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Wetland vegetation of the lower Orinoco Delta plain (Venezuela): A preliminary approach

by

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Abstract

This is a preliminary study of the vegetation of a potential oil prospecting zone of remote areas of the Orinoco Delta. It aims to provide a scientific basis to delineate efficient conservation strategies. Flora, life and growth forms were examined along with ethnobotanical aspects, as there are three Warao Indian settlements in the area. Various vegetation patterns were identified from satellite images and aerial photographs: swamp and palm forests, mangroves, shrubland and meadows. The first vegetation map of the zone was elaborated (1:25.000). Over 500 botanic samples encompassing 77 families, 148 genera and 205 species were collected. Twenty-two families had 3 to 20 species, the remaining families had only one or two, being Orchidaceae, Araceae and Bromeliaceae the best represented ones. Endemic species known for the Venezuelan Guayana were not observed in the study area. A non-gramineous meadow, not reported before for the Venezuelan Guayana, combines three dominant species, the fern *B. serrulatum* and the cyperaceous herb *Lagenocarpus guianensis*. The main forest forming species showed morphological adaptations to flood and anoxic conditions, for which they are expected to be particularily sensitive to oil pollution. Around 40 % of the plants species used by the Warao Indians in the study area are for medical purposes.

Keywords: **Biodiversity, swamp forest, *Mauritia* sp., meadow, mangrove, natural resources.**

Resumo

Este é um estudo preliminar de vegetação de uma potencial zona de prospecção de crude em áreas remotas do Delta de Orinoco, de modo a fornecer uma base científica para o delineamento de estratégias eficientes de conservação. Flora local, formas de vida e crescimento foram examinados conjuntamente com aspectos de etnobotânica, devido à presença de três povoamentos de índios Warao nesta região. Vários padrões de

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vegetação foram diferenciados com base em imagens de satélite e fotografias aéreas: paúis e florestas de palma, mangais, áreas arbustivas e pradarias. Elaborou-se o primeiro mapa de vegetação da zona (1:25.000). Mais de 500 amostras botânicas englobando 77 famílias, 148 géneros e 205 espécies foram recolhidas. Vinte e dois famílias incluem 3 a 20 espécies, enquanto as restantes famílias abrangem apenas uma ou duas espécies, sendo Orchidaceae, Araceae e Bromeliaceae as melhor representadas. Na presente área de estudo não foram observadas espécies endémicas características da flora da Guiana Venezuelana. Um prado não-graminàceo, dominado pelo feto *B. serrulatum* e a Cyperacea *Lagenocarpus guianensis*, é pela primeira vez descrito para a Guiana Venezuelana. Nas formações florestais, as principais espécies apresentam adaptações morfológicas para resistir a cheias e condições de anóxia, pelo que se espera serem particularmente sensíveis à poluição por petróleo. Cerca de 40 % das espécies de plantas utilizadas pelos índios Warao são empregadas a fins medicinais.

Introduction

One of the main objectives of nature conservation activities is to assure the long-term survival of the largest possible number of species, in accordance with the precautionary principle (CLUBBE 1996). To promote conservation, information about species location, descriptions, specific composition and the needs of natural communities is urgently required, in particular about high biodiversity hot spots. However, in recent times, taxonomic concern for biodiversity has been accompanied by a dismissal of the basis of biodiversity work, which involves the proper description of taxa (VALDECASAS et al. 2000).

Venezuela has been qualified as one of the six South American "megadiversity" countries (WWF & IUCN 1994). The Orinoco Delta region largely contributes to this perception, as it is a landscape with considerable biogeographical significance that concentrates an important number and variety of species (STEYERMARK et al. 1995). When the Orinoco reaches its delta, it splits in over 30 river branches and 300 labyrinth-like currents (caños) before flowing into the Atlantic Ocean. This gives rise to numerous islands, riversides and vast wetlands. Luxuriant swamp forests and several types of mangroves grow in these environments that are rich in terrestrial and aquatic fauna (LINARES 1998). Access to this remote region is difficult, unsafe and expensive, which may explain the current lack of scientific information.

In 1896, the North American botanist H.H. Rugby assembled the first lower Orinoco Delta region plant collections, (STEYERMARK el al. 1995). Since then, national and foreign botanists have put together other collections (SOCIEDAD DE CIENCIAS NATURALES LA SALLE 1954; DANIELO 1964; STEYERMARK 1968, 1979; DELASCIO CHITTY 1985; COLONNELLO 1995; COLONELLO & MEDINA 1998; MONTOYA 2003). In addition, some existing vegetation-related studies, which are not strictly floristic, are considered to be pioneers for the region (MÜLLER 1959; VAN ANDEL 1967; PANNIER 1979; SHEIHING & PFEFFERKORN 1984; HOFFMAN 2002; RABOLD 1990). The results of these explorations have made it clear that, to a large extent, the flora of the Orinoco Delta belongs to the physiographic and biogeographical region of the South American Guayana. The Venezuelan Guayana (VG), located in the Guayana Shield, is the main core of this region (STEYERMARK et al. 1995). Documents dealing with land use planning also contain useful information (TAMAVENCA 1971; MARNR 1982, 1983-1984; CANALES 1985; ASERRADERO ZAMORA 1996; MANACA ORINOCO C.A. 1993).

In the nineties, different initiatives came together to promote oil prospecting in extensive areas of the upper, middle and lower Orinoco Delta (LANDER 1997). Little or no environmental and ecological information was available for these areas. To date, the best floristic and biogeographical descriptions of the Orinoco delta plains are furnished by STEYERMARK et al. (1995), but there are still to general for specific managerial purposes. Therefore it became essential to inventory the existing and still unknown natural elements of the study area to delineate concrete conservation strategies. Such inventories would also provide scientific knowledge that could become unobtainable if these pristine environments are disturbed or lost.

This paper is a preliminary study of the different vegetation formations in a vast potential oil and gas prospecting area of the lower Orinoco Delta. It gives an insight into the so far poorly known vegetation of the Orinoco Delta. It also represents a baseline state against which changes in distribution and extention of vegetation formations and transformation of areas can be assessed through time. The first vegetation map of the area is provided. Species richness, endemisms related to the Venezuelan Guayana region and aspects related to ethnobotany are assessed as biodiversity values.

The study site

The Orinoco Delta is a large wetland formed by a fluviomarine sedimentary plain. It covers a surface area of 42,000 km^2, has slopes <1 % and elevations <10 m a.s.l. Geologically it is located in the sub-basin of Maturín which is part of the Eastern Venezuela basin. Structurally, it is an active faults zone (GONZÁLEZ DE JUANA et al. 1980). Seismic evidence and natural oil seeps have shown the existence of crude oil. Subsidence, tectonic and geotectonic processes, and the effect of fluvial inputs and marine currents as well, have given raise to three distinct physiographic landscapes: a) the Upper Delta with prevalent fluvial processes of sedimentation; b) the Middle Delta, dominated by swampy fluviomarine plains; c) the Lower Delta, next to the Atlantic Ocean. This lower area is the most extensive and includes marshes, estuaries and minor fluviomarine forms that are subjected to tidal influence (DELASCIO CHITTY 1985; WARNE et al. 2002). The study area extends over 941.9 km^2. It is situated between Punta El Tigre and Punta Tolete. To the north, it borders the Atlantic Ocean along 80 km of coast. It also extends about 20-30 km inland (Fig. 1). A moist tropical climate prevails, with precipitations surpassing 1800 mm $year^{-1}$ (PDVSA 1992). Flood conditions are almost permanent throughout the year. The area is drained by shallow water channels called "caños", which are subjected to the tidal dynamics of marshy-swampy areas. These channels join at Cocuina island (Fig. 1). Soils are organic and hydromorphic and include: Tropofibrists, Tropohemists, Sulfhemists, Hydraquents and Sulfaquents having bad drainage, acidic pH and a low base exchange capacity (MARNR 1982; PDVSA 1992). Apart from the hydrological impacts of damming Caño Mánamo (COLONELLO & MEDINA 1998), human activities still had little effect on the delta processes and environment. Three Warao Indian settlements exist in the mouth of the Orinoco; at Mariusa, Cocuina and Macareo caños outlet (Fig. 1).

