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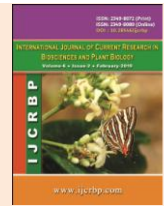

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Characterization of vegetation in the mangrove forest of the Rio del Rey estuary of the South-West of Cameroon

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ABSTRACT

The aim of this study is to describe the spatial heterogeneity of the vegetation of the Rio del Rey estuary in the South-West of Cameroon by identifying and characterizing their plant communities. The study also highlights the sociological organization of the forest and contributes to knowledge on the phytosociology of Cameroon's forest ecosystems, which is still fragmentary. The analyses are based on data collected from 14 phytosociological plots in Rio del Rey estuary forest and from measurements of tree diameter at breast height or under for the bushes, along these transects. An area of 0.5 ha was inventoried per sampling of 25×200 m plots, of a total area 7 ha. Ligneous plants (1 cm ≤ diameter) were inventoried: 15 vascular species, 11 genera and 11 families were recorded; 1 herbaceous species; 10227 shrubs 1≤dbh<10 cm and, 9079 trees 10 cm ≤ dbh. The species-accumulating curve showed an important diversity in the category of shrubs 1 <dbh>10 cm than those of 10cm ≤ dbh. The minimal area was reached at 5 ha inventoried. For the ligneous plants, stem density was 2758 stems ha^{-1} and basal area $412.7 m^2 ha^{-1}$. Species diversity as measured by Shannon diversity index was 1.81. Three species were common and widely distributed among 13 over 15 (86.6%) sampling forests. *Rhizophora racemosa* is the species having the strongest IVI value (95.72) and *Rhizophoraceae,* the family having the highest FIV value (171.11). The forest is marked by the abundance of the *Rhizophoraceae, Avicenniaceae, Meliaceae* and *Combretaceae*. Four plant communities were identified and characterized and their higher taxa classified. The water salinity clearly influences the biological diversity of the plant communities; however, the heterogeneity of the vegetation seems to correspond to local soil submersion phenomena in the same vegetation context.

Introduction

A much more explanatory approach to the structure of the mangrove vegetation landscape and its evolution requires a phytoecological analysis. This technique leads to a partition of space into management units (Bowman, 1917; Jordan, 1963; Letouzey, 1968, 1985; Villiers, 1973). These authors indicate that the series of vegetation is individualized on the basis of quantitative criteria related to tidal movements, the depths of water bodies, drier soil surfaces, firewood cuts resulting from urbanization in the city; and by qualitative criteria related to the zonation of plant groups.

The phytosociological specificity of the mangrove is expressed by the presence of plant groups that are individualized by structural characters (floristic composition) and functional (primary productivity). These groups are associated in original combinations in spatial units or take turns in chronosequences on the same portion of the territory. This suggests, to answer the following question: does the vegetation of a mangrove structurally correspond to one and the same biological entity or is it the expression of distinct, more or less autonomous combinations, that is to say, subjected to a determinism of its own and whose horizontal organization would be of the zonal type? The present study concerns the mangroves of the Rio del Rey estuary of southwestern Cameroon. This forest suffers from low anthropic pressure (illegal harvesting of animal and plant resources, etc.), linked to low population density. In the year 1994, the entire mangroves area around the Bakassi Peninsula, extending over 1000 km², was the subject of territorial conflict between Cameroon and Nigeria (Fomete & Tchanou, 1998). This area has remained for several years a military area prohibited from civilians and especially from researchers (Nfotabong, 2011). The Rio del Rey area has had very few studies. The studies that were done there after the end of the conflict clearly reveal the low anthropic pressure (Ndema et al., 2015), 124.12 inhabitants/km²(Mbarga, 2010). There are still large, relatively intact mangroves depending on ecological parameters (Dansereau,1947; Ndongo and Baltzer, 2006; Guiral et al., 1999). The characterization of Rio del Rey mangrove vegetation is therefore timely to contribute to its optimal conservation, with plant communities constituting complexes with phytocenosis values (Dajoz, 2006; Fomete and Tchanou, 1998; Thevand, 2002). Can this plant group present unique plant and plant characteristics conducive to its characterization? The purpose of the present study is to identify the floristic species of the site and to describe the plant communities as expressed in the mangrove of Rio del Rey.

Materials and methods

Erect or prostate herb or sub-shrub; leaf blade margin entire, rounded to acute at base, obtuse to acuminate at apex. Inflorescences terminal or axillary, panicles, racemes, or rarely solitary sometimes spikes or dense clusters; bracts present; bracteoles. Calyx deeply 5-lobed; lobes narrow, equal or sub-equal. Corolla tubular to funnel form at base; lower lip 3-lobed; upper lip entire or 2-lobed. Stamens 2.

Results

Description of the study area

The Rio del Rey estuary is located in the Soud-West, Region, Ndian Division (with 8 subdivisions). Geographically, it is through of the Gulf of Guinea, on the border between Cameroon and Nigeria (4° 20'-4° 50' 'N latitude, 8°30'-9 ° E longitude), at the mouth of Akpa, Yafe, Ndian and Meme rivers (Fig. 1). The study covered four subdivisions: Kombo-Abetimo, Isangele, Ekondo-Titi and Bamusso, in a mangrove area around Bakassi peninsula. This forest extends over an area of more than 1000 km², on a more or less swampy ground the altitude " zero ", at the level of the surface of the Atlantic Ocean.

Summarily describing mangrove vegetation, Letouzey (1985) states that it is dominated by tree species such as *Avicennia germinans*, *Rhizophora mangle*, *Rhizophora racemosa*which can reach 25 m in height. The presence of species such as *Dalbergia ecastaphyllum* and *Paspalum vaginatum* indicate the presence of sandy littoral deposits. The climate of the Bakassi region is influenced by the proximity of the Atlantic Ocean and Mount Cameroon, on the one hand and on the other hand, by the meteorological equator where the Azores anticyclone converges from the northern hemisphere and that of Saint Helena coming from the Southern hemisphere (Waffo, 2009). This climate belongs to the equatorial regime, the Cameroonian domain and the maritime type. It is characterized by a rainy season during the 12 months of the year with a decline in December and January, with no ecologically dry period; the average rainfall is always greater than 2T (P> 2T) (Waffo 2009, Ndema et al., 2015). The average annual rainfall is 5394.7 mm. These climatic conditions are favorable to the cultivation of cocoa developed on firm land for a long time, to the cultivation of oil palms by large industrial companies (like PALMOL). The fishing and their smoking are really the activities economically developed in the riparian villages of the Rio del Rey mangroves.

