). The wetlands location and altitude were determined using the Global Position System (GPS).

Algae collections were carried out using a water-bottle sampler of 200 ml in the sub-superficial water of the studied wetlands (10 cm water depth). Each wetland was represented by one sample collected in different habitats of the littoral zone (areas of mud, organic debris, rooted macrophytes and dominant vegetation). The samples were fixed *in situ* with 2 ml of formaldehyde, kept in the dark and taken to the laboratory. Subsamples of 10 ml were centrifuged at 1,600 rpm during 15 minutes. Of the sedimented material, five slides per sample were observed using a microscope (400X magnification – Zeiss, Axioplan model). The analysis was carried out with a superior sampling efficiency of 80% (Pappas and Stoermer, 1996).

The material was identified following the general literature and specific to some algal groups (Prescott, 1978; Sant'Anna, 1984; Torgan, 1985; Round *et al.*, 1990; Nogueira, 1991; Sisin, 1994; Velez and Maidana, 1995; Alves-da-Silva and Ávila, 1997; Flores, 1997; Hegewald, 2000; Werner, 2002; Fortes *et al.*, 2003; Bicudo and Menezes, 2005). The classification used for the divisions was based on Hoek *et al.* (1995). The samples are kept in the laboratory of Ecology and Conservation of the Aquatic Ecosystems from UNISINOS.

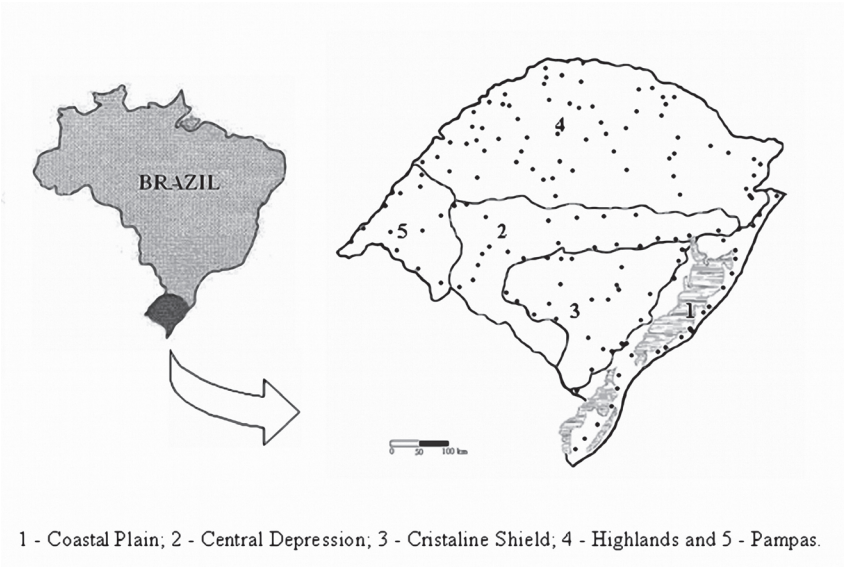

Figure 1. Distribution of the 146 wetlands sampled in Rio Grande do Sul along the five geomorphologic provinces.

Data analyses

The algae richness corresponded to the number of genera in each sampled area. Regarding the algal frequency in the wetlands, the genera were classified into constant (100% of the collections), frequent (99-50%), sporadic (49-10%) and occasional (9-1%) (Ávila *et al.*, 2002). The hierarchical clustering analysis was carried out through the Ward's method (Romesburg, 1984) to recognize the degree of similarity among the five geomorphologic provinces based on the algae genera (presence and absence). The distance metric used between objects was the Percent. The analyses were carried out with the Systat software package (Version 11).

Stepwise discriminant analyses were performed through the SPSS software package (Version 13) to determine if the wetland classes (emergent or aquatic bed) and types (permanent and intermittent) were discriminated by the algae community. Only the genera that occur in 10 or more studied wetlands were included in the discriminant analyses.

Results

A total of 107 genera of algae were found in the wetlands of Rio Grande do Sul State, distributed along five divisions: Cyanophyta-Cyanobacteria, Heterokontophyta, Dinophyta, Euglenophyta and Chlorophyta. The highest richness was found in the Chlorophyta (57), followed by Heterokontophyta-Bacillariophyceae (25) (Table 1).

