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FLORISTIC COMPOSITION AND STAND STRUCTURE OF THE MANGROVE FOREST IN CROSS RIVER STATE, NIGERIA

Egor B. Etigale[1], Oluwayinka S. Oke[2], Shadrach O. Akindele[2], Victor A. J. Adekunle[2] and Opeyemi Olajide[1]
[1]Department of Forestry and Wildlife, Faculty of Agriculture, University of Uyo, Uyo, Nigeria
[2]Department of Forestry and Wood Technology, School of Agriculture and Agricultural Technology, The Federal University of Technology, Akure, Nigeria
Email: egoretigale@uniuyo.edu.ng

ABSTRACT
The mangrove forest in Cross River State was assessed for information on its current plant species composition and density as well as trees stem-diameter distribution. Simple random sampling technique was used to select ten sample points on a gridded map of the mangrove forest. The ten selected sample points were located on the ground using their coordinates. At each sample point, one cluster consisting of five 20 m x 20 m nested plots laid alternately at 20 m intervals along a 200 m long transect was established. At the centre of each plot, a 2 m x 2 m quadrat was established as a nest. All living trees, shrubs and palms (with erect stems) ≥ 5cm in dbh were identified, counted and measured in the 20 m x 20 m plots, while trees' and palms' juveniles (<5cm in dbh), *Acrostichum aureum*, *Nypa fruiticans* fronds and their stumps were identified and counted in the 2 m x 2 m quadrats. The data were analysed using Microsoft Excel. A total of 22 plant species, belonging to 20 genera and 15 families were encountered in this study. These consisted of 15 species of trees, 2 species of shrubs, 4 species of palms and 1 species of ferns. *Nypa fruticans* was the most abundant species in the area. Total number of adult trees recorded was 547. *Rhizophora racemosa* (156), with a population density of 78 stems per hectare was the most abundant tree species. The stand structure showed an inverse J-shaped diameter distribution pattern.

Keywords: *species Composition, Density, Trees Stem-Diameter Distribution, Mangrove Forest, Cross River State.*

INTRODUCTION
Mangrove is a unique ecosystem that constitutes just 0.1% of the earth's continental land surface (Giri *et al*., 2011), about 0.5% of the world costal

area (Alongi, 2014; Nwobi and Williams, 2021), 0.4% of the world's forested areas (FAO and JRC, 2012) and 0.7% of the tropical forest areas (Donato *et al*., 2011), yet they are very important ecological and socio-economic resource. These keystone coastal ecosystems link terrestrial and aquatic environments, thus providing numerous key ecosystem services which are ecologically, economically and socially important at local, regional and global scales (Kauffman and Donato, 2012; Cohen *et al*., 2013; Feliciano *et al*., 2014). These services include sediment and nutrient retention, erosion control, coastal protection from storms and tsunamis (Giesen *et al*., 2007; Mitsch and Gosselink, 2007; Alongi, 2008; Alongi, 2009; Barbier *et al*., 2011; Zhang *et al*., 2012a). It also regulates water quality, provides breeding and rearing habitats for many species of fish and shellfish, wood and other forest products for local populations, and harbours unique biodiversity, including many rare and endangered species (Duke *et al*., 2007; FAO, 2007; Giri *et al*., 2011). Due to their high productivity, large ecosystem carbon stocks and unique location at the interface of land, coasts and watersheds, which allows them to minimize climate-change induced detrimental impacts of sea level rise, salt-water intrusion and tidal surges, mangrove ecosystems play very significant roles in climate change mitigation (Barbier *et al*., 2011; Camacho *et al*., 2011). Their conservation and sustainable management can contribute significantly in reducing greenhouse gas emission (Jerath, 2012).

