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Tree Species Composition and Diversity in Oban Forest Reserve, Nigeria

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Abstract

Tree species composition and diversity were assessed in Oban Forest Reserve. Three stage sampling procedure was used to collect data on tree parameters – diameter at breast height (dbh); diameters over bark at the base, middle and top; merchantable height and total height using a minimum dbh limit of ≥10 cm in the tertiary sample plots. A total of 808 trees were measured and 72 species identified in the study area. Stand level parameters were estimated and tree diversity assessed. Results indicate that an average number of stems encountered per hectare were 306. Population densities of individual tree species ranged from 1 to 22 ha^{-1}. Population densities of species were poor. The basal area/ha estimated is 34.67m^2 and the species richness index obtained was 10.605, which indicate high species richness. The value of Shannon's Index (H^I) is 3.795 which is quite high. The results show that the forest reserve is a well-stocked tropical rainforest in Nigeria. The relative richness of the forest reserve in terms of individual tree species does not correlate well with the abundance because the abundance of each of the species was quite low and density poor. While there is paucity of most species, *Staudtia stipitata* was the most abundant (22 tree/ha). The forest has reverted back to the turbulent agrading stage of the forest growth cycle.

Keywords: Oban Forest Reserve, Species diversity, Tree density, Floristic composition

1. Introduction

Oban Forest Reserve habours a significant portion of Nigeria's remaining tropical rainforest. The entire landscape is recognized internationally as biodiversity hotspot (USAID, 2006). The tropical rainforest has been identified as the most biologically diverse terrestrial ecosystem on earth (Turner, 2001; Gillespie *et al.*, 2004, Onyekwelu *et al*., 2008; Schmitt *et al*., 2009, FAO 2010, and IUCN 2010). In terms of tree composition and species diversity, tropical rain forests are Earth‟s most complex ecosystems (Gebreselasse, 2011). Trees are often the most conspicuous plant life form in a typical tropical rainforest. The rainforest act as main repository of the genetic diversity of both flora and fauna.

Nigerian land, which covers a total area of 92.4 million hectares, has 9.7 million hectares, about 10% of the country, as forest reserves (ITTO, 2011). Out of which, only a small part of this forest is lowland rainforest. Even in the late 1990s it was estimated that only 1.19 million hectares of lowland rainforest remained in the country, and about 288 000 hectares of which was in official forest reserves (ITTO, 2011). The degradation, fragmentation and conversion of the forests to other forms of land uses in Nigeria, are currently progressing at alarming rates. Between 1990 and 2000, Nigeria lost about 2.7% of its natural forests to deforestation which increased to about 18.56% (about 2.06 million ha) between 2000 and 2010 (FRA, 2010; FAO, 2011). A cumulative 47.5% of Nigeria's natural forests were lost to deforestation between 1990 and 2010 (FRA, 2010). Recent global forest resources assessment revealed that Nigeria is one of the five countries in the world with the highest annual rate of deforestation for the period 2000 – 2010 (FRA, 2010).These changes have caused the loss of some plant species and a decline in the biodiversity conservation status of the forest and environmental quality. The sustainable management and use of these resources is essential for the nation's economic and environmental security (Akinsanmi, 1999). The need to provide adequate quantitative and qualitative ecological data to guide forest owners and managers in fashioning out realistic and effective management strategies is imperative. This study therefore provides baseline and impact data on species composition and diversity in Oban Forest Reserve, Nigeria.

2. Methodology

Oban Forest Reserve lies within longitude 8°20′ E and 8°55′ E and latitudes 5°00′ N and 6°00′ N. Presently, it cover an area of 742.55km^2 (figure 1).

