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ASSESSMENT OF TREE DIVERSITIES IN OBAN DIVISION OF THE CROSS RIVER NATIONAL PARK (CRNP), NIGERIA

BY

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ABSTRACT

Many tropical forests are under great anthropogenic pressure and require management intervention to maintain the overall biodiversity, productivity and sustainability. This cannot be possible without proper understanding of their structure and species diversities. Tree diversity in Oban Division of the CRNP was assessed. Systematic sampling technique was adopted for plot locations. Two transects, 2km long with a distance of 600m apart were cut in each of the three study sites. Four plots of 50m×50m were laid alternately along each transect at 500m intervals in the closed canopy and secondary forests. Forty-eight plots were used for the study. Tree growth parameters were measured on all the trees with Dbh≥10cm within each plot. All the measured trees were identified and classified into their respective families. Species diversity indices were computed for the trees in the two forest types. The canopy layer to which each tree belongs was noted. Data were analyzed using descriptive statistics, Diversity Indices, t-test as well as analysis of variance. A total of 118 species (107 genera and 37 families) of trees were recorded, with 72 and 69 species in the closed canopy and secondary forests respectively. The *Strombosia spp.* was the most abundant species in the forests. The family, *Olacaceae* accounted for 11.94% of the total individuals recorded in the area. This was followed by *Mimosoideae* (8.4%). The average tree stems/ha was 158 and 130 in the closed canopy and secondary forest respectively. The Simpson' Indices were 0.99 and 0.98 for the two forest types respectively, which implied high floristic richness. The Shannon-Wiener's Indices (4.36 and 4.14) and the equitability ratios (0.9513 and 0.9506) were high for the two forest types, which indicated moderate representation of most of the species in the area. The tree growth parameters significantly differ under different canopy layers ($P<0.05$). However, most of the parameters were not significantly different in the two forest types ($P>0.05$).

Key words: forest-types, species, families, diversity indices, growth parameters

INTRODUCTION

Tropical forests represent one of the most species-diverse terrestrial ecosystems. Their immense biodiversity generates a variety of natural resources, which help to sustain the livelihoods of local communities (Kumar *et al.*, 2002). However, many tropical forests are under great anthropogenic pressure and require management intervention to maintain the overall biodiversity, productivity and sustainability. This cannot be possible without a proper understanding of their diversities, structures and species richness. There has been a consistent deforestation of Nigeria's tropical rain forests for more than two decades. This is being done without a plan for replacement. Today, a semblance of the remaining tropical rainforests in the country is only found within Cross River National Park (CRNP), while forest disturbance and fragmentation caused by illegal logging and land conversion for local agriculture are visibly increasing in the remaining parts of the country (Ogunjobi *et al.*, 2010). There is a dearth of information on the species diversity and richness in Oban Division of the CRNP, which happens to be the most diverse in Nigeria at present. This information could guide the sustainable management of the Park and its components.

Moreover, evidence has pointed to how inadequate information on ecosystem diversity has resulted in poor forest policies, planning and management in the park (e.g. Bisong and Mfon, 2006). It has hampered efforts to reduce illegal and unsustainable extraction of forest resources, and improve transparency. Also, it has resulted in undervaluation of forest resources. According to FAO (2005), such conditions, in turn, could contribute to continuous decline in area, health, stock, and flows of forest resources.

This study was undertaken to assess tree species diversity in Oban Division of the CRNP. Relevant information on tree species and structural diversities is useful for effective formulation and implementation of policies and serves as guide to effective forest management (Irland, 2007). This information is needed since it can provide a baseline data for which changes in the forest resource base and causes for change could be subsequently monitored. It will also help to identify ways to integrate forest development efforts with overall sustainable development in Nigeria.

METHODOLOGY

The Study Area

The study was carried out in Oban Division of CRNP, Nigeria. Oban Division lies between longitudes 8° 02'E and 8°55'E; and latitudes 5° 00'N and 6° 00'N. The Oban Division is 300,000ha in land area. It was carved out of Oban Group Forest Reserve in 1991. It is located in the south-eastern part of the Cross River State in Akamkpa Local Government Area (Fig.1). It shares border with Korup National Park of Cameroon in the east and is about 42km from Calabar, the state capital (Ogunjobi *et al.*, 2010). The three study sites used for this study were *Aking*, *Ekang* and *Old Netim*.

The study area has a raining season of at least nine months (March-November) and receives over 3500mm of rain annually (Ogunjobi *et al.*, 2010). Oban Division is contiguous with Korup National Park. The Cross River and its tributaries drain northern parts of Oban Division, while southern parts are drained by the Calabar, Kwa and Korup Rivers. The terrain is rough and elevation rises from the river valleys to over 1000m above sea level in mountainous area. The temperature ranges from 25°C to 27°C in January, but in July, it normally rises up to slightly above 30°C. Relative Humidity is between 75% and 95% in January, but toward the end of the year, it reduces gradually as a result of harmattan (Bisong and Mfon, 2006). The vegetation is lowland rain forest. In the less accessible areas, the forest has had little interference, but elsewhere the vegetation has been much influenced by human activities.

