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GROWTH VARIABLES AND WEIBULL DIAMETER DISTRIBUTION MODELS FOR MANGROVE SPECIES IN FORESTRY RESEARCH INSTITUTE OF NIGERIA,ONNE, RIVERS STATE, NIGERIA

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ABSTRACT

Identification and estimation of quantitative variables of tree stands are basic requirements for forest planning, management and production. This study was conducted to assess the growth variables and diameter distribution models of mangrove species in swamp forest of Onne and to ascertain the best fitting models using Weibull diameter distribution. Systematic sampling technique was employed for plot location. The design used four – 10m x 20m rectangular plots laid along four 100m transects at intervals of 10m; with 5 x 5m sub-plots nested within them and in an alternate manner. All mangrove trees with diameter > 10cm were measured in the entire plots while on the 5 x 5m sub-plots, all trees with diameter < 10cm and height > 1.3m were measured. The mangrove species composition in the study zone revealed 231 mangrove tree stands belonging to two families namely: Rhizophoraceace and Avicenniaceace. Species richness of the mangrove species in the study area shows that Rhizophora racemosa were the most abundant with 212 stands and 0.073m^3 of volume, followed by Avicennia germinans and Rhizophora mangle. The Rhizophoraceace was the most prevalent family, while low diversity of some families may be attributed to natural competition. There were strong correlations among the species growth parameters with significant correlation coefficients at P<0.05. The goodness of fit for the mangrove species revealed that Kolmogorov Smirnov (Ks) had the better ranking followed by Anderson Darling (H_A) and Chi-Squared (R^2). This is indicative of plausible potential of Weibull diameter probability distribution function (PDF) in fitting diameter classes for sustainable management of mangrove ecosystem.

Keywords: growth variables, weibull distribution function, sustainable management, mangrove

INTRODUCTION

Africa is regarded as the continent with the greatest diversity of animals and plants, and the tropical rainforests are the world's largest forests, noted for their prolific growth and renewal of trees and bushes year after year (Oyebade et. al, 2010). Biogeography, niche requirements, and human induced factors all influence tree diversity, growth characteristics, and distribution of diameter in Africa (Huang *et al.*, 2003). Many tropical forests are undergoing significant changes due to anthropogenic factors, including the installation of plantations, poorly skilled farming practices, and non - certified hunting and capturing methods (Ndah *et al.*, 2012). To maintain a healthy profile of diversity and ecological productivity, implementing sustainable practices are required (Reddy and Ugle, 2008).

Distribution of diameter models are dimension class simulations that provide details for every diameter class, including the number of decision trees, basal area, and volume in a unit given area, and are typically determined by the estimation of the various theoretical distributions parameters (Kangas and Maltamo, 2000). Information on growth and yield is critical for long-term forest conservation and management (Burkhart, 1977). To predict growth, whole stand models only need just few elements, but they convey a lot of basic information regarding the actual future stand. They forecast future yield based on stand-level characteristics like age of stand, index of site, and the density. According to Scolforo (2008), knowing the distribution of diameter in a planted forest is a fundamental necessity for yield forecast or prognosis. There is also interests in defining distributions of diameter frequency by making use of functions such as probability density during the evaluation of diameter structure (Campos and Leite, 2006). A probability density function can explain the relative/absolute distribution of frequency of particular size of tree, or specify the likelihood value that is associated with the variable in consideration (Campos and Leite, 2006). Models such as "diameter distribution models" can be used to predict trees' number per unit hectare in each diameter class at present or in the future. Therefore, using a volume or taper or volumetric ratio equation, may permit the estimation of yield in a unit diameter class, which is a useful tool when dealing with numerous products of wood (Miguel *et al.*, 2010). Forest management strategies, growth/yield modeling, and inventories of forest have all benefited from the adoption of diameter-class distribution modelling. One of the most well-known long-lasting distributions is the Weibull distribution. It effectively represents many distinct forms of component and phenomenon failures.

Nigeria's mangrove forest is the world's third largest and Africa's largest. The Niger-Delta region of Nigeria has almost 60% of these mangroves which is about 6,000km^2.