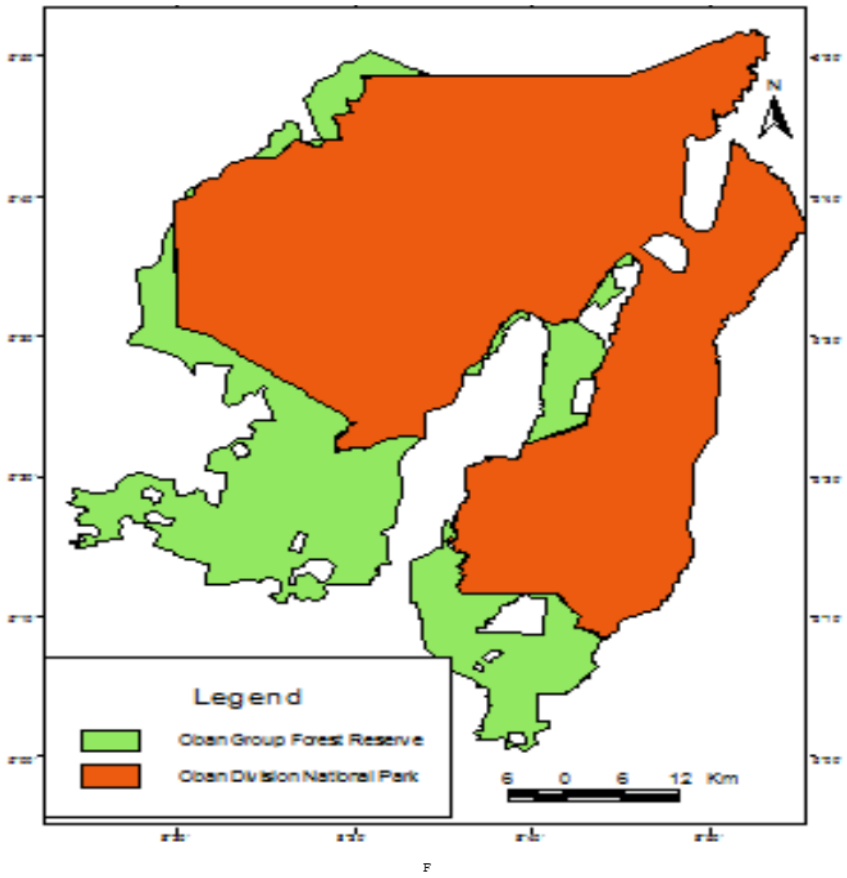

Figure 1. Map of Oban Forest Reserve

The terrain is rugged and elevation rises from the river valleys to over 1,000 m in mountainous areas (Jimoh *et al.*, 2012). Most of the area is characterized by hilly terrain ranging from 100 to over 1,000m. The dominant rock types are ancient metamorphic rocks of the Basement Complex which covers 50% of Nigeria. The metamorphic rocks are mainly gneisses (biotite-hornblende, granite and migmatitic gneiss and to a lesser extent amphibolite (schist) (Holland *et al*, 1989; Schmitt, 1996). Less sandy soils are found in areas with igneous rocks and deeper soils prevail in the plains of the southern part of the park whilst on steeper slopes they are increasingly stony, shallow and erodible (Holland *et al*, 1989).

Temperatures are generally high (average around 27 ℃) and vary little throughout the year with the annual range of the monthly average temperature varying only between 3 ºand 3.5 ºC. Mean monthly relative humidity varies between 78% and 91% with an average of Annual rainfall is generally, between 2,500mm- 3,000mm. At times, it can be up to 4,000mm.85%. (Holland *et al*, 1989; Schmitt, 1996).

2.1 Data Collection

Multistage sampling technique was used to establish primary (1000m x 1000m), secondary (1000m x 50m) and tertiary (40m x 50m) plots. Fourteen tertiary plots were randomly established within the secondary plots and trees randomly selected for measurement within the tertiary plots (0.20 ha). Growth data including: diameter at breast height (dbh, at 1.3m);

diameters over bark at the base, middle and merchantable top; merchantable height and total height were collected on trees with dbh ≥ 10 cm in all the 14 tertiary sample plots.

2.2 Data Analysis

Basal Area Estimation

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

$$BA = \pi D^2/4 \quad (1)$$

Where BA = basal area (m^2)

π = 3.142 (a constant)

D = dbh (m)

Basal area per plot was obtained by adding the basal area of all individual trees within the plot. Mean plot basal area were computed by summing the total plot basal areas of the sample plots selected from the primary unit and dividing by the number of sample plots selected from that primary unit . Basal area per hectare was then obtained by multiplying the mean plot basal area by the number of sample plots per hectare.

