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Original Paper

Structure and floristics of the plant community in Lagoa do São Bento, Maricá, Rio de Janeiro state, Brazil

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Abstract

Lagoa do São Bento is a coastal restinga wetland, remnant of a paleolake, located in Maricá, RJ. The study aimed to inventory native aquatic plants, make a floristic comparison with other coastal lagoons and analyze the regeneration of this community after anthropic impacts. In the floristic analysis of aquatic plants, 45 species were listed, 39 of which are Angiosperms and six are Ferns. *Aeschynomene paniculata*, *Hymenachne amplexicaulis*, *Montrichardia linifera* and *Torenia thouarsii* are new records for the municipality and *Tabebuia cassinoides* is threatened. Emerging plants (21 spp.) stand out, followed by amphibians (16 spp.), free floating (4 spp.), fixed floating (3 spp.) and tolerant (1 sp.). The comparison showed greater similarity with the Jacarepiá lagoon, in Saquarema, sharing 21 species. The phytosociological inventory listed 87 species, 83 of which were Angiosperms and four Ferns. The species with the highest IVI were: *Fuirena umbellata*, *Pleroma gaudichaudianum*, *Xyris jupicai*, *Typha domingensis*, *Salvinia* aff. *auriculata*, *Eleocharis interstincta*, *Rhynchospora gigantea*, *Nymphoides humboldtiana*, *Nymphaea caerulea* and *Clitoria laurifolia*. Shannon, Simpson and equity indexes were 3.83, 0.03 and 0.85, respectively. Native aquatic species represent the majority of the total inventoried (54%), with a considerable supply of exotic and ruderal, whose colonization reflects the anthropic interventions.

Key words: conservation, phytosociology, regeneration, restinga, wetlands.

Resumo

A Lagoa do São Bento é uma área úmida costeira de restinga, resquício de uma paleolagoa, localizada em Maricá, RJ. O estudo objetivou inventariar as plantas aquáticas nativas, fazer a comparação florística com outras lagoas costeiras e analisar a regeneração dessa comunidade após impactos antrópicos. Na análise florística de plantas aquáticas foram listadas 45 espécies, das quais 39 são Angiospermas e seis são Samambaias. *Aeschynomene paniculata*, *Hymenachne amplexicaulis*, *Montrichardia linifera* e *Torenia thouarsii* são novos registros para o município e *Tabebuia cassinoides* é ameaçada de extinção. Sobressaem as plantas emergentes (21 spp.), seguida de anfíbias (16 spp.), flutuante livres (4 spp.), flutuante fixas (3 spp.) e tolerantes (1 sp.). A comparação mostrou maior similaridade com a lagoa de Jacarepiá, em Saquarema, compartilhando 21 espécies. O inventário fitossociológico listou 87 espécies, sendo 83 Angiospermas e quatro Samambaias. As espécies com maior IVI foram: *Fuirena umbellata*, *Pleroma gaudichaudianum*, *Xyris jupicai*, *Typha domingensis*, *Salvinia* aff. *auriculata*, *Eleocharis interstincta*, *Rhynchospora gigantea*, *Nymphoides humboldtiana*, *Nymphaea caerulea* e *Clitoria laurifolia*. Os índices de Shannon, Simpson e equabilidade foram 3,83, 0,03 e 0,85, respectivamente. As aquáticas nativas representam a maior parte do total inventariado (54%), havendo um aporte considerável de exóticas e ruderais, cuja colonização reflete as intervenções antrópicas.

Palavras-chave: conservação, fitossociologia, regeneração, restinga, áreas úmidas.

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Introduction

Wetlands are ecosystems arranged at the interface between terrestrial and aquatic, continental or coastal, natural or artificial environments, endowed with soaked soils permanently or periodically flooded by shallow, sweet, brackish or salty waters, with communities of plants and animals adapted to the hydrous dynamics (Junk *et al*. 2011). They comprise approximately 20% of the Brazilian territory (Junk *et al*. 2011) but are still shortly known in terms of biological diversity. Despite the important ecological and economic functions, these environments have suffered from the action of various human activities over time (Bozelli *et al*. 2018). Due to the socio-environmental importance of these environments, groups of nations established in 1971 the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat (Secretariado da Convenção Ramsar 2004). Brazil is a signatory to this convention, since 1975 (Brasil 1992, 1996), expanding the protection of wetlands, previously legally protected only in protected areas (Tavares *et al*. 2012).

The plants which constitute this type of environment are aquatic macrophytes, defined as macroscopic forms of aquatic vegetation, whose photosynthetically active parts are permanently, or for some months of the year submerged in the water body or floating on the water surface (Irgang & Gastal Jr. 1996). This vegetation is composed of hydrophytes, plants that are periodically submerged at different levels and amphibious species (Bove *et al*. 2003). These plants play important ecological functions: cycling the organic matter from this environment; favoring the increase of fauna diversity; reducing the erosion and filtering the material of allochthonous origin (Esteves & Camargo 1986).

Brazil has the largest hydrographic network in the world with 55.5 km² (Medeiros *et al*. 2011), with well-represented ecosystems in rivers and permanent or temporary lakes (Cervi *et al*. 2009). However, despite their large dimensions and the diversity of these ecosystems, the floristic and structural inventories of aquatic macrophytes need to be further intensified (Rodrigues *et al*. 2017). To help filling part of this gap in studies that focus on aquatic plants, Pivari *et al*. (2019) presented the data repository and an online platform, created specifically for the management of information about these plants in Brazil, with the first results for the Southeast Region.

In the state of Rio de Janeiro few inventories of aquatic plants have been carried out, however, there are some studies, with different approaches, carried out in restingas that also included these species in their listings (Tab. 1). A more comprehensive study was carried out by Bove *et al*. (2003), listing the species of the coastal plain, presenting their biological forms and habitat. Another contribution was to the organization of the Flora of Rio de Janeiro, registering 17 families with aquatic plants (Coelho *et al*. 2017; Lourenço & Bove 2019).

A greater intensification of urbanization, since it was possible to establish a road relationship with large urban centers, resulted in the growth of irregular and illegal allotments in the municipality (Aliprandi *et al*. 2014). This form of occupation proved to be disordered and with no commitment to conservation. In the municipality of Maricá, water bodies, especially the lagoon system and wetlands have been exposed to environmental degradation in recent decades, either through pollution or landfilled for real estate occupation and which have historically been filled and drained, as in the district of Itaipuaçu (*e.g.*, Lamego 1946; Ramadon 1996; Eirin & Bento 2005; Coyunji 2013; Fernandez *et al*. 2018; Pontes *et al*. 2020). This form of urban development was considered a milestone in the struggle for civilization, as in the state capital (Godoy *et al*. 2011). Currently, the biggest threat to the remaining restingas of Itaipuaçu and the Barra de Maricá is the possibility of building a Portuguese-Spanish residential and tourist complex (Souza 2015; Diniz *et al*. 2015; Cantarelli *et al*. 2019). Its destruction results in the extinction of species, including endemic and endangered species (Araujo 2008; Souza 2015).

With the mobilization of organized civil society, the local and academic communities, part of what remained of the typical vegetation was transformed into a conservation unity in the category of Environmental Protection Area (Rio de Janeiro 1984). Then, this restinga has been historically studied by several areas of academic knowledge, being considered one of the most researched in Brazil (Cantarelli *et al*. 2019).

The restingas and the wetlands have very particular characteristics and any environmental change can generate different responses, negatively impacting them (Minshall & Rugenski 2007; Pompêo 2008). Few areas of restinga, still well preserved, remained in the middle of the urban advance outside the conservation unit in Maricá, especially wetlands (Aliprandi *et al*. 2014; Castro 2015).

Table 1 – Water plants inventories made in the state of Rio de Janeiro, Brazil.

Municipality	Area	Richness	Reference
Macaé	Lagoa de Jurubatiba (Cabiúnas)	58 species 42 genera 27 families	Bove & Paz (2009)
Carapebus	Lagoa de Carapebus	48 species 43 genera 31 families	Bove & Paz (2009)
Macaé	Lagoa Comprida	45 species 34 genera 24 families	Bove & Paz (2009)
Carapebus	Lagoa Paulista	45 species 34 genera 23 families	Bove & Paz (2009)
Saquarema	Lagoa de Jacarepiá	42 species 34 genera 21 families	Barros (2009)
Quissamã	Lagoa Pires	24 species 21 genera 15 families	Bove & Paz (2009)
Quissamã	Lagoa Amarra-boi	20 species 18 genera 15 families	Bove & Paz (2009)
Quissamã	Lagoa Preta	16 species 15 genera 11 families	Bove & Paz (2009)
Quissamã	Lagoa das Garças	7 species 7 genera 6 families	Bove & Paz (2009)
Macaé	Lagoa Encantada	2 species 2 genera 2 families	Bove & Paz (2009)
Quissamã	Lagoa do Visgueiro	2 species 2 genera 2 families	Bove & Paz (2009)
Quissamã	Lagoa do Piripiri	1 species 1 genus 1 family	Bove & Paz (2009)

A first intervention by the municipality of Maricá in the wetland known as Lagoa do São Bento, in the late 1990s, which aimed to transform it into a balneary, introduced exotic plant species and elements of urbanization. After public abandonment in the following years part of that area underwent a natural recovery of the environment. In 2017, a project was presented to city hall proposing to protect this lagoon as a fully municipal protected area "Refúgio de Vida Silvestre" (Brasil 2000; Pontes *et al.* 2020). This proposal was made by researchers based on local studies, which registered several animal and plant species, endemic and endangered [*e.g.*, *Parides ascanius* (Cramer 1775); *Tabebuia cassinoides* (Lam.) DC.] (Pontes & Pontes 2016; Duarte 2019; Pontes *et al*. 2020). In June 2018, despite the popular appeal and conservationist arguments, an intervention by the "Secretaria Municipal de Obras", destroyed 40% of this wet area and part of the biota it held (Pontes 2018, 2019; Pontes *et al*. 2020) (Fig. 1a-e).

The study aimed to inventory native aquatic plants occurring in Lagoa do São Bento, make a floristic comparison with other coastal lagoons in the state of Rio de Janeiro and analyze the regeneration of this community after anthropic impacts. In addition, estimate the amounts lost in terms of ecosystem services.

Materials and Methods

Study area

Lagoa do São Bento is located in Barroco, Itaipuaçu district, municipality of Maricá, state of Rio de Janeiro, approximately with 6.9 ha including unoccupied areas (23K 706951,85 E - 7459952,46 N, UTM, SIRGAS 2000), distant 9.9 km from Maricá lagoon system (Figs. 1a-e; 2). Although it is recognized locally as a "lagoon", it is actually a remnant lake of a larger water body (paleolake), which was fed by rain and river drains that came from the local restinga and forested areas of the Serra da Tiririca slope. This wetland has been recovered naturally, after the end of the activities of mineral exploration, landfills, and drainage (Pontes 2018, 2019; Pontes *et al*. 2020).