Despite their ecological and socio-economic importance, mangrove forests and their services are seriously threatened by anthropogenic disturbances and climate change effects (Alongi, 2002). The high rate of their destruction far exceeds those of upland forests (Valiela *et al*., 2001; Langner *et al*., 2007). In Nigeria, the increasing human population in and around the mangrove forest areas has led to the conversion of some mangrove areas to urban spaces and agricultural lands. In the western lagoons, large areas of mangrove have been lost to urban and agricultural expansions (Spalding *et al*. 2010). Chima and Olarinde (2016) observed that building of settlements, public facilities and infrastructures as well as large scale fish farming have led to degradation and destruction of large areas of mangrove forest in the Niger Delta region. Babalola *et al*. (2016) noted that even the remaining parches of mangroves have been degraded through various anthropogenic activities. Information on species composition of mangrove forest ecosystems is important for describing and evaluating their ecological conditions. Forest stand structure is useful in assessing stand stability, evaluating potential forest sustainability and planning of silvicultural treatments (Carretero and Alvarez, 2013; Aigbe and Omokhua, 2014). Thus, it provides the basic information for sound decision-making to enhance the sustainable management of forest stands. It is commonly described by stem diameter size-class distributions, which shows the distribution patterns of the numbers, basal areas, volumes and biomasses of trees among the size-classes. Therefore, survey of the mangrove forest in Cross River State is needed to obtain necessary information on its current stand composition and structure for monitoring its status and trends and implementing sound forest management interventions that will help to maintain and enhance its ecological and socio-economic benefits to mankind.

MATERIALS AND METHODS

Study Area

The study was conducted in the mangrove forest of Cross River State, which is part of the large eastern block of mangrove forests in Nigeria. The area is located between latitudes 4°41′30″ and 5°03′20″N, and longitudes 8°06′10″ and 8°35′05″E. It extends eastwards from the Cross River estuary to the Nigeria boundary with Cameroon, reaching 7-8 km in width and stretching inland into the estuary for about 26 km (FAO, 2005). The mangroves in this area cut across Odukpani, Calabar South, Akpabuyo and Bakassi Local Government Areas of Cross River State (Figure 1). .

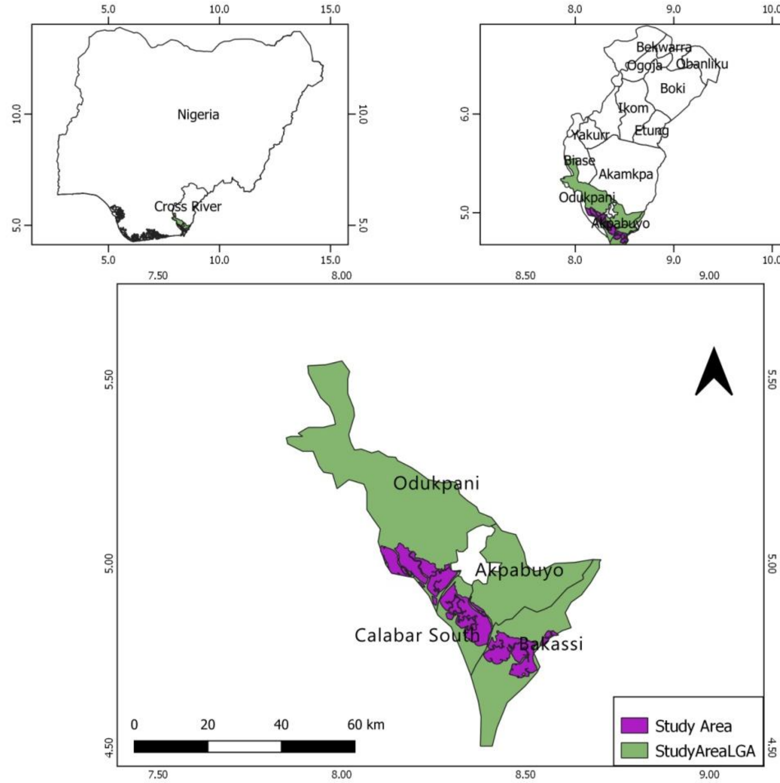

Figure 1: Map showing the location of mangrove in Cross River State with maps of Nigeria and Cross River State inset

Sampling Techniques

The mangrove forest was sampled for an assessment of its stand composition and structure. A gridded map of the area was prepared from the vegetation map of Cross River State. The intersections of the grid lines were clipped to form sampling points on the map. Simple random sampling technique was used to select ten points for the study. The coordinates of the ten selected sample points were obtained on the map and used to locate them on the ground. At each location, a cluster was laid. A cluster consisted of one 200 m long transect laid in the South-North direction, with five nested square plots laid alternately at 20 m interval on either side of the transect. Each of the nested sample plots consisted of two nests, namely, a 20 m x 20 m plot and a 2 m x 2 m quadrat at the centre of the 20 m x 20 m plot. In all, 10 transects, with a total length of 2000 m (10 x 200 m), 50 sample plots of 20 m x 20 m, with a total area of 20000 m^2 (50 x 400 m^2) and 50 quadrats of 2 m x 2 m, with a total area of 200 m^2 (50 x 4m^2) were laid. The design of the field plot is shown in Figure 2.

