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RICHNESS OF THE AQUATIC MACROPHYTES IN THE TEMPORARY LAGOONS IN THE SEMIARID OF NORTHEASTERN BRAZIL

[1] MARIA JACIANE DE ALMEIDA CAMPELO

[1] Centro de Referência para Recuperação de Áreas Degradadas da Caatinga (CRAD), Universidade Federal do Vale do São Francisco (UNIVASF), Petrolina-PE, Brazil.
E-mail: [1]jaciane.campelo@univasf.edu.br

ABSTRACT

*Ipueiras, in the strict sense, are temporary aquatic ecosystems which include ponds, wetlands and intermittent lagoons. In these types of aquatic ecosystems, the flora is associated with and adapted to hydrological extreme conditions: floods and drought. To this end, we investigated the richness, similarity and the conservation status of aquatic macrophytes within the Northeastern semiarid region. Random collections of aquatic macrophytes were performed in the margins and in the center of the ipueiras between 2009 and 2014, aiming to know the flora of rivers, lagoons, weirs and temporary lagoons in the region. The specimens are deposited in the HVASF herbarium at the Federal University of Vale do São Francisco. A significant flora record with 23 families, 36 genera and 42 species is noticed. The ipueiras were characterized in several families, especially in the Plantaginaceae and Alismataceae (*9.5% families each*). Amphibious (57.2%) and emerging (16.6%) species prevailed among the life forms. None of the aquatic macrophytes cited in the Caatinga ipueiras was assessed regarding its conservation status. According to the Simprof analysis on the composition of aquatic macrophytes in the studied water sources, there is little sharing among their species. It is considered that the conservation of the aquatic macrophytes in the ipueiras from the Northeastern semi-arid region is closely related to the awareness of aquatic communities and their role in the environment. Such knowledge is also important for the strengthening and construction of a database.*

Keywords: ***Aquatic macrophytes, Caatinga, Temporary lagoons, Life forms*.**

1. INTRODUCTION:

Ipueiras, in the *strict sense*, are seen as temporary aquatic ecosystems which include ponds, wetlands and intermittent lagoons. According to Gil & Bove (2004), they are called marshes, swamps, wetlands, or floodplains, which are dry during the dry season, but return to their flooded state during the rainy season. According to Esteves (1998), in Brazil they are defined by areas in which the colonizing vegetation is tolerant or adapted to wet soils or soils that suffer from daily or seasonal flooding.

In the Brazilian semi-arid region, which occupies the entire Northeast region, the main natural wetlands are rivers and ipueiras or temporary lagoons. From the nature conservation point of view, semi-arid ipueiras are biodiversity spots, not only with regard to the aquatic fauna and flora, but also because of the concentration of other animals and plants in their vicinity. This aspect becomes even more important when one considers that the portion of protected surface area in the Northeast region (in the form of conservation units) is very small: only 1.13%. The concern increases in cases such as that of Paraíba State, which has almost its entire surface (94%) categorized as semi-arid and the minimal part of it (0.11%) is categorized as protected (Maltchik 2000).

According to Bianchini & Cunha-Santino (2006), the flora, in these types of aquatic ecosystems, is associated with and adapted to hydrological extreme conditions: floods and drought. These two extremes are considered as environmental disturbances and their influence on the biological community varies according to their attributes (intensity, frequency, duration, time of occurrence and predictability). The dynamics of the aquatic macrophyte community within these ecosystems varies according to annual cycles and is associated with the species' resistance and resilience strategies in the system. Changes in the composition of aquatic macrophytes occur over time by substitution and variations in the biomass and in the relative abundance of species.

It is also noticed that aquatic macrophytes can withstand short periods of drought due to morphological and physiological adaptations. However, after long periods of drought, the reestablishment of plants may depend on the seed bank or on propagules present in the sediment (Bianchini & Cunha-Santino 2006). Accordingly, the notable features of water level fluctuations show that such features may lead to the isolation of water sources able to raise relevant questions during investigations on colonization processes and on the dynamics of aquatic macrophyte communities.

According to Bove *et al*. (2003), plants that colonize this type of environment are adaptable to seasonality due to some of their features such as annualism or resistance to terrestrial life during dry seasons. Thus, one may consider that these environments are highly endangered because of riparian forest destructions and diversion of watercourses aiming to optimize agricultural activities, pollution directly or indirectly caused by the local population and by groundings performed with real estate purposes, the need for a survey becomes clear, as well as the need for a systematic study on species found in the aforementioned environment.

