



## STRUCTURE COMMUNITY OF AQUATIC MACROPHYTES IN SPRINGS OF THE SEMIARID, NORTHEAST BRAZIL

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### ABSTRACT

*The objective was to analyze the aquatic macrophytes structure community in springs of the semiarid, in the Northeast Brazil, in both wet and dry seasons. Collecting expeditions took place monthly from July 2009 to April 2013, in both wet and dry seasons. The aquatic macrophyte inventory was done in 27 streams including temporary lakes, dams and reservoirs reservoirs of Semiarid, Northeast Brazil. All of the collected material was registered and incorporated in the collection of the Herbarium of Vale do Sao Francisco (HVASF), of the Universidade Federal do Vale do Sao Francisco. The catchment areas mentioned above were georeferenced with a Garmin EtrexR GPS in order to determine occurrence frequency and distribution of aquatic macrophyte species along the construction areas of the channels and reservoirs of SFRIP. Plant samples were collected using aluminum boats equipped with an outboard motor and, on land, a 4x4 utility vehicle as well as during walks along the banks of the reservoirs. For structural characterization of the community, were analyzed the species relative frequency, the family relative frequency and the Shannon-Weaver index diversity ( $H'$ ). A total of 192 taxons were recorded, belonging to 117 genera and 49 families. The following distribution was observed for the various plant groups: liverworts and algae (1 family each), pteridophytes (4 families), angiosperms (43 families). The most species-rich families were Cyperaceae (26 species), Fabaceae (17 species), Asteraceae (13 species), Plantaginaceae (12 species), Onagraceae and Poaceae (9 species each). Most species were classified as amphibious (57.1%) and emergent (16.2%). Finally, this study provides important elements for management plans of water bodies that have historically been ignored as regards biodiversity conservation of aquatic ecosystems of semiarid.*

**Keywords:** *Aquatic macrophytes, Semiarid, Caatinga, Sao Francisco River, Conservation.*

### 1. INTRODUCTION

Brazil has the largest hydrographic network in the world, with fluvial aquatic ecosystems as well as permanent or temporary lacustrine ecosystems that are of great significance within Brazilian ecosystems. The vegetation consists of algae and true hydrophytes, as well as plants that are periodically submerged at various levels or on the banks of these aquatic habitats, like, for instance, amphibious and emergent species (Pott *et al.*, 1992; Pedralli, 1990). Within this context, the areas of the Semiarid in the Sao Francisco River watershed stand out. As the scenario for the present study, the Semiarid is a little known sector in Brazil and for this reason its biological diversity has been underestimated (MMA, 2004).

The lack of studies may lead to a loss of landscapes with grave consequences for maintaining biodiversity (MMA, 2002). Several studies are changing this panorama for restricted biological groups (MMA, 2004), but the data are still scarce for some plant groups. It is important to note that although the social and environmental importance of the Sao Francisco River is acknowledged, there is widespread physical and biological mischaracterization along the river, arising mainly from urbanization, intensive timber and energy use, mining of sand and clay, pasturelands, hydroelectric plants, intensive agriculture and a network of roads that lead to



deforestation of riverine forests and water pollution, thus endangering the fauna and flora.

In spite of the urgent conditions of the Sao Francisco River caused by the above-mentioned activities, as well as by the Sao Francisco River Integration Project, natural stretches of caatinga vegetation are being diverted to construct irrigation canals and 29 artificial reservoirs. Various plant populations are endangered due to the destruction of riverine forests and the detour of water courses. Therefore, the knowledge gained by floristic surveys and other studies on key plant groups will produce important comparative data, thus contributing to biodiversity conservation and adequate management of the flora.

Aquatic macrophytes are the focus of this study. This group is named for the plants' ecological traits, not taxonomy, including those plants that live in wet areas or totally underwater (Esteves, 1998). In tropical regions, aquatic macrophytes are abundant due to environmental conditions that favor their growth (Pott *et al.*, 1992). According to Hoehne (1945), in no other part of the world are there as many water plants as in Brazil.

