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ABORDAGEM FLORÍSTICA E QUANTITATIVA DE ÁREAS ÚMIDAS NO SUL DO BRASIL

LUKIEL DOS SANTOS OLIVEIRA

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Dissertação apresentada ao Programa de Pós Graduação em Botânica da Universidade Federal do Rio Grande do Sul como parte dos requisitos para a obtenção do título de Mestre em Botânica.

Orientadora: Maria Cecilia de Chiara Moço
Coorientadora: Ilsi Iob Boldrini

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"A lake is a landscape's most beautiful and expressive feature. It is Earth's eye; looking into which the beholder measures the depth of his own nature."

"The indescribable innocence and beneficence of nature - of sun and wind and rain, of summer and winter - such health, such cheer, they afford forever! and such sympathy have they ever with our race, that all nature would be affected, and the sun's brightness fade, and the winds would sigh humanely, and the clouds rain tears, and the woods shed their leaves and put on mourning in midsummer, if anyone should ever for a just cause grieve. Shall I not have intelligence with the earth? Am I not partly leaves and vegetable mould myself?"

Henry David Thoreau

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SUMÁRIO

INTRODUÇÃO GERAL

Nos últimos tempos, a diversidade e a integridade dos organismos vem sendo ameaçada por diversos fatores, principalmente de origem antrópica. Entre os principais ecossistemas frente às ameaças, estão os ecossistemas aquáticos. Portanto, para discussões e medidas conservacionistas de âmbito internacional, unificaram-se os vários tipos de ecossistemas aquáticos do mundo em uma terminologia ampla (*wetlands*), na convenção de Ramsar (1971). No Brasil, pela diversidade desses ecossistemas e muitas terminologias empregadas regionalmente para caracterizá-los, comumente utiliza-se o termo "áreas úmidas" para referir-se de forma geral a esses ambientes.

As áreas úmidas possuem importância de âmbito cultural, social, ambiental e econômico no Brasil e no mundo. Essas áreas possuem relações bióticas e abióticas particulares responsáveis por muitos serviços ecossistêmicos (Zedler e Kercher 2005), tais como, retenção de carbono, proteção contra alagamentos, purificação da água, habitat para diversas espécies da flora e fauna (Woodward e Wui, 2001; Junk, 1997). Dentre os principais fatores que regem as peculiaridades desses ambientes estão a água, o solo e a vegetação (Medina, 1996).

A vegetação característica das áreas úmidas é constituída pelas macrófitas aquáticas. A utilização desse termo foi proposta por Cook (1974) e adaptada por Irgang e Gastal (1996) em que "macrófitas aquáticas são os vegetais visíveis a olho nu, cujas partes fotossintetizantes ativas estão permanentemente, oupor diversos meses, todos os anos, total ou parcialmente submersas em água doce ou salobra, ou ainda flutuantes na mesma". Para sobreviver aos ambientes aquáticos, essas plantas apresentam várias adaptações morfofisiológicas, por exemplo, redução de xilema, pouca lignificação, heterofilia, e desenvolvimento de aerênquima (Sculthorpe 1967). Algumas espécies desenvolveram adaptações reprodutivas tão especializadas que apresentam distribuição cosmopolita (Barrat-Segretain 1996, Santamaria 2002). Várias funções essenciais para o equilíbrio biótico e abiótico em ecossistemas aquáticos são regidas por essas plantas, por exemplo: alimento e abrigo para muitos animais, regulação de fatores físicos e químicos, redução da velocidade e preservação da qualidade da água (Newman 1991, Srivastava et al. 2008). Meras mudanças na estrutura da vegetação local podem causar sérios impactos nesse ecossistema.

A grande importância ecológica das áreas úmidas em esferas globais e regionais é proporcional à vulnerabilidade a que estes ecossistemas estão submetidos. Somente no último século, em torno de 70% desses ecossistemas tiveram suas áreas reduzidas ou foram completamente destruídas em diferentes áreas do planeta (Gardner et al. 2015). Devido a essa alta taxa de degradação, eles estão entre os ambientes mais ameçados globalmente. Na região sul do Brasil os números são ainda mais alarmantes, aproximadamente 90% das áreas originais foram detruídas nas últimas décadas (Rolon e Maltchik, 2006). Nessa região, esses ecossistemas são confrontados pela deterioração constante através da expansão urbana, atividades agrícolas e desenvolvimento industrial. Consequentemente, medidas de proteção devem ser implementadas e estudos objetivando conhecer esses ecossistemas tornam-se necessários para mitigar futuros prejuízos.

Neste contexto, este trabalho visa contribuir ao conhecimento das macrófitas aquáticas ocorrentes no Sul do Brasil, discutindo padrões regionais florísticos e amostragens quantitativas locais com abordagens conservacionistas.

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Capítulo 1

Aquatic plants of Southern Brazil: checklist and a comparative floristic approach

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Aquatic plants of Southern Brazil: checklist and a comparative floristic approach

Lukiel dos Santos Oliveira[1,2], Bianca Ott Andrade[2], Ilsi Iob Boldrini[2], Maria Cecilia de Chiara Moço[2]

[1] Parte da dissertação de mestrado do primeiro autor no Programa de Pós- Graduação em Botânica, Universidade Federal do Rio Grande do Sul.

[2] Programa de Pós-graduação em Botânica, Universidade Federal do Rio Grande do Sul. Av. Bento Gonçalves 9500, Bloco IV, Prédio 43433, Campus do Vale, Bairro Agronomia, CEP 91501-970, Porto Alegre, RS. lukieloliveira@gmail.com

ABSTRACT

Macrophytes play an integral ecological role in wetlands, supporting species diversity, increasing habitat heterogeneity, and maintaining ecosystem balance. Hence, the knowledge on aquatic plant species and its distribution become essential for wetlands conservation programs. This study deals to assess the richness of macrophytes within Southern Brazil wetlands and their floristic affinities with South America phytogeographical domains. To this end, we developed a checklist of species based on compiling data from floristic lists, regional taxonomic works, and electronic database information available for Southern Brazil wetlands. Further, we compiled checklists of macrophytes of other regions in order to apply cluster analysis and to assess the similarity among them. As a result, we gathered 780 species in 277 genera belonging to 85 families of vascular plants for Southern Brazil. Families with higher species richness were Cyperaceae (128), Poaceae (102), Asteraceae (69), Plantaginaceae (21), Lentibulariaceae (20), and Onagraceae (20). The most representative genera were *Eleocharis* (41) and *Cyperus (24)*. Cluster analysis revealed similarities among Chaco, Pampa, and Atlantic Forest and low similarity among Pantanal, Caatinga and Amazon Rainforest. The significant number of aquatic plant families related to temperate and tropical climates suggests a transition zone between different climate types over the Southern Brazil region. Compiled dataset reveal high biodiversity in Southern Brazil wetlands, providing a baseline for future research and highlighting the need to regional conservation planning efforts.

Key words: species diversity, macrophytes distribution, wetlands conservation

INTRODUCTION

Wetlands are important sites for conservation given their significant role in performing ecological functioning and the ability to support biological diversity (Mitsch and Gosselink, 2015). Although these ecosystems comprise only about 4% of the earth's surface (Mitsch and Gosselink, 2000), they harbor a large fraction of earth's biodiversity and contribute approximately 45% of global environmental services (Costanza et al., 1997; Wittman et al., 2015). Despite their high ecological values, a large number of wetlands have significantly decreased by unsustainable use of resources combined with agricultural and urban expansion (Bergier, 2013; Roque et al., 2016). As one of the consequences, an accelerated decline of biological diversity has been experienced in these ecosystems (Mittermeier, 2004). Extensive conversion and degradation become wetlands the most vulnerable and threatened ecosystems, with between 64 -71% of the world areas destroyed in the last century (Gardner et al., 2015). Larger rates of changes in the area of the natural areas have been evidenced in South America (Davidson, 2014). For instance, in a historical perspective, conservative data indicate that about 90% of the area of wetlands has been lost during the last decades in Southern Brazil.

Within the Brazilian territory, the extent of wetlands is estimated at 20 % of the total area (Neiff, 2001; Junk et al., 2014). Several wetland types, of diverse origins and physiographic characteristic, result of multiple interactions among physical factors (e.g. climate, soil, hydroperiods, hydrogeomorphology, and water chemistry) and biota along Brazil's extension. Aquatic plant communities contribute to this habitat heterogeneity playing key roles in different processes since they are one of the main and often the most conspicuous components of wetland ecosystems. However, species composition and distribution tend to follow patterns influenced by environmental conditions (Cronk and Fennessy, 2001; Pennings, 2014). The primary constraints that explain the distribution of many species of aquatic plants on a global scale include ecological restrictions (in large part climate), the geographical barriers and historical factors (Crow, 1993; Santamaría, 2002). In response to such factors, some aquatic species acquired a set of adaptations (e.g. phenotypic plasticity and reproductive innovations) allowed a wide ecological amplitude and extensive geographical distributions, while other species due to ecological peculiarities of certain regions have distribution confined to a small geographical area. Therefore, within the Brazilian context, the aquatic plant species influenced by environmental factors can vary widely among regions over the vast territory.

From an ecological standpoint, the variations in the distribution, composition, and productivity of aquatic plants are extremely relevant for structure in aquatic ecosystems since they support species diversity (Waters and San Giovanni, 2002; Petry et al., 2003), increase habitat heterogeneity (Hutchens et al., 2004; Thomaz et al., 2010), and maintain ecosystem balance (Carpenter and Lodge, 1986; Engelhardt and Ritchie, 2001). Altogether, information about aquatic plants becomes a necessary prerequisite to implementing conservation policies for wetlands on regional and global scales (Pressey and Adam, 1995; Tiner, 1993; Davison and Finlayson, 2007). Although databases on species numbers in most taxa that occur in South American wetlands are still incomplete, the information concerning aquatic plant biodiversity has increased over the last decades, mainly in Southern Brazil (Padial et al., 2008; Wittman et al., 2015). However, only a few studies have focused on grouping it, hence, the information is still scattered in different sources, making it difficult to access or use.

Due to integrating ecological role in highly threatened environments, the knowledge of species diversity and its distribution become essential to establish a biodiversity baseline to implement wetland conservation practices. Therefore, in the present study, we compile the available floristic data from wetlands in Southern Brazil and then, we compare with other macrophytes checklists of South American regions. With this dataset, we sought patterns of species distribution within Southern Brazil wetlands and its floristic affinities with South America phytogeographical domains. We addressed the following questions: (i) what is the number of species recorded for the Southern Brazil? (ii) How strong are the floristic links between wetlands found in Southern Brazil (Pampa and Atlantic Forest) with others South American regions such as Pantanal, Caatinga, Amazon Rainforest, and Argentinian Chaco? We briefly discuss some possible implications for results and pointed knowledge gaps for future researches.

MATERIAL AND METHODS

The geographical range covered by this work comprises the Southern Brazil region, which includes state of Paraná (PR), Santa Catarina (SC), and Rio Grande do Sul (RS). The natural vegetation of the region is characterized by the coexistence of two phytogeographic domains: Atlantic Forest and Pampa.

Atlantic Forest occupies the eastern slopes and valleys of the south Brazilian plateau, from the northeast of Rio Grande do Sul to the coastal plain and highland slopes of Santa Catarina and Paraná (Overbeck et al., 2007). Different types of forest are found under distinct climatic conditions and grasslands form isolated patches within this forested landscape (Andrade et al., 2016).

Pampa occupies the southern half of the Rio Grande do Sul and it is restricted to this state in Brazil. The predominant vegetation is natural grasslands that cover continuous areas. Forests tend to occur mostly restricted to rivers.

The climate zone in Southern Brazil is humid subtropical with an oceanic climate without a dry season, with areas characterized by hot (Cfa Köppen’s) and temperate summers (Cfb Köppen’s). Cfa climate type covers 63% of the region and occurs at altitudes lower to 500m (RS) and 700m (PR). Cfb type includes the coldest regions in Brazil and occupies remaining of territory where the altitude (or temperature) limits Cfa (37%) (Alvares et al., 2013). Both climate types cover mainly the southern states in Brazil. Annual precipitation ranges from 1050mm to 2050mm (INMET, 2016).

Conceptualizing Macrophytes

In this study, we employed a general conceptualization under the terms ‘macrophytes’ or ‘aquatic plants’. According to Barrat-Segretain et al. (1996), the term 'macrophyte' is widely used and frequently treated as a synonym for 'aquatic plant'; however, it does not refer to any strict taxonomic definition. We adopted these terms to refer to palustrine plants, hydrophytes, wetland plants or any other nomenclature attributed to vegetation occurring in the water-saturated environment. This concept agrees with that by Irgang and Gastal (1996) adapted from Cook (1974), wherein macrophytes are “plants in which photosynthetically active parts are permanently or for several months of the year totally or partially submersed in freshwater or floating in aquatic habitats".

There is a semantic discussion related to the terminology used in this plant group for a long time due to the complexity and different environment types in which the species occur. Therefore, some of the species recorded in our bibliographical compiled list are also found in well-drained soils and may create doubts regarding to their classification; however, we gave credibility to the studies' authors in which (1) all species recorded were classified by life forms and indicated by the authors of the study as macrophytes, or (2) the environment was classified by the authors as wetland. Nevertheless, eventual taxa with doubtful taxonomy were removed.

Data source and methods

The species data set of Southern Brazil was based on the compilation of studies (published and gray literature) carried out between the years 1984 and 2015. We consulted books, national and international scientific papers, and additionally, Ph.D. and master's thesis that specifically contained floristic lists of vascular plants in wetlands in Southern Brazil. We also added information from taxonomic studies of families that possess aquatic plants and supplemented by species gathered through the electronic dataset of the Brazil Flora Group (BFG, 2015), that is still under construction. Here, we used as filters the region, the phytogeographical domains Pampa and Atlantic Forest, and preference for the aquatic environment.

The data set of Southern Brazil consists of 35 floristic lists and 17 taxonomic studies, totaling 52 consulted sources (as seen in Appendix S1- Supporting information). For similarity analysis, we used checklists of macrophytes of other Brazilian phytogeographical domains as Caatinga (Moura Júnior et al., 2013), Pantanal (Pott and Pott, 1997) and Amazon Rainforest (Moura Júnior et al., 2015). We also included an Argentinian area "Iberá wetlands" belonging to the Argentinian Chaco (Arbo et al., 2002). There is no dataset or checklist of aquatic plants available for the Cerrado domain. However, according to some authors (Pott et al., 2011; Cunha et al., 2016), the Pantanal is inside to Cerrado phytoecological domain and Cerrado vegetation predominates in a great part of the areas in the Pantanal. For these reasons, Cerrado was not included in our analysis.

After data compilation, we checked the nomenclature and taxonomy of the Southern Brazil species list using the Missouri Botanical Gardens' Tropicos website (http://www.tropicos.org) and the families' classification in the systems proposed by APG IV (2016) for angiosperms, and Smith et al. (2008) for ferns. The checking and updating process were also accomplished with the list of other regions. Exotic species, infraspecific taxa or non-confirmed taxonomic entities were excluded from the analysis (92 taxa). The plant species reported to the Rio Grande do Sul had their distribution confirmed in the Global Biodiversity Information Facility (GBIF; http://www.gbif.org) since in this state are found two phytogeographical domains (Pampa and Atlantic Forest).

Data analysis

To evaluate vegetation similarity among different phytogeographic domains, we used a matrix of binary data containing the presence (1) and absence (0) of species. Thereafter, for exposition and better interpretation of the results, we conducted an agglomerative dendrogram analysis (Legendre and Legendre, 2012). The Agglomerative techniques begin with clustering the most similar sites and aggregating these into still larger clusters until there is a single cluster containing all sites (Roleček et al., 2009). This analysis was performed using UPGMA (average linkage) and as similarity measure the Sørensen index (1948), using the vegan package (Oksanen et al., 2013) in R 3.2.0 (www.r-project.org). The Sørensen's coefficient quantifies the dissimilarity in species composition, i.e. values approximate to 1 (one) show little species correlation and values close to 0 (zero) show species composition almost identical (similarity).

RESULTS

The states which presented the highest number of floristic studies were Rio Grande do Sul (57%), Paraná (29%) and Santa Catarina (14%). Concomitant to the highest number of studies, these states also had the highest number of species, with 555, 444, and 395, respectively.

Regarding phytogeographical domains in Southern Brazil, the number of species restricted to Pampa was 9% and for Atlantic Forest 43%, while 48% of species showed a wide occurrence.