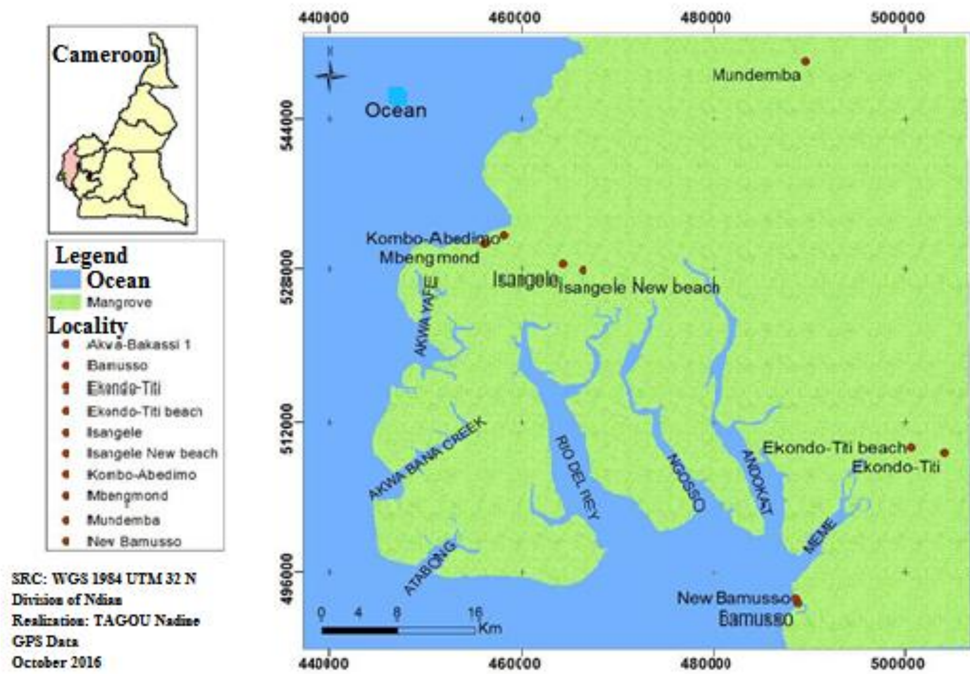

Fig. 1: Location map of the Rio del Rey estuary in the Gulf of Guinea.

Table I. Climatological data from the Ndian station (1984-2014) (PALMOL Company, 2016)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sept	Oct	Nov	Dec
Rainful (mm)	53.8	91.9	213.3	312.8	459.9	580.8	850	1141.2	712.7	555.6	328.8	93.9
Average T (° C)	26.7	29.3	28.1	27.6	27.2	26.5	25.5	25.1	25.7	26.5	26.9	26.7
Rainful to draw the diagram	53.8	91.9	111.33	121.28	135.99	148.08	175.0	204.12	161.27	145.56	122.88	93.9

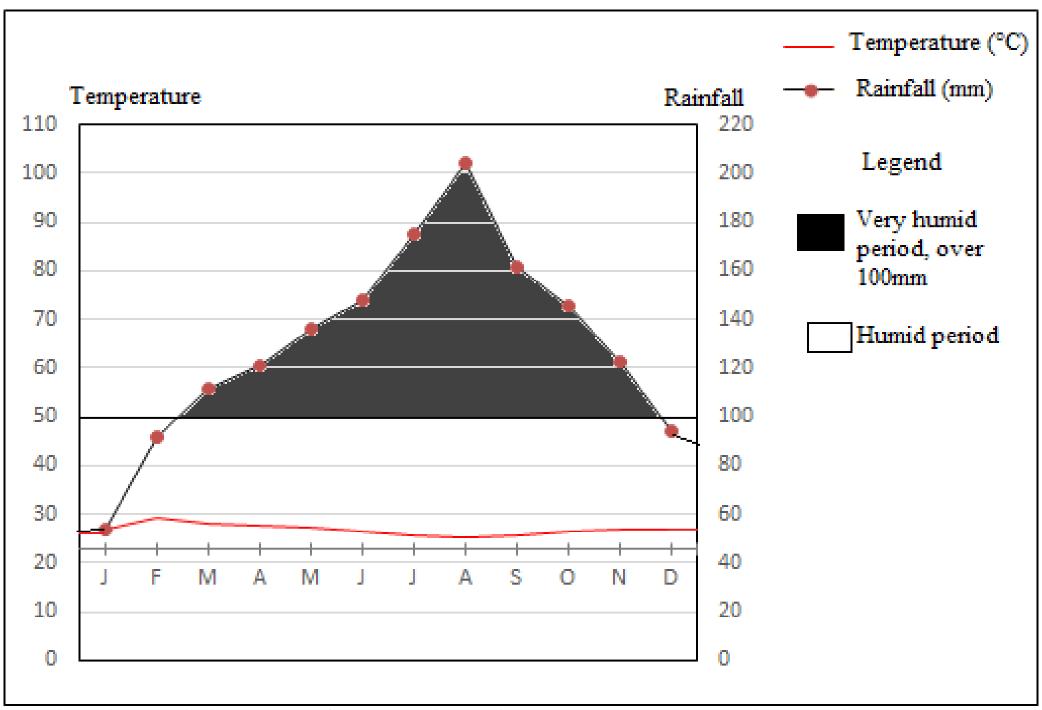

Fig. 2: Ombrothermal diagram of Bagnouls and Gaussen (1957), and according to WalterandLieth (1964), in the Ndian Area (1984-2014). Source: PALMOL Company, 2016.

In the area of the Rio del Rey estuary, there are ancient sedimentary soils from cretaceous sandstones and non-volcanic coastal plains as well as soils resulting from the degradation of Precambrian source rocks: granites, gneisses, shales, ectinites (Gartlan, 1986). These soils tend to be extremely sandy and have a low water retention capacity. They are usually very acidic. The soil contains a large fraction of clay and silt, often compact, black in color, with few organic elements (Anonyme, 2008).

Sampling methods

Field work was conducted from November 2016 to December 2017. The total area sampled was 7 ha. All plants were inventory in 14 Rio del Rey localities, on 5000m² per dition, called a sampling. Once the parcel was chosen and the device put in place, the floristic surveys were carried out (Braun-Blanquet, 1965; Gounot, 1969) and the specific list established. All plant species, herbaceous and lineous individual's ≥ 1 cm diameter above the soil were collected and identified. The sampling in the forest area study was terminated when the species-accumulation curve reached an asymptote (Hutchinson and Daziel, 1954-1972; Lebrun and Stork, 1991-1997; Liben, 1983; Tardieu-Blot, 1964; Villiers, 1975). The identification of specimens were confirmed at National herbarium of Cameroon (Yaounde). Herbarium specimens were deposited at the Department of Biological Sciences, Higher Teacher's Training College of the University of Yaounde I.

From the original data, we calculated the density of trees and basal area. To assess forest structure, (a) all vascular plants were grouped in families and (b) trees were grouped in diameter classes. The results were plotted in histograms. Using standard methodology (Curtis and McIntosh, 1951; Cottam and Curtis, 1956; Mori et al., 1983), the following parameters were calculated. At specific and relative level: relative density and relative dominance; at specific level only: relative frequency and at the family level only: relative diversity. From these data, Importance Value Index (IVI) and Family Importance Value (FIV), frequency; at the family level only: relative diversity were calculated.

In order to construct species-area curve, the number of additional species occurring in each consecutive sub-sample unit (40 x 25m, five times on each locality) was plotted against surface increment. The sampling in the mangrove was terminated when the species-accumulation curve reached an asymptote. It has been shown that the comparison of diversity between strata must be taken into account in the sampling effort (Condit et al., 1996).

Species-individual curves have been plotted on the same axis, but rather on the horizontal axis (X-axis).We used the cumulative number of individuals in an increasing order. The floristic diversity was considered in a synthetic manner by the hand physiognomic and phytogeographic spectra.

The Biologic Types (BT) were distinguished according to the classification of Raunkiaer (1934), done by Schnell (1971) and the species were designated as: mesophanerophyte, 10-30 m high (me), microphanerophyte, 2-10 m (mi), nanophanerophyte, 0.4-2 m (nan), ligneous phanerophyte climbing (Phgr), Geophytes rhizomatous (Gr), chamephyte graminae, (Ch-ces). Information pertaining to the geographical distribution of each specie was obtained from literature (Schnell, 1970; White, 1979)and the species were designated as: Pantropical (Pan), Paleotropical (Pal), Afro-American (Aam), Afro-Tropical (At). Raunkiaer (1934) established a classification of foliar types later modified by Evrard 1968: megahylls (s> 20 dm²); macrophylls (s = 2-20 dm²); mesophylls (s = 20-200 cm²); microphylls (s = 2-20 cm²). Woody trees with a diameter greater than 1 cm are taken into account.
The types of dissemination were determined according to the classification of Molinier and Müller (1938), Dansereau and Lems (1957) and Evrard (1968). The following types have been distinguished: Anemochoria (Pterochoras); Zoochoria (Sarcochore); Autochoria (Barochore, Ballochore); Hydrochoria (Pleochore).