Studies focusing on the floristics and ecology of this group of plants in streams of Northeast Brazil report that the flora is poorly known. They mention several works for the region such as that by Pedro *et al.* (2006) on the hydrological cycle and dynamics of aquatic macrophytes in two intermittent rivers of the semi-arid region; Franca *et al.* (2003) on the vascular

flora of reservoirs in a semi-arid region of Bahia; Henry-Silva *et al.* (2010) who studied the richness and distribution of aquatic macrophytes in wet habitats of the Apodi/Mossoro watershed in the semi-arid region of Rio Grande do Norte; and Sobral-Leite *et al.* (2010) who made a checklist of vascular macrophytes of Pernambuco, including species richness, life forms and distribution.

Several studies have been made and others are in the making in areas of the eastern and northern axes of the Sao Francisco River Integration Project (SFRIP) regarding both limnology and ecology, but from a floristic point of view, they are still incipient or scarce. The objective was to analyze the aquatic macrophytes structure community in springs of the semiarid, in the Northeast Brazil, in both wet and dry seasons.

**2. MATERIAL AND METHODS**

**2.1 Sampling and study methods**

Collecting expeditions took place monthly from July 2009 to April 2013, in both wet and dry seasons. The aquatic macrophyte inventory was done in 27 streams including temporary lakes, dams and reservoirs of Semiarid, Northeast Brazil (Figure 1; Table 1).

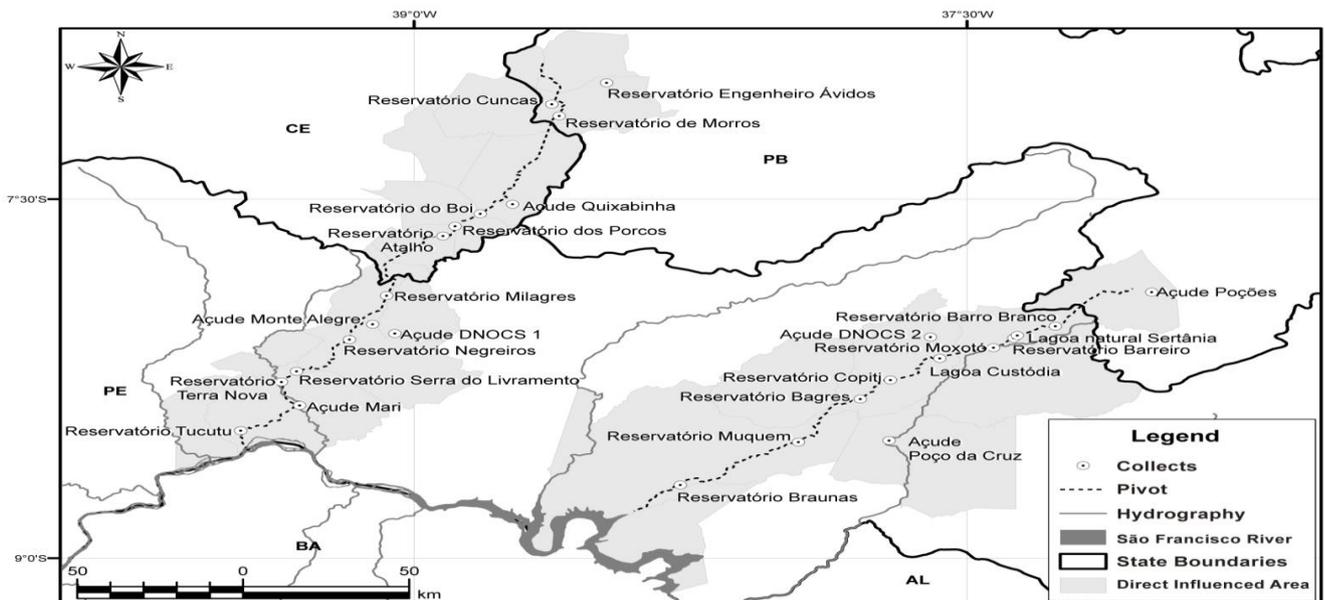


Figure 1. Map of the location of water sources in the Semiarid, Northeast Brazil. Source: Brazil (2004, 2006, 2010), modified



Table 1. Location of water source (springs) and area (hectares) of the Semiarid, Northeast Brazil.