2.3 Diversity Analysis

The Shannon-Weiner diversity (H'), Evenness (E) and Simpson Dominance index were all calculated to determine the tree species diversity.

2.3.1 Shannon-Wiener Diversity Index (H^I)

The Shannon-Wiener diversity index has been the most widely used index in community ecology, equation 3 is used in computing this index.

$$H' = \sum_{i=1}^{s} pi \ln(pi) \quad (2)$$

Where:

H' = Shannon diversity index

P_i = proportion S (species in the family) made up of the i^{th} species

ln = natural logarithm

The values of Shannon-Wiener diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Magurran, 1988).

2.3.2 Species Evenness Index (E)

The ratio of the observed diversity (H) to the maximum diversity (H_{max}) is taken as a measure of evenness (E).

$$\text{Evenness} = \frac{H}{H_{max}} = \frac{H}{logs} \quad (3)$$

Where S is the total number of species. If H^I is used, therefore,

$$\text{Evenness } E^I = \frac{H^I}{InS} \quad (4)$$

E is constrained between 0 and 1.0 with 1.0 representing a situation in which all species are equally abundant.

2.3.3 Simpson's dominance Index

Simpson's dominance index is weighted towards the abundance of the commonest species.

$$\text{Simpson Index (C)} = \sum P_i^2 \quad (5)$$

Where P_i is the proportional abundance of the ith species ($\boldsymbol{P_i} = \frac{\boldsymbol{n_i}}{\boldsymbol{N}}$)

Simpson's index varies from 0 to 1 and gives the probability that two individuals drawn at random from a population belong to the same species. If the probability is high, then the diversity of the community sample is low. The higher the dominance index the lower the Shannon diversity.

An unbiased estimator for sampling from an infinite natural population, which is the modified formula is:

$$D = \sum \frac{n_i(n_i-1)}{N(N-1)} \quad (6)$$

The reciprocal (D^1) of Simpson's index (defined as number of very abundant species) will ensure that the index D^1 increases with increasing diversity.

2.3.4 Species Richness

$$\text{Margalef' Index (d)} = \frac{S-1}{In(N)} \quad (7)$$

Where S is the total number of species, 'N' is the total number of individuals and '*ln'* is the natural logarithm.

3. Results and Discussion

A total of 808 trees in different girth classes were measured in 14 tertiary sample plots (40m x 50m, temporary) from the forest reserve. The results indicate that Oban Forest Reserve has an average density of 306 trees per hectare (Table 1). Findings from research conducted across different eco-regions of the tropics reveal diverse results. In tropical Barro Island, Panama, Hubbell and Foster (1983) and Thorington *et al* (1983) reported 152/ha and 171/ha respectively; while Ho *et al*, (1987) found 104/ha in tropical Jengka Reserve, Malaysia. However, Oban Forest Reerve has lower tree density than the 385/ha and 535/ha reported by Sidiyasa, (2001) in Wain River, East Kalimantan, and 1420/ha (Campbell *et al*, 1986) and 1720/ha (Campbell *et al*, 1992) both in tropical Amazonia forest.

Although the minimum and maximum dbh range from 10cm and 138cm, tree distribution was positively skewed towards lower dbh classes (figure 2); implying that the forest reserve has reverted to agrading and fairly turbulent stage of the forest growth cycle which is often characterized by high abundance of trees with smaller dbh. Similar results have been reported by scientists in other parts of Nigeria (*cf.* Adekunle *et al.,* 2004; Adekunle and Olagoke, 2008) and other tropical regions (e. g. Boubli *et al.,* 2004 and Bobo *et al.,* 2006). The reason for relatively fewer number of tree individuals of larger dbh values greater than 50cm (dbh> 50cm) can be attributed to limited number of species that naturally grow up to this diameters (Hartshorn, 1980) and the numbers of certain big tree species could have been already reduced by selective extraction for some uses in the past (Hadi *et al.,* 2009).

