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ECOLOGY

A checklist of aquatic macrophytes of the Guaraguaçu river basin reveals a target for conservation in the Atlantic rainforest

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ABSTRACT. Describing and understanding distribution of species in natural ecosystems is the first step to establish conservation efforts. In aquatic habitats, macrophytes play a central role in promoting biodiversity and ecosystem functioning. This study aimed to create the first checklist of aquatic macrophyte species occurring in the Guaraguaçu river, the largest river in Paraná State coast, Brazil. Species herborized, identified and incorporated into the Herbarium collection of the *Universidade Federal do Paraná*. A total of 47 species were registered corresponding to 37 genera and 29 botanical families; Cyperaceae and Poaceae were the most representative families. In addition, the wide invasion of the non-native species *Urochloa arrecta* (Hack. ex T. Durand & Schinz) Morrone & Zuloaga was registered and the presence of the floating-leaved non-native species *Nymphaea caerulea* Savugny was recorded. Even so, the inventory shows a noteworthy richness of aquatic macrophytes species in the Guaraguaçu river, and it is clear macrophyte species reflect a gradient of anthropic impact and salinity in this tidal estuarine river. Our study contributes to the creation of public policies to aid in the protection of this river that represents a central site for biological conservation efforts, yet is constantly threatened by anthropic activities.

Keywords: floristic composition; aquatic plants; invasive species; anthropogenic impact; Paraná Coastal Basin; lagamar.

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Introduction

The Neotropical region has the highest water availability and number of aquatic ecosystems in the world (see Freshwater Ecoregions of the World [FEOW], 2019), which stand out for their high ecological, social and economic value (Pott & Pott, 2000; Pompêo, 2008). Brazil is privileged with such natural resources, presenting complex water bodies with unique characteristics (Bove, Gil, Moreira, & Anjos, 2003) that promote high biodiversity (Padial et al., 2021). However, such biodiversity has been altered for a long time due to anthropic actions such as dam constructions, fishing activities, destruction of riparian forests, as well as the introduction of non-native species (Agostinho, Thomaz, & Gomes, 2005; Pelicice, Vitule, Lima, Orsi, & Agostinho, 2014; Vitule et al., 2015; Lees, Peres, Fearnside, Schneide, & Zuanon, 2016).

Aquatic macrophytes are considered an important ecological group due to their structuring role in water bodies (França, Melo, Oliveira, Reis, Alves, & Costa, 2010; Campelo, Siqueira-Filho, & Cotarelli, 2013), and can be considered ecosystem engineers or strong interactive actors in many freshwater ecosystems. They present a great variety of ecological functions and requirements (Pedralli, 1990). Indeed, aquatic biodiversity is usually determined by the colonization and establishment of aquatic plants (Ferreira, Mormul, Thomaz, Pott, & Pott, 2011; O'Hare et al., 2018, Wolters, Verdonschot, Schoelynk, Verdonschot, & Meire, 2018).

The richness, composition, and structure of aquatic macrophyte communities are, at least partially, determined by abiotic characteristics of the water. The variations of the hydrological regime and other abiotic parameters are shown to be important variables shaping aquatic vegetation and filtering organisms more adjusted to the environmental requirements (Sobral-Leite, Campelo, Siqueira-Filho, & Silva, 2010; Meyer & Franceschinelli, 2011, Fernandes, Oliveira, & Lacerda, 2016). As a consequence, floristic and ecological studies are key to understanding patterns and processes of aquatic communities, highlighted by the increased knowledge on the geographic distributions of species and on the relationship between biotic and abiotic factors (Thomaz & Bini, 2003; Pompêo & Moschini-Carlos, 2003).

In the South Region of Brazil, floristic studies of the aquatic biota are concentrated in the Upper Paraná River (Kita & Souza, 2003; Ferreira, Mormul, Thomaz, Pott, & Pott, 2011), in the Itaipu Reservoir (Bini, Thomaz, Murphy, & Camargo, 1999; Thomaz, Souza, & Bini, 2003) and in aquatic ecosystems of Rio Grande do Sul State (Oliveira, Neves, Strehl, Ramos, & Bueno, 1988; Gastal & Irgang, 1997; Lisboa & Gastal, 2003). There is a clear gap in the literature on other rivers and reservoirs of the region, particularly in coastal rivers from Paraná State (e.g. Vitule, Silva, Bornatowski, & Abilhoa, 2013).