The continuous demand for forest resources have brought intense pressure on the forest ecosystem thereby leading to rapid loss of biodiversity species in natural habitat (Adeyemi *et al.*, 2013). The advent of rapidly growing species and agricultural products have resulted in the loss of many of the world's most diverse natural forests (Wilson, 1989). This in turn has exposed forest ecosystem to environmental and ecological changes, decreasing the optimum functions of the forest (Adeyemi *et al.*, 2013). Forest ecological systems are recognized as critical sources for the sustenance of household in the African continent (Adeyemi *et al.*, 2008). However, the processes underlying forest use and dilapidation in the Niger Delta region of Nigeria and the whole of Africa remain unclear (Adeyemi *et al.*, 20008). Nigeria's abundant biodiversity have been poorly documented, making the available data woefully inadequate (Adeyemi *et al.*, 2008). The objective of this study is to assess the growth variables and Weibull diameter probability distribution models of mangrove species in Onne Forestry Research Institute of Nigeria.

METHOD

The study was carried out at the Forestry Research Institute, Onne, in Eleme Local Government Area, Rivers State, Nigeria. According to NDES (2011), rainfall in this forest is between 2000 to 2470mm per annum and terrain is undulating in the lowland areas. This study strictly focuses on mangrove species in Onne Swamp Forest and the tree variables enumerated were tree diameters of various points, basal area, height, and volume in the sampled plots. Figure 1 shows the map of Eleme Local Government in Rivers State showing Swamp Forest Research Station at Forest Research Institute of Nigeria (FRIN), Onne.

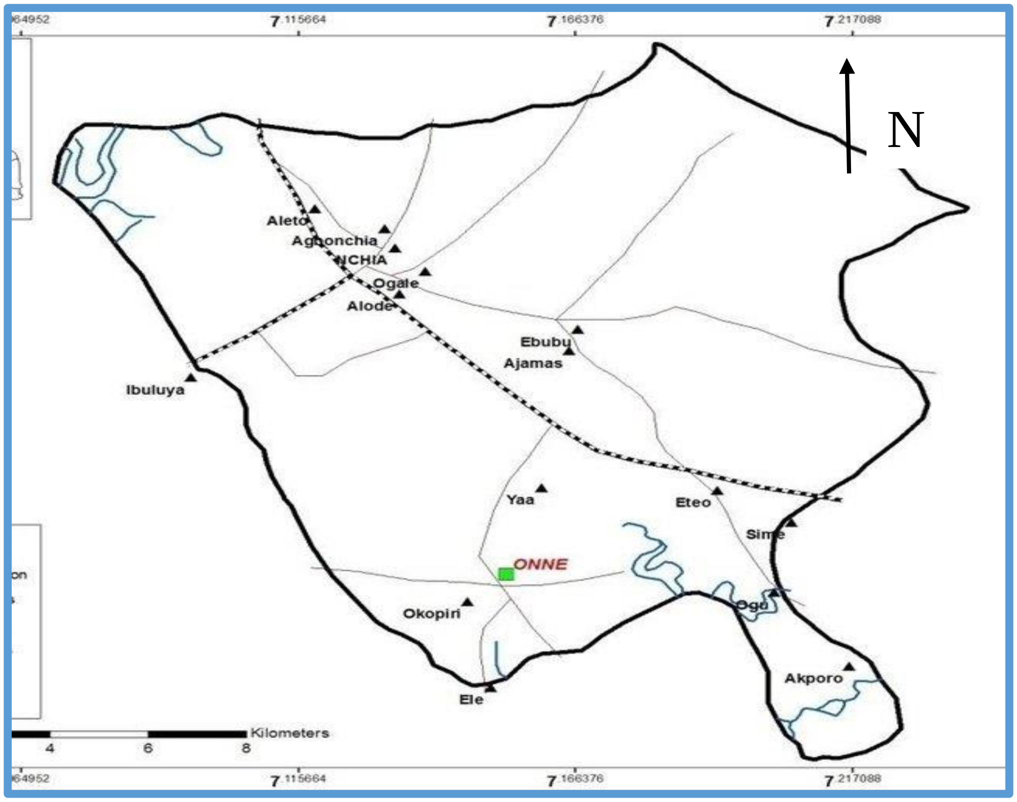

Fig. 1: Map of Eleme Local Government in Rivers State showing Swamp Forest Research Station at Forest Research Institute of Nigeria (FRIN), Onne (Oyebade, et al, 2010).