Material and methods

A vegetation map of the study area (1:25,000) was elaborated using photogrammetry and remote sensing techniques to interpret the different plant communities' spatial patterns. The 1997 Amoco Ven mission provided color aerial photographs of about 60 % of the study area to a scale of 1:25,000. They were rectified, restituted, interpreted and finally divided into sectors on a digitalizing table. The remaining 40 % of the study area was examined with the help of scene 001/053 (July 1991) of a Landsat 5-TM (7-channel scanning radiometer) satellite image. Combinations of infrared bands (mid-infrared band 5, near-infrared band 4, and visible band 2) were utilized to outline different vegetation formations and operational types (UNESCO, 1993; BERRY et al. 1995). A non-supervised classification (isodata) was applied on the Landsat-image to corroborate the definition of the vegetation units based on the aerial photographs interpretation. Scene 233/053 (December 1986) was used only as reference to visualize cloudy areas. To designate structural vegetation categories and draw up the map legend, we combined photogrametry and field verification. The main criteria applied were canopy cover, height and density. The obtained photogrammetric and digital classifications based on visual patterns were supported by an extensive and thorough field survey comprising 227 regularely distributed checking points (1 point/4 km^2). Canopies were categorized "in situ" as "height" (30-20 m), "mid" (19-5 m) and "low" (<5 m). Canopy density was qualified as "dense" when it was uneven and tree crowns touched each other with interlocking; "mid" when it was regular and tree crowns touched each other without interlocking, and "open" when tree crown did not touch each other leaving canopy gaps or clearings. These data were complemented by identifying the most frequent combination of forest forming species in each checking point, with the help of specialized literature (STEYERMARK el al. 1995). Dasonomic and floristic data were then associated to each distinct vegetation formation and type previously identified on the image. The original color vegetation map was delivered to the Venezuelan Ministry of the Environment and Natural Resources (MARNR) as part of the baseline study of the area (GEOHIDRA CONSULTORES 1998). A simplified version of this map on a 1:400,000 scale is provided in this paper, showing only five vegetation formations (Fig. 2), and a summary of the preliminary vegetation types encountered (Table 1).

Field work to assess species richness and life forms was carried out between April and June 1998 with the help of helicopter flights. The selection of sampling points for plant collection was based on a preliminary version of the vegetation map and on field accessibility (helipads). In forested and shrub areas, floristic description was undertaken in 0.1 ha plots: 28 in swamp forests (SF), 16 in mangroves (MG), 8 in palm forests (MO), 3 in shrubland (SHR) and 4 in wooded meadows (MD). In 16 treeless meadows, species were identified along 50 m^2 strips of herbaceous vegetation. Figure 1 shows the 59 locations of the plots and strips. Botanical samples and their replicates were collected, labeled and preserved with 70 % isopropyl alcohol. Collected specimens were deposited in the Universidad Nacional Experimental de Los Llanos Ezequiel Zamora (UNELLEZ) herbarium. Botanists from this herbarium carried out most of the taxonomic determinations. Species were classified according to their life (RAUNKIAER 1934) and growth forms (MÜLLER-DOMBOIS & ELLENBERG 1974; VARESCHI 1992). If species were or not endemic of the Venezuelan Guayana was checked against the "Flora of the Venezuelan Guayana" (STEYERMARK et al. 1995), the Internet database W3 TROPICOS and the checklist of the Biological Diversity of the Guianas program of the Smithsonian Institute. Qualitative ethnobotanical information was collected "in situ" from the indigenous Warao population settled at Cocuina, with the help of José Güiria and Pedro Guarena, two Warao guides, which lived in the study area and were incorporated into the project.

Results

Vegetation patterns

Swamp forest, meadow, mangrove, *Mauritia flexuosa* palm forest (locally known as "morichales"; GONZÁLEZ 1987), and shrubland were the main vegetation formations found. They were arranged in a mosaic pattern, covering 34,477 ha (36,8 %), 30,752 ha (32,8 %), 20,696 ha (22,1 %), 4,827 (8,41 %) ha and 3,070 ha (3,27 %) of the study area, respectively (Fig. 2). Meadows and swamp forests were the best represented in terms of coverage, swamp forests and mangroves showed the most conspicuous patterns. Vegetation cover patterns based on density, height and species arrangement enabled different and preliminary vegetation types to be distinguished within each plant formation. Different combinations of the most frequent species were observed in each category (Table 1). *Rhizophora mangle* and *R. racemosa* were the most frequent among mangrove trees. Mangroves of *R. mangle*, *Avicennia germinans* and *Laguncularia racemosa* either grew along the ocean coast - exposed to direct tidal action and marine currents - or in more inland positions in basins or depressions. *Rhizophora* spp. formed dense gallery forests bordering the caños tens of kilometers upstream. In more inland ecotonal areas, mangrove stands were mixed with palms (*Euterpe* spp.) and the tree *Pterocarpus officinalis*. Swamp forests grew behind the mangrove belt, being the most conspicuous species *Tabebuia insignis* var. *monophylla*, *Pterocarpus officinalis* and

Diospyros lissocarpoides (Table 1). They developed landwards into the interdistributary alluvial plains, extending onto terrain flooded by water from pluvial, fluvial or fluvio--marine origin. The understory is open and trees can reach 30 m in height. Many of them have pneumatophores and adventitious, tabular or stilt roots. *P. officinalis* was one of the best equipped trees to succeed in swampy, oxygen-depleted environments. The swamp forest was still relatively pristine, with only occasional human intervention. *Mauritia flexuosa* is the most important species in palm forests locally known as "morichales" ("cananguchales" in Colombia, "buritizales" in Brazil), followed by *T. insignis* and *P. officinalis* (Table 1). The "morichales" were most frequently located between forests and meadows. However east of the Cocuina Island along the caño Simoina (Fig. 2), they occurred in patches within the meadow matrix. This vigorous palm tree sometimes attains 30 m in height. It has a flabelliform crown made up of 10-14 large costa-palmate leaves, which are about 6 m long. *M. flexuosa* was never found exposed to brackish water inputs. Shrubland was sparse and azonal. It appeared in isolated patches, growing between mangroves and swamp forests. It consisted of stunted-looking shrubs, with stems oriented to the west probably due to influence of the winds. The main species were *Chrysobalanus icaco* and *Ilex martiniana* (Table 1). Meadows evolved mostly within the deltaic plain away from the caño's influence in areas with bad drainage and long-lasting floods. They were characterized by a continuous 1-1.5 m high herbaceous cover. Isolated or patchy wooded components were occasionally observed. Meadows were dominated by the fern *Blechnum serrulatum* and the cyperaceous herbs *Lagenocarpus guianensis* and *Rhynchospora gigantea*, which prevailed both in treeless and wooded meadows. *I. martiniana* and *M. flexuosa* were the main woody elements (Table 1).

Species richness

A floristic inventory of the study area is provided in Appendix 1. It indicates the species identified, their life and corresponding growth forms, and the plant formations where they were found. In total, 583 botanic samples and their replicates were collected. Their identification resulted in 77 families, 148 genera and 205 species (192 phanerogams and 13 cryptogams). Nineteen families had between 3 and 20 species; the remaining 55 had only one or two. Orchidaceae was the best represented family with 9.8 % of the total number of species and 14 genera. Araceae accounted for 5,9 % of the species and 6 genera, Bromeliaceae for 5,4 % and 4 genera, and Moraceae, Fabaceae, Clusiaceae and Arecaceae each accounted for 4,4 % of the species. Total species distribution among the five plant formations was as follows: 152 (74,5 %) in swamp forests, 75 (36,8 %) in mangrove, 49 (24,0 %) in "morichales", 51 (25,8 %) in shrubland and 33 (16,2 %) in meadows. Regarding species distribution among vegetation types, 131 (64,2 %) species appeared only in one type of vegetation. Only 8 (3,9 %) species were found in all five types. Over 55,3 % of the plant species collected in the swamp forest was not found in the other vegetation types. This percentage was 34,7 % in mangroves, 18,4 % in "morichales", 5,9 % in shrubland and 27,3 % in meadows. Tree species of the forested areas in 0.1 ha plots was 13-31 (average 20±6 sp.) in SF, 1-19 (average 10±4 sp.) in MG and 2-16 (in average 10±6 sp.) in MO. We did not collect samples until species saturation, due to the preliminary nature of this work. Therefore, an increase in species richness is expectable with increasing sampling area.