The Guaraguaçu River is among those that did not have a formal floristic inventory up to the present study. The Guaraguaçu River basin is located within the limits of the Guaratuba Environmental Protection Area (APA Guaratuba), and part of its course is also within the limits of the Guaraguaçu River Ecological Station, in an ecoregion called 'Lagamar', i.e., an estuarine complex in the most preserved region of the Atlantic Forest Biome (Souza & Oliveira, 2016). Therefore, the Guaraguaçu River is a critical ecosystem for aquatic conservation. The Guaraguaçu River water course is affected by tidal regimes and most of its extension is composed of freshwater. This is a rare condition in water bodies of the Lagamar.

Although the Guaraguaçu River presents great ecological and socioeconomic importance for the region, there is a large deficit in respect to studies regarding conservation efforts. The present study carried out the first formal checklist of aquatic macrophytes of the Guaraguaçu River, with the purpose of contributing with information about regional biodiversity, as well as generating important data to be used in public policies.

Material and methods

Study site

The checklist was entirely made in the Guaraguaçu River (25°40'19.95''S; 48°30'47.20''W, Figure 1). This is the largest river of the Coastal Basin of Paraná State, South Brazil. Its headwaters are multiple streams located in the Serra da Prata/Serra do Mar high-hills, 766 m above sea level, in the Saint-Hilaire/Hugo Lange National Park and it discharges into the Paranaguá Bay. Its drainage area is 395.5 km^2, much of which is in an extensive coastal plain where the meandering river floods through an area rich in swamps and lateral lakes with important biodiversity. The region has a tropical, super-humid climate, without real dry seasons. The rain is distributed throughout the year with July being the driest month and February is the rainiest month. The annual water levels are greater than 1000 mm and the mean temperature is between 17 and 21 °C (Vitule, Umbria, & Aranha, 2006). This river is an environment of high biological importance that suffers from great anthropogenic impacts such as overfishing (Lana, Marone, Lopes, & Machado, 2001) introduction of exotic species (Vitule, Umbria, & Aranha, 2006), and the effects of being utilized as a major port area (Caires, Pichler, Spach, & Ignácio, 2007; Contente, Stefanoni & Spach, 2011). In addition to the abovementioned impacts, other common but poorly documented threats for biodiversity and ecosystem functioning are a constant matter for legal contests given the environmental laws (see also Reis, França, Motyl, Cordeiro, & Rocha, 2015), such as plans for a construction of a new port near the mouth of the river, frequent dredging for sand extraction, discharge of untreated domestic sewage and slurry escapes from an overfilled dumping ground (see also Singo, Araújo-Ramos, & Rocha, 2020).

The river is about 60 km long and presents a well-defined longitudinal gradient from the headwaters to the river mouth. In general, it is characterized by dark waters with high levels of humic compounds. After the headwaters region, there is a large area where the river presents its most navigable stretch, approximately 30 m wide, and a good conservation status. Interestingly, the first navigable stretch is a large 'Caixetal', a unique and rare ecosystem with a large presence of *Tabebuia cassinoides* (Lam.) DC, listed as endangered in the 1997 The IUCN Red List[1] and characterized by high water transparency, low tidal influence, the occurrence of many species typical of riparian vegetation, and low abundance of invasive grasses. Even so, this area is not included in a restrictive conservation unit.