Phytophysiognomically it is characterized by restinga vegetation with a swampy margin, occupied by coastal vegetation, typical of these environments. Inside the lake body there are three dunes that form small islands in times of rain, upon which a shrub and herbaceous vegetation develops. It has 6.16 ha, with its marginal strip and a perimeter of 974 m, with a maximum depth of 1.60 m in periods of flood (Pontes 2018, 2019; Pontes *et al*. 2020). The climate of the region, according to the Köppen-Geiger classification, is of the *Aw* type, that is, rainy tropical, with hot rainy summer and dry winter. The annual average temperature varies between 22 ^{o}C and 24 ^{o}C, with average of the total precipitation between 1,250 and 1,500 mm/year (Nimer 1989; Kottek *et al*. 2006).

Floristic inventory

The floristic inventory of Lagoa de São Bento was carried out from February 2018 to January 2020, and the walking method was used (Filgueiras *et al*. 1994). Both the surroundings and the interior of the lagoon were covered on foot to collect ideal material, according to techniques used in floristic inventories (Peixoto & Maia 2013). The samples were registered in the RFFP and RB herbaria [acronyms according to Thiers (continuously updated)]. For the identification of species, specialized bibliography was used, along with comparisons in the collection of RB and RFFP herbaria, in addition to consultation with specialists, when necessary. To complement the information, consultations were carried out at online scientific collections of herbaria from the state of Rio de Janeiro which have records for the studied region using the JABOT platform (JBRJ 2021). The spellings of the species were checked based on Flora do Brasil 2020 (continuously updated).

The floristic list was organized for families of Angiosperms based on APG IV (2016) and Ferns on PPG I (2016), with Leguminosae following the LPWG (2017) proposal. The species were classified according to habits based on Barros (2009) in herbs, shrubs and trees. The new occurrences for the municipality of Maricá were verified based on the consultation made in the R, RB, and RFFP herbaria, in the online databases JABOT and speciesLink and in the studies of Gil & Bove (2007), Lourenço & Bove (2019), in addition to the volume 68 of Rodriguésia, which deals with 16 families occurring in aquatic environments in the state of Rio de Janeiro (Coelho *et al*. 2017). Data on endemic species in Brazil and distribution in the five regions were obtained from Flora do Brasil 2020 (continuously updated).

The aquatic species were classified according to their biological forms based on Irgang *et al*. (1984) and Novelo & Gallegos (1988), five categories being considered: amphibians - aquatic plants that are in the surroundings, able to withstand periods of drought and tolerate high humidity for a short time; emergent - with the root fixed to the substrate being partially submerged and the aerial part outside the water depth; fixed floating - with root fixed on the substrate and having or not floating stem, branches or leaves; free floating - floating plants not fixed to the substrate, even with the flowers protruding into the air; tolerant - terrestrial plants that have much of their life cycle in completely dry soils, but tolerate high moisture in the sediment for a short time.

Phytosociological inventory

After the 2018 anthropic intervention, floristic regeneration was evaluated with the present study. Thus, four equidistant points in Lagoa do São Bento were randomly selected, which had different physiognomic characteristics (Fig. 1e). Point 1 (22º57'22.38"S, 42º58'52.95"W) is

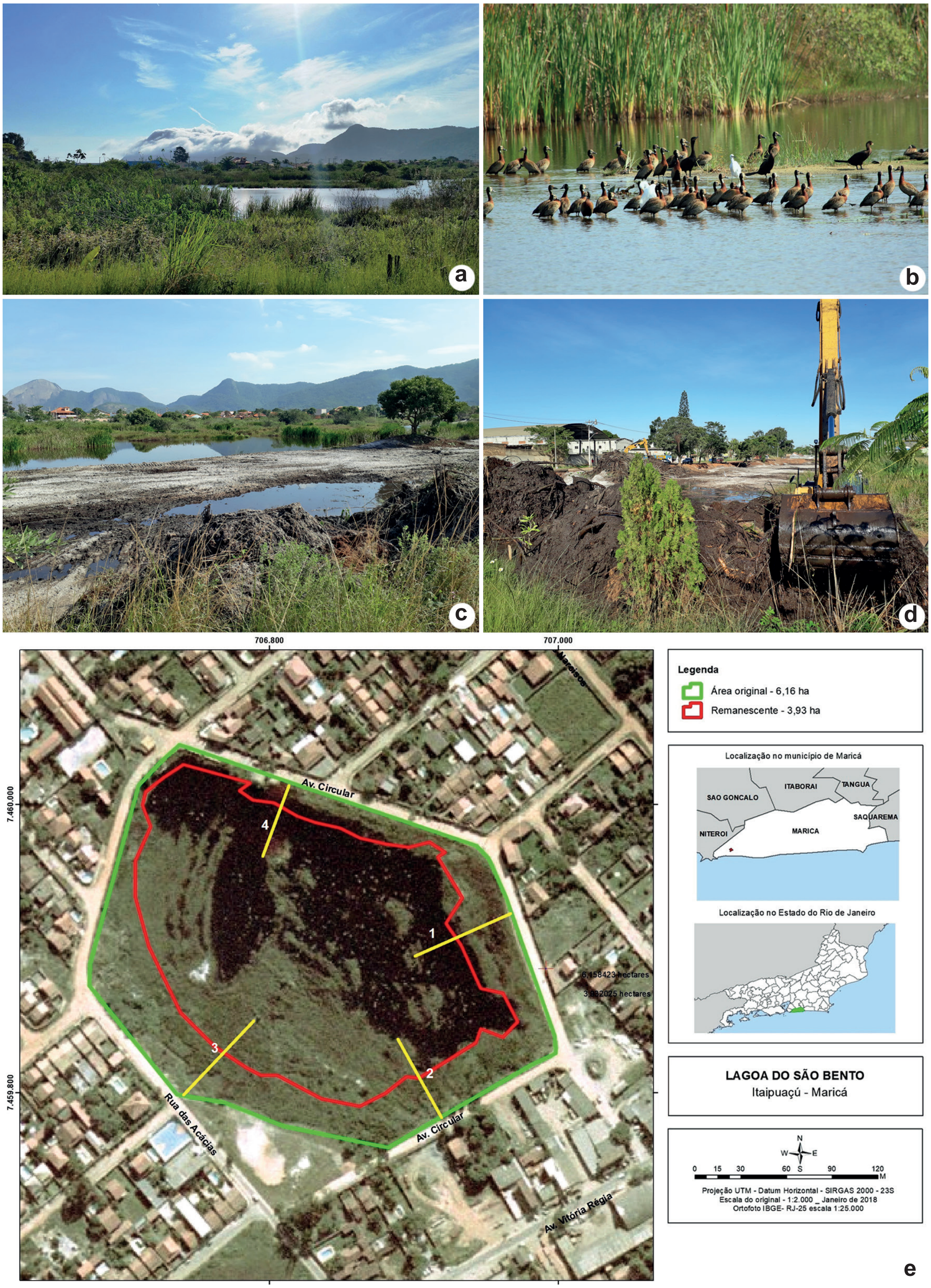

Figure 1 – a-e. Aspects and location of Lagoa do São Bento, Barroco, Itaipuaçu, Maricá, state of Rio de Janeiro, Brazil – a-b. vegetation cover of the lagoon and part of the fauna in 2016; c-d. aspects of the same location during the intervention of the municipal works department of the Municipality of Maricá in 2018; e. map of the location of Lagoa de São Bento indicating the area where its marginal vegetation was removed (red line) and four points sampled for analysis of vegetation regeneration after the anthropic impact that occurred in 2018 (yellow lines). Photos: a-d. Jorge Antônio Lourenço Pontes (2018); e. Pontes 2020 (modified).

permanently flooded and its substrate is organic on a sandy bottom. Point 2 (22º57'26.35"S, 42º58'54.34"W) is partially flooded (flood periods), with a predominantly organic soil. Point 3 (22º57'25.37"S, 42º59'01.08"W) was the most impacted, where residues from works discarded by residents are found; it is partially flooded, its end coinciding with one of the dunes remnants. Point 4 (22º57'18.91"S, 42º58'57.97"W) in addition to being impacted by the intervention, has an old concrete deck in the vicinity where an area with gym equipment was built, a remnant of the urbanization attempt undertaken in the 1990s; it is predominantly flooded and its end coincides with a small sandy island.

From each point, lines of 50 m were stretched towards the interior of the lagoon, perpendicular to the margin. Along each line, the surface sampling method (Boldrini *et al.* 2008) was used, using plots of 1 m² (1 m × 1 m) (Fig. 3a-c). The coverage values of each species were estimated according to the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974), four classes being considered: C1 (25% of the plot area); C2 (50%); C3 (75%) and C4 (100%). All collected data was entered in an Excel spreadsheet (version 2010) to calculate the phytosociological parameters of absolute coverage (AC), relative coverage (RC%), absolute frequency (AF), relative frequency (RF%) and the importance value (IV%) for each of the sampled species. 13 visits were made to the area, with the participation of four researchers, who spent a total sampling effort of 260 h.

In addition to native aquatic plants, ruderal and exotic plants were considered also in the phytosociological inventory. Ruderal species were separated according to Kissmann & Groth (1997, 1999, 2000) and exotic species according to Flora do Brasil 2020 (continuously updated).

Statistical analysis

Shannon's diversity indices (H'), equability (J') and Simpson's concentration (C) (Magurran 2011) were also calculated in the Microsoft Excel (2010). Rarefaction curves were generated based on individuals with a 95% confidence interval, using the rarecurve function of the R software (R Core Team 2017), in order to compare the species richness. Cluster analysis was used to assess the similarity between the four lines and also among

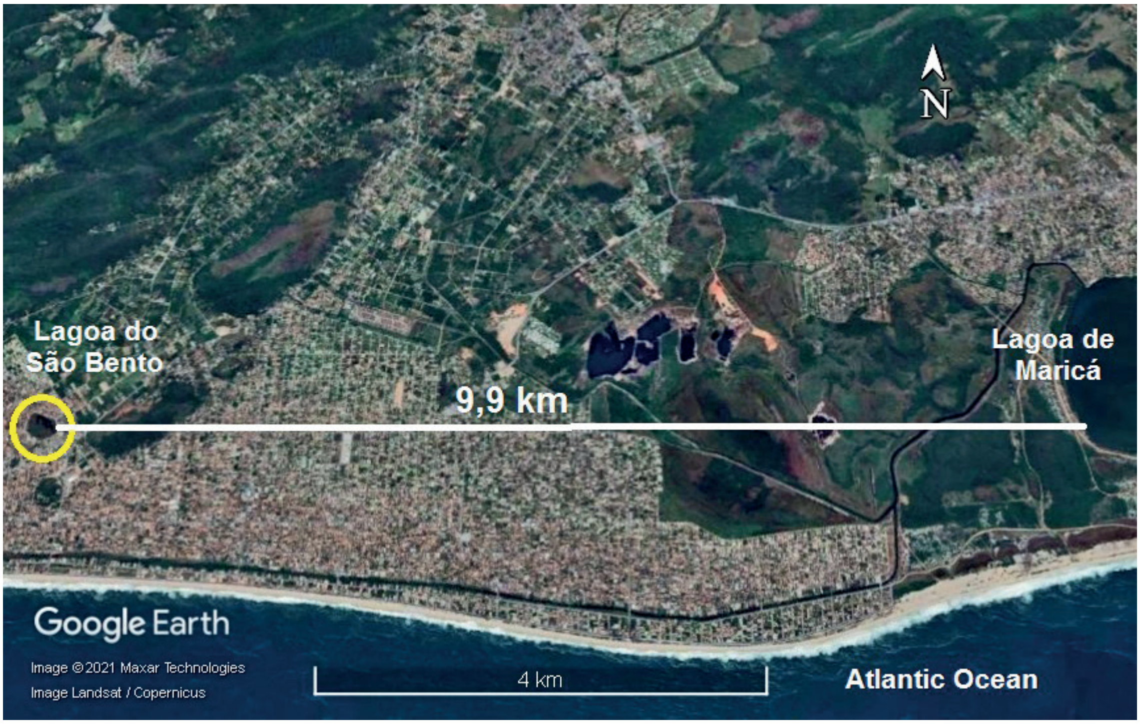

Figure 2 – Distance from the study area of the Maricá Lagoon System, state of Rio de Janeiro, Brazil. Image: Google Earth (2021), modified by the authors.