Data Collection

Systematic sampling technique was adopted in each of the three study sites (*Aking*; *Ekang* and *Old-Netim*) for plot locations (Adekunle *et al.*, 2004; Akindele, 2005; Adekunle and Olagoke, 2008). Two transects,2km long with a distance of 600m apart,were cut in each of the study sites. Four sample plots of 50m×50m (0.25ha) were laid alternately along each transect at 500m intervals. This procedure was replicated in the closed canopy and secondary forests, thus summing up to 4 sample plots per 2km-transect, and a total of 16 sample plots per study site. In all, 48 sample plots were used for the study. The tree growth parameters [Diameter at breast height (Dbh), diameters at the base (D_b), middle (D_m) and merchantable top (D_t), crown diameter (CD), total height (THT), merchantable height (MHT) and crown length (CL)] were measured on all the trees with 10cm and above within each plot. All measured tree stems were identified and classified into their respective genera and families. Species diversity indices were also computed for the tree species in the two forest types. In addition, the canopy layer to which each tree within each plot belongs was noted.

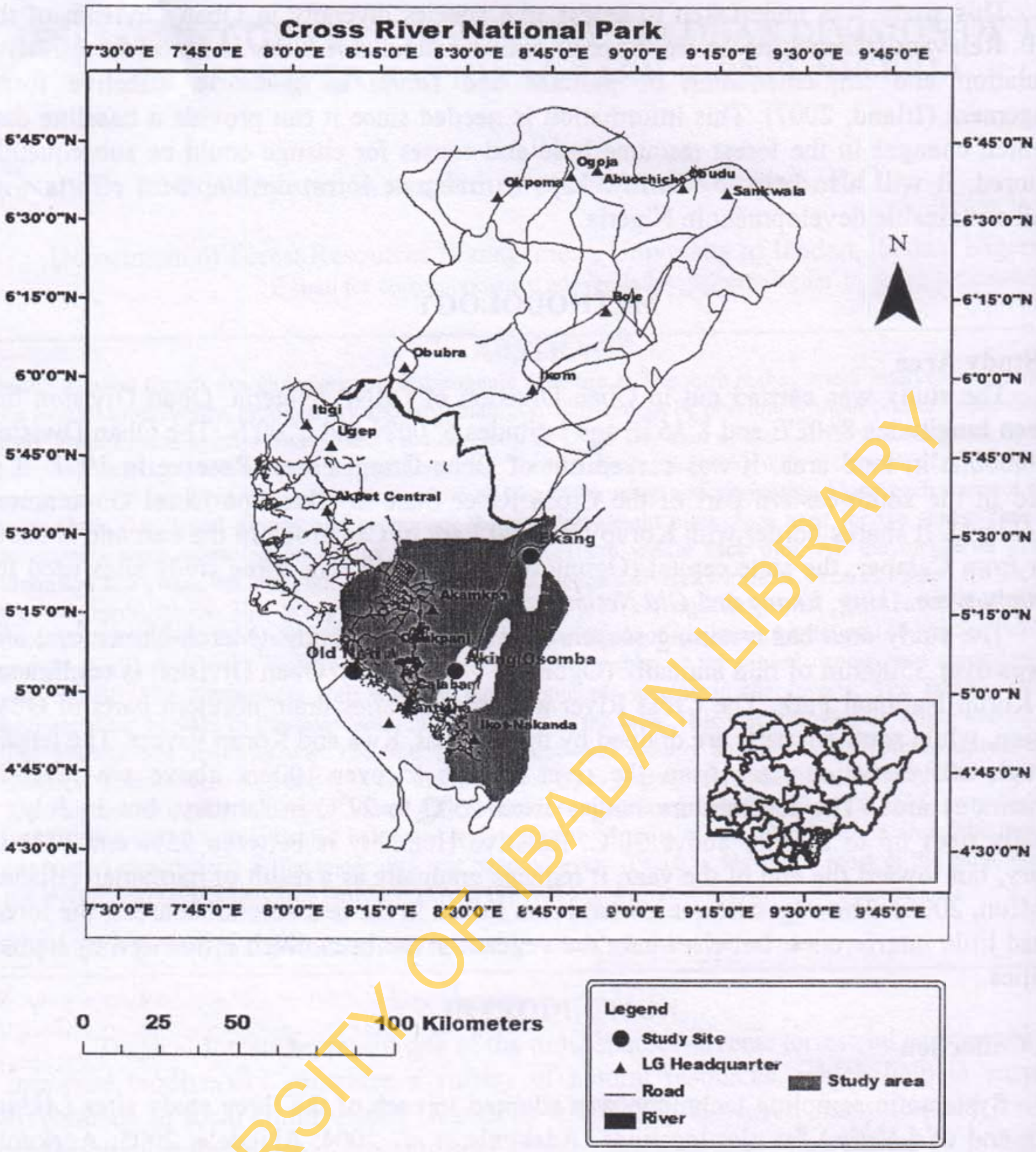

Fig: Map of the Cross River State showing the study area

Data Analysis

Computation of the Simpson's and Shannon-Wiener's indices of diversity

Simpson's index

$$D = 1 - \sum_{i=1}^{s}\left(\frac{n_i}{N}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where, n_i = number of individuals of the *ith* species; N = total number of individuals in the plot; S = number of species in the plot (Simpson, 1949).

Shannon-Wiener index for tree size diversity:

$$H_d = -\sum_{i=1}^{m} p_i \times \log p_i \quad \text{...} 2$$

Where, p_i = the proportion of trees in the *ith* diameter class and d = the number of diameter classes (Buongiorno *et al*., 1994).