[1] Retrieved from https://www.iucnredlist.org/

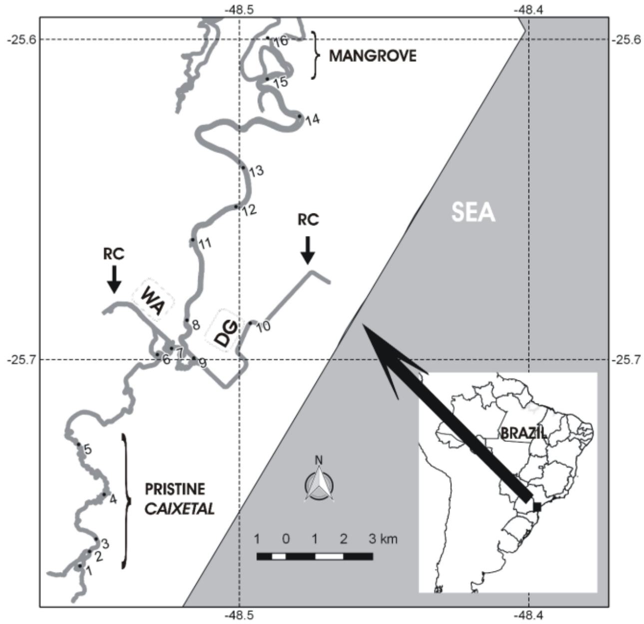

Figure 1. Geographical location of the Guaraguaçu River, Paraná Brazil, showing the location of the 'Pristine Caixetal' area and the 'Mangrove' area where water is permanently brackish. The intermediate area between 'Caixetal' and 'Mangrove' is the one of greater anthropogenic impact. Numbers indicate locations of monitored sampling sites (see Material and methods), although the checklist was done after an active search of the entire length of the river. In the intermediate areas it is also highlighted the rectified channels (RC). The one on the right has a dumping ground (DG) and receives a great amount of domestic effluents from municipalities; whereas the RC on the left has a water catchment station (WA) from the State Sanitation Company.

In the intermediate region there are two rectified channels that are being used as water catchment systems for public supply as well as for the reception of effluents from bathhouses, a sanitary landfill, and large irregular human occupation in the river margins. The intermediate region can therefore be considered the most impacted by anthropogenic stressors, reflected directly by the species composition of the aquatic plant community; the typical riparian vegetation has been replaced by species considered potentially invasive with high colonization and establishment capacities, such as *Urochloa arrecta* (Hack. ex T. Durand & Schinz) and *Pontederia* (*Eichhornia) crassipes* (Mart.) Solms-Laub. (even if this last species is native, it can develop to an invasive status, see also Schultz & Dibble, 2012; Michelan, Thomaz, & Bini, 2013; Pavão, Santos, Bottino, Benasse, & Calijuri, 2017). The topographic and physiognomic aspects of this region of the river are bound to favor the establishment and dispersion of *U. arrecta* and *P. crassipes*, considering the high nutrient inputs from the sections with high anthropic impacts (see Singo, Araújo-Ramos, & Rocha, 2020). Downstream, the river passes through the 'Guaraguaçu River Ecological Station', a large conservation unit, until it reaches a mangrove with many halophytic species and where the occurrence of freshwater aquatic macrophytes ends. It is important to point out that the river has a strong tidal influence, presenting a reflux of water in the lowlands. Even so, freshwater is predominant in most of its course (personal observation and local reports).

Data sampling

The botanical material was collected over four different periods between March 2016 and October 2017. The aquatic macrophytes floristic composition survey followed Pedralli (1990), which presents information on herborization methods and classification of species into life forms. A field guide for identification of plants (in Portuguese only) was also generated and is available at https://lasbufprbio.wixsite.com/home.

The aquatic environment was sampled by boat maintained at low speed while the river banks were sampled during walks, known as a walk-collection method, following Mormul, Ferreira, Carvalho, Michelan, Silveira, & Thomaz (2010). The collected material was forwarded for the assembly of exsiccates, identified, and later deposited in the scientific Herbarium collection of the *Universidade Federal do Paraná* (UPCB). The identification of the taxa was carried out through a comparison of the collected material with the aid of a specialized bibliography and expert consultation. The classification of phanerogamic botanical families was based on Souza & Lorenzi (2008) and The Angiosperm Phylogeny Group - APG IV et al. (2009), while the classification of pteridophytes followed Smith, Pryer, Schuettpelz, Korall, Shneider, & Wolf (2006), and life forms followed Pedralli (1990). All species recorded by intensive searches since 2016 on all stretches of the river are reported in the checklist, but we also used standardized samplings to report the distribution of most emblematic species (see below). Species distribution has been being monitored since 2016 in a long-term ecological survey, in which species and several functional traits are recorded in a standard sampling procedure carried out in 16 sampling sites along this river (see in Figure 1). All data is available for free use at https://lasbufprbio.wixsite.com/home. We consider emblematic species those that have high abundance (abundance data available at https://lasbufprbio.wixsite.com/home) and those with very restricted distribution. To describe distribution, we applied a Principal Coordinate Analysis with Sorensen dissimilarity, calculated at the matrix composed by species sampled only at the 16 sampling sites of the standardized monitoring. We indicated the occurrence of emblematic species in the graph.