WATER SOURCE	MUNICIPALITY	STATE	LONGITUDE (W)	LATITUDE (S)	AREA (ha)
Açude Poções	Monteiro	PB	36°59'57,5"	07°53'18,8"	441,02
Reservatório do Boi	Brejo Santo/Mauriti	CE	38° 49' 12.50"	7° 33' 38.37"	179,76
Reservatório Barro Branco	Sertânia	PE	37° 15' 39.81"	8° 1' 51.53"	8,73
Reservatório Barreiro	Sertânia	PE	37° 22' 26.69"	8° 4' 49.10"	74,13
Reservatório Cuncas	São José de Piranhas	PB	38° 37' 35.42"	7° 6' 8.92"	1657,74
Reservatório dos Porcos	Jati/Brejo Santo	CE	38° 53' 17.22"	7° 36' 45.96"	802,52
Reservatório de Morros	São José de Piranhas	PB	38° 36' 22.99"	7° 9' 4.92"	94,91
Lagoa natural Sertânia	Sertânia	PE	37°21'49,7"	08°04'10,6"	3,96
Reservatório Muquem	Floresta	PE	37° 57' 25.82"	8° 30' 52.90"	79,11
Reservatório Braúnas	Floresta	PE	38° 16' 42.35"	8° 41' 38.09"	131,35
Reservatório Moxotó	Sertânia	PE	37° 25' 42.35"	8° 7' 15.04"	78,32
Reservatório Milagres	Verdejante/Salgueiro	PE	39° 4' 25.43"	7° 54' 11.21"	1114,52
Reservatório Copiti	Custódia	PE	37° 42' 27.30"	8° 15' 21.25"	149,10
Reservatório Serra do Livramento	Cabrobó	PE	39° 19' 4.30"	8° 13' 9.73"	155,88
Reservatório Terra Nova	Cabrobó	PE	39° 21' 29.26"	8° 15' 51.07"	230,65
Reservatório Negreiros	Salgueiro	PE	39° 10' 26.75"	8° 5' 11.89"	244,69
Reservatório Engenheiro Ávidos	São José de Piranhas	PB	38° 28' 39.78"	7° 0' 49.62"	1890,79
Açude Poço da Cruz	Ibimirim	PE	37°42'41,3"	08°30'29,5"	5005,59
Reservatório Bagres	Custódia	PE	37° 47' 21.97"	8° 20' 6.05"	74,52
Açude Mari	Cabrobó	PE	39°18'33,00"	08°21'43,20"	16,00
Barragem da Mangueira	Custódia	PE	37°34'27,3"	08°9'54,2"	2,00
Reservatório Tucutu	Cabrobó	PE	39° 28' 9.72"	8° 28' 4.00"	351,98
Açude Quixabinha	Mauriti	CE	38°43'58,3"	07°31'13,5"	151,16
Açude Bela Vista	Salgueiro	PE	39°03'07,3"	08°03'40,6"	300,00
Reservatório Atalho	Jati/Brejo Santo	CE	38° 55' 17.22"	7° 39' 13.72"	554,53
Açude da Marreca	Custódia	PE	37°35'59,3"	08°04'33,9"	300,00
Açude Monte Alegre	Salgueiro	PE	39°06'43,4"	08°01'22,3"	55,63