Floristic lists contributed to 624 species, while taxonomic studies contributed with 41 species. The filter selection accomplished in Flora do Brasil website found 305 species, among which only 115 species were additions to the checklist based on the 52 sources. The final list, thus included 780 species of aquatic plants for Southern Brazil (Appendix 2) belonging to 277 genera and 85 families. The most representative families on the number of species were Cyperaceae (128), Poaceae (102), Asteraceae (69), Plantaginaceae (21), Lentibulariaceae (20), Onagraceae (20), Rubiaceae (19), Eriocaulaceae (18), Fabaceae (18), and Xyridaceae (17), recording 55% of the overall species in this region. 24 families (4% of overall plant species) were represented by one species only. The most representative genera were *Eleocharis* and *Cyperus* with 41 and 24 species, respectively.

Considering the frequency of occurrence, 44% of species were recorded in only one compiled source, while 49% were reported between 2 and 10, and 6% was recorded between 11 and 19 sources. Few species were recorded in 20 or more sources, such as *Hydrocotyle ranunculoides* L.f., *Nymphoides indica* (L.) Kuntze, *Myriophyllum aquaticum* (Vell) Verdc., *Polygonum punctatum* Elliott, *Polygonum hydropiperoides* Michx., *Typha domingensis* Pers., *Eichhornia azurea* Sw. (Kunth) and *Pontederia cordata* L. The families with the most frequent species were Cyperaceae, Poaceae, Asteraceae, Polygonaceae, Onagraceae, Pontederiaceae, Araceae, Lentibulariaceae, Alismataceae and Juncaceae.

Taking into account the compiled sources for Southern Brazil and the other regions of Southern America, 1443 species were gathered for cluster analysis.

The phytogeographical domains in decrescent order of macrophytes richness were Atlantic Forest (only Southern region) (707 spp.), Amazon Rainforest (515), Pampa (405), Caatinga (372), Argentinian Chaco (349), and Pantanal (220).

The dendrogram built using the Sørensen’s index showed distinction among the phytogeographic domains (Fig.1). The first group was formed by Amazon Rainforest, Pantanal and Caatinga wherein only 55 species were shared among them, representing low indices of similarity.

In the second group, Argentinian Chaco clustered two other subgroups, one composed by Pampa and Atlantic Forest RS (28% dissimilarity), and another formed by Atlantic Forest SC and Atlantic Forest PR (36% dissimilarity). Pampa and Atlantic Forest RS had the highest similarity.

Overall, 589 species were shared among different domains (Fig.1). From the total species compiled, 26 species (2%) occurred in all domains, while 828 (57%) had exclusive occurrence.

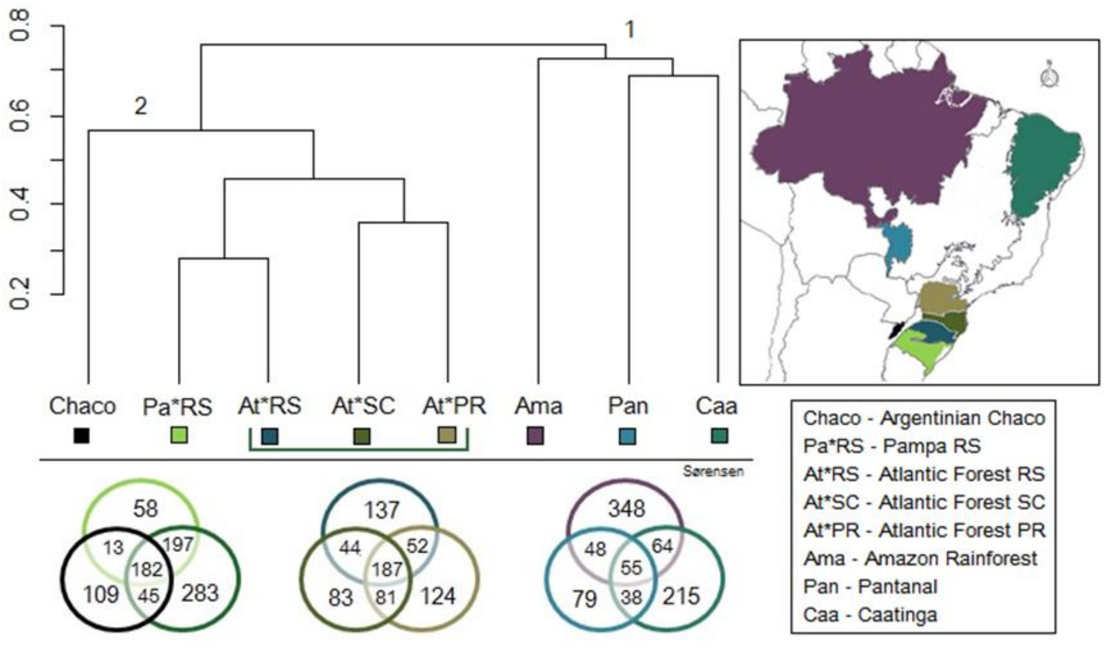

Fig.1. Dendrogram produced by group averaging of Sørensen’s index presenting floristic similarity for species of the eight regions. Each color represents a domain or region and the dissimilarity’s coefficients are written between 0.2 and 0.8. The Venn’s diagram shows the regions, and the number of restricted and shared species. Map shows each domain/region. RS = Rio Grande do Sul state, SC = Santa Catarina state, PR= Paraná state.

DISCUSSION

Concerning our large data set of wetlands, the Southern Brazil revealed a high number of macrophytes. These findings were previously reported in regional studies accomplished by Irgang and Gastal (1996), which estimated between 400 and 500 species for the coast of Rio Grande do Sul. According to these authors, this is due to the variation of the aquatic environment factors which allows macrophytes a wide phytogeographic distribution. Environmental factors such as light, temperature, substrate, water nutrient, and water flow act as habitat filters that may influence species distribution and abundance across the landscape (Poff, 1997). In addition, the site conditions and habitat heterogeneity are crucial factors for plant species richness in wetland ecosystems (Shi et al., 2010). The habitat heterogeneity hypothesis assumes a correlation between an area and the number of different habitats, as well as that different habitats host a different array of species (Drakou et al., 2009; Williams, 1964). In this sense, the macrophytes diversity in Southern Brazil is hypothesized to have resulted from the large variability of habitats in the region (e.g. lakes, wet grasslands, ponds, lagoons, floodplains, marshes).

Furthermore, the presence of ecological gradients and two major phytogeographic domains - Atlantic Forest and Pampa – along the region may be other relevant factors for the number of species found. The total number of species recorded in Southern Brazil was higher than in other regions, even comparing Atlantic Forest and Pampa separately to other domains. However, the sampling effort was not controlled in either compiled source and thus, it is important to observe that, inferences should be viewed with caution (Ferreira et al., 2011; Magurran, 2013).

Of the total number of species, a high number (44%) was recorded in only one compiled source. A certain percentage comprises species with more restricted distribution provided by the compilation of taxonomic works. Furthermore, a high percentage is due to the fact that many species reported in the sources have a difficult distinction as to their habitat. This occurs because a variety of plants exhibit so great plasticity in responses to water dynamics that it is difficult to draw a demarcation between aquatic and terrestrial plants, and thus, to determine the outer boundary of a wetland (Lavania et al., 1990; Barret et al., 1993; Crow and Hellquist, 2006).

Families recorded with the higher number of species in Southern Brazil (Cyperaceae, Poaceae) were also among the richest families in checklists of other regions. Possible explanations for the high occurrence of these families may be related to success in the dispersion of sexual propagule (Santamaria, 2002) and also, given their cosmopolitan distribution with relevant morphological and ecological amplitude in their taxa. Poaceae and Cyperaceae are among the most abundant families of wetland plants (Keddy, 2000; Sieben et al., 2010). They tend to dominate wetlands due to the presence of rhizomes, tubers and stolons that allow them spreading vegetatively (Goetghebeur, 1998).

Cyperaceae is often recorded in floristic and ecological studies in Brazilian wetlands and in many other studies in the Neotropical region (Leon and Young, 1996; Ritter, 2004; Kutschker et al., 2014). It is a monocotyledons' family with greatest diversity in humid and semihumid tropics (Goetghebeur, 1998) so, its influence reflects in the most highly represented genera in this study - *Eleocharis* and *Cyperus*, which are cosmopolitan genera and are among the most species-rich of Cyperaceae in Brazil (Govaerts, 2016; Alves et al., 2009).

As is known, climatic differences of tropical and temperate zones are limiting in species distribution. Although many aquatic plants are restricted to very broad climatic regions, their distribution reflects to some extent this zonation (Santamaría, 2002). In a study addressing latitudinal patterns in aquatic angiosperms, Crow (1993) pointed some families with strong tropical affinities (e.g. Hydrocharitaceae, Limnocharitaceae, Mayacaceae, Nymphaeaceae, Podostemaceae, Eriocaulaceae, Pontederiaceae, Xyridaceae), families with temperate affinities (e.g. Potamogetonaceae, Juncaginaceae, Haloragaceae and Elatinaceae), and another well represented in both latitudes (e.g. Lentibulariaceae). In the same context, Pott and Pott (1997) pointed some families that do not occur in the Pantanal (e.g. Juncaginaceae and Juncaceae) but occur in Southern Brazil because of subtropical and temperate climates covering the southern region. This distinction between the tropical and temperate aquatic floras was also assigned to climatic barriers in a study conducted by Jacobs and Wilson (1996). It is interesting to note that all these families mentioned as tropical and temperate affinities were gathered in our checklist. Furthermore, some tropical families are among the families with the highest number of species (Xyridaceae, Lentibulariaceae and, Eriocaulaceae).

Those families indicated with temperate affinities (like Juncaginaceae, Juncaceae and Potamogetonaceae) are represented by a few species in Brazil; however, the vast majority of species have their restricted distribution in the south. For instance, Juncaginaceae family has two species in Brazil (Sobral, 2015), which both were recorded in our study. Similarly, Juncaceae is represented by 22 species in Brazil (Alves, 2015), of these, 16 species were gathered in this checklist, mainly in the Pampa domain (13 spp.). Potamogetonaceae family has a high diversity in North America and Europe; however, it is represented by 13 species in Brazil (Bove, 2015), of which 10 species occur in the south.

Tropical and temperate zones are not defined by abrupt changes in physical conditions (e.g. climate and temperature). There is a gradual transition where features are mixed and, in some extent, the species-distribution responses to this gradient. In this context, the significant number of families with tropical affinities and temperate families with diversity restricted to the south of Brazil reflect a transitional zone between tropical and temperate climates over Southern Brazil region. From an evolutionary viewpoint, transition zones deserve special attention because they represent areas of intense biotic interaction (Morrone, 2009). Hence, it can explain the high number of species found and highlight the need for conservation approaches in wetlands of Southern Brazil.

The cluster analysis based on wetland species revealed distinct distribution patterns among domains. Group1 had low similarity and was composed by Amazon Rainforest, Pantanal, and Caatinga. This group agrees, in part, with previous studies wherein Northern and Northeast regions were grouped (Moura Júnior et al., 2015; Ferreira et al. (2011). However, in these same studies, Pantanal was grouped with the Paraná River floodplain (Moura Júnior et al., 2015; Ferreira et al. (2011). For a better explanation of our study, other wetlands were included in addition to the Paraná River in the state of Paraná. Consequently, this state may have been grouped with Santa Catarina as the Atlantic Forest encompasses both states.

The low similarities suggest floristic particularities among Amazon Rainforest, Pantanal and Caatinga. The Pantanal is often called the “pantanal complex” due to its vegetation mosaic with elements of the major nearby vegetation types: Cerrado, Chaco and Amazonian Forest (Prance and Schaller, 1982). The floristic particularities associated to Amazon rainforests have already been reported by Junk (1986) whereas few aquatic plants are adapted to extreme hydrological conditions of the region and are unable to disperse over long distances.

Group 2 jointed Southern Brazil domains/regions with the Argentinian Chaco. This is not surprising given the number of species shared among them and their geographical proximity. In a general context, this result is in accordance with Morrone

(2013) in which Pampa domain is related with Chaco domain, and also, the assumption of Irgang and Gastal (1996) which Uruguay, Argentina, Paraguay and south of Brazil form a phytogeographic unit regarding aquatic plants.

Considerations

An unexpected diversity of macrophytes for southern Brazil was hereby evidenced. The total number of species probably will increase as new species are discovered, taxonomic revisions are undertaken, and new inventories are conducted in the region. In this context, it is necessary to intensify collection efforts, for instance, in Santa Catarina state, and in the Rio Grande do Sul state (mainly Pampa domain) wherein a shortage of floristic inventories was identified. Some possible explanations for the lack of inventories in wetlands are their remote location, the limited mobility in water, and also the difficulty of identifying and collecting submerged species. In addition, seasonality has a great importance for inventories in wetland ecosystems. For instance, it must be recognized that, for many species, a reliable determination of plant identity will require flowering and/or fruiting material (Crow and Hellquist, 2006); however, many species are restricted only to underground organs during adverse times (e.g. dry or flood season) and thus, they can easily be overlooked in floristic inventories. Furthermore, the identification of such plant group is often hampered by poor taxonomic knowledge. Taxonomic studies are essential to increase the information on restricted species that are not commonly found in floristic studies and also, to understand the relationships between geographical variants and species. In southern Brazil, taxonomic studies of macrophytes are scarce and relatively old, but they contributed significantly in the number of species to this list and should, therefore, be highlighted. Future studies should be developed pointing out areas not yet inventoried and priority for conservation, and taxonomic revisions associating species distribution in this transitional tropical/temperate climate zone in southern Brazil.

This checklist provided a synthesis of knowledge of the plant species diversity in Southern Brazil wetlands. Lists like this, enumerating plants that occur in wetlands, have been used for over two decades in the United States. The US national list of wetland plant species was generated from regional lists aiming to identify wetland indicator plants and helping to determine the presence of these ecosystems (Tiner, 1993;

Tiner, 2006). In addition, it served as the basis for scientific discussion on edge species in wetlands since that distinguishing limits between ecosystems can be difficult. In Southern Brazil, as well as the rest of the country, there is a lack of information due to the outdated methods used concerning this sum, and also the intense degradation of these threatened ecosystems, making it difficult to keep track of their species. Considering international experience as a reference, this study can serve as a starting point for conservation discussions and implementation of protection policies in legislation.

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Appendix 1. Bibliographies used to elaborate the checklist of aquatic plants of Southern Brazil and sources used to compare with other South American regions.

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Appendix 2. Checklist of aquatic plants of Southern Brazil, frequency of species and phytogeographic occurrence. Pa=Pampa, af=Atlantic forest.

