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Diversity Shifts in the Mangrove Vegetation of the Rio del Rey-Estuary (Cameroon)

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Abstract: *Rio del Rey Estuary mangroves are the most widespread in Cameroon but remain poorly known. This study aims to determine changes in the floristic composition and structure. The survey was conducted in seven localities of the SW region. Transects were opened perpendicular to the main tidal channels. Sampling plots (25 m x 25 m) were established to evaluate the structure of the vegetation. All African Atlantic mangroves characteristics species are present. Rhizophora spp. predominate as in most African stands. Floristic diversity was low and varied according to localities. The Shannon diversity index H' ranged from 0.34 to 1.91 and the Margalef specific richness index varied from 1.08 to 4.45. The mean diameter was 20.38 ± 18.79 cm; and trees height ranged from 3.82 to 37 m. The absolute density was 934.19 ± 564.88 stem ha^{-1} and the basal area was 1.54 ± 0.99 m^2 ha^{-1}. In many cases, the diameter class distribution has shown characteristics of disturbed stands. The Newman-Keuls test has shown differences between plots. The sample unit sizes, the degree of vegetation evolution, the Nypa fruticans invasion and the anthropogenic activities extent affect significantly the characteristic of mangrove stands.*

Keywords: *anthropogenic activities, diversity, floristic composition, structural parameters.*

1. Introduction

Mangrove forests cover an estimated 152 361 000 ha of the tropical and subtropical shorelines of the world [1, 2, 3, 4] and deliver important ecosystem functions, goods and services [5, 6]. Therefore, any loss of mangrove forest means a loss of subsistence and cash-based livelihoods and ecological and conservation function [7]. However, as a consequence of enormous anthropogenic pressure and multiple threats, western African mangroves have declined by >25% over the past 25 years [4, 8] and 53.216 ha of the Cameroon's mangrove forests have been lost over the last 13 years [3, 9].

Although moderate natural expansion of mangrove has been reported in certain parts of the world [10, 11, 12], this phenomenon is relatively rare in Africa [13] where mangrove deforestation and degradation still appears to be dominant [1, 14, 15, 16]. It is now commonly recognized that mangrove wood harvesting is a core economic activity for coastal communities in Cameroon and the rest of Central and Western Africa [17, 18, 19, 20]. The unsustainable use of mangrove resources as a result of increasing population size and loss through ecosystems conversion for development activities is fragmenting and depleting this system on a large scale [21, 22].

Anthropogenic pressures combined with climate change and sea-level rise, urge the need to conserve, protect, and restore tidal wetlands [23, 24]. However, knowing the exact specific composition of mangroves in a country is important and is a prerequisite for understanding all aspects of the structure and function of mangroves as well as their bio-geographical affinity for their conservation and management [25].

Cameroon mangrove forests are divided into two major groups on which the Rio del Rey stands is the most widespread. These ecosystems do not take advantage of the biological diversity conservation laws, even for those that are located in a natural reserve. Due to the lack of policy regulation in the management of coastal ecosystems, anthropogenic activities play a major role in reducing mangrove biodiversity and provision of ecosystem services [20, 26, 27].

The development of strategies for sustainable management of these ecosystems requires a good knowledge of their structure, composition and ecology [28]. Actually, the mangrove ecosystem of the Cameroon estuary has been mainly studied [9, 18, 20, 27, 29, 30, 31, 32,33,34, 35, 36], but the Rio del Rey ecosystem remains poorly known because of the distance and especially the Bakassi border army conflict between Cameroon and Nigeria [37].

The recent end of the above conflict has favored the implementation of research surveys [19, 32, 38, 39, 40]. The structure and composition of the near shore mangroves have been affected by coastal erosion and climate change [32]. The last phenomenon is supposed to be worsen in mangrove ecosystem worldwide. Before estimating the impact of coastal hazards on the alteration of local ecosystems, the diversity of these areas must be known in order to prepare further adaptation measures. The objective of this study is to evaluate the spatial variation in the structure and the composition of mangrove vegetation between seven sites of the Rio del Rey estuary.