Shannon-Wiener index for tree height diversity:

$$H_h = -\sum_{i=1}^{h} p_i \times \log p_i \quad \text{...} 3$$

Where, p_i = the proportion of trees in the *ith* height class, and h = the number of height classes (Staudhammer and LeMay, 2001).

Descriptive and Inferential Statistics

Descriptive statistics, t-test and analysis of variance were also conducted on the data set. T-test was conducted to investigate significant differences in tree species growth parameters and diversities between the two forest types. Analysis of variance was used to compare the growth parameters under different canopy layers.

RESULTS AND DISCUSSION

Tree Species Composition

A total of 118 species (107 genera and 37 families) of trees were recorded in the study area with 72 species in the closed canopy forest and 69 species in the secondary forest. Details are presented in Table 1. *Strombosia pustulata* (5.04%) and *S. grnadifolia* (4.05%) of the family *Olacaceae* were the most represented in the two forest types. Species like *Khaya grandifoliola* (0.12%), *Lophira alata* (0.64%) and *Terminalia ivorensis* (0.12%) were less represented with very few individuals in the study area (Table 2).

A total of 1726 tree stems were recorded in the study plots, with 947 (54.87%) in the closed canopy forest and 779 (45.13%) individuals in the secondary forest. The members of family *Olacaceae* accounted for 11.94% of the total individuals with three members (*S. pustulata* with 42.85%; *S. grandifolia* with 34.48%; *Coula edulis* with 22.66%). *Mimosoideae* accounted for 8.4% and is represented by seven species. Among the species, *Parkia bicolor* (35.17%), *Pentaclethra macrophylla* (25.52%) and *Calpocalyx cauliflorus* (17.24%) were the most common in the family. The following species; *Piptadeniastrum africanum* (9.66%), *Calpovalyx brevibracteatus* (6.21%), *Albizia zygia* (4.14%) and *Cylicodiscus gabunensis* (1.38%) were present in lesser amount in this family.

The values recorded for tree species in the two forest types were higher in comparison to the values reported by Adekunle (2006) in other tropical rain forests of Nigeria. Higher species occurrence in the area may be attributed to the success of conservation efforts and the recent ban on logging and illegal extraction of forest resources in the area by the Cross River State government.

Table 1: Tree species compositions in the two forest types

SN	Tree species		SN	Tree species	
	Closed canopy forest	Secondary forest		Closed canopy forest	Secondary forest
1	*Afzelia bipindensis*	*Ficus capensis*	37	*Hylodendron gabunense*	*Funtumia elastica*
2	*Allanblackia floribunda*	*Musanga cecropioides*	38	*Irvingia sp*	*Hannoa klaineana*
3	*Alstonia boonei*	*Xylopia aethiopica*	39	*Khaya grandifoliola*	*Dialium guineense*
4	*Amphimas pterocarpoides*	*Ceiba pentandra*	40	*Klainedoxa gabonensis*	*Cola altissima*
5	*Anonidium mannii*	*Distemonanthus benthamianus*	41	*Lannea welwitschii*	*Brenania brieyi*
6	*Barteria fistulosa*	*Sterculia rhinopetala*	42	*Lophira alata*	*Millettia griffoniana*
7	*Berlinia Bracteosa*	*Maesobotrya barteri*	43	*Lovoa trichiloides*	*Hunteria umbellate*
8	*Berlinia confuse*	*Lepidobotrys staudtii*	44	*Mammea Africana*	*Panda oleosa*
9	*Blighia sapida*	*Treculia obovoidea*	45	*Manikara obovata*	*Cinnamomum zeylanicum*
10	*Bosqueia angolensis*	*Coula edulis*	46	*Mitragyna stipulosa*	*Garcinia mannii*
11	*Brachystegia eurycoma*	*Lophira alata*	47	*Nauciea diderichii*	*Uapaca staudtii*
12	*Brachystegia nigerica*	*Cleistopholis patens*	48	*Octoknema affinis*	*Combretodendron macrocarpum*
13	*Calpocalyx cauliflorus*	*Antrocaryon micraster*	49	*Omphalocarpum elatum*	*Baphia nitida*
14	*Canarium schweinfurthii*	*Bosqueia angolensis*	50	*Parinari exelsa*	*Guarea glomerulata*
15	*Carapa procera*	*Antiaris toxicaria*	51	*Phyllanthus discoideus*	*Spathodea campanulata*
16	*Carapa procera*	*Hylodendron gabunense*	52	*Piptadeniastrum africanum*	*Morinda lucida*
17	*Celtis brownie*	*Angylocalyx oligophyllus*	53	*Psydrax palma*	*Nesogordonia papaverifera*
18	*Celtis mildbraedii*	*Piptadeniastrum africanum*	54	*Pterocarpus osun*	*Carapa procera*
19	*Chrysophyllum albidum*	*Chrysophyllum albidum*	55	*Pterygota macrocarpa*	*Antidesma vogelianum*
20	*Cinnamomum zeylanicum*	*Strombosia pustulata*	56	*Rhizophora recemosa*	*Klainedoxa gabonensis*
21	*Coelocaryon preusii*	*Tabernaemontana pachysiphon*	57	*Ricinodendron heudelotii*	*Allanblackia floribunda*
22	*Cola argentea*	*Antiaris toxicaria*	58	*Rothmannia hispida*	*Diospyros suaveolens*
23	*Cola gigantean*	*Pentaclethra macrophylla*	59	*Santiria trimeria*	*Irvingia sp*
24	*Corynanthe pachyceras*	*Albizia zygia*	60	*Spathodea campanulata*	*Octoknema affinis*
25	*Cylicodiscus gabunensis*	*Guibourtia ehie*	61	*Sterculia oblonga*	*Corynanthe pachyceras*
26	*Dacryodes edulis*	*Zanthozyllum zanthozylloides*	62	*Stombosia pustulata*	*Staudtia stipitata*
27	*Dialium guineense*	*Neoboutonia glabrescens*	63	*Strombosia grandifolia*	*Vitex ferruginea*
28	*Diospyros mespiliformis*	*Pycnanthus angolensis*	64	*Symphonia globulifera*	*Strombosia grandifolia*
29	*Distemonanthus benthamianus*	*Diospyros mespiliformis*	65	*Terminalia ivorensis*	*Celtis zenkerii*
30	*Enantia chlorantha*	*Poga oleosa*	66	*Treculia oblonga*	*Barteria fistulosa*