Systematic sampling technique was employed for plot location. The design uses four – 10m x 20m rectangular plots laid along four 100m transects at intervals of 10m; with 5 x 5m sub-plots nested within them and in an alternate manner. All mangrove trees with diameter > 10cm were measured in the entire plots. On the 5 x 5m sub-plots, all trees with diameter < 10cm and height > 1.3m were measured. Instruments such as Haglof Electronic Clinometer, diameter tape, caliper and tree height app were used to measure tree parameters namely diameter, basal area, volume and height of the selected trees in sample plots. The tree heights were measured using clinometer while diameters at various points were measured using diameter tape and caliper.

At the end, a total of two hundred and thirty one (231) trees were measured; and they were divided into five diameter classes: 10-15cm, 15-20cm, 20-30cm, 30-40cm and >40cm; tree heights were classified into five classes which are <5m, 5-10m, 10-15m, 15-20m and >20m and, the various tree volumes in sampled plots were computed and grouped into five which are 10-15cm, 15-20cm, 20-30cm, 30-40cm and>40cm. The basal area for each tree in the enumerated plots were computed using:

$$BA = \frac{\pi D2}{4} \qquad \text{(equ.1)}$$

Where BA = basal area (m^2), D = diameter at breast height (cm) and п = 3.142.

Volume computation using Newton's formular

$$V = H/6(g_b + 4g_m + g_t) \qquad \text{(equ.2)}$$

Descriptive statistics were used for the growth variables in Microsoft excel while correlation analysis were used to ascertain the association among the measurable and computed variables in the study area with SPSS Statistics software. Easyfit 5.5 standard software were used to generate the Weibull distribution models. Data obtained from tree species composition were analyzed by relative density (%) and relative abundance.

$$RD = \frac{Number\ of\ individual\ species}{Total\ number\ of\ trees} \times 100 \qquad \text{(equ.3)}$$

Where RD = Relative density of species.

$$Pi = \frac{Relative\ density\ of\ species}{100} \qquad \text{(equ.4)}$$

Where Pi = Species' relative abundance.

The diverse species were given a score based on their unique characteristics; relative densities (RD): abundant (RD≥5.00), frequent (4.00≤RD≤4.99), occasional (3.00≤RD≤3.99), rare (1.00≤RD≤2.99) and threatened or endangered (0.00≤RD≤1.00) as used by Edet *et al*. (2011)

The Shannon-Diversity Wiener's Index (H), was computed using data obtained from relative abundance which is used to measure the degree of uncertainty of predicting the species of a random sample in the park.

$$H = - \sum Pi\ InPi \qquad \text{(equ.5)}$$

Given that H = Diversity Index of Shannon-Wiener. Pi = The i^{th} species' relative abundance and InPi = The natural logarithm of the species' corresponding relative abundance (pi).

RESULTS AND DISCUSSION

Table1: Summary Statistics of Growth Variable of Mangrove Species in Onne Swamp Forest.

Table 1 shows the result for mangrove species composition in Onne mangrove swamp forest with total of 231 mangrove tree stands belonging to two families. Species composition shows that *Rhizophora racemosa* is the most abundant and in volume as well (212 stands & 0.073m^3), followed by *Avicennia germinans* with 11 stands & 0.046m^3 and *Rhizophora mangle* with eight stands & 0.043m^3. Also, the table shows that *Rhizophora mangle* has highest number of mean height, followed by *Rhizophora racemosa* and finally *Avicennia germinans*.

Table 1: Summary statistics of growth variable of mangrove species in Onne Swamp Forest.

Species	Family	No of Family	No of species	Mean DBH (cm)	Mean BA (m^2)	Mean Vol (m^3)	Mean Height (m)
Avicennia germinans	*Avicenniaceae*	1	11	14.127	0.162	0.046	2.845
Rhizophora mangle	*Rhizophoraceae*	1	8	13.900	0.016	0.043	3.475
Rhizophora racemosa	*Rhizophoraceae*	1	212	16.175	0.022	0.073	3.383

Where: DBH = diameter at breast height, BA = basal area, and Vol. = volume

Table 2: Ecological Indices of Mangrove Species in Onne Swamp Forest.