Family/Species	(pa)	RS (af)	SC (af)	PR (af)	Rel. Freq.
Acanthaceae					
Hygrophila costata Nees	+	+	+	+	0,48
Hygrophila guianensis Nees ex. Benth	+	+	-	+	0,33
Justicia comata (L.) Lam	-	+	-	+	0,11
Justicia laevilinguis (Nees) Lindau	+	+	-	-	0,15
Alismataceae					
Echinodorus floribundus (Seub.) Seub.	-	+	+	+	0,04
Echinodorus grandiflorus (Cham. & Schltr.) Micheli	+	+	+	+	0,62
Echinodorus longiscapus Arechav.	+	-	-	-	0,22
Echinodorus macrophyllus (Kunth) Micheli	-	-	+	-	0,04
Echinodorus paniculatus Micheli	-	-	-	+	0,04
Echinodorus reptilis Lehtonen. S.	+	-	-	-	0,04
Echinodorus scaber Rataj	-	-	-	+	0,04
Echinodorus uruguayensis Arechav.	+	+	+	+	0,04
Helanthium bolivianum (Rusby) Lehtonen & Myllys	-	+	+	-	0,04
Helanthium tenellum (Martius) Britton	+	+	+	+	0,29
Hydrocleys nymphoides (Willd.) Buchenau	+	+	+	+	0,29
Limnocharis flava (L.) Buchenau	-	-	-	+	0,04
Sagittaria guayanensis Kunth	-	-	+	-	0,04
Sagittaria lancifolia L.	+	-	-	-	0,07
Sagittaria montevidensis Cham. & Schltdl.	+	+	+	+	0,66
Sagittaria rhombifolia Cham.	-	+	+	+	0,07
Alstroemeriaceae					
Alstroemeria isabelleana Herb.	-	-	-	+	0,04
Amaranthaceae					
Alternanthera aquatica (D.Parodi) Chodat	-	-	-	+	0,04
Alternanthera brasiliana (L.) Kuntze	+	-	-	-	0,07
Alternanthera philoxeroides (Mart.) Griseb	+	+	+	+	0,69
Alternanthera reineckii Briq.	+	-	-	+	0,07
Alternanthera tenella Colla	-	-	-	+	0,04
Atriplex montevidensis Spreng.	+	-	-	-	0,04
Atriplex undulata (Moq.) Dietr.	-	+	-	-	0,04
Gomphrena elegans Mart.	-	-	-	+	0,04
Amaryllidaceae					
Crinum americanum L.	-	+	+	+	0,11
Hippeastrum angustifolium Pax	+	+	-	-	0,04
Hippeastrum breviflorum Herb.	-	+	+	-	0,04
Hippeastrum santacatarina (Traub) Dutilh	-	+	+	+	0,04
Nothoscordum gracile (Aiton) Stearn	+	+	-	-	0,07
Nothoscordum montevidense Beauverd	+	-	-	-	0,07

Apiaceae					
Bowlesia incana Ruiz & Pav.	+	+	-	-	0,04
Eryngium balansae H.Wolff	+	+	-	-	0,04
Eryngium chamissonis Urb.	+	-	+	+	0,04
Eryngium ebracteatum Lam.	+	+	+	+	0,15
Eryngium eburneum Decne.	+	+	-	-	0,18
Eryngium ekmanii H. Wolff	-	-	-	+	0,07
Eryngium floribundum Cham. & Schltdl.	+	+	+	-	0,07
Eryngium mesopotamicum Pedersen	+	-	+	-	0,15
Eryngium pandanifolium Cham. & Schltdl.	+	+	-	-	0,40
Lilaeopsis attenuata (Hook. & Arn.) Fernald	-	+	+	-	0,18
Lilaeopsis brasiliensis (Glaz.) Affolter	+	+	+	+	0,18
Lilaeopsis carolinensis J.M. Coult. & Rose.	+	+	-	-	0,22
Lilaeopsis tenuis A. W. Hill	-	+	+	+	0,07
Apocynaceae					
Rhabdadenia madida (Vell.) Miers	+	+	-	+	0,15
Araceae					
Landoltia punctata (G.Mey.) Les & D.J.Crawford	-	-	+	+	0,04
Lemna aequinoctialis Welw.	+	+	+	-	0,11
Lemna minuta Kunth	+	+	+	+	0,29
Lemna valdiviana Phil.	+	-	+	+	0,62
Pistia stratiotes L.	+	-	+	+	0,62
Spathicarpa lanceolata Engl.	-	+	-	-	0,04
Spirodela intermedia W. Koch	+	-	+	+	0,44
Wolffia brasiliensis Wedd.	-	+	-	+	0,40
Wolffia columbiana Karsten	+	-	+	-	0,11
Wolffiella lingulata (Hegelm.) Hegelm.	+	-	-	+	0,18
Wolffiella oblonga (Phil.) Hegelm.	-	+	+	+	0,48
Araliaceae					
Hydrocotyle bonariensis Lam.	+	+	-	+	0,33
Hydrocotyle leucocephala Cham. & Schldtl.	-	-	+	+	0,07
Hydrocotyle ranunculoides L.f.	+	-	+	+	0,88
Hydrocotyle verticillata Thunb.	+	-	+	+	0,33
Asteraceae					
Achyrocline alata (Kunth.) DC.	+	-	+	-	0,07
Achyrocline satureioides (Lam.) DC.	-	-	+	-	0,04
Ageratum conyzoides L.	+	-	+	+	0,18
Aspilia pascalioides Griseb.	+	+	-	+	0,07
Austroeupatorium inulaefolium (Kunth.) R.M.King & H.Rob.	-	-	-	+	0,04
Austroeupatorium picturatum (Malme) R.M.King & H.Rob.	-	-	-	+	0,04
Baccharis articulata (Lam.) Pers	+	+	-	-	0,04
Baccharis breviseta DC.	-	-	+	-	0,04
Baccharis crispa Spreng.	+	+	+	-	0,18
Baccharis megapotamica Spreng.	-	-	+	-	0,04
Baccharis microcephala (Less.) DC.	+	+	-	-	0,22
Baccharis penningtonii Heering	+	-	-	-	0,07

Baccharis sagittalis (Less.) DC.	+	+	-	-	0,04
Baccharis spicata (Lam.) Baill.	+	+	+	-	0,22
Baccharis vulneraria Baker	-	-	-	+	0,04
Baccharis weirii Baker	+	+	-	-	0,04
Barrosoa betonicaeformis (DC.) R.M.King & H.Rob.	-	-	-	+	0,04
Barrosoa candolleana (Hook. & Arn.) R.M. King. & H. Rob.	-	-	-	+	0,04
Bidens laevis (L.) Britton et al.	+	-	+	+	0,33
Campovassouria cruciata (Vell.) R.M.King & H.Rob	-	-	+	-	0,04
Campuloclinium purpurascens (Sch. Bip.) R.M. King & H.Rob.	-	-	-	+	0,04
Chrysolaena simplex (Less.) Dematt.	-	-	+	-	0,04
Conyza bonariensis (L.) Cronquist	+	+	-	-	0,07
Conyza pampeana (Parodi) Cabrera	+	-	-	-	0,04
Cotula coronopifolia L.	+	+	-	-	0,11
Eclipta elliptica DC.	+	+	-	-	0,07
Eclipta megapotamica (Spreng.) Sch.Bip. ex S.F.Blake	+	+	-	-	0,18
Eclipta prostrata (L.) L.	+	+	+	+	0,40
Elephantopus mollis Kunth	+	+	-	+	0,07
Enydra anagallis Gardner	+	-	+	+	0,48
Erechtites hieracifolius (L.) Raf. ex DC	+	-	-	-	0,07
Erigeron maximus (D. Don) Otto ex DC.	-	-	-	+	0,07
Erigeron tweediei Hook. & Arn.	-	-	-	+	0,04
Eupatorium serratum Spreng.	-	-	+	-	0,04
Eupatorium serrulatum DC.	+	+	-	-	0,04
Eupatorium subhastatum Hook. & Arn.	+	-	-	-	0,04
Eupatorium tremulum Hook. & Arn.	+	-	-	-	0,04
Eupatorium tweedieanum Hook. & Arn.	+	-	-	-	0,04
Gamochaeta americana (Mill.) Wedd.	+	+	+	-	0,07
Gamochaeta filaginea (DC.) Cabrera	+	+	-	+	0,07
Gamochaeta pensylvanica (Willd.) Cabrera	-	-	-	+	0,04
Gymnocoronis spilanthoides DC.	+	-	-	-	0,15
Hypochaeris lutea (Vell.) Britton	+	+	-	+	0,07
Jaegeria hirta (Lag.) Less.	+	+	+	+	0,22
Leptostelma catharinensis (Cabrera) A.M. Teles & Sobral	-	-	+	-	0,04
Leptostelma maximum D. Don	-	-	+	-	0,04
Lessingianthus cataractarum (Hieron.) H.Rob.	-	+	-	-	0,04
Lessingianthus glabratus (Less.) H. Rob.	-	-	+	+	0,07
Mikania cordifolia (L.f.) Willd.	+	+	-	+	0,11
Mikania micrantha Kunth	+	+	-	+	0,18
Mikania periplocifolia Hook. & Arn.	+	-	-	-	0,15
Picrosia longifolia D. Don	+	+	-	-	0,11
Pluchea oblongifolia DC.	-	-	-	+	0,04
Pluchea sagittalis (Lam.) Cabrera	+	+	+	+	0,40
Porophyllum lanceolatum DC.	-	-	+	-	0,04
Pterocaulon balanse Chodat	+	+	-	-	0,04
Senecio bonariensis Hook. & Arn.	+	+	-	-	0,29
Senecio grisebachii Baker	+	-	-	-	0,11

Senecio heterotrichius DC.	+	-	-	-	0,04
Senecio icoglossus DC.	+	+	-	-	0,07
Senecio juergensii Mattf.	-	+	-	+	0,26
Senecio selloi (Spreng.) DC.	+	+	-	-	0,07
Senecio tweediei Hook. & Arn.	+	-	-	-	0,18
Sonchus oleraceus L.	-	-	-	+	0,04
Sphagneticola trilobata (L.) Pruski	-	+	+	-	0,04
Stevia veronicae DC.	-	-	+	-	0,04
Symphyotrichum graminifolium (Spreng.) G.L.Nesom	-	-	+	-	0,04
Symphyotrichum squamatum (Spreng.) G.L.Nesom	+	+	-	-	0,18
Trixis lessingii DC.	-	-	+	-	0,04
Begoniaceae					
Begonia cucullata Willd.	+	+	+	-	0,29
Begonia fischeri Schrank	-	-	+	+	0,07
Blechnaceae					
Blechnum brasiliense Desv.	+	+	-	+	0,07
Blechnum schomburgkii (Klotzsch) C.Chr.	-	-	+	-	0,04
Blechnum serrulatum Rich.	+	+	-	+	0,11
Boraginaceae					
Euploca procumbens (Mill.) Diane & Hilger	+	-	+	+	0,11
Brassicaceae					
Cardamine bonariensis Pers.	+	+	-	+	0,15
Cardamine chenopodiifolia Pers.	+	-	-	-	0,04
Burmanniaceae					
Burmannia australis Malme	+	+	-	-	0,04
Burmannia flava Mart.	-	+	-	-	0,04
Cabombaceae					
Cabomba aquatica Aubl.	-	-	-	+	0,04
Cabomba caroliniana A. Gray	+	+	+	+	0,37
Cabomba furcata Schult. & Schult. f.	+	+	+	+	0,11
Campanulaceae					
Lobelia aquatica Cham.	-	-	-	+	0,04
Lobelia camporum Pohl	-	+	+	+	0,04
Lobelia hassleri Zahlbr.	-	-	-	+	0,07
Lobelia hederacea Cham.	+	-	+	+	0,33
Lobelia nummularioides Cham.	-	-	+	-	0,04
Siphocampylus verticillatus (Cham.) G.Don.	-	-	+	+	0,07
Cannaceae					
Canna glauca L.	+	+	-	-	0,11
Caryophyllaceae					
Cerastium glomeratum Thuill.	+	+	-	-	0,07
Cerastium humifusum Cambess.	+	-	-	-	0,07
Ceratophyllaceae					
Ceratophyllum demersum L.	+	+	+	+	0,26
Cleomaceae					
Cleome trachycarpa Klotsch ex Eichler	+	-	-	-	0,07

Tarenaya hassleriana (Chodat) Iltis	+	+	+	+	0,15
Tarenaya spinosa (Jacq.) Raf.	-	-	-	+	0,04
Commelinaceae					
Commelina diffusa Burm. F.	+	+	+	+	0,51
Commelina erecta L.	+	+	-	+	0,18
Commelina obliqua Vahl	+	+	+	+	0,04
Commelina platyphylla Klotzsch ex Seub.	+	-	-	-	0,04
Commelina schomburgkiana Klotzsch ex Seub.	-	-	-	+	0,04
Floscopa glabrata (Kunth) Hassk.	+	+	+	+	0,40
Murdannia nudiflora (L.) Brenan	-	+	+	+	0,04
Tradescantia fluminensis Vell.	-	-	-	+	0,04
Tripogandra diuretica (Mart.) Handlos	+	+	+	+	0,07
Tripogandra glandulosa (Seub.) Rohweder	+	-	+	+	0,07
Tripogandra serrulata (Vahl) Handlos	+	-	-	-	0,04
Convolvulaceae					
Ipomoea alba L.	-	-	-	+	0,07
Ipomoea cairica (L.) Sweet	+	+	-	+	0,18
Ipomoea carnea (Mart. ex. Choisy) D.F. Austin	-	-	-	+	0,04
Ipomoea fimbriosepala Choisy	+	-	-	-	0,04
Ipomoea indivisa (Vell.) Hallier f.	+	+	-	-	0,07
Crassulaceae					
Crassula peduncularis (Sm.) Meigen	+	+	+	-	0,04
Cucurbitaceae					
Cayaponia podantha Cogn.	-	-	-	+	0,04
Cyclanthera hystrix (Gill.) Arn.	-	-	-	+	0,04
Cymodoceaceae					
Halodule wrightii Asch.	-	-	+	+	0,04
Cyperaceae					
Ascolepis brasiliensis (Kunth) Benth. ex. C.B.Clarke	+	+	+	-	0,11
Becquerelia muricata Nees	-	+	-	-	0,04
Bolboschoenus robustus (Pursch) Soják	+	+	+	+	0,11
Bulbostylis capillaris (L.) C.B.Clarke	+	+	-	+	0,18
Carex albolutescens Schwein.	-	+	-	-	0,04
Carex bonariensis Desf. ex Poir.	+	+	-	+	0,11
Carex brasiliensis A. St-Hil.	-	-	-	+	0,07
Carex chilensis Brongn.	+	-	-	-	0,04
Carex feddeana H.Pfeiff.	+	+	+	-	0,07
Carex longii (Kük.) Luceño & M.Alves	+	+	-	-	0,11
Carex polysticha Boeckeler	+	+	+	-	0,11
Carex purpureovaginata Boeckeler	-	+	+	+	0,11
Cladium jamaicense Crantz	+	+	+	+	0,11
Cladium mariscus (L.) Pohl.	+	+	+	+	0,07
Cyperus aggregatus (Willd.) Endl.	+	+	-	+	0,11
Cyperus cellulosoreticulatus Boeckeler	+	+	-	-	0,04
Cyperus corymbosus Rottb.	+	+	-	-	0,04
Cyperus digitatus Roxb.	-	+	-	+	0,04

Cyperus distans L.	+	+	-	-	0,04
Cyperus eragrostis Lam.	+	+	-	-	0,07
Cyperus giganteus Vahl	+	+	+	+	0,37
Cyperus haspan L.	+	+	+	+	0,48
Cyperus hermaphroditus (Jacq.) Standl.	+	+	+	+	0,40
Cyperus imbricatus Retz.	+	-	-	-	0,11
Cyperus intricatus Schrad. ex Schult.	+	+	-	+	0,29
Cyperus iria L.	+	+	+	+	0,04
Cyperus laxus Lam.	-	-	-	+	0,07
Cyperus luzulae (L.) Retz.	+	+	+	+	0,48
Cyperus mundtii (Nees) Kunth	-	-	-	+	0,07
Cyperus odoratus L.	+	+	+	+	0,48
Cyperus pohlii (Nees) Steud.	+	+	+	+	0,07
Cyperus prolixus Kunth	+	+	-	-	0,11
Cyperus rigens C.Presl	+	+	-	+	0,33
Cyperus sphacelatus Rottb.	-	+	-	-	0,04
Cyperus squarrosus L.	+	-	-	-	0,04
Cyperus surinamensis Rottb.	+	+	+	+	0,22
Cyperus virens Michx.	+	+	-	+	0,18
Eleocharis acutangula (Roxb.) Schult.	+	+	+	+	0,33
Eleocharis angustirostris R. Trevis. & Boldrini	+	-	-	-	0,04
Eleocharis atrobrunnea R. Trevis. e S. González	-	+	-	-	0,04
Eleocharis bicolor (Chapm.)	-	+	+	+	0,07
Eleocharis bonariensis Nees	+	+	+	+	0,26
Eleocharis capillacea Kunth	-	-	+	+	0,04
Eleocharis contracta Maury	-	-	+	-	0,04
Eleocharis debilis Kunth	-	-	+	+	0,04
Eleocharis dunensis Kük.	+	-	-	+	0,07
Eleocharis elegans (Kunth) Roem. & Schult.	+	-	+	-	0,11
Eleocharis elongata Chapm.	-	-	+	-	0,04
Eleocharis filiculmis Kunth	+	-	-	+	0,15
Eleocharis flavescens (Poir.) Urb.	+	+	+	+	0,22
Eleocharis geniculata (L.) Roem & Schult.	+	+	+	+	0,15
Eleocharis interstincta (Vahl.) Roem. & Schul.	+	+	+	+	0,37
Eleocharis jelskiana Boeckeler	-	-	-	+	0,04
Eleocharis kleinii Barros	-	+	+	+	0,07
Eleocharis laeviglumis R. Trevis & Boldrini	+	+	+	+	0,07
Eleocharis loefgreniana Boeckeler	-	+	+	+	0,04
Eleocharis maculosa (Vahl.) Roem & Schult.	+	+	+	+	0,37
Eleocharis minima Kunth	+	+	+	+	0,37
Eleocharis montana (Kunth) Roem. & Schult.	+	+	+	+	0,37
Eleocharis montevidensis Kunth	+	-	+	-	0,07
Eleocharis mutata (L.) Roem. & Schult.	-	-	+	+	0,04
Eleocharis nana Kunth	-	+	+	+	0,15
Eleocharis neesii R. Trevis. & Boldrini	+	-	-	-	0,04
Eleocharis niederleinii Boeckeler	+	+	+	+	0,18