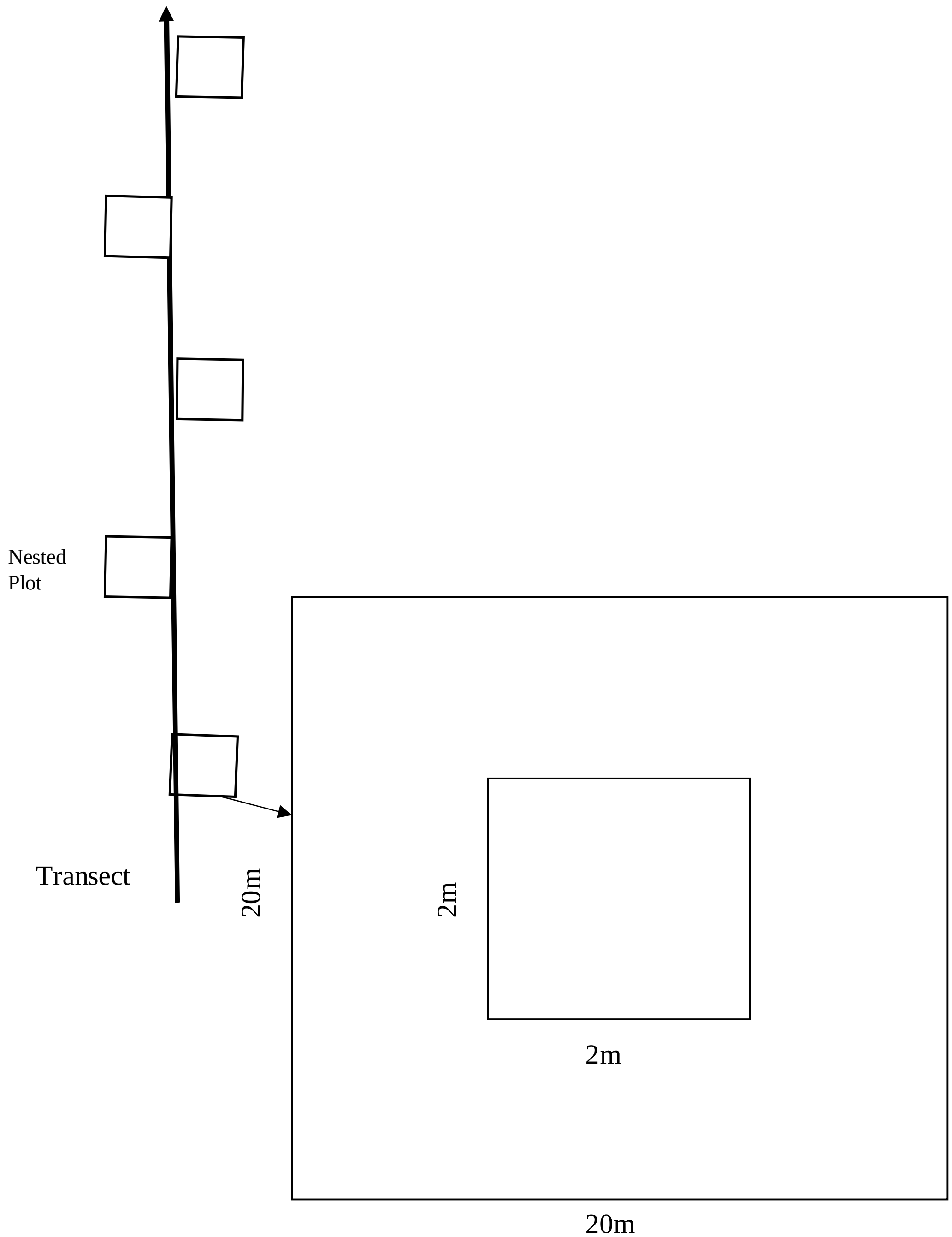

Figure 2: Field plot design.