31	*Ficus sp*	*Diospyros zenkerii*	67	*Trilepisium madagascariensis*	*Parkia bicolour*
32	*Guibourtia ehie*	*Berlinia confuse*	68	*Uapaca staudtii*	*Ouratea calophylla*
33	*Hannoa klaineana*	*Anonidium mannii*	69	*Uvariodendron callophyllum*	*Guarea thompsonii*
34	*Hannoa klaineana*	*Trichilia tessmannii*	70	*Vitex ferruginea*	
35	*Holoptelea grandis*	*Sterculia oblonga*	71	*Xylopia aethiopica*	
36	*Hunteria eburnean*	*Rothmannia hispida*	72	*Zanthozyllum zanthozylloides*	

The dominance of the *Strombosia spp.* in the area may be the result of edaphic factors of the area, or, due to adaptation of the species to the area. The maximum representation of the family *Sterculiaceae* may have also resulted from ecological adaptations of members of this family to the ecosystem. A similar case was reported by Vasanthraj and Chandrashekar (2006) in a tropical forest, where *Dipterocarpaceae* dominated due to their adaptations to the forest ecology.

The average numbers of tree stems/ha was 158 and 130 in the closed canopy and secondary forest respectively. These values were higher compared to those reported by Adekunle *et al.* (2004), Ojo (2004), Adekunle and Olagoke (2008) for other tropical rainforests of Nigeria. This is an indication that the Oban forest is less disturbed compared to others previously studied.

Table 2: Tree species and their respective families in the study area

S/N	Species	Family	%	S/N	Species	Family	%
1	*Afzelia bipindensis*	Caesalpinioideae	0.46	60	*Hunteria eburnean*	Apocynaceae	1.04
2	*Albizia zygia*	Mimosoideae	0.35	61	*Hunteria umbellate*	Apocynaceae	0.81
3	*Allanblackia floribunda*	Guttiferae	0.81	62	*Hylodendron gabunense*	Caesalpinioideae	1.10
4	*Alstonia boonei*	Apocynaceae	0.58	63	*Irvingia sp*	Irvingiaceae	2.26
5	*Amphimas pterocarpoides*	Papilionoideae	0.12	64	*Khaya grandifoliola*	Meliaceae	0.12
6	*Angylocalyx oligophyllus*	Papilionoideae	0.58	65	*Klainedoxa gabonensis*	Irvingiaceae	2.95
7	*Anonidium mannii*	Annonaceae	0.23	66	*Lannea welwitschii*	Anacardiaceae	0.35
8	*Antiaris toxicaria*	Moraceae	0.41	67	*Lepidobotrys staudtii*	Lepidobotryaceae	0.17
9	*Antidesma vogelianum*	Euphorbiaceae	0.12	68	*Lophira alata*	Ochnaceae	0.64
10	*Antrocaryon micraster*	Anacardiaceae	1.16	69	*Lovoa trichiloides*	Meliaceae	0.17
11	*Baphia nitida*	Papilionoideae	0.58	70	*Maesobotrya barteri*	Euphorbiaceae	0.35
12	*Barteria fistulosa*	Passifloraceae	0.46	71	*Mammea Africana*	Guttiferae	0.64
13	*Berlinia Bracteosa*	Caesalpinioideae	0.35	72	*Manikara obovata*	Sapotaceae	0.70
14	*Berlinia confuse*	Caesalpinioideae	0.70	73	*Microdesmis puberula*	Pandaceae	0.06
15	*Blighia sapida*	Sapindaceae	1.04	74	*Millettia griffoniana*	Papilionoideae	0.98