Eleocharis nudipes (Kunth) Palla	+	+	+	+	0,11
Eleocharis obtusetrigona (Lindl. & Nees) Steud.	+	+	+	+	0,26
Eleocharis parodii Barros	+	-	-	-	0,04
Eleocharis parvispicula R.Trevis. & Boldrini	-	-	-	+	0,04
Eleocharis pauciglumis R. Trevis. & D. J. Rosen	-	-	+	-	0,04
Eleocharis plicarhachis (Griseb.) Svenson	-	-	-	+	0,04
Eleocharis rabenii Boeckeler	-	+	+	+	0,11
Eleocharis radicans (Poir.) Kunth	-	+	+	+	0,15
Eleocharis riograndensis R. Trevis. & Boldrini	-	-	+	+	0,04
Eleocharis sellowiana Kunth	+	+	+	+	0,40
Eleocharis squamigera Svenson	-	+	+	+	0,04
Eleocharis subarticulata (Nees) Boeckeler	+	+	+	+	0,26
Eleocharis urceolatoides R. Trevis. & Boldrini	+	-	-	-	0,04
Eleocharis viridans Kük ex. Osten	+	+	-	+	0,18
Fimbristylis autumnalis (L.) Roem & Schult.	+	+	-	+	0,26
Fimbristylis complanata (Retz.) Link	-	-	-	+	0,04
Fimbristylis dichotoma (L.) Vahl	+	+	-	-	0,18
Fimbristylis spadicea (L.) Vahl	+	+	-	-	0,04
Fimbristylis squarrosa Vahl	+	-	-	+	0,11
Fuirena incompleta Nees	+	+	+	+	0,11
Fuirena robusta Kunth	-	+	+	+	0,11
Fuirena umbellata Rottb.	-	+	+	+	0,04
Isolepis cernua (Vahl) Roem. & Schult.	+	-	-	-	0,04
Kyllinga odorata Vahl	+	+	-	+	0,37
Kyllinga pumila Michx.	+	+	-	+	0,07
Kyllinga vaginata Lam.	+	+	-	-	0,15
Lipocarpha humboldtiana Nees	+	+	+	+	0,15
Oxycaryum cubense (Poepp. & Kunth) Lye	+	+	+	+	0,40
Pycreus lanceolatus (Poir.) C.B.Clarke	+	+	+	+	0,37
Pycreus megapotamicus (Kunth) Nees	+	+	-	-	0,22
Pycreus niger (Ruiz & Pav.) Cufod.	+	+	-	+	0,07
Pycreus polystachyos (Rottb.) P.Beauv.	+	+	-	-	0,22
Pycreus tener C.B.Clarke	+	-	-	-	0,15
Pycreus unioloides (R.Br.) Urb.	-	-	+	-	0,04
Rhynchospora asperula (Nees) Steud.	+	+	+	+	0,18
Rhynchospora barrosiana Guagl.	+	+	-	-	0,07
Rhynchospora brasiliensis Boeckeler	-	+	+	+	0,04
Rhynchospora brittonii Gale	+	-	-	-	0,11
Rhynchospora conferta (Nees) Boeckeler	+	-	+	+	0,04
Rhynchospora confinis (Nees) C.B.Clarke	+	+	-	-	0,04
Rhynchospora corymbosa (L.) Britton	+	+	+	+	0,59
Rhynchospora emaciata (Nees) Boeckeler	-	-	+	-	0,04
Rhynchospora gigantea Link	+	+	+	-	0,11
Rhynchospora gollmeri Boeckler	-	-	-	+	0,04
Rhynchospora holoschoenoides (Rich.) Herter	+	+	+	+	0,18
Rhynchospora junciformis (Kunth) Boeckeler	-	-	+	-	0,04

Rhynchospora marisculus Lindl. & Nees	+	+	+	+	0,18
Rhynchospora nervosa (Vahl.) Boeckler	-	-	+	-	0,04
Rhynchospora organensis C.B.Clarke	+	-	-	-	0,04
Rhynchospora robusta (Kunth) Boeckeler	+	+	+	+	0,04
Rhynchospora rostrata Lindm.	+	+	-	-	0,07
Rhynchospora rugosa (Vahl) Gale	+	+	+	+	0,11
Rhynchospora tenuis Link	+	+	+	-	0,07
Rhynchospora velutina (Kunth) Boeckeler	+	+	-	-	0,04
Schoenoplectiella supina (L.) Lye	-	+	+	-	0,07
Schoenoplectus americanus (Pers.) Volkart	+	-	+	-	0,07
Schoenoplectus californicus (C.A.Mey.) Soják	+	+	+	+	0,59
Schoenoplectus tabernaemontani (C.C.Gmel.) Palla	+	-	+	+	0,04
Schoenus lymansmithii M.T.Strong	-	-	+	-	0,04
Scleria distans Poir.	+	+	-	-	0,19
Scleria gaertneri Raddi	+	-	-	+	0,07
Scleria leptostachya Kunth	-	-	+	-	0,04
Dennstaedtiaceae					
Pteridium arachnoideum (Kaulf.) Maxon	+	+	-	-	0,04
Droseraceae					
Drosera brevifolia Pursh	+	+	-	-	0,15
Drosera communis A.St.-Hil.	-	+	+	+	0,04
Drosera montana A.St.-Hil.	-	-	+	-	0,04
Drosera villosa A.St.-Hil.	-	-	+	+	0,04
Elatinaceae					
Elatine lindbergii Rohrb.	-	+	+	+	0,04
Elatine triandra Schkuhr	+	-	-	-	0,04
Equisetaceae					
Equisetum giganteum L.	+	+	+	-	0,22
Ericaceae					
Agarista nummularia (Cham. & Schldlt) G. Don.	+	+	-	-	0,04
Eriocaulaceae					
Eriocaulon arechavaletae Herter	+	-	-	-	0,04
Eriocaulon candidum Moldenke	-	+	-	-	0,04
Eriocaulon crassiscapum Bong.	-	+	+	+	0,04
Eriocaulon elichrysoides Bong.	-	-	-	+	0,04
Eriocaulon gomphrenoides Kunth	-	+	+	+	0,07
Eriocaulon leptophyllum Kunth	+	+	-	-	0,04
Eriocaulon ligulatum (Vell.) L.B.Sm.	-	-	+	+	0,07
Eriocaulon magnificum Ruhland	+	+	+	-	0,15
Eriocaulon megapotamicum Malme	-	+	-	-	0,04
Eriocaulon modestum Kunth	+	+	+	+	0,26
Eriocaulon reitzii Moldenke & L.B.Sm.	-	-	+	-	0,04
Eriocaulon sellowianum Kunth	-	-	+	+	0,04
Eriocaulon ulaei Ruhland	-	-	+	-	0,04
Eriocaulon vaginatum Körn.	-	-	-	+	0,04
Paepalanthus caldensis Malme	-	-	-	+	0,04

	Syngonanthus caulescens (Poir.) Ruhland	-	-	+	+	0,07
	Syngonanthus chrysanthus (Bong.) Ruhland	+	+	-	-	0,04
	Syngonanthus fischerianus (Bong.) Ruhland	-	-	+	+	0,04
Euphorbiaceae						
	Caperonia castaneifolia (L.) A.St-Hil.	-	-	-	+	0,07
	Caperonia linearifolia A.St.-Hil.	+	-	-	-	0,07
	Euphorbia hirta L.	-	-	+	-	0,04
	Sapium haematospermum Müll.Arg.	+	-	-	+	0,07
Fabaceae						
	Adesmia latifolia (Spr.) Vogel	+	+	-	-	0,04
	Aeschynomene denticulata Rudd	+	+	+	+	0,15
	Aeschynomene montevidensis Vogel	-	-	-	+	0,04
	Aeschynomene rudis Benth.	+	-	+	+	0,04
	Aeschynomene sensitiva Sw.	+	+	-	+	0,07
	Clitoria falcata Lam.	+	+	-	-	0,04
	Desmodium triarticulatum Malme	-	-	+	-	0,04
	Erythrina cristagalli L.	+	+	-	-	0,40
	Indigofera sabulicola Benth.	+	+	-	-	0,04
	Mimosa bimucronata (DC.) Kuntze	+	+	-	-	0,26
	Mimosa pigra L.	-	-	-	+	0,07
	Mimosa pudica L.	-	-	+	-	0,04
	Sesbania punicea (Cav.) Benth.	+	+	+	+	0,37
	Sesbania virgata (Cav.) Pers.	+	+	-	-	0,07
	Stylosanthes viscosa (L.) Sw.	-	-	+	-	0,04
	Vigna lasiocarpa (Mart.ex Benth.) Verdc.	-	-	-	+	0,04
	Vigna longifolia (Benth.) Verdc.	+	+	-	-	0,18
	Vigna luteola (Jacq.) Benth.	+	+	-	-	0,29
Gesneriaceae						
	Sinningia elatior (Kunth) Chautems	+	+	-	-	0,04
Haloragaceae						
	Laurembergia tetrandra (Schott) Kanitz	+	+	+	+	0,22
	Myriophyllum aquaticum (Vell) Verdc.	+	+	+	+	0,84
	Myriophyllum quitense Kunth	+	+	-	-	0,11
	Proserpinaca palustris L.	-	+	+	-	0,15
Hydrocharitaceae						
	Egeria densa Planch.	+	-	+	+	0,40
	Egeria najas Planch.	+	-	-	+	0,26
	Limnobium laevigatum (Humb. & Bonpl. ex Willd.) Heine	+	-	-	+	0,40
	Najas conferta (A.Braun) A.Braun	+	-	-	+	0,18
	Najas guadalupensis (Spreng.) Magnus	+	-	+	-	0,18
	Najas microcarpa K.Schum.	-	-	-	+	0,04
	Ottelia brasiliensis (Planch.) Walp.	-	-	-	+	0,04
Hydroleaceae						
	Hydrolea spinosa L.	+	+	+	+	0,29
Hypericaceae						
	Hypericum brasiliense Choisy	-	-	+	+	0,15

Hypericum rigidum A. St.-Hil.	-	-	+	+	0,11
Iridaceae					
Cypella aquatilis Ravenna	-	+	+	+	0,04
Phalocallis coelestis (Lehm.) Ravenna	+	+	+	-	0,07
Sisyrinchium commutatum Klatt	+	-	-	+	0,07
Sisyrinchium micranthum Cav.	+	+	+	-	0,11
Sisyrinchium palmifolium L.	+	+	-	+	0,07
Sisyrinchium rambonis R.C.Foster	-	-	-	+	0,07
Sisyrinchium restioides Spreng.	-	-	-	+	0,04
Sisyrinchium vaginatum Spreng.	+	+	+	+	0,15
Isoetaceae					
Isoetes brasiliensis H.P.Fuchs	+	-	-	-	0,04
Isoetes maxima Hickey, Macluf & Link-Pérez	-	+	-	-	0,04
Isoetes mourabaptistae J.B.S. Pereira et al.	-	+	-	-	0,04
Isoetes quiririensis J.B.S. Pereira & Labiak	-	-	+	-	0,04
Isoetes ramboi Herter	-	+	+	-	0,04
Isoetes sehnemii H.P.Fuchs	-	+	-	-	0,04
Isoetes spannagelii H.P.Fuchs	-	-	+	-	0,04
Isoetes weberi Herter	+	-	-	-	0,04
Juncaceae					
Juncus acutus L.	+	-	-	-	0,04
Juncus bufonius L.	+	+	-	-	0,26
Juncus capillaceus Lam.	+	+	-	-	0,15
Juncus capitatus Weigel.	+	-	-	-	0,04
Juncus densiflorus Kunth	+	+	-	-	0,07
Juncus dichotomus Elliot	-	+	-	+	0,07
Juncus effusus L.	+	+	+	+	0,29
Juncus ilanquihuensis Barros	+	-	-	-	0,04
Juncus imbricatus Laharpe	+	-	-	-	0,04
Juncus marginatus Rostk.	+	+	-	-	0,18
Juncus micranthus Schrad. ex Meyers	-	-	-	+	0,07
Juncus microcephalus Kunth	+	+	+	+	0,62
Juncus pallescens Lam.	+	+	-	-	0,15
Juncus ramboi Barros	-	-	+	-	0,04
Juncus scirpoides Lam.	+	+	+	-	0,29
Juncus tenuis Willd.	+	+	-	-	0,15
Juncaginaceae					
Lilaea scilloides (Poir.) Hauman	+	-	-	-	0,07
Triglochin striata Ruiz & Pav.	+	-	+	+	0,15
Lamiaceae					
Clinopodium brownei (Sw.) Kuntze	+	-	+	-	0,04
Cunila galioides Benth.	-	-	+	-	0,04
Hyptis balansae Briq.	+	-	-	-	0,07
Hyptis brevipes Poit.	+	+	+	-	0,07
Hyptis lacustris A.St. -Hil. ex Benth.	-	+	-	-	0,04
Hyptis lappaceae Benth.	+	+	-	-	0,04

Hyptis lappulacea Mart. ex Benth.	-	-	+	+	0,07
Hyptis lorentziana O. Hoffm.	+	-	-	-	0,04
Hyptis muelleri Briq.	-	-	+	-	0,04
Hyptis tetracephala Bordignon	-	+	-	-	0,04
Hyptis uliginosa A. St.-Hil. ex Benth.	-	-	-	+	0,11
Salvia procurrens Benth.	+	+	+	-	0,04
Scutellaria racemosa Pers.	+	+	-	+	0,11
Lentibulariaceae					
Genlisea aurea A.St.-Hil.	-	-	+	+	0,07
Genlisea repens Benj.	-	-	-	+	0,04
Utricularia breviscapa C.Wright ex Griseb.	+	+	-	-	0,29
Utricularia cucullata A.St.-Hil. & Girard	-	-	-	+	0,04
Utricularia erectiflora A.St.-Hil. & Girard	-	-	+	-	0,04
Utricularia flaccida A.DC.	-	-	+	+	0,04
Utricularia foliosa L.	+	+	+	+	0,62
Utricularia gibba L.	+	-	+	+	0,69
Utricularia hydrocarpa Vahl	-	-	+	-	0,04
Utricularia laxa A.St.-Hil. & Girard	+	+	+	+	0,11
Utricularia nana A.St.-Hil. & Girard	-	-	-	+	0,04
Utricularia nigrescens Sylvén	-	-	-	+	0,04
Utricularia olivacea C.Wright ex Griseb.	-	+	-	-	0,07
Utricularia platensis Speg.	+	+	-	-	0,07
Utricularia praelonga A.St.-Hil. & Girard	+	-	+	+	0,15
Utricularia reniformis A.St.-Hil.	-	+	+	+	0,04
Utricularia subulata L.	-	+	+	+	0,15
Utricularia tricolor A.St.-Hil.	+	+	+	+	0,18
Utricularia tridentata Sylvén	+	+	+	+	0,07
Utricularia triloba Benj.	-	-	+	+	0,04
Linaceae					
Linum littorale A.St.-Hil	-	-	+	-	0,04
Linderniaceae					
Lindernia dubia (L.) Pennell	+	-	-	-	0,04
Lindernia rotundifolia (L.) Alston	-	-	+	+	0,11
Micranthemum umbrosum (Walter ex J.F.Gmel.) S.F.Blake	+	+	+	+	0,29
Loganiaceae					
Spigelia kleinii L.B.Sm	-	-	+	-	0,04
Lycopodiaceae					
Lycopodiella alopecuroides (L.) Cranfill	+	+	+	-	0,11
Lythraceae					
Ammannia robusta Heer & A.Regel	-	-	+	-	0,04
Cuphea aperta Koehne	-	-	+	-	0,04
Cuphea calophylla Cham. & Schltdl.	-	-	-	+	0,07
Cuphea carthagenensis (Jacq.) J. Macbr.	+	+	+	+	0,55
Cuphea glutinosa Cham. & Schltdl.	+	+	-	+	0,15
Cuphea ingrata Cham. &Schltdl.	-	-	+	-	0,04
Cuphea lindmaniana Bacig.	+	+	+	-	0,07