Data Collection

Data were collected on live trees, palms and under-flora in each sample plot. All trees with stems ≥ 5 cm in Dbh were identified and counted in all the 20 m x 20 m sample plots and measured for diameter. Diameter at breast height was measured at 1.3m above the ground using Girth/Diameter Tape. For species with stilt roots higher than 1.3m (e.g. *Rhizophora* spp.), stem diameter was measured with Haglof Gator Eyes Calliper either directly above the highest stilt root (Clough and Scott 1989; Komiyama *et al*. 2005) or at where a true main stem begins, for some individuals with prop roots extending well into the canopy, since it is not necessary, practical or accurate to measure above the highest prop root (Kauffman and Donato, 2012). In addition, all the shrubs and palms with erect stems ≥ 5 cm in Dbh were identified and counted in all the 20 m x 20 m sample plots, since they were not densely populated in the area. Under-flora, such as juveniles of trees and palms (< 5 cm in Dbh) as well as ferns, were enumerated in the 2 m x 2 m quadrats. They were identified and their densities determined by counting their individuals in each plot. The density of Nipa palms (*Nypa fruticans)* was determined by counting the numbers of their palm fronds and stumps within the 2 m x2 m quadrats, since the species has underground stem which could not be counted from the surface. The palm fronds refer to the complete palm leaves, each comprising the main leaf stalk extending from the base to the tip with all their leaflets intact. The stumps are the bulbous leaf bases of the palm fronds that remain after all their leaflets and the top of their leaf stalks had been lost as a result of dieback due to old age.

Data Analyses

All the data were inputted into the computer and subjected to statistical analysis using Microsoft Excel. The data in each plot were first sorted by species. Each species' population density in each plot was obtained and scaled to area (No. of stem/ha) with equation 1, while their average densities in the study area were obtained using equation 2.

$$P_D = \frac{n_p}{A} \qquad \text{Equation 1}$$

Where; P_D= Population density of ith species in ith plot (No. of stems/ha),
n_p = Number of individuals of ith species in ith plot and
A = Area of one sample plot (0.04ha for trees, shrubs and palms with erect stems and 0.0004 ha for Nipa palm and seedlings).

$$\bar{P}_D = \frac{\sum P_D}{NP} \qquad \text{Equation 2}$$

Where; $\bar{P}_D$= Mean population density of ith species in the study area (No. of stems/ha),
NP = Number of sample plots enumerated (50 plots) and
P_D= as defined in equation 1.

All the species were also sorted into their various life forms and families using Keay (1989). Tree population structure was determined using their stem-diameter distribution per unit area. Using Microsoft Excel, all the trees encountered were sorted into the following ten diameter classes of 5 cm interval: 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm, 40-45 cm, 45-50 cm and ≥ 50 cm. Mean population density of the trees per hectare in each diameter class was obtained using equation (3),

$$N_d = \frac{\sum \frac{n_d}{A}}{NP}$$ Equation 3

Where; N_d = population density of tree stems in ith diameter class,
n_d= number of tree stems in ith diameter class enumerated in ith sample plot
A = area of each sample plot (0.04 ha) and
NP = total number of sample plots enumerated (50 plots).

Results

Species Composition and Density in Cross River Mangrove Forest

Adult and juvenile individuals of 22 plant species belonging to 20 genera and 15 families were encountered in this study as shown in Table 1. These consisted of 15 species of trees belonging to 13 genera and 11 families, 2 species of shrubs representing 2 genera and 2 families, 4 species of palms representing 4 genera and 1 family, and 1 species of ferns. In the adult tree category (trees ≥ 5 cm Dbh), a total of 547 individuals were recorded and this was estimated at 274 individuals per hectare. In terms of individual species occurrence, *Rhizophora racemosa* had the highest population density of 78 stems/ha, followed by *Rhizophora harrisonii* (56 stems/ha), *Oxystigma mannii* (53 stems/ha) and *Rhizophora mangle (*47 stems/ha). *Antrocaryon klaineanum, Celtis zenkeri, Cola laurifolia* and *Xylopia rubescens* had the least population density of less than 1 stem/ha. Each of the other species had population densities ranging from 1 stem/ha (*Avicennia germinans* and *Baphia nitida*) to 13 stems/ha (*Carapa procera*). In the juvenile tree category, only

3 species were represented, with population densities of 300 stems/ha (*Carapa procera*), 1350 stems/ha (*Oxystigma mannii*) and 4550 stems/ha (*Rhizophora* species). The two species of shrubs encountered were only represented by their adult individuals. They were *Dactyladenia barteri* and *Machaerium lonatum*, having population densities of 3 and 2 stems/ha, respectively. Out of the 4 palms species encountered, *Nypa fruticans* was the most abundant, having 13300 fronds/ha, 16350 stumps/ha and 2750 juveniles/ha. This was followed by *Raphia hookeri* with 56 adult stems/ha and 3450 juveniles/ha. *Elaeis guineensis* had 2 adult stems/ha and 500 juveniles/ha, while *Phoenix reclinata* had 3 adult stems/ha and 150 juveniles/ha. The only species of ferns, *Acrostichum aureum,* was represented by 3300 individuals/ha.