2. Material and Methods

2.1. Study Site

This study was carried out in seven localities of the Ndian Division in the South West Region (SWR) of Cameroon (Figure 1). The coastal border of the SWR falls along the Gulf of Guinea in Western Africa. The climate is an especial equatorial type strongly influenced by the proximity of Mount Cameroon (4 095 m), the highest peak in West and Central Africa. The average annual rainfall ranges from 5 000 mm to 10 000 mm with the number of rainy days' approaches 250 [37]. The mean annual temperature ranges from 25.5 °C to 27 °C [19, 37].

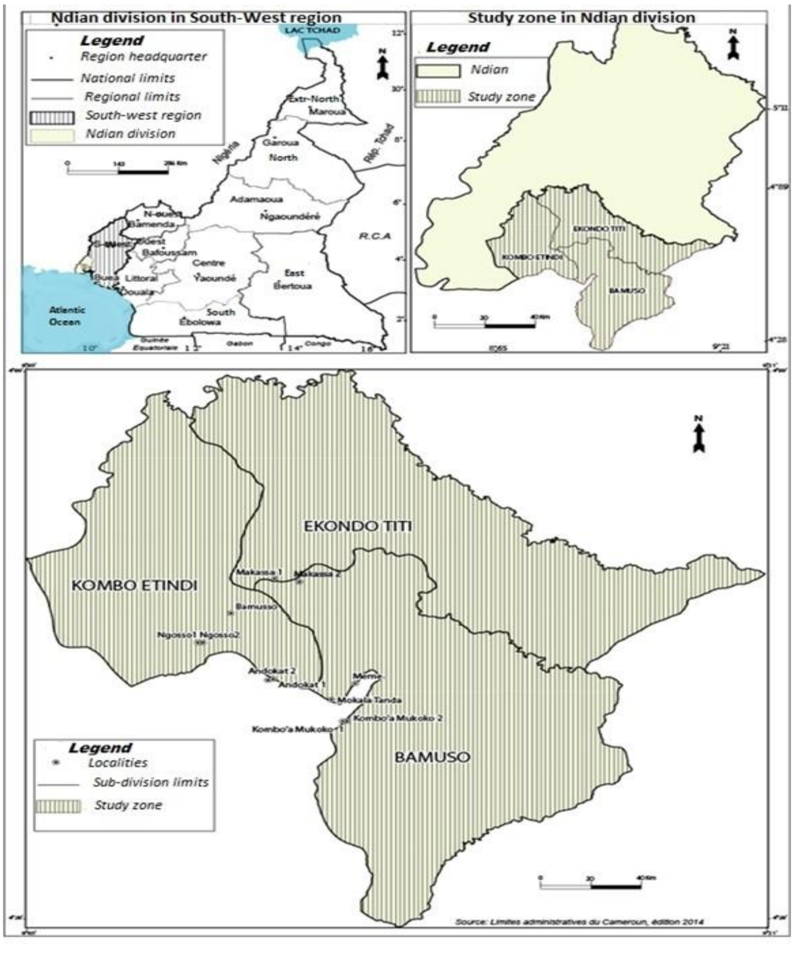

Figure1. *Localities of study in the mangroves of the Rio del Rey estuary*

2.2. Data Collection

In each locality, transects were opened perpendicular to the main channels, from water to landward in order to access homogenous stands of *Rhizophora* spp. and from land to water channels for assessing mixed vegetation stands. After this operation, all species along the trail have been identified and vegetation zone determined. Inside every homogenous band, a plot of 25 x 25 m^2 was established occupying each side of the trail evenly. The coordinates of each plot were recorded using a GPS "etrex Garmin".

