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# Diversity, bioforms and abundance of aquatic plants in a wetland of the Orinoco floodplains, Venezuela

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## Abstract

Richness (alpha and beta diversity), abundance and dominance of bioforms of aquatic vegetation in a wetland of the Orinoco floodplains in Venezuela, studied over an annual cycle are described. In a lowland extension of 65,000 hectares including a whole range of aquatic habitats (shallows, marshes, ponds and streams), 197 species belonging to 122 genera and 56 families were recorded. Beta diversity was higher in lentic than in lotic wetlands, the emergent rooted bioform being the most abundant in all habitats and throughout the year. Considering the most persistent species (spatially and temporally), *Eichhornia crassipes* (Mart) Solms., *Hymenachne amplexicaulis* (Rudge) Nees and *Luziola subintegra* Swallen obtained the highest relative importance values. The most abundant species in all environments and throughout the year was *Salvinia auriculata* Aubl. Brief comments on the limited use of these aquatic plants are given.

**Key words.** Llanos. Macrophytes. Species richness. Importance value. Aquatic vegetation.

## Resumen

Se describen la riqueza (alfa y beta diversidad), abundancia y dominancia de bioformas de plantas acuáticas en un humedal de los Llanos del Orinoco, Venezuela, estudiada durante un ciclo anual. En una extensión de 65.000 ha que incluye toda la variedad de hábitats acuáticos del bajo llano venezolano (bajíos, esteros, lagunas y caños), se registraron 197 especies pertenecientes a 122 géneros y 56 familias. La diversidad beta fue mayor en los ambientes lénticos que en los lóticos, siendo la bioforma arraigada emergente la más abundante en todos los ambientes y durante todo el año. Considerando las especies mas persistentes espacial y temporalmente del inventario, *Eichhornia crassipes* (Mart) Solms., *Hymenachne amplexicaulis* (Rudge) Nees and *Luziola subintegra* Swallen, obtuvieron los mayores valores de importancia relativa. La especie más abundante en todos los ambientes y durante todo el año fue *Salvinia auriculata* Aubl. Se comenta brevemente sobre el escaso aprovechamiento de estas plantas acuáticas.

**Palabras clave.** Llanos. Macrofitas. Riqueza. Valor de importancia. Vegetation acuática.

## Introduction

Humid lowlands of South America have a unique geographical and ecological importance compared with other landmasses (Morello 1984) including the largest wetlands of the biosphere. Indeed, one of

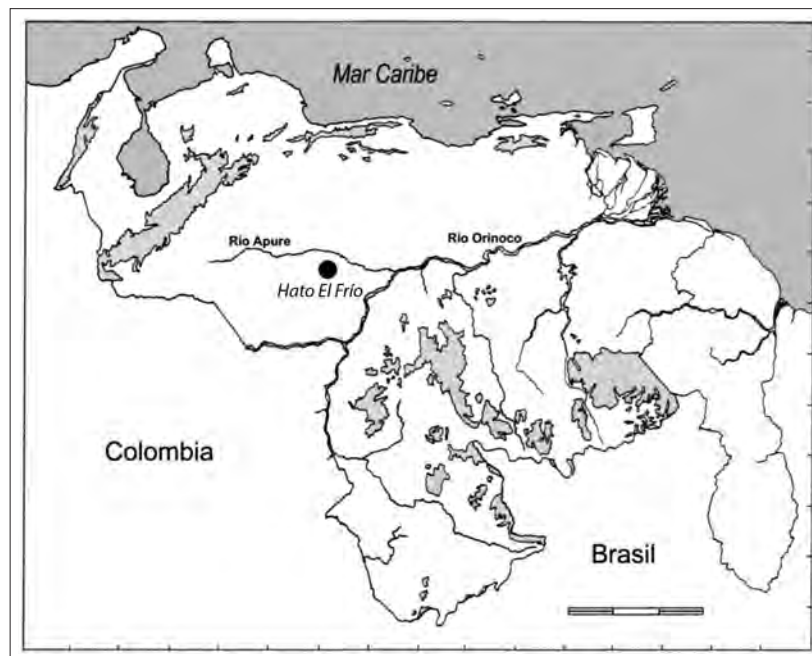
the most important characteristics of this region is the existence of large wetlands within the drainage basins of major tropical and subtropical rivers (Neiff 1999) such as the Amazon, Paraná or in the case of