Cuphea melvilla Lindl.	-	-	-	+	0,07
Cuphea racemosa (L.f.) Spreng.	+	+	+	+	0,11
Cuphea sessiliflora A. St.-Hil.	-	-	-	+	0,04
Cuphea tuberosa Cham. & Schltdl.	+	+	+	+	0,04
Lythrum hyssopifolia L.	+	-	-	-	0,04
Rotala mexicana Cham. & Schltdl.	-	+	-	+	0,07
Malvaceae					
Byttneria scabra L.	-	-	-	+	0,04
Hibiscus cisplatensis A. St-Hil.	+	-	-	-	0,04
Hibiscus diversifolius Jacq.	-	+	-	-	0,07
Hibiscus sororius L.	-	-	-	+	0,07
Hibiscus striatus Cav.	+	-	-	-	0,07
Melochia arenosa Benth.	-	-	-	+	0,04
Monteiroa ptarmicifolia (St.-Hil. & Naudin.) Krapov.	-	+	-	-	0,04
Pavonia distinguenda A. St-Hill. & Naudin	+	+	-	-	0,07
Pavonia guerkeana R.E.Fr.	-	-	-	+	0,07
Sida rhombifolia L.	+	+	-	-	0,11
Marantaceae					
Thalia geniculata L.	+	+	+	+	0,18
Thalia multiflora Horkel ex Körn.	+	+	-	-	0,07
Marsileaceae					
Marsilea ancylopoda A. Braun	+	+	-	-	0,15
Pilularia americana A. Braun	-	+	-	-	0,07
Regnellidium diphyllum Lindm.	+	+	+	-	0,22
Mayacaceae					
Mayaca fluviatilis Aubl.	-	+	+	+	0,37
Mayaca kunthii Seub.	-	+	-	-	0,04
Mayaca sellowiana Kunth	+	+	+	+	0,37
Melastomataceae					
Tibouchina asperior (Cham.) Cogn.	+	+	-	-	0,29
Tibouchina cerastifolia Cogn.	-	-	+	+	0,11
Tibouchina cisplatensis Cogn.	+	+	-	-	0,18
Tibouchina clinopodifolia Cogn.	-	-	-	+	0,07
Tibouchina gracilis (Bonpl.) Cogn.	+	+	+	-	0,07
Tibouchina herbacea (DC.) Cogn.	-	-	-	+	0,04
Tibouchina trichopoda (DC.) Baill.	-	+	-	-	0,04
Tibouchina ursina (Cham.) Cogn.	-	-	-	+	0,04
Tibouchina urvilleana (DC) Cogn.	-	-	+	-	0,04
Menyanthaceae					
Nymphoides indica (L.) Kuntze	+	+	+	+	0,88
Molluginaceae					
Mollugo verticillata L.	+	-	-	-	0,04
Nymphaeaceae					
Nymphaea amazonum Mart. & Zucc.	+	+	+	+	0,29
Nymphaea gardneriana Planch.	-	-	-	+	0,04
Nymphaea mexicana Zucc.	-	+	-	-	0,04

Nymphaea odorata Aiton	-	+	-	-	0,04
Nymphaea prolifera Wiersema	-	+	-	-	0,07
Nymphaea pulchella DC.	+	-	+	+	0,04
Nymphaea rubra Roxb. ex Andrews	-	-	+	-	0,04
Nymphaea rudgeana G.Mey.	-	-	-	+	0,04
Ochnaceae					
Sauvagesia erecta L.	-	-	+	-	0,04
Onagraceae					
Ludwigia caparosa (Cambess.) H.Hara	+	+	-	-	0,07
Ludwigia decurrens Walter	+	+	-	-	0,22
Ludwigia elegans (Cambess.) H.Hara	+	+	-	+	0,11
Ludwigia erecta (L.) H.Hara	-	-	-	+	0,04
Ludwigia filiformis (Micheli) Ramamoorthy	-	-	-	+	0,04
Ludwigia grandiflora (Michx.) Greuter & Burdet	+	+	-	+	0,44
Ludwigia helminthorrhiza (Mart.) H. Hara	-	-	-	+	0,07
Ludwigia hexapetala (Hook. & Arn.) Zardini et al.	+	+	-	+	0,22
Ludwigia hookeri (Micheli) H.Hara	-	-	-	+	0,11
Ludwigia hyssopifolia (G.Don) Exell	-	-	-	+	0,04
Ludwigia lagunae (Morong) H.Hara.	-	-	+	+	0,15
Ludwigia leptocarpa (Nutt.) H.Hara	+	+	+	+	0,59
Ludwigia longifolia (DC.) H.Hara	+	+	+	+	0,44
Ludwigia major (Micheli) Ramamoorthy	+	+	+	+	0,11
Ludwigia multinervia (Hook. & Arn.) Ramamoorthy	+	+	+	-	0,33
Ludwigia octovalvis (Jacq.) P.H. Raven	-	-	+	+	0,07
Ludwigia peploides (Kunth) P.H.Raven	+	-	+	+	0,37
Ludwigia peruviana (L.) H.Hara	+	+	-	+	0,37
Ludwigia sericea (Cambess.) H.Hara	+	+	+	+	0,22
Ludwigia tomentosa (Cambess) H.Hara	-	+	-	-	0,04
Orchidaceae					
Cyclopogon apricus (Lindl.) Schltr.	-	-	-	+	0,07
Epidendrum dendrobioides Thunb.	-	-	-	+	0,04
Habenaria bractescens Lindl.	-	-	-	-	0,04
Habenaria imbricata Lindl.	-	+	-	-	0,04
Habenaria inconspicua Cogn.	-	+	-	-	0,04
Habenaria johannensis Barb.Rodr.	+	-	-	-	0,04
Habenaria macronectar (Vell.) Hoehne	-	-	+	+	0,07
Habenaria montevidensis Spreng.	-	-	+	+	0,07
Habenaria paranaensis Barb. Rodr.	-	-	-	+	0,04
Habenaria parviflora Lindl.	+	+	-	+	0,15
Habenaria repens Nutt.	-	+	+	+	0,22
Orobanchaceae					
Buchnera longifolia Kunth	-	-	+	-	0,04
Osmundaceae					
Osmunda regalis L.	+	+	-	-	0,04
Phyllanthaceae					
Margaritaria nobilis L.f.	-	-	+	+	0,04

Phyllanthus niruri L.	-	-	-	+	0,04
Phyllanthus sellowianus (Klotzsch) Müll.Arg.	+	+	-	-	0,11
Plantaginaceae					
Bacopa australis V.C.Souza	+	-	+	+	0,07
Bacopa dubia Chodat & Hassl.	-	-	-	+	0,04
Bacopa lanigera (Cham. & Schltdl.) Wettst.	-	+	-	-	0,18
Bacopa monnieri (L.) Pennell	+	+	+	+	0,44
Bacopa myriophylloides (Benth.) Wettst.	-	-	-	+	0,04
Bacopa salzmannii Wettst. ex Edwall.	+	-	-	+	0,11
Bacopa serpyllifolia (Benth.) Pennell	-	+	+	+	0,04
Bacopa tweedii (Benth.) Parodi	+	+	-	-	0,07
Callitriche deflexa A. Braun ex Hegelm.	+	+	-	+	0,07
Callitriche heterophylla Pursh	+	-	-	-	0,11
Callitriche rimosa Fassett.	-	+	-	-	0,15
Callitriche stagnallis Scop.	-	-	-	+	0,07
Gratiola peruviana L.	+	+	+	+	0,26
Mecardonia grandiflora (Benth.) Pennell	+	+	+	+	0,04
Mecardonia procumbens (Mill.) Small	+	+	+	+	0,33
Mecardonia pubescens Rossow	-	+	-	-	0,04
Mecardonia serpylloides (Cham. & Schltdl.) Pennell	-	+	+	+	0,04
Scoparia dulcis L.	-	-	-	+	0,07
Scoparia montevidensis (Spreng.) R.E.Fr.	-	-	-	+	0,04
Stemodia stricta Cham. &Schltdl.	-	-	+	-	0,04
Stemodia trifoliata (Link.) Rchb.	-	-	+	-	0,04
Plumbaginaceae					
Limonium brasiliense (Boiss.) Kuntze	+	-	-	-	0,04
Poaceae					
Acroceras zizanioides (Kunth) Dandy	-	-	-	+	0,04
Agrostis lenis Roseng. et al.	-	+	+	+	0,11
Agrostis longiberbis Hack. ex L.B. Sm.	-	+	+	+	0,04
Agrostis platensis Parodi	-	+	-	-	0,04
Andropogon bicornis L.	+	+	-	+	0,11
Andropogon lateralis Nees	+	+	+	+	0,11
Andropogon leucostachyus Kunth	+	+	-	-	0,04
Andropogon macrothrix Trin.	-	-	+	-	0,04
Andropogon virgatus Desv.	+	+	+	-	0,11
Axonopus compressus (Sw.) P. Beauv.	+	+	+	-	0,07
Axonopus fissifolius (Raddi) Kuhlm.	+	+	+	-	0,11
Axonopus obtusifolius (Raddi) Chase	-	+	-	-	0,04
Axonopus ramboi G. A. Black	-	-	+	-	0,04
Bromidium hygrometricum (Nees) Nees & Meyen	+	-	+	+	0,07
Bromidium ramboi (Parodi) Rúgolo	-	-	-	+	0,04
Calamagrostis reitzii Swallen	-	-	+	-	0,04
Calamagrostis rupestris Trin.	-	-	+	-	0,04
Calamagrostis viridiflavescens (Poir.) Steudl.	+	+	-	+	0,11
Canastra aristella (Döll) Zuloaga & Morrone	-	-	-	+	0,04

Cenchrus purpureus (Schumach.) Morrone	-	-	-	+	0,07
Chascolytrum calotheca (Trin.) Essi, Longhi-Wagner & Souza-Chies	+	+	+	-	0,11
Chascolytrum poomorphum (J. Presl) Essi, Longhi-Wagner & Souza-Chies	+	+	-	-	0,07
Coleataenia prionitis (Nees) Soreng	-	+	-	+	0,22
Deschampsia cespitosa (L.) P. Beauv.	-	-	+	-	0,04
Dichanthelium sabulorum (Lam.) Gould & C.A. Clark	+	+	+	+	0,26
Digitaria cuyabensis (Trin.) Parodi	+	+	-	-	0,04
Echinochloa polystachya (Kunth) Hitchc.	+	-	+	+	0,29
Eragrostis bahiensis Schrad. ex Schult.	+	+	-	+	0,15
Eragrostis hypnoides (Lam.) Britton, Sterns & Poggenb.	+	+	-	+	0,15
Eragrostis japonica (Thunb.) Trin.	-	+	+	-	0,04
Eragrostis purpurascens (Spreng.) Schult.	-	+	-	-	0,04
Eriochloa punctata (L.) Desv. ex Ham.	+	-	-	+	0,11
Eriochrysis cayennensis P. Beauv.	+	+	+	-	0,07
Eriochrysis villosa Swallen	-	-	+	-	0,04
Glyceria multiflora Steud.	-	-	+	-	0,04
Hemarthria altissima (Poir.) Stapf. & C.E.Hubb.	-	-	+	+	0,07
Homolepis glutinosa (Sw.) Zuloaga & Soderstr.	-	-	+	-	0,04
Hymenachne amplexicaulis (Rudge) Nees	+	-	+	+	0,33
Hymenachne donacifolia (Raddi) Chase	+	-	+	+	0,11
Hymenachne grumosa (Nees) Zuloaga	+	-	+	+	0,26
Hymenachne pernambucensis (Spreng.) Zuloaga	+	+	+	+	0,29
Imperata brasiliensis Trin.	+	+	-	-	0,11
Ischaemum minus J.Presl	+	+	-	-	0,22
Leersia hexandra Sw.	+	+	+	+	0,44
Leersia ligularis Trin.	-	-	+	+	0,04
Louisiella elephantipes (Nees ex Trin.) Zuloaga	+	+	-	-	0,07
Luziola bahiensis (Steud.) Hitchc.	-	+	+	+	0,04
Luziola brasiliensis (Trin.) Pilg.	-	-	+	-	0,04
Luziola peruviana Juss. ex J.F.Gmel.	+	+	+	+	0,69
Luziola spruceana Benth. ex Döll	-	-	-	+	0,04
Oplismenopsis najada (Hack. & Arechav.) Parodi	+	-	-	-	0,07
Oryza latifolia Desv.	-	-	+	+	0,04
Panicum aquaticum Poir.	+	-	+	+	0,15
Panicum dichotomiflorum Michx.	+	-	+	+	0,18
Panicum glabripes Döll	-	-	-	+	0,04
Panicum gouinii E.Fourn.	+	-	-	-	0,07
Panicum pedersenii Zuloaga	+	+	+	+	0,04
Parodiophyllochloa cordovensis (E.Fourn.) Zuloaga & Morrone	-	+	-	-	0,04
Paspalidium geminatum (Forssk.) Stapf	+	-	+	-	0,15
Paspalum acuminatum Raddi	+	+	-	-	0,04
Paspalum conspersum Schard.	-	-	-	+	0,15
Paspalum dilatatum Poir.	+	+	+	-	0,11
Paspalum distichum L.	+	-	-	-	0,18
Paspalum exaltatum J. Presl.	-	-	+	-	0,04
Paspalum glabrinode (Hack.) Morrone & Zuloaga	-	-	-	+	0,04

Paspalum intermedium Munro ex Morong & Britton	+	-	+	+	0,04
Paspalum jesuiticum Parodi	+	-	-	-	0,04
Paspalum minus E.Fourn.	+	-	-	-	0,04
Paspalum modestum Mez	+	-	-	-	0,11
Paspalum orbiculatum Poir.	+	-	-	-	0,04
Paspalum pumilum Nees	+	+	-	-	0,22
Paspalum repens P.J.Bergius	+	-	-	+	0,29
Paspalum urvillei Steud.	+	+	+	-	0,18
Paspalum vaginatum Sw.	+	-	-	-	0,18
Paspalum wrightii Hitchc. & Chase	-	-	-	-	0,04
Polypogon elongatus Kunth	+	+	-	-	0,07
Rhynchoryza subulata (Nees) Baill.	+	-	+	-	0,04
Rugoloa pilosa (Sw.) Zuloaga	-	-	-	+	0,04
Rugoloa polygonata (Schrad.) Zuloaga	-	-	+	-	0,04
Saccharum asperum (Nees) Steud.	-	-	+	-	0,04
Saccharum villosum Steud.	+	+	+	-	0,07
Sacciolepis angustissima (Hochst. ex Steud.) Kuhlm.	-	+	-	+	0,04
Sacciolepis indica (L.) Chase	-	-	+	+	0,04
Sacciolepis vilvoides (Trin.) Chase	+	+	+	+	0,15
Schizachyrium microstachyum (Desv ex Ham) Roseng., B.R. Arrill. & Izag.	+	+	-	+	0,07
Setaria parviflora (Poir.) Kerguélen	-	-	-	-	0,04
Sorghastrum nutans (L.) Nash	-	-	+	-	0,04
Sorghastrum setosum (Griseb.) Hitchc.	+	+	-	-	0,07
Spartina alterniflora Loisel.	+	+	+	+	0,07
Spartina densiflora Brongn.	+	+	-	-	0,15
Sporobolus indicus (L.) R.Br.	-	-	+	-	0,04
Steinchisma decipiens (Nees ex Trin.) W.V.Br.	+	+	+	+	0,18
Steinchisma hians (Elliott) Nash	+	+	+	+	0,11
Steinchisma laxum (Sw.) Zuloaga	-	+	+	+	0,11
Steinchisma spathellosum (Döll) Renvoize	-	+	+	+	0,04
Steinchisma stenophyllum (Hack.) Zuloaga & Morrone	-	+	+	+	0,04
Stephostachys mertensii (Roth) Zuloaga & Morrone	-	-	-	+	0,11
Trichanthecium cyanescens (Nees ex Trin.) Zuloaga & Morrone	-	+	+	+	0,04
Trichanthecium parvifolium (Lam.) Zuloaga & Morrone	+	+	-	-	0,04
Trichanthecium schwackeanum (Mez) Zuloaga & Morrone	+	+	+	+	0,40
Zizaniopsis bonariensis (Balansa & Poitr.) Speg.	+	-	+	+	0,15
Zizaniopsis microstachya (Nees ex Trin.) Döll & Asch.	-	+	+	+	0,04
Podostemaceae					
Apinagia yguazuensis Chodat & Vischer	-	+	+	+	0,04
Marathrum azarensis Tur	-	-	+	-	0,07
Mourera aspera (Bong.) Tul.	-	-	-	+	0,04
Podostemum comatum Hicken	+	+	+	+	0,07
Podostemum distichum (Cham.) Wedd.	+	+	+	+	0,11
Podostemum irgangii C.T.Philbrick & Novelo	-	+	+	+	0,07
Podostemum muelleri Warm.	+	+	+	+	0,07
Podostemum rutifolium Warm.	+	+	+	+	0,11

