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Original Paper
An update on the knowledge of aquatic macrophytes in Northeast Brazil

Edson G. de Moura Júnior[1,2,3,4] & *Vinicius M. Cotarelli*[1]

Abstract
We updated the first checklist of aquatic macrophytes from Northeast Brazil (First Flora), which included data collected up to 2010, with a new checklist based on data from works published between 2011 and 2017 (New Flora). Together, these checklists record 637 species of 89 families, with an emphasis on strictly amphibious or emergent species, with 392 and 115 species, respectively. We found differences in observed richness between New Flora and First Flora, with an increase of 106 species in the New Flora. The rarefaction curve shows that a considerable increase in collection effort is necessary to determine the aquatic flora of the studied region. From the compiled data, we suggest new perspectives for floristic inventories of aquatic macrophytes, highlighting the prioritization of poorly studied areas; the exploration of ecological information of the species (*e.g.*, endemism, rarity, threat of extinction or invasive potential); and the promotion of projects on a regional scale.
Key words: aquatic plants, biotic limnology, Caatinga.

Resumo
Atualizamos o primeiro *checklist* de macrófitas aquáticas do Nordeste do Brasil (Primeira Flora), que incluiu dados coletados até 2010, com uma nova lista de espécies baseada em dados de trabalhos publicados entre 2011 e 2017 (Nova Flora). Juntas, estas listagens registram 637 espécies de 89 famílias, com ênfase em espécies estritamente anfíbias ou emergentes, com 392 e 115 espécies, respectivamente. Encontramos diferenças na riqueza observada entre a Nova Flora e Primeira Flora, com aumento de 106 espécies na Nova Flora. A curva de rarefação mostrou que é necessário um aumento considerável no esforço de coleta para que possamos determinar a flora aquática da região estudada. A partir dos dados compilados, sugerimos novas perspectivas para inventários florísticos de macrófitas aquáticas, destacando a priorização de áreas mal estudadas, a exploração de informações ecológicas das espécies (*e.g.*, endemismo, raridade, ameaça de extinção ou potencial invasivo), e a promoção de projetos em escala regional.
Palavras-chave: plantas aquáticas, limnologia biótica, Caatinga.

Introduction

Although the Northeast Region of Brazil encompasses substantial watersheds (*e.g.*, Apodi, Parnaiba, Recôncavo Bahiano, São Francisco), until recently there has been a lack of knowledge regarding the aquatic vegetation of the area (Moura-Júnior *et al*. 2013). Some researchers relate this poor knowledge to the lack of macrophytes specialists in the region (Thomaz & Bini 2003; Machado-Filho *et al*. 2014). This scarcity of knowledge was most pronounced during the 1980s and 1990s, a period when only two papers were published for the region, according to the scientometric work on aquatic macrophytes by Thomaz & Bini (2003).

However, between the years 2000 and 2010, the number of papers published relating to floristic surveys of aquatic macrophytes in Northeast Brazil increased significantly, as noted by the first checklist of macrophytes for

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[1] Universidade Federal do Vale do São Francisco (UNIVASF), Núcleo de Ecologia e Monitoramento Ambiental (NEMA), BR-407, km 12, lote 543, Projeto de Irrigação Nilo Coelho s/n, 56300-000, Petrolina, PE, Brazil.

[2] Sociedade Botânica do Brasil, Núcleo de Especialistas em Plantas Aquáticas (NEPA), Ed. Constrol Center, Asa Norte, SCLN 307, bl. B, s/ 218, 70746-520, Brasília, DF, Brazil.

[3] ORCID: <https://orcid.org/0000-0001-9029-7618>

[4] Author for correspondence: mourajunioreg@gmail.com

this region. This checklist was developed with metadata obtained from scientific works and the SpeciesLink network (Moura-Júnior *et al.* 2013), and noted 13 publications during the 2000s with a floristic focus of aquatic macrophytes. In total it recorded 412 species distributed among 27 genera and 72 families.