16	*Bosqueia angolensis*	Moraceae	2.32	75	*Mitragyna stipulosa*	Rubiaceae	0.12
17	*Brachystegia eurycoma*	Caesalpinioideae	0.06	76	*Monodora myristica*	Annonaceae	0.52
18	*Brachystegia nigerica*	Caesalpinioideae	0.12	77	*Morinda lucida*	Rubiaceae	0.41
19	*Brenania brieyi*	Rubiaceae	0.17	78	*Musanga cecropioides*	Moraceae	1.04
20	*Bridelia micrantha*	Euphorbiaceae	0.12	79	*Nauclea diderichii*	Rubiaceae	0.12
21	*Calpocalyx brevibracteatus*	Mimosoideae	0.52	80	*Neoboutonia glabrescens*	Euphorbiaceae	0.98
22	*Calpocalyx cauliflorus*	Mimosoideae	1.45	81	*Nesogordonia papaverifera*	Sterculiaceae	0.93
23	*Canarium schweinfurthii*	Burseraceae	0.12	82	*Octoknema affinis*	Octoknemaceae	1.78
24	*Carapa procera*	Meliaceae	1.39	83	*Omphalocarpum elatum*	Sapotaceae	0.23
25	*Ceiba pentandra*	Bombacaceae	0.17	84	*Ouratea calophylla*	Ochnaceae	0.81
26	*Celtis brownie*	Ulmaceae	0.98	85	*Panda oleosa*	Pandaceae	0.93
27	*Celtis mildbraedii*	Ulmaceae	0.23	86	*Parinari exelsa*	Chrysobalanaceae	0.12
28	*Celtis zenkerii*	Ulmaceae	0.52	87	*Parkia bicolour*	Mimosoideae	2.95
29	*Chrysophyllum albidum*	Sapotaceae	0.46	88	*Pentaclethra macrophylla*	Mimosoideae	2.14
30	*Cinnamomum zeylanicum*	Lauraceae	0.93	89	*Phyllanthus discoideus*	Euphorbiaceae	0.64
31	*Cleistopholis patens*	Annonaceae	0.64	90	*Piptadeniastrum africanum*	Mimosoideae	0.81
32	*Coelocaryon preusii*	Myristicaceae	1.10	91	*Poga oleosa*	Anisophylleaceae	0.23
33	*Cola altissima*	Sterculiaceae	0.35	92	*Psydrax palma*	Rubiaceae	0.46
34	*Cola argentea*	Sterculiaceae	0.06	93	*Pterocarpus osun*	Papilionoideae	0.87
35	*Cola gigantean*	Sterculiaceae	0.58	94	*Pterygota macrocarpa*	Sterculiaceae	0.35
36	*Cola hispida*	Sterculiaceae	0.12	95	*Pycnanthus angolensis*	Myristicaceae	3.36
37	*Combretodendron macrocarpum*	Lecythidaceae	0.29	96	*Rhizophora recemosa*	Rhizophoraceae	0.06
38	*Corynanthe pachyceras*	Rubiaceae	0.93	97	*Ricinodendron heudelotii*	Euphorbiaceae	0.29
39	*Coula edulis*	Olacaceae	2.67	98	*Rothmannia hispida*	Rubiaceae	0.29
40	*Cylicodiscus gabunensis*	Mimosoideae	0.12	99	*Santiria trimeria*	Burseraceae	1.68
41	*Dacryodes edulis*	Burseraceae	0.35	100	*Spathodea campanulata*	Bignoniaceae	0.29
42	*Dialium guineense*	Caesalpinioideae	1.85	101	*Staudtia stipitata*	Capparaceae	3.77
43	*Diospyros mespiliformis*	Ebenaceae	2.67	102	*Sterculia oblonga*	Sterculiaceae	2.38
44	*Diospyros suaveolens*	Ebenaceae	0.29	103	*Sterculia rhinopetala*	Sterculiaceae	0.52
45	*Diospyros zenkerii*	Ebenaceae	2.78	104	*Sterculia tragacantha*	Sterculiaceae	0.70
46	*Distemonanthus benthamianus*	Caesalpinioideae	0.87	105	*Strombosia grandifolia*	Olacacea	4.05
47	*Enantia chlorantha*	Annonaceae	0.12	106	*Strombosia pustulata*	Olacaceae	5.04
48	*Entandrophragma cylindricum*	Meliaceae	0.23	107	*Symphonia globulifera*	Guttiferae	0.23
49	*Ficus capensis*	Moraceae	0.17	108	*Tabernaemontana pachysiphon*	Apocynaceae	0.81
50	*Ficus sp*	Moraceae	0.17	109	*Terminalia ivorensis*	Combretaceae	0.12

51	*Funtumia elastica*	Apocynaceae	0.35	110	*Treculia oblonga*	Moraceae
52	*Garcinia cola*	Guttiferae	0.12	111	*Treculia obovoidea*	Moraceae
53	*Garcinia mannii*	Guttiferae	0.70	112	*Trichilia tessmannii*	Meliaceae
54	*Guarea glomerulata*	Meliaceae	1.97	113	*Trilepisium madagascariensis*	Moraceae
55	*Guarea thompsonii*	Meliaceae	0.17	114	*Uapaca staudtii*	Euphorbiaceae
56	*Guibourtia ehie*	Caesalpinioideae	0.29	115	*Uvariodendron callophyllum*	Annonaceae
57	*Hannoa klaineana*	Simaroubaceae	1.33	116	*Vitex ferruginea*	Verbenaceae
58	*Holoptelea grandis*	Ulmaceae	0.12	117	*Xylopia aethiopica*	Annonaceae
59	*Homalium letestui*	Samydaceae	0.06	118	*Zanthozyllum zanthozylloides*	Rutaceae

Species Diversities

The species diversity indices for the tow forest types are presented in Table 3. The high values for Simpson's Index (0.99 and 0.98) in the closed canopy and secondary forests respectively indicated high species richness in the forests. The Shannon-Wiener's Indices (4.366 and 4.14) and the equitability ratios (0.951 and 0.959) were high for the two forest types, which indicate moderate representations of most of the species in the area. In the same vein, the species evenness (0.8337 and 0.8344) were also high in each of the closed canopy and the secondary forests, which means that there were less variation in species diversities in the two forest types. Details are shown in Table 3.