No genus was classified as constant. The Chlorophyta genera classified as frequent were *Closterium* (81.5%), *Xanthidium* (75%), *Cosmarium* (72%), *Eudorina* (52.7%), *Monoraphidium* (52.7%), *Scenedesmus* (52.7%). Among the Bacillariophyceae, *Nitzschia* (89.7%), *Navicula* (87 %), *Eunotia* (72%), *Frustulia* (67%), *Gomphonema* (61.6%), *Encyonema* (52.7%) and *Stauroneis* (50.7%) were classified as frequent. *Oscillatoria* (61.6%) and *Anabaena* (52%) were the genera of Cyanophyta classified as frequent. The Euglenophyta genera, *Euglena*

(74.6%), *Trachelomonas* (74%) and *Phacus* (56.8%) and the Heterokontophyta genus, *Mallomonas* (52.7%) were classified as frequent in wetlands of Rio Grande do Sul State. However, most of the genera observed (71%) in wetland systems was sporadic and occasional (Table 1).

A total of 72 genera (67.3%) were observed in the five geomorphologic provinces. While *Tetraedron* was observed only in the Cristaline Shield, *Microcystis* and *Chlorella* were observed only in the Coastal Plain, and *Botryococcus, Nostoc* and *Cyclotella* were observed only in the Highlands (Table 1). The highest richness of algae was observed in the Highlands (89), followed by the Coastal Plain (87), the Cristaline Shield (82), the Central Depression (77) and the Pampas (74). *Nitzschia* presented the highest frequency in all geomorphologic provinces (P = 100%, CD = 95.45%, CP = 92.31%, CS = 86.96% e H = 85.48%). While *Closterium* presented high frequency in the Central Depression (95.45%), *Pinnularia* was highly frequent in the Cristaline Shield (86.96%) and the Pampas (100%).

The wetland algal composition was similar among Cristaline Shield and Central Depression. The algal composition among the Pampas, Central Depression and Cristaline Shield was similar, and the algal composition of the Highlands and Coastal Plain was different from the others geomorphologic provinces (Figure 2).

The algal genera discriminated 83.2% of the wetlands, according to the type of vegetation (emergent and aquatic beds) (Wilks'Lambda = 0.509; r = 0.701; P<0.001). *Gymnodinium, Scenedesmus* and *Ankistrodemus* were more associated to aquatic beds, and *Oscillatoria* and *Encyonema* were more associated to emergent wetlands. The lack of *Penium* was associated with the aquatic bed wetlands.

The algal genera discriminated 72.6% of the wetlands, according to hydrology (intermittent and permanent) (Wilks'Lambda = 0.674; r = 0.571; P<0.001). *Ankistrodesmus* and *Dictyosphaerium* were more related to permanent wetlands and *Anabaena* and *Nostoc* were associated with intermittent wetlands. The lack of *Ankistrodesmus* and *Dictyosphaerium* was more related to intermittent wetlands and the lack of *Nostoc* was more associated with permanent wetlands.

Discussion

Chlorophyta, Bacillariophyceae and Cyanobacteria were dominant in the wetlands of five geomorphologic provinces of RS. These findings confirm the results found in the Sinos River basin (Ávila *et al.*, 2002; Matsubara *et al.*, 2002), tropical lakes (Huszar *et al.*, 1990) and in the wetlands of the others Continents (Goldsborough and Robinson, 1996). The Chlorophyta represents one of the most diversified groups of organisms in number of species, morphology (unicellular, filamentous, colony) and habitats (planktonic, benthonic, and periphytic). Our results have possibly been influenced by our collection, since all of them were performed in the littoral zone, where the interaction between sediment, surface water and aquatic plants is intensified due to the low water depth.

Most of the observed genera presented a wide geographical distribution in the wetlands of Rio Grande do Sul. This result demonstrated that the algae community has a high adaptation capacity to different environmental conditions, as mentioned by Round (1981) and Hoek *et al.* (1995).