the Llanos de Apure, the Orinoco Basin, which drains nearly 64 % of the continent, providing 13 % of the world total solids supplied to the ocean (Tundisi 1994). Thus, South America has the most positive water balance of all continents (Puhe 1997). In Venezuela there are 158 wetlands occupying 39,517 km<sup>2</sup> (4.3 % of the territory). In the northern region of the Orinoco Basin it has been estimated that there are 5,946 km<sup>2</sup> of artificial wetlands and about 1,826 km<sup>2</sup> of natural ones (Rodríguez-Altamiranda 1999), including the Wildlife Refuge Caño Guaritico and the flooded savannas of Hato el Frío in Apure State. The national inventory of wetlands has identified three remarkable categories in this area: 1) permanent streams and rivers, 2) open flooded savanna on inorganic soils; 3) riparian floodplain forests, with semi-deciduous and evergreen sclerophyllous trees. This ecoregion is a large grassland savanna in which the woody vegetation is restricted to gallery forests along the banks of rivers and streams (*Nectandra pichurrini* (HBK) Mez., *Duguetia riberensis* Aristeg.) with isolated patches of savannah forests (*Spondias mombin* L., *Coccoloba caracasana* Meisn., *Cecropia peltata* L., *Ceiba pentandra* (L.) Gaertn., *Pithecellobium* sp) locally called “matas”. The monomodal rain-

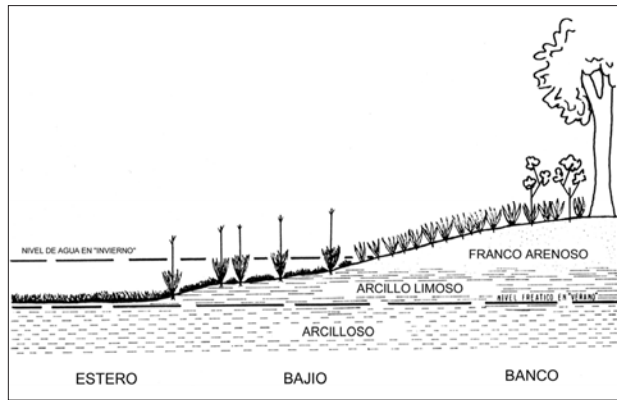
drought regime and the flood pulse (Junk 1989, Neiff 1999) brings overflowing rivers and streams that waterlog the savannah, becoming the decisive event of all wetland bio-ecological processes. The aquatic vegetation is of great importance in these ecosystems, and although it had been included in the inventory of Castroviejo and Lopez (1985), this is the only systematic study of aquatic plants in this wetland and its various environments during the 12 months of an entire annual hydrological cycle (Rial 2009). Below are shown the results of the inventory of species, the alpha and beta diversity, presence and dominance of bioforms in different types of environments, the most abundant species based on their monthly and annual coverage, and those with the highest rate of important habitats studied during the one year rain - drought cycle of 1997.

#### Study area

The Apure River is the main tributary of the Orinoco plains and caño Guaritico is one of its tributaries, located near the northern boundary of the study area (Hato El Frío) 7.81169 N -68.8976 W (Figure 1). The study area, according to the classification of



**Figure 1.** Geographic location of the study area. El Frío Biological Station (Hato El Frío) in the Orinoco floodplains, Apure State, Venezuela.



**Figure 2.** Physiographic units in the Apure plains. Source: Ramia (1967).

Huber and Alarcón (1988), is part of the open flooded savanna. It lies at an altitude between 65 and 100 m asl and has a gentle slope (0.02 % west to east) in which the minimum two meters differences include three microrelief units (Ramia 1967) (Figure 2): “bancos”, the highest places in the savannah, always dry; “bajíos”, depressions covered by water only part of the year; and “esteros”, lower than the bajíos, where water remains in the dry season. In this alluvial physiography, the soil brought by rivers and streams from the Andes, had been deposited according to the size of its particles, with the heaviest and largest deposited on the banks of rivers and the lightest, smallest particles travelling to more remote areas such as the esteros and lagoons. Thus, there is some correlation between soil texture and microrelief: sandy loam in bancos, silt and clay in bajíos and esteros. In this way a mosaic of high and low places, can be observed in this wetland, due to the continuous process of change of tributary channels and waterflow through the lower terrain (Ramia 1972). In this tropical region also known as “Tierra Caliente” (Jahn: Vila, 1969) the dry season lasts from November to March with average temperatures of 27 °C, and the rainy season from April to October with an average rainfall of 200 mm/month. The most representative environments also include a combination of temporary and permanent waterbodies, lentic and lotic wetlands with an average depth of two meters at its deepest part during the high water, except Caño Guaritico; generally low water transparency (white waters *sensu* Sioli 1984) and pH values ranging from 5 to 8 during the annual cycle. The importance of the Orinoco floodplains was