The number of specialists on aquatic macrophytes working in Northeast Brazil seems to have increased in the same proportion as the number of works published in this region, after the year 2000. According to information provided by the Núcleo de Especialistas em Plantas Aquáticas do Brasil - NEPA (Brazilian Aquatic Plants Specialist Group), 42 researchers from eight states of the region have registered with the NEPA after the year 2008 (NEPA 2019). In this context, it is important that we recognize how much the new specialists and research groups focused on aquatic macrophytes of Northeast Brazil are contributing to the expansion of knowledge on these plants.

The lack of knowledge regarding the aquatic macrophytes of Northeast Brazil, as pointed out by Moura-Júnior *et al.* (2013), highlights the need to update data on these plants. According to those authors, there were no publications on the floristics of aquatic plants for the states of Alagoas, Sergipe, Maranhão and Piauí until 2010.

In addition, the use of data from the SpeciesLink network for the preparation of the first checklist of aquatic macrophytes in Northeast Brazil may result in a biased knowledge of these plants. The possibility of errors in taxonomic identification of specimens deposited in the herbaria that provide data to the SpeciesLink network may result in an underestimation of species richness or an imprecise description of the floristic composition of a given region (Moura-Júnior *et al.* 2015). Therefore, it is recommended that species surveys or macroecological studies based on metadata prioritize information published in scientific articles or book chapters, with fewer misidentifications due to deeper research by the authors combined with thorough peer review (Moura-Júnior *et al.* 2015).

The Flora do Brazil 2020 (2017) network is a botanical data platform that can complement these regional surveys of aquatic macrophytes (Moura-Júnior *et al.* 2015), since in addition to updated taxonomic classifications, it provides ecological and biogeographic information for the species. The updated taxonomic information in the Flora do Brazil network implies an upgrade in the floristic knowledge of the states of Brazil, which reiterates the need to update the first checklist of the macrophytes in the Northeast Region.

Therefore, the objectives of the present study were to: i - evaluate the progress of acquiring knowledge regarding the aquatic macrophytes for the states of Northeast Brazil based on scientific studies published since 2010; ii - compile data from these two historical collection periods to update the checklist of aquatic macrophytes in the region, including complementing species data with information from Flora do Brazil 2020; and iii - use the collected data to suggest new perspectives for floristic inventories of aquatic macrophytes in the region.

Material and Methods

We performed a comprehensive search for articles, book chapters and doctoral theses containing floristic surveys of aquatic macrophytes in the states of the Northeast Region published between January 2010 and June 2017. For this purpose, we visited the websites of the main indexers of scientific journals (Web of Science, Scopus, Scielo, Springer, Elsevier), of Google Scholar and of graduate programs in ecology, biodiversity, botany and plant ecology located in Northeast Brazil. The words used in these searches were: aquatic macrophytes, aquatic plants, aquatic ferns, aquatic angiosperms, aquatic herbaceous plants and wetland plants (in Portuguese and English). The list of works consulted and the location of the studied areas are shown in Table 1 and Figure 1, respectively.

Next, we developed a checklist of the species mentioned in these scientific works adding the species mentioned in previous checklist (Moura-Júnior *et al.* 2013). Thus, we generate the Cumulative Flora (CF). We did not include taxa in CF that were identified only to generic level or that needed their identity confirmed. We included information regarding endemism (to Brazil), origin (native, cultivated or naturalized) and species geographic distribution amont the states of the Northeast Region from the Flora do Brazil 2020 (2017) network. We reported the biological forms of the species of CF based on the works consulted for the development of this checklist or published works for other regions (Pott & Pott 2000; Amaral *et al.* 2008; Ferreira *et al.* 2011; Moura-Júnior *et al.* 2015).

The taxonomic classification was based on APG IV (2016) for angiosperms, Smith *et al.* (2006)

Table 1 – Lists of works consulted for the development of Cumulative Flora (CF), including types of environment and states or region where the studies were carried out. Legend: (BA) Bahia; (CE) Ceará; (PB) Paraíba; (PE) Pernambuco; (PI) Piauí; (RN) Rio Grande do Norte; (NO) Northeast of the Brazil.