The minimum and maximum merchantable height obtained is 1.74m and 40m respectively. The minimum and maximum total tree heights indicate 4.5m and 44m respectively for the forest reserve. The basal area/ha recorded in this study is 34.67m^2. The value obtained in the forest reserve is higher than those reported by Adekunle *et al*, (2004) and reasonably high when compare to basal area/ha reported by Kumar *et al*, (2002) for other tropical forest of the world. And also, it is higher than the 15m^2 suggested by Alder and Abayomi, (1994), 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 and also the high annual precipitation rate and equable tropical climate of the study area may have contributed to high tree growth rates and high tree basal area. The high basal area value obtained in this study is an indication that Oban Forest Reserve is probably one of the richest of the tropical rainforest left in Nigeria. This may also indicate that, the reserve is probably well regulated.

Table 1. Result of preliminary data analysis.

Oban Forest Reserve

Number of trees/hectare	306			
	Min	Max	Mean	Std Error
Dbh(cm)	10.0	138.0	33.7	0.007
D_{st}(cm)	11.1	160.0	38.1	0.008
MTH(m)	1.74	40	16.94	0.265
THT(m)	4.5	44	21.65	0.254
BA/ha(m^2/ha)	24.84	60.44	34.67	0.0051

Dbh- diameter at breast height; D_{st}-stump diameter; MTH- merchantable height; THT- total tree height; BA- basal area