Species were identified using specialized literature (Souza & Lorenzi, 2008; Picelli-Vicenti *et al.* 2004, Pott & Pott, 2000, Bove & Paz, 2009, Bueno *et al.* 2011). Furthermore, collections were identified by comparison with herbarium material from IPA, UFP, HUEFS and RB (Thiers, 2012). Finally, unidentified material was sent to specialists for identification of the respective taxonomic groups. The classification of phanerogamic plant families was based on Souza & Lorenzi (2008) and on APG III (2009). Taxonomic nomenclature followed that of the data banks available in the *Flora do Brasil* (2012) and, when

necessary, *The International Names Plant Index* (IPNI, 2012) was consulted as was *Tropicos* of the Missouri Botanical Garden (Mobot, 2012). For pteridophytes, the classification system adopted was that of *Flora do Brasil* (2012). For liverworts, we used Crandall-Stoler & Stoler (2000) and for macroalgae, Hoek *et al.* (1996).

All of the collected material was registered and incorporated in the collection of the Herbarium of Vale do São Francisco (HVASF), of the Universidade Federal do Vale do São Francisco; duplicates were deposited in the herbaria CGMS and RB. The



catchment areas mentioned above were georeferenced with a Garmin EtrexR GPS in order to determine occurrence frequency and distribution of aquatic macrophyte species along the construction areas of the channels and reservoirs of SFRIP.

Plant samples were collected using aluminum boats equipped with an outboard motor and, on land, a 4x4 utility vehicle as well as during walks along the banks of the reservoirs. The usual methods of plant collection and pressing were used and are described in Mori *et al.* (1985) and Fidalgo & Bononi (1989); according to these references, collections should include three to five samples of fertile individuals.

Data Analysis Species frequency per area over the collection period was determined based on the number of occurrences, classified as follows: Constant =  $F > 50\%$ , Common =  $10\% < F \leq 50\%$ , or Rare =  $F \leq 10\%$  (Lobo & Leighton, 1986).

As regards life forms, we used the classification of Irgang *et al.* (1984) who recognize seven types: attached submerged (SF) – plants submerged and attached to the substrate; free submerged (SL) – plants submerged but not attached to the substrate; attached floating (FF) – plants with all or some parts floating on the surface, but attached to the substrate by roots; free floating (FL) – floating plants not attached to the substrate; amphibious (A) – plants that usually grow on the banks and tolerate dry periods; emergent (E) – plants attached to the substrate with prominent vegetative and reproductive organs partly emerging from the water surface; epiphyte (EP) – plants that grow on another plant.

### 3. RESULTS AND DISCUSSION

A total of 192 taxons were recorded, belonging to 117 genera and 49 families. The following distribution was observed for the various plant groups: liverworts and algae (1 family each), pteridophytes (4 families), angiosperms (43 families). The most species-rich families were Cyperaceae (26 species), Fabaceae (17 species), Asteraceae (13 species), Plantaginaceae (12 species), Onagraceae and Poaceae (9 species each), Charophyceae (8 species) (figure 2). The most species-rich genera were *Ludwigia* (9 species), followed by *Cyperus* and *Chara* (7 species each). In agreement with the data acquired here on the flora, note that Cyperaceae, Fabaceae, Asteraceae, Plantaginaceae and Poaceae are often cited as being important families in studies done in the Northeast (Lima *et al.* 2011; Sobral-Leite *et al.* 2010; Henry-Silva *et al.* 2010; Neves *et al.* 2006; Matias *et al.* 2003; Franca *et al.* 2003). According to Pivari *et al.* (2008), the marked presence of representatives of Cyperaceae suggests recent modification of a site, such as the growth of floating islands, possibly related to man-made processes. It is also important to note that this family stands out because of an intense presence in many regions and due to the high species richness, thus characterizing aquatic ecosystems (Gil & Bove 2004).