ID	References	State or region	Type of data of enviroment
1	Mathias & Nunes (2001)	CE	Coastal lagoon
2	França *et al.* (2003)	BA	Reservoir
3	Matias *et al.* (2003)	CE	Coastal lagoon
4	Neves *et al.* (2006)	BA	Coastal lagoon
5	Pedro *et al.* (2006)	PB	River
6	Moura-Júnior *et al.* (2009)	PE	Reservoir
7	Lima *et al.* (2009)	PE	Herbarium compilation
8	Nascimento (2009)	PE	Reservoir
9	Henry-Silva *et al.* (2010)	RN	Rivers
10	Matias (2010)	NO	Shallow lakes, rivers, floodplains, oxbow lakes, temporary ponds, permanent ponds, coastal lagoons, lakes, permanent and temporary swamps, reservoir
11	Moura-Júnior *et al.* (2010)	BA	Reservoir
12	Sobral-Leite *et al.* (2010)	PE	Herbarium compilation
13	França *et al.* (2010)	BA	River, temporary and permanent ponds
14	Moura-Júnior *et al.* (2011a)	PI	Metadata compilation
15	Moura-Júnior *et al.* (2011b)	BA	Reservoir
16	Lima *et al.* (2011)	PE	Reservoir
17	Silva (2011)	PE	Reservoir
18	Campelo *et al.* (2012)	PE,PB,CE	Lakes,permanent and temporary swamps, reservoir
19	Araújo *et al.* (2012)	PE,PB,CE	Reservoir
20	Xavier *et al.* (2012)	PE	Reservoir
21	Lima *et al.* (2013)	PB	Permanent and temporary ponds
22	Campelo *et al.* (2013)	PE,PB,CE	Reservoir
23	Cordeiro *et al.* (2013)	PE	Temporary ponds
24	Andrade *et al.* (2014)	PI	River, temporary ponds and permanent ponds
25	Lacet *et al.* (2014)	PB	Reservoir
26	Santos *et al.* (2014)	BA	River, reservoir
27	Aona *et al.* (2015)	BA	Rivers, floodplains, temporary ponds, permanent ponds, permanent and temporary swamps
28	Sabino *et al.* (2015)	PE,PB,CE	Reservoir
29	Sousa *et al.* (2016)	PI	River
30	Xavier *et al.* (2016)	PE	River
31	Moura-Júnior *et al.* (2016)	PE	Reservoir
32	Torres *et al.* (2016)	PB	Rivers, temporary and permanent ponds, permanent and temporary swamps, reservoir

for ferns, Buck & Goffinet (2000) for mosses and hepatics, and Lee (2008) for green macroalgae. Flora do Brazil 2020 (2017) was used to check the correct spelling of the valid taxa names and their authors, as well as to evaluate synonymy. We chose to eliminate from CF species that had no record for Brazil or for the Northeast Region of the country, as well as names with dubious spelling, according to Flora do Brazil 2020 (2017). In the future, these taxa can be new records for the country or the region, and so we decided to list them in the Table S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.10142789.v1>.

We use our experience with aquatic macrophytes in natural environments to eliminate from CF some species erroneously termed macrophytes (Eliminated species checklist), for example, trees, subshrubs or hemiparasites with terrestrial habit strictly and typical of marine or xerophytic areas.

We used a matrix of presence/absence of species per state (P/A sta) to estimate richness of species noted in the current checklist (New Flora - NF) and the initial checklist of Moura-Júnior *et al.* (2013) (First Flora - FF). We used CHAO 2 to estimate richness and compared the estimated richness of NF and FF using their maximum and minimum confidence intervals (CI). We also computed rarefaction curves to evaluate the increase in the number of macrophyte species compiled through the sampling effort of these two checklists. In order to compute the rarefaction curve, we used a matrix of presence/absence of species per consulted scientific work (P/A wrk). We used the software Estimates 9.1 (Colwell 2013) to compute richness estimates and the rarefaction curve.