Even with all requirements for plant colonization fulfilled, aquatic macrophytes may constitute the primary organic matter producers, thus reaching around 100t of dry weight / ha / year (Piedade *et al*. 1991). This value is higher than that of sugar cane, even if applying large amounts of agricultural inputs. According to Junk (1980) and Pompêo & Henry (1996), macrophytes play an important role in the exchange of nutrients and can become the major controllers of nutrient dynamics within the ecosystem.

As for the floristic and ecological studies on aquatic macrophytes, an increasing interest in this aquatic plant group is noticed due to its significant importance in different trophic chains and to the possibility of its commercial application in different areas, such as: nutrition, human and animal health, waste water treatments, energy production and the obtainment of compounds under the interest of the food, chemical and pharmaceutical industries, among others (Borowitzka, 1993; Bruno, 2001; Richmond, 2004). As discussed above, the temporary aquatic ecosystems also have great representativeness in the Northeastern semi-arid region. The existence of ipueiras in the Northeastern Caatinga and their use as environment make it necessary to perform a botanical, zoological and ecological characterization. It is done by taking the aquatic plant community as biological parameter and associating it with physical-chemical parameters. The awareness of the key factors that influence the development.

Of aquatic macrophytes within these ecosystems in the semi-arid region becomes relevant in order to comment on biological groups. These groups depend on the conservation of Caatinga ipueiras, which are extremely rich, dynamic and dependent on climatic fluctuations such as temperature, light and humidity, due to low levels of precipitation, irregular rainfall and high evaporation rates. It is critical to understand their biocenosis colonization and adaptation processes.

The ipueiras are present in the semiarid region almost all year long, but they are found in larger quantities mainly after heavy rains. It may also be noticed that, after intense rainfall, the reflecting pools of several lagoons join each other to form a single lagoon. These temporary lagoons may dry up completely within three weeks. However, when rain is abundant, it is enough to fill the ipueiras with water. A study conducted in the Northeastern semi-arid region by Maltchik (2006) points out that temporary lagoons are more numerous in the states of Bahia, Ceará and Pernambuco (Maltchik, 2000). As for their physical characteristics, it is considered that most ipueiras are isolated, without marginal vegetation and surrounded by sand only. Recent investigations (Santos & Morais 2012) point out that morphometric analyses show that lagoons present varied shape, low depth and short width, length, area, volume and perimeter. According to Panosso *et al*. (1995), these characteristics suggest that the lagoons are very dynamic and mainly influenced by external environmental conditions and they probably have daily mixing periods.

Thus, this proposal investigates the richness, similarity and the conservation status of aquatic macrophytes within the Northeastern semiarid region.

2. MATERIAL AND METHODS:

The collecting expeditions were monthly conducted from July 2009 to march 2014, during the dry and rainy seasons. The aquatic macrophytes inventory was performed in 41 Caatinga aquatic ecosystems.