Methods of data analysis

The determination of plant groups or plant communities was made on the basis of the specie matrix with their presence/absence using the Multi-Variant Statistical Package (MVSP) software (Kovach, 1997). This technique has provided us with a dendrogram that discriminate plant groups. The UPGMA method (Unweighted Pair Group Method with Arithmetic mean) based on the

Sorensen similarity index (1948) (K) was used. This index is given by the following formula (1):

K = 100 x 2a/2a + b + c, where ''a'' is the number of species common to both plant groups compared, ''b'' and ''c'' are the number of species absent in one but present in the other.

The links between ecological variability and the spatial distribution of plant groups have been demonstrated through the indirect analysis of PCA gradients (Principal Component Analysis)(Hill, 1994). This method proved to be adequate for the analysis of data from this study in which we did not measure environmental values. The comparison of the specific diversity of plant groups were carried out on the basis of the respective species richness (S) and the diversity indices calculated with the floristic inventories obtained and whose thresholds are defined by Gillet (2000) and Dajoz (2006). The indices selected include:

- Shannon index (H) (Weaver, 1949):

H = -Ni / N log2Ni / N, where Ni is the strength of the species "i" and N the strength of all species. It is expressed in bits.

- Pielou index (R) (Pielou, 1966):

R = H / Hmax, where ''*H*'' is the Shannon index and Hmax the maximum diversity.

Results

Floristic composition

Fifteen species have been identified. The nomenclature is made following Lebrun and Stork (1991-1997). These species are grouped into Vascular Cryptogamous (*Acrostichum guineense*, Adiantaceae, and Phanerophytes, including 4 Monocotyledons and 11 Dicotyledons), which are grouped into 11 genera and 11 families. The richest families are Arecaceae, Combretaceae, Leguminosae and Rhizophoraceae, each represented by 2 species. These species are grouped into 4 morphological types. Generally, there is a dominance of tree species (5 at least 33.33%) and shrubs (8 at least 53.33%). The morphological herbaceae type (1 at least 6.66) only develops in the peripheral areas of the mangrove. The rhizomatous geophyte develops in areas where the influence of the tide is least strongly felt. It is also the external plant of the mangroves which marks a certain degradation of the medium.

Sampling (1≤dbh<10 cm) on 7 hectares

The number of species (1 ≤ dbh<10cm) taken in the inventory on 7-ha is 14, with 10227 individuals (at least 1461-ha^{-1}) (Table I). The basal area is $24.3m^2$ (at least $12.96m^2\text{-ha}^{-1}$). Among them 8 species don't have any representatives in the category dbh ≥ 10cm. The most dense are *Rhizophora racemosa* (5457, at least $779\text{-ha}^{-1}$of bushes), *Avicennia germinans* (2562, at least $366\text{-ha}^{-1}$of bushes), *Rhizophora mangle* (1622, at least 231-ha^{-1} of bushes). At least 94% of bushes belong to 3 species: *Rhizophora racemosa* (5457, at least 53% of bushes), *Avicennia germinans* (2562, at least 25% of bushes), *Rhizophora mangle* (1622, at least 15%).The inventory inform on regeneration of the main forest species, throughout the young plants 1cm ≤ dbh <10cm and also the tendency to the gregariousness in that forest storey. A more important number of stilt roots (corresponding to a bigger surface) strongly increase the difficulties to delimit a homogeneous zone in a forest. The realization of a sampling by plots as done in the present survey is then generally incontournable. The specie individual curves were constructed for the 3 categories of the dbh: 1cm ≤dbh <10 cm for the bushes and 2 others for the trees with 10cm ≤dbh and 30cm ≤ dbh (Fig. 3).

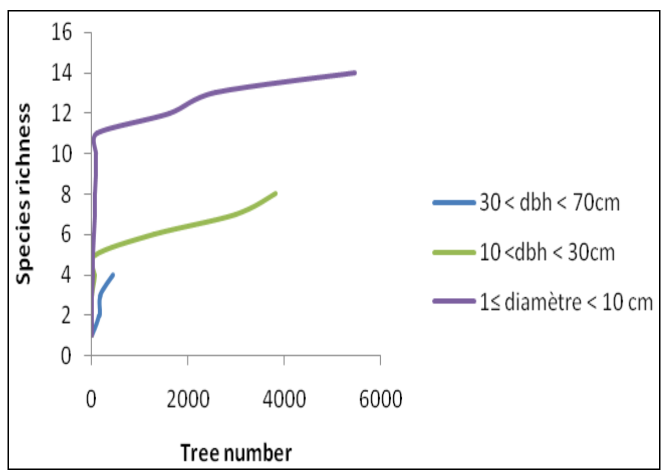

Fig. 3: The species individual curves drawn for the bushes (1 cm < dbh < 10 cm) and for the category of dbh > 10cm, on the entirety of inventories are relative to the two categories.

Table II. Floristic list of the mangroves of the Rio del Rey estuary, with the number of Individuals per diameter middle class (diameter> 1 cm).

TB	TD	TP	G eco	TF	Species	Families	[1-10]	[10-20]	[20-30]	[30-40]	[40-50[	[50-60]	[60-70]	Total stems
me	Bal	A-am	Av-rh	mes	*Rhizophora mangle* L.	*Rhizophoraceae*	1622	2995	834	199	139	89	25	5903
me	Bal	At	Av-rh	mes	*Rhizophora racemosa* G. F. W. Mey	*Rhizophoraceae*	5457	2244	749	107	35	35		8627
me	Bar	A-am	Av-rh	mes	*Avicennia germinans* (L.) L.	*Avicenniaceae*	2562	1009	285	132	6	35		4017
me	Bar	Pan	St-pa	mic	*Carapa procera* DC.	*Meliaceae*	88	62	15	18				183
mi	Pter	A-am	Av-rh	mes	*Conocarpus erectus* .L	*Combretaceae*	115	64						179
me	Sar	Pal	mytr	mac	*Pandanus candelabrum* P. Beauv.	*Pandanaceae*	30	12						42
me	Sar	At	Av-rh	mes	*Syzygium guineense* va. *Littorale* Keay	*Myrtaceae*	12	1						13
Gr	Pleo	Pan	Av-rh	meg	*Acrostichum aureum* L.	*Adianthaceae*	74	1						75
mi	Pter	A-am	Av-rh	micr	*Laguncularia racemosa* Gaertn.	*Combretaceae*	96							96
mi	Bar	Pan	Mytr	macr	*Alchornea cordifolia* (Schum et Thonn.) Müll. Arg.	*Euphorbiaceae*	68							68
mi	pter	Pan	Av-rh	mes	*Pterocarpus santalinoides* L'Hérex DC.	Leguminosae	50							50
na	Pter	A- am	Av-rh	mes	*Dalbergia ecastaphyllum* (L.) Taub.	Leguminosae	23							23
mi	Pleo	Pan	Av-rh	mac	*Nypa fruticans* Wurmb.	*Arecaceae*	18							18
mi	pleo	AT	mytr	macr	*Raphia palma-pinus* (Gaertn.) Hutch.	*Arecaceae*	12							12
Ch	pleo	Cosm	mytr	micr	*Paspalum vaginatum* Sw.	*Poaceae*								+
						Total	10227	6388	1883	456	180	147	25	19306

Table III. Number of species, genera and families of morphological types in the mangrove forest of Rio del Rey. The density of the woody type individuals is also indicated.

