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Forest Structure Analysis in the Oban Division of Cross River National Park, Nigeria

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Abstract: Information on forest structure is important for forest management decisions. This is inadequate in many situations, especially where timber is not of primary interest. We analyzed the structure of two forest types in the Oban Division of Cross River National Park, Nigeria. Systematic sampling technique was used to establish two transects measuring 2,000 × 2 m, at 600 m interval in the two forest types in four locations. Four 50 m × 50 m plots were located alternately at 500 m intervals along each transect, constituting 32 plots per forest type and 64 plots in all. Diameters at breast height (DBH), base; middle and top; crown diameter; total height and crown length were measured on all trees with DBH ≥ 10 cm. There were 159 stems/ha in the close-canopy forest and 132 stems/ha in the secondary forest. The mean DBH were 34.5 cm and 33.62 cm respectively. The mean heights were 24.79 m and 23.97 m, respectively. Basal area/ha were 41.59 m^2 ha^{-1} and 27.38 m^2 ha^{-1} for the two forest types. Majority of the trees encountered in the two forest types belonged to the middle stratum which has implication for small mammals' populations. Emergent trees which are otherwise scarce in other parts of the country were recorded, which also has implications for density thinning and seed supplies.

Key words: Rainforest, forest structure, size, systematic sampling technique, distribution, management.

1. Introduction

Forest structure is both a product and driver of ecosystem processes and biological diversity. Information on forest structure is an essential ingredient for sustainable forest management planning. The importance of forest structure is especially apparent in tropical rainforests where trees can reach great heights and diameters [1, 2]. In these forests, structures play many roles in the ecosystem functioning. For instance, large leaf areas intercept radiation and precipitation; gaps in dense canopies allow trees, shrubs, and herbs to regenerate; and large live and dead trees provide specialized habitats for many animal species [3, 4]. Height and diameter distributions may provide an indication of the relative proportion of old to young trees, which has implication for conservation and management.

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The bulk of the remaining virgin tropical rainforests in Nigeria is found within Cross River National Park (CRNP), while forest disturbance and fragmentation, caused by illegal logging as well as land conversion for local agriculture, is visibly increasing in the remaining parts of the country [5, 6]. Although logging companies have operated systematically in some parts of the CRNP in the past, there are portions, which have managed to escape the onslaught. An understanding of the structure of the remnant virgin forest will give an indication of the physical characteristics of the original primary forest for historical purpose.

It is therefore necessary to assess the structure of the vegetation of the park, which will provide the baseline data on which subsequent assessments will be based for conservation and management decisions. The objective of this study was to conduct a structure analysis of two forest types in the Oban Division of CRNP with a view to generating necessary data for the management of the park.

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2. Materials and Methods

2.1 Study Area

The study was conducted in the Oban Division of CRNP, Nigeria. The park was established under Decree 36 of 1991 with total land area of 4,000 km^2. It is one of the seven national parks in Nigeria. It comprises of two divisions (Oban and Okwangwo). Oban Division lies within longitude 8°20′ E and 8°55′ E and latitudes 5°00′ N and 6°00′ N; while Okwangwo Division is located on longitudes 9°02′ E and 9°27′ E and latitudes 6°04′ N and 6°28′ N [6]. The Oban Division was carved out of Oban group Forest Reserve in 1991. The total area is about 3,000 km^2 and it shares boundary with Korup National Park of Cameroon in the east (Fig. 1).

The terrain is rugged and elevation rises from the river valleys to over 1,000 m in mountainous areas. The area has a raining season of at least nine months (March-November) and receives over 3,500 mm of precipitation annually [6].

The vegetation of the park is characteristically moist tropical rainforest. In the less accessible areas, the forest has had little interference, but elsewhere the vegetation has been much influenced by human activities. Exploitation in the buffer zone has resulted in secondary regrowth. Tree height reaches 50 m to about 65 m and sometimes more [6].