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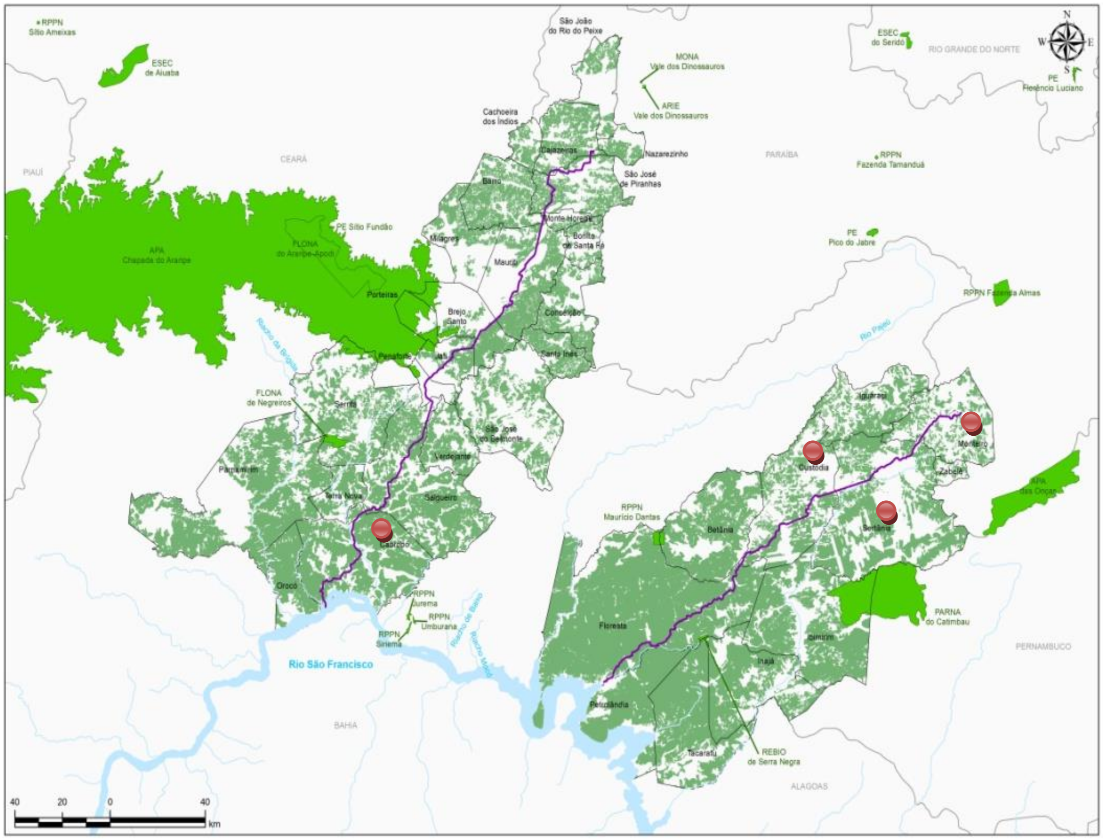

Figure 1. Map of the location of temporary lagoons in the Semiarid, Northeast Brazil. Source: Brazil (2004, 2006, 2010).

The current study only emphasized the aquatic macrophytes from the 04 ipueiras studied within the Northeastern semiarid region (Figure 1). Plants sampling was performed during walks taken on the margins and in the center of ipueiras by using the usual collection and botanical herborization methods described by Mori *et al*. (1985) and Fidalgo & Bononi (1989), according to which the collection should involve the obtainment of three to five samples from a fertile individual. The specialized literature was used in order to identify species (Souza & Lorenzi, 2008; Picelli-Vicentim *et al*. 2004, Pott & Pott, 2000; Bove & Paz, 2009; Bueno *et al*. 2011). In addition, the obtained collections were identified by means of comparing them with those from herbaria IPA, UFP, HUEFS and RB (Thiers, 2012). Finally, the unidentified material was sent to specialists in order to be identified in the relevant taxonomic groups.

The classification of phanerogam botanical families was based on Souza & Lorenzi (2008) and on APG III (2009). The taxonomic nomenclature followed the one indicated in the databases available in Flora do Brasil (2014) and, when necessary, the International Plant Names Index (IPNI, 2012), the Tropics of the Missouri Botanical Garden (Mobot, 2012) were also consulted. As for the pteridophytes, Flora do Brasil (2014) was the adopted classification system. With respect to macroalgae, the adopted system was that by Hoek *et al*. (1996). All collected material was listed and included in the collections of the Vale do São Francisco Herbarium (HVASF), at the Federal University of Vale do São Francisco.

As regards life forms, we used the classification of Irgang et al. (1984) who recognize six 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

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vegetative and reproductive organs partly emerging from the water surface.

To assess the conservation status of aquatic macrophytes followed Martinelli & Moraes (2013).

The floristic similarity between different Caatinga of aquatic ecosystems was accomplished through a cluster analysis. The date of floristic composition was subjected to an analysis of similarity by the Jaccard index (Magurran 2004).