Results

A total of 47 species belonging to 37 genera and 29 botanical families have been recorded (Table 1). In general, the most representative family was Cyperaceae (15%, seven species), followed by Poaceae and Onagraceae (8.5%, four species each) and Polygonaceae (6.3%, three species). The most common biological forms found were amphibious (34%, 16 species) and emergent (32%, 15 species) individuals. Two recorded species are non-native for the Guaraguaçu River basin: *U. arrecta* and *Nymphaea caerulea* Savugny.

Table 1. List of aquatic macrophytes and respective life forms recorded in Guaraguaçu River, Paraná, Brazil between March 2016 and October 2017. AM = amphibious; EM = emergent; EP = epiphyte; FF = free floating; FS = free submerged; RF = rooted floating; and RS = rooted submerged.

Family/Species	Life Forms	Voucher
ALISMATACEAE		
Echinodorus grandiflorus (Cham. & Schltr.) Micheli	EM	92723
Helanthium tenellum (Mart. ex Schult.f.) J.G.Sm.	AM	87714
AMARANTHACEAE		
Alternanthera philoxeroides (Mart.) Griseb.	AM	92713
AMARYLLIDACEAE		
Crinum americanum L.	EM	92712
ARACEAE		
Lemna valdiviana Phil.	FF	92716
Pistia stratiotes L.	FF	58254
ARALIACEAE		
Hydrocotyle leucocephala Cham. & Schltdl.	FF	92717
ASTERACEAE		
Wedelia paludosa DC.	AM	92721
BEGONIACEAE		
Begonia fischeri Schrank	AM	92711
COMMELINACEAE		
Commelina nudiflora L.	AM	87705
CONVOLVULACEAE		
Ipomoea carnea Jacq.	AM	92598
CYPERACEAE		
Cyperus pohlii (Nees) Steud.	AM	92710
Eleocharis geniculata (L.) Roem. & Schult.	AM	92730
Eleocharis interstincta (Vahl) Roem. & Schult.	EM	92704
Eleocharis tenuissima Boeckeler	EM	92724
Oxycaryum cubense (Poepp. & Kunth) Lye	EP	87707
Rhynchospora corymbosa (L.) Britton	EM	92709
Scirpus californicus (C.A. Mey.) Steud.	EM	87708
HALORAGACEAE		
Myriophyllum aquaticum (Vell.) Verdc.	RS	87712
HYDROCHARITACEAE		
Egeria densa Planch.	RS	92600

Family/Species	Life Forms	Voucher
JUNCACEAE		
Juncus brasiliensis Breistr.	AM	87706
LENTIBULARIACEAE		
Utricularia gibba L.	FS	92596
LYCOPODIACEAE		
Palhinhaea cernua (L.) Franco & Vasc.	AM	87704
MAYACACEAE		
Mayaca sellowiana Kunth	RS	92731
MALVACEAE		
Talipariti pernambucense (Arruda) Bovini	AM	92705
MELASTOMATACEAE		
Tibouchina trichopoda (DC.) Baill.	AM	92301
NYMPHAEACEAE		
Nymphaea caerulea Savugny	RF	92595
ONAGRACEAE		
Ludwigia grandiflora (Michx.) Greuter & Burdet	EM	92597
Ludwigia erecta (L.) H.Hara	AM	92732
Ludwigia helminthorrhiza (Mart.) H.Hara	FF	92733
Ludwigia octovalvis (Jacq.) P.H.Raven	AM	92722
ORCHIDACEAE		
Habenaria repens Nutt.	EM	92729
POACEAE		
Hymenachne amplexicaulis (Rudge) Nees	EM	92702
Panicum aquaticum Poir.	EM	92715
Panicum schwackeanum Mez	EM	92707
Urochloa arrecta (Hack. ex T.Durand & Schinz) Morrone & Zuloaga	EM	87713
POLYGONACEAE		
Polygonum hidropiperoides Michx.	EM	92720
Polygonum punctatum Elliott	AM	92714
Polygonum stelligerum Cham.	AM	92701
PONTEDERIACEAE		
Pontederia (Eichhornia) azurea (Sw.) Kunth	FF	92599
Pontederia (Eichhornia) crassipes (Mart.) Solms-Laub.	FF	52526
POTAMOGETONACEAE		
Potamogeton illinoensis Morong	RF	91220
PTERIDACEAE		
Ceratopteris thalictroides (L.) Brongn.	AM	87703
RICCIACEAE		
Ricciocarpus natans (L.) Corda	FF	92725
SALVINIACEAE		
Azolla caroliniana Willd.	FF	58257
Salvinia biloba Raddi	FF	87715
TYPHACEAE		
Typha dominguensis Pers.	EM	92726