Results

Cumulative Flora

The CF included 637 species distributed among 320 genera and 89 families (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.10142789.v1>). Of this total richness, 586 species (92%) are native

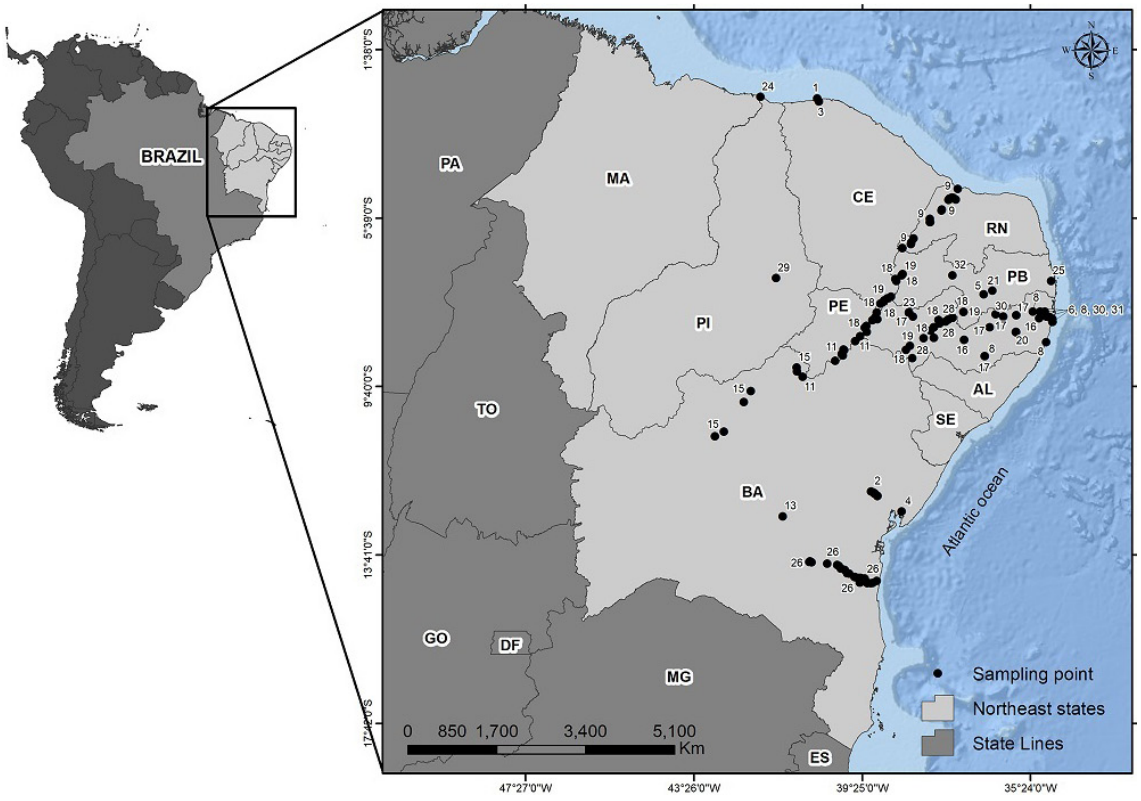

Figure 1 – Map of the Northeast Region of Brazil and the location of the sites where the consulted scientific works were performed. Legend: (AL) Alagoas; (BA) Bahia; (CE) Ceará; (MA) Maranhão; (PB) Paraíba; (PE) Pernambuco; (PI) Piauí; (RN) Rio Grande do Norte; (SE) Sergipe; (1,2,3 ... 32) identification of the scientific work consulted (see Table 1).

to Brazil, 49 species (7.69%) naturalized and two species (0.31%) cultivated. Of the native CF species, 92 (14.42%) are endemic to Brazil.

The states with the greatest observed richness were Bahia and Pernambuco with 593 and 531 species, respectively. The other states, in sequence, are Ceará (479 species), Paraíba (445 species), Alagoas (387 species), Piauí (376 species), Maranhão (373 species), Sergipe (366 species) and Rio Grande do Norte (350 species).

The families with the greatest observed richness were Cyperaceae with 80 species, followed by Poaceae (59 species), Fabaceae (50 species), Asteraceae (36 species), Malvaceae (25 species), Convolvulaceae (21 species), Rubiaceae (19 species) and Plantaginaceae (16 species), which together account for 48.03% of the total encountered species. Twenty-six families were represented only by a single species (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.10142789.v1>).

The genera with the greatest observed richness were *Cyperus* with 24 species, followed by *Eleocharis* (15 species), *Rhynchospora* (11 species), *Utricularia* (10 species), *Nymphea* (10 species), *Ipomoea* (9 species), *Solanum* (8 species), *Ludwigia* (8 species), *Cuphea* (8 species), *Echinodorus* (7 species), *Chara* (7 species), *Stylosanthes* (7 species).