3. RESULTS AND DISCUSSION:

Richness and floristic similarity of aquatic macrophytes in Caatinga

Regarding the knowledge on the aquatic flora within the Northeastern semi-arid region, the growing number of publications and the expansion of the floristic and ecological information on aquatic macrophytes can be noticed (Campelo *et al*. 2012, 2013; Moura-Júnior *et al*. 2011, 2013; Sobral-Leite *et al.* 2010; Pedro *et al*. 2006; França *et al*. 2003). The study by Campelo *et al*. (2012) resulted in the compilation of 192 aquatic macrophyte species in the Northeastern Caatinga watersheds. Of this total, 42 species distributed in 23 families and 36 genera are considered as usual in Caatinga ipueiras (Table 1). The Alismataceae and Plantaginaceae families stand out with great species representativeness (9.5% each). *Cyperus*, *Chara* and *Echinodorus* are the most numerous genera and, finally, *Anamaria heterophylla* and *Hydrothrix gardneri* are species that colonize the Caatinga ipueiras.

Most species were classified as amphibious (57.2%) and emergent (16.6%), followed by attached submerged (11.9%), free floating (9.6%) and attached floating (4.7%).

Campelo *et al*. (2013) emphasize that the species richness, in general, does not significantly differ among ipueiras, weirs, rivers and artificial reservoirs. According to the Simprof analysis on the composition of aquatic macrophytes in the studied water sources, there is little sharing among their species. The Jaccard test (S) showed that among all the subgroups, 09 are above 0.25, thus indicating a reasonable similarity in the floristic structure of the analyzed water sources. In the same formed grouping, it is noticed that all links in red represent similar subgroups, i.e., there is no significant difference among them; those in black are significantly different from each other and, therefore, are not similar. Besides, only a subgroup was formed from 0.48, thus showing high degree of similarity when compared with other subgroups. These data may suggest that the aquatic macrophyte communities from the semi-arid region that colonize these water sources behave independently, therefore indicating no relation with the origin of the basin and with water sources proximity. The groups formed by such analysis showed floristic heterogeneity in the aquatic ecosystems of the studied area (Figure 2).

Conservation and threats to the dynamics of Caatinga aquatic ecosystems

The conservation of aquatic macrophytes is closely related to the conduct of scientific expeditions aiming at making a complete inventory of the Caatinga vegetation biodiversity. It is noticed that this biome shows high endemism rates (Giulietti *et al*., 2002). Examples of this biome are the Alismataceae: *Echinodorus palaefolius, E. pubescens*; Pontederiaceae: *Hydrothrix gardneri*; the Asteraceae: *Enydra radicans*; Plantaginaceae: *Anamaria heterophylla, Angelonia biflora*; Rubiaceae: *Mitracarpus longicalyx*; and the Melastomataceae: *Pterolepis polygonoides.*

They are found on the margins of Caatinga water sources. Recent studies (Karla, 2014) point to the description of a new species *Nymphaea vanildae* C.T. Lima & Giul. (Lima & Guilietti 2013). In this context, we emphasize that the mentioned species occur in specific habitats and in habitats degraded by anthropic action.