Life and growth forms

Figure 3a shows the distribution of life forms within the plant formations. Phanerophytes were predominant, followed by hemicryptophytes. Therophytes, helophytes and hydrophytes were rather rare. Regarding growth forms, transport and support functions were mostly provided by tree-like structures (Fig. 3b). Epiphytic forms of Orchidaceae, Araceae and Bromeliaceae were frequent, especially in swamp forests and mangroves. In mangroves, Orchidaceae accounted for 20 % of the species encountered, Araceae for 36,4 % and Bromeliaceae for 63,6 %. Lianas preferentially grew in forest and shrublands; herbaceous growth forms, such as ferns and Cyperaceae, in meadows.

Ethnobotanical aspects

The Warao are the aboriginal inhabitants of the Orinoco Delta. They call themselves "people of water" or "people of canoe". In the study area they live in palaffites along the mangrove shores or in open waters, like in Mariusa and Cocuina. Handicraft and subsistence fishing and hunting, and harvesting of forest products constitute the main land uses in these communities. Table 2 summarizes the ethnobotanical information collected in the field. It includes 29 plant species, their corresponding Warao and scientific names, and their uses in the afore mentioned communities. Of the reported species, 37,9 % are allotted to health care, 27,5 % to food supply, 27,5 % to weapon, canoe, and tool production, 20,7 % to buildings, 3 % to handicraft and 3 % to commercialization.

Discussion

The wetland forests of the lower Orinoco Delta correspond to the Tropical Ombrophilous Forest Formation (HUBER & ALARCÓN 1988; UNESCO 1973). Relatively little is known about them in comparison to their homologous of the upper, middle and lowland (non-delta) reaches of the basin, which have high species diversity (HUBER 1995). There are no single or generally accepted methods for assessing species diversity. One of its most basic expression is species richness (BEGON et al. 1999; WHITTAKER et al. 2001). Tree species number in 0.1 ha plots of wetland forests in the study area were between 1 and 31, being SF the most diverse. URREGO (1997) recorded 139 species in plots of 0.6 ha in the Colombian Amazon swamp forests. In the Amazonian Pantanal region, forest studies yielded 18 and 42 species in 0.33 ha, 11 species in 0,42 ha, 33 species in 0,49 ha (SOUZA et al. 1997), 7 species in 0,2 ha (DUBS 1994) and 12 species in 0.1 ha (DAMASCENO-JUNIOR et al. 2005). In the Amazon estuary near Bélem, CATTANIO et al. (2002) reported 45 and 67 species in 0,2 ha plots.These examples and others found in the literature show differences in the sample sizes and criteria employed, making comparisons of species richness with our results difficult. However, it is a general statement that forested wetlands have lower species richness if compared with their upland, alluvial or "terra firme" counterparts (KLINGE et al. 1973; GENTRY & ORTIZ 1993; PETERS 1994; DALY & MITCHELL 2000; ELLISON 2004). It has been suggested that species richness within forested wetlands may be controlled by the cumulative number of environmental constraints (KEOGH et al. 1998). In fact, wetland forests of Punta Pescador develop in a deltaic environment where prolonged flooding (5-10 months), oxygen-poor flood water (0.52±0.72 mg/L), low pH of soil and water (averages 5.06±1.15 and 4.84±133 units respectively), and periodic (semi-diurnal tides) or occasional exposition to brackish water inputs are common

(VEGAS-VILARRÚBIA et al. 2006; GEOHIDRA CONSULTORES 1998). The combined effects of these variables makes it difficult for some species to become established, while others are highly specialized to survive in adverse habitats, like *P. officinalis* (WEAVER 1997; SAUR et al. 1998). This may result in distinct composition of plant communites growing in highly heterogeneous environments at a local scale.

The study area assembled 2,1 % of the species reported for the VG. To date, from the 9411 species reported for this region 2136 species (22.7 %) and 34 genera (1.9 %) are endemic (BERRY et al. 1995). From the species collected in the study area, 193 had been reported in the "Flora of the Venezuelan Guayana" as non endemic for this region, while the 12 remaining species (Annex 1) were not included in this work (STEYERMARK et al. 1995). Among the latter 12, *Pachira insignis*, *Epiphyllum hoockeri*, *Sloaena durissima*, *Reimarochloa aberrans* and *Boehmeria grandiflora* had been found in other places of the Guayana Shield. The remaining 7 species are common in Central or Northern South America outside of the Guayana region.

Mauritia palms are native flora in the lowlands of the Amazon and Orinoco (CLAY & CLEMENT 1993; RULL 1998). They grow in a variety of vegetation types (MÜLLER 1959; GONZÁLEZ 1987; TISSOT et al. 1988), but most often occur in nearly pure stands of gallery forests along water courses (HUBER 1986; PETERS et al. 1989, GONZÁLEZ 1987). They are found less frequently over wide areas of badly drained alluvial plains, such as those in Punta Pescador. To survive *M. flexuosa* has secondary roots where air can circulate freely (GRANVILLE 1974, 1992). In the study area the "morichales" develop on silt, peaty and very acidic, soils covered with almost anoxic flood water (VEGAS VILARRÚBIA 2006). URREGO (1997) reported ample *M. flexuosa* forests evolving in flooded alluvial basins under similar conditions in Colombia's Middle Caquetá region. According to GONZÁLEZ (1987), this species' seedlings are strongly light dependent and only grow in open places. This suggests that isolated individuals or stands of *Mauritia* evolving in some meadow matrices may correspond to early development stages that gradually expand to the neighboring swamp forest. Another possibility is that some stands are remains of fragmented "morichales". Alternatively, they may represent secondary growth stands substituting swamp forests affected by fires. *Mauritia* can rapidly colonize habitats created by fire (RULL 1999). In fact, fire is an active disturbance factor in the area. We observed evidences of a recent fire in a meadow within the study area. We also noted no less than five fires burning simultaneously in the neighborhood during the dry season, coinciding with a peak of fire activity in the Orinoco Delta (GRÉGOIRE et al. 1998).

The Punta Pescador meadows were found to differ floristically from the middle and lower Orinoco Delta described by HUBER (1995). According to this author, *B. serrulatum, Acrostichum aureum, Cyperus articulatus* and *Scleria* spp. (Cyperaceae) formed dense, herbaceous communities growing on water-logged histosols in middle Orinoco Delta meadows. Other lower Orinoco Delta meadows were dominated by the giant herb *Montrichardia arborescens* (Araceae) growing in nearly pure stands, with an odd appearance. Except for *B. serrulatum*, neither of these species was conspicuous in the study area. The non-gramineous meadows described in this paper combine two dominant species, the fern *B. serrulatum* and the Cyperacea *Lagenocarpus guianensis*. These cover a vast surface area and represent an Orinoco Delta meadow type that has not been reported before. The underlying soils resemble those supporting the "morichales".

Shrubland was dispersed in azonal patches. According to HUBER (1995), most VG shrublands are restricted to rock outcrops, sandy soils or peat. However, in the study area the shrubland appeared in swampy back-mangrove zones. In beach environments, *Chrysobalanus icaco* forms scrubs on coastal sand and dune substrates (SCHNEE 1984; VARGAS-SIMON et al. 1997). Back-mangrove environments differed greatly from typical beach and dune habitats. The substrate consisted of peaty organic soil, composed mainly of silt and clay. It was water saturated almost year round. *C. icaco* has been observed in similar conditions in wetlands of Mexico, Guatemala and Hawaii (SMITH 1985; RAMSAR 1999; UNEP-WCMC 2004). It is not clear whether the study's area *C. icaco* shrubland is a natural vegetation formation, such as an early successional re-growth of disturbed forest. In any case, it has not yet been described as a shrub formation of the VG region.

Mangroves develop in a variety of situations in Punta Pescador: beside river channels, along the coastal fringe, within depressions or basins, representing a transition to more inland environments (Table 1). They tolerate a wide range of water salinity values (0,1-31,4 ‰) depending on the season (GEOHIDRA CONSULTORES 1998). In areas with fairly flat topography, like the lower Orinoco Delta alluvial plains, different mangrove types are a result of local hydrology and geomorphology (CINTRÓN et al. 1985; cited in CINTRÓN & SHAEFFER 1992; KJERFVE 1990). The profile of the study area's mangrove forests fitted the schemes proposed by these authors: fringe, basin and riparian mangroves. Mangroves form a belt along riversides and shorelines of the central and eastern coast, where they are subject to sediment deposition and permanent tidal flood. From a sedimentological point of view, protection from wave action and an adequate supply of silt and clay are essential to provide a suitable environment for growing mangrove trees (CHAPMAN 1976). However, the north-western coastal shoreline, which has no mangroves, is subjected to marine erosion and sediment starvation. Mangrove colonization is probably restrained by the effect of strong currents at the Boca de Serpientes constriction (WARNE et al. 2002). A particular characteristic of the deltaic mangroves was the frequency of epiphytes growing on mangrove trees. This could be explained by the lower Delta region's high precipitation levels. Most epiphytic seed plants and ferns are found in tropical rainforests, as they require high humidity.