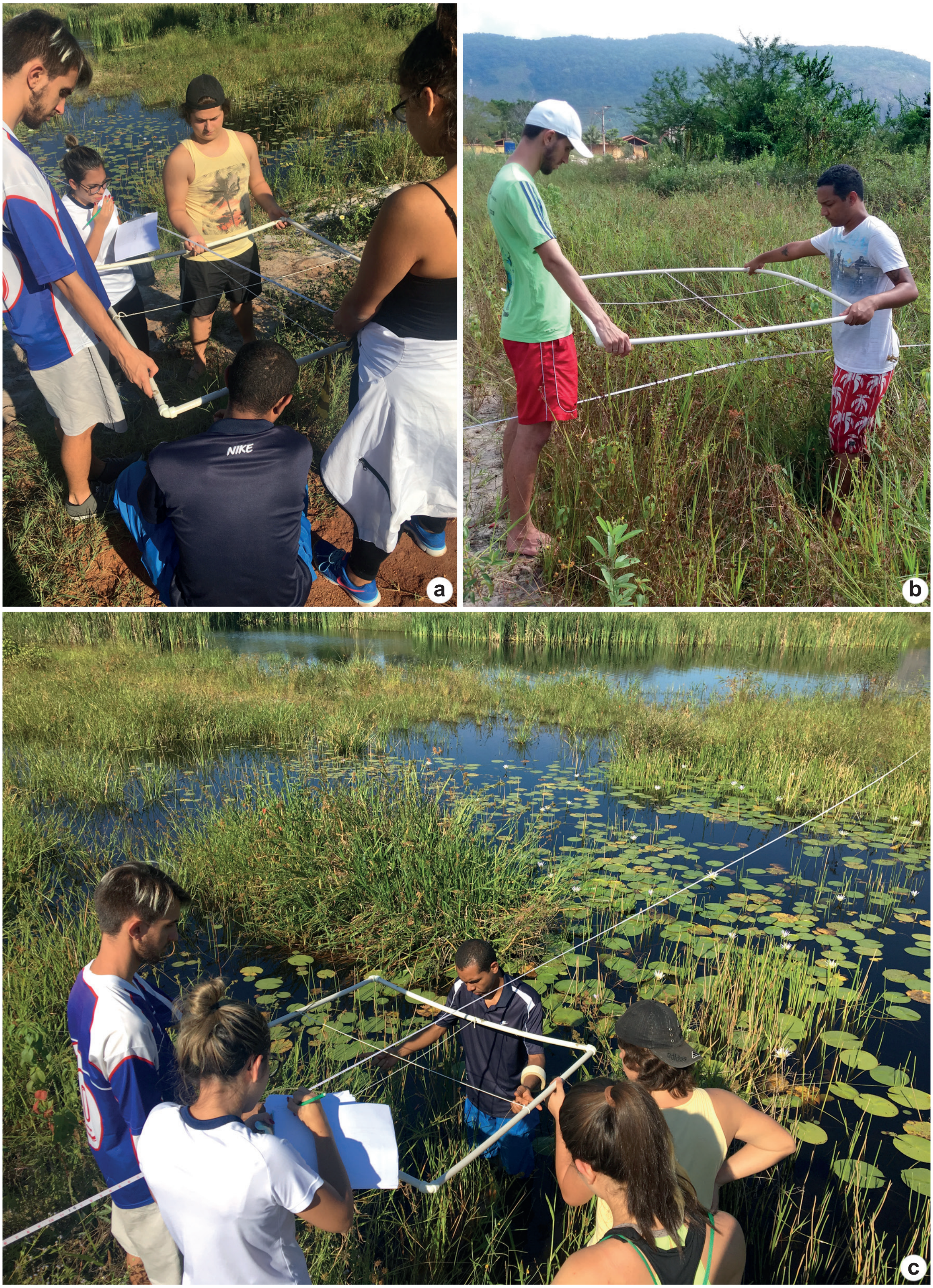

Figure 3 – a-c. Phases of structural analysis in Lagoa do São Bento, Barroco, Itaipuaçu, Maricá, state of Rio de Janeiro, Brazil – a. delimitation of a sampling unit to be inventoried at a point; b. sampling at point 3, close to the dune remnant; c. point 1 being inventoried. Photos: a, c. Daniel Luiz da Silva Dutra Jr. (2019); b. Davi N. da Silva Machado (2019).

the floristic list of aquatic plants found in Lagoa do São Bento with other coastal lagoons in the state of Rio de Janeiro. In both situations, based on the occurrence of each species, a binary matrix was organized, and the cluster analysis was performed using the UPGMA method, considering the Jaccard Index as a measure of similarity (Mueller-Dombois & Ellenberg 1974). Statistical calculations were performed using the PAST software (Hammer *et al.* 2001). Venn diagram was made to visualize species shared (Gotelli & Ellison 2016).

Additionally, the global value of ecosystem services provided by Lagoa do São Bento and the possible economic loss by the municipality, after the 2018 intervention, was calculated based on the immediate loss of 40% of the area, using ArcGIS and Photoshop software, on ESRI Basemap with resolution of 30 cm from the date before the impacts observed in 2018 (Pontes *et al*. 2020). The values of the ecosystem services provided were calculated according to the table for wetlands in Costanza *et al*. (1997, 2014, 2017), with adjustments to the US dollar and accumulated inflation (Pontes *et al*. 2020).

Results and Discussion

Floristic analysis of aquatic plants

The floristic inventory registered 45 species, distributed in 26 families and 38 genera. Of which, 39 species are Angiosperms, belonging to 22 families and 32 genera. Six are Ferns, corresponding to four families and six genera (Tab. 2; Fig. 4a-f). Among the Angiosperms, the families with the greatest richness of species Cyperaceae (7 spp.), Araceae e Plantaginaceae (3 spp. each) stood out, representing 28.9% of the total richness. The genera *Bacopa*, *Cyperus*, *Eleocharis*, *Ludwigia*, *Nymphaea*, *Polygonum* and *Rhynchospora* (2 spp., each) were the most representative, being 31% of the total inventoried. The remaining 31 genera have one species each. Among the Ferns, Pteridaceae stood out with three species and the other families with one species each (Tab. 2).

The richness of aquatic macrophytes found in the study area is close to that inventoried in other regions of the state of Rio de Janeiro, as the Lagoa de Jacarepiá in Saquarema (42 spp.) (Barros 2009) and part of the lagoons of the PNRJ (Restinga de Jurubatiba National Park), conservation unit that covers Macaé, Carapebus and Quissamã, where the richness varied between 58 and 16 species (Lagoas do Amarra-Boi, Carapebus, Comprida, Jurubatiba, Paulista, Pires and Preta) (Bove & Paz 2009). Areas with lesser aquatic macrophytes richness include PNRJ ponds (Encantada, Piripiri and Visgueiro), which are represented by one or two species (Bove & Paz 2009).

When the PNRJ lagoons were analyzed together, the total richness found corresponds to 100 species, however when viewed individually, a variation in this parameter is observed. This difference is due to issues such as the different processes that originated each one, in addition to being very different in terms of chemical composition, extent and depth. Furthermore, Lagoas Encantada, Pires, Piripiri, Preta, Sea bass and Visgueiro are hypersaline, a limiting factor for the occurrence of aquatic macrophytes (Bove & Paz 2009). On the other hand, the inventory carried out in Lagoa de Jacarepiá (Barros 2009) registered a richness greater than that pointed out in the present study (101 spp.), since it included typical species of sandy and ruderal plains. However, for comparison purposes, only aquatic macrophytes were considered, which justifies the differentiated richness value.

The inventoried Angiosperms are common to those found in other studies in the state of Rio de Janeiro, with 24 species also registered in the PNRJ lagoons (Bove & Paz 2009) and 18 in the Lagoa de Jacarepiá (Barros 2009). The ferns found are in accordance with the knowledge of the pteridophytic flora of the restingas of the state (Santos & Araujo 2007).

Among the families highlighted in this study, Cyperaceae emerges with greater richness in the areas of Rio de Janeiro, a result that is also similar to that found in other studies in different regions in Brazil (Pott *et al*. 1989 - Midwest; Kita & Souza 2003 - South; Matias *et al*. 2003 - Northeast; Pivari *et al*. 2008 - Southeast; Pinheiro & Jardim 2015 - North). This data is supported mainly by the genera *Cyperus* and *Eleocharis*, with *Cyperus* being the second richest in the family, occurring in different environments, while *Eleocharis* is found exclusively in humid areas (Gil & Bove 2007; Gonçalves 2014).

From the total inventoried, seven species are registered for the first time for the municipality of Maricá: *Aeschynomene paniculata*, *Hymenachne amplexicaulis*, *Montrichardia linifera* and *Torenia thouarsii*. These new occurrences are related to the sampled herbaceous form of life. The lack of data regarding floristic inventories in coastal lakes makes comparative analyses and records

Table 2 – Species of aquatic plants inventoried at Lagoa do São Bento, Barroco, Itaipuaçu, Maricá, state of Rio de Janeiro, Brazil. # = new occurrences for the municipality of Maricá; * = species endemic to Brazil; F. Biological = biological form; H = habit (He = herb; Sh = shrub; Tr = tree).