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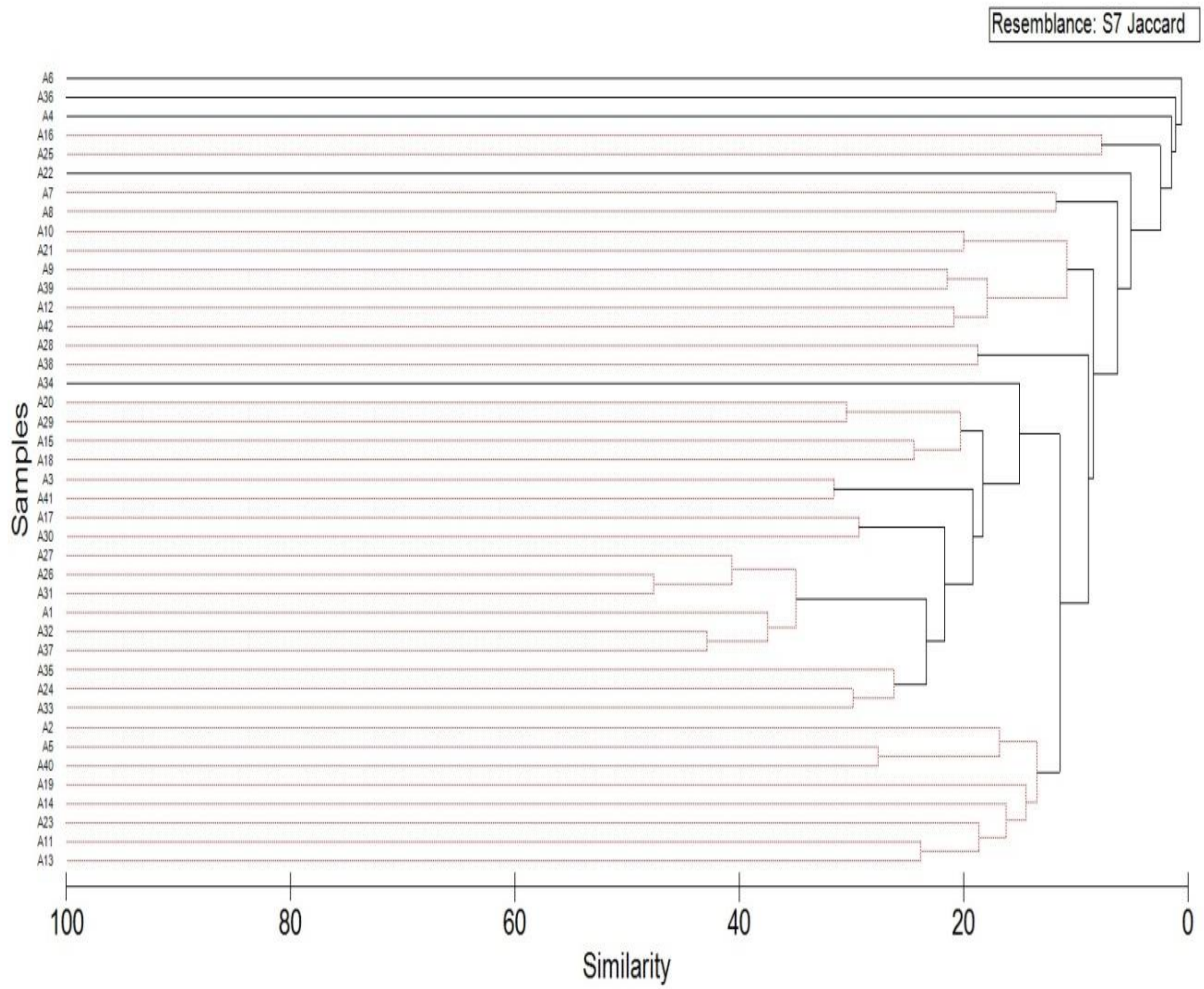

Figure 2. Dendrogram of floristic similarity (Jaccard coefficient) of aquatic macrophytes in Caatinga of aquatic ecosystems.

Based on the floristic and ecological studies on the aquatic macrophytes community within the 27 aquatic ecosystems of the Northeastern semi-arid region, including temporary lagoons, weirs and reservoirs along the Transposition of São Francisco River (Campelo *et al*. 2012; 2013), it was possible to see the factors determining the composition, abundance and distribution of aquatic macrophytes species in the Northeast region.

The determining factors reflect the existence of a particular organism. The influence happens due to tolerance limits in which an organism can live and reproduce. The limits correspond to the minimum and maximum rates of certain environmental factors such as temperature, light and nutrients (Odum 1988).

According to Campelo *et al*. (2012), the aquatic ecosystems in the semiarid region show advanced successional level of aquatic vegetation, which is marked by the presence of amphibious and emerging species, in addition to a gradual replacement of the native vegetation by exotic species and potentially invasive species, such as: *Azolla pinnata* R.Br., *Amaranthus blitum* L. and *A. viridis* L., *Ipomoea wrightii* A. Gray, *Oryza sativa* L.; *Physalis angulata* L. and *P. pruinosa* L. and *Sphenoclea zeylanica* Gaertn. It is worth highlighting species considered as opportunistic and/or of wide distribution, such as *Eichhornia crassipes* (Mart.) Solms, *E. azurea* Kunth, *Ipomea carnea* Jacq., *Cyperus odoratus* L., *Egeria densa* Planch., *Pistia stratiotes* L. and *Paspalum repens* P.J. Bergius. These species may represent a disturbing factor in Caatinga water sources due to their excessive and fast propagation in eutrophic environments.

There can be an overgrowth of opportunistic species in aquatic macrophyte communities, which can affect and hamper the use of water sources. Generally, such optimal development conditions occur due to human actions, mainly through the release of organic wastes that increase the availability of nutrients in aquatic ecosystems, thus favoring the growth of aquatic macrophytes (Seshavatharam 1990).