Tristicha trifaria (Bory ex Willd.) Spreng.	+	+	+	+	0,07
Wettsteiniola pinnata Suess.	-	-	-	+	0,07
Polygalaceae					
Monnina tristaniana A.St-Hill. & Moq.	-	-	+	-	0,04
Polygala appendiculata Vell.	+	-	-	-	0,15
Polygala linoides Poir.	-	-	+	-	0,04
Polygala longicaulis Kunth	+	-	-	-	0,04
Polygala molluginifolia A.St.-Hil. & Moq.	+	+	-	-	0,07
Polygala paniculata L.	-	-	+	-	0,04
Polygala timoutoides Chodat	+	+	-	-	0,07
Polygonaceae					
Polygonum acuminatum Kunth	+	+	+	+	0,55
Polygonum diospyrifolium Cham.	-	-	-	+	0,04
Polygonum ferrugineum Wedd.	+	+	+	+	0,48
Polygonum glabrum Willd.	+	-	+	+	0,15
Polygonum hispidum Kunth	+	-	-	-	0,04
Polygonum hydropiperoides Michx.	+	+	+	+	0,77
Polygonum meisnerianum Cham.	+	-	+	+	0,66
Polygonum persicaria L.	+	+	+	+	0,33
Polygonum punctatum Elliott	+	+	+	+	0,84
Polygonum rubricaule Cham.	-	-	-	+	0,11
Polygonum stelligerum Cham.	+	-	+	+	0,33
Rumex hasslerianus Rech. f.	+	-	-	-	0,04
Rumex paraguayensis D.Parodi	+	-	-	-	0,04
Pontederiaceae					
Eichhornia azurea Sw. (Kunth)	+	+	+	+	0,73
Eichhornia crassipes (Mart.) Solms	+	+	+	+	0,59
Eichhornia diversifolia (Vahl) Urb.	-	-	-	+	0,07
Heteranthera limosa (Sw.) Willd.	+	-	-	+	0,07
Heteranthera multiflora (Griseb.) C.N.Horn	+	-	-	-	0,04
Heteranthera reniformis Ruiz & Pav.	+	+	+	+	0,48
Heteranthera seubertiana Solms	-	-	-	+	0,04
Heteranthera zosterifolia Mart.	+	+	+	+	0,26
Pontederia cordata L.	+	+	+	+	0,73
Pontederia parviflora Alexander	-	+	-	-	0,04
Pontederia rotundifolia L.f.	-	+	+	+	0,07
Pontederia sagittata C.Presl	-	-	+	+	0,04
Pontederia subovata (Seub.) Lowden	+	+	+	+	0,18
Pontederia triflora (Seub.) G. Agostini, D. Velásquez & Velásquez	-	-	-	+	0,04
Potamogetonaceae					
Potamogeton ferrugineus Hagstr.	+	+	+	-	0,33
Potamogeton gayi A.Benn.	-	+	+	+	0,15
Potamogeton illinoensis Morong	+	+	+	+	0,26
Potamogeton montevidensis A.Benn.	+	+	+	+	0,15
Potamogeton polygonus Cham. & Schldtl.	+	+	+	+	0,22
Potamogeton pusillus L.	+	+	+	+	0,29

Potamogeton spirilliformis Hagstr.	+	-	-	-	0,15
Potamogeton ulei K.Schum.	+	+	+	+	0,07
Stuckenia pectinata (L.) Börner	+	-	+	-	0,26
Zannichellia palustris L.	-	+	+	-	0,07
Primulaceae					
Lysimachia filiformis (Cham. & Schltdl.) U. Manns & Anderb	-	-	+	+	0,11
Lysimachia minima (L.) U. Manns & Anderb.	-	+	+	+	0,18
Samolus valerandi L.	-	+	+	-	0,07
Pteridaceae					
Acrostichum danaeifolium Langsd. & Fisch.	-	+	-	-	0,07
Ceratopteris pteridoides (Hook.) Hieron.	-	-	-	+	0,04
Ceratopteris thalictroides (L.) Brongn.	-	-	-	+	0,04
Pityrogramma calomelanos (L.) Link	+	+	-	+	0,04
Pityrogramma trifoliata (L.) R.M.Tryon	-	-	-	+	0,04
Ranunculaceae					
Ranunculus apiifolius Pers.	+	+	-	+	0,26
Ranunculus bonariensis Poir.	+	+	+	+	0,22
Ranunculus flagelliformis Sm.	+	+	+	+	0,33
Ranunculus muricatus L.	+	+	+	+	0,04
Rubiaceae					
Borreria multiflora (DC.) Bacigalupo & E.L.Cabral	-	-	-	+	0,04
Borreria palustris (Cham. & Schltdl.) Bacigalupo & E.L.Cabral	+	+	+	+	0,37
Borreria schumannii (Standl. ex Bacigalupo) E.L. Cabral & Sobrado	+	-	+	+	0,04
Cephalanthus glabratus (Spreng.) K.Schum.	+	+	-	-	0,37
Diodia kuntzei K.Schum.	+	+	+	+	0,04
Diodia saponariifolia (Cham. & Schltdl.) K.Schum.	+	+	+	+	0,37
Emmeorhiza umbellata (Spreng.) K.Schum.	-	-	-	+	0,04
Galianthe brasiliensis (Spreng.) E.L.Cabral & Bacigalupo	-	-	-	+	0,04
Galianthe centranthoides (Cham. & Schltdl.) E. L. Cabral	-	-	+	-	0,04
Galianthe cymosa (Cham.) E.L.Cabral & Bacigalupo	-	-	-	+	0,04
Galianthe dichasia (Sucre & C.G.Costa) E.L. Cabral	-	-	-	+	0,04
Galium equisetoides (Cham. & Schltdl) Standl.	-	+	+	+	0,15
Galium humile Cham. & Schltdl.	+	-	+	-	0,07
Galium hypocarpium (L.) Endl. ex Griseb.	+	+	-	-	0,04
Oldenlandia dusenii Standl.	-	+	+	+	0,04
Oldenlandia lancifolia (Schumach.) DC.	-	-	-	+	0,04
Oldenlandia salzmannii (DC.) Benth. & Hook.f. ex B.D.Jacks	+	+	+	+	0,40
Spermacoce riparia Cham. & Schltdl.	-	-	+	+	0,07
Staelia virgata (Link ex Roem. & Schult.) K.Schum.	-	-	-	+	0,04
Ruppiaceae					
Ruppia maritima L.	-	-	+	+	0,22
Salviniaceae					
Azolla filiculoides Lam.	+	+	+	+	0,62
Salvinia auriculata Aubl.	+	+	+	+	0,44
Salvinia biloba Raddi.	+	+	+	+	0,59
Salvinia minima Baker	+	+	+	+	0,51

Scrophulariaceae					
Buddleja thyrsoides Lam.	+	+	-	-	0,04
Solanaceae					
Schwenckia americana Rooyen ex L.	-	-	-	+	0,04
Schwenckia curviflora Benth.	+	-	+	+	0,11
Schwenckia juncoides Chodat	-	-	+	-	0,04
Solanum amygdalifolium Steud.	+	-	-	-	0,04
Solanum capsicoides All.	+	+	-	-	0,11
Solanum glaucophyllum Desf.	+	-	+	+	0,22
Solanum laxum Spreng.	+	+	-	-	0,07
Solanum pseudocapsicum L.	+	+	-	+	0,11
Solanum sisymbriifolium Lam.	+	+	-	-	0,07
Thelypteridaceae					
Thelypteris interrupta (Willd.) K.Iwats.	+	+	+	+	0,26
Thelypteris opposita (Vahl) Ching	-	-	+	-	0,04
Thelypteris rivularioides (Fée) Abbiatti	+	+	-	-	0,04
Thelypteris serrata (Cav.) Alston	-	-	-	+	0,04
Typhaceae					
Typha angustifolia L.	-	-	+	+	0,04
Typha domingensis Pers.	+	+	+	+	0,77
Typha latifolia L.	-	+	+	+	0,22
Urticaceae					
Boehmeria cylindrica (L.) Sw.	+	+	-	+	0,18
Xyridaceae					
Xyris capensis Thunb.	-	+	+	+	0,04
Xyris filifolia L.A. Nilsson	-	+	+	-	0,04
Xyris guaranitica Malme	+	+	+	+	0,04
Xyris hymenachne Mart.	-	-	+	+	0,04
Xyris jupicai Rich.	+	+	+	+	0,33
Xyris lucida Malme	-	-	+	+	0,04
Xyris neglecta L.A.Nilsson	-	-	+	+	0,04
Xyris regnellii Alb. Nilsson	+	+	+	+	0,04
Xyris reitzii L.B.Sm. & Downs	-	-	+	+	0,04
Xyris rigida Kunth	-	+	+	+	0,04
Xyris savanensis Miq.	+	-	+	+	0,04
Xyris schizachne Mart.	-	+	+	+	0,04
Xyris sororia Kunth	-	-	+	+	0,04
Xyris stenophylla L.A. Nilsson	+	+	+	+	0,11
Xyris teres L.A. Nilsson	+	-	+	+	0,04
Xyris tortula Mart.	-	+	+	+	0,07
Xyris vacillans Malme	-	+	+	+	0,04

Capítulo II

Does species diversity predict the water level in the South Brazilian wetlands?

[2]Artigo a ser submetido à Revista AoB Plants

Does species diversity predict the water level in the South Brazilian wetlands?

Lukiel dos Santos Oliveira[1,2], Bianca Ott Andrade[2], Ilsi Iob Boldrini[2], Maria Cecilia de Chiara Moço[2]

[1] Parte da dissertação de mestrado do primeiro autor no Programa de Pós- Graduação em Botânica, Universidade Federal do Rio Grande do Sul.

[2] Programa de Pós-graduação em Botânica, Universidade Federal do Rio Grande do Sul. Av. Bento Gonçalves 9500, Bloco IV, Prédio 43433, Campus do Vale, Bairro Agronomia, CEP 91501-970, Porto Alegre, RS. lukieloliveira@gmail.com

ABSTRACT

Conservative approaches require an integrated understanding of the major threats and natural drivers of biodiversity. Nevertheless, most studies focus on individual characteristics and rarely address the relationship between aquatic community and environmental gradient in wetlands. In this paper, we search for patterns of plant distribution along water level gradient and accurate indicator species for elucidating microenvironment variance (i.e. water level) in two wetlands in Southern Brazil. To this end, we sampled five plots (1 m^2), along six belts transects (from wetland edge to center), totaling 30 plots per area. Sampled values of all plots were subjected to k-mean clustering to form groups. Indval determined species within these groups. The relationships between water level and vegetation cover were analyzed using Kruskal-Wallis test. As a result, we found 89 plant taxa distributed in 25 families across the sampling sites. Families with highest overall species richness were Poaceae, Cyperaceae and Asteraceae. Kruskal-Wallis test revealed differences among three groups/zones along the water gradient. Indval indicated species with affinities to wet and dry sides of gradient. Taken together, our results suggest that the plants distribution on these studied areas is conditioned on the water gradient. Finally, we briefly discussed about the need of new methods to identify wetlands in Southern Brazil and to implement conservative efforts.

Key words: indicator species, Pampa, species diversity, biodiversity conservation

INTRODUCTION

Wetlands are complex ecosystems that provide a high level of productivity and sustain high biodiversity (Engelhardt and Ritchie 2001; Lavoie et al. 2016). The wetlands' structure is influenced by biotic interactions and abiotic factors, such as climatic conditions, soil features, and then geomorphologic settings and their resulting difference in hydrologic conditions (Lefeuvre and Bouchard 2013). Despite the extreme variations from one year to another, water levels have a strong influence in the biological balance of the wetlands (Magee and Kentula 2005; Strayer and Findlay 2010). Water oscillation and soil conditions are natural drivers in productivity, species richness and zonation patterns of plant communities (van der Valk 2005; Maltchik et al. 2007; Keddy 2010). Since the flooding stress is a limiting factor for the local aquatic community (Keddy 2010; Casanova and Brock 2000; Strayer and Findlay 2010), the vegetation exhibit zonation patterns characterized by groups of species which have similar habitat preferences and hydrostatic tolerances (Murray-Hudson et al. 2012). To survive under water conditions, plant species need regulatory and efficiently mechanisms to adapt to changes in these complex environments, such as xylem reduction, little lignification, heterophylly, and aerenchyma development (Sculthorpe 1967).

Although aquatic systems are generally viewed as resilient to natural disturbances, extreme changes in abiotic factors outside of the adaptive capabilities of the plant species can break the ability of natural ecosystems to rebound their ecological integrity after disturbance (Poff et al. 2002; Middleton 1999). Approximately half of the world's wetlands have disappeared and much of the area that remains is degraded due to human activities (Shine and Klemm 1999; Mitsch and Gosselink 2007). Despite their importance economic, social, and biological value (Woodward et al. 2001; Munishi et al. 2016), wetlands are highly threatened by anthropogenic impacts such as eutrophication, habitat conversion and hydrologic alteration (Middleton and Souter 2016). In Brazil, the largest threats and loss are progressives with urban expansion, agricultural activities, and industrial development over the territory. In Southern Brazil, for example, about 90% of wetlands area has been lost during the last decades. Since less than 2% of the Southern Brazil territory is protected by conservation areas (Maltchik, 2012; MMA, 2006), the loss rates for wetlands tends to increase. Such negligence with these ecosystems is extremely worrisome, for the reason that various wetland types occur in southern Brazil. Typical wetlands found in this region are known as “banhados”. This type of ecosystem often occurs in isolated areas where the topographic depressions are surrounded by uplands with grassland vegetation in Pampa Biome. Phreatic water levels or rainfall frequency characterizes the permanence time of such environments as ephemeral, temporary, or permanent (Vaira, 2002; Murray-Hudson et al. 2012). Isolated wetlands provide a wide array of ecosystem services from habitat for fauna (Josens et al. 2009; Maltchik et al., 2012; Moreira et al. 2016), to the maintenance of water quality. Despite the importance of these ecosystems, the knowledge of the vegetation distribution in regard to the environmental factors remains poor for wetlands in Southern Brazil. In addition, the floristic knowledge of the wetlands in the Pampa Biome is still scarce.

Therefore, the main purposes of the present research are (i) to identify groups of species which have similar diversity’ trends and to determine whether such groupings correspond to ecological similarities (i.e. zonation in regard to water level) in wetlands in Southern Brazil (ii) to determine whether vegetation structure (i.e. maximum plant height) is correlated with water depth.

METHODS

Study area

Two study areas (wetlands in Itaqui and Pantano Grande municipalities) were selected in the Pampean phytogeographic region, southern Brazil (Fig. 1). This region is characterized by a grassland matrix, with forests inclusions along riverine areas. Different grassland types can be found in this region due to the diverse geological, geomorphological, and climatic conditions, making the Brazilian Pampa region highly heterogeneous (Boldrini et al., 2010; Overbeck et al. 2007). According to Köppen's classification, the climate across the region is Cfa type (humid subtropical climate) marked by abundant rainfall and hot summers (Alvares et al. 2013).

In Itaqui municipality (29º01'19.91" S, 56º12'00.85" W) the main soil classes are Alfisols (*Luvissolo Háplico*) and Molisols (*Chernossolo Ebânico*) (Soil Survey Staff 2010; Streck at al., 2008). The average temperatures for the hottest month and the coldest month are 26.4 °C and 14.2 °C, respectively. The mean annual temperature is 20.3 °C and mean annual precipitation is 1438 mm, with water deficit in August (INMET 2016).

In Pantano Grande (30º13'33.11" S, 52º21'03.04" W) the main soil classes are Ultisols (*Argissolo Vermelho-Amarelo*) and Alfisols (*Planossolo Háplico*) (Soil Survey Staff 2010; Streck at al., 2008). The mean annual temperature is 19.4ºC, being 24.8ºC the mean temperature of the hottest month and 14.8 ºC of the coldest month. The mean annual precipitation is 1350 mm, being May the driest month.