2.2 Data Collection

Systematic sampling technique was used to establish two transects [7, 8], each measuring 2,000 × 2 m and at 600 m interval in each of the forest types (closed-canopy forest and secondary forest) in four locations (Aking, Ekang, Old Netim and Old Ekuri) (Fig. 1). Transects were evenly distributed over the study area. Four 50 m × 50 m (0.25 ha) plots were located alternately at 500 m intervals along each of the transects. This was replicated in the four sites. Growth data including: stem diameter at breast height; diameters over bark at the base, middle and merchantable top; crown diameter; total height and crown length were collected on trees with DBH ≥ 10 cm in all the 64 sample plots.

2.3 Data Analysis

All the trees sampled were grouped into four diameter classes viz. 10-50 cm, 50-90 cm, 90-130 cm, and > 130 cm. Tree heights were classified into five including: < 10 m, 10-21 m, 21-31 m, 31-40 m, and > 40 m following Clutter et al. [9].

2.3.1 Basal Area Estimation

The basal area for each tree in the enumerated plots was computed using:

$$BA = \frac{\pi D^2}{4} \quad (1)$$

Where, BA = basal area (m^2), D = diameter at breast height (cm), and $\pi = 3.142$ [10].

2.3.2 Volume Estimation

Volume of each tree was calculated using the Newton's formula as expressed by Husch et al. [10] and adopted by Adekunle et al. [7].

$$V = \frac{h}{6}(A_b + 4A_m + A_t) \quad (2)$$

Where V = tree volume (m^3), A_b, A_m and A_t = tree cross-sectional areas (m^2) at the base, middle and top of the tree, respectively; h = tree total height (m).

2.3.3 Correlation Analysis

Growth variables were paired to examine the linear relationships among them. The Karl Pearson's product moment correlation coefficient is given by:

$$r = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{N}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{N}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{N}\right]}} \quad (3)$$

Where, X and Y are individual measurements of the tree growth variables to be compared, N is the total number of trees/ha.

2.3.4 Comparisons of the Two Forest Types

Student t-test was used to investigate significant differences between the tree growth variables in the two forest types. The t-statistics is given as:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{S^2 \frac{(N_1 + N_2)}{(N_1)(N_2)}}} \quad (4)$$