It is noted that the temporary lagoons studied vary as the area between ha to 3.96 46301950.00 ha.

According to Gopal & Junk (2000), knowing the factors that influence the development of these plants is of great importance in studies on the primary production of phytoplankton and aquatic macrophytes, since these plants, when under conditions close to their limits of tolerance, can perform photosynthetic processes enough for their survival only. On the other hand, an increase in primary production and, consequently, an increase in sexual and vegetative reproduction may occur when the environmental conditions are favorable.

Therefore, it is important to know the optimal environmental conditions for aquatic plants growth, as well as the species biological and self-ecological aspects for the proper management and control of aquatic plants (Camargo *et al*. 2003). According to Palombo (1997), some floating aquatic macrophytes frequently occur in eutrophic environments, as well as those considered as opportunistic and/or of wide distribution. These conditions may show high biomass values and cover large areas, such as *P. stratiotes* and *E. crassipes* banks.

According to Tundisi (1986), eutrophication is mainly caused by the following activities: domestic sewage dumps; dumps from agricultural activities; air pollution and the falling of the material from the atmosphere (in the form of particles coming down with rainwater); remnant vegetation in dams that were not cleared prior to closing. Eutrophication main consequences on aquatic systems are: increase in biomass and primary production of phytoplankton; decrease in species diversity; decrease in dissolved oxygen concentration; decrease in the concentration of ions; increase in total phosphorus within the sediment; increased frequency of Cyanophyceae flowering.

In addition to the eutrophication that threatens the establishment of temporary and/or permanent water sources in Caatinga, it is noticed that the practice of agriculture also represents a threat. Everything starts with the use of fertilizers and herbicides in fruit irrigated cultivations. They contaminate the soil and run into the rivers, lagoons, weirs and ipueiras. It is also worth mentioning drainage, changes in the hydrological regime and the invasion of exotic species that reduce the biodiversity of these aquatic ecosystems within the semi-arid region. This bioinvasion is associated with the trend of filling the lagoons with water from irrigation canals and with exotic plant and animal species.

Another investigated factor was the conservation status of aquatic macrophytes in Caatinga, and based on the red list of Flora do Brasil (Martinelli & Moraes 2013) no aquatic macrophyte species was assessed regarding such status.

4. FINAL CONSIDERATIONS:

The abundance of aquatic macrophytes and biological forms may vary among the water sources' types and among ipueiras throughout the year. It is noticed that the water level fluctuates a lot in the ipueiras because the major source of water ingress is fast, due to the scarcity and irregularity of rainfall in the Caatinga. Thus, the ipueiras can remain dry for a long period of the year (Figure 3), and the plants require adaptive strategies to overcome water stress. In this context, amphibious and emerging biological forms dominate aquatic macrophytes communities.

The conservation of aquatic macrophytes is closely related to the awareness of aquatic communities and their role in the environment. Such awareness is also important for the strengthening and construction of a database. These guidelines represent a breakthrough for the monitoring and management of aquatic vegetation. Future actions should include the management and control of native species that benefit from water sources eutrophication, exotic species and those of wide distribution. These strategies are important so that greater attention can be given to the water quality bioindicators regarding its use for irrigation and human consumption.

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Figure 3. Temporary lagoon in the rainy (A) and dry (B) season. (BR 428 – Floresta - PE, Brazil).

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Table 1. Richness of the aquatic macrophytes in the temporary lagoons of the Caatinga**.** Life Forms: attached submerged (SF), free submerged (SL), attached floating (FF), free floating (FL), amphibious (A), emergent (E). Temporary *lagoons*: A – Monteiro (Paraíba); B - Sertânia; C – Custódia; D – Cabrobó, Pernambuco, Brazil.