Families (n genera/species)	Species	F. Biological	H	Voucher
Angiosperms				
Araceae (3/3)	*Lemna aequinoctialis* Welw.	Free floating	He	*Silva 26*
	# *Montrichardia linifera* (Arruda) Schott	Emergent	He	*Santos 03*
	Pistia stratiotes L.	Free floating	He	*Silva 41*
Asteraceae (1/1)	*Barrosoa betonicaeformis* (DC.) R.M. King & H.Rob.	Amphibian	He	*Santos 32*
Begoniaceae (1/1)	*Begonia fischeri* Schrank	Emergent	He	*Santos 33*
Bignoniaceae (1/1)	* *Tabebuia cassinoide*s (Lam.) DC.	Emergent	Tr	*Silva 89*
Cyperaceae (4/7)	*Cyperus aggregatus* (Willd.) Endl.	Amphibian	He	*Silva 60*
	Cyperus ligularis L.	Amphibian	He	*Santos 46*
	Eleocharis geniculata (L.) Roem. & Schult.	Emergent	He	*Santos 24*
	Eleocharis interstincta (Vahl) Roem. & Schult.	Emergent	He	*Santos 14*
	Fuirena umbellata Rottb.	Amphibian	He	*Barros 985*
	Rhynchospora gigantea Lin*k*	Amphibian	He	*Barros 986*
	Rhynchospora holoschoenoides (Rich.) Herter	Amphibian	He	*Santos 41*
Eriocaulaceae (1/2)	* *Leiothrix rufula* (A.St.-Hil.) Ruhland	Amphibian	He	*Sousa 350*
	Paepalanthus tortilis (Bong.) Mart.	Amphibian	He	*Silva 94*
Euphorbiaceae (1/1)	*Caperonia heteropetala* Didr.	Amphibian	He	*Silva 01*
Gentianaceae (1/1)	*Schultesia guianensis* var. *latifolia* (Mart. *ex* Progel) E.F.Guim. & Fontella	Emergent	He	*Silva 77*
Leguminosae (2/2)	# *Aeschynomene paniculat*a Willd. *ex* Vogel	Emergent	He	*Santos 105*
	Stylosanthes viscosa (L.) Sw.	Tolerant	He	*Santos 17*
Lentibulariaceae (1/1)	*Utricularia gibba* L.	Emergent	He	*Silva 12*
Linderniaceae (1/1)	# *Torenia thouarsii* (Cham. & Scltdl.) Kuntze	Emergent	He	*Santos 28*
Melastomataceae (2/2)	*Rhynchanthera dichotoma* (Desr.) DC.	Amphibian	Sh	*Silva 47*
	* *Pleroma gaudichaudianum* (DC.) A. Gray	Amphibian	Sh	*Silva 38*
Menyanthaceae (1/1)	*Nymphoides humboldtiana* (Kunh) Kuntze	Fixed floating	He	*Sousa 353*
Nymphaeaceae (1/2)	*Nymphaea pulchella* DC.	Fixed floating	He	*Pontes*
	Nymphaea rudgeana G.Mey.	Fixed floating	He	*Pontes*
Ochnaceae (1/1)	*Sauvagesia erecta* L.	Amphibian	He	*Silva 10*
Onagraceae (1/2)	*Ludwigia leptocarpa* (Nutt.) H.Hara	Emergent	He	*Santos 52*
	Ludwigia octovalvis (Jacq.) P.H.Raven	Emergent	He	*Silva 46*
Plantaginaceae (2/3)	* *Bacopa lanigera* (Cham. & Schltdl.) Wettst.	Emergent	He	*Santos 15*
	Bacopa stricta (Schrad.) Wettst. *ex* Edwall	Emergent	He	*Silva 28*

Families (n genera/species)	Species	F. Biological	H	Voucher
	Matourea ocymoides (Cham. & Schltdl.) Colletta & V.C. Souza	Emergent	He	*Santos 37*
Poaceae (2/2)	# *Hymenachne amplexicaulis* (Rudge) Nees	Emergent	He	*Silva 30*
	Trichanthecium parvifolium (Lam.) Zuloaga & Morrone	Emergent	He	*Silva 29*
Polygonaceae (1/2)	*Polygonum acuminatum* Kunth	Amphibian	He	*Santos 89*
	Polygonum persicaria L.	Amphibian	He	*Santos 90*
Pontederiaceae (1/1)	*Eichhornia crassipes* (Mart.) Solms	Free floating	He	*Santos 81*
Typhaceae (1/1)	*Typha domingensis* Pers.	Emergent	He	*Silva 14*
Xyridaceae (1/1)	*Xyris jupicai* Rich.	Amphibian	He	*Santos 19*
Ferns				
Blechnaceae (1/1)	*Telmatoblechnum serrulatum* (Rich.) Perrie, D.J. Ohlsen & Brownsey	Amphibian	He	*Machado 2322*
Pteridaceae (3/3)	*Acrostichum danaeifolium* Langsd. & Fisch.	Emergent	He	*Santos 61*
	Ceratopteris thalictroides (L.) Brongn.	Emergent	He	*Santos 29*
	Pityrogramma calomelanos (L.) Link	Emergent	He	*Santos 53*
Salviniaceae (1/1)	*Salvinia* aff. *auriculata* Aubl.	Free floating	He	*Santos 48*
Thelypteridaceae (1/1)	*Cyclosorus interruptus* (Willd.) H. Ito	Emergent	He	*Machado 2323*

of characteristic species in these environments difficult. Rodrigues *et al*. (2017) raise other issues as limitations for improving this knowledge such as the lack of collections in these water bodies, the large number of indeterminate or wrongly identified specimens, the lack of revisions in families and genera with almost exclusive occurrence in these environments, the great phenotypic plasticity they present, being easily modified by environmental conditions, and very small floral structures.

Montrichardia linifera is considered an endangered (EN) species in the state of Rio de Janeiro by Dutra Jr. *et al.* (2021). Despite having a wide distribution in the north and northeast regions of Brazil, in Rio de Janeiro it occurs only in the estuary of the Paraíba do Sul river, in the northeast region of that state, and in the Lagoa do São Bento in Maricá, in an area threatened by the process of local urbanization. Another species is also categorized as endangered, *Tabebuia cassinoides.* Its removal or alteration of habitat is prohibited by Ordinance MMA 443/2014 (Brasil 2014). The maintenance of water bodies and restingas is of fundamental importance for the conservation of these species with a reduced area of occupancy.

As for biological forms, emerging ones stood out (21 spp. - 46.7%), followed by amphibians (16 spp. - 35.5%), free floating (4 spp. - 8.9%), fixed floating (3 spp. - 6.7%) and tolerant (1 sp. - 2.2%). This distribution is different from that found in the PNRJ lagoons, where amphibious species obtained the highest percentage of biological forms (Bove & Paz 2009). It is believed that this difference is due to the higher level of conservation in the PNRJ lagoons, as the Lagoa do São Bento has recently suffered several impacts (Pontes 2018, 2019). The dominance shown by these life forms has been associated with environmental factors such as seasonal floods, shallow waters, and species resistance to decreasing water volume (Alves *et al*. 2011).

Among the emerging ones, the Cyperaceae *Eleocharis geniculata*, *Eleocharis interstincta* and *Fuirena umbellata* species, present in abundance in the most inland part of the lagoon, are fully submerged in flood periods. In addition to these, *Typha domingensis* and *Acrostichum danaeifolium* are also common, the first being large in density on the banks of the pond. *Montrichardia linifera* occupies the south bank of the lagoon, in two parts, one closer to the edge and the other more to the interior of the flooded portion, these being formed

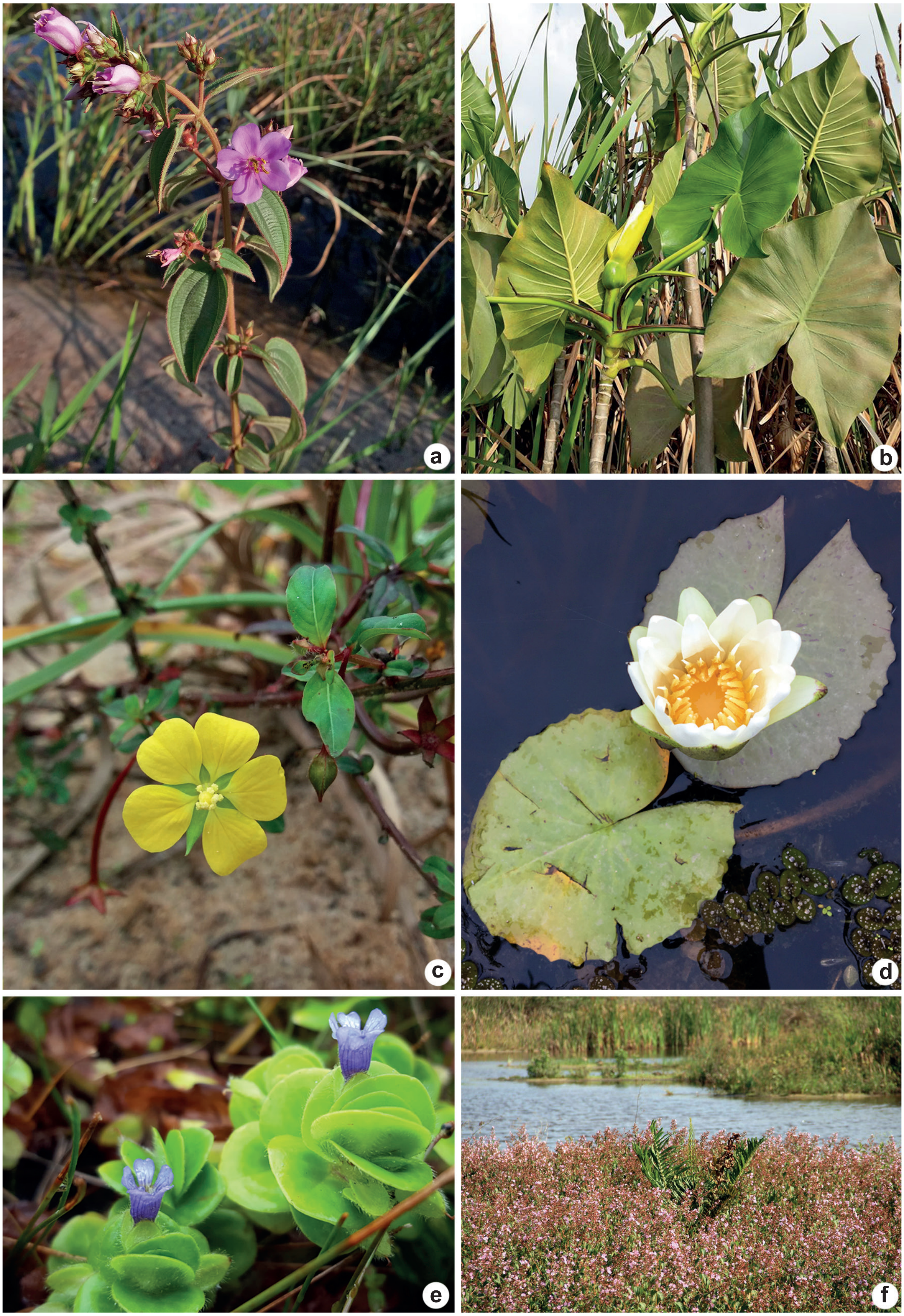

Figure 4 – a-f. Aquatic plants inventoried in the present study – a. *Rhynchanthera dichotoma*; b. *Montrichardia linifera*; c. *Ludwigia leptocarpa*; d. *Nymphaea pulchella*; e. *Bacopa lanigera*; f. *Begonia fischeri* and *Acrostichum danaeifolium*. Photos: a, c. Davi Nepomuceno da Silva Machado (2019); b, d, f. Jorge Antônio Lourenço Pontes (2018); e. Ana Angélica Monteiro de Barros (2018).

by the last specimens that remained after the 2018 anthropic intervention.

Among the amphibians, *Cyperus ligularis* and *Pleroma gaudichaudianum* were found close to the margins and in areas further inside, close to *Xyris jupicai*, but always in stretches with sandy soil. Among the floating ones, three species were observed with greater abundance: *Nymphaea pulchella*, *Nymphoides humboldtiana* and *Salvinia* aff. *auriculata*.