A more detailed floristic, phenologic and physiognomic description of the plant formations (Fig. 2) and vegetation types (Table 1) is needed, to confirm and refine the preliminary classification and the vegetation map offered. The mosaic arrangement of plant formations probably reflects the interplay of seasonal fluvial dynamics with the action of semidiurnal tides, environmental constrains and short-middle term and historic processes and evolution. The complex deltaic dynamics at work is likely to create a variety of changing habitats resulting in combinations of diverse plant species, at different stages of development. However, the specific cause-effect relations are still under documented.

In the study area grow plant species that may be particularly sensitive to oil spills beyond the inherent toxicity of the oil itself. They have pneumatophores, adventitious roots and hypertrophied lenticels to facilitate respiration that can be mechanically obstructed by crude oil coating. Physical suffocation causes dead. These structures use to be located in the same portions of the intertidal zone most heavily affected by stranded oil (DICKS 1986; Böer 1993; GARRITY et al. 1994; HOFF et al. 2002). In the study area *Pterocarpus officinalis, Symphonia globulifera, Rhizophora* spp., *Avicennia germinans, Laguncularia racemosa, Mauritia flexuosa* and *Euterpe oleracea* had such adaptations. Most of them are dominant forest forming species, thus we suspect that oil spill damages would imply more than the death of the single species and strongly impact the community level as well. This supposition is based on the traditional ecological approach, stating that dominat species are the ecological controllers of the ecosystem processes (LOUREAU et al. 2001). If these controlers are damaged, the ecosystems will suffer. Additionally, in anoxic soils oil degradation is inhibited, thus oil may persist for very long periods in peaty and muddy sediment (HOFF et al. 2002) like those of the study area. Salt tolerant and strictly fresh water species coexist in Punta Pescador, and are only separated by short distances. A further handicap in wetland areas is that draining, dredging and channeling needed to install infrastructures and transport routes during oil prospecting and production, can involuntarily induce hydrological changes. Freshwater species may be threatened by abnormal intrusions of salty water, while dilution of brackish water by freshwater influx would produce changes in salt-tolerant vegetation (BALDWIN & MENDELSSOHN 1998).

The Orinoco delta has been recognized as the home of the Warao Indians since early Indo-Hispanic times (WILBERT 1993). To date 21, 125 Warao live in the Orinoco delta, representing 20 % of the Delta Amacuro State's population (INDIGENOUS CENSE 1991). The "morichales" form part of the Indians life. *M. flexuosa* provides them with food, drink, and material for their tools, housing and socio-religious customs (DELASCIO CHITTY 1985; WILBERT 1996). The Warao use other local plants as well, such as *Euterpe* spp., *Chrysobalanus icaco* and *Diospyros lissocarpoides* for food, *Pterocarpus* spp. for handicrafts, *Montrichardia arborescens, Tabebuia aquatilis* and *Symphonia globulifera* for medicinal applications and different species of mangrove for housing. In the study area, nearly 40 % of the plant species used by the Warao aborigines are for health care.

If the structures and processes supporting the integrity of the Orinoco Delta's ecosystems, the services, uses and benefits provided are to be preserved, we should be cautious about exploiting the natural resources. Our understanding of the interrelations between the processes and structures on which life support functions rely is still incomplete. On the other hand the Orinoco Delta's importance as a source of medicines is largely unknown. Bioprospecting of wild species is essential to establish the biochemical value of the area, ideally letting the indigenous people take part of the lucrous results. Therefore, existing knowledge does not enable sound and sustainable resource management to be supported in the Orinoco Delta region. In comparison, its reputation as a huge source of oil and gas has grown constantly since the beginning of the last century. Environmental management associated with any kind of resource exploitation of the Orinoco Delta' resources should set ecological limits and provide direction and guidance. Up to date, the only practical way to conserve biodiversity is to protect natural vegetation.

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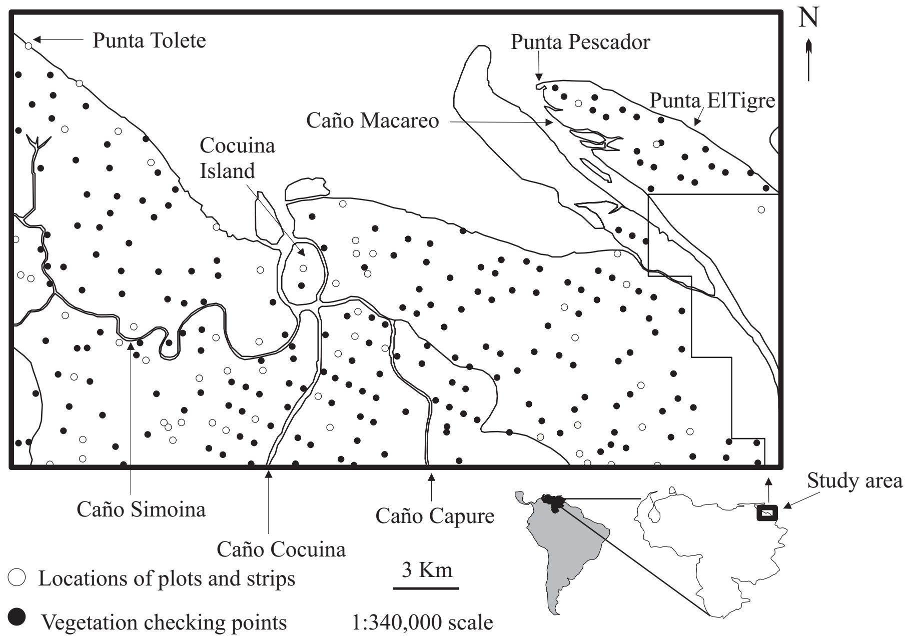


Fig. 1:
Location map. Position of vegetation plots, strips and checking points within the study area.

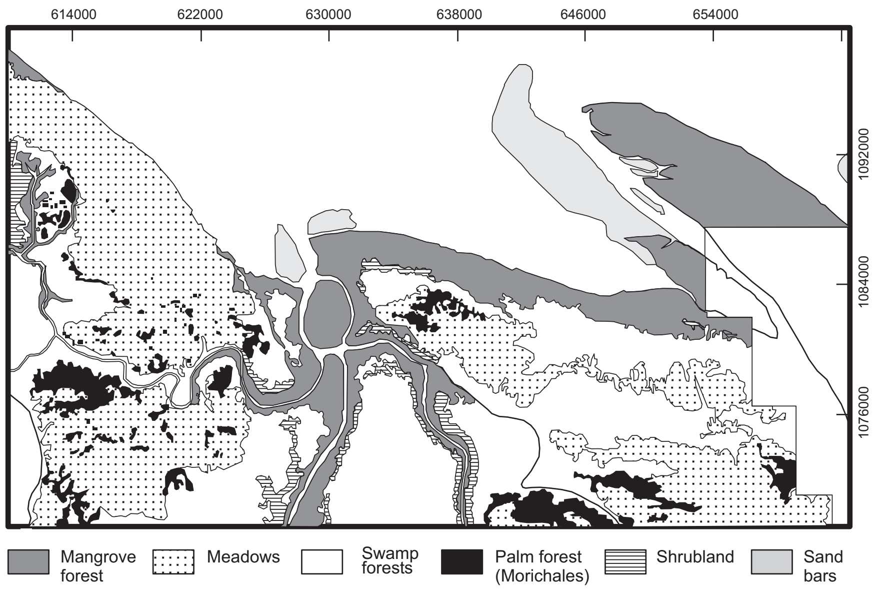
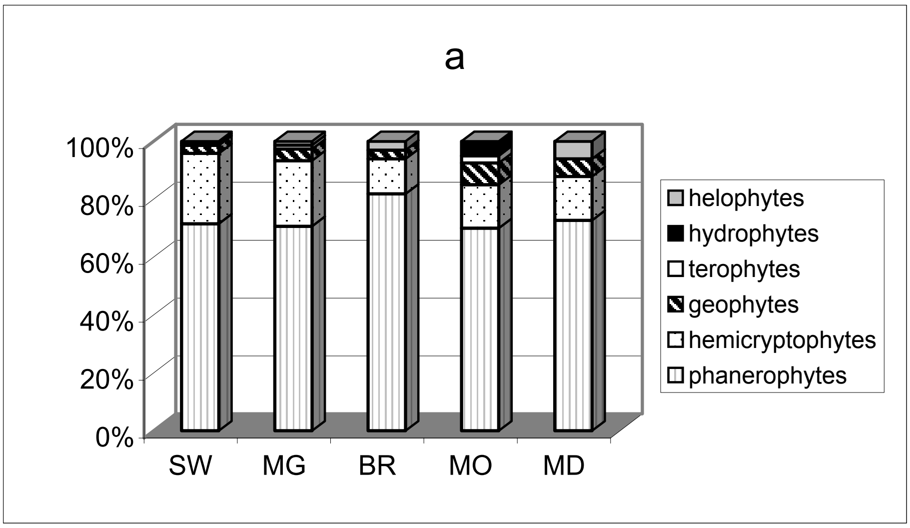


Fig. 2:
Vegetation map.