Family / species	**VOUCHERS**	**CN (HVASF)**	**A**	**B**	**C**	**D**	**Life form**
CHAROPHYCEAE							
Chara angolensis A.Braun	V.M. Cotarelli 1111	12676	1				SF
Chara rusbyana Howe	A.P. Fontana 6100	5602	1				SF
Nitella cernua A. Braun	A.P. Fontana 6560	7539		1			SF
MARSILEACEAE							
Marsilea deflexa A. Braun	J.A. Siqueira-Filho 2250	5183				1	FF
ALISMATACEAE							
Echinodorus subalatus (Mart.) Griseb.	D. Araújo 1404	7998			1		E
Echinodorus palaefolius (Nees & Mart.) J.F. Macbr.	J.A. Siqueira-Filho 2211	5093	1				E
Hydrocleys martii Seub.	D. Araújo 1384	7980			1		E
Sagittaria guayanenesis Kunth	M. Oliveira 5724	11534				1	FF
SALVINIACEAE							
Azolla caroliniana Willd.	A.P. Fontana 6587	7561		1			FL
AMARANTHACEAE							
Amaranthus blitum L.	E. Souza 90	10475		1			A
ARACEAE							
Lemna aequinoctialis Welw.	J.A. Siqueira-Filho 2152	5049	1				FL
ASTERACEAE							
Eclipta prostrata (L.) L.	J.R. Maciel 587	2309				1	A
Egletes viscosa (L.) Less.	J.G. Carvalho-Sobrinho 1984	3031		1			A
Lepidaploa chalybaea (Mart. ex DC.) H. Rob.	N.M.S. Ferraz 22	1774			1		A
BORAGINACEAE							
Euploca procumbens (Mill.) Diane & Hilger	J.G. Carvalho-Sobrinho 1839	3234			1		A
Heliotropium elongatum Willd. ex Cham.	A.P. Fontana 6168	5670		1			A
CAPPARACEAE							
Tarenaya spinosa Jacq.	A.C.C.P. Silva 51	10540				1	A
CONVOLVULACEAE							
Ipomoea asarifolia (Desr.) Roem. & Schult.	J.R. Maciel 583	2284			1		A
CYPERACEAE							
Cyperus distans L. f.	R.E.M. Diniz 35	1905			1		A
Cyperus surinamensis Rottb.	M. Oliveira 4408	6024			1		A
Cyperus odoratus L.	A.P. Fontana 6901	8911		1			A

FABACEAE							
Centrosema brasilianum (L.) Benth.	J.G. Carvalho-Sobrinho 2073	3352			1		A
Macroptilium lathyroides (L.) Urb.	J.R. Maciel 605	2340			1		A
HYDROCHARITACEAE							
Apalanthe granatensis (Bonpl.) Planch.	J. Antunes 31	2653				1	SF
LOGANIACEAE							
Spigelia polystachya Klotzsc ex. Prog.	V.M. Cotarelli	1346				1	A
LYTHRACEAE							
Ammannia latifolia L.	J.R. Maciel 625	2691				1	A
MOLLUGINACEAE							
Glinus radiatus (Ruiz & Pav.) Rohrb.	M. Oliveira 5192	10153		1			A
Mollugo verticillata L.	N.M.S. Ferraz 32	1784		1			A
NYMPHAEACEAE							
Nymphaea lasiophylla Mart. & Zucc.	A.P. Fontana 6590	7564			1		FF
Nymphaea pulchella DC.	J. Antunes 28	2650				1	FF
ONAGRACEAE							
Ludwigia erecta (L.) H. Hara	A.P. Fontana 6573	7552				1	E
Ludwigia octovalvis (Jacq.) P.H. Raven	A.P. Fontana 6625	8430			1		A
PLANTAGINACEAE							
Anamaria heterophylla (Giul. & V.C.Souza) V.C.Souza	M. Oliveira 5726	11536	1				A
Angelonia salicariifolia Bonpl.	M. Oliveira 5222	10183				1	E
Bacopa gratilioides (Cham.) Edwall	V.M. Cotarelli 1355	14080				1	A
Stemodia maritima L.	J.R. Maciel 582	2282				1	A
POACEAE							
Echinochloa polystachya (Kunth) Hitchc.	A.P. Fontana 7194	9891		1			E
Luziola brasiliana Moric.	M. Oliveira 4092	4641			1		A
POLYGONACEAE							
Polygonum ferrugineum Wedd.	A.P. Fontana 6934	9093		1			E
PONTEDERIACEAE							
Heteranthera oblongifolia Mart.	J.G. Carvalho-Sobrinho 2086	3377				1	A
Hydrothrix gardneri Hook. f.	G.G. Ribeiro-Júnior 23	1967	**1**				SF
SOLANACEAE							
Physalis angulata L.	M. Oliveira 4017	4566		1			A