The negative environmental impacts on the ecosystem affected the composition of the community of Lagoa do São Bento, as species such as *Leiothrix rufula*, registered in the collection of the herbarium consulted for the locality, were not found during this study, even before the 2018 intervention; while *Hydrocleys nymphoides* was no longer seen after this disorder. Other species such as *Matourea ocymoides*, *Bacopa lanigera*, *Barrosoa betonicaeformis*, *Begonia fischeri*, *Caperonia heteropetala*, *Ceratopteris thalictroides*, *Eicchornia crassipes*, *Montrichardia linifera*, *Pistia stratiotes*, *Sauvagesia erecta*, *Tabebuia cassinoides*, *Torenia thouarsii*, *Utricularia gibba* had population reduction. The study carried out in the municipalities of Recife, Santa Cruz do Capibaribe and Toritama, in the state of Pernambuco, which border the Rio Capibaribe, showed a result similar to that presented in this study. The authors compared different points on the riverbank and concluded that urbanization significantly influenced the floristic composition and structure of macrophyte communities (Xavier *et al.* 2016).

These impacts may also have represented an economic loss of at least US$ 72,516.56 in the 12 months following the 2017 intervention of the municipal works department, as Lagoa do São Bento provides a total of US$ 181,291.40 per year in environmental services, for the municipality of Maricá. These values were based on studies by Costanza *et al*. (1997, 2014, 2017) on the economy provided by ecosystem services in natural environments, and Pontes *et al*. (2020) for the locality.

Phytosociological inventory

The phytosociological inventory sampled 200 m^2 of Lagoa do São Bento, and 87 species were found, belonging to 39 families and 74 genera (Tab. 3). Of these, 83 species are Angiosperms, belonging to 37 families and 70 genera and four are Ferns, belonging to two families and four genera. Of the Angiosperm families, the richest were Leguminosae (12 spp.), Poaceae (11 spp.), Cyperaceae (10 spp.) and Asteraceae (7 spp.), representing 46% of the total, while of the Ferns, three are Pteridaceae and one is Salviniaceae (4.6%).

The ten species which stood out presenting the biggest indexes on importance value (IVI) were *Fuirena umbellata* (16.31%), *Pleroma gaudichaudianum* (14.30%), *Xyris jupicai* (13.12%), *Typha domingensis* (10.91%), *Salvinia* aff. *auriculata* (10.82%), *Eleocharis interstincta* (9.55%), *Rhynchospora gigantea* Link (8.80%), *Nymphoides humboldtiana* (7.87%), *Nymphaea caerulea* Savigny (7.40%) and *Clitoria laurifolia* Poir. (6.28%) (Fig. 5a-f; Tab. 3).

The richness found in this sample is considered close to that reported for other phytosociological studies carried out in different regions in Brazil, such as in the Midwest (Moreira *et al*. 2011 - 77 spp.), Northeast (Sabino *et al*. 2015 - 77 spp.) and South (Boldrini *et al*. 2008 - 77 spp., Alves *et al*. 2011 - 62 spp., Kafer *et al*. 2011 - 82 spp.). Henriques *et al.* (1988) in the phytosociological study carried out in Lagoa de Jurubatiba, also known as Cabiúnas (Macaé, state of Rio de Janeiro), inventoried species found in the present study, such as *Aeschynomene fluminensis*, *Cyperus ligularis*, *Eichhornia crassipes*, *Eleocharis interstincta*, *Nymphoides humboldtiana*, *Rhynchospora holoschoenoides*, *Salvinia auriculata* and *Typha domingensis*. Among these, *Nymphoides humboldtiana* also stood out as the most frequent in the sampling made.

The Shannon diversity index (H') was 3.83 and the Simpson concentration was 0.03, indicating that it is an area with relatively high diversity and low concentration of species. The Pielou equability value (J') was 0.85, which shows the uniform distribution of individuals in populations of different species, that is, there is no domain in the community by a small group of species. These results were different from those inventoried for other Brazilian areas (Tab. 4). The rarefaction curves based on the richness and abundance obtained in this sample did not reach stability (Fig. 6). The stabilization of the curve indicates that an increase in the sampling effort will no longer increase the species richness, meaning that practically all the richness of the area has been sampled. However, it is very difficult to detect all species or individuals in a given area (Gotelli & Colwell 2001).

Table 3 – Phytosociological descriptors, presented in decreasing order of Importance Value (IV), of the species sampled in Lagoa do São Bento, Barroco, Itaipuaçu, municipality of Maricá, state of Rio de Janeiro, Brazil: SUi = number of Sample Units where the species "i" occurs; AF = absolute frequency of species "i"; RF = relative frequency; AC = absolute coverage; RC = relative coverage. # = ruderal species; * = exotic or cultivated species.

Species	Family	SUi	AF	RF	AC	RC	IV	Voucher
*Fuirena umbellat*a Rottb.	Cyperaceae	45	22.50	7.11	287.5	9.20	16.31	*Barros 985*
Pleroma gaudichaudianum (DC.) A. Gray	Melastomataceae	48	24.00	7.58	210	6.72	14.30	*Silva 38*
Xyris jupicai Rich.	Xyridaceae	40	20.00	6.32	212.5	6.80	13.12	*Santos 19*
Typha domingensis Pers.	Typhaceae	24	12.00	3.79	222.5	7.12	10.91	*Silva 14*
Salvinia aff. *auriculata* Aubl.	Salviniaceae	31	15.50	4.90	185	5.92	10.82	*Santos 48*
Eleocharis interstincta (Vahl) Roem. & Schult.	Cyperaceae	24	12.00	3.79	180	5.76	9.55	*Santos 14*
Rhynchospora gigantea Link	Cyperaceae	30	15.00	4.74	127	4.06	8.80	*Barros 986*
Nymphoides humboldtiana (Kunh) Kuntze	Menyanthaceae	23	11.50	3.63	132.5	4.24	7.87	*Sousa 353*
**Nymphaea caerulea* Savigny	Nymphaeaceae	19	9.50	3.00	137.5	4.40	7.40	*Pontes*
Clitoria laurifolia Poir.	Leguminosae	20	10.00	3.16	97.5	3.12	6.28	*Santos 92*
Cyperus ligularis L.	Cyperaceae	17	8.50	2.69	92.5	2.96	5.65	*Santos 46*
#*Indigofera hirsuta* L.	Leguminosae	13	6.50	2.05	97.5	3.12	5.17	*Machado 2660*
Eleocharis geniculata (L.) Roem. & Schult.	Cyperaceae	14	7.00	2.21	85	2.72	4.93	*Santos 24*
**Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs	Poaceae	10	5.00	1.58	100	3.20	4.78	*Santos 80*
#*Paspalum millegrana* Schrad. *ex* Schult.	Poaceae	11	5.50	1.74	80	2.56	4.30	*Silva 44*
Bacopa lanigera (Cham. & Schltdl.) Wettst.	Plantaginaceae	11	5.50	1.74	65	2.08	3.82	*Santos 15*
Hymenachne amplexicaulis (Rudge) Nees	Poaceae	22	11.00	3.48	10	0.32	3.80	*Silva 30*
#*Cyperus odoratus* L.	Cyperaceae	19	9.50	3.00	12.5	0.40	3.40	*Silva 39*
Rhynchospora holoschoenoides (Rich.) Herter	Cyperaceae	9	4.50	1.42	55	1.76	3.18	*Santos 41*
Nymphaea pulchella DC.	Nymphaeaceae	5	2.50	0.79	50	1.60	2.39	*Pontes*
Trichanthecium parvifolium (Lam.) Zuloaga & Morrone	Poaceae	9	4.50	1.42	22.5	0.72	2.14	*Silva 29*
Ludwigia octovalvis (Jacq.) P.H.Raven	Onagraceae	10	5.00	1.58	17.5	0.56	2.14	*Silva 46*
#*Cyperus polystachyos* Rottb.	Cyperaceae	5	2.50	0.79	35	1.12	1.91	*Silva 09*
#*Cynodon dactylon* (L.) Pers.	Poaceae	6	3.00	0.95	30	0.96	1.91	*Silva 32*
#*Croton lundianus* (Didr.) Müll.Arg.	Euphorbiaceae	7	3.50	1.11	25	0.80	1.91	*Machado 2661*
Torenia thouarsii (Cham. & Schltdl.) Kuntze	Linderniaceae	7	3.50	1.11	22.5	0.72	1.83	*Santos 28*
Rhynchanthera dichotoma (Desr.) DC.	Melastomataceae	6	3.00	0.95	25	0.80	1.75	*Silva 47*
Polygonum acuminatum Kunth	Polygonaceae	5	2.50	0.79	25	0.80	1.59	*Santos 89*

Species	Family	SUi	AF	RF	AC	RC	IV	Voucher
Alchornea triplinervia (Spreng.) Müll.Arg.	Euphorbiaceae	6	3.00	0.95	20	0.64	1.59	*Santos 53*
#*Borreria verticillata* (L.) G.Mey.	Rubiaceae	6	3.00	0.95	17.5	0.56	1.51	*Santos 01*
Sesbania virgata (Cav.) Pers.	Leguminosae	5	2.50	0.79	20	0.64	1.43	*Santos 79*
**Turnera ulmifolia* L.	Turneraceae	4	2.00	0.63	22.5	0.72	1.35	*Santos 44*
#*Crotalaria lanceolata* E.Mey.	Leguminosae	5	2.50	0.79	15	0.48	1.27	*Santos 39*
Leptospron adenanthum (G. Mey.) A. Delgado	Leguminosae	4	2.00	0.63	17.5	0.56	1.19	*Silva 37*
Ludwigia leptocarpa (Nutt.) H.Hara	Onagraceae	1	0.50	0.16	27.5	0.88	1.04	*Santos 52*
#*Crotalaria pallida* Aiton	Leguminosae	4	2.00	0.63	12.5	0.40	1.03	*Machado 2662*
* *Urochloa plantaginea* (Link) R.D.Webster	Poaceae	4	2.00	0.63	12.5	0.40	1.03	*Silva 31*
#*Varronia curassavica* Jacq.	Cordiaceae	4	2.00	0.63	12.5	0.40	1.03	*Santos 06*
Acrostichum danaeifolium Langsd. & Fisch.	Pteridaceae	2	1.00	0.32	20	0.64	0.96	*Santos 61*
#*Emilia sonchifolia* (L.) DC. *ex* Wight	Asteraceae	4	2.00	0.63	10	0.32	0.95	*Silva 58*
#*Erechtites hieracifolius* (L.) Raf. *ex* DC.	Asteraceae	4	2.00	0.63	10	0.32	0.95	*Santos 50*
#*Polygala paniculata* L.	Polygalaceae	4	2.00	0.63	10	0.32	0.95	*Santos 27*
#*Campuloclinium macrocephalum* (Less.) DC.	Asteraceae	4	2.00	0.63	10	0.32	0.95	*Machado 2669*
#*Cissus verticillata* (L.) Nicolson & C.E.Jarvis	Vitaceae	4	2.00	0.63	10	0.32	0.95	*Santos 78*
#*Ageratum conyzoides* L.	Asteraceae	5	2.50	0.79	5	0.16	0.95	*Machado 2663*
Sporobolus virginicus (L.) Kunth	Poaceae	2	1.00	0.32	17.5	0.56	0.88	*Machado 2671*
Lantana camara L.	Verbenaceae	3	1.50	0.47	12.5	0.40	0.87	*Santos 96*
#*Andropogon bicornis* L.	Poaceae	3	1.50	0.47	10	0.32	0.79	*Santos 45*
#*Mucuna pruriens* (L.) DC.	Leguminosae	3	1.50	0.47	10	0.32	0.79	*Santos 87*
Stylosanthes viscosa (L.) Sw.	Leguminosae	3	1.50	0.47	10	0.32	0.79	*Santos 17*
Bacopa stricta (Schrad.) Wettst. *ex* Edwall	Plantaginaceae	3	1.50	0.47	7.5	0.24	0.71	*Silva 28*
#*Mimosa candollei* R.Grether	Leguminosae	3	1.50	0.47	7.5	0.24	0.71	*Santos 74*
Schinus terebinthifolia Raddi	Anacardiaceae	3	1.50	0.47	7.5	0.24	0.71	*Santos 59*
Zornia latifolia Sm.	Leguminosae	3	1.50	0.47	7.5	0.24	0.71	*Silva 18*
Polygonum persicaria L.	Polygonaceae	2	1.00	0.32	10	0.32	0.64	*Santos 90*
#*Cyperus haspan* L.	Cyperaceae	2	1.00	0.32	10	0.32	0.64	*Santos 36*
#*Porophyllum ruderale* (Jacq.) Cass.	Asteraceae	2	1.00	0.32	7.5	0.24	0.56	*Santos 70*
**Syzygium cumini* (L.) Skeels	Myrtaceae	2	1.00	0.32	7.5	0.24	0.56	*Silva 70*
Aeschynomene paniculata Willd. *ex* Vogel	Leguminosae	3	1.50	0.47	2.5	0.08	0.55	*Santos 105*