Two hundred and eight species had records for all nine states of the Northeast Region. Of this total, four species were recorded in more than half of the consulted articles: *Salvinia auriculata* Aubl. with 21 records, *Eichhornia crassipes* (Mart.) Solms and *Nymphoides indica* (L.) Kuntze with 20 records (each species) and *Pistia stratiotes* L. with 17 records. There were 312 species cited in only one of the consulted articles. Of this total, 40 species were recorded for only one state, seven of which are endemic to Brazil (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.10142789.v1>): *Acmella paniculata* (Wall. *ex* DC.) R.K.Jansen, *Eriocaulon aquatile* Körn., *Schultesia gracilis* Mart., *Scleria myricocarpa* Kunth, *Utricularia laciniata* St-Hil. & Girard, *Achetaria ocymoides* (Cham. & Schltdl.) Wettst. and *Stachytarpheta bicolor* Hook.f.

The species with strictly amphibious or emergent biological form represented 61.54% or 18.05% of the CF richness, respectively. In contrast, the species with strictly submerged or floating biological form represented 5.97% or 5.65% of the CF richness, respectively (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.10142789.v1>). Fifty-six species can occur as more than one biological form in nature, particularly those with the potential of being amphibious or emergent (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.10142789.v1>). The predominance of species with an amphibious or emergent biological form occurred in all states of the Northeast Region.

Eliminated species

We eliminated 60 species form the final list because they were erroneously termed macrophytes, *Calotropis procera* (Aiton) W. T. Aiton, *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. *ex* S.Moore, *Cordia superba* Cham., *Cynophalla flexuosa* (L.) J.Presl, *Maytenus gonoclada* Mart., *Licania leptostachya* Benth., *Hirtella glandulosa* Spreng., *Vismia guianensis* (Aubl.) Choisy, *Combretum fruticosum* (Loefl.) Stuntz, *Conocarpus erectus* L., *Laguncularia racemosa* (L.) C.F.Gaertn., *Erythroxylum macrocalyx* Mart., *Croton heliotropiifolius* Kunth, *Jatropha gossypiifolia* L., *Ricinus communis* L., *Pogonophora schomburgkiana* Miers *ex* Benth., *Anadenanthera colubrina* (Vell.) Brenan, *Lonchocarpus cultratus* (Vell.) A.M.G.Azevedo & H.C.Lima, *L. sericeus* (Poir.) Kunth *ex* DC., *Machaerium lunatum* (L.f.) Ducke, *Mimosa arenosa* (Willd.) Poir., *M. hexandra* Micheli, *M. ophthalmocentra* Mart. *ex* Benth., *M. tenuiflora* (Willd.) Poir., *M. bimucronata* (DC.) Kuntze, *Parkinsonia aculeata* L., *Muellera monilis* (L.) M.J. Silva & A.M.G. Azevedo, *Pithecellobium dulce* (Roxb.) Benth., *Poincianella pyramidalis* (Tul.) L.P. Queiroz, *Prosopis juliflora* (Sw.) DC., *Sesbania exasperata* Kunth, *Vachellia farnesiana* (L.) Wight & Arn., *Aegiphila verticillata* Vell., *Vitex megapotamiga* (Spreng.) Moldenke, *Myrcia guianensis* (Aubl.) DC., *M. splendens* (Sw.) DC., *Ouratea hexasperma* (A.St.-Hil.) Baill., *Coccoloba alnifolia* Casar., *C. declinata* (Vell.) Mart., *C. parimensis* Benth., *C. striata* Benth., *Ruprechtia laxiflora* Meisn., *Coutarea hexandra* (Jacq.) K. Schum., *Genipa americana* L., *Gonzalagunia dicocca* Cham. & Schltdl., *Machaonia acuminata* Bonpl., *Tocoyena formosa* (Cham. & Schltdl.) K.Schum., *Nicotiana glauca* Graham, *Solanum stipulaceum* Willd. *ex* Roem. & Schult., *Cecropia pachystachya* Trécul , *Vochysia*

Table 2 – Observed richness of the states of Northeast Brazil for Cumulative Flora (CF), First Flora (FF) and New Flora (NF). Legend: (AL) Alagoas; (BA) Bahia; (CE) Ceará; (MA) Maranhão; (PB) Paraíba; (PE) Pernambuco; (PI) Piauí; (RN) Rio Grande do Norte; (SE) Sergipe.