According to the vegetation structure, eleven plots were established in Andokat (2), Bamusso (1), Kombo'a Mukoko (2), Massaka (2), Meme (1), Ngosso (2) and Mukala Tanda (1). Six of the plots were established in a homogeneous band of *Rhizophora* spp., four in a mixed zone of *Rhizophora* spp. and *Avicennia germinans*. The last plot in which *Rhizophora* was not present was examined to estimate the characteristics of the trees without the influence of the predominant species. All trees with stem circumference > 15 cm were sampled. The circumference measurements were taken over the stilt roots for *Rhizophora* trees and at 1.30 m above the ground for other tree species by using a plastic measure tape of 150 cm or 5 m. The previous operation was coupled with the measure of distance between neighboring trees with a decameter tape. Height measurements were conducted using Suunto Clinometer [19].

2.3. Data Analysis

Species richness indexes and structure parameters were calculated from field data using classic formula [9, 41]. Thus, the diameter (*D*), the absolute density (*Da*) and the basal area (*Ba*) were obtained from the tree circumference measures. Relationship between plant structural parameters (DBH, height, basal area, density, distance between trees) were establish. Regression equations were assessed using the number of individuals, the mean tree diameter, the mean distance between trees and the density of plots. The Newman-Keuls test was used to compare the structure of the diameters at different sites or plots. They were performed using STATISTICA 10 software.

3. Results and Discussion

3.1. Species Richness

The plant survey conducted in the open transects in each community permitted to identify 21 species and 19 genus belonging to 11 families (Table 1). The most represented family is Fabaceae (five species). Then comes Arecaceae, Combretaceae, Rhizophoraceae (three species) and finally seven families consist of a single species (Acanthaceae, Euphorbiaceae, Malpighiaceae, Malvaceae, Meliaceae, Pandanaceae and Pteridaceae). The distribution of species in communities occurs in localities as follows: 06 species (Andokat, Bamusso, Kombo'a Mukoko and Ngosso), 07 species (Massaka), 15 species (Mukala Tanda) and 18 species (Meme). The least diverse locality was Bamusso, while that of Meme had the greatest specific diversity.

Table1. *Distribution of species in the sample localities. And, Andokat ; Bam, Bamusso ; KoM, Kombo'a Mukoko; Mas, Massaka; Mem, Meme ; MuT, Mukala Tanda ; Ngo, Ngosso*

Species	Families	Localities						
		And	MuT	Mas	Ngo	Mem	Bam	KoM
Acrostichum aureum Linn.	Pteridaceae	●	●	●	●	●	●	●
Alchornea cordifolia Müll. Arg.	Euphorbiaceae					●		
Anthocleista vogelii Planch.	Combretaceae					●		
Avicennia germinans (L.) Stearn	Acanthaceae	●	●	●		●		
Carapa procera DC	Meliaceae		●					
Conocarpus erectus Linn.	Combretaceae		●			●		
Cynometra mannii Oliv.	Fabaceae					●		
Dalberbia ecastaphyllum Taub.	Fabaceae	●	●	●	●	●	●	●
Drepanocarpus lunatus G. F. Meyer	Fabaceae		●			●		
Guibourtia demeusei J. Leonard	Fabaceae		●					
Heteropteris leona (Cav.) Exell	Malpighiaceae					●		
Hibiscus tiliaceus Linn.	Malvaceae		●			●		
Laguncularia racemosa Gaertn.	Combretaceae					●		
Nypa fruticans (Thurnb.) Wurmb.	Arecaceae	●	●	●	●	●	●	●
Ormocarpum verrucosum P. Beauv.	Fabaceae					●		
Pandanus sabatiei Huynh	Pandanaceae		●					
Phoenix reclinata Jacq.	Arecaceae		●			●		
Raphia palma-pinus Hutch.	Arecaceae		●			●		
Rhizophora harrisonii Leechman	Rhizophoraceae		●	●	●	●	●	●
Rhizophora mangle L.	Rhizophoraceae	●	●	●	●	●	●	●
Rhizophora racemosa Meyer	Rhizophoraceae	●	●	●	●	●	●	●

Floristic composition varies. Indeed, the inventory in communities makes it possible to identify globally not only the 06 species reported by [1] and 07 characteristic species highlighted by many authors for the mangroves of Cameroon [3, 37, 42, 43], but also the presence of accompanying species that some authors call related species. In addition, by including species not mentioned by [1], *Acrostichum aureum*, which is present and common in Cameroon mangroves, low species richness of Cameroon mangroves remains a reality. This situation was confirmed in this survey by a low index of specific richness of Margalef (S) which varies from 0.23 to 4.4 and a low Shannon diversity index (H') which ranged from 0.35 to 1.91.