Variables	All species, herbaceous and ligneous	All herbaceous species	All ligneous species		
			Dbh ≥1 cm	Shrubs 1≤dbh<10 cm	dbh ≥10 cm
Species richness	15	1	14	14	8
Number of genera	14	1	13	13	7
Number of families	11	1	10	10	7
Shannon index (*H'*)	1.81	-	1.81	1.82	1.60
Total area sampled (ha)	7	7	7	7	7
Number of individuals	19306	-	19306	10227	9079
Stem density (stems ha^{-1})	2758	-	2758	1461	1297
Basal area (m^2 ha^{-1})	412.7	-	412.7	24.3	308.9
Basal area of main trunk (m^2 ha^{-1})	168.41	-	168.41	12.96	164.56

Sampling (1 cm≤dbh) on 7 hectares

Structure

The number of species (1 cm ≤ dbh) taken in the inventory on a 0.5-ha plot, varied from 3 to 15 with a mean value of 10.2 species per plot. The basal area is 168.41 m^2 (at least 412.7 m^2/ha). Considering tree diameters, the maximum dbh are between 60 and 70 cm, values attained by 25 individual trees of *Rhizophora racemosa*. However, such values remain rare if the sampling was made in station without *Rhizophora mangle*. In the 7 ha taken in the inventory, 6388 individual trees occur in the 10 to 20 cm dbh class-size. All together, all trees are less than 70cm dbh (Table I). Distribution in dbh classes shows an inverse J-shaped curve (Fig. 4).

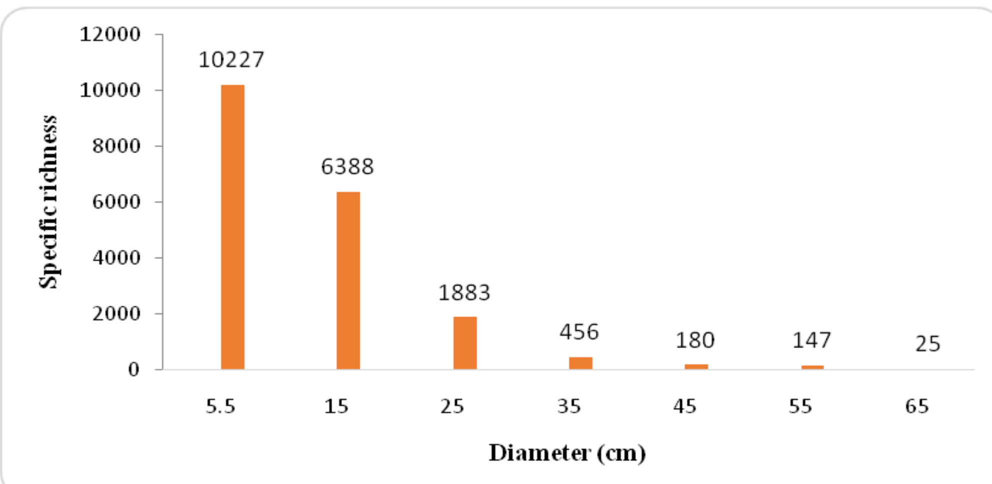

Fig. 4: Distribution of trees in 10 cm dbh interval size classes. The number of recorded individuals is indicated for every size class.

Floristic composition

Species occurrence, stem density and basal area

Because of the strictly shrubby appearance of several facies of the mangrove, all trees with a diameter greater than 1 cm are taken into account.The frequency distribution of species among forest localities revealed 3 species occurring in a large number of localities, and the majority in a limited number of samplings; 1 (6.66%) species were recorded in 3 (21.4%) forest samplings; 2 (13.33) in 4 (28.7%); 3 (20%) in 2 (21.4%); 4 (26.66) in 2 (14,28) and 6 (40%) in 2 (14.28). 11 species (78.57%) occurred at landscape densities >1 stem 7 -ha^{-1}. Stem density was 2758 stems ha^{-1} and basal area 412.7m^2 ha^{-1}

for the ≥1cm diameter and dbh classes. 3 species, *Rhizophora racemosa* (44% of stems), *Rhizophora mangle* (30%) and *Avicennia germinans* (20%) were numerous and comprised over 94% of the stems sampled (Table V). They have the 3 first values in IVI.

Table V. Species with the highest values of relative occurency, relative density, relative dominance, and IVI in descending order.

Relative occurency [x 100]		Relative density [x 100]		Relative dominance [x 100]		IVI [x 300]	
Rhizophora racemosa	19.44	*Rhizophora racemosa*	44.69	*Rhizophora mangle*	48.71	*Rhizophora racemosa*	95.72
Avicennia germinans	18.06	*Rhizophora mangle*	30.58	*Rhizophora racemosa*	32.85	*Rhizophora mangle*	94.87
Rhizophora mangle	16.67	*Avicennia germinans*	20.81	*Avicennia germinans*	16.49	*Avicennia germinans*	54.18
Nypa fruticans	8.33	*Carapa procera*	0.95	*Carapa procera*	1.09	*Nypa fruticans*	13.09
Acrostichum aureum	8.33	*Conocarpus erectus*	0.93	*Conocarpus erectus*	0.41	*Carapa procera*	8.53
Carapa procera	5.56	*Laguncularia racemosa*	0.50	*Acrostichum aureum*	0.17	*Acrostichum aureum*	8.35
Raphia palma-pinus	5.56	*Acrostichum aureum*	0.39	*Pandanus candelabrum*	0.08	*Raphia palma-pinus*	5.27
Dalbergia ecastaphyllum	4.17	*Alchornea cordifolia*	0.35	*Laguncularia racemosa*	0.07	*Dalbergia ecastaphyllum*	4.03
Alchornea cordifolia	2.78	*Pterocarpus santalinoides*	0.26	*Alchornea cordifolia*	0.05	*Conocarpus erectus*	3.93
Conocarpus erectus	2.78	*Pandanus candelabrum*	0.22	*Pterocarpus santalinoides*	0.03	*Alchornea cordifolia*	3.00
Pandanus candelabrum	2.78	*Dalbergia ecastaphyllum*	0.12	*Dalbergia ecastaphyllum*	0.02	*Pandanus candelabrum*	2.90
Pterocarpus santalinoides	2.78	*Nypa fruticans*	0.09	*Syzygium guineense va. littorale*	0.01	*Pterocarpus santalinoides*	2.89
Laguncularia racemosa	1.39	*Syzygium guineense va. littorale*	0.07	*Nypa fruticans Murmb.*	0.01	*Laguncularia racemosa*	1.86
Syzygium guineense	1.39	*Raphia palma-pinus*	0.06	*Raphia palma-pinus*	0.01	*Syzygium guineense va. littorale*	1.38
	100		100		100		300

Families richness, stem density and basal area

There were 2 species of *Arecaceae, Combretaceae, Leguminosae* and *Rhizophoraceae respectively* (Table V). *Rhizophoraceae* had the largest number of individuals (75.26% of stems), followed by *Avicenniaceae* (20.8%), *Meliaceae* (0.9%) and *Combretaceae* (0.49%). *Rhizophoraceae* (81.56%) and *Avicenniaceae* (16.49%) had the highest basal area (Table III). *Rhizophoraceae* had the highest FIV value (171.11) followed by *Avicenniaceae (*44.44), *Combretaceae (*16.18), *Leguminosae* (14.71) and *Arecaceae (*14.46). The specie-area curve (Fig. 5) presents certain regularity. The slope decreases and the specie-area curves reached an asymptote in about 5 ha (10 plots, Fig. 7). Nevertheless in plots, additional species were not encountered every time. In this area, the mesologic variations do not lay to fluctuations, and determine a least heterogeneous forest massif. The critical survey (having as aim to distinguish the quality and the shortcomings) permits us to note the large uniformity floristic, original and fundamental of the Rio del Rey estuary, at the mangrove storey.