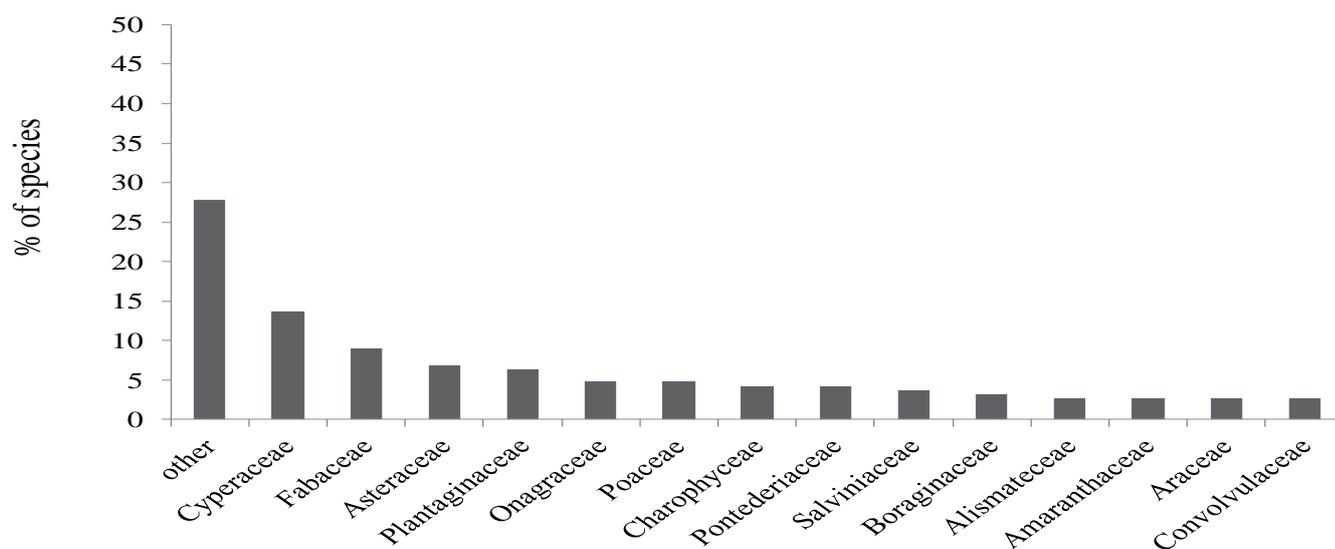




Figure 2. Percentage distribution of aquatic macrophyte species by family in the water source of the Semiarid, northeast Brazil.

According to Pott & Pott (2000), the importance of the genus *Ludwigia* in wetlands that have been studied can be explained by the presence of species of this genus at all stages of succession, and individuals with life forms that vary from palustrine to amphibious and submerged, providing these species with the capacity to exploit different habitats. In relation to floristics, several new species records in this study deserve mention since two new occurrences were cited for Brazil (*Azolla pinnata* and *Physalis pruinosa*), ten for the Northeast (*Chara guairensis*, *C. globularis*, *C. kenoyeri*, *C. zeylanica*, *Amaranthus blitum*, *Cabomba haynesii*, *Ceratophyllum demersum*, *Luffa operculata*, *Juncus bufonius* and *Pontederia parviflora*) and six for the Caatinga (*Chara indica*, *C. hydrophytes*, *C. rusbyana*, *Ricciocarpos natans*, *Sagittaria guayanensis* subsp. *guayanensis* and *Caperonia palustris*). The expanded geographic distribution of these taxons will allow us to make new interpretations and comparative analyses concerning temporal and spatial dynamics of aquatic macrophytes in the Caatinga.

Other relevant contributions cited recently by Pivari *et al.* (2011) also deserve mention because they increase our knowledge of aquatic plant diversity in an important wetland of Brazil, until now poorly known floristically. In this study there are 152 first citations of macrophyte species for the Rio Doce valley, in Minas Gerais, and two new occurrences for this state (*Ceratopteris thalictroides* and *Habenaria nabucoi*). This clearly shows how important floristic works are for the group in question.