proposed as a World Biosphere Reserve in 2005 and listed as a wilderness area of global importance for conservation (Mittermeier *et al.* 2002), an Important Bird Area (IBAs) (Lentino & Esclasans 2009) and one of the priority areas for conservations in the Orinoco Basin (Lasso *et al.* 2010, 2011). The rich fauna includes four of the five species of felines in Venezuela (*Panthera onca*, *Puma concolor*, *Felis pardalis*, *Leopardus yaguarundi*), 60 species of mammals, also emblematic species such as the chiguire or capybara (*Hydrochoerus hydrochaeris*), the giant otter *Pteronura brasiliensis*, the river dolphin *Inia geoffrensis* and the anteater *Myrmecophaga tridactyla*. The ichthyofauna includes 198 species of fishes (Lasso 2004) and includes species of freshwater stingrays (*Paratrygon aiereba* and *Potamotrygon orbignyi*), electric eels (*Electrophorus electricus*) and many commercially valuable species which are important for the livelihood of local populations (e. g. *Prochilodus mariae*, *Cichla orinocensis*, *Piaractus brachypomum* and *Pseudoplatystoma* spp). The avifauna is also rich, with around 300 species including the largest neotropical Ciconiidae (*Jabiru mycteria*) and many migratory birds. This region is also home to 18 species of amphibians and 29 species of reptiles, including the Orinoco crocodile (*Crocodylus intermedius*), an endangered species which has been successfully reintroduced into the wild (Estación Biológica El Frio) (Antelo 2008, Rial & Lasso 2003, Rial 2011).

## Material and methods

Fifteen occasional sampling stations and fourteen permanent transects in 29 different and representative aquatic environments were established. Occasional sampling stations included environments not represented by the permanent transects such as temporary ponds and lentic water bodies inaccessible during the rainy season. Ecological observations were carried out on permanent transects. The transect proceeded from the shore, which is here defined as the edge of the water body in the first month of sampling (January) - towards the center of the water body, ten consecutive plots of 1m<sup>2</sup> were used to conduct the inventory and ecological records. Coverage was estimated monthly for each species along the depth

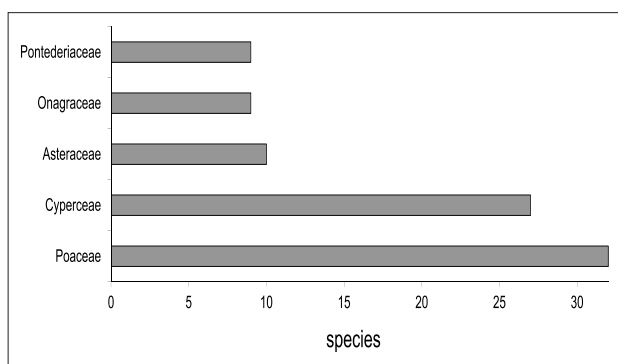
gradient of each transect, using a set of intervals corresponding to the percentage of abundance of each species in each quadrat. These percentages varied between 100 % coverage to less than 1 % of the square of area due to the presence of an individual of a given species. The spatio-temporal presence of the species was obtained from the monthly records in each habitat.

The set of bioforms are represented in the four groups of the Sculthorpe (1967) system: emerging rooted, rooted floating, submerged and free floating. The Importance Value of the most representative species -those with the highest spatial and temporal constancy was obtained with the IV equation,  $IV = CR + FR$ , where FR: frequency sp x 100 / sum of frequencies of all species and CR: coverage of species a x 100 / sum of cover of all species.