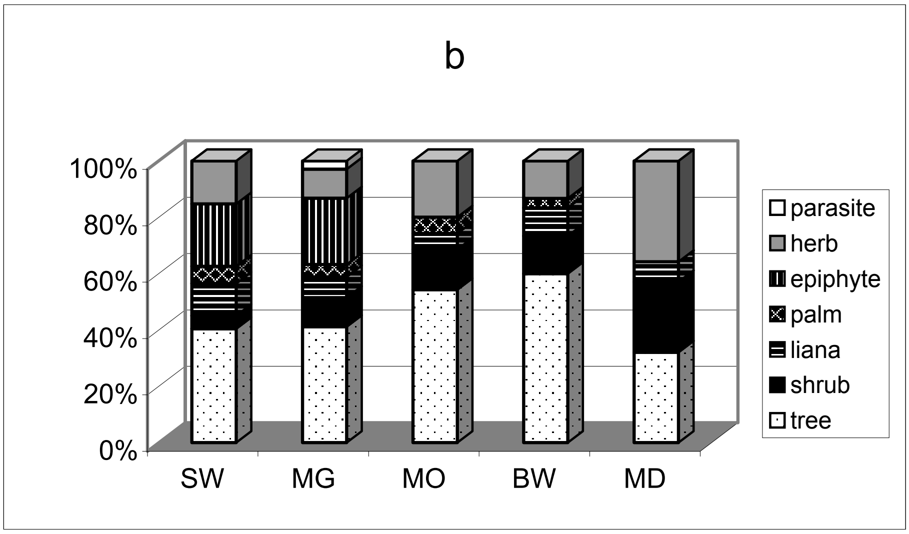


Fig. 3:
a: Distribution of life forms among the different vegetation units. **b**: Distribution of growth forms among the different vegetation units.

Table 1: Plant formations and combinations of the most frequent species.
cf: coastal fringe; *bd*: basin or depression; *r*: riverside, interior fringe.

Plant formations	**Combiantion of the most frequent species**
Swamp forest	
Low open	*Ilex martiniana, Rhizophora mangle, Ouratea cassinifolia, Tabebuia insignis* var. *monophylla, Pterocarpus. officinalis, T. insignis* var. *monophylla, T. insignis* var. *monophylla, Mauritia flexuosa*
Low mid	*P. officinalis, Diospyros. lissocarpoides, P. officinalis, R. harrisonii, P. officinalis, T. insignis* var. *monophylla, D. lissocarpoides, Chrysobalanus. icaco, T. insignis* var. *monophylla, M. flexuosa, D. lissocarpoides, T. insignis* var. *monophylla, P. officinalis, Ch. icaco*
Low dense	*Eugenia coffeifolia, Clusia grandiflora*
Mid open	*P. officinalis, T. insignis* var. *monophylla*
Mid mid	*T. insignis* var. *monophylla, D. lissocarpoides*
	P. officinalis, Symphonia globulifera, P. officinalis, S. globulifera
Mid dense	*T. insignis* var. *monophylla, O. cassinifolia*
Mangrove forest	
Mid dense	*Avicennia germinans, Rhizophora mangle (cf)*
Mid mid	*Laguncularia racemosa, Rhizophora racemosa (cf), R. racemosa (cf), R. racemosa, Rhizophora harrisonii (cf), R. mangle, R. racemosa (bd)*
High open	*R. racemosa, Ilex guianensis (bd)*
Low open	*Laguncularia racemosa, I. guianensis (bd)*
High dense	*R. mangle, Cassipourea guianensis (bd), A. germinans, R. mangle (bd)*
Mid mid	*D. lissocarpoides, R. racemosa (r)*
Palm forest or Morichal (Mo)	
Mid mid Mo	*M. flexuosa, T. insignis* var. *monophyla, M. flexuosa, P. officinalis*
Mid open Mo	*M. flexuosa, Tapira guianensis*
Shrubland (Shr)	
Mid dense Bw	*Ch. icaco, I. guianensis*
Herbaceous vegetation or meadows (Md)	
treeless	*Lagenocarpus guianensis, Blechnum serrulatum*
with bushy elements	*B. serrulatum, Rhynchospora gigantea, Rhynchantera grandiflora, B. serrulatum, L. guianensis, Montrichardia arborescens, Sagittaria lancifolia, Rhy. grandiflora, Mo. arborescens*
with woody elements	*B. serrulatum, Rh. gigantea, M. flexuosa, B. serrulatum, I. martiniana, Mo. arborescens, B. serrulatum, I. martiniana, T. insignis* var. *monophyla*
with individual trees	*B. serrulatum, M. flexuosa, T. innsignis* var. *monophyla*

Table 2: Plant species commonly utilized by the Warao Indians.

Species	**Utilization**
Annona glabra	food supply
Avicennia germinans	building
Bactris campestris	weapon fabrication
Calophyllum brasiliense	building
Cassipourea guianensis	tool fabrication
Chrysobalanus icaco	food supply
Diospyros lissocarpoides	medicinal use
Epiphyllum phyllantus	medicinal use
Euterpe oleracea	food supply
Euterpe precatoria	food supply
Euterpe sp.	commercialization
Ficus sp.	medicinal use
Malouetia flavescens	tool fabrication, medicinal use
Manilkaria bidentata	food supply
Mauritia flexuosa	food supply, building, tool and weapon fabrication
Miconia prasina	food supply
Montrichardia arborescens	medicinal use
Norantea guianensis	furniture fabrication
Phitecellobium inequale	building
Phthirusa pyrifolia	medicinal use
Phoradendron piperoides	medicinal use
Pterocarpus officinalis	handicraft art
Rhizophora harrisonii	building
Rhizophora mangle	building
Rhizophora racemosa	building, food supply
Sarcostema claususm	medicinal use
Symphonia globulifera	canoe fabrication, building, medicinal use
Tabebuia insignis var. *monophylla*	medicinal use, paddle fabrication
undetermined species	medicinal use
Virola surinamensis	canoe fabrication

Table 3: Averages of physical and chemical variables of soils and flood waters (modified from Geohidra Consultores, 1998).

Variables	Mangrove		Shrubland		Swamp forest		Morichal		Meadow	
	surface[1]	bottom[2]	surface[1]	bottom[2]	surface[1]	bottom[2]	surface[1]	bottom[2]	surface[1]	bottom[2]
Granulometry:										
sand (%)		14.6±2.4		6.26±2.3		8.47±1.20		8.78±3.8		9.18±1.7
silt (%)		63.3±1.90		78.2±4.30		66.5±1.5		58.9±2.3		60.7±1.6
clay (%)		22.2±1.5		15.6±4.20		24.9±1.50		33.3±5.2		30.1±2.0
Organic matter (%)	37.9±1.26	6.58±0.29	39.2±1.91	7.77±0.88	39.0±0.87	6.68±0.26	41.7±1.63	7.13±0.65	40.3±0.76	7.32±0.30
Natural moisture (%)	79.6±1.32	53.1±1.09	80.0±4.07	49.6±2.66	84.7±0.88	51.6±0.90	85.6±2.42	52.6±2.05	87.8±0.75	53.3±2.44
Soil salinity (%)	1.80±0.12	1.59±0.10	0.94±0.20	0.78±0.12	0.35±0.06	0.48±0.05	0.06±0.02	0.22±0.03	0.22±0.106	0.48±0.06
Soil pH	5.96±0.11	6.78±0.07	5.40±0.17	6.71±0.18	4.59±0.08	6.49±0.06	4.09±0.17	6.21±0.09	4.39±0.06	6.47±0.06
Thickness of the organic layer (m)	0.65±0.07		1.33±0.16		1.44±0.75		2.70±0.26		2.78±0.11	
Water salinity (‰)	3.58±0.35		3.02±0.23		0.96±0.19		0.91±0.74		0.55±0.21	
Water pH	5.64±0.28		3.86±0.76		4.37±0.08		4.30±0.41		4.23±0.12	
Dissolved oxygen (mg/l)	0.36±0.07		0.32±0.08		0.41±0.05		0.74±0.33		0.47±0.07	

[1] samples from the soil surface organic layer; [2] samples from the soil mineral layer.