	AL	BA	CE	MA	PB	PE	PI	RN	SE	Total
First Flora (Moura-Júnior *et al.* 2013)	197	347	256	181	252	357	149	186	172	402
New Flora	304	473	385	309	355	423	310	295	289	508
Cumulative Flora	387	593	479	373	445	531	376	350	366	637

pyramidalis Mart., *Dialium guianense* (Aubl.) Sandwith, *Zygia latifolia* (L.) Fawc. & Rendle, *Cassytha filiformis* L., *Struthanthus flexicaulis* Mart., *Byrsonima sericea* DC., *Ruppia maritima* L., *Halodule emarginata* Hartog, *Halodule wrightii* Asch and *Avicennia germinans* (L.) L. Of these species, *R. maritima*, *H. emarginata* and *H. wrightii* are rooted submerged, *C. filiformis* is a holoparasite, *S. flexicaulis* is a hemiparasite and 55 species are amphibious.

Comparison between New Flora (NF) and First Flora (FF)

Comparing NF with FF, 311 species, 21 families and 129 genera were exclusive to NF, and there were 26 name updates. We recorded 282 native species and 52 endemic species in NF. Annual accumulation of richness recorded the greatest increases in 2012 and 2015 (Fig. 2). The works of Campelo *et al.* (2012) and Aona *et al.* (2015) made the greatest contributions to NF with 58 and 96 species, respectively (Fig. 1 nº 18 and 26, respectively).

The families with the greatest number of species exclusive to NF were Fabaceae and Poaceae (29 species), Malvaceae (19 species), Asteraceae (19 species), Malvaceae (19 species), Asteraceae (19 species), Cyperaceae (15 species) and Convolvulaceae (15 species). The genus *Chara* and *Nymphaea* were the most representative with six species each and *Cuphea* with five species. Together amphibian and emergent species predominate (90.68%) of the NF richness. This predominance of species with an amphibious or emergent biological form of the NF richness occurred in all states of the Northeast Region.

We found a difference between the observed richness of FF and NF, with 106 species increase of the NF (Tab. 2). All of the states exhibited increased observed richness in NF compared with FF (Tab. 2). The state that exhibited the highest increase in observed richness in NF was Piauí with 161 species.

The CHAO 2 confidence intervals for NF and FF exhibited significant differences in estimated richness, with an increase for NF (Fig. 3). The rarefaction curve showed continuous growth in aquatic macrophyte richness considering the works used to compile the checklists (Fig. 4).

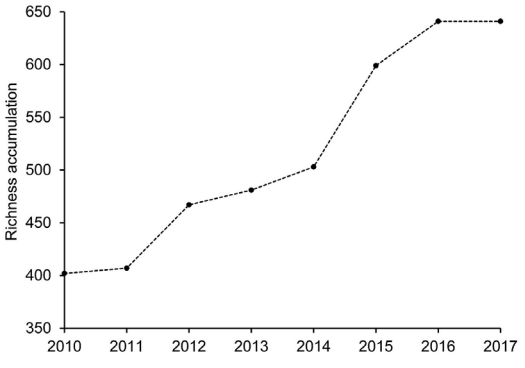

Figure 2 – Annual accumulated richness, according to the consulted scientific works.

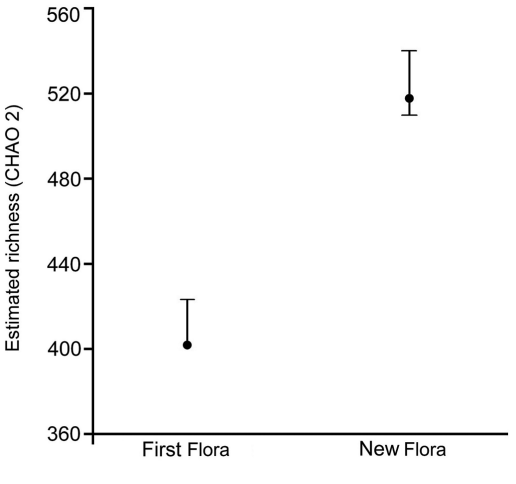

Figure 3 – Estimated richness (CHAO 2) and confidence intervals for First Flora (FF) and New Flora (NF).