Table 3: Summary of diversity indices for the two forest types of CRNP

Index	Closed canopy forest			Secondary forest		
	Mean value	Lower limit	Upper limit	Mean value	Lower limit	Upper lim
Simpson's	0.986	0.9855	0.9861	0.983	0.923	0.9831
Shannon-Wieners'	4.366	4.34	4.37	4.17	4.14	4.175
Evenness	0.8337	0.7895	0.8591	0.8344	0.7955	0.8614
Equitability ratio	0.9513	0.9386	0.9581	0.9506	0.9375	0.9586

The Simpson's Index values for two forest types were higher compared to the values reported for various tropical rain forests in Asia and Africa (Shivaprasad *et al.*, 2002; Vasanthraj *et al.*, 2004; Vasanthraj and Chandrashekar, 2006; Adekunle, 2007). The value was slightly higher in the closed canopy forest than in the secondary forest. This is because of higher species diversity in the former than the latter.

Structural Diversity

The Shannon-Wiener's Indices for tree size diversity in the study area are presented in Fig. 2. In the closed canopy forest, the tree diameter class 20-30cm is the most structurally diverse in the ecosystem, with a diversity index of 3.224. This is followed by the diameter class 10-20cm, which has a diversity index of 3.044. Similarly, the diameter classes 10-20cm and 20-30cm had the highest tree size diversity index of 2.962 each in the secondary forest. The diameter class 80-90cm for the closed canopy forest and the diameter class 90-100cm for the two forest types had zero Index values, which indicated poor diversity since very few individuals fall into these categories in the two forest types. The study also revealed that the two forest types were characterized by abundance of relatively small-diameter trees (of Dbh of 40cm and below) making about 75% in the closed canopy forest and 69% in the secondary forest. These trends are common in near-primary tropical rain forests, which is an indication of high potential of these forests for regeneration processes (Hadi *et al*., 2009). These percentages are higher than the values reported by the previous workers for other tropical forest ecosystems of Nigeria (Adekunle *et al*., 2004; Akindele, 2005; Adekunle and Olagoke, 2008). The values are also higher than the 60.91% reported by Hadi *et al*. (2009) for a lowland rain forest in Indonesia.

In terms of the vertical structural diversity, the intermediate canopy (15-27m height class) of the closed canopy forest and the secondary forest had the highest Indices of 3.802 and 3.601 respectively (Fig. 3). This is followed by the suppressed canopy layer (≤15m height) in both cases, with index values of 2.477 and 2.327 respectively. The dominant canopy layer is the least structurally diverse in the tow forest types with diversity indices of 1.809 and 1.662 respectively.