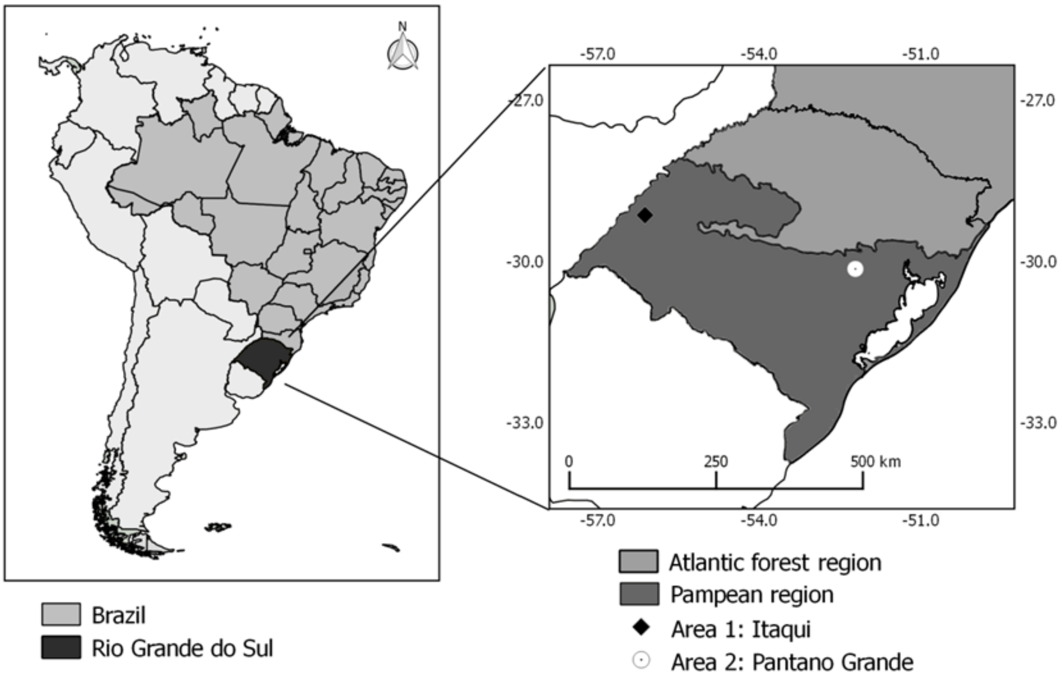

Fig. 1. Localization of sampling sites in the Pampean phytogeografic region, South Brazil.

Data collection

Field work was carried out using 30 $1m^2$ plots distributed on each site, along a water level gradient (ranged from 0 to +50cm from soil surface). The study sites were sampled in January 2015 to examine ecological characteristics at different distances in six radial transects laid out from higher water level nuclei to the better soil drainage edge. In each transect were distributed five plots with 5m between them. We delimited groups according to transects distribution. The groups were allocated gradually from the center (group 1 - first samples of each transect) to edge of wetland and dry soil (group 5 - latest samples of each transect).

All plant species occurring within $1m^2$ plot had its percentage cover estimated using a decimal scale adapted from Londo (1976). We also estimated bare soil per sampling unit and average height of five larger individuals. The depth of water was measured for each plot.

Data Analysis

In order to evaluate the reliability of groups, the water level and vegetation cover data were normalized and was applied in the K-means nonhierarchical clustering method. The significance of K-means groups was tested using 10,000 permutations.

For testing the difference among groups along the water level gradient, a nonparametric Kruskal-Wallis test was used in association with the post-hoc Dunn test. We applied these tests because the assumptions for parametric ANOVA were not met. Pearson correlation coefficient was calculated to evaluate the relationship between water level and vegetation height. Statistical significance was assessed at $P < 0.05$. All tests were performed for each site and were undertaken in software R 3.2.0.

Due to the difficulty of finding other areas with similar vegetation composition to the studied areas, we could not use truly replicates. Although there is a lack of true replicates, inferential statistics should always be used (Oksanen 2001); however, the interpretation of results should be viewed with special care.

To identify indicator species for groups with distinct water levels, we used abundance data and species groups stated by the clustering to calculate the IndVal index (Dufrêne and Legendre, 1997). The significance of indval values was assessed using randomization (10,000 iterations).

To detect the main pattern of distribution of plots among groups and the species that govern the patterns, we conducted an ordination analyses based on species abundances. We applied principal coordinates analysis (PCoA), using Chord distance as a resemblance measure for ordination. Chord distance was chosen because it removes differences in abundance data and keeps the variation in species composition among sites (Legendre and Legendre 1998). Ordination was tested by bootstrap (10,000 permutations) to verify the stability of the axes. The PCoA analysis was performed in software Multiv 2.3.3 (Pillar, 2004).

RESULTS

Species diversity

We found 89 plant taxa distributed in 25 families across the sampling sites. Families with highest overall species richness were Poaceae, Cyperaceae and Asteraceae.

In Itaqui, we found a total of 40 species within 16 families. Poaceae and Cyperaceae were the most species-rich families with 14 and 8 species, respectively. The most dominant species were: *Luziola peruviana* Juss. ex J.F.Gmel. (importance value 23%), *Ludwigia grandiflora* (Michx.) Greuter & Burdet (14%), *Heteranthera reniformis* Ruiz & Pav. (8%), *Marsilea ancylopoda* A. Braun, and *Eleocharis obtusetrigona* (Lindl. & Nees) Steud. (6%).

A total of 62 species belonging to 15 families were recorded in Pantano Grande. Cyperaceae (19), Poaceae (18) and Asteraceae (7 species) were the families with the highest species richness. The most important species were: *Luziola peruviana* Juss. ex J.F.Gmel. (importance value 21%), *Centella asiatica* (L.) Urb. (9%), *Paspalum pumilum* Nees (7%), *Oxycaryum cubense* (Poepp. & Kunth) Lye (7%), and *Eleocharis maculosa* (Vahl.) Roem & Schult. (4%).

Both sites shared 13 species. In Appendix S1 we provide a data matrix with species composition used in our analysis.

Vegetation – water level

The K-means analyses achieved a reduction in sums of squares of the 50,4% in Itaqui, and 46,9% in Pantano Grande. With this reduction, the five initial groups established in the field were reducted to three.

The Kruskal–Wallis test revealed differences between groups stated by k-means clustering method in both areas (area1: $\chi2$=11.94, df = 2, P< 0.002; area 2: $\chi2$=17.673, df = 2, P< 0.000). Post hoc Dunn test detected a difference among groups in both areas. In area 1, group 1 differs from group 2 ($p < 0.006$) and group 3 ($p < 0.003$). However, the groups 2 and 3 did not differ between them ($p < 0.265$) (Fig.2a). In area 2, group 1 did not differ from group 2 ($p < 0.465$), but it differ from 3 ($p < 0.000$) and group 3 differs from group 2 ($p < 0.001$) (Fig. 2a).

The structure of vegetation also can predict the water level. Water level and vegetation height were positively correlated in area 1 ($p < 0.05$, $r = 0.78$, r^2=0.62) and 2 ($p < 0.05$, r= 0.94, r^2=0.89) (Fig. 2b).

The first axis of the PCoA ordination explained 29% of data variation (Fig. 3), showing that the vegetation cover of plots, even not analyzed with water height data, denotes a gradient positively associated with the level of water in both areas. Therefore, the ordination confirmed the vector abundance associated with the flooding gradient.

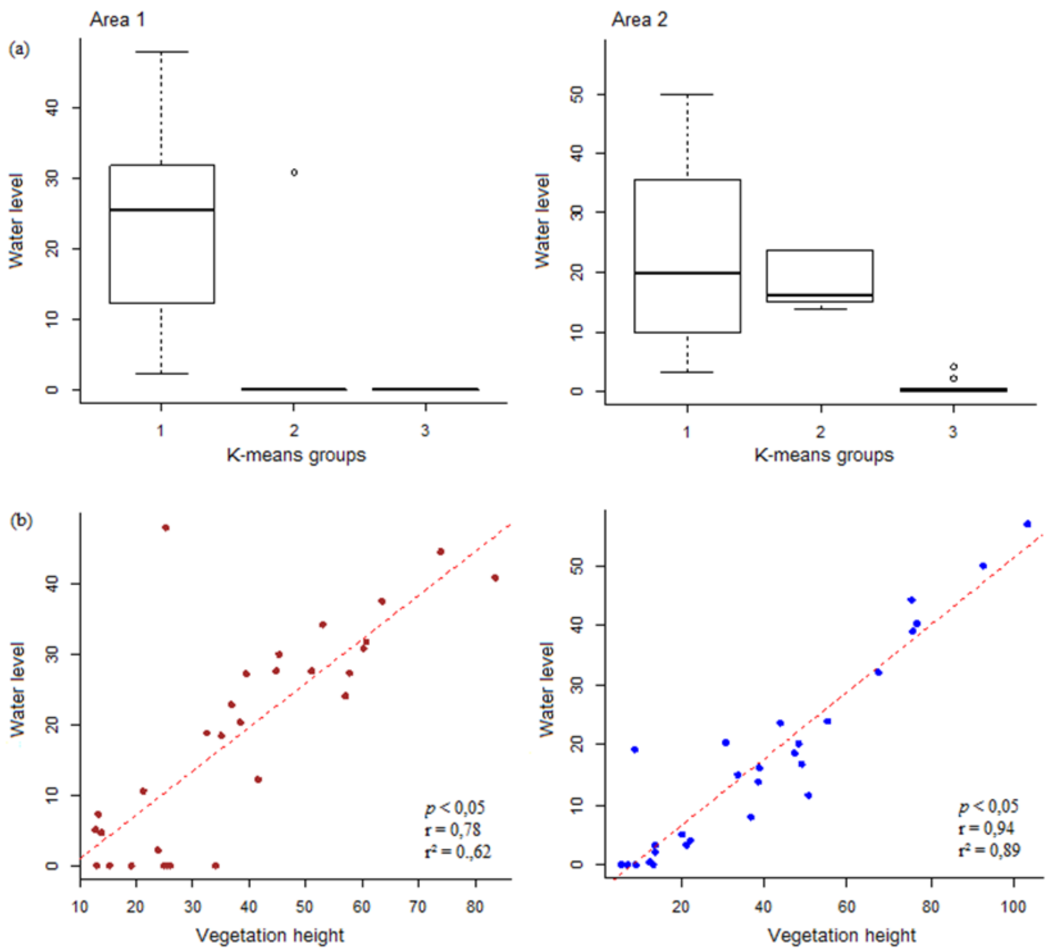

Fig. 2. Mean and variance of water level along the flooding gradient and vegetation structure response to its microenvironment variance. a) Mean water level along flooding gradient: groups 1, 2 and 3; (b) Correlation between vegetation height and water level.

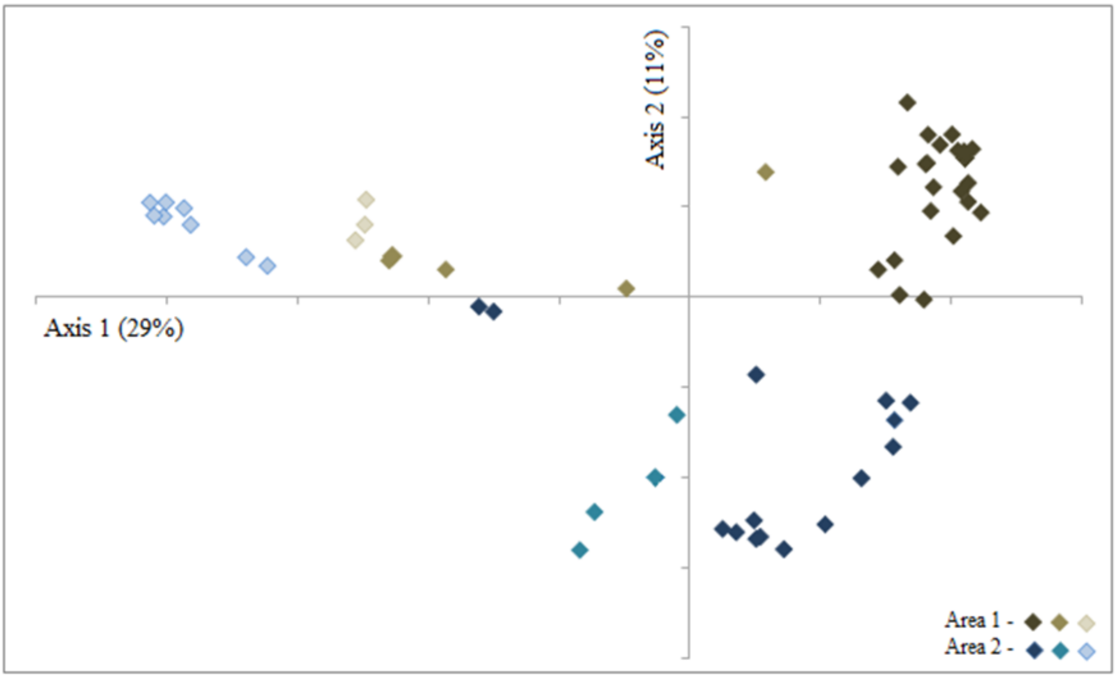

Fig. 3. Ordination axes 1 and 2 based on vegetation cover for the Itaqui (area 1) and Pantano Grande (area 2). Each dot represents a single plot. The plots are differentiated by colors for the groups (K -means) representing the water levels. Lighter colors represent portions where the water level is almost nonexistent. Darker colors represent plots located in deeper areas.

Floristic – indicator species

The indicator species identified in our analyses had relations with the water level in each group (Table 1).

In Itaqui, the group 1 was composed exclusively of aquatic species such *Heteranthera reniformis* and *Ludwigia grandiflora*, occupying the wettest part of the gradient. IndVal analyses did not indicate species for group 1 in Pantano Grande; however, group 2 was representative in relation to strictly aquatic species (i.e. *Eleocharis acutangula*, *Leersia hexandra* and *Mayaca sellowiana*) in this area. These trends were identified by Post hoc test wherein height water level in group 1 did not differ from group 2 in Pantano Grande.

Post hoc test did not reveal differences in water level height between groups 2 and 3 in Itaqui. Therefore, pasture grasses (*Axonopus affinis* and *Steinchisma hians*) and an aquatic species (*Bacopa monnieri*) tolerant to drought condition (Debnath 2008) were identified by IndVal.

Group 3 were composed primarily of species that occur in drought conditions in both sampled areas. For example, common grass species (*Andropogon lateralis*, *Paspalum notatum* and *P. pumilum*), a grass species characteristic of the Pampa region (*Axonopus jesuiticus*) and two legumes (*Desmodium incanum* and *D. adscendens*). However, aquatic species were also identified in this group such as *Centella asiatica* and six species of sedges.

Table 1. Indicator species. G1 = deep water, G2 = low - moderate water, G3 = dry soil

	Indicators species	G1	G2	G3	G1+G2	G2+G3
Area 1	*Ludwigia grandiflora* (Michx.) Greuter & Burdet	***	-	-	-	-
	Heteranthera reniformis Ruiz & Pav.	0.010	-	-	-	-
	Bacopa monnieri (L.) Pennell	-	0.006	-	-	-
	Axonopus affinis Chase	-	0.013	-	-	-
	Steinchisma hians (Elliott) Nash	-	0.014	-	-	-
	Axonopus jesuiticus (Araújo) Valls	-	-	***	-	-
	Polygonum punctatum Elliott	-	-	0.004	-	-
	Andropogon lateralis Nees	-	-	0.007	-	-
	Luziola peruviana Juss. ex J.F.Gmel.	-	-	-	0.001	-
	Eleocharis viridans Kük ex. Osten	-	-	-	-	0.004
	Kyllinga brevifolia Rottb.	-	-	-	-	0.006
	Paspalum notatum Flüggé	-	-	-	-	0.029
Area 2	*Trichanthecium schwackeanum* (Mez) Zuloaga & Morrone	-	0.002	-	-	-
	Eleocharis acutangula (Roxb.) Schult.	-	0.025	-	-	-
	Leersia hexandra Sw.	-	0.023	-	-	-
	Mayaca sellowiana Kunth	-	0.032	-	-	-
	Rhynchospora tenuis Link	-	-	***	-	-
	Paspalum pumilum Nees	-	-	***	-	-
	Desmodium adscendes (Sw.) DC.	-	-	***	-	-
	Centella asiatica (L.) Urb.	-	-	***	-	-
	Andropogon lateralis Nees	-	-	0.002	-	-
	Fimbristylis complanata (Retz.) Link	-	-	0.005	-	-
	Fimbristylis dichotoma (L.) Vahl	-	-	0.009	-	-
	Eleocharis maculosa (Vahl.) Roem & Schult.	-	-	0.013	-	-
	Paspalum notatum Flüggé	-	-	0.013	-	-
	Rhynchospora barrosiana Guagl.	-	-	0.013	-	-
	Kyllinga brevifolia Rottb.	-	-	0.027	-	-
	Desmodium incanum (Sw) DC.	-	-	0.047	-	-
	Luziola peruviana Juss. ex J.F.Gmel.	-	-	-	***	-
	Oxycaryum cubense (Poepp. & Kunth) Lye	-	-	-	0.002	-
	Hydrocotyle bonariensis Lam.	-	-	-	0.023	-

(*** = $p < 0.001$)

DISCUSSION

The families Poaceae, Cyperaceae, and Asteraceae were also among the richest families in other wetlands studies (Rolon et al. 2010; Ferreira et al. 2010; Magalhães et al. 2016). According to Giulietti et al. (2005) such families are among the largest families in Brazil. Poaceae and Cyperaceae are often the most important plant functional types in wetlands because they form the “matrix species" for several habitats (Keddy, 1993). Many species of Cyperaceae has different morphological adaptations to survive in wetting conditions and inhabit wetlands (Gao et al. 2015; Hough-Snee et al. 2015), for this reason, they are often reported in floristic inventories in wetlands.