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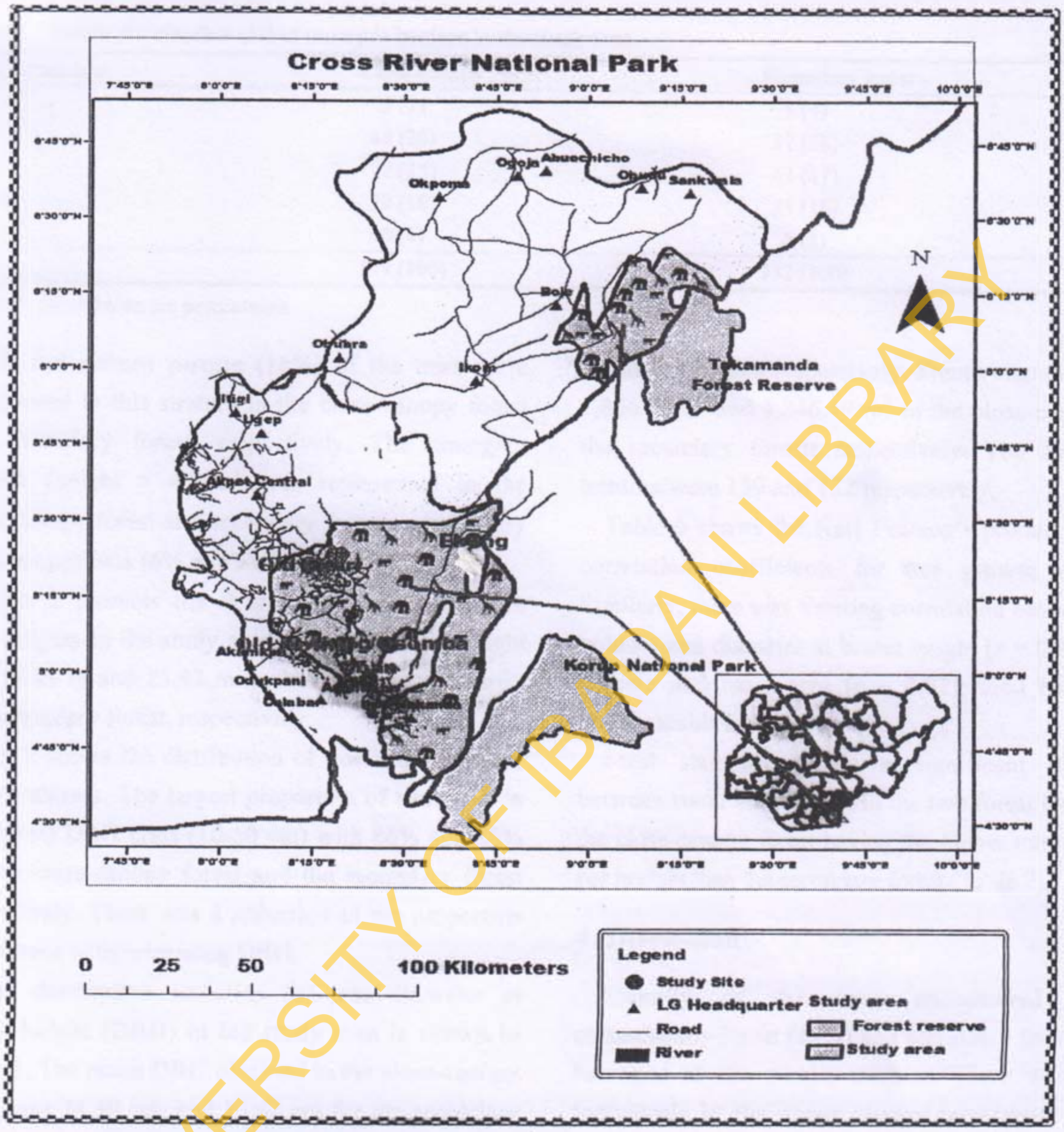

Fig. 1 Map of cross river national park showing the study areas.

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Where, $\overline{X}_1$ = mean of the measured values for a particular growth variable in the close-canopy forest, $\overline{X}_2$ = mean of the measured values for the variable in the secondary forest, N_1 = number of trees/ha in the close-canopy forest, N_2 = number of trees/ha in the secondary forest, and S^2 = pooled within-group variance (for independent samples with equal variance). The *t* has $(N_1\text{-}1) + (N_2\text{-}1)$ degrees of freedom.

3. Results

Distribution of trees into height classes corresponding to each of the strata in the two forest types is presented in Table 1. Five strata including: emergent, dominant, co-dominant, intermediate and the suppressed existed in the two forest types. The highest proportion of the trees encountered in the park (45% in the close-canopy forest and 47% in the secondary forest) belonged to the middle stratum (tree height 21-31 m). About 28% of the trees fall into the lower stratum (heights are 10-21 m) in the two forest types. The upper storey (height of 31-40 m) was the third richest stratum of the vegetation. Eighteen percent

Table 1 Height distribution (M) of trees per hectare in the study area.

Height class (m)	Close-canopy forest	Secondary forest
<10	3 (2)	5 (4)
10-21	45 (28)	37 (28)
21-31	72 (45)	63 (47)
31-40	29 (18)	21 (16)
>40	10 (6)	6 (5)
Total	159 (100)	132 (100)

values in parentheses are percentages.

(18%) and sixteen percent (16%) of the trees were represented in this stratum in the close-canopy forest and secondary forest, respectively. The emergent stratum (height > 40 m) was represented in the close-canopy forest and secondary forest, only in very small proportions (6% and 5%, respectively).

Table 2 presents the descriptive statistics of tree total heights in the study area. The mean total height was 24.83 m and 23.97 m in the close-canopy forest and secondary forest, respectively.