Table V. Familial composition, diversity and number of individuals of Rio del Rey mangrove.

Families	Diversity	Number of stems	Total stems	%
Rhizophoraceae	2	5903	14530	30.58
Rhizophoraceae		8627		44.69
Avicenniaceae	1	4017		20.81
Meliaceae	1	183		0.95
Combretaceae	2	179	275	0.93
Combretaceae		96		0.50
Pandanaceae	1	42	42	0.22
Myrtaceae	1	13	13	0.07
Adianthaceae	1	75	75	0.39
Euphorbiaceae	1	68	68	0.35
Leguminosae	2	50	73	0.26
Leguminosae		23		0.12
Arecaceae	2	18	30	0.09
Arecaceae		12		0.06
Poaceae		+		+
Total		19306		100

Table VI. Families with highest values of relative diversity, relative density, relative dominance, and FIV, in descending order.

Relative density [x 100]		Relativedominance [x 100]		Relative diversity [x 100]		FIV [x 300]	
Rhizophoraceae	75.26	*Rhizophoraceae*	81.56	*Rhizophoraceae*	14.29	*Rhizophoraceae*	171.11
Avicenniaceae	20.81	*Avicenniaceae*	16.49	*Combretaceae*	14.29	*Avicenniaceae*	44.44
Combretaceae	1.42	*Meliaceae*	1.09	*Leguminosae*	14.29	*Combretaceae*	16.18
Meliaceae	0.95	*Combretaceae*	0.47	*Arecaceae*	14.29	*Leguminosae*	14.71
Adianthaceae	0.39	*Adianthaceae*	0.17	*Avicenniaceae*	7.14	*Arecaceae*	14.46
Leguminosae	0.38	*Pandanaceae*	0.08	*Meliaceae*	7.14	*Meliaceae*	9.18
Euphorbiaceae	0.35	*Leguminosae*	0.05	*Adianthaceae*	7.14	*Adianthaceae*	7.70
Pandanaceae	0.22	*Euphorbiaceae*	0.05	*Pandanaceae*	7.14	*Euphorbiaceae*	7.54
Arecaceae	0.16	*Arecaceae*	0.02	*Euphorbiaceae*	7.14	*Pandanaceae*	7.44
Myrtaceae	0.07	*Myrtaceae*	0.01	*Myrtaceae*	7.14	*Myrtaceae*	7.22
	100		100		100		300

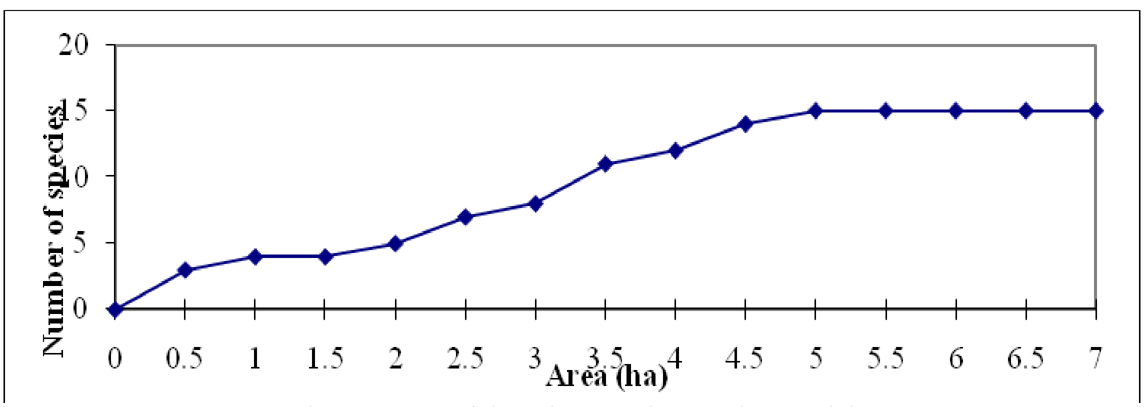

Fig. 5: Specie-area accumulating curve of the 7-ha sampling in the Rio del Rey Mangrove area. Each sub-unit is represented by a 0.5-ha plot.

Study of the mangrove spectra of Rio del Rey

Biological type spectra

The results of the analysis of the biological type of the forests (Table II) are taken in the Table VII. The importance of the mesophanerophytes (40%) and microphanerophytes (40%) for the raw spectrum is put in evidence. Also the weighted spectrum is dominated by the mesophaneropytes that reaches 99.24% of the relative dominance. The geophyte rhizomatous, Nanophanerophytes and Chamephytes erected are least represented in terms of relative dominance.

Table VII. Biological type spectra.

Life-form types	Raw spectrum		Weighted spectrum	
TB	Number of species	Percentage (%)	Basal area	Relative dominance
Mesophanerophytes (me)	6	40	343.1	99.24
Microphanerophytes (mi)	6	40	1.98	0.57
Nanophanerophytes (Nan)	1	6.67	0.055	0.016
Géophyte rhizomateux(Gr)	1	6.67	0.58	0.17
Chamephytes erected (ch)	1	6.67	-	-
Total	15	100	345.72	100

Spectrum of diaspore types

The table VIII summarizes the results of the analysis of the types of diaspores as presented in the Table II. The importance of the pleochore for the raw specter (26.67%), the weighted specter (0.19%) and pterochore for the raw specter (26.67%), the weighted specter (0.52%)are put in evidence.

Spectrum of leafy types

The results of the analysis of the foliar size types are presented in table IX. The raw spectrum is largely dominated by mesophyll and Macrophyll species (33.33% respectively). The microphylls coming in 3rd position (26.67% for the raw spectrum). The megaphylls come in last position for the relative spectrum of the basal area with 0.17%.

Table VIII. Diaspore types spectra.

Types of diaspores	Raw spectrum		Weighted spectrum	
	Number of species	Percentage (%)	Basal area	Relative dominance
Sarcochore (Sar)	2	13.33	57.4	16.6
Ballochore (Ball)	2	13.33	281.97	81.56
Pterochore (Ptero)	4	26.67	1.81	0.52
Barochore (Bar)	3	20	3.93	1.14
Pleochore (Ple)	4	26.67	0.65	0.19
Total	15	100	345.76	100

Table IX. Leaf size spectra.

Leaf size types	Raw spectrum		Weighted spectrum	
	Number of species	Percentage (%)	Basal area	Relative dominance
Mesophyll (Mes)	5	33.33	340.62	98.53
Megaphyll (Mega)	1	6.67	0.58	0.17
Macrophyll (Mac)	5	33.33	0.52	0.15
Microphyll (Mic)	4	26.67	4.00	1.16
Total	15	100	345.72	100

Phytogeographic groups

The distribution of species on the 7-ha area surveyed was done according to Schnell (1970) and White (1983) classification. Different groups based on this classification were distinguished (Table X). In all, we observed a great predominance of the Pantropical species in the raw spectrum (40%) with only 1.35% in the weighted spectrum. Then followed by the Afro- American (Aam,33.33%) species, the Afro-tropical species (At, 20%) and the paleotropical (pal, 6.67). All species are widely geographically distributed. The species repartition is therefore discontinuous throughout the world.