Table 1: Plant species diversity and abundance enumerated in mangrove ecosystem, Cross River, Nigeria.

Life forms	Species	Family	No./ha
Trees	*Antrocaryon klaineanum* Piere.	*Anacardiaceae*	<1
	Avicennia germinans (Linn.) Linn.	*Avicenniaceae*	1
	Baphia nitida Lodd.	*Papilionoideae*	1
	Carapa procera DC.	*Meliaceae*	13
	Celtis zenkeri Engl.	*Ulmaceae*	<1
	Cola laurifolia Mast.	*Sterculiaceae*	<1
	Hylodendron gabunense Taub.	*Caesalpinioideae*	5
	Oxystigma mannii (Baill.) Harms.	*Caesalpinioideae*	53
	Pandanus candelabrum P. Beauv.	*Pandanaceae*	14
	Pterocarpus santalinoides L' Heri. ex DC.	*Papilionoideae*	3
	Rhizophora harrisonii Leechman.	*Rhizophoraceae*	56
	Rhizophora mangle Linn.	*Rhizophoraceae*	47
	Rhizophora racemosa G.F.W.Meyer.	*Rhizophoraceae*	78
	Uapaca staudtii Pax.	*Euphorbiaceae*	2
	Xylopia rubescens Oliv.	*Annonaceae*	<1
	Total		**274**
Shrubs	*Dactyladenia barteri* (Hook.f. ex Oliv.) Prance & F. White	*Chysopbalanaceae*	3
	Machaerium lunatum (L. f.) Ducke	*Fabaceae*	2
	Total		**5**
Palms	*Elaeis guineensis* Jacq.	*Palmae*	2
	Phoenix reclinata Jacq.	*Palmae*	3
	*Raphia hooker*i Mann and Wendland	*Palmae*	56
	Total		**61**

Life forms	**Species**	**Family**	**No./ha**
	Nypa fruticans Wurmb (Fronds)	*Palmae*	13300
	Nypa fruticans (Stumps)		16350
	Total *Nypa fruticans* (Fronds + Stumps)		**29650**
Ferns	*Acrostichum aureum* L.	*Pteridaceae*	3300
Juveniles	*Carapa procera*	*Meliaceae*	300
	Oxystigma mannii	*Caesalpinioideae*	1350
	Rhizophora spp.	*Rhizophoraceae*	4550
	Elaeis guineensis	*Palmae*	500
	Phoenix reclinata	*Palmae*	150
	Raphia hookeri	*Palmae*	3450
	Nypa fruticans	*Palmae*	2750
	Total (Ferns + Juveniles)		**16350**

Stand Structure of Cross River Mangrove Forest

The distribution of individual adult trees into diameter classes is presented in Table 2, while estimated tree population densities in the various diameter classes and their respective proportions of the total population density are presented in Figure 3 and Appendix, respectively. The distribution showed that *Rhizophora racemosa* was represented in all the diameter classes, while *Oxystigma mannii* and *Carapa procera* were represented in 9 and 6 classes, respectively. All the other species had representatives in less than 5 classes. Most of the trees are in lower size classes. Diameter class 5.0-10.0 cm had the highest number of stems, 156 trees/ha (57%), followed by 10.0-15.0 cm with a population density of 52 trees/ha (19%) and 15.0-20.0 cm having a population density of 30 trees/ha (11%). Diameter class 40.0-45.0 cm had only one tree/ha. Diameter classes 35.0-40.0 cm and ≥ 50.0 cm were represented by 2 trees/ha each. All other diameter classes had between 3 and 12 trees/ha.

Table 2: Stem diameter-class distribution in Cross River mangrove ecosystem, Nigeria.