Appendix 1: Inventory of species, growth and life forms, and corresponding habitats.

Family	Genus and species	growth form	life form	habitat
Alismataceae	*Sagittaria lancifolia* subsp. *lancifolia*	geophyte	herb	Md
Amaranthaceae	*Amaranthus australis* (A. GRAY) J.D. SAUER	terophyte	herb	Mg, Sf, Mo
Amaranthaceae	*Blutaparon vermiculare* (L.) MEARS	microphanerophyte	herb	Md
Anacardiacaeae	*Tapirira guianensis* AUBL.	mesophanerophyte	tree	Mg, Sf, Mo, Shr, Md
Anacardiacaeae	*Tapirira* sp. AUBL.	mesophanerophyte	tree	Sf,Mo
Annonaceae	*Annona glabra* L.	microphanerophyte	tree	Mg, Sf, Shr
Apiaceae	*Hydrocotyle umbellata* L.	hydrophyte	herb	Mo
Apocynaceae	*Allamanda cathartica* L.	mesophanerophyte	liana	Sf, Mo, Shr
Apocynaceae	*Malouetia flavescens* (WILLD. EX ROEM. & SCHULT.) MÜLL. ARG.	mesophanerophyte	tree	Mg, Sf
Apocynaceae	*Odontadenia nitida* (VAHL.) MÜLL. ARG.	microphanerophyte	liana	Sf
Apocynaceae	*Rhabdadenia biflora* (JACQ.) MÜLL. ARG.	mesophanerophyte	liana	Mg
Aquifoliaceae	*Ilex guianensis* (AUBL.) KUNTZE	mesophanerophyte	tree	Mg, Sf, Shr
Aquifolicaeae	*Ilex martiniana* D. DON	mesophanerophyte	tree	Mg, Sf, Shr
Araceae	*Anthurium crassinervium* hort. ex ENGL.	microphanerophyte	herb	Mg
Araceae	*Heteropsis flexuosa* (KUNTH) BUNTING	microphanerophyte	semi-epiphyte	Sf
Araceae	*Monstera adansonii* var. *laniata* (SCHOTT) MADISON	microphanerophyte	semi-epiphyte	Mg
Araceae	*Montrichardia arborescens* (L.) SCHOTT	microphanerophyte	shrub	Mg, Sf, Mo, Md
Araceae	*Philodendron acutatum* SCHOTT	microphanerophyte	semi-epiphyte	Sf
Araceae	*Philodendron fragantissimum* (HOOK) G. DON	microphanerophyte	semi-epiphyte	Sf
Araceae	*Philodendron linnaei* KUNTH	microphanerophyte	semi-epiphyte	Sf
Araceae	*Philodendron grandifolium* (JACQ.) SCHOTT	microphanerophyte	semi-epiphyte	Mg

Family	Genus and species	growth form	life form	habitat
Araceae	*Philodendron muricatum* WILLD. ex SCHOTT	microphanerophyte	semi-epiphyte	Sf
Araceae	*Spathiphyllum cannifolium* (DRYAND.) SCHOTT	nanophanerophyte	herb	Sf
Araceae	*Urospatha sagittifolia* (RUDGE) SCHOTT	nanophanerophyte	herb	Md
Araliaceae	*Didymopanax morototoni* (AUBL.) DECNE et PLANCH	megaphanerophyte	tree	Sf
Arecaceae	*Bactris campestris* POEPP. ex MART.	microphanerophyte	multicaulis palm	Mg, Sf, Mo
Arecaceae	*Bactris major* JACQ.	microphanerophyte	multicaulis tree palm	Sf
Arecaceae	*Desmoncus orthacanthos* MART.	microphanerophyte	climbing palm	Mg, Sf
Arecaceae	*Desmoncus polyacanthos* MART.	mesophanerophyte	climbing palm	Sf
Arecaceae	*Euterpe precatoria* MART.	mesophanerophyte	monocaulis tree palm	Mg, Sf, Mo, Shr
Arecaceae	*Euterpe* sp. MART.	mesophanerophyte	monocaulis tree palm	Sf
Arecaceae	*Manicaria saccifera* GAERTN.	microphanerophyte	multicaulis tree palm	Sf
Arecaceae	*Mauritia flexuosa* L.f.	megaphanerophyte	monocaulis tree palm	Sf, Shr, Md
Asclepiadaceae	*Matelea stenopetala* SANDWITH	microphanerophyte	herb	Sf
Asclepiadaceae	*Sarcostemma clausum* (JACQ.) SHULT.	microphanerophyte	herb	Sf, Md
Asteraceae	*Mikania micrantha* KUNTH	microphanerophyte	herb	Mo, Sf, Shr
Bignoniaceae	*Cydista* sp.	mesophanerophyte	liana	Sf
Bignoniaceae	*Macfadyena uncata* (ANDREWS) SPRAGUE & SANDWITH	microphanerophyte	liana	Sf
Bignoniaceae	*Tabebuia aquatilis* (E. MEY.) SPRAGE & SANDWITH	mesophanerophyte	tree	Mg, Sf, Mo, Shr, Md
Bignoniaceae	*Tabebuia insignis* var. *monophylla* (MIQ.) SANDWITH	mesophanerophyte	tree	Mg, Sf, Mo, Shr, Md
Bombacaceaea	*Pachira insignis* (SW.) SW. ex SAVIGNY	megaphanerophyte	tree	Sf
Boraginaceae	*Heliotropium indicum* L.	nanophanerophyte	herb	Sf
Bromeliaceae	*Aechmea lingulata* (L.) BAKER	protohemicryptophyte	epiphyte	Mg, Shr

Family	Genus and species	growth form	life form	habitat
Bromeliaceae	*Aechmea aquilega* (SALISB.) GRISEB.	protohemicryptophyte	epiphyte	Mg, Shr
Bromeliaceae	*Aechmea mertensii* (G. MEY.) SCHULT. & SCHULT. f.	protohemicryptophyte	epiphyte	Sf
Bromeliaceae	*Aechmea nudicaulis* (L.) SALISB. var. *nudicaulis*	protohemicryptophyte	epiphyte	Mg
Bromeliaceae	*Catopsis sessiliflora* (RUIZ & PAVÓN) MEZ	protohemicryptophyte	epiphyte	Sf
Bromeliaceae	*Guzmania lingulata* (L.) MEZ	protohemicryptophyte	epiphyte	Mg
Bromeliaceae	*Guzmania monostachia* (L.) RUSBY ex MEZ	protohemicryptophyte	epiphyte	Sf
Bromeliaceae	*Tillandsia bulbosa* HOOK.	protohemicryptophyte	epiphyte	Mg
Bromeliaceae	*Tillandsia fasciculata* SW.	protohemicryptophyte	epiphyte	Mg, Sf
Bromeliaceae	*Tillandsia flexuosa* SW.	protohemicryptophyte	epiphyte	Sf
Bromeliaceae	*Tillandsia usneoides* (L.) L.	protohemicryptophyte	epiphyte	Mg,Sf
Cabombaceae	*Cabomba aquatica* AUBL.	helophyte	herb	Sf
Cactaceae	*Epiphyllum hookeri* (LINK & OTTO) HAWORTH	nanophanerophyte	epiphyte	Mg
Cactaceae	*Epiphyllum phyllanthus* (L.) HAW.	nanophanerophyte	epiphyte	Sf
Cactaceae	*Rhipsalis baccifera* (J.S. MÜLL.) STEARN	nanophanerophyte	epiphyte	Mg, Sf
Caesalpiniaceae	*Macrolobium acaciifolium* (BENTH.) BENTH.	mesophanerophyte	tree	Sf
Cecropiaceae	*Cecropia peltata* var. *lingua* MART.	mesophanerophyte	tree	Sf, Mo, Shr, Md
Cecropiaceae	*Cecropia sciadophylla* MART.	mesophanerophyte	tree	Sf
Chrysobalanaceae	*Chrysobalanus icaco* L.	microphanerophyte	tree	Mg, Sf, Mo, Shr, Md
Clusiaceae	*Calophyllum brasiliense* CAMBESS	mesophanerophyte	tree	Sf
Clusiaceae	*Clusia flavida* (BENTH.) PIPOLY	mesophanerophyte	shrub	Shr
Clusiaceae	*Clusia grandiflora* SPLITG.	mesophanerophyte	tree	Mg, Sf, Mo, Shr, Md
Clusiaceae	*Clusia myriandra* (BENTH.) PLANCH & TRIANA	mesophanerophyte	tree	Sf, Mo, Md
Clusiaceae	*Clusia nemorosa* G. MEY.	mesophanerophyte	tree	Sf, Shr
Clusiaceae	*Clusia panapanari* (AUBL.) CHOISY	mesophanerophyte	liana	Sf