Ecosociological affinities

Regarding at the phytosociologic aspect, the different taxa are shown in table XI. A Strong proportion of the species belongs to the mangrove forests groups (*Avicennio-Rhizophoretea* Schnell 1952 *sensus larto,* 66.67%) associated with marine alluvium regularly or frequently bathed in salt water. The other species are features of the edaphic forests link to hydromorphic soils (*Mitragynetea* Schmitz 1963, 26.67%) and rainforests (*Strombosio-Parinarietea* Lebrun and Gilbert 1954, 6.67%).

Table XI. Ecosociological affinities in the Rio del Rey mangrove.

Phytosociological groups	Raw spectrum		Weighted spectrum	
Avicennio-Rhizophoretea Schnell 1952 (Av-rh- 10)	10	66.67	341.48	98.77
Mytragynetea Lebrun et Gilbert 1954 (Mytr-4)	4	26.67	0.31	0.09
Strombisio-Parinarietea Lebrun et Gilbert 1954 (St-pa-1)	1	6.67	3.77	1.09
Total	15	100	345.56	100

Ecological groups

The study of the environment makes it possible to define characteristic species. They are first indicator species of the station before being those of the association (Duchaufour, 1948) the characteristics of the association by the identity of their requirements is an association that reflects the local environment (Villiers, 1973; Guillaumet, 1687). Schnell (1970) recognizes 7 ecological groups with a remarkable tendency towards monospecificity. We will be interested in the ability to supersede the submergence of a 4 of them.

(a)Ecological groups with high submersion: 30 <tide <180cm

Group 1: very hydrophilic (60 <tide <180 cm) only on vase, *Rhizophora racemosa* (to which we add *Rhizophora mangle*).

Group 2: mesohydrophilic (15 <tide <60 cm) on bedrock, *Laguncularia racemosa*.

Group 3: mesohydrophilic substrate with coarse grain size, *Avicennia germinans*.

b) Ecological groups that do not withstand heavy submersion: tide <15 cm

Group 4: low amplitude of submersion (5 <tide <15 cm.) on psammo-vasophilic substrate. Coarse granulation (pebbles). *Paspalum vaginatum*.

Group 5: psammophile with very low amplitude of submersion (tide <5 cm). *Acrostichum aureum*.

Group 6: mesosaxiphile with low amplitude of submersion. (5 <tide <10 cm); *Philixerus vermicularis* (species not found in this study).

Group 7: saxiphile with very low amplitude of submersion (tide <5 cm). Conocarpus

Groups 8: on sandy coastlines. *Carapa procera*, *Dalbergia escastaphyllum, Nypa fruticans, Pterocarpus santalinoides* and *Syzygium guineense var*. littoral of brackish waters and rivers.

Group 9: Species at the tide limit on estuarine shores. A vegetation corresponding to a less saline and characterized by the presence of continental species making a transition towards certain hygrophilous groups of dry land *Alchornea cordifolia*, *Pandanus candelabrum*, *Pterocarpus santalinoides*. The submersion even lowervalie of 0-5 cm. This part of mangrove is on fine vase very furnished flush of water at high tide.

Characterization of Rio del Rey mangrove vegetation groups

Determination of plant groupings

Starting from the matrix of 14 surveys and 15 identified species, four groups were highlighted on the basis of the relative frequencies of the species (Fig. 6). The level of 0.36% (Bray Curtis) of dissimilarity considered for the definition of these groupings made it possible to obtain the maximum possible. The criterion of the stratification of the surveys and the realities of ground guided the determination of the zone of vegetation corresponding to each of the four individualized groups.

- Grouping with *Rhizophora racemosa* and *Pandanus candelabrum*; it corresponds to the vegetation of the upper outer mangrove zone bordering the estuary (Gr 1).
- Grouping with *Acrostichum aureum*, *Avicennia germinans* and *Rhizophora* spp. *Rhizophora racemosa* and *Rhizophora mangle*, which corresponds to the vegetation of a mangrove swamp between the mangrove and the mainland (Gr 2).
- Grouping with *Raphia palma-pinus*, *Avicennia germinans* and *Rhizophora* spp.,

corresponding to the vegetation of an intermediate mangrove of brackish water (Gr 3).

- Grouping with *Conocarpus erectus*, *Avicennia germinans* and *Rhizophora* spp.: it corresponds to the zone on the periphery of the mangrove in contact with the mainland only reached by the high tides and where the periophthalmus (*Perophtalmus koeleureri* Pallas) (Gr 4) live in abundance.

Dendrogram

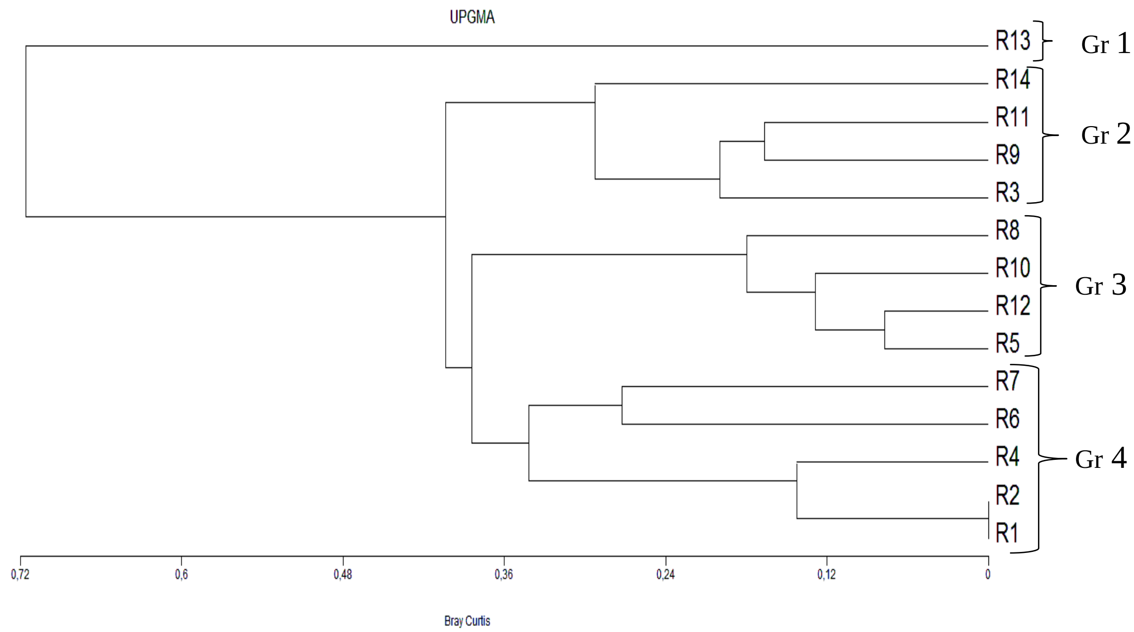

Fig. 6: Disposition of the four individualized groups in the mangroves of the Rio del Rey estuary of South Western Cameroon.