Fig. 2 shows the distribution of trees into diameter (DBH) classes. The largest proportion of trees was in the lowest DBH class (10-50 cm) with 86% and 85% for the close-canopy forest and the secondary forest respectively. There was a reduction in the proportion of the trees with increasing DBH.

The descriptive statistics for tree diameter at breast height (DBH) in the study area is shown in Table 3. The mean DBH obtained in the close-canopy forest was 34.50 cm, and 33.62 cm for the secondary forest.

The distribution pattern of tree crown diameter in the study area is presented in Table 4. About 76% of the trees were in the lowest crown diameter class (0-10 m) in the close-canopy forest while 75% of the trees in the secondary forest belong to the same class. About 22% of the trees in the primary forest and 23.4% in the secondary forest are in the middle class (10-20 m). Only 1.9% and 1.6% respectively are in the upper crown diameter class (> 20 m).

Table 5 presents a summary of the tree growth variables in the study area. The basal areas/ha were 41.59 m^2 and 27.38 m^2 for the close-canopy and secondary forests respectively. Stem volumes/ha were 1,866.91 m^3 and 1,246.49 m^3 in the close-canopy and the secondary forests respectively. The number of trees/ha were 159 and 132 respectively.

Table 6 shows the Karl Pearson's product moment correlation coefficients for tree growth variables. Similarly, there was a strong correlation between stem volume and diameter at breast height (r = 0.83); stem volume and basal area (r = 0.82); total height and merchantable height (r = 0.82).

t-test statistics shows a significant difference between stand volumes/ha in the two forest types, with the close-canopy forest having the higher mean volume per hectare than the secondary forest (Table 7).

4. Discussion

Majority of the trees encountered in the close-canopy forest (45%) and secondary forest (47%) belonged to the middle stratum. There were fewer individuals in the upper canopy (emergent) and the lower forest canopy (suppressed). The trend in vertical structure observed in this study is similar to those reported by Adekunle [11] for other tropical forests in southwest Nigeria. Trees in the emergent stratum are difficult to find in many Nigerian tropical rainforests today, due to logging pressures. The fact that we still have them represented in the area is a good indicator of conservation success. The common practice in local communities in Nigeria currently, is that trees of large dimensions are logged immediately, they are discovered, especially the most economic and highly sought-after species such as *Mansonia altisima*, *Milicia excelsa*, *Afzelia africana* and *Khaya* spp.

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Table 2 Descriptive statistics for tree height (M) per hectare in the study area.

Parameter	Value obtained	
	Close-canopy forest	Secondary forest
Mean	24.83	23.97
Standard error	0.315	0.366
Minimum	8.000	5.600
Maximum	48.500	51.600
Skewness	0.16	0.17

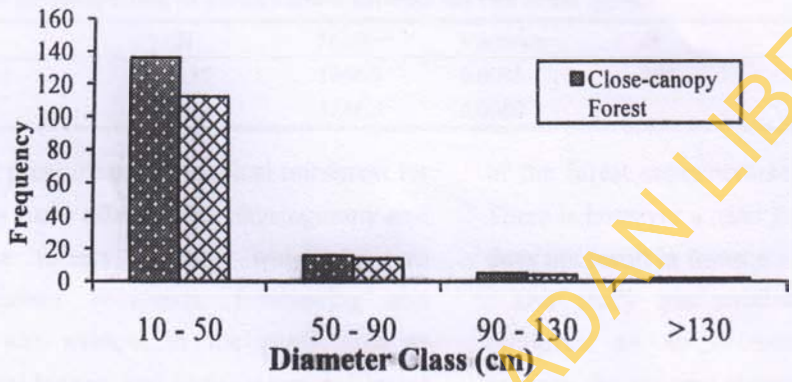

Fig. 2 Diameter distribution of trees in the two forest types.

Table 3 Descriptive statistics for mean DBH (cm) per hectare in the study area.