S/N		Trees stems distribution into diameter classes (No. of stems in sample)									
	Species	**5.0-10.0**	**10.0-15.0**	**15.0-20.0**	**20.0-25.0**	**25.0-30.0**	**30.0-35.0**	**35.0-40.0**	**40.0-45.0**	**45.0-50.0**	**≥50.0**
1	*Antrocaryon klaineanum*				1						
2	*Avicennia germinans*	1	1								
3	*Baphia nitida*		1	1							
4	*Carapa procera*	8	3	3	5	5	2				
5	*Celtis zenkeri*				1						
6	*Cola laurifolia*			1							
7	*Hylodendron gabunense*	1	3	5		1					
8	*Oxystigma mannii*	46	23	17	5	9	2	1		1	1
9	*Pandanus candelabrum*	16	11								
10	*Pterocarpus santalinoides*	2		2	2						
11	*Rhizophora harrisonii*	95	14	2	1						
12	*Rhizophora mangle*	85	8	1							
13	*Rhizophora racemosa*	57	39	27	6	7	9	2	2	5	2
14	*Uapaca staudtii*		1		1			1			
15	*Xylopia rubescens*					1					

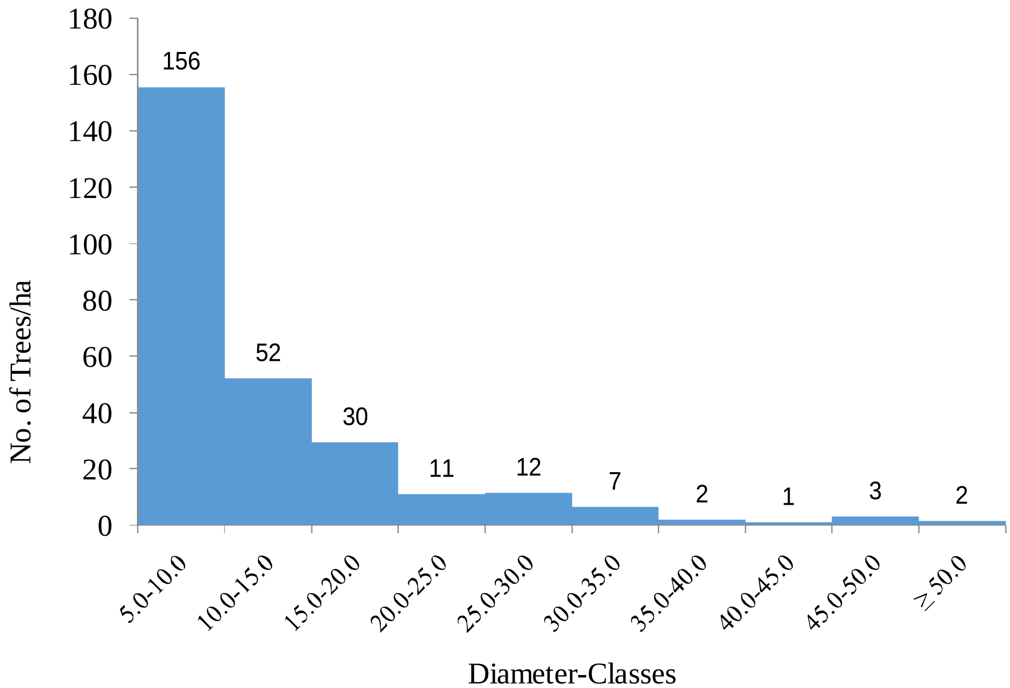

Figure 3: Diameter distribution of adult trees/ha in Cross River mangrove ecosystem, Nigeria.

DISCUSSION

Only 22 plant species were recorded, of which 15 were tree species and the remaining 7 distributed among shrubs, palms and ferns. Six (6) species, namely: *Acrostichum aureum, Avicennia germinans Rhizophora harrisonii, Rhizophora mangle, Rhizophora racemosa* and *Nypa fruiticans* are obligate mangroves (species found exclusively in mangrove habitat), while the remaining 16 species are mangrove associates (species that are found in mangroves and other wet environments). According to FAO (2007), mangrove associates are often found at the landward edge of mangrove ecosystems, along river banks or in beach forests, but do not possess the morphological and eco-physiological characteristics and adaptations of true mangrove species.