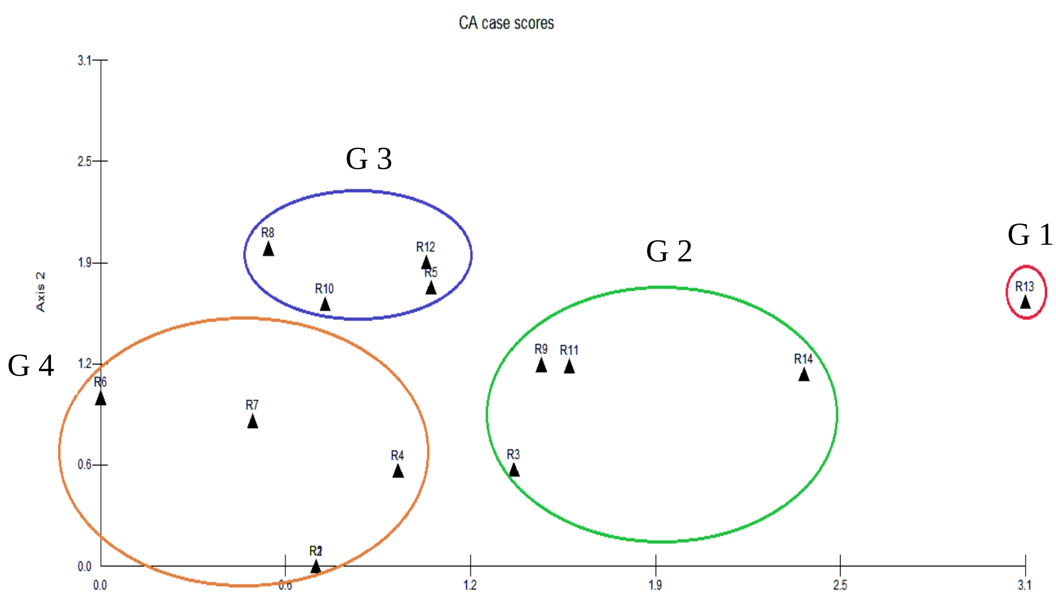

Fig. 7: Representation of the distribution of plant groups in the plan of axes 1 and 2 of the PCA. Axis 1 represents the degree of salinity of the seawater while axis 2 expresses the increasing gradient of submersion by the tides.

Ecological determinism of individualized plant communities

The spatial distribution of the individualized groups is shown in Fig. 7. The ecological significance of the two axes is explained by the field observations, the stratification of the surveys and the ecology of the characteristic species.

Thus, on the positive side of the axis 1 (on the abscissa), on the edge of the negative side and on the positive side of this same axis, distribute the readings (R1, R2, R4, R6 and R7) forming the grouping 4. The R6 survey carried by the ordinate axis, thus located at the point "0" of the abscissa axis, shows that the hygrophilous subgroup (R6 and R7) to *Conocarpus erectus* is in contact with dry land. It is only reached by high tides and retains little or no tidal water. The salinity level of the water is at zero level. On the same side of the axis (between 0.8 and 1.2) are placed on the surveys (R5, R8, R10, R12) forming group 3 (brackish water), with slightly salty waters; and group 2 (between 1.2 and 2.5), making the transition from mangrove to dry land with slightly saltier waters. The group 1 corresponds to the zone of high mangroves with higher salinity. Evidently, the axis 1 thus expresses a growing gradient of saltwater from these coastal areas bordering mangroves to the beaches.

Likewise on the positive side of the axis 2 (on the ordinate) are the surveys forming the group 4 of the mangrove in contact with the mainland. The influence of the tides there is little felt and becomes zero as the survey R2 is carried on the abscissa axis, therefore located at the zero point of the ordinate axis. In the same way, the group 2 with *Raphia palma-pinus* is projected between 0.2 and 1.9 on the ordinate axis. The raphial breaks and slows down the magnitudes of the tides by their stems and their leaves in height and by their roots in hairy clumps or pneumatophores on the edaphic level.

The group 1 is projected at point 1.9 on the Y-axis, at a submersion level higher than groups 4 and 2. The group 3 brackish water projects between 1.8 and 2.4 of axis 2, the highest level of the 4 groups of vegetation studied in this work. It is bathed by fresh water in river mouths which, due to its lower density, flows over salt water and amplifies the depth of submerged water. Evidently, the axis 2 expresses the increasing gradient of submergence depth.

Biological diversity of plant groups

The values of the Margalef index show that the group 2 corresponding to the transition between the mangrove and the mainland, the group 3 of the brackish water and the group 4 in land contact are floristically more diversified than the group 1 corresponds to the area of high mangroves with higher salinity. For these groupings, the value of the Margalef index is higher (RMg = 0.8) than that of group 1 (0.5). The values of the Pielou index are greater than 0.5 for all groupings 3 and 4. This means that in both groupings, the species share the ecological riches relatively equitable. The values of total species richness and other indices of diversity and equitability are provided in Table XII.

Table XII. Biodiversity index of plant communities in the Rio del Rey estuarine mangrove.

Grouping	Number of samples	RS	H'	RMg	R	Δ' Simpson
Total grouping	14	19308	1.81	1.3	0.48	0.34
Grouping 1	1	478	0.75	0.5	0.48	0.77
Grouping2	4	7456	1.65	0.8	0.43	0.36
Grouping3	4	7029	1.65	0.8	0.55	0.35
Grouping4	5	4345	1.99	0.8	0.66	0.34

S: specific wealth ; H ': Shannon-Weaver diversity index; RMg: Margalef diversity index; R: Pielou's fairness index.

The degree of similarity between the five plant groups compared two by two by the Sorensen similarity index is shown in table XIV. The floristic affinity between the four groups is in all cases less than 50%. This shows that each individualized group is a relatively distinct unit from the others.

Table XIII. Sorensen similarity values (in %) between pairs of Rio del Rey estuary mangrove vegetation groupings

	Grouping 1	Grouping 2	Grouping 3	Grouping 4
Grouping1	100	50	33.3	16.7
Grouping2	50	100	75	50
Grouping3	33.3	75	100	62.5
Grouping4	16.7	50	62.5	100

Class of *Avicennio-Rhizophoretea* Schnell 1952, represented by all the halophile groups of the intercotidal zone with *Avicennia germinans*, *Rhizophora racemosa*, in West Africa. According to Schnell (1952), only one species of *Rhizophora*: *R. racemosa* G. F. W. Mey. equivalent of *Rhizophora mangle* South America is found in all the mangroves of West Africa. Later studies describe the two species of Rhizophora (*R. racemosa* and *R. mangle*) in the mangroves of the sub-element of Central Africa Atlantic (Letouzey, 1968). We keep the same nomenclature (*Avicennio-Rhizophoretea* Schnell, 1952) to designate the class of mangroves in this study.

Order of Avicennio-Rhizophoretalia (Lebrun and Gilbert, 1954). This order of mangroves defined by Lebrun and Gilbert (1954), groups various shrubs or pre-forest formations that belong to the same syngenetic series with various types of transition between the mangroves properly so called and the marsh or inundable forests. Among the characteristics of the order of the *Avicennio-Rhizophoretalia* (Lebrun and Gilbert, 1954). We note the following essential elements: *Avicennia germinans* and *Rhizophora* spp.

***Alliance of Avicennio-Rhizophorion*all. nov.** This is the typical alliance chosen for the order of the *Avicennio-Rhizophoretalia* (Lebrun and Gilbert, 1954).

Four vegetation groups are found in the mangroves of the Rio del Rey estuary.

A) Rhizophora mangrove

The upper outer mangrove with large *Rhizophora racemosa* and *Pandanus candelabrum* along the estuaries grows up on the muddy plains bordering the coast and on the banks of estuaries and rivers where the tide rises. Its phytogeographical area in Cameroon is located along the Gulf of Guinea and in the Croos-river estuaries of Ndian and Wouri. The tree stratum reaches a 90-95% overlap. The dominant species is *Rhizophora racemosa*, a mesophanerophyte up to 15-30 m tall.