Parameter	Value obtained	
	Close-canopy forest	Secondary forest
Mean	34.5	33.6
Standard error	1.1	1.1
Minimum	10.5	10.1
Maximum	304.5	168.0
Skewness	0.9	0.9

Table 4 Crown diameter (m) distribution of trees per hectare in the study area.

Class	Close-canopy forest	Secondary forest
0-10	120 (75.5)	99 (75)
10-20	36 (22.6)	31 (23.4)
20-30	3 (1.9)	2 (1.6)
Total	159 (100)	132 (100)

Numbers in parentheses are percentages.

Table 5 Summary of tree growth variables in the study area.

Variables	Value obtained	
	Close-canopy forest	Secondary forest
Basal area (m^2/ha)	41.6	27.4
Volume (m^3/ha)	1,866.9	1,246.5
Average DBH (cm)	34.5	33.6
Average crown length (m)	8.2	7.8
No. of stems/ha	159	132

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Table 6 Correlation coefficient for tree growth variables in the study area.

	THT	MHT	Dbh	CL	CD	BA
MHT	0.822					
DBH	0.615	0.403				
CL	0.487	0.117	0.422			
CD	0.495	0.318	0.649	0.362		
BA	0.421	0.235	0.881	0.340	0.534	
SV	0.488	0.307	0.832	0.343	0.533	0.821

THT: tree total height; MHT: tree merchantable height; DBH: tree diameter at breast height; CL: crown length; CD: crown diameter; BA: basal area; SV: stem volume.

Table 7 *t*-statistic for comparison of yields/hectare between the two forest types.

Variables	N	Mean	Variance	df	*t*-stat	*P*-level
Close-canopy forest	159	1866.9	0.0035	289	12708.43	0.0000*
Secondary forest	132	1246.5	0.0060			

The increased pressure on the tropical rainforest for several uses may have affected the physiognomy and structure of the forests [8, 12], which in turn negatively influence ecosystem functioning and stability. This was evident in the study area as activities of illegal loggers and *Irvingia* spp. collectors are prevalent especially in the buffer zone (secondary forest). Furthermore, though the proportion of emergent species was slightly higher in the close-canopy forest than in the secondary forest, the difference is insignificant, indicating that the secondary forest, if left for sufficiently long enough, will return to climax.

In late serial stage of secondary regrowth, there is likelihood of occurrence of large trees and with complex under-storey. According to Carey [13], this is an indication that density thinning may not have immediate adverse effect on wildlife habitat particularly for arboreal animals such as flying squirrels. It has been shown that maintaining old coarse forest structure may not be favourable to populations of small mammals as would a secondary regrowth with some prescribed thinning [13]. This may have to do with availability of fruits, seeds, sometimes flowers in extensively managed forest with thinned younger growths.

Thus, control logging within the buffer zone, if done with proper planning may help the conditioning of the forest ecosystem for some species of wildlife. There is however a need for caution to ensure that this does not result in forest ecosystem degradation.

Our study has confirmed the potential of this rainforest as an ecotourism destination. This is because the canopy structure is such that the largest proportion of the trees is in the middle canopy, which according to Michael [14], this canopy layer harbours most species of rainforest wildlife due to availability of food at this level. This presents a good habitat for certain wildlife species which may stimulate ecotourism.

The two forest types investigated in this study were characterized by abundance of trees with small DBH. This trend is not unusual for the tropical rainforests, which are only slightly affected by human use pressure. Similar results have been reported by previous workers in other tropical rainforests of Nigeria [7, 8] and a tropical lowland rainforest in Indonesia [15]. The relatively fewer number of individuals with DBH values > 50 cm can be explained by two main, but mutually exclusive factors. Firstly, there might be a limited number of species that naturally grow up to this diameters [16] and their seedlings need to meet optimal conditions for growth, to out-compete other (especially fast growing) species. Secondly, the numbers of certain big tree species could have been already reduced by selective

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extraction for some uses in the past [15].