Applying the correlation analysis using data of vegetation cover and water level, we concluded that plant species are not uniformly within wetlands, and their distribution reflects the gradient which they are submitted. The distinct zonation among species suggests the ability to survive under water level with fits to wet-and-dry seasonality (Tabacchi, 1995; Brock et al. 2003).

Since the species can differ in anatomical and ecological aspects to optimize the use of water in its metabolism, zonation patterns can also be related to the type of photosynthetic pathways of species. For example, in this study, species with a C4 pathway such as *Axonopus jesuiticus*, *Paspalum notatum* and *Andropogon lateralis* were restricted to the driest end of the gradient whereas *Eleocharis acutangula*, *Leersia hexandra* and *Luziola peruviana* with C3 pathway were most frequent at the wettest part of the gradient.

Several studies have related zonation patterns in wetlands around the world (Simpsson et al. 1994; Lenssen et al. 2009; Shi et al. 2015). In Brazil, studies with this approach are still scarce. However, there is a study conducted by Magalhães et al. 2016 which zonation patterns were assessed using indicators species in wetlands of highland grasslands in Southern Brazil. In such study, they recorded 12 species as the indicator of gradient level for three wetlands. It is noteworthy that some species reported as indicator by these authors occurred in our sampling and were also identified as indicator species in our analysis, such as *Mayaca sellowiana* and *Rhynchospora corymbosa.* In addition, the zones in which these species were found correspond with those identified in our analysis. Consequently, it suggests that the species occupying the wet side of the gradient, probably, will always occupy deeper water than the species which occupy the dry side (Jonhston et al. 2007).

Few indicators species were shared in both areas. Overall are species with a wide distribution in the Rio Grande do Sul State such as *A. affinis*, *P. notatum*, *A. lateralis* and a strictly aquatic *Luziola peruviana*. These results show that the studied sites do not share the same indicator species, but in spite of this difference, the vegetation respond to similar zonation patterns with cover and height follow the water gradient. Therefore, using indicator species can be a useful tool to recognize wetlands or to characterize the boundaries of them.

Implications for conservation

The correlation approach used in conjunction with vegetation data works well for predicting zonation patterns in wetlands. Indicator species have been used to indicate ecological changes, monitor environmental integrity and evaluate habitat restoration (Siddig et al. 2016; Stapanian et al. 2016). Few studies have been conducted using species to indicate physical environmental factors (Johnston et al. 2007). However, our analysis indicated that the structure and zonation of species in wetlands can be an important indicator of the water level.

Although wetlands are covered by protective legislation, the lack of good indicators methods and law restrictions subject such ecosystems to drainage and habitat conversion in Southern Brazil. Currently, only environmental factors such flood time are used to identify wetlands. However, this method is inefficient due to fluctuations of water conditions during the year. Furthermore, the current list contained in the regional legislation (Rio Grande do Sul state) includes exotic species and few native species, most with floating lifeform restricting wetlands to environments permanently flooded. Hence, the weak method used to identify wetlands creates a legislative gap. Due to the ecological and economic importance provided by wetlands, steps must be taken to reverse it. For this change, new measures should be employed for identifying wetlands.

Several types of wetlands are characterized by different plant species, so vegetation can be used to easily identify these ecosystems (Tiner, 1993). In this sense, a potential application could be to employ a generic method to identify wetlands using indicator species. A first step is to expand the list of species contained in legislation and prioritizing native species as predictors of aquatic conditions. Therefore, are necessary to provide rigorous studies addressing knowledge of the wetlands in southern Brazil and floristic lists supplementing the distribution of species.

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Appendix 1. Floristic survey. A.A. = Absolut abundance, R.A.= Relative abundance, A.F.= Absolut frequency, R.F. = Relative frequency, IVI = Importance value index.

		Area 1					Area 2				
Families	Species	A.A.	R.A.	A.F.	R.F.	IVI (%)	A.A.	R.A.	A.F.	R.F.	IVI (%)
Alismataceae	*Hydrocleys nymphoides* (Willd.) Buchenau	3,20	1,12	13,33	1,96	1,54	-	-	-	-	-
Amaranthaceae	*Alternanthera philoxeroides* (Mart.) Griseb	0,70	0,24	10,00	1,47	0,86	-	-	-	-	-
Apiaceae	*Centella asiatica* (L.) Urb.*	-	-	-	-	-	30,60	12,24	40,00	5,61	8,92
Apiaceae	*Cyclospermum leptophyllum* (Pers.) Britton P.Wilson	-	-	-	-	-	5,80	2,32	36,67	5,14	3,73
Araliaceae	*Hydrocotyle bonariensis* Lam.	-	-	-	-	-	7,00	2,80	40,00	5,61	4,20
Araliaceae	*Hydrocotyle exigua* (Urb.) Malme	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Asteraceae	*Baccharis crispa* Spreng.	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Asteraceae	*Chevreulia acuminata* Less.	-	-	-	-	-	0,20	0,08	6,67	0,93	0,51
Asteraceae	*Gamochaeta purpurea* (L.) Cabrera	-	-	-	-	-	0,20	0,08	6,67	0,93	0,51
Asteraceae	*Pluchea sagittalis* (Lam.) Cabrera	-	-	-	-	-	0,60	0,24	6,67	0,93	0,59
Asteraceae	*Pterocaulon* sp.	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Asteraceae	*Senecio selloi* (Spreng.) DC.	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Asteraceae	*Vernonanthura nudiflora* (Less.) H.Rob.	-	-	-	-	-	0,20	0,08	6,67	0,93	0,51
Asteraceae	*Eclipta prostrata* (L.) L.	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Asteraceae	*Pterocaulon* sp.	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Campanulaceae	*Lobelia hederacea* Cham.	-	-	-	-	-	0,30	0,12	10,00	1,40	0,76
Convolvulaceae	*Dichondra macrocalyx* Meisn.	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Convolvulaceae	*Dichondra sericea* Sw.	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Cyperaceae	*Eleocharis acutangula* (Roxb.) Schult.	-	-	-	-	-	7,60	3,04	20,00	2,80	2,92
Cyperaceae	*Eleocharis maculosa* (Vahl.) Roem & Schult.	-	-	-	-	-	14,50	5,80	23,33	3,27	4,53
Cyperaceae	*Eleocharis minima* Kunth	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25

Cyperaceae	*Eleocharis obtusetrigona* (Lindl. & Nees) Steud.	18,80	6,57	43,33	6,37	6,47	1,30	0,52	16,67	2,34	1,43
Cyperaceae	*Eleocharis viridans* Kük ex. Osten	14,80	5,17	30,00	4,41	4,79	0,50	0,20	3,33	0,47	0,33
Cyperaceae	*Fimbristylis complanata* (Retz.) Link	0,20	0,07	6,67	0,98	0,53	2,70	1,08	33,33	4,67	2,88
Cyperaceae	*Fimbristylis dichotoma* (L.) Vahl	0,20	0,07	6,67	0,98	0,53	1,30	0,52	16,67	2,34	1,43
Cyperaceae	*Fuirena incompleta* Nees	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Cyperaceae	*Kyllinga brevifolia* Rottb.	8,00	2,80	23,33	3,43	3,11	2,40	0,96	16,67	2,34	1,65
Cyperaceae	*Kyllinga vaginata* Lam.	-	-	-	-	-	0,50	0,20	3,33	0,47	0,33
Cyperaceae	*Lipocarpha humboldtiana* Nees	-	-	-	-	-	3,40	1,36	20,00	2,80	2,08
Cyperaceae	*Oxycaryum cubense* (Poepp. & Kunth) Lye	-	-	-	-	-	16,70	6,68	50,00	7,01	6,84
Cyperaceae	*Pycreus lanceolatus* (Poir.) C.B.Clarke	-	-	-	-	-	10,90	4,36	33,33	4,67	4,52
Cyperaceae	*Pycreus polystachyos* (Rottb.) P.Beauv.	-	-	-	-	-	0,70	0,28	10,00	1,40	0,84
Cyperaceae	*Rhynchospora asperula* (Nees) Steud.	-	-	-	-	-	0,50	0,20	3,33	0,47	0,33
Cyperaceae	*Rhynchospora barrosiana* Guagl.	-	-	-	-	-	0,40	0,16	13,33	1,87	1,01
Cyperaceae	*Rhynchospora brittonii* Gale	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Cyperaceae	*Rhynchospora corymbosa* (L.) Britton	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Cyperaceae	*Rhynchospora tenuis* Link	-	-	-	-	-	9,90	3,96	30,00	4,21	4,08
Cyperaceae	*Carex sororia* Kunth	0,50	0,17	3,33	0,49	0,33	-	-	-	-	-
Cyperaceae	*Cyperus eragrostis* Lam.	0,50	0,17	3,33	0,49	0,33	-	-	-	-	-
Cyperaceae	*Kyllinga odorata* Vahl	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Eriocaulaceae	*Syngonanthus caulescens* (Poir.) Ruhland	-	-	-	-	-	0,10	0,04	3,33	0,47	0,25
Fabaceae	*Desmodium adscendes* (Sw.) DC.*	-	-	-	-	-	4,70	1,88	26,67	3,74	2,81
Fabaceae	*Desmodium incanum* (Sw) DC.*	-	-	-	-	-	1,10	0,44	10,00	1,40	0,92
Fabaceae	*Stylosanthes leiocarpa* Vogel	-	-	-	-	-	0,30	0,12	10,00	1,40	0,76
Hypoxidaceae	*Hypoxis decumbens* L.	-	-	-	-	-	0,20	0,08	6,67	0,93	0,51
Juncaceae	*Juncus microcephalus* Kunth	-	-	-	-	-	0,70	0,28	20,00	2,80	1,54
Juncaceae	*Juncus capillaceus* Lam.	0,20	0,07	6,67	0,98	0,53	-	-	-	-	-
Juncaceae	*Juncus tenuis* Willd.	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-

Lamiaceae	*Scutellaria racemosa* Pers.	0,10	0,03	3,33	0,49	0,26	0,10	0,04	3,33	0,47	0,25
Marsileaceae	*Marsilea ancylopoda* A. Braun	13,10	4,58	76,67	11,27	7,93	-	-	-	-	-
Mayacaceae	*Mayaca sellowiana* Kunth	-	-	-	-	-	3,70	1,48	16,67	2,34	1,91
Menyanthaceae	*Nymphoides indica* (L.) Kuntze	2,10	0,73	30,00	4,41	2,57	-	-	-	-	-
Onagraceae	*Ludwigia octovalvis* (Jacq.) P.H. Raven	-	-	-	-	-	1,40	0,56	16,67	2,34	1,45
Onagraceae	*Ludwigia grandiflora* (Michx.) Greuter & Burdet	48,30	16,88	76,67	11,27	14,08	-	-	-	-	-
Orobanchaceae	*Buchnera integrifolia* Larrañaga	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Plantaginaceae	*Bacopa monnieri* (L.) Pennell	11,60	4,05	26,67	3,92	3,99	-	-	-	-	-
Plantaginaceae	*Bacopa salzmannii* Wettst. ex Edwall.	0,80	0,28	13,33	1,96	1,12	-	-	-	-	-
Poaceae	*Andropogon lateralis* Nees	0,60	0,21	6,67	0,98	0,60	7,00	2,80	20,00	2,80	2,80
Poaceae	*Andropogon selloanus* (Hack.) Hack.	-	-	-	-	-	0,20	0,08	6,67	0,93	0,51
Poaceae	*Axonopus affinis* Chase	6,00	2,10	10,00	1,47	1,78	4,80	1,92	20,00	2,80	2,36
Poaceae	*Dichantelium sabulorum* (Lam.) Gould & C.A. Clark	-	-	-	-	-	0,30	0,12	10,00	1,40	0,76
Poaceae	*Eragrostis cataclasta* Nicora	-	-	-	-	-	0,30	0,12	10,00	1,40	0,76
Poaceae	*Eragrostis plana* Nees*	-	-	-	-	-	0,70	0,28	10,00	1,40	0,84
Poaceae	*Eriochrysis cayennensis* P. Beauv.	-	-	-	-	-	6,20	2,48	23,33	3,27	2,88
Poaceae	*Leersia hexandra* Sw.	-	-	-	-	-	9,00	3,60	6,67	0,93	2,27
Poaceae	*Luziola peruviana* Juss. ex J.F.Gmel.	93,10	32,54	86,67	12,75	22,64	80,10	32,03	73,33	10,28	21,15
Poaceae	*Paspalum notatum* Flüggé	3,40	1,19	16,67	2,45	1,82	9,10	3,64	13,33	1,87	2,75
Poaceae	*Paspalum pauciciliatum* (Parodi) Herter	1,50	0,52	6,67	0,98	0,75	0,10	0,04	3,33	0,47	0,25
Poaceae	*Paspalum pumilum* Nees	-	-	-	-	-	23,50	9,40	36,67	5,14	7,27
Poaceae	*Paspalum urvillei* Steud.	-	-	-	-	-	0,60	0,24	6,67	0,93	0,59
Poaceae	*Saccharum villosum* Steud.	-	-	-	-	-	0,60	0,24	6,67	0,93	0,59
Poaceae	*Setaria parviflora* (Poir.) Kerguélen	0,10	0,03	3,33	0,49	0,26	0,20	0,08	6,67	0,93	0,51
Poaceae	*Sorghastrum* sp.	-	-	-	-	-	1,60	0,64	10,00	1,40	1,02
Poaceae	*Steinchisma hians* (Elliott) Nash	1,60	0,56	10,00	1,47	1,01	0,30	0,12	10,00	1,40	0,76
Poaceae	*Trichanthecium schwackeanum* (Mez) Zuloaga & Morrone	-	-	-	-	-	9,00	3,60	13,33	1,87	2,73

Poaceae	*Axonopus jesuiticus* (Araújo) Valls	27,00	9,44	10,00	1,47	5,45	-	-	-	-	-
Poaceae	*Cynodon dactylon* (L.) Pers.	0,50	0,17	3,33	0,49	0,33	-	-	-	-	-
Poaceae	*Eleusine tristachya* (Lam.) Lam.	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Poaceae	*Eragrostis cataclasta* Nicora	0,60	0,21	6,67	0,98	0,60	-	-	-	-	-
Poaceae	*Paspalum dilatatum* Poir.	0,30	0,10	10,00	1,47	0,79	-	-	-	-	-
Poaceae	*Paspalum vaginatum* Sw.	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
Poaceae	*Sporobolus indicus* (L.) R.Br.	1,10	0,38	6,67	0,98	0,68	-	-	-	-	-
Polygonaceae	*Polygonum punctatum* Elliott	1,10	0,38	23,33	3,43	1,91	-	-	-	-	-
Pontederiaceae	*Heteranthera reniformis* Ruiz & Pav.	24,60	8,60	56,67	8,33	8,47	-	-	-	-	-
Rubiaceae	*Galium humile* Cham. & Schltdl.	-	-	-	-	-	0,30	0,12	10,00	1,40	0,76
Salviniaceae	*Salvinia minima* Baker	0,40	0,14	13,33	1,96	1,05	-	-	-	-	-
Xyridaceae	*Xyris jupicai* Rich.	-	-	-	-	-	2,20	0,88	16,67	2,34	1,61
	N.d.1	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-
	N.d.2	0,10	0,03	3,33	0,49	0,26	-	-	-	-	-

CONSIDERAÇÕES FINAIS

Os dados obtidos nesse trabalho contribuíram para o conhecimento da vegetação aquática no Sul do Brasil.

No primeiro artigo, evidenciamos grande riqueza de espécies aquáticas para o Sul do Brazil e inferimos sobre os padrões aos quais elas estão submetidas em âmbito Sul-americano. Além disso, unificamos informações de anos de pesquisa dessa região. Essa unificação de dados contribuirá para novas pesquisas e discussão no núcleo de especialistas de macrófitas aquáticas do Brasil.

No segundo artigo testamos o método de espécies indicadoras em duas áreas úmidas, até então não testado na região. Evidenciamos padrões de zonação similares em ambas as localidades estudadas e inferimos sobre a aplicabilidade de usar espécies indicadoras de áreas úmidas no Sul do Brasil.