Table XV. Groupe 1: *Rhizophora racemosa* and *Pandanus candelabrum.*

TB	TD	TP	G eco	TF	*Rhizophoretum racemosae* Schnell1952 (*Avicennio-Rhizophoretea* Schnell 1952. *Avicennio-Rhizophoretalia* Lebrun et Gilbert 1954. *Avicennio-Rhizophorion* all. nov.)		
					Survey n°	R13	
					Strate arborescente %)	90	
					Number of species	5	
					Characteristics of the association and upper units		
						Number of individuals	**%**
me	Bal	At	Av-rh	mes	*Rhizophora racemosa*	417	87.24
me	Sar	Pal	mytr	mes	*Pandanus candelabrum*	27	5.65
					Compagn species		
Gr	Pleo	Pan	Av-rh	meg	*Acrostichum aureum*	21	4.39
me	Sar	At	Av-rh	mes	*Syzygium guinnensis var. littorale*	13	2.72
Ch-er	Pleo	Cosm	mytr	micr	*Paspalum vaginatum*	+	-
					Total	478	100

B) Vegetation with *Carapa procera* and *Acrostichum aureum*

It is a formation on the periphery of the mangrove. It is a transitional group which, without belonging to the class of *Avicennio-Rhizophoretea*, contains some species of the mangrove and constitutes the transition between this one and the vegetation of the land.

The group bears clumps of *Acrostichum aureum* related to the nature of the substratum; sandy soil containing an appreciable content of sand and gravel and constituting the driest part of the mangrove (Tardieu-Blot, 1964). It also bears species such as *Carapa procera*, *Dalbergia ecastaphyllum* shrubby thickets on sandy coasts. This *Acrosticumaureum* mangrove, *Rhizophora* spp. and *Carapa procera* of the estuary of Rio del Rey exists only in certain forms (peripheral or degraded) of the mangrove and seems to constitute a grouping to be revisited. The grouping is a shrubby curtain 6-8 meters high. The tree layer reaches a coverage of 60-65%. The dominant species are three mesophanerophytes. *Rhizophora racemosa* and *Rhizophora mangle* (8m), *Avicennia germinans* (5m) and *Carapa procera*.

Table XVI. Group 2: *Carapa procera* and *Acrostichum aureum*.

TB	TD	TP	G eco	TF	Vegetation with *Carapa procera* et *Acrostichum aureum*						
					Survey n°	R3	R9	R11	R14		
					Strate arborescente %)	75	85	90	90		
					Number of species	4	6	6	5		
					Characteristics of the association and upper units						
						Number of individuals				**Total individuals**	**%**
me	Bal	At	Av-rh	mes	*Rhizophora racemosa*	180	1973	542	702	3397	46.18
me	Bal	A-am	Av-rh	mes	*Rhizophora mangle*	252	1993	357		2602	35.37
me	Sar	A-am	Av-rh	mes	*Avicennia germinans*	42	600	205	275	1122	15.25
Gr	Pleo	Pan	Av-rh	meg	*Acrostichum aureum*		3	12	6	21	0.29
					Compagn species						
me	Baro	Pan	St-pa	mic	*Carapa procera*	33	120	2	28	183	2.49
mi	Pleo	Pan	Av-rh	mac	*Nypa fruticans*		6			6	0.08
na	Per	A- am	Av-rh	mes	*Dalbergia ecastaphyllum*			10		10	0.14
me	Sar	Pal	mytr	me	*Pandanus candelabrum*				15	15	0.20
					Total	507	4695	1128	1026	7356	100

C) Mangrove to *Avicennia and Rhizophora*: *Avicennio-Rhizophoretum* Schnell 1950

It is group 4 (Gr 4), characterized as a group on the periphery of the mangrove in contact with the mainland. It should be pointed out that the grouping at *Avicennia germinans* constitutes the secondary young mangroves on muddy soil. There is still *Conocarpus erectus*, which grows on the edge of the mangrove in contact with the mainland with gravel soil, coarse sand from brief, infrequent and shallow submersions. The grouping also exists on a thick layer vase temporally flooded. The tree layer has a coverage of 85 to 90%. Its phytogeographic area ranges from the coasts of Senegal to those of the Gulf of Guinea. The abundant and frequent species are *Avicennia germinans* and *Rhizophora* spp.

The R6 and R7 surveys with *Conocarpus erectus* thus concern the outer zone bordering the mangrove and the land boundary. In this zone, these records appear thus reconstituted an edaphic variation grouping with *Conocarpus erectus*.

Table XVII. Group 4: *Avicennio-Rhizophoretum* Schnell 1950.

TB	TD	TP	G eco	TF	*Avicennio-Rhizophoretum Schnell 1950 (Avicennio-Rhizophoretea. Avicennio-Rhizophoretalia. Avicennio-Rhizophorion)*							
					Survey n°	R1	R2	R4	R6	R7		
					Strate arborescente %	70	70	70	85	75		
					Number of species	4	4	3	6	5		
					Characteristics of the association and upper units							
						Number of individuals					**Total individuals**	**%**
me	Bal	At	Av-rh	mes	*Rhizophora racemosa*	118	130	274	511	544	1577	36.29
me	Bal	A-am	Av-rh	mes	*Rhizophora mangle*	109	119	545	335	222	1330	30.61
me	sarc	A-am	Av-rh	mes	*Avicennia germinans*	25	104	441	376	134	1080	24.86
mi	Ptéro	A-am	Av-rh	mes	*Conocarpus erectus*				115	64	179	4.12
					Compagn species							
mi	baro	Pan	My tr	macr	*Alchornea cordifolia*	37	31				68	1.57
mi	ptéro	A-am	Av-rh	micr	*Laguncularia racemosa*				96		96	2.21
mi	ptéro	Pan	Av-rh	mes	*Pterocarpus officinalis*				12		12	0.28
mi	Pléo	Pan	Av-rh	mac	*Nypa fruticans*					3	3	0.07
					Total	289	384	1260	1445	967	4345	100
						Association type : mangrove on fin vase			*sous-ass. Conocarpodetosum erecti*			

Discussion and conclusion

The individualized vegetation groups in the secondary mangrove of the Rio del Rey explain the spatial heterogeneity of this forest ecosystem. The analysis of this spatial heterogeneity shows that the secondary mangrove appears to consist of three edaphic variants: the drier part of the mangrove (group 2) has the characteristic of numerous clumps of *Acrostichum aureum,* a Pteridophyte of the family Adiantaceae (group 2).

A *Raphia palma-pinus* rear mangrove raphial is an area where the influence of tides and salt water is still felt. This brackish water palm is in a stand (group 3) which forms the mangrove in *Avicennia-Rhizophora-Raphia*. *Rhizophora-Acrostichum* is an edaphic variation of *Avicennio-Rhizophoretum* (sub-association *Acrostichetosum*). At the edge of the mangrove in contact with the mainland lives the grouping with predominance of *Conocarpus erectus* with only infrequent, shallow and brief submersions. Several species are common to it like *Laguncularia racemosa*. The *Avicennia-Rhizophora-Acrostichum* mangrove is an edaphic variation of *Avicennio-Rhizophoretum* (sub-association *Acrostichetosum erecti*).

The mangrove forest of the estuary of Rio del Rey presents and a varied organization. This characteristic, confirmed by the low values of the Sorensen index (Table XIII), had already been underlined by the studies on humid tropical forests carried out by Oldeman (1990). The Pielou equitability index values (Table XII) show that the species of the four plant groups share more or less equitably the biotopes.

This study made it possible to identify and characterize the vegetation groups forming the Rio del Rey mangrove vegetation. Compared with the results obtained, there are emerging research perspectives that should be undertaken in the near future.

These include:

- In-depth analysis of the life traits and ecology of the main mangrove tree species;
- In-depth study of the mechanisms of natural regeneration, mortality, growth and recruitment of tree species to better understand the natural renewal dynamics of the Rio del Rey mangrove.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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