Species	Family	SUi	AF	RF	AC	RC	IV	Voucher
Allagoptera arenaria (Gomes) Kuntze	Arecaceae	1	0.50	0.16	10	0.32	0.48	*Santos 66*
Tabebuia cassinoides (Lam.) DC.	Bignoniaceae	1	0.50	0.16	10	0.32	0.48	*Silva 89*
#*Stachytarpheta cayennensis* (Rich.) Vahl	Verbenaceae	2	1.00	0.32	5	0.16	0.48	*Santos 94*
Barrosoa betonicaeformis (DC.) R.M.King & H.Rob.	Asteraceae	2	1.00	0.32	5	0.16	0.48	*Santos 32*
Eichhornia crassipes (Mart.) Solms	Pontederiaceae	2	1.00	0.32	5	0.16	0.48	*Santos 81*
**Eleusine indica* (L.) Gaertn.	Poaceae	2	1.00	0.32	5	0.16	0.48	*Silva 33*
#*Phyllanthus niruri* L.	Phyllanthaceae	2	1.00	0.32	5	0.16	0.48	*Santos 25*
#*Sporobolus indicus* (L.) R.Br.	Poaceae	2	1.00	0.32	5	0.16	0.48	*Santos 20*
Sida sp.	Malvaceae	2	1.00	0.32	2.5	0.08	0.40	*Santos 63*
#*Cyperus surinamensis* Rottb.	Cyperaceae	2	1.00	0.32	2.5	0.08	0.40	*Silva 49*
Begonia fischeri Schrank	Begoniaceae	1	0.50	0.16	5	0.16	0.32	*Santos 33*
**Allamanda cathartica* L.	Apocynaceae	1	0.50	0.16	2.5	0.08	0.24	*Santos 67*
Cecropia pachystachya Trécul	Urticaceae	1	0.50	0.16	2.5	0.08	0.24	*Santos 68*
Ceratopteris thalictroides (L.) Brongn.	Pteridaceae	1	0.50	0.16	2.5	0.08	0.24	*Santos 29*
Cassytha filiformis L.	Lauraceae	1	0.50	0.16	2.5	0.08	0.24	*Silva 16*
Echinochloa colona (L.) Link	Poaceae	1	0.50	0.16	2.5	0.08	0.24	*Silva 50*
**Handroanthus serratifolius* (Vahl) S.Grose	Bignoniaceae	1	0.50	0.16	2.5	0.08	0.24	*Machado 2670*
**Inga edulis* Mart.	Leguminosae	1	0.50	0.16	2.5	0.08	0.24	*Machado 2664*
#*Mikania cordifolia* (L.f.) Willd.	Asteraceae	1	0.50	0.16	2.5	0.08	0.24	*Santos 60*
Mollugo verticillata L.	Molluginaceae	1	0.50	0.16	2.5	0.08	0.24	*Machado 2665*
#*Oxalis barrelieri* L.	Oxalidaceae	1	0.50	0.16	2.5	0.08	0.24	*Silva 43*
Pistia stratiotes L.	Araceae	1	0.50	0.16	2.5	0.08	0.24	*Silva 41*
Pityrogramma calomelanos (L.) Link	Pteridaceae	1	0.50	0.16	2.5	0.08	0.24	*Santos 53*
Schultesia guianensis var. *latifolia* (Mart. *ex* Progel) E.F.Guim. & Fontella	Gentianaceae	1	0.50	0.16	2.5	0.08	0.24	*Silva 77*
#*Sida linifolia* Cav.	Malvaceae	1	0.50	0.16	2.5	0.08	0.24	*Silva 21*
Spigelia flemmingiana Cham. & Schltdl.	Loganiaceae	1	0.50	0.16	2.5	0.08	0.24	*Machado 2317*
#*Tarenaya aculeata* (L.) Soares Neto & Roalson	Cleomaceae	1	0.50	0.16	2.5	0.08	0.24	*Silva 48*
#*Urena lobata* L.	Malvaceae	1	0.50	0.16	2.5	0.08	0.24	*Machado 2666*

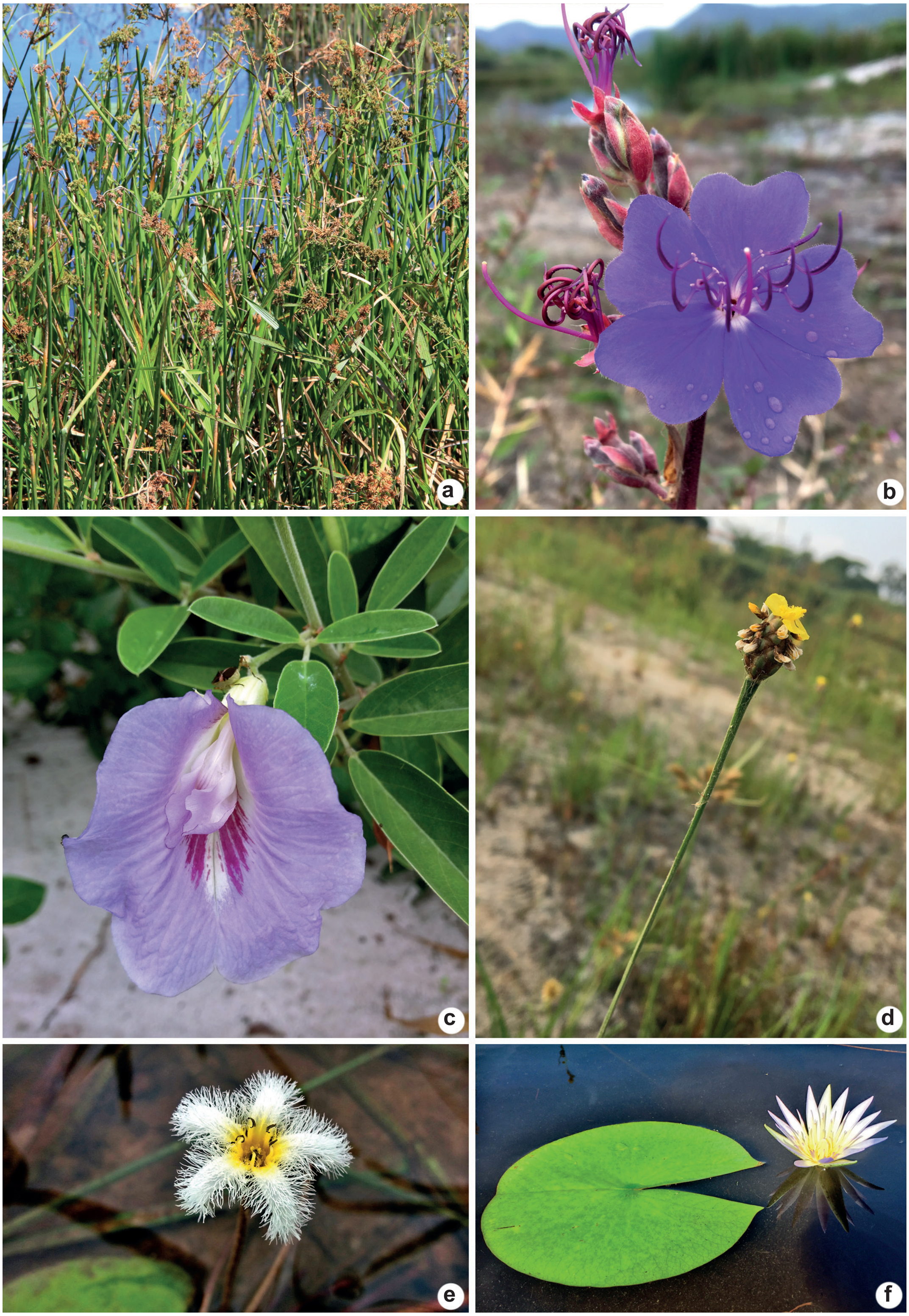

Figure 5 – a-f. Species which stood out in the phytosociological sampling among the ten with biggest importance value – a. *Fuirena umbellata*; b. *Pleroma gaudichaudianum*; c. *Clitoria laurifolia*; d. *Xyris jupicai*; e. *Nymphoides humboldtiana*; f. *Nymphaea caerulea*; Photos: a. Jorge Antônio Lourenço Pontes (2018); b, d, f. Thamyres Lima dos Santos (2019); c, e. Davi Nepomuceno da Silva Machado (2019).

Table 4 – Comparison between Shannon diversity index, Simpson concentration and Pielou equability value obtained for different areas.

Area	Simpson concentration	Pielou equability	Shannon diversity	Reference
Lagoa do São Bento/RJ	0.03	0.85	3.83	Present study
Lagoa do Armazém/RS	0.07	0.68	2.97	Boldrini *et al*. (2008)
Rio Miranda/MS	-	-	2.44 (linear intersection method) 2.47 (plot method)	Lehn *et al*. (2011)
Lagoa de Vereda/MS	-	-	2.00 (rainy season) 3.25 (dry season)	Moreira *et al*. (2011)
Nossa Senhora do Livramento/MT	-	-	4.01 (rainy season) 3.29 (dry season)	Rebellato & Nunes da Cunha (2005)

Among the species with the highest IVI, *Fuirena umbellata* stood out (Fig. 5a), a Cyperaceae with pantropical distribution (Prata 2002) and occurring in the five regions of Brazil (Alves *et al.* 2021). The 2018 intervention in Lagoa do São Bento favored the expansion of this species, which is not as demanding as the others in relation to environmental conditions. This condition is also verified in areas degraded by mining (Neri *et al*. 2011), showing the favoring of certain species in anthropized environments.