The basal area/ha in this study was lesser in the secondary forest than the close-canopy forest. The values obtained in the two forest types were higher than those reported by Adekunle et al. [7] for some other tropical rainforests in Nigeria, and far higher than the 15 m^2 suggested by Alder and Abayomi [17] for a well-stocked tropical rainforest in Nigeria. This is to be expected since the study area is under protection by law, with minimal human use pressure. The tree basal area value (41.6 m^2/ha) obtained in this study for the close-canopy forest is higher in comparison to the value (39.2 m^2/ha) reported by Zapfack et al. [18] in Southern Cameroon, and it compares well with 42.6 m^2/ha reported elsewhere in the South province of Cameroon by van Gemerden [19]. The value recorded for the close-canopy forest is slightly higher than the value (40.8 m^2/ha) reported by Zent and Zent [20] for a tropical rainforest in Venezuelan Guayana. However, the value obtained in the secondary forest was lower than that reported by Zapfack et al. [18] for a secondary forest in Cameroon. The lower values obtained in the secondary forest may be the fact that some level of use is allowed in the forest since it serves as buffer for the protected area. Logging and farming activities are clearly responsible for this difference.

The total number of trees/ha (159 and 132 respectively) obtained in this study were higher in the two forest types than the values reported by Adekunle et al. [7]. The values were however lower than the 385/ha and 535/ha reported by Sidiyasa [21] in Wain River, East Kalimantan. The stem volumes per hectare recorded (1,866.9 m^3 and 1,246 m^3 respectively) for the close-canopy forest and secondary forest were far higher than the values reported by previous workers for other tropical rainforests of Nigeria [7, 8, 11]. The higher values obtained in this study is an indication that CRNP remains the richest of the tropical rainforest left in Nigeria as stated by Bisong and Mfon [5]. This may also be an indication of conservation success in the park. The value recorded for the secondary forest was lower than that for the close-canopy forest. This implies that the close-canopy forest is better stocked than the secondary forest as a result of restrictions of human activities especially in the close-canopy forest located in the core of the park.

The high value of the standard deviation for the tree sizes, both in the close-canopy and secondary forest is in line with a priori expectation in a tropical rainforest, which is under protection. The skewness of the DBH distribution is positive because there are more trees in the lower DBH classes than in the upper classes. This is consistent with the previous reports for two other tropical rainforest [22, 23]. The implication of this is that the forests are still undergoing regeneration and recruitment, which are vital indicators of forest health and vigour.

The strong correlation observed between stem volume and basal area is expected since an increase in basal area results in an increase in tree volume. Similar observations were reported by Adekunle et al. [7] and Adekunle [11]. The weak correlation between crown length and merchantable height is due to the fact that crown depth decreases with increases in tree merchantable height.

5. Conclusion and Recommendations

The small percentage of trees in the emergent, dominant and co-dominant height classes in the study area is an indication that the vegetation has been disturbed in the recent past, but currently displays signs of recovery. Trees in these categories are still present because of restriction to human perturbations in the park. Evidently, the park is very rich in trees in the lower diameter classes, which is an indication of a healthy and vigorous stand. The basal area per hectare obtained in this study for the two forest types were higher than the value suggested for a well-stocked tropical rainforest in Nigeria. The values were higher than those reported for other tropical rainforests with similar ecosystem in the country and compared well

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with the values reported for forests in other parts of Africa. There was a significant difference in mean stem volume per hectare in the two forest types with closed canopy forest having the highest mean volume per hectare.

The close-canopy forest is more structurally diverse than the secondary forest of the area. This is because the restriction to human activities in the close-canopy forest is taken more seriously than in the secondary forest (buffer), which serves as the interface between the free area and the core of the park (close-canopy forest). There are indications that conservation efforts in the study area are yielding positive results. Park authorities should therefore step up efforts at law enforcement and enlightenment campaigns to ensure adequate protection of the park. Some control logging at the buffer zone may be beneficial to small mammals' populations; but this must be done with a lot of caution in order to prevent degradation of the forest ecosystem.

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