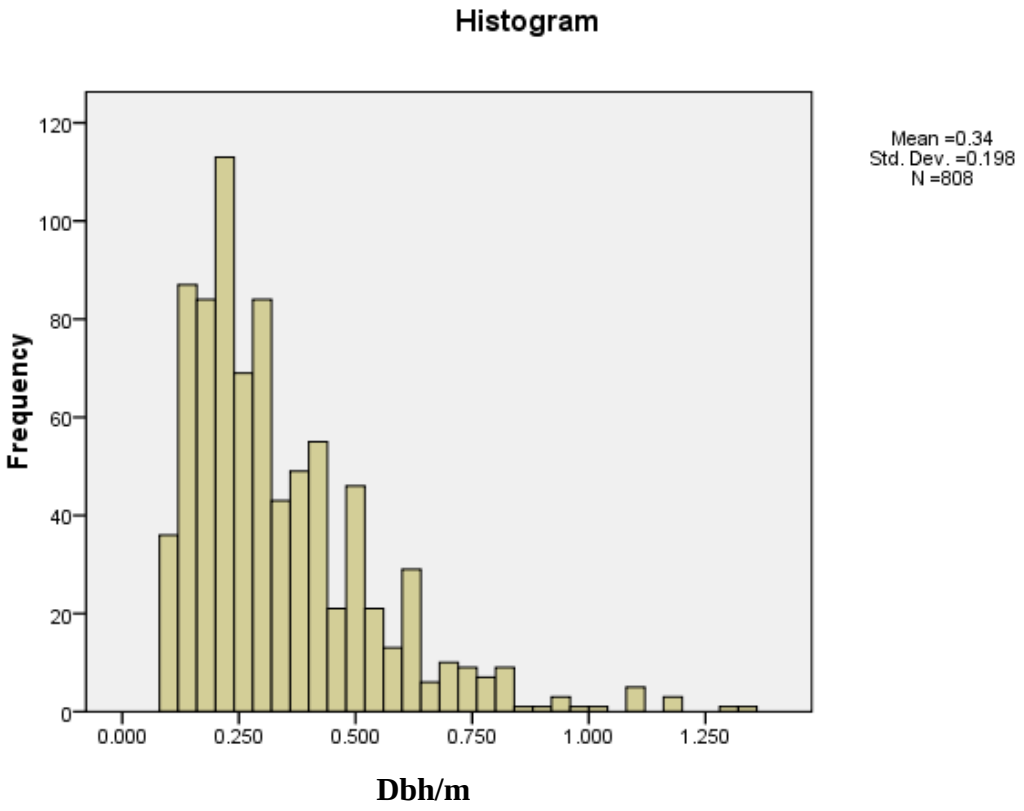

Figure 2. Dbh Distribution Pattern of Oban Forest Reserve

3.1 Floristic Composition

A total of 72 species distributed into 30 families and 65 genera were identified in the study area (Table 2 and 3). The following tree species (*Futumia elastica, Uapaca heudelotti, Carapa procera, Pycnathus angolensis, Staudtia stipitata, Sterculia oblonga and Celtis zenkeri*) were more prevalent in the study area with an average trees per hectare greater than or equal to nine (trees/ha ≥ 9). *Staudtia stipitata* and *Uapaca heudelotti* are the richest individual species with an average of 22 and 19 trees per hectare respectively, which represent 7.6% and 6.5% of the total tree stand respectively (Table 2). As shown in table 3, the following families (Apocynaceae, Caesalpinioideae, Combreteceae, Ebenaceae, Euphorbiaceae, Meliaceae, Mimosoideae, Moraceae, Myristicaceae, Papilionoideae, Steculiaceae and Ulmaceae) have average tree species per hectare greater than ten (trees/hectare > 10). Caesalpinioideae is the richest family being represented by 10 species and 10 genera. The second richest family is Mimosoideae with 7 species and 5 genera followed by Meliaceae consisting of 5species and 5 genera. The following species (*Alstonia boonei, Ceiba pentandra, Detarium macrocarpum, Distemonathus benthamianus, Agauria salicifolia, Allanblackia floribunda, Hypodaphnis zenkeri, Petersianthus macrocarpus, Khaya ivorensis, Lovoa trichilioides, Cylicodiscus*

*gabunensis, Tetrapleura tetraptera, Treculia obovoidea, Coelocaryon preussii, Pentaclethra mycophylla, Pterocarpus soyauxii, Anopyxis Klaineana, Nauclea diderrichii,*and *Cola spp.*) had one tree species per hectare and are threaten to go into extinction due to anthropogenic factor except urgent steps therefore need to be taken to arrest the dwindling density of timber species.

The poor population density encountered in the study area, may be attributed to unfavorable microclimate within the forests and the paucity of viable seeds of the trees to sustain regeneration. For instance, a tree species that is not shade tolerant would find it difficult to regenerate in a rainforest with closed canopy, which definitely would affect the population density of such a tree species. Christie and Armesto (2003) reported very low population densities of quite a number of economically valuable tree species occasioned by dearth of viable seeds and poor micro-sites for regeneration. Also, abundance or rarity of a timber tree species of economic value in an area of rainforest is a function of the intensity and pattern of its exploitation. Therefore, the fewer population of individual tree species observed in the study areas can be linked to anthropogenic factor. This would also cause gross inadequacy of seeds for regeneration, as a lot of mother trees must have been felled. It is of the fact that, there is a positive relationship between poor population densities of some tree species and the mortality of their old mother trees (Olajide, 2004).

Table 2. Timber Species of Oban Forest Reserve Identified by their Families and Relative Density

Family	Species name	No. of stem per Hectare	Relative Density/Hectare
Anacardiaceae	*Lannea welwitschii*	6	0.01854
Anisophylleaceae	*Poga oleosa*	7	0.02224
Annonaceae	*Pachypodathium staudtii*	2	0.00494
Annonaceae	*Xylopia aethiopica*	2	0.00741
Apocynaceae	*Alstonia boonei*	1	0.00371
Apocynaceae	*Futumia elastica*	9	0.02842
Apocynaceae	*Voacanga africana*	2	0.00618
Bombacaceae	*Bombax buonopozense*	3	0.00865
Bombacaceae	*Ceiba pentandra*	1	0.00371
Burseraceae	*Canarium schweinfurthii*	5	0.0173
Caesalpinioideae	*Afzelia Africana*	7	0.02224
Caesalpinioideae	*Berlinia grandiflora*	2	0.00618
Caesalpinioideae	*Brachystegia eurycoma*	4	0.01483
Caesalpinioideae	*Daniellia ogea*	8	0.02719
Caesalpinioideae	*Detarium macrocarpum*	1	0.00247
Caesalpinioideae	*Distemonathus benthamianus*	1	0.00124
Caesalpinioideae	*Erythrophleum suaveolens*	3	0.00989
Caesalpinioideae	*Gossweilerodendron balsamiferum*	7	0.02472
Caesalpinioideae	*Hylodendron gabunense*	2	0.00618
Caesalpinioideae	*Oxystigma manni*	2	0.00618