The numbers of plant species (22), genera (20) and families (15) encountered in this study agree with some observations that mangrove forest has few plant species. Obadimu *et al* (2016) observed that the flora of the mangrove forest in Nigeria consists of trees and shrubs of few species. Alongi (2002) reported that the physiognomy of mangrove forests is simple compared to rainforests, often lacking an under-storey of ferns and scrubs, and are ordinarily less species-rich than other tropical forests. Feliciano *et al*. (2014) also noted that mangroves are relatively simple in structure. Globally, there are 9 orders, 20 families, 27 genera and about 70 species of obligate mangroves (Spalding *et al*., 1997). Indo-Pacific region is the most diverse, with a record of 52 species of obligate mangroves and 268 species that can be found in mangroves and other wet environments (Alongi, 2002; Giesen *et al*., 2007; Kauffman and Donato, 2012). The Sub-Saharan African countries, including Nigeria have 17 species of obligate mangroves (Ibe, 2016), only 8 of them are found in Nigeria (FAO, 2007) and 6 out .of these 8 obligate mangroves were encountered in this study.

The occurrence of few plant species in the mangrove ecosystem is attributed to the harsh growth conditions, such as salinity, poor soil aeration and frequent flooding, found in the environment, which require special adaptation features for species to survive and thrive well. According to FAO (2007), only very few families like *Rhizophoraceae*, *Avicenniaceae* and *Combretaceae* have developed physiological and structural adaptations to the brackish water habitat in which mangroves live. Such adaptation features include aerial roots, salt excretion glands, viviparous embryos, tolerant of high salinity and abundant and frequent seeds production (Tomlinson, 1986; Nwoboshi, 1982; Etukudo *et al.,* 1994).

Assessment of the stand density showed that only *Rhizophora racemosa, Rhizophora harrisonii, Rhizophora mangle*, *Oxystigma mannii*, *Carapa procera, Nypa fruticans* and *Raphia hookeri* had densities of more than 10 individuals per hectare. A species with less than ten individuals per hectare in an area is considered as rare and endangered species in the area (Parthasarathy and Karthikeyan 1997). The results of *Nypa fruticans* (Nipa palm) density indicated that there were more stumps (bulbous leaf bases) than fronds (the complete living palm leaves), which is in line with reports that the crown of each mature stand of Nipa palm usually contains more stumps than fronds (Matsui *et al.*, 2014; Hossain and Islam, 2015). The results also showed that Nipa palms had the highest density in this ecosystem and these corroborate the findings of Ukpong (1991 and 2002) in the Creek Town/Calabar River area of the Cross River mangrove forest.

The indigenous mangroves species in the Niger Delta are under intense pressure from the local communities who depend on them for sources of livelihood and are exploiting them unsustainably (Nwobi and Williams, 2021). Over-exploitation and reduction in population of the indigenous tree species in the area has given way for Nipa palms to spread rapidly and thrive well in the area (James *et al*., 2007; Numbere, 2019), thereby dominating the vegetation in most places. The destruction and degradation of the Nigerian mangroves due to firewood gathering, construction of navigational canals, villages and the activities of oil companies are encouraging their replacement by the invasive species, *N. fruticans*, which unlike the indigenous mangroves species in the area, is not well exploited due to lack of knowledge and appropriate technologies for its utilisation (USDAID 2008).

Stem diameter distribution is well known and widely used for analysing and describing forest structure (Gove and Patil, 1998; Burgess *et al*., 2005; Duan *et al*., 2013). They provide very important information for decision making in sustainable forest management. The results of the diameter distribution curve followed an inverse J-shaped pattern, having many small and few large trees, which is typical of an uneven aged stand (Husch *et al.,* 2003). The results agree with the observations of Abayomi (2001), Adekunle, *et al.* (2002), Aigbe and Omokhua (2014) and Etigale *et al*. (2014) from separate studies of natural tropical forest ecosystems in Nigeria. The results also agree with those obtained by Bosire *et al*. (2003) from the mangroves at Gazi bay, Kenya and Kamruzzaman *et al*. (2018) from the oligohaline zone of the Sundarbans mangrove forest, Bangladesh. They all recorded a large number of small trees and few large trees. Furthermore, Kauffman *et al*. (2011) observed that smaller trees generally dominate the stand composition of many mangroves.