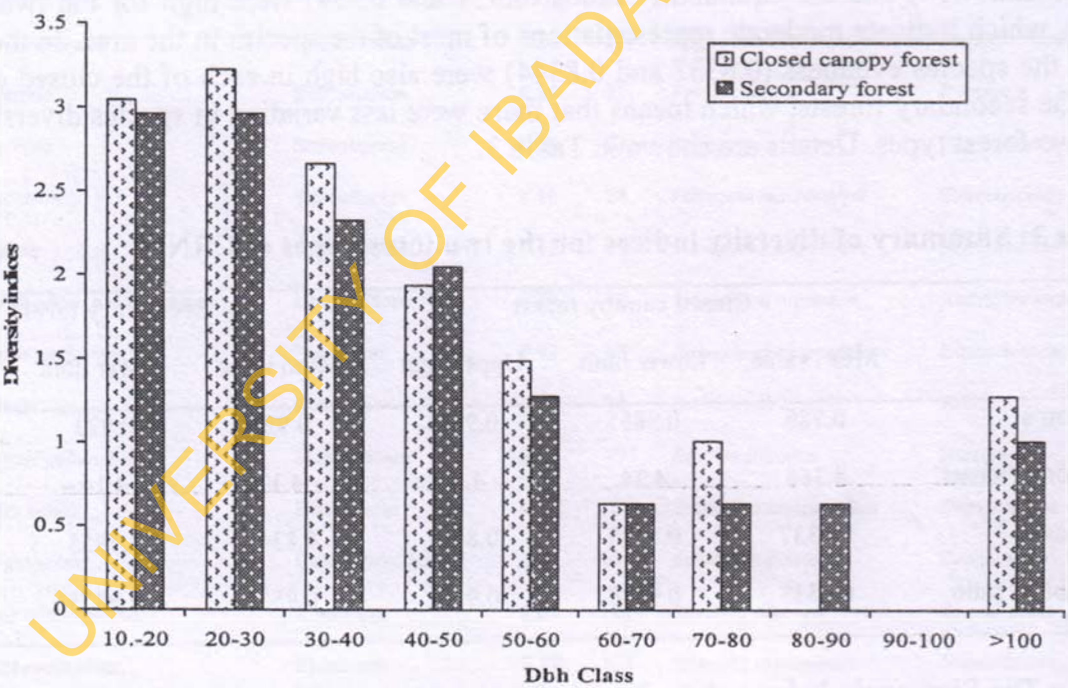

Fig. 2: Tree size diversities in the two forest types

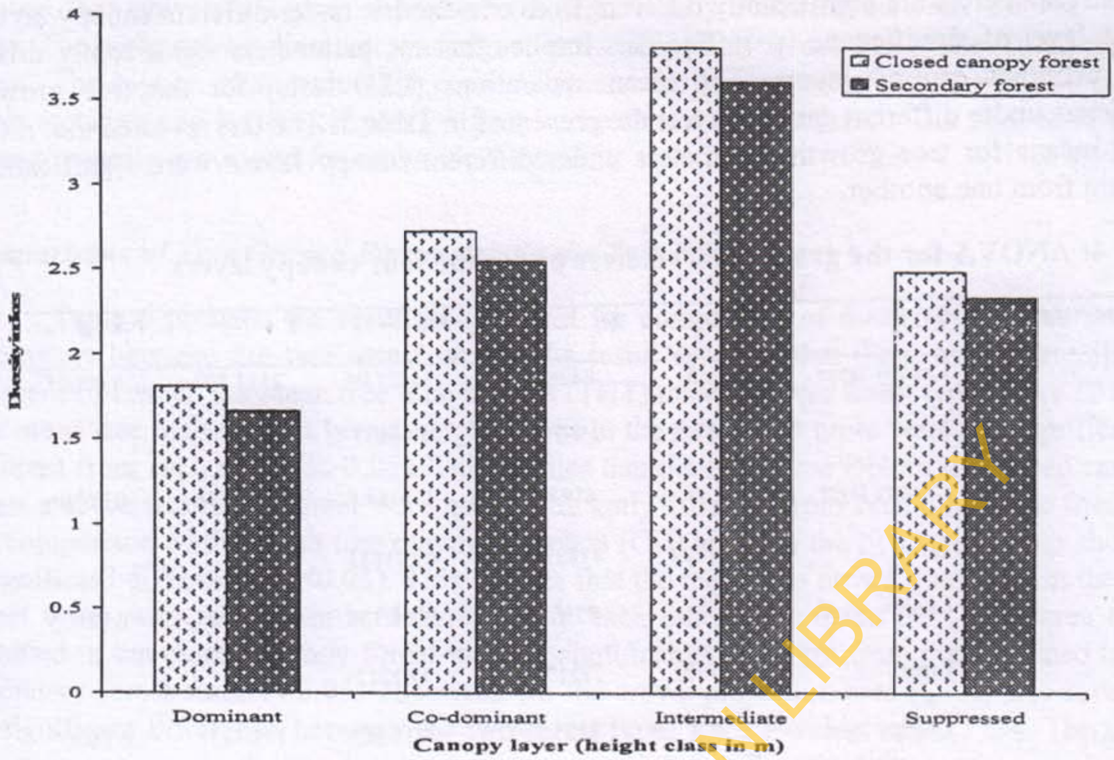

Fig. 3: Trees species diversities under different canopy layers in the two forest types

The Shannon-Wieners Indices for structural diversity were higher when compared to the values reported for Western Ghat forest in India by Vasanthraj *et al*. (2004). However, the values were lower when compared with the result obtained by Vasanthraj and Chandrashekar (2006). This ecosystem has been adjudged the richest in the country due to minimal disturbance, its species richness and diversity (Ogunjobi *et al*., 2010). Species in this ecosystem are very important for the fauna diversity conservation, soil enrichment and microclimatic amelioration. Species of *Caesalpinioideae* and *Mimosoideae* encountered are also noted for their ability to fix atmospheric nitrogen, thereby improving soil fertility, and hence, enhancing luxuriant tree species growth in the area. The study further revealed that stand structural diversity indices involving diameter and height were different throughout the forest strata. Higher index indicates greater complexity in forest structure. Similar results have been reported in previous studies by Spies (1997) and Lei *et al*. (2009). The intermediate height layer in the two forest types is the most diverse. This is consistent with observation by O'hara *et al*. (2007) who reported an increasing trend in structural diversity over time in multi-age forest stands. This could also be due to tree size differentiation caused by competitions, mortality and regeneration processes. Stands incorporating large individuals appear to have large ranges in Dbh and hence, higher tree size diversity (McRoberts *et al*., 2008).

Comparisons of Growth Parameters under Different Canopy Layers

The results of analysis of variance for the tree growth parameters under different canopy layers are presented in Table 4. The results for all the tree growth parameters show that, the parameters are significantly different from one another under different canopy layers at 0.05 level of significance ($p<0.05$). This implies that the parameters significantly differ under different canopy layers. The mean separations (LSD tests) for the tree growth parameters under different canopy layers are presented in Table 5. The test revealed that most of the means for tree growth parameters under different canopy layers were significantly different from one another.