As regards the importance of aquatic macrophytes for each axis of SFRIP, there was similarity of 26.8% for the flora of both axes. As a result of the transposition of the Sao Francisco River waters on the aquatic macrophyte community, we can infer that there will be an impact of almost 30% species dissimilarity in the catchments studied, since any alteration in the aquatic macrophyte community such as a change in water-flow direction will imply that physical and chemical changes in the water will take place which will also influence other aquatic organisms. The Northern axis had a higher number of aquatic macrophytes totaling 140 species, with 43.9% exclusive to this axis, as follows: *Chara globularis*, *C. hydrophytes*, *C. indica*, *C. kenoyeri*, *C. zeylanica*, *Ricciocarpos natans*, *Ceratopteris*

*pteridoides*, *Salvinia oblongifolia*, *Alternanthera ramosissima*, *Wolffia brasiliensis*, *Cyperus surinamensis*, *Utricularia gibba* and *Pontederia parviflora*, *Thalia densibracteata*, among others.

The Eastern axis had 105 species of aquatic macrophytes with 27.2% exclusive to this axis, the most important being: *Riccia stenophylla*, *Azolla filiculoides*, *Hydrocleys martii*, *Ceratophyllum demersum*, *Bulbostylis scabra*, *Cyperus articulatus*, *C. luzulae*, *C. odoratus* and *Anamaria heterophylla*, among others.

Species richness of vascular and nonvascular aquatic macrophytes surveyed for the two axes of the Project is representative to some extent when compared to studies done in the Northeast, such as Franca *et al.* (2003), citing 121 species in 46 families; Neves *et al.* (2006), who did a floristic survey of vascular aquatic plants in a coastal lagoon, Candeias municipality (BA), and collected 28 species in 20 families; Henry-Silva *et al.* (2010), who assessed the richness and distribution of 40 species of aquatic macrophytes; and Sobral-Leite *et al.* (2010), who stressed the richness of macrophytes for the state of Pernambuco, listing 189 species distributed in 54 families; of this total only 51 species of aquatic macrophytes are cited for the Pernambuco outback. In general, it appears that information from the present study indicates that aquatic macrophyte richness in the Caatinga is similar to that of other ecosystems in Brazil (Rolon *et al.*, 2011; Pivari *et al.*, 2011; Moura Junior *et al.*, 2011; Henry-Silva *et al.*, 2010; Mormul *et al.*, 2010).

When life forms (*sensu* Irgang *et al.* 1984) are considered, all representatives were found in both axes of the SFRIP (figure 3). Most species were classified as amphibious (57.1%) and emergent (16.2%), followed by attached submerged (11%), free floating (7.8%) and attached floating (6.3%). The lower percentages belong to the epiphytes (1.1%) with only *Oxycaryum cubense* and *Habenaria repens* and the free submerged (0.5%), *Utricularia gibba*. In agreement with the data found in the SFRIP, Lima *et al.* (2011), studying aquatic macrophyte diversity in three public supply reservoirs, located in different phytographic regions of Pernambuco known as the Zona da Mata/Litoral, Agreste and Sertao cite as predominant life forms amphibious plants, with 36 species (61.01%), followed by emergents, with 14 species (23.73%).