## Results and discussion

### *Species richness ( $\alpha$ and $\beta$ diversity)*

The species richness of this floodplain is more than 200 species, 197 of them have been identified, listed and described in Rial (2009). Most of the species of this wetland are Neotropical (original distribution), including some of restricted distribution such as *Ipomoea pittieri* O'Donnell (Convolvulaceae). More than 30 % of species belong to Poaceae (32 sp.) and Cyperaceae (27 sp.) which are typically dominant in savanna ecosystems, followed by Asteraceae (10 sp.), Onagraceae (9 sp.) and Pontederiaceae (7 sp.) (Figure 3). This study extends the geographic distribution of 24 species, of which two are new records for

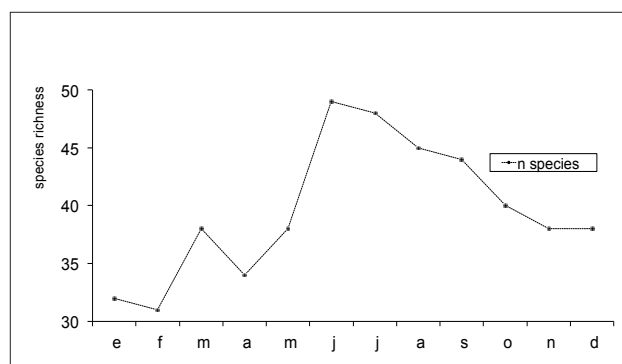


**Figure 3.** Families of aquatic plants best represented (number of species) in the wetland.

Venezuela (Rial & Lasso 1998, Rial & Pott 1999), three for the Llanos region and the remaining for the Apure state (Rial 1998, Rial & Fedón 1999).

Of the total species recorded in the area, 37 % (72 species) correspond to fourteen permanent transects studied monthly during the annual cycle, the remaining species were found only in the environments sampled just occasionally. Species richness was higher in lentic water bodies than in lotic ones, with the largest number of species in the lagoons (76 %) compared to the “esteros” (67 %) and channels (caños) (Macanillal and Mucuritas) (43 %). Caño Guaritico main channel was the environment with the lowest species richness throughout the annual cycle, due to the velocity of flow and the verticality of its edges. Both characteristics hinder the colonization of aquatic plants. In this lotic freshwater mangrove community (*Coccoloba obtusifolia* Jacq.) usually associated with coastal beaches, we found along with some ferns (*Ceratopteris pteridoides* (Hook.) Hieron., *Azolla caroliniana* Willd.) and *E. crassipes* (Mart.) Solms.

Species richness responded immediately and positively to an increase in water level, especially the drastic change of conditions seen during the drought - rainy season transition (Figure 4). During the annual cycle of this study, an early rain fell in March and stimulated a brief increase in the richness of aquatic plants in all environments, which was then followed by a sharp decrease as a result of continued drought. The rains favored the colonization of new species, reaching a maximum average value during the month of June (high water).



**Figure 4.** Monthly species richness in the fourteen study transects during the annual cycle.

Species richness in the lagoons was more varied, influenced by the timing of the water level changes. Temporary environments (those that are dried in large part or in whole for part of the year) experienced an increase of more than 50 % species richness during the brief transition period of drought to rain when compared with environments that usually maintained water throughout the year (e. g. “esteros”). The beginning of the rainy season produced an immediate change in the values of richness and abundance of plant communities along a depth gradient. This was especially noticeable on the borderlines of the water bodies, which are the most dynamic areas of the wetland, we call “moveable shoreline”; we imagine a movable, dynamic shoreline which responds to changing water levels in a similar way to that described by Junk *et al.* (1989) but on a smaller scale. In response to the changing water levels, community structure and abundance varied continuously, going through the various states between from total soil dehydration (January-March) to waterlogging (May-October).