However, [29], justify the low diversity of the African Atlantic mangroves in that it could be related to a definition that does not analyze in an objective manner, the flora evolution in all regions. These authors and others [44, 45, 46] add that no doubt hangs over membership of the mangrove species that [47] calls as major, but the exclusion of several species of this vegetation still lacks conclusive scientific evidence and confirms the lack of consensus expressed by some authors on their classification [44, 46, 48, 49, 50].

In addition, the predominance of the genus *Rhizophora* spp. with 85.82%) (351 individuals) but also the species *Avicennia germinans* which represents (12.47%) (51 individuals) confirms that the genera *Rhizophora* and *Avicennia* are most dominant in stands of mangroves in the world [51]. These two species represent 98.29% (402 individuals on 418 inventoried). Also, the percentage occupied by *Rhizophora* spp. corroborates with some authors who believe that this genus is most numerous in the Cameroon mangroves [1, 13, 18, 52, 53].

3.2. Structure Parameters

There is a variation of the structure parameters in the different stands (Table 2). In the plots of the monospecific *Rhizophora* spp. stand, the mean density (744 ± 386 stem ha^{-1}) and the mean diameter of the individuals (15.61 ± 5.44 cm) were low. Also, the mean height was (11.62 ± 3.51 m) and the mean distance between the trees was 2.98 ± 0.54 m. In mixed vegetation of *Rhizophora* spp. and *A. germinans*, the mean density (444 ± 160 stem ha^{-1}) was low but the mean diameter of the individuals (35.17 ± 11.82 cm) was very high. Meanwhile, the mean height was (21.19 ± 5.76 m) and the average distance between the trees (4.89 ± 1.33 m) was also high. For the plot where *Rhizophora* spp. was absent, the structural parameters also differ from those of the first and second stands. The density (448 stem ha^{-1}) was low whereas the mean diameter of individuals (26.76 ± 26.84 cm), the average height (15.74 ± 8.89 m) and the mean distance between the trees (3.77 ± 2.56 m) were high.

The regression analysis has shown that there is a strong positive relationship between the mean diameter and the mean height of the trees (R^2 = 0.9369, n = 11), and the regression equation generated is of the type $y = 9.5103x - 11.586$. There was also a relationship between mean height and mean diameter (R^2 = 0.9777, n = 11) and the regression equation generated is of the type $y = 0.5005x + 3.5991$. Furthermore, the regression analysis shows also a negative relationship between the mean diameter and the number of individuals and between the mean distance and the density (Figure 2).

Table2. *Structural attributes of the mangroves of the Rio del Rey estuary. Lat, Latitude; Lon, Longitude; NI, Number of individuals; NS, Number of species; MDis, Mean distance (m); MDia, Mean diameter (cm); MHei, Mean height (m); Den, Density (stem ha^{-1}); BA, Basal area (m^2 ha^{-1})*