Distribution of species is summarized in Figure 2. It is noteworthy that *U. arrecta* distribution does not include the 'Pristine Caixetal', the most preserved area of the river; neither the mangroves, where salinity predominates (see location in Figure 1). In the mangroves, there is a dominance of *Crinum americanum* L. (Amaryllidaceae), which also occurs in all the extent of the river, showing the plasticity of this species to salt concentrations. The common and usually invasive (although native) free-floating species *Pontederia (Eichhornia) crassipes* (Mart.) Solms-Laub. (Pontederiaceae) and *Pistia stratiotes* L. (Araceae) occur mainly with *U. arrecta* in the most polluted areas of the river, although sporadic occurrence is observed in the entire river length. Another species with large distribution is this river is the species *Scirpus californicus* (C.A. Mey.) Steud (Cyperaceae), which forms large beds that are apparently being decreased by the expansion of *U. arrecta*. Finally, it is noteworthy to mention the very local distribution of *Potamogeton illinoensis* Morong and *Mayaca sellowiana* Kunth, occurring in low abundances only in the stretches of the river with relativity high flow (between sampling sites 5 and 6 in Figure 1, *P. illinoensis* was not recorded in the standardized monitoring, but was recorded in the extensive searches in the abovementioned region); and the high abundances of the Ricciaceae species *Ricciocarpus natans* (L.) Corda and the Cyperaceae species *Eleocharis geniculata* (L.) Roem. & Schult., *Eleocharis interstincta* (Vahl) Roem. & Schult, and *Eleocharis tenuissima* Boeckeler only in the pristine Caixetal (see location in Figure 1).

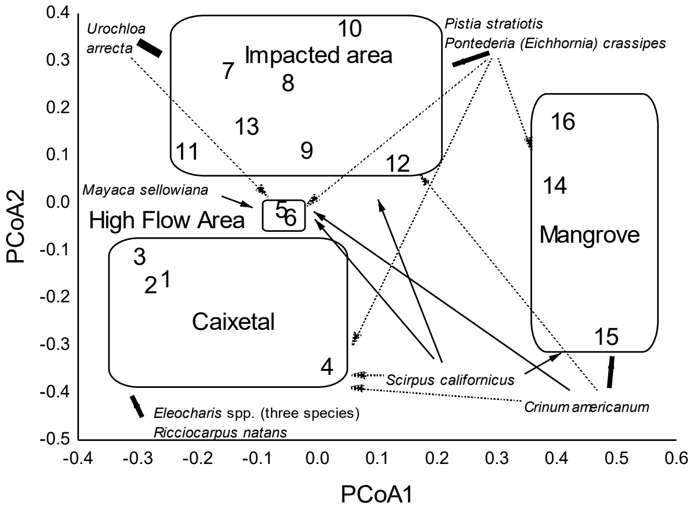

Figure 2. Results of a Principal Coordinate Analysis showing the relative location of the 16 monitoring sampling units considering macrophyte composition (see Figure 1 for geographical location of sampling units). The most emblematic macrophytes are shown in the graph. In this case, the thicker the line of axis, the higher the abundance in sampling units (complete data available at https://lasbufprbio.wixsite.com/home). Boxes separate the sampling sites according to general environmental, as described in Methods.