Combretaceae	*Terminalia ivorensis*	8	0.02842
Combretaceae	*Terminalia superba*	6	0.01977
Ebenaceae	*Diospyros crassiflora*	15	0.05067
Ericaceae	*Agauria salicifolia*	1	0.00124
Euphorbiaceae	*Klainedoxa gabonensis*	3	0.01112
Euphorbiaceae	*Ricinodendron africanum*	2	0.00741
Euphorbiaceae	*Uapaca heudelotii*	19	0.0655
Flacourtiaceae	*Homalium spp.*	7	0.02224
Guttiferae	*Allanblackia floribunda*	1	0.00124
Guttiferae	*Mamea Africana*	3	0.00865
Irvingiaceae	*Irvingia gabonensis*	7	0.02472
Lauraceae	*Hypodaphnis zenkeri*	1	0.00371
Lecythidaceae	*Petersianthus macrocarpus*	1	0.00124
Loganiaceae	*Anthocleista djalonensis*	2	0.00494
Meliaceae	*Carapa procera*	15	0.05067
Meliaceae	*Entandrophragma cylindricum*	2	0.00494
Meliaceae	*Guarea thompsonii*	2	0.00741
Meliaceae	*Khaya ivorensis*	1	0.00247
Meliaceae	*Lovoa trichilioides*	1	0.00247
Mimosoideae	*Albizia ferruginea*	3	0.00989
Mimosoideae	*Albizia gumifera*	2	0.00741
Mimosoideae	*Albizia zygia*	3	0.01112
Mimosoideae	*Cylicodiscus gabunensis*	1	0.00124
Mimosoideae	*Parkia bicolor*	2	0.00618
Mimosoideae	*Piptadeniastrum africanum*	3	0.00989
Mimosoideae	*Tetrapleura tetraptera*	1	0.00371
Moraceae	*Antiaris welwitschii*	2	0.00494
Moraceae	*Ficus lutea*	2	0.00741
Moraceae	*Ficus mucuso*	3	0.00989
Moraceae	*Milicia excelsa*	4	0.01359
Moraceae	*Treculia africana*	2	0.00618
Moraceae	*Treculia obovoidea*	1	0.00124
Myristicaceae	*Coelocaryon preussii*	1	0.00247
Myristicaceae	*Pycnathus angolensis*	12	0.04202
Myristicaceae	*Staudtia stipitata*	22	0.07662
Ochnaceae	*Lophira alata*	7	0.02348
Olacaceae	*Strombosia pustulata*	4	0.01236

Papilionoideae	*Amphimas pterocarpoides*	3	0.00865
Papilionoideae	*Baphia nitida*	2	0.00494
Papilionoideae	*Pentaclethra mycophylla*	1	0.00124
Papilionoideae	*Pterocarpus osun*	5	0.01607
Papilionoideae	*Pterocarpus soyauxii*	1	0.00124
Rhizophoraceae	*Anopyxis klaineana*	1	0.00247
Rubiaceae	*Mitragyna stipulosa*	2	0.00741
Rubiaceae	*Nauclea diderrichii*	1	0.00124
Rubiaceae	*Pausinystalia macrocera*	2	0.00494
Simaroubaceae	*Hannoa klaineana*	2	0.00741
Sterculiaceae	*Cola spp*	1	0.00371
Sterculiaceae	*Sterculia oblonga*	12	0.04078
Sterculiaceae	*Triplochiton scleroxylon*	4	0.01483
Ulmaceae	*Celtis zenkeri*	13	0.04572
Verbenaceae	*Vitex gradifolia*	8	0.02719