Several authors showed that the presence or absence of macrophytes influences the algae composition and distribution (Garcia-de-Emiliani, 1997; Donk and Bund, 2002; Takamura *et al.*, 2003). However, surveys that related the vegetation type (emergent and aquatic bed) to the algae composition are scarce. Borics *et al.* (2003) observed the predominance of desmids, diatoms, euglenoids and epiphytic cyanobacteria in wetlands with high macrophyte biomass. Cattaneo *et al.* (1998) observed that the diatoms were more associated with emergent plants in a shallow lake in Italy, while the cyanobacteria were more associated with aquatic bed plants. In wetlands of Rio Grande do Sul, we observed different algae composition among the wetland classes. While the planktonic algae were more associated with the vegetation type aquatic bed (free-floating and rooted), the periphytic algae were more associated with the emergent plants.

Izaguirre *et al.* (2004) regarded that the success of planktonic algae is influenced by several factors, besides hydro-

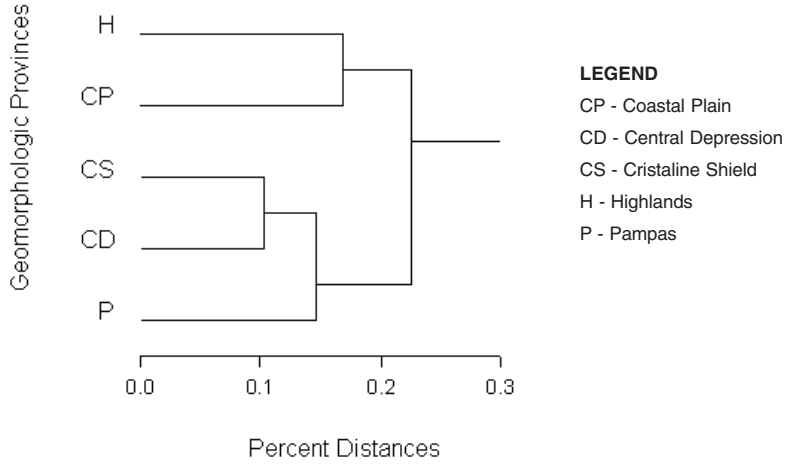

Figure 2. Dendograms based on the composition of the algal genera among the geomorphologic provinces from cluster analyses carried out through the square sum method (minimum variance) using the Percent distance

Table 1. List of the algal genera found in the 146 wetlands (collection sites) distributed along the five geomorphologic provinces (GP, see legend in Figures 1 and 2) in Rio Grande do Sul, and genera frequency in the sampled wetlands.