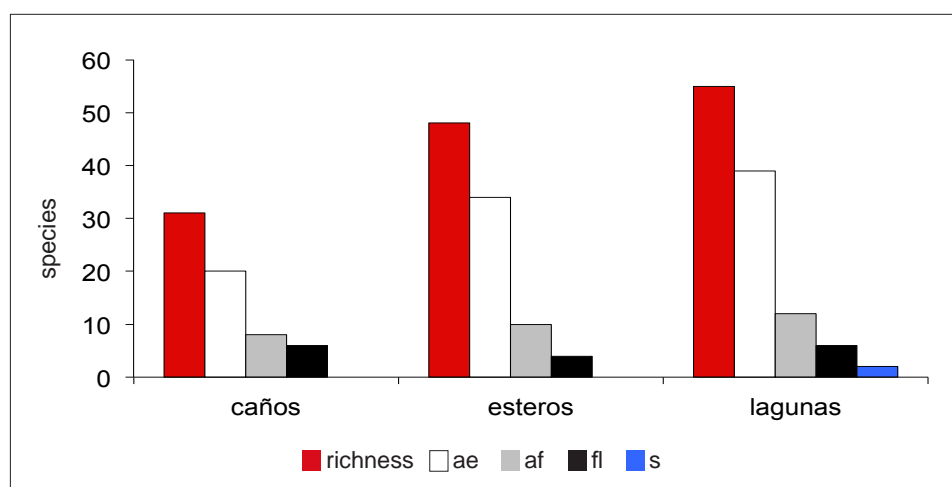
#### *Growth habits (bioforms)*

Emerging rooted plants dominate over other habits around the wetland (Figure 5). Most bioforms inhabit these transition zones or areas of shallow water bodies as a whole and are more abundant than free and rooted floating or submerged, the latter being scarce due to limiting water transparency. In general the distribution of rooted bioforms are restricted to

the shallower and coastal areas, while the free floating forms are distributed more widely in the gradient, and came to dominate the outer fringes (towards the water surface) in high water. Submerged plants are generally present in certain shallow lentic environments (less than 50 cm deep) over a period of the annual cycle in which water transparency is higher (high water).

#### *Abundance (species cover)*

The vegetation cover in different environments progressively increased throughout the year in response to higher hydrometric level (Figure 6 a, b), highest values were observed in high water (July) in all environments: creeks “caños” and lagoons (13 %) and “esteros” (11 %), and the lowest abundance occurs in the driest month (April) (3 %). The drastic change of conditions during rain - drought transition directly influenced the abundance of plant species. The largest significant increase in abundance of species (50 %) occurred in temporary habitats, those going from flooded to dry during the annual cycle. Furthermore, environments with greater vegetation cover along the year were less influenced by wind and currents, and had a mild depth gradient due to a less rugged terrain on the shore, allowing the colonization of aquatic rooted plants. By contrast, environments with less relative abundance of aquatic plants were those more open and exposed to wind and currents, and whose margins more vertical walls made it difficult for rooted aquatic plants to become established. The most abundant species were the fern



**Figure 5.** Distribution of the bioforms on the main types of environments studied at El Frío Biological Station. **ae:** rooted emergent **af:** rooted floating, **fl:** floating, **s:** submerged.



**Figure 6.** **a)** Drought (February) and **b)** high water (August) in a lotic ambient. Variation in water depth and vegetation cover can be seen along the transect.

*Salvinia auriculata* Aubl. and some Poaceae species like *Hymenachne amplexicaulis* (Rudge) Nees or *Leersia hexandra* Sw. (lambdora-grass) which have high palatability and nutritional value for cattle and other herbivores of this wetland.

#### Importance value IV

When considering the 17 most common species represented in the 14 environments during the 12 months of data, it is concluded that *E. crassipes* (present throughout the annual cycle) was the species with the highest importance (IV) in the majority (5) of the studied water bodies, followed by *Luziola subintegra* Swallen and *H. amplexicaulis* (Table 1). These species obtained superior frequency values compared with other species in the community, especially in lentic habitats. In both lotic studied environments the species with the highest importance values were *Ludwigia helminorrhiza* (Mart.) Hara (38,9) and *E. crassipes* (34,2). *E. crassipes* is known for its great ecological plasticity and its persistence in different wetlands (Neiff & Poi de Neiff 1984, Carignan & Neiff 1992, Terneus 2007) so its importance value corroborates its visible presence throughout the year in this wetland environments. *Luziola subintegra* and *H. amplexicaulis* both are native grasses, - part of the diet of cattle and wild fauna- with a wide coverage in the water bodies of the Apure lowlands, also in other

wetlands of South America (Terneus *op. cit.*). The behavior of these species in the Orinoco floodplains of El Frío can also be observed i.e. in the Pantanal (Catian *et al.* 2012).

Overall the richness and abundance of these aquatic plant communities respond primarily to changes in the water level in different habitats. It can be said that the stability of the wetland depends on the hydrological dynamics and flood pulse. Its identity as an ecosystem is based on the variations that occur during different phases between flood and drought. Hence, the definition of aquatic plant including ecophases (Rial 2003) and the term “dynamic climax” (Rial 2002) as a result of dynamic successional stages that occur during critical periods of the natural cycle of the wetland.