Sites of plots	Coordinates		NI	NS	MDis	MHei	MDia	Den	BA
	Lat. N	Lon. E							
Ngosso 1	4°33'52.23"	8°47'13.35"	31	1	3.47	14.54	22.28	496	1.21
Ngosso 2	4°33'50.82"	8°47'12.49"	40	1	3.58	10.53	15.02	640	0.71
Bamusso	4°35'33.15"	8°48'50.10"	96	1	2.36	9.69	11.95	1536	1.08
Kombo'a Mukoko 1	4°28'57.54"	8°54'5.78"	19	1	2.13	5.77	6.52	304	0.06
Kombo'a Mukoko 2	4°28'59.91"	8°54'4.31"	44	1	3.23	16.67	21.63	704	1.62
Massaka 1	4°38'02.1"	8°50'50.2"	35	2	3.27	14.38	20.29	560	1.02
Massaka 2	4°37'58.7"	8°52'18.6"	49	1	2.97	12.52	16.29	784	1.13
Andokat 1	4°31'38.3"	8°51'24.4"	16	2	5.51	25.74	45	256	2.54
Andokat 2	4°31'38.3"	8°51'24.4"	20	2	6.64	27.94	48.4	320	3.68
Meme	4°31'25.5"	8°54'25.2"	40	2	3.96	16.70	27.01	640	2.29
Mukala Tanda	4°30'20.6"	8°53'42.4"	28	4	3.74	15.74	26.76	448	1.57

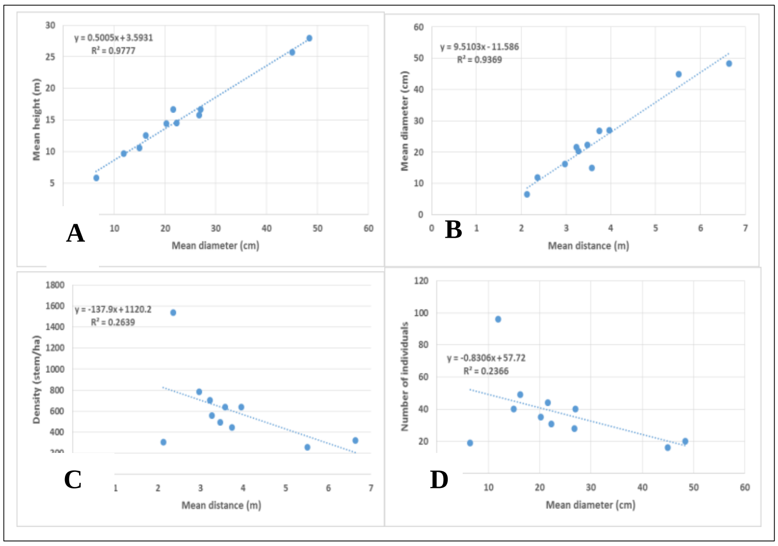

Figure2. *Relationship between some structure parameters:* ***A,*** *mean height vs. mean diameter;* ***B,*** *mean diameter vs. mean distance;* ***C,*** *density vs. mean distance;* ***D,*** *number of individuals vs. mean distance. The equation and the correlation coefficient (R^2) are given in each case*

The basal area as well as diameter is a good parameter to express the level of development of a stand [54]. In monoculture plots of *Rhizophora* spp., structural parameters are variable. The density and the basal area varied from 304-1536 stem ha^{-1} and from 0.06 to 1.62 m^2 ha^{-1} respectively. In mixed plots of *Rhizophora* spp. and *A. germinans*, structural attributes ranged from 256-640 stem ha^{-1} for the density and the basal area of 1.13 to 3.68 m^2 ha^{-1}. In the plot where the predominant species *Rhizophora* spp. is absent, the density is 448 stem ha^{-1} and the basal area of 1.57 m^2 ha^{-1}. Overall, the structural parameters are close to those obtained by [38] in the mangrove of Bamusso in Cameroon. On the other hand the results of the densities and the basal areas were lower than those obtained by [19] in the mangroves of SW Cameroon. Our results of these two structural parameters are also lower than those obtained by [55] in mangroves of Tudor Creek in Kenya and those of [56] in the mangroves of India.