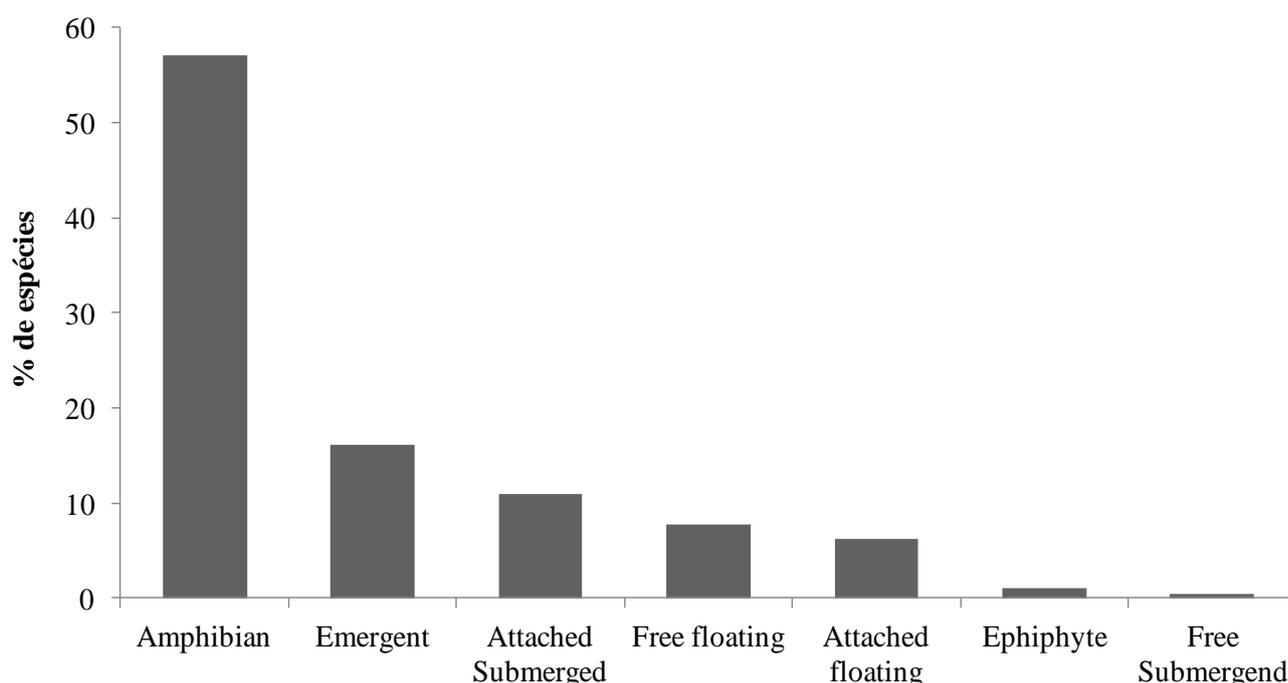


Figure 3. Percentage of life forms of aquatic macrophytes sampled in the water source of the Semi-arid, northeast Brazil.

The fact that amphibious and emergent macrophytes tend to predominate in Neotropical wetlands has been cited in many articles (Rolon *et al.*, 2011, Pivari *et al.*, 2011, Henry-Silva *et al.*, 2010; Mormul *et al.*, 2010; Bove & Paz, 2009; Pott & Pott, 1997). According to some authors (Junk & Piedade 1993 and Bove *et al.*, 2003), the reason that there are more amphibious and emergent species is because many habitats are subject to seasonal or daily flooding regimes, a result of semi-diurnal tides, and these species are adapted to both aquatic and terrestrial environments. The populations of annual species shrink or may even disappear during the dry season, while the perennial species often dominate these habitats, changing the landscape.

According to Neves *et al.* (2006), the predominance of species with amphibious and emergent life forms appears to be related to shallow water and to the fact

that most of these species are resistant to low water volume. In aquatic macrophyte studies, it is relevant to discuss exotic invasive species, that is, those species found outside their natural distribution area (see chapter 10). Records of invasion by exotic species are found in almost all ecosystems on the planet. However, there is special concern for continental aquatic ecosystems. On the SFRIP axes, the list of exotic and subspontaneous aquatic macrophytes includes 4.3% of the species, as follows: *Azolla pinnata* (Salviniaceae), *Amaranthus blitum* and *A. viridis* (Amaranthaceae), *Ipomoea wrightii* (Convolvulaceae), *Oryza sativa* (Poaceae), *Physalis angulata* and *P. pruinosa* (Solanaceae) and *Sphenoclea zeylanica* Gaertn. (Sphenocleaceae).