#### Comments on potential uses

The importance of biological and ecological value of the wetland aquatic plants refers not only to its quality as a filter and sewage treatment plants as food, shelter and habitat for micro-invertebrates, alevines, juveniles and adults of important species of fish fauna, birds, amphibians and even mammals, but to all other potential uses that have not yet been determined or used by humans in regions such as the Orinoco Llanos.

**Table 1.** Relative Importance Value (IVI) of the most common species in the fourteen environments studied monthly during an annual cycle.

SPECIES	TRANSECTS													
	Lag. 1	Lag. 2	Estero 1	Estero 2	Estero 3	Lag. 3	Caño 1	Caño 2	Lag. art.	Lag. 4	Lag. 5	Lag. 6	Estero 4	Estero 5
<i>C. laxus</i>	0	0	0	0	0	4,06	2,39	9,02	2,75	0	1,09	7,79	2,87	0
<i>C. palustris</i>	4,33	7,89	3,62	5,97	1,27	0	0	3,03	0	0	8,98	10,48	5,42	8,6
<i>E. azurea</i>	4,99	20,3	0	0,91	26,58	0	16,1	17,15	0	0	11,38	0	2,81	<b>31,87</b>
<i>E. crassipes</i>	<b>40,2</b>	21,62	<b>27,4</b>	<b>40,6</b>	0	<b>42,95</b>	0	<b>34,23</b>	0	0	1,09	12,64	0	0
<i>H. amplexicaulis</i>	4,5	<b>25,93</b>	15,75	6,83	9,23	34,73	6,32	17,9	51,72	0	5,02	15,21	<b>26,62</b>	6,02
<i>L. punctata.</i>	0	1,2	1	4,61	1,5	0	4,6	2,89	0	0	2,64	1,35	0	0
<i>L. helminthorrhiza</i>	6,5	11,32	0	15,36	0	10,27	<b>38,91</b>	27,59	0	0	0	11,98	0	0,99
<i>L. hexandra</i>	0,99	8,87	1,1	0,91	9,53	1,34	0	2,07	14,75	0	1,02	6,93	7,94	14,11
<i>L. laevigatum</i>	6,8	5,83	17,3	24,54	0	0	0	11,26	0	0	0	0	0	7,93
<i>L. subintegra</i>	5,7	2,79	3,24	5,29	<b>48,48</b>	14,79	7,49	5,42	3,05	0	<b>23,52</b>	<b>21,46</b>	8,79	27,91
<i>M. polycarpa</i>	3,26	0	0	0	0	1,48	8,42	5,32	0	0	18,9	3,85	0	18,12
<i>O. cubensis</i>	3,3	3,8	0	11,21	17,87	21,87	11,93	12,68	<b>52,46</b>	0	14,79	13,47	0	1,28
<i>P. repens</i>	5,11	5,7	0	0	0	0	7,28	6,83	0	0	0	5,23	1,48	0
<i>P. stratiotes</i>	25,94	1,8	13,8	11,56	0	0	17,21	1,96	0	0	0	6,79	0	0
<i>P. subovata</i>	12,79	0	18,82	0	0	0	0	0	0	0	0	1,92	2,8	11,85
<i>S. auriculata</i>	19,23	14,8	25,45	21,35	38,3	6,51	6,15	14,83	40,55	4,61	19,7	15,18	17,97	25,86
<i>S. guayanensis</i>	0,99	3,2	0	0	0	2,88	0	0	0	0	0	3,06	2,33	

Several authors in South America (Pott & Pott 2000, Meerhoff y Mazzeo 2004, Mereles 2004) have mentioned various uses of aquatic plants in our region, ranging from medicine and agriculture to handicraft and ornamental. In aquariophilia, species of the genera *Cabomba*, *Ceratopteris*, *Echinodorus*, *Ludwigia*, *Sagittaria* and *Pontederia* are highly appreciated. Moreover, the local medicinal and artisanal value of many of these plants has been shown (Bermudez *et al.* 2004, Giraldo *et al.* 2004) and in many countries, including Venezuela, fertilizers and nutritional supplements are already produced using free floating species such as *Azolla*. In the case of *E. crassipes*, considered a weed in most of its current distribution area, we find it an ecologically successful plant, whose use can be an opportunity of development and sustainable use given its proven qualities (Rial 2014).

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