Family	Genus and species	growth form	life form	habitat
Clusiaceae	*Clusia rosea* JACQ.	mesophanerophyte	tree	Sf, Mo
Clusiaceae	*Clusia* sp.	mesophanerophyte	tree	Sf, Shr
Clusiaceae	*Symphonia globulifera* L.f.	mesophanerophyte	tree	Mg, Sf, Mo, Shr
Combretaceae	*Laguncularia racemosa* (L.) C.F. GAERTN	mesophanerophyte	tree	Mg, Sf, Shr
Commelinaceae	*Tripogandra serrulata* (VAHL) HANDLOS	nanophanerophyte	herb	Mg, Sf
Costaceae	*Costus arabicus* L.	microphanerophyte	shrub	Sf
Costaceae	*Costus guanaiensis* RUSBY	microphanerophyte	herb	Sf
Costaceae	*Costus spiralis* (JACQ.) ROSCOE	microphanerophyte	shrub	Mg, Sf, Md, Mo
Cyperaceae	*Cyperus odoratus* L.	protohemicryptophyte	herb	Sf
Cyperaceae	*Fuirena umbellata* ROTTB.	protohemicryptophyte	herb	Md
Cyperaceae	*Lagenocarpus guianensis* (NESS)	protohemicryptophyte	herb	Mg, Sf, Shr, Md
Cyperaceae	*Rhynchospora gigantea* LINK	protohemicryptophyte	herb	Mo, Shr, Md
Cyperaceae	*Scleria stipularis* NEES	protohemicryptophyte	herb	Sf
Cyperaceae	*Torulinium odoratum* (L.) S.S. HOOPER	protohemicryptophyte	herb	Mg
Dioscoreaceae	*Dioscorea coriacea* HUMB. & BONPL. ex WILLD.	microphanerophyte	herb	Sf
Ebenaceae	*Diospyros lissocarpoides* SANDW.	microphanerophyte	tree	Mg, Sf, Mo, Shr
Elaeocarpaceae	*Sloaena durissima* SPRUCE ex BENTH.	mesophanerophyte	tree	Sf
Euphorbiaceae	*Omphalea diandra* L.	microphanerophyte	liana	Mg, Sf, Md
Fabaceae	*Andira inermis* (W.WRIGHT) KUNTH ex DC.	mesophanerophyte	tree	Sf, Mo
Fabaceae	*Dalbergia monetaria* L.f.	microphanerophyte	liana	Sf
Fabaceae	*Dioclea malacocarpa* DUCKE	microphanerophyte	liana	Sf
Fabaceae	*Machaerium lunatum* (L.f.) DUCKE	microphanerophyte	shrub	Mg
Fabaceae	*Muellera frutescens* (AUBL.) STANDL.	microphanerophyte	shrub	Mg
Fabaceae	*Pterocarpus officinalis* JACQ.	mesophanerophyte	tree	Mg, Sf, Mo, Shr, Md
Fabaceae	*Pterocarpus rohrii* VAHL	mesophanerophyte	tree	Mg, Sf, Mo

Family	Genus and species	growth form	life form	habitat
Fabaceae	*Pterocarpus santalinoides* L. HÉR. ex DC.	mesophanerophyte	tree	Mg, Sf
Fabaceae	*Vigna juruana* (HARMS) VERD.	microphanerophyte	liana	Sf
Gentianaceae	*Irlbachia alata* (AUBL.) MAAS ssp. *longistyla* PERSOON & MAAS	nanophanerophyte	bush	Mo, Shr, Md
Gesneriaceae	*Drymonia serrulata* (JACQ.) MART.	nanophanerophyte	herb	Sf
Heliconiaceae	*Heliconia psittacorum* L.f.	helophyte	herb	Mg, Shr, Md
Lauraceae	no determined	mesophanerophyte	tree	Sf
Lauraceae	no determined	mesophanerophyte	tree	Sf
Liliaceae	*Crinum erubescens* AITON	geophyte	herb	Mg, Sf
Liliaceae	*Crinum* sp.	geophyte	herb	Mo, Shr, Md, Md
Liliaceae	*Hymenocallis tubiflora* SALISBURY	geophyte	herb	Mg, Sf
Liliaceae	*Hymenocallis venezuelensis* TRAUB.	geophyte	herb	Sf, Mo
Loranthaceae	*Phthirusa pyrifolia* (KUNTH) EICHLER	microphanerophyte	parasite	Mg
Malpighiaceae	*Tetrapterys discolor* (G. MEY.) DC.	mesophanerophyte	liana	Sf
Malvaceae	*Hibiscus furcellatus* DESR.	microphanerophyte	shrub	Mg
Malvaceae	*Hibiscus pernambucensis* ARRUDA	microphanerophyte	shrub	Mg
Malvaceae	*Malvaviscus longifolius* (a. ST.-HIL.) SPACH	nanophanerophyte	shrub	Mg
Malvaceae	*Pavonia* sp.	nanophanerophyte	shrub	Sf, Shr
Marantaceae	*Ischnosiphon arouma* (AUBL.) KÖRN	geophyte	herb	Sf, Mg
Marcgraviaceae	*Marcgravia coriacea* VAHL	mesophanerophyte	liana	Sf
Marcgraviaceae	*Norantea guianensis* AUBL. ssp. *japurensis* (MART.) BEDELL	mesophanerophyte	liana	Mo, Sf
Marcgraviaceae	*Souroubea guainensis* AUBL.	mesophanerophyte	liana	Sf
Melastomataceae	*Miconia ciliata* (RICH.) DC.	microphanerophyte	bush	Md
Melastomataceae	*Miconia prasina* (SW.) DC.	microphanerophyte	bush	Mo, Shr, Md
Melastomataceae	*Nepsera aquatica* NAUDIN	helophyte	aquatic herb	Md

Family	Genus and species	growth form	life form	habitat
Melastomataceae	*Rhynchanthera dichotoma* (DESR.) DC.	microphanerophyte	bush	Mo, Md
Melastomataceae	*Rhynchanthera grandiflora* (AUBL.) DC.	microphanerophyte	bush	Mo, Shr, Md
Melastomataceae	*Tococa nitens* (BENTHh.) TRIANA	microphanerophyte	bush	Md
Menyanthaceae	*Nymphoides indica* (L.) KUNTZE	hydrophyte	herb	Mo
Mimosaceae	*Entada polystachya* (L.) DC.	microphanerophyte	bush	Mg, Sf
Mimosaceae	*Inga edulis* C. MART.	mesophanerophyte	tree	Mg, Sf, Shr
Mimosaceae	*Inga* sp.	mesophanerophyte	tree	Sf
Mimosaceae	*Inga spuria* HUMB. & BONPL. ex WILLD.	mesophanerophyte	tree	Sf
Mimosaceae	*Phitecellobium inaequale* HUMB. & BONPL. ex WILLD.	mesophanerophyte	tree	Mg, Sf
Mimosaceae	*Zygia cauliflora* (WILLD.) KILLIP ex RECORD	nanophanerophyte	tree	Sf
Moraceae	*Ficus caballina* STANDL.	mesophanerophyte	tree	Sf
Moraceae	*Ficus maxima* MILL.	mesophanerophyte	tree	Mg, Sf
Moraceae	*Ficus obtusifolia* KUNTH	mesophanerophyte	tree	Sf, Shr
Moraceae	*Ficus pertusa* L.f.	mesophanerophyte	epiphyte	Sf, Md, Shr
Moraceae	*Ficus schumacheri* (LIEBM.) GRISEB.	mesophanerophyte	tree	Sf
Moraceae	*Ficus* sp. 2	mesophanerophyte	tree	Sf, Shr, Md, Mo
Moraceae	*Ficus* sp. 1	mesophanerophyte	epiphyte	Mg, Mo, Shr
Myristicaceae	*Virola surinamensis* (ROL. ex ROTTB.) WARB.	mesophanerophyte	tree	Mg, Sf, Mo, Md
Myrsinaceae	*Cybianthus spicatus* (KUNTH) AGOSTINI	microphanerophyte	bush	Sf, Mo, Shr
Myrsinaceae	*Myrsine guianensis* (AUBL.) KUNTZE	microphanerophyte	tree	Sf
Myrtaceae	*Eugenia coffeifolia* D.C.	microphanerophyte	tree	Mg, Sf, Mo, Md
Nyctaginaceae	*Guapira olfersiana* (LINK, KLOTZSCH. & OTTO) LUNDELL	mesophanerophyte	tree	Sf, Mo, Shr
Ochnaceae	*Ouratea castaneifolia* (D.C.) ENGL.	mesophanerophyte	tree	Mg, Sf, Mo, Md, Shr
Onagraceae	*Ludwigia affinis* (DC) H. HARA	microphanerophyte	herb	Sf