Henry-Silva *et al.* (2010) point out that 47.5% of the species identified in the drainage basin of the

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Apodi/Mossoro River were considered to be invasive species. Costa Neto *et al.* (2007) mention several invasive, ruderal or opportunistic species for the lake region of Amapá; these include *Ipomoea asarifolia*, *Ipomoea carnea* subsp. *fistulosa*, *Cyperus luzulae*, *Pycnus polystachyos* and *Solanum grandiflorum*, among others. According to the authors, these species compete with native forage species, with their rapid growth, high seed production, high adaptive capacity and resistance. Along the SFRIP axes, there are several species that are seen as opportunistic and/or widespread, such as *Eichhornia crassipes*, *E. azurea*, *Ipomoea carnea*, *Cyperus odoratus*, *Egeria densa*, *Pistia stratiotes* and *Paspalum repens*. The presence of these species may be cause for concern because of rapid, prolific propagation in eutrophic environments. However, Moura-Junior *et al.* (2010) state that, based on data of stand size and biomass of these macrophytes in the lower-middle São Francisco, it is not yet time to consider this to be a problem for the region.

For Pivari *et al.* (2008), the presence of potentially invasive species suggests a certain degree of disturbance in these areas. Furthermore, the state of conservation of the aquatic environments can be seen by the species that are found there, for invasive species have a remarkable capacity to compete with native species, especially due to the lack of natural predators. So the invading species swiftly dominate the environment, causing a decrease in species richness. According to Vitousek *et al.* (1997), introduction of invasive species is seen today as the second largest determinant of biodiversity decline, losing only to natural habitat destruction. But invasive aquatic organisms are a problem not only for ecosystems, but also for human activities, including industrial and production systems.

According to Pedralli & Gonçalves (1997), the presence of invasive species reflects man's activities in the neighborhood of lakes that interfere with the floristic composition of the aquatic plant community. Rampant growth of invading species of aquatic macrophytes generally suggests that the environment where this occurs is undergoing a rapid eutrophication process. Summing up, bioinvasion, or the introduction of a species, can cause negative effects on associated organisms, mainly when we are dealing with aquatic macrophytes, because this group plays a central role in the structure and dynamics of the entire aquatic community and the functioning of aquatic ecosystems.

As regards the occurrence frequency of species on the SFRIP axes, it should be noted that no constant species were recorded. The common category holds

60 species, including *Salvinia auriculata*, *Hydrocleys martii*, *Ludwigia helminthorrhiza*, *Pistia stratiotes*, *Nymphoides indica*, *Stemodia maritima*, *Hydrothrix gardneri*, *Heteranthera limosa*, *Angelonia salicariifolia*, *Enydra radicans*, *Nymphaea pulchella* and *Egeria densa*. Aquatic macrophytes considered rare constitute 130 species, that is, almost 70% of the known species, with special emphasis on *Chara globularis*, *Tristichia trifaria*, *Ricciocarpos natans*, *Riccia stenophylla*, *Ceratopteris pteridoides*, *Ceratophyllum demersum*, *Utricularia gibba*, *Anamaria heterophylla* and *Wolffiella lingulata*.

The data on the SFRIP axes are significant in relation to rare species when compared to percentages found by Henry-Silva *et al.* (2010) for the Apodi/Mossoro drainage basin, where the percentage of rare and constant species was 37.5% and, for the common category, 55%. Also, in studies by Rolon *et al.* (2011), aquatic macrophytes in Lagoa do Peixe National Park (Rio Grande do Sul) were classified mostly as rare (50%) and common (36%).

#### 4. CONCLUSION

The inventory of aquatic macrophytes on the SFRIP axes reveals an important flora when compared to other floristic work done in the region. Furthermore, it showed the predominance of amphibious and emergent life forms, in agreement with other surveys of this vegetation that have been done in Brazil.

In the future, it will be necessary to continue monitoring these communities, as well as differential management to conciliate: 1) the control of native species that benefit from eutrophication of aquatic habitats, as well as exotic species that are classical invaders, and 2) use of bioindicator species of water quality, considered rare, to determine water use for irrigation and human consumption.

Finally, this study provides important elements for management plans of water bodies that have historically been ignored as regards biodiversity conservation of aquatic ecosystems in the semi-arid, northeast Brazil.

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