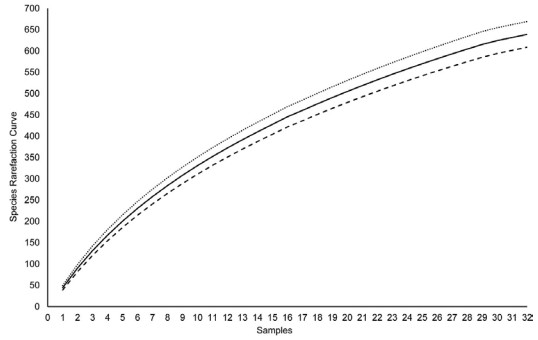

Figure 4 – Species rarefaction curve and the maximum (dotted line) and minimum (dashed line) confidence intervals of the aquatic macrophytes richness, according to the consulted scientific works to compile the checklists.

Discussion

The most represented families in CF were the same as those in the first checklist (Moura-Júnior *et al.* 2013). Most of the species of Cyperaceae and Poaceae possess vegetative propagation and fast-growing root systems (Souza & Lorenzi 2012). This finding may explain the strong representation of these families in CF and NF, as well as the observed richness of *Cyperus*, *Eleocharis* and *Rhynchospora* in CF. In addition, species of Cyperaceae and Poaceae well suited to floodable areas or ecotones between terrestrial and aquatic environments (Souza & Lorenzi 2012), what explains the representation of amphibious species of these families in CF. The shallow depth, minimal influence of winds and long presence of water in the Aquatic/Terrestrial Transition Zone - ATTZ (Wantzen *et al.* 2008) make this zone more favorable to amphibious and emergent aquatic macrophytes, as compared to the more central and deeper zones of aquatic environments (Esteves 2011). Given the recognized predominance of emerging amphibious species in surveys with macrophytes in the Neotropics (Machado-Filho *et al.* 2014), the high number of species of *Chara* (fixed submerged, but not rooted) and *Nymphaea* (rooted floating) with occurrence restricted to NF caught our attention. Such results led us to the understanding that researchers observed submerged and floating aquatic macrophytes with greater detail in the floristic inventories they undertook in Northeast Brazil, after the year 2010.

Fabaceae is one of most represented families in the majority of natural ecosystems in Brazil, mainly due to the extensive morphophysiological plasticity possessed by the species of this family (Souza & Lorenzi 2012). Fabaceae predominates in different vegetation types of the Caatinga domain (Moro *et al.* 2014, 2015), which covers more than 70% of the Northeast Region of Brazil (Prado 2003). These findings may explain the high level of observed richness of Fabaceae in CF and NF.

The most frequently encountered species of CF (*E. crassipes*, *S. auriculata*, *N. indica* and *P. stratiotes*) are cited as invasive or very frequent in several aquatic ecosystems of Brazil (Ferreira *et al.* 2011; Amaral *et al*. 2008; Pereira *et al.* 2012; Moura-Júnior *et al.* 2015), especially those with high trophic degree (Pott & Pott 2000; Pompêo 2017). Two species endemics to Brazil, exclusive of a state and cited by only one consulted papers (*Eriocaulon aquatile* and *Stachytarpheta bicolor*), are on the Red List of species threatened with extinction of the International Union for Conservation of Nature - IUCN (IUCN 2017).

Although biological and/or ecological information about species can help to characterize a studied environment, this type of discussion is uncommon among the floristic surveys of macrophytes in Northeast Brazil. Information on endemism, rarity, invasive potential and threat of extinction for species is easily obtained from the literature and can enrich the content of floristic works. Therefore, we encourage macrophyte specialists to explore biological and/or ecological information for the species in their floristic inventories.