Pleroma gaudichaudiana and *Clitoria laurifolia* (Fig. 5b-c) occupied the 2nd and 10th IVI values, respectively. They are common species in Restinga de Maricá (Araujo 2000), also occurring in Lagoa do São Bento, since this wetland corresponds to a remainder of a restinga flooded area. The presence of *Clitoria laurifolia* can help in the recovery of the local environment, since it has characteristics such as adaptability and rusticity, which allows the colonization of degraded areas with low fertility. In addition to propagating by seeds, the species also has vegetative development, forming underground stems, an attribute that expands the colonization of new stretches where it occurs (Rodrigues *et al*. 2007).

Eleocharis interstincta, *Nymphoides humboldtiana*, *Rhynchospora gigantea*, *Typha domingensis* and *Xyris jupicai* are common species in the flooded areas inventoried in the state of Rio de Janeiro (Tab. 1), with occurrence also registered in the APA da Restinga de Maricá (Araujo 2000). *Eleocharis interstincta* and *Typha domingensis* are emerging species that are of great importance in aquatic environments, as they have a high rate of primary productivity (Santos & Esteves 2002; Marques 2015) and serve as a nesting shelter for waterfowl species (Tavares 2003). Both have phytoremediation potential (Marques 2015; Ribeiro 2015), which makes them promising species for absorbing potentially toxic elements from the soil. In addition, *Typha dominguensis* also has the ability to control margin erosion (Tavares 2003). *Rhynchospora gigantea* and *Xyris jupicai* are two amphibious species, the first of which occurs in open margins, wet savannas and swamps, forming dense colonies and being an important element in the consolidation of floating islands (Guaglianone 2001; Fedón & Colonnello 2004). The second (Fig. 5d) preferably inhabits swampy environments, reaching greater proportions as there is an increase in water saturation (Lozano 2015).

Nymphoides humboldtiana and *Salvinia* aff. *auriculata* are normally observed in lentic environments (Barros 2009; Rodrigues *et al*.

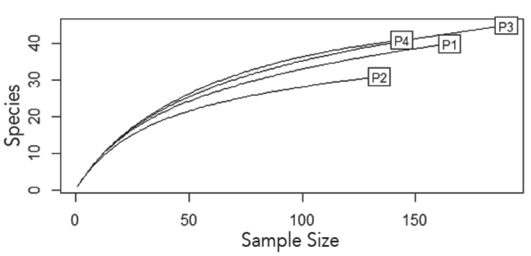

Figure 6 – Rarefaction curve for the sampled species throughout the four plots in Lagoa do São Bento, Barroco, Itaipuaçu, municipality of Maricá, state of Rio de Janeiro, Brazil.

2017) and in this study were among the ten species with the highest IVI, being categorized as fixed and free floating, respectively. Some studies carried out in the state of Rio de Janeiro (Tab. 1) had been identifying the collections of *Nymphoides humboldtiana* as *Nymphoides indica*, however Tippery & Les (2011) showed, based on nuclear molecular data, the distinction between *Nymphoides indica* and *Nymphoides humboldtiana* and that the first is related to the Paleotropical Region. Thus, Barcelos & Bove (2017) identified the specimens occurring in the state only as *Nymphoides humboldtiana* (Fig. 5e).

Similarity analysis

The cluster analysis (Fig. 7; Tab. 5) based on the floristic list of native aquatic plants gathered a total of 131 species, with presence and absence data for nine wetlands in the state of Rio de Janeiro. Out of the 131 species, twelve were more present in the wetlands analyzed, making up 9% of the total: *Eleocharis geniculata*, *Ludwigia leptocarpa*, *Nymphoides humboldtiana*, *Salvinia biloba* and *Typha domingensis* (8 areas each), *Centella asiatica* and *Oldenlandia salzmannii* (7 areas each), *Bacopa monnieri*, *Coccocypselum capitatum*, *Nymphaea pulchella*, *Utricularia gibba*

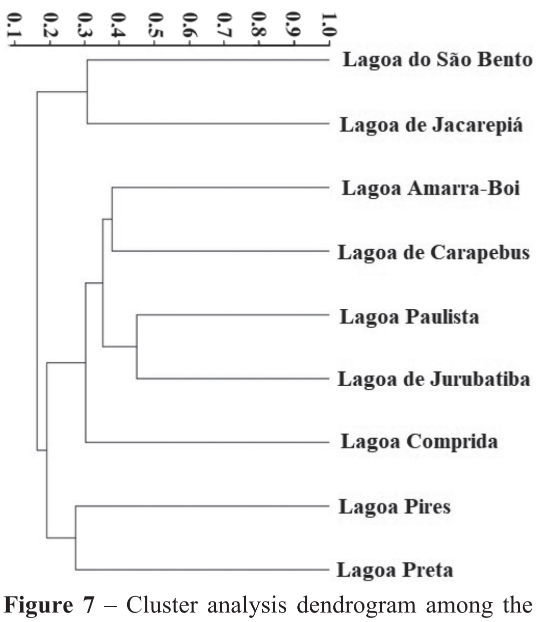

Figure 7 – Cluster analysis dendrogram among the eight coastal lagoons in the state of Rio de Janeiro, compared with Lagoa do São Bento, Barroco, Itaipuaçu, Maricá, state of Rio de Janeiro, Brazil. Cophenetic coefficient (Jaccard = 0.86).

and *Xyris jupicai* (6 areas each). On the other hand, 50 taxa, that is, 38% of all registered species, are present in a single occurrence area.

The dendrogram (Fig. 7) presents successive variations in the levels of similarities, showing two groups well supported by a cophenetic correlation coefficient of 0.86, with the cut-off line at 0.15. The analysis showed a high level of dissimilarity, highlighting the heterogeneity of these flooded environments in the state of Rio de Janeiro.

The first group united the Jacarepiá and São Bento lagoons. They are located in different regions of the state of Rio de Janeiro, but in neighboring municipalities. Lagoa de Jacarepiá is located in Saquarema, in the Baixadas Litorâneas region (formerly Região dos Lagos) and Lagoa do São Bento is in Maricá in the Metropolitan East. The second group is formed by seven lakes located in the Norte Fluminense region, between the municipalities of Macaé, Carapebus and Quissamã. This group is subdivided into a larger group (Amarra-Boi, Carapebus, Comprida, Jurubatiba and Paulista lakes) and a smaller group (Pires and Preta lakes).

The lagoons of Jacarepiá and São Bento are water bodies that have 30% of similarity to each other and are spaced about 60 km apart. They have 42 and 47 species, respectively, sharing 21 species (Fig. 8). Six species occur only in these lagoon bodies: *Cyperus aggregatus*, *Pistia stratiotes*, *Pleroma gaudichaudianum*, *Rhynchanthera dichotoma*, *Salvinia auriculata* and *Tabebuia cassinoides*. They presented species richness values close to or greater than those recorded in the PNRJ lakes.

The seven lakes in the North Fluminense Region are part of the Parque Nacional da Restinga de Jurubatiba (PNRJ), which represents the largest restinga area in the state of Rio de Janeiro and is the first National Park in Brazil to exclusively comprise this type of vegetation (Rocha *et al*. 2004). These lagoon bodies are very variable in terms of their abiotic and biotic components, but all are considered shallow, not exceeding the maximum depth of 3.0 m. The subgroups formed show exactly the separation of the hypersaline lagoons (Pires and Preta) from the freshwater lagoons. These water bodies are 27% similar to one another and are adjacent. Both are parallel to the coastline and are located at the eastern end of the PNRJ, Preta lagoon being the second largest of all with 5.30 km^2, while Pires has 1.62 km^2. Both have an alkaline pH and, although Preta receives fluvial

Table 5 – Similarity coefficients of eight coastal lagoons in the state of Rio de Janeiro, compared with Lagoa do São Bento, Barroco, Itaipuaçu, Maricá, state of Rio de Janeiro, Brazil. Cophenetic coefficient (Jaccard = 0.86).

	LPR	**LPI**	**LA**	**LPA**	**LCA**	**LCO**	**LJU**	**LSB**	**LJA**
LPR	1	0.275862	0.285714	0.22449	0.166667	0.111111	0.15873	0.068966	0.163265
LPI	0.275862	1	0.228571	0.218182	0.206897	0.135593	0.19403	0.095238	0.163636
LA	0.285714	0.228571	1	0.404255	0.38	0.269231	0.253968	0.133333	0.188679
LPA	0.22449	0.218182	0.404255	1	0.430769	0.323529	0.450704	0.15	0.16
LCA	0.166667	0.206897	0.38	0.430769	1	0.367647	0.325	0.217949	0.184211
LCO	0.111111	0.135593	0.269231	0.323529	0.367647	1	0.256098	0.194805	0.12987
LJU	0.15873	0.19403	0.253968	0.450704	0.325	0.256098	1	0.235294	0.234568
LSB	0.068966	0.095238	0.133333	0.15	0.217949	0.194805	0.235294	1	0.308824
LJA	0.163265	0.163636	0.188679	0.16	0.184211	0.12987	0.234568	0.308824	1

Legend: LPR = Lagoa Preta; LPI = Lagoa Pires; LA = Lagoa Amarra-Boi; LPA = Lagoa Paulista; LCA = Lagoa de Carapebus; LCO = Lagoa Comprida; LJU = Lagoa de Jurubatiba; LSB = Lagoa do São Bento; LJA = Lagoa de Jacarepiá.

input from the Rio Preto, both are hypersaline (Bove & Paz 2009), which is reflected in the composition of the aquatic plants present in these lagoon bodies.

The five lakes located in the extreme west of the PNRJ are grouped into Amarra-Boi/Carapebus (38% similarity) and Paulista/Jurubatiba (45%), with the Lagoa Comprida standing out. The latter has 45 species, eight of which are exclusive (*Diodia gymnocephala*, *Eleocharis minima*, *Irlbachia purpurascens*, *Perama hirsuta*, *Potamogeton montevidensis*, *Rhynchospora hirta* and *Scleria soronia*). It does not receive constant river input, but it is freshwater. It is rich in humic compounds, which is reflected in its acidic pH (Bove & Paz 2009).

Amarra-Boi is the lake with one of the lowest levels of salinity and has the most acidic pH (about 3.91), being susceptible to drought in the dry season (Luz *et al*. 2011). 21 species were recorded at the site (the second lowest richness value among the nine areas). Of the 21 species inventoried, in the Amarra-Boi lagoon 90% of the species (19 spp.) are common to the Carapebus lagoon, with which it obtained 38% similarity. The Carapebus lagoon is the largest in the PNRJ, although it is not the richest in species. It is subject to intense anthropogenic pressure, especially with regard to the discharge of domestic and industrial effluents, which increases the degree of local eutrophication (Paula 2014). The opening of the bar in these lakes during periods of high precipitation by the surrounding community, as well as in Jurubatiba and Paulista, makes contact with sea water at that time.