Family	Genus and species	growth form	life form	habitat
Onagraceae	*Ludwigia nervosa* (POIR.) H. HARA	microphanerophyte	tree	Mo, Shr, Md
Orchidaceae	*Campylocentrum micranthum* (LINDL.) ROLFE	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Dimerandra* sp.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Encyclia fragans* (SW.) LEMEE	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Encyclia leucantha* SCHLTR.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Epidendrum ciliare* L ssp. *squamum* SCHNEE	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Epidendrum ibaguense* KUNTH	protohemicryptophyte	epiphyte	Mg
Orchidaceae	*Epidendrum nocturnum* JACQ.	protohemicryptophyte	epiphyte	Mg, Sf
Orchidaceae	*Epidendrum paniculatum* RUÍZ & PAVÓN	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Epidendrum rigidum* JACQ.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Epidendrum secundum* JACQ.	protohemicryptophyte	epiphyte	Mg, Sf
Orchidaceae	*Lockhartia imbricata* (LAM.) HOEHNE	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Maxillaria camaradii* RCHB. f.	protohemicryptophyte	epiphyte	Mg
Orchidaceae	*Neolehmannia* sp.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Oncidium cebolleta* (JACQ.) SW.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Phragmorchis pusilla* (SW.) DOD. & DRES.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Pleurothallis uniflora* LINDL.	protohemicryptophyte	herb	Sf
Orchidaceae	*Rodrigueiza lanceolata* RUÍZ & PAVÓN	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Sobralia* sp.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Stanhopea grandiflora* (LOOD.) LINDL.	protohemicryptophyte	epiphyte	Sf
Orchidaceae	*Trizeuxis falcata* LINDL.	protohemicryptophyte	epiphyte	Sf
Piperaceae	*Peperomia glabella* (SW.) A. DIETR.	protohemicryptophyte	epiphyte	Sf
Piperaceae	*Peperomia magnoliaefolia* (JACQ.) A. DIETR.	protohemicryptophyte	herb	Sf
Poaceae	*Hymenachne amplexicaulis* (RUDGE) NEES	protohemicryptophyte	herb	Md
Poaceae	*Hymenachne amplexicaulis* (RUDGE) NEES	protohemicryptophyte	herb	Md
Poaceae	*Reimarochloa aberrans* (DÖLL) CHASE	protohemicryptophyte	herb	Md
Poaceae	*Sacciolepis myuras* (LAM) BEAV	protohemicryptophyte	herb	Mo

Family	Genus and species	growth form	life form	habitat
Poaceae	*Setaria vulpisieta* (LAMARK) ROEM. & SCHULT.	protohemicryptophyte	herb	Mo
Polygonaceae	*Coccoloba latifolia* LAM.	mesophanerophyte	tree	Sf, Shr, Md
Polygonaceae	*Coccoloba marginata* BENTH.	mesophanerophyte	tree	Sf
Polygonaceae	*Polygonum acuminatum* KUNTH	hydrophyte	herb	Mo
Rapataceae	*Rapatea paludosa* AUBL.	protohemicryptophyte	herb	Mg, Shr
Rhizophoraceae	*Cassipourea guianensis* AUBL.	mesophanerophyte	tree	Mg, Sf, Mo, Shr
Rhizophoraceae	*Rhizophora harrisonii* LEECHM.	mesophanerophyte	tree	Mg, Sf
Rhizophoraceae	*Rhizophora mangle* L.	mesophanerophyte	tree	Mg, Sf
Rhizophoraceae	*Rhizophora racemosa* G. MEY.	mesophanerophyte	tree	Mg, Sf
Rubiaceae	*Coccocypselum hirsutum* BARTL. ex DC.	microphanerophyte	shrub	Mo
Rubiaceae	*Duroia eriophyla* L.f.	mesophanerophyte	tree	Mo, Sf
Rubiaceae	*Genipa caruto* KUNTH.	mesophanerophyte	tree	Mg, Sf
Rubiaceae	*Malanea macrophylla* var. *bahiensis* (M. ARG.) STEYERM.	mesophanerophyte	tree	Sf
Sapindaceae	*Paullinia pinnata* L.	mesophanerophyte	liana	Mg, Sf, Shr, Md
Sapindaceae	*Toulicia guianensis* AUBL.	mesophanerophyte	tree	Sf
Sapotaceae	*Manilkara bidentata* (A.DC.) A. CHEV.	megaphanerophyte	tree	Shr
Smilaceae	*Smilax schomburgkiana* KUNTH.	mesophanerophyte	liana	Mg, Sf, Shr, Md
Solanaceae	*Solanum lanceifolium* JACQ.	nanophanerophyte	liana	Sf, Shr
Solanaceae	*Solanum stramonifolium* JACQ.	nanophanerophyte	shrub	Shr
Sterculiaceae	*Byttneria uaupensis* SPRUCE ex K. SCHUM.	mesophanerophyte	herb	Sf
Sterculiaceae	*Sterculia pruriens* (AUBL.) K. SCHUM. var. *pruriens*	megaphanerophyte	tree	Sf
Urticaceae	*Boehmeria ramiflora* JACQ.	microphanerophyte	shrub	Sf
Urticaceae	*Pilea pubescens* LIEBM	microphanerophyte	herb	Sf

Family	Genus and species	growth form	life form	habitat
Verbenaceae	*Avicennia germinans* (L.) STEARN	mesophanerophyte	tree	Mg
Viacaceae	*Phoradendron piperoides* (KUNTH) TREL.	microphanerophyte	parasite	Mg
Vitaceae	*Cissus sicyoides* L.	mesophanerophyte	liana	Mg
Cryptogames				
Pteridophyta				
Aspleniaceae	*Polybotrya caudata* KUNZE	protohemicryptophyte	epiphyte	
Blechnaceae	*Blechnum serrulatum* L.C. RICH.	protohemicryptophyte	fern	Sf, Mo, Shr, Md
Lycopodiacae	*Huperzia dichotoma* (JACQ.) TREVIS	microphanerophyte	epiphyte	Sf
Polypodaceae	*Campyloneurum phyllitidis* (L.) C. PRESL	protohemicryptophyte	fern	Mg
Polypodaceae	*Microgramma reptans* (CAV.) A.R. SM.	protohemicryptophyte	fern	Mg, Sf, Mo, Md, Shr
Polypodaceae	*Microgramma persicariifolia* (SCHRAD.) C. PRESL	protohemicryptophyte	fern	Sf
Polypodaceae	*Polypodium polypodioides* (L.) WATT.	protohemicryptophyte	epiphyte	Sf
Pteridaceae	*Acrostichum aureum* L.	protohemicryptophyte	fern	Mg, Sf, Shr
Vittariaceae	*Vittaria lineata* (L.) SM.	protohemicryptophyte	epiphyte	Mg
Fungi				
Dematiaceae	*Cercospora* sp.		fungus	Sf
Bryophyta				
Meteoriaceae	*Zelometeorium patulum* (HEDW.) MANUEL	protohemicryptophyte	mosses	Sf
Pterobryaceae	*Orthostichopsis tetragona* (Hedw.) Broth.	protohemicryptophyte	mosses	Sf
Lichens				
Usneaceae	*Ramalina* sp.	protohemicryptophyte	lichen	Sf