Discussion

The species richness is considerable compared to other studies carried out in the South Region of Brazil, such as Rocha & Martins (2011) which collected 54 species in the municipality of Ponta Grossa (PR) through 10 samplings, and Alves, Tavares, & Trevisan (2011) which registered 63 taxa in the Environmental Protection Area (APA) of the Coastal Environment (SC). Even when compared to intensive inventories made in Paraná State, the Guaraguaçu River has a substantial amount of species. For instance, Ferreira Mormul, Thomaz, Pott, & Pott (2011) collected a total of 153 species in the Upper Paraná River floodplain by compiling data from several years of samplings in a geographical extension of hundreds of kilometers; Cervi, Bona, Moço, & Von-Linsingen (2009) surveyed 117 taxa in ponds, reservoirs and streams of the General Carneiro Municipality, south of Paraná, after decades of samplings. Indeed, the fact that our list includes a smaller number of species compared to such inventories may be associated with: i) a relatively short time span for our samplings, ii) the size of the Guaraguaçu River, iii) the fact that part of this river is affected by saltwater, which means that ecological gradient include a clear floristic transition zone (from sampling sites 14-16 there are records of mangrove species, indicating salt water intrusion, see also Bora, Thomaz, & Padial, 2020), and iv) and the degree of isolation of this river considering the other major aquatic basins. Given the major mountain chains adjacent to most of the Brazilian coastline, estuarine systems have poor connection with other inland waters. Relatedly, it has been shown that the richness of aquatic macrophytes is associated to the area in different scales and bioclimatic factors (Campelo Siqueira-Filho, & Cotarelli, 2013, Moura-Junior, Lima, Silva, Paiva, Ferreira, Zickel, & Pott, 2015). In addition, it is important to emphasize that this is the first formal study of the floristic composition in the whole extension of the Guaraguaçu River, in which the sampling effort will be expanded in the coming years. Only a partial floristic inventory was done within the limits of the Guaraguaçu River Ecological Station, and the species list of terrestrial and aquatic plants was published only in a technical report available on the website of the Environmental Institute of Paraná State, the local governmental agency responsible for this conservation unit (see http://www.iap.pr.gov.br/pagina-1206.html). In this technical report, less than 20 aquatic macrophyte species are listed, and all of them were confirmed in the present checklist. Therefore, our study is pivotal to inform conservation efforts of aquatic environments in the Lagamar Region, the set of estuaries in Paraná and São Paulo States that are considered by UNESCO as a core zone of the Atlantic Forest Biosphere Reserve, and a natural World Heritage Site.

Other studies have already demonstrated the remarkable presence of Cyperaceae and Poaceae species in rivers (Pivari, Oliveira, Costa, Ferreira, & Salino, 2011; Campelo, Siqueira-Filho, Cotarelli, Souza, Pimenta & Pott, 2012), reservoirs (Moura-Junior, Abreu, Severi & Lira, 2011; Sabino, Araujo, Cotarelli, Siqueira-Filho & Campelo, 2015) and floodplains (Ferreira, Mormul, Thomaz, Pott, & Pott, 2011; Pott, Pott, Lima, Moreira & Oliveira, 2011). This common occurrence can be explained by the fact that they are cosmopolitan families with high numbers of species, which have high vegetative dispersal capacity due to the presence of rhizomes and tubers (Souza & Lorenzi, 2008). According to Pivari, Oliveira, Costa, Ferreira, & Salino (2011), the striking occurrence of Cyperaceae suggests environmental changes in the aquatic ecosystems and formation of floating islands, possibly related to anthropogenic processes.

The predominance of amphibious and emergent life forms is an expected result, similar to that obtained in other studies of aquatic macrophytes in the Neotropical Region (Henry-Silva, Moura, & Dantas, 2010; Mormul et al., 2010, Pivari, Oliveira, Costa, Ferreira, & Salino, 2011; Ferreira, Mormul, Thomaz, Pott, & Pott, 2011; Rolon, Rocha, & Maltchik, 2011). The large number of amphibious and emergent species may be related to the adaptability to both the aquatic and terrestrial environments, especially to environments subject to pulses of seasonal or daily floods from tides (Bove, Gil, Moreira, & Anjos, 2003), as occurring in the Guaraguacu River. In addition, the high number of species of the most representative families (Cyperaceae and Poaceae) is related to the high richness of amphibious and emergent species in tropical aquatic ecosystems (Ribeiro, Takao, Matsumoto, Urbanetz, & Lima, 2011).