The mistaken inclusion of amphibious species in aquatic macrophyte inventories is another point that deserves special attention. Many of the eliminated species are pioneer or invasive trees and shrubs. Our "eliminated species" checklist considered many species whose physiology is well suited to dry areas and xerophytic environments (Souza & Rodal 2010; Barbosa *et al.* 2012; Moro *et al.* 2015). The inclusion of records of these species in floristic inventories of aquatic macrophytes is often caused by difficulty in recognizing the physical boundary between wetland and dry areas. In many cases, the erroneous collection of terrestrial plants in aquatic macrophyte inventories is due to environmental changes that occurred few days before field sampling (*e.g.*, rapid increase accumulated water in wet ecosystem due to heavy rainfall).

The problem with the classification of amphibious macrophytes in floristic macrophyte inventories can be mitigated by increasing the

number of collection expeditions. The greater the number of collections, the better understanding of the ecology of the species that survive in terrestrial/aquatic ecotones. The regime of water level fluctuation can change daily (*e.g.*, Amazonian ecosystems), seasonally or annually (*e.g.*, intermittent lagoons of the semi-arid region of Brazil). Thus, it is important to understand the regime of the hydrological cycle of the ecosystem being studied to establish the number of expedition necessary to properly sample and sufficiently understand, with a high degree of confidence, the amphibious macrophyte flora of a given study area. Therefore, in general, we recommend, a minimum of three collection expeditions to sites for aquatic macrophyte inventories in order to encompass an entire hydrological cycle (flood, ebb and dry).

The scale of study is another relevant aspect of inventories of aquatic macrophytes. Of the works we consulted for this checklist, the greatest contribution to richness in NF was made by those developed on a regional scale, such as Campelo *et al.* (2012) for the area of influence of the São Francisco river transposition project, and Aona *et al.* (2015) for the Recôncavo basin of Bahia. Moro *et al.* (2015) found that point surveys can underestimate plant richness in the Caatinga domain. We also highlight the considerable increase in species richness for the state of Piauí in NF. This state had the smallest number of species sampled in FF and there had been no floristic surveys of aquatic macrophytes until 2010 (Moura-Júnior *et al.* 2013). The first floristic inventories undertaken for Piauí after 2010 certainly explain the increase in richness of this state in NF.

Increased collection effort in floristic inventories of aquatic macrophytes and/or the selection of less explored areas may bring unprecedented data for the knowledge on these plants in the Northeast Region of Brazil (Campelo *et al.* 2012). Increased sampling effort can also help to understand the biogeography of species, and avoid false indications of rarity, endemism or threat with extinction (Ladle & Whittaker 2011). The high number of species cited by only one consulted work and exclusively for a single state in the Northeast Region reiterates the need to expand the collection effort in this region, and especially in poorly sampled areas.

The expansion of regional knowledge on aquatic plants can refine the delineation of the actual flora in the region and enable reliable floristic comparisons to be made with other regions (Moura-Júnior *et al.* 2015). However, many centric areas in Northeast of Brazil need research about aquatic macrophytes, especially in the states of Maranhão, Piauí, Rio Grande do Norte Alagoas and Sergipe.

With the aim of characterize the aquatic macrophyte flora of the different ecosystems of Brazil and fostering macroecological studies in the country, NEPA established its main objective for the current decade of compiling regional checklists of data on these plants in a digital platform available to the scientific community (NEPA 2019). Our manuscript is part of this NEPA objective and will certainly contribute to future comprehensive investigations on aquatic macrophytes in Brazil and other Neotropical regions. For this reason, we suggest some new directions for floristic surveys on aquatic plants, among which we highlight: the exploration of poorly studied areas; the incorporation of available information on endemism, rarity, threat of extinction or invasive potential of species; discussion of the conservation status of areas studied; and the promotion of projects on regional and long-term scales.

The simple comparison of our results with the data available in Flora do Brazil 2020 (2017) shows the relevance of species survey to obtaining knowledge for a particular biological group. According to Flora do Brazil 2020 (2017), the aquatic vegetation of the Northeast Region is composed of 378 species of 59 families, which underestimates 41% of the observed richness by our checklist. However, our rarefaction curve shows that a larger sampling effort than the current one is still necessary to determine, with some degree of confidence, the size of the aquatic flora of the studied region.

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