Table 4: ANOVA for the growth parameters under the four canopy layers

Tree parameter	SV	df	SS	MS	F	P-level
THT	Canopy layer	3	94281.12	31427.04	2111.502	0.0000*
	Error	1722	25629.783	14.8837		
Dbh	Canopy layer	3	414493.8	138164.6	290.7575	0.0000*
	Error	1722	818274.25	475.1883		
CD	Canopy layer	3	8299.002	2766.334	224.5185	0.0000*
	Error	1722	21217.106	12.3212		
CL	Canopy layer	3	8155.509	2718.503	175.8457	0.0000*
	Error	1722	26621.431	15.4596		
SV	Canopy layer	3	26751.801	8917.267	227.7228	0.0000*
	Error	1722	67430.765	39.1584		

significant (P<0.05)

THT=tree total height; Dbh=diameter at breast height; CD=crown diameter; CL= crown length; SV = stem volume

Table 5: LSD tests for the tree growth parameters under the four canopy layers

	Mean values of the tree growth parameters						
Canopy layer	THT	Dbh	CD	CL	BA	CPA	SV
Dominant	41.3831[a]	80.6204[a]	12.6589[a]	13.3808[a]	0.6580[a]	150.8611[a]	15.6432[a]
Co-dominant	32.7893[b]	47.3846[b]	8.3672[b]	10.1906[b]	0.2257[b]	66.4909[b]	4.6657[b]
Intermediate	22.6100[c]	28.7036[c]	5.6791[c]	7.3647[c]	0.0903[c]	33.0034[c]	1.1730[c]
Suppressed	13.5125[d]	20.5891[d]	4.0641[d]	4.9407[d]	0.0446[d]	20.3635[d]	0.3907[c]

N.B: Means in the same column with the same alphabet are not significantly different from each other

THT=tree total height; Dbh=diameter at breast height; CD=crown diameter; CL= crown length; BA = basal area; CPA = crown projection area; SV = stem volume

The different canopy layers in the two forest types represent different forest strata. Hence, the tree growth parameters vary greatly at these layers. A similar observation has been made by Bobo *et al.* (2006) in a tropical rain forest in Cameroon. However, this study showed that only tree crown diameter was significantly different between the two forest types. The mean crown diameter was higher in the secondary forest than in the closed canopy forest. The higher mean value for crown diameter in the secondary forest may be due to lower stocking and lesser competition than in the closed canopy forest. The trees have more space to rapidly grow, and for crown development.

Comparisons of Tree Growth Parameters in the Two Forest Types

Table 6 presents the result of the t-test for comparison of means of the tree growth parameters between the two forest types. The result revealed that there was no significant difference between the mean tree total heights (THT) under the two forest types since P>0.05. The mean tree diameters at breast height (Dbh) in the two forest types were not significantly different from each other (P>0.05). This implies that the mean tree Dbh in the closed canopy forest and the secondary forest were not significantly different from each other. The t-test for the comparison of the mean tree crown diameters (CD) between the two forest types showed a significant difference (P<0.05). This implies that the mean tree crown diameters in the two forest types were significantly different from each other. The mean tree basal area (BA) obtained in the closed canopy forest was not significantly different from that obtained in the secondary forest since P>0.05. The result for the crown projection area (CPA) also revealed no significant difference between the two forest types since P-value was 0.1154. The mean tree stem volumes in the two forest types were not also significantly different from each other (P>0.05).

The non-significant difference for most of the tree growth parameters between the two forest types implied that the secondary forest stock is relatively similar to the closed canopy forest. This trend was observed by van Gemerden (2004) and Bobo *et al.* (2006), who noted that, secondary forest, if left undisturbed for a while, could grow into the near-primary forest.

Table 6: t-tests for the tree growth parameters between the two forest types

Growth parameters	Forest Type	N	Mean	S.D	Df	t-stat	P-value
THT	CCF	947	24.3946	8.3027	1724	1.2757	0.2022
	SCF	779	24.9090	8.3762			
Dbh	CCF	947	35.4524	27.9940	1724	0.7873	0.4312
	SCF	779	34.4342	25.1213			
SQ	CCF	947	16.3046	6.9377	1724	2.0099	0.0446*
	SCF	779	16.9693	6.7112			
CD	CCF	947	6.2885	4.0573	1724	2.1413	0.0324*
	SCF	779	6.7165	4.2215			
BA	CCF	947	0.1602	0.4221	1724	1.0083	0.3134
	SCF	779	0.1426	0.2664			
CPA	CCF	947	43.9746	70.0042	1724	1.5750	0.1154

	SCF	779	49.4096	72.9387			
SV	CCF	947	2.7180	7.6144	1724	0.6117	0.5408
	SCF	779	2.9366	7.1086			

**significant (p<0.05)*

N.B: CCF: closed canopy forest; SCF: secondary forest; THT=tree total height; Dbh = diameter at breast height; SQ = stem quality; CD = crown diameter; BA = basal area; CPA = crown projection area; SV = stem volume

CONCLUSION AND RECOMMENDATIONS

This study has revealed the current status, tree species diversity and structure in the Oban Division of Cross River National Park, Nigeria. The higher diversity and species richness in the area implied some conservation success in the Park. The ecosystem is very rich in floral diversity and harbour many species of biological importance. Although the secondary forest is less diverse than the closed canopy forest, the difference in diversities indices appeared negligible. This is an indication that the secondary forest in the area is fast regaining high level of biological diversity, and if left undisturbed for a long period of time could reach its climax.

The Park authority is therefore implored to intensify the conservation and protection efforts in the area, and by extension, it is recommended that such effective measures be adopted in every other tropical rain forest of Nigeria in order to regain the lost ecosystem diversity. However, some illegal activities were noticed in the secondary forest, which serves as the buffer for the protected area. This may have contributed to the lesser number of tree species and stems recorded in the secondary forest. In order to prevent the occurrence of such in the core of the protected park, it is recommended that the possibility of joint forest management be considered. By embracing this, the surrounding indigenous communities would consider themselves as part of the park management, thereby, contributing to the security of the forest resources in the area.

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