In some plots of pure stands of *Rhizophora* spp., analysis of the distribution of diameter classes shows a disturbed stand. Some classes are absent and young individuals are not always the most abundant. In plots of mixed stands and in those where the predominant species was not present (Masaka 1, Andokat 1, Andokat 2, Meme and Mukala Tanda), all classes are present but younger individuals are not always the most represented (Figure 3). Theoretically, in an uneven-aged forest there is a normal series of age-gradations, depicted by the reversed J curve [55]. This normal situation in size classes is observed in our survey only on the site of plot Bamusso. The distribution of diameter size classes in the ten other sites of plots indicates a forest disturbance regime according to direct needs by the people. According to [55], this forest disturbance revealed a lack of a harvesting plan, resulting in a haphazard spatial distribution of different size classes, with a highly selective graphical frequency distribution. Likewise, as a consequence of tree harvesting, the proliferation of *Nypa fruticans* induced the disturbance of the vegetation structure of the Cameroon mangroves [37].

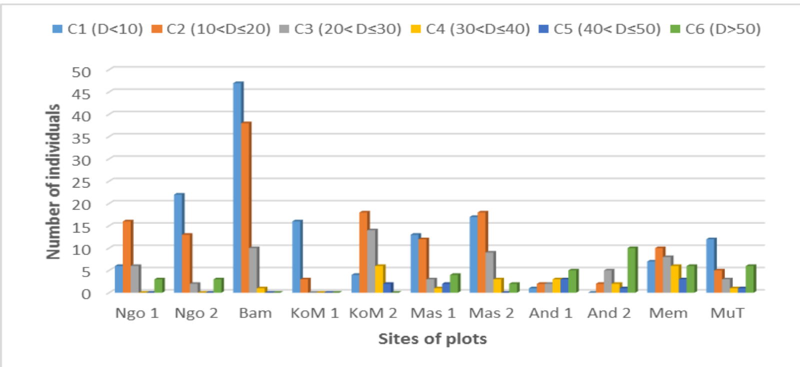

Figure3. *Number of individuals per diameter class in the sites of plots. And 1, Andokat 1; And 2, Andokat 2; Bam, Bamusso; KoM 1, Kombo'a Mukoko 1; KoM 2, Kombo'a Mukoko 2; Mas 1, Massaka 1; Mas 2, Massaka 2; Mem, Meme; MuT, Mukala Tanda; Ngo1, Ngosso 1; Ngo 2, Ngosso 2*

In the monospecific plots of *Rhizophora* spp., the mean diameter is low (15.61 ± 5.44 cm). There are very few trees with a large diameter (D>20 cm) that close the opening of the canopy. In addition, there is strong intraspecific competition that limits the density of individuals at the adult stage. It is noted that individuals of class I (D<10 cm), with a proportion of 44.81%, are by far the most dominant of the diametric structure of this stand. In contrast, in mixed plots of *Rhizophora* spp. and *A. germinans*, the mean diameter is great (35.17 ± 11.83 cm). Trees with large diameters (D>20 cm), with a proportion of 63.33%, are the most dominant of the diametric structure of this stand. In the plot where the predominant species is absent, the mean diameter is large (26.76 ± 26.35 cm). Despite the presence of a few stem of *Drepanocarpus lunatus* and *Pandanus candelabrum*, trees with large diameters (D>20 cm), with a proportion of 33.33%, are not the most dominant of the diametric structure of the stand.

Allometric relationships in the mangroves are of considerable interest [30]. The present study has shown strong positive relationships on the one hand between mean diameter and mean distance of the trees and on the other hand between mean height and mean diameter.

Statistical analysis of the diameter distribution showed that sites of plots 8 (Andokat 1) and 9 (Andokat 2) are significantly different from other. Thus, F (10, 407) = 15.445 at p = 0.0000. Otherwise, the block 1 (Ngosso 1, Ngosso 2, Bamusso and Kombo'a Mukoko 1), block 2 (Kombo'a Mukoko 2, Massaka 1 and Massaka 2) and the block 4 (Meme and Mukala Tanda) are different (Figure 4). But the 'Newman-Keuls post hoc test' showed that they are not significantly different; meanwhile, this test confirms that the blocks 1, 2 and 4 are significantly different from block 3.