Table 3. Pattern of Families Distribution by Genera and Species

Families	Number of genera	Number of species	Average trees/Hectare
Anacardiaceae	1	1	6
Anisophylleaceae	1	1	7
Annonaceae	2	3	4
Apocynaceae	3	3	12
Bombacaceae	2	2	5
Burseraceae	1	1	5
Caesalpinioideae	10	10	37
Combretaceae	1	2	14
Ebenaceae	1	1	15
Ericaceae	1	1	1
Euphorbiaceae	3	3	24
Flacourtiaceae	1	1	7
Guttiferae	2	2	4
Irvingiaceae	1	1	7
Lauraceae	1	1	1
Lecythidaceae	1	1	1
Loganiaceae	1	1	2
Meliaceae	5	5	21
Mimosoideae	5	7	15
Moraceae	3	6	14
Myristicaceae	3	3	35
Ochnaceae	1	1	7
Olacaceae	1	1	4
Papilionoideae	4	5	12

Rhizophoraceae	1	1	1
Rubiaceae	3	3	5
Simaroubaceae	1	1	2
Sterculiaceae	3	3	17
Ulmaceae	1	1	13
Verbenaceae	1	1	8

3.2 Diversity Index

Table 4 shows summary of diversity indices for Oban Forest Reserve. The species richness index obtained was 10.605, which indicate high species richness. The Shannon index measures the relative abundance of species. The value of Shannon-Wiener Index (H^I) is 3.795 which is quite high compared to 2.20–2.65 for the tropical forests of Kodayar in the Western Ghats of southern India (Sundaranpandian *et al*, 2000). The Shannon-Wiener Index (H^I) can as well be compare to tree species diversity values in tropical forests of Kalakad Reserved Forests in Western Ghats which were reported as 3.31and 3.69 (Parthasarathy *et al*, 1992), and in tropical forests of Barro Colorado Island in Panama as 4.8 (Knight, 1975). However, quantitative comparisons of species diversities in this study area with other studies elsewhere depend on sample size, plot size, environmental conditions, and other site factors.

The Simpson's Index (D^I) (reciprocal form) obtained was 33.490 (Table 4), which mean Oban Forest Reserve has a high diversity value. This is in agreement with Young and Swiacki (2006) who stated that diversity was made up of the variety of species present and the relative abundance of those species. The higher the values, the higher the diversity (Ojo 2004). The Simpson's Index (D) of 0.029 (Table 4) indicates that the diversity of the reserve is high and it is an indicative of a healthy reserve.

Table 4. Summary of the Various Diversity Calculated for Oban Forest Reserve

Characteristic	Oban Forest Reserve
Species Richness(d)	10.605
Shannon-Wiener (H^I)	3.795
Evenness Index(E)	0.887
Simpson's Index(D)	0.030
Simpson's Index(D^I)	33.490

4. Conclusion

Oban Forest Reserve is not only important in terms of plant biodiversity but also they are considered as important destination point for rich timber resources. In this forest, economically and ecologically very important tree species such as *Diospyros crassiflora, Petersianthus macrocarpus, Entandrophragma cylindricum, Khaya ivorensis, Piptadeniastrum africanum, Milicia excelsa, Lophira alata, Strombosia pustulata* etc are found. Hence, it is very crucial to protect these important forests from biodiversity, sustainable management and environmental perspectives.

The presence of *Thaumatococcus danielli, Musanga cecropioides* and *Aframomum latifolium* in the study area, is an indication that the vegetation has been disturbed in the recent past, but

currently displays signs of recovery. Evidently, the forest reserve is very rich in trees in the lower diameter classes, which is an indication of a healthy and vigorous stand. The high species diversity and the relative richness in timber species of the forest reserve does not correlate well with the abundance because the abundance of each of the species was quite low and density poor. Some tree species encountered translates to one stand per hectare. To prevent the extinction of some families particularly the monospecific ones, urgent steps therefore need to be taken to arrest the dwindling density of timber and the forest reserve should be restocked, especially the species having only one stand. Exploitation of timber resources need to be drastically reduced to allow the forest to regenerate itself.

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