In studies of aquatic macrophyte communities it is essential to discuss the presence of exotic invasive species. In the Guaraguaçu River, the most abundant species is the *U. arrecta* (personal observation, see also Vitule, Umbria, & Aranha, 2006), which has caused serious ecological changes regarding the dynamics of tropical aquatic ecosystems (Carniatto, Thomaz, Cunha, Fugi, & Ota, 2013; Fernandes, Teixeira, & Thomaz, 2013; Michelan, Thomaz, & Bini, 2013), especially due to its high biomass that allows high dispersion and establishment capacities (Michelan, Thomaz, Mormul, & Carvalho, 2010; Amorim, Umetsu, & Camargo, 2015). This species was already recorded in 2006 in this river, identified as *Brachiaria* spp. Vitule, Umbria, & Aranha (2006); and had strong impacts on fish fauna, possibly favoring the invasive catfish *Clarias gariepinus* Burchell, 1822 (Siluriformes, Clariidae) (Vitule, Umbria, & Aranha, 2006). Another non-native species recorded in the Guaraguaçu River is *N. caerulea*. Although several species of the family Nymphaeaceae are native and common in Brazil, the species recorded in the Guaraguaçu River is originally from the Nile Basin. The occurrence of the two non-native species above mentioned suggest that study and conservation efforts should be concentrated in sites such as the Guaraguaçu River, considered vulnerable to biological invasion (Vitule, Umbria, & Aranha, 2006).

Up to date, no formal study was done describing the environmental gradient and its effect on biota. Our paper is the first describing the remarkable changes of species composition of macrophytes along this river in a way related to anthropogenic disturbances and environmental features. In the areas of high human disturbance, there is a disproportional abundance of species that commonly are reported as invasive, such as *U. arrecta*, *P. crassipes* and *P. stratiotes*. Indeed, anthropic actions usually promote invasive species (Vitule, Freire, Vazquez, Nuñes, & Simberloff, 2012). A set of environmental features also likely promote species filtering and compositional changes along the river. At saline areas, there is a dominance of *C. americanum* (as already described by Ribeiro, Takao, Matsumoto, Urbanetz, & Lima, 2011), with only sporadic occurrence of other species. On the other hand, at the pristine Caixetal, the water is visually different, full of humic compounds from the decomposition of terrestrial vegetation from the major mountain chain nearby ('Serra do Mar Mountain Chain'), and with much more lentic flow. In this area, composition changes accordingly in line with a recent review on the effect of carbon concentration on macrophytes (Reitsema, Meire, & Schoelynck, 2018).

The occurrence of species used for aquarium trade such as *P. illinoensis*, *M. sellowiana* and the Haloragaceae *Myriophyllum aquaticum* (Vell.) Verdc M. may also represent a conservation challenge. Particularly *P. illinoensis* and *M. sellowiana* occur in small beds in a very restricted range of the Guaraguaçu River. At the same time, such submerged species likely present a key role in the aquatic community, for example, by increasing the periphytic microalgae species richness (Fernandes, Oliveira, & Lacerda, 2016). In summary, the present study revealed a high richness and a complex pattern of spatial variability of aquatic macrophytes in the Guaraguaçu River, demonstrating that despite presenting a high degree of anthropogenic impacts and degree of isolation, it is an important water body for the conservation of aquatic biodiversity. This claim is highlighted by the fact that Guaraguaçu River is the largest river in the Paraná Coastal Basin and has a strong environmental gradient ranging from pristine Caixetal areas, passing through anthropic-impacted landscapes and ending in a large and well-preserved mangrove. We argue that the aquatic flora is a good indicator that Guaraguaçu River represents a unique ecosystem for the Lagamar, a critical area for conservation in the Atlantic Forest hotspot.

Conclusion

Our study is the first formal report of the astonishing macrophyte diversity of the Guaraguaçu River in the Lagamar. We revealed serious conservation challenges related: to the overwhelming invasion of the African tanner grass *U. arrecta*; and to species commonly explored for aquarium trade. We also demonstrated that species vary over the river mainly due to anthropogenic impacts. The high species richness for a relatively small and isolated basin and the 'Pristine Caixetal' and mangrove areas reinforce that Guaraguaçu River basin is of outmost importance for biological conservation.

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