Jurubatiba and Paulista are among the richest in the PNRJ, having 58 and 45 species, respectively, and sharing 32 species (45% similarity). *Eleocharis equisetoides*, *Fuirena robusta*, *Mayaca fluviatilis* and *Najas arguta* were inventoried only in these areas. They are lakes that extend perpendicularly to the coastline and have depths of 2.90 m, this being the deepest in the analysis (Jurubatiba), followed by Paulista with 2.20 m. According to Bove & Paz (2009), the Jurubatiba lake is the richest in species due to the physical-chemical composition of the water and the evolutionary history of its formation.

The results indicate that the composition of aquatic plants in the evaluated coastal lakes can be influenced not only by biogeochemical factors, but also by human interventions. The current process

Figure 8 – Venn diagram produced from shared and exclusive species between Lagoa do São Bento, Maricá and Lagoa de Jacarepiá, Saquarema, state of Rio de Janeiro, Brazil.

of anthropization and decharacterization of water bodies is a preponderant factor to be discussed in comparative analyses and may guide questions of richness and beta diversity.

The cluster analysis (Fig. 9; Tab. 6) based on the species sampled in the phytosociological inventory was supported by the cophenetic correlation coefficient of 0.97 and indicated the formation of a group joining plots 1 and 4 with a similarity of 40%. These two areas were the most affected by anthropic interventions carried out by the city of Maricá, reducing species richness and selecting those that are more general. Plots 2 and 3 appeared isolated in the dendrogram, associating in approximately 30% and 20%, respectively, with the formed group. Although 87 species were sampled, the greatest richness was observed in plot 3 (45 spp.), that is, approximately half of the total inventoried. The major contribution to this result may have been due to the fact that 40 species (46% of the total inventoried) were only sampled in one of the four plots, while only seven (8%) occurred in all plots. The latter are precisely among the 10 with the highest IVI (*Eleocharis interstincta*, *Fuirena umbellata*, *Nymphoides humboldtiana*, *Pleroma gaudichaudianum*, *Rhynchospora gigantea*, *Salvinia* aff. *auriculata* and *Xyris jupicai*).

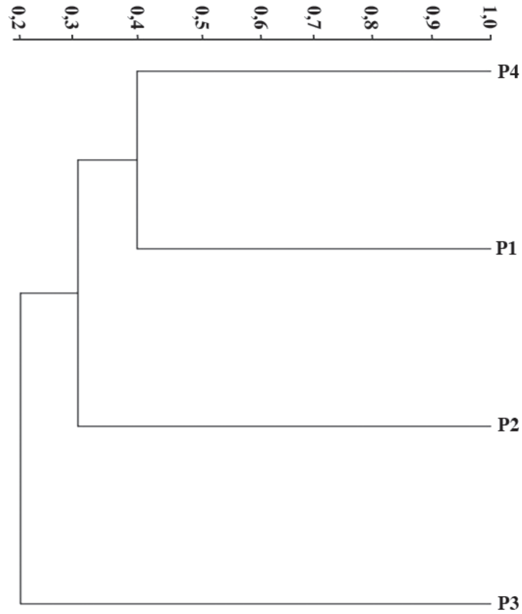

Figure 9 – Cluster analysis dendrogram among the four plots sampled in Lagoa do São Bento, Barroco, Itaipuaçu, municipality of Maricá, state of Rio de Janeiro, Brazil. Cophenetic coefficient (Jaccard = 0.97).

Exotic species in Lagoa do São Bento

The fixed floating *Nymphaea caerulea* (Fig. 5f) is of African origin but occurs as a subspontaneous in the Neotropical Region (Padgett & Les 2004). This species was reported for the state of São Paulo (Amaral *et al*. 2008), Roraima (Pinheiro & Jardim 2015) and recorded in two studies carried out in the state of Minas Gerais by Pivari *et al*. (2011) and Tavares-Silva *et al*. (2018) in the lacustrine system of Vale do Rio Doce and in the Botanical Garden of Juiz de Fora, respectively. In the state of Rio de Janeiro there are records of collections of this species for the municipalities of Cachoeiras de Macacu, Campos dos Goytacazes, Itatiaia, Macaé, Magé and Vassouras (Moreira & Bove 2017). In Lagoa do São Bento there is a report that it was introduced between the 1980s and 1990s, when there was an attempt to transform the lagoon into a balneary. The present study observed that *Nymphaea caerulea* benefited from the anthropic alteration process that occurred, presenting a high IVI. It is similar to *Nymphaea pulchella*, which also occurs in this wetland and also has a daytime floral anthesis, with *N. caerulea* being differentiated by the lilac-bluish coloration on the apex of the petals and leaves with margins from entire to slightly crenate. *Nymphaea pulchella* presents white petals and irregularly jagged leaves (Moreira & Bove 2017).

Six other exotic plants were recorded in the sampling, such as *Allamanda cathartica* L., *Eleusine indica* (L.) Gaertn., *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs, *Syzygium cumini* (L.) Skeels, *Turnera ulmifolia* L. and *Urochloa plantaginea* (Link) R.D.Webster, making up 8% of the total sample. These plants, along with 33 other ruderal species (38%) (Tab. 3) have significantly colonized the lagoon's surroundings. The presence of these species in flooded environments has also been verified in other studies (Barros 2009; Xavier *et al*. 2016; Rodrigues *et al*. 2017). They are related to the anthropic disturbance that has been occurring in the flooded areas over the years and to characteristics such as propagule pressure, strong adaptation to low water depth, large seed production and resistance to environmental adversities (Havel *et al*. 2015).

A ipê-amarelo, *Handroanthus serratifolius* (Vahl) S.Grose, and an ingá-de-metro, *Inga edulis* Mart., which have no natural occurrence in the area and were planted by the lagoon, the first by the city hall and the second by a local resident. Around

Table 6 – Similarity coefficients of the four plots sampled in Lagoa do São Bento, Barroco, Itaipuaçu, municipality of Maricá, state of Rio de Janeiro, Brazil. Cophenetic coefficient (Jaccard = 0.97).

	P1	**P2**	**P3**	**P4**
P1	1	0.314815	0.25	0.421053
P2	0.314815	1	0.245902	0.333333
P3	0.25	0.245902	1	0.194444
P4	0.421053	0.333333	0.194444	1

the area some exotic species were cultivated with the purpose of afforestation and landscaping (*Cajanus cajan* (L.) Millsp., *Delonix regia* (Hook.) Raf., *Furcraea foetida* (L.) Haw., *Moquilea tomentosa* Benth., *Mangifera indica* L., *Morinda citrifolia* L. and *Syzygium cumini*). In addition, the hemiepiphyte *Syngonium podophyllum* Schott, grown in the homes as an ornamental plant, was discarded as "garden garbage" on the margins of this wetland and, due to its vegetative propagation, has been growing on the trees.

Mucuna pruriens (L.) DC., *Ricinus communis* L. and *Tithonia diversifolia* (Hemsl.) A. Gray, although not sampled in the inventory, were observed occupying part of the south bank of the lagoon, where an extensive *Montrichardia linifera* imbezal occurred, destroyed in the intervention carried out in 2018. Several adult individuals of *Albizia lebbeck* (L.) Benth. and *Terminalia catappa* L. were also registered on the margins of this wetland. *Albizia lebbeck* occurs as an exotic invader and was maintained during the process of removing the vegetation cover. *Terminalia catappa* occurs as a result of the dispersion of its seeds by bats of the family Phyllostomidae. These animals, common in the region, are great seed dispersers of native and exotic species, as in the case of this species (Teixeira & Peracchi 1996; Plucênio *et al*. 2013).

The presence of these species in this restinga wetland goes against conservation, as one of the factors that aggravate environmental degradation is biological contamination by exotic plants (Machado *et al*. 2020). Among the species reported for the lagoon, six are mentioned with occurrence in the restingas of the Southeast Region: *Delonix regia*, *Furcraea foetida*, *Megathyrsus maximus*, *Ricinus communis*, *Syzygium cumini* and *Terminalia catappa* (Ribas 2018). *Furcraea foetida* and *Megathyrsus maximus* show serious invasive behavior, as verified by Machado *et al*. (2020) in areas close to the lagoon in Serra da Tiririca. Havel *et al*. (2015) point out that freshwater ecosystems have greater biodiversity per surface area than marine and terrestrial ecosystems and, at the same time, have been profoundly transformed by invasive exotic species linked to a wide variety of taxonomic groups.

The high richness of species associated with wetlands and the little knowledge of their ecological aspects demonstrate the importance of intensifying floristic and phytosociological studies in these environments. In the state of Rio de Janeiro, the swamps and coastal regions are subject to environmental impacts, as they are occupied by allotments and urban projects (Rocha *et al*. 2003). The history of the capital of Rio de Janeiro is marked by the transformation of wetlands into landfills, which at the time was considered a symbol in the struggle for progress (Godoy *et al*. 2011).

Some of the species of aquatic plants inventoried in the present study had already been highlighted in lagoons in the city by Oliveira *et al*. (1955), which drew attention to the first allotments implemented. Ramadon (1996), Pontes (2018, 2019) and Pontes *et al*. (2020) indicated, precisely, the consequence of all these years of investee due to the occupation of Restinga de Itaipuaçu by real estate speculation. This area of sandy plain extended up to the slopes of Serra da Tiririca and the flooded environments were very common and endowed with a flora adapted to the characteristics of these swampy stretches. However, as highlighted by Araujo (2008) and Neves *et al*. (2017), the search for conservation goes beyond the inventory of biological diversity and lies mainly in the fact that these ecosystems peripheral to the Atlantic Forest have limiting characteristics to their colonization, so that 45% of all species in this biome occur only in these bank habitats, such as restinga. This means that the destruction or mischaracterization of these environments incurs the inestimable loss of a series of species, many endemic and threatened with extinction.

The richness of aquatic plants in this wetland is recorded in the present study and, concomitantly, it is presented, in the phytosociological analysis, a contribution of species that is mostly composed of native ones. However, the interventions that were carried out in Lagoa do São Bento, followed by the abandonment of the site, the lack of governmental commitment to an effective conservation project, in addition to the disposal of household and garden waste, have led to the population decline of many native species and favoring colonization by exotic and ruderal plants. This process of biological invasion expansion is registered in several areas of the state of Rio de Janeiro, and must be fought with public policies (Bergallo *et al*. 2021). The urbanization of the surroundings of Lagoa do São Bento facilitated the occupation, dispersion and introduction of invasive alien species on its banks by residents. Maricá does not yet have a protection policy for the area, nor for combating these species (Pontes *et al*. 2020), as we see in Brazil (Ziller & Dechoum 2013; Ziller *et al*. 2020), especially in the state of Rio de Janeiro (Bergallo *et al*. 2021).

Due to the threats that it suffers and its relevant biota with the presence of species threatened with extinction of both flora and fauna, its legal protection is indicated as a restinga remnant, set amid a recently urbanized matrix. This instrument will allow the re-planning of actions aimed at local conservation, monitoring of fauna and the management of exotic and ruderal species in what is one of the last wetlands that remains in the municipality of Maricá.

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