Division	Genera	Frequency (%)	GP
Cyanophyta	*Anabaena*	52	1,2,3,4,5
	Aphanocapsa	15	1,2,3,4,5
	Aphanothece	11.65	1,2,3,4,5
	Chroococcus	11.65	1,3,4,5
	Coelomoron	11.65	1,2,3,4,5
	Komvophoron	0.68	1
	Leptolyngbya	8.2	1,2,3,4,5
	Merismopedia	11.65	1,2,3,4
	Microcystis	0.68	1
	Nostoc	1.37	4
	Oscillatoria	61.6	1,2,3,4,5
	Phormidium	48	1,2,3,4,5
	Planktolyngbya	22	1,2,3,4,5
	Pseudoanabaena	4.8	1,2,3,4
	Spirulina	11.65	1,2,3,4,5
	Stigonema	8.22	1,2,3,4,5
Heterokonthophyta	*Achnanthes*	26	1,2,3,4,5
	Aulacoseira	31.5	1,2,3,4,5
	Brachysira	25.35	1,2,3,4,5
	Cocconeis	12.32	1,2,3,4,5
	Cyclotella	2	4
	Cymbella	4.8	1,3
	Dinobryon	17.8	1,2,3,4
	Dimerogramma	0.7	4
	Diploneis	26.7	1,2,3,4,5
	Encyonema	52.7	1,2,3,4,5
	Eunotia	72	1,2,3,4,5
	Fragilaria	1.37	1,4
	Frustulia	67	1,2,3,4,5
	Gyrosigma	16.5	1,2,3,4,5
	Gomphonema	61.6	1,2,3,4,5
	Mallomonas	52.74	1,2,3,4,5
	Navicula	87	1,2,3,4,5
	Nitzschia	89.7	1,2,3,4,5
	Pinnularia	83.5	1,2,3,4,5
	Rophalodia	17.8	1,2,3,4,5
	Stauroneis	50.7	1,2,3,4,5
	Stokesiella	2.1	1,2,3
	Surirella	50	1,2,3,4,5
	Synedra	42.5	1,2,3,4,5
	Synura	2.1	1,2,3
Dinophyta	*Gymnodinium*	2	2,4
	Peridinium	46.57	1,2,3,4,5
Euglenophyta	*Euglena*	74.6	1,2,3,4,5
	Lepocinclis	26	1,2,3,4,5
	Peranema	12.33	1,2,3,4,5
	Phacus	56.85	1,2,3,4,5
	Strombomonas	8.22	1,2,3,4
	Trachelomonas	74	1,2,3,4,5
Chlorophyta	*Actinastrum*	4.8	1,2,3
	Actinotaenium	32.2	1,2,3,4,5
	Ankistrodesmus	31.5	1,2,3,4,5
	Arthrodesmus	30.15	1,2,3,4,5
	Bambusina	9.6	1,2,3,5
	Botryococcus	0.7	4
	Bulbochaete	13	1,2,3,4,5
	Chlorella	0.68	1
	Closterium	81.5	1,2,3,4,5
	Coelastrum	24	1,2,3,4,5
	Cosmarium	72	1,2,3,4,5
	Crucigenia	2.74	1,4
	Cylindrocystis	0.68	1
Chlorophyta	*Desmidium*	36.3	1,2,3,4,5
	Dictyosphaerium	39	1,2,3,4,5
	Dimorphococcus	13	1,2,3,4,5
	Docidium	2.74	3,4,5
	Elakatothrix	23.3	1,2,3,4,5
	Euastrum	46.6	1,2,3,4,5
	Eudorina	52.7	1,2,3,4,5
	Eutetramorus	1.37	1
	Geminella	2.74	1,4
	Gloeocystis	23.3	1,2,3,4,5
	Golenkinia	2	1,4
	Gonatozygon	26	1,2,3,4,5
	Kirchneriella	12.3	1,3,4
	Koliella	11	1,2,3,4
	Micrasterias	32.9	1,2,3,4,5
	Monoraphidium	52.74	1,2,3,4,5
	Mougeotia	58.2	1,2,3,4,5
	Nephrocytium	12.33	1,2,3,4,5
	Netrium	28	1,2,3,4,5
	Oedogonium	31.5	1,2,3,4,5
	Onychonema	15	1,2,3,4,5
	Oocystis	35.6	1,2,3,4,5
	Ophiocytium	22.6	1,2,3,4,5
	Pandorina	28	1,2,3,4,5
	Pediastrum	27.4	1,2,3,4,5
	Penium	3.4	1,3,4
	Phytelios	2	4
	Quadrigula	13	1,2,3,4,5
	Scenedesmus	52.74	1,2,3,4,5
	Schroederia	1.37	4,5
	Selenastrum	17.12	1,2,3,4,5
	Sirogonium	16.44	1,2,3,4,5
	Sorastrum	9	1,3,4
	Sphaerocystis	9	1,2,3,4,5
	Sphaerozosma	36.3	1,2,3,4,5
	Spirogyra	32.9	1,2,3,4,5
	Spondylosium	28	1,2,3,4,5
	Staurastrum	41.8	1,2,3,4,5
	Staurodesmus	6.2	2,3,4,5
	Teilingia	17.12	1,2,3,4,5
	Tetraedron	0.68	3
	Volvox	3.42	1,5
	Xanthidium	75	1,2,3,4,5
	Zygnema	39	1,2,3,4,5

logy. Oliveira and Calheiros (2000) related the predominance of Cryptophyceae and Chlorophyceae to the period of high and low waters, respectively. In wetlands of RS, the wetland types were discriminated by the algal composition (permanent and intermittent). While the planktonic algae (*Dictyosphaerium* and *Ankistrodesmus*) were more associated with permanent wetlands, *Nostoc* was more associated with intermittent wetlands. The dominance of *Nostoc* can be due to its benthic habit, providing higher maintenance capacity during the lack of surface water period.

Our results showed a high richness of algae in the wetlands of RS and identified the efficiency of the Aqua-Rap Program as an important tool to know the biodiversity in the Neotropical region. This study revealed that a lot of genera had a wide geographical distribution in wetlands of the RS and that some genera of algae discriminate some wetland classes and types. These results contribute to the knowledge of the diversity and distribution of algae in wetlands of Rio Grande do Sul, however new surveys of diversity of algae at more specific level also should be developed.

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