Stem diameter distribution into classes usually provide information on the number of trees in each of the diameter classes. This can be used to assess whether or not the density of smaller trees in a stand is sufficient to replace the current population of larger trees and to evaluate the sustainability of the forest (Sheykholeslami *et al*., 2011; Aigbe and Omokhua, 2014). The results of this study on stand structure, generally, showed that the density of smaller trees in the study area is sufficient to replace the current population of larger trees. This implies that regeneration and recruitment, which are vital indicators of forest health and vigour, are taking place in the forest (Jimoh *et al.* (2012). It was observed that those species encountered in this study that were represented only in the higher stem diameter classes are not true mangrove species and do not possess the type of reproduction system suitable for their healthy and vigorous regeneration in this environment. Mangrove is a unique environment, where only species with special adaptation features for regeneration can naturally regenerate their populations successfully. Accordingly, most specialised mangrove species have some very efficient reproduction systems, such as viviparous embryos and tidal dispersal of propagules, suitable for their successful regeneration in the mangrove environment (Alongi, 2002; FAO, 2007). In addition, human disturbance in the form of forest exploitation causes paucity of stems, especially, of target species in some size classes. Omeja *et al*. (2004) observed that exploitation of some tree species for drum making drastically reduced their populations and affected their stems diameter distribution in a forest in Central Uganda.

CONCLUSION

The study has provided quantitative scientific information that can be used for planning and implementation of sustainable management of the forest. The numbers of plant species, genera and families encountered and the species composition of the forest are typical of mangrove ecosystems. Most parts of the vegetation were degraded and dominated by Nipa palm, which was the most abundant species. The stand structure showed a large number of small trees and few large trees, indicating that regeneration and recruitment are taking place in the forest and that the density of smaller trees in the study area is sufficient to replace the larger trees. The presence of both small and large diameter trees in the ecosystem is very important for sustainable production of forest goods and ecosystem services.

Trees should be allowed to grow to maturity before cutting to ensure optimum yield and sustainability of its products. For each tree harvested, at least 10 young trees should be planted to fill the gap created to ensure effective replacement of the older tree that is harvested or dead. The mangrove forest in Cross River State should be managed sustainably to conserve its immeasurable economic and ecological values.

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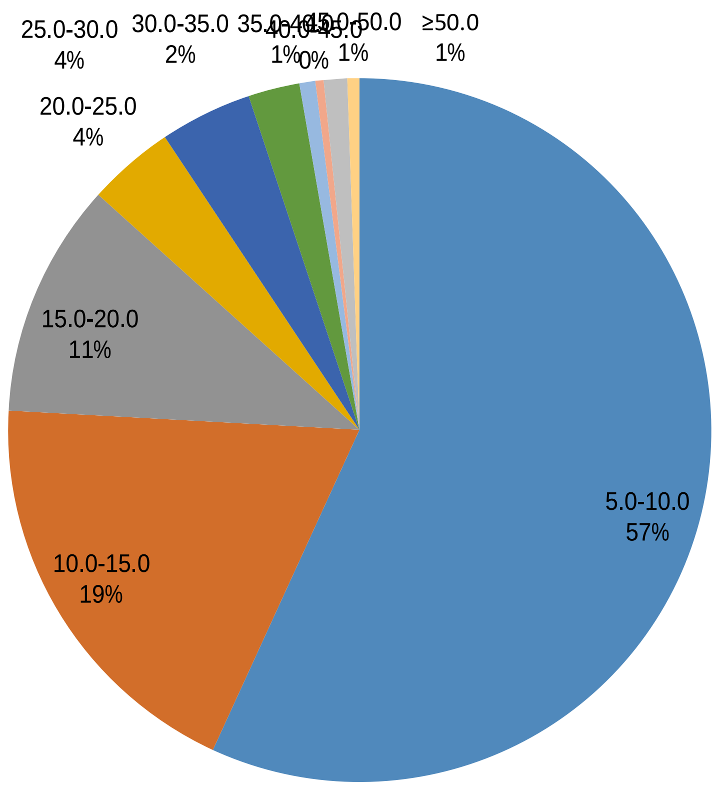
Appendix : **Percentage of total tree population density in each diameter class in Cross River Mangrove Ecosystem, Nigeria.**


25.0-30.0
4%
30.0-35.0
2%
35.0-40.0
1%
40.0-45.0
0%
45.0-50.0
1%
≥50.0
1%
20.0-25.0
4%
15.0-20.0
11%
10.0-15.0
19%
5.0-10.0
57%