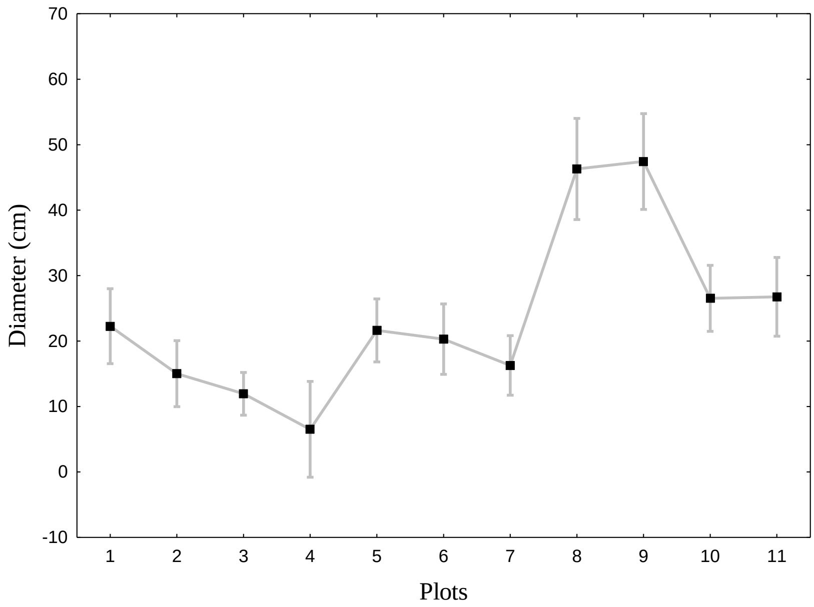

Figure4. *Analysis of diameter distribution in the Rio del Rey estuary mangroves.* ***1****, Ngosso 1;* ***2****, Ngosso 2;* ***3****, Bamusso;* ***4****, Kombo'a Mukoko 1;* ***5****, Kombo'a Mukoko 2;* ***6****, Massaka 1;* ***7****, Massaka 2;* ***8****, Andokat 1;* ***9****, Andokat 2;* ***10****, Meme;* ***11****, Mukala Tanda*

The variations of diameter distribution, density and basal area are explained by the combination of some environmental factors such as erosion and sedimentation and the type of mangroves sampled. In addition, human activity mainly induce the variation of these parameters. It comes down by the collection of firewood and timber, construction of huts like in the Wouri estuary mangrove [37] and the settlement of some fisheries. In the monospecific stand, intra-specific competition prevent a large number of young plants reaching the mature age and canopy closure is a limiting factor for the growth of individuals [55]. This phenomenon is also observed in the Wouri estuary mangroves [18, 20, 37].

Also, according to [19], selective logging of the species of a certain diameter and even some species according to the needs of residents can consistently interpret the diametric structure and that of other parameters. For [57], mangrove destruction appears in South-east Asia generally as the result of their use for aquaculture, agriculture, the extension of the village, eco-tourism. Particularly in Thailand, the culture of shrimp is the leading cause of mangrove destruction [58, 59].

4. CONCLUSION

The floristic inventory of the Rio del Rey estuary mangroves has highlighted seven major species of African Atlantic mangroves and fourteen accompanying species. The Fabaceae family is the most represented and the locality of Meme is the most diverse. The basal area is low and ranges from 0.06 to 3.68 m^2 ha^{-1}. The absolute densities varied from 256 stem ha^{-1} to 1536 stem ha^{-1}. Analysis of structure parameters shows differences in the sites of plots. These variations are explained by a combination of environmental factors, type of sampled mangroves and the degree of evolution of the stands. From the data of this survey, management strategies shall be implemented to boost the ecosystem resilience to both anthropogenic and climate change stressor expected in the Rio del Rey estuary mangroves. It would be useful to assess the temporal dynamics of this ecosystem and implement conservation measures to regulate human activities which are sum to logging activities and the setting of fisheries and to mitigate the impact of climate change.

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