Table 2 presents mangrove species richness in the study area. The species with least and highest basal area and relative density are *Avicennia germinans* and *Rhizophora racemosa* with 0.162m^2 & 4.76 and 0.022m^2 & 91.77 respectively. The relative density of the various species indicate that *Rhizophora racemosa* were the most abundant species with 91.77 while *Avicennia germinans* and *Rhizophora mangle* are frequent and occasional species with 4.76 & 3.46 respectively.

Table 2: Ecological indices of mangrove species in Onne Swamp Forest.

Species	No of Specie	DBH Mean: Max - Min	Mean BA (m^2)	RD	RD_0	H	SIV

Avicennia germinans	11	10.00 – 18.90	0.162	4.76	3.63	-0.14498	13.15115
Rhizophora mangle	8	10.40 -19.70	0.016	3.46	2.54	-0.11647	9.465797
Rhizophora racemosa	212	10.10 – 28.70	0.022	91.77	93.83	-0.07877	277.3831

Where H = Shannon-Wiener's Diversity Index, RD = Relative Density, RD_0 = Relative Abundance and SIV = Species Important Value.

Table 3a: Growth variable correlation matrix of *Avicennia germinans* in the study area.
Table 3a shows the association between dbh, height, basal area and volume of *Avicennia germinans* in the study area. There is a perfect correlation among the growth variables.

Table 3a: Growth variable correlation matrix of *Avicennia germinans* in the study area.

	DBH	H	BA	VOL.
DBH	1			
H	0.559	1		
BA	0.981**	0.553	1	
VOL.	0.902**	0.790**	0.914**	1

DBH = diameter at breast height, H= height, BA = basal area, and VOL. = volume

Table 3b: Growth variable correlation matrix of *Rhizophora mangle* in Onne Swamp Forest.
Table 3b shows the association between DBH, basal area, height and volume of *Rhizophora mangle* in the sampled area. There is a perfect correlation among the growth variables.

Table 3b: Growth variable correlation matrix of *Rhizophora mangle* in the study area.

	DBH	H	BA	VOL
DBH	1			
H	-0.080	1		
BA	0.908**	0.000	1	
VOL	0.844**	0.372	0.845**	1

DBH = diameter at breast height, H= height, BA = basal area, and VOL. = volume

Table 3c: Growth variable correlation matrix of *Rhizophora racemosa* in the study area.
The table 3c shows the association between dbh, height, basal area and volume of *Rhizophora racemosa* in the study area. There is a perfect correlation among the growth variables.

Table 3c: Growth variable correlation matrix of *Rhizophora racemosa* in the study area.

	DBH	H	BA	VOL
DBH	1			
H	0.257**	1		
BA	0.866**	0.325**	1	
VOL	0.600**	0.470**	0.652**	1

DBH = diameter at breast height, H= height, BA = basal area, and VOL. = volume

Table 4: Diameter distribution class of *Avicennia germinans, Rhizophora mangle, Rhizophora racemose and Nypa fruticans* in the study area.
Table 4 shows the diameter classes distribution of mangrove species in the sampled area. It shows that the mangrove species with the diameter class of 6-10cm and 16-20cm were the most prevalent, while other diameter classes have almost the same frequent occurrence as shown in Figures 4a, 4b, 4c and 4d.

Table 4: Diameter distribution classes of the mangrove species in the study area.

Species	Diameter Class (cm)	Frequency	Relative Frequency (%)
	<5	5	23.81
Avicennia germinans	6 - 10	6	28.57
	11 – 15	5	23.81
	16 - 20	5	23.81
	<5	12	52.17
Rhizophora mangle	6 - 10	3	13.04
	11 – 15	5	21.74
	16 - 20	3	13.04
Rhizophora racemosa	<5	68	22.08
	6 - 10	28	9.09
	11 – 15	63	20.46
	16 - 20	133	43.18
	21 - 25	12	3.89
	26 - 30	4	1.31
Nypa fruticans	<5	3	50
	6 - 10	1	16.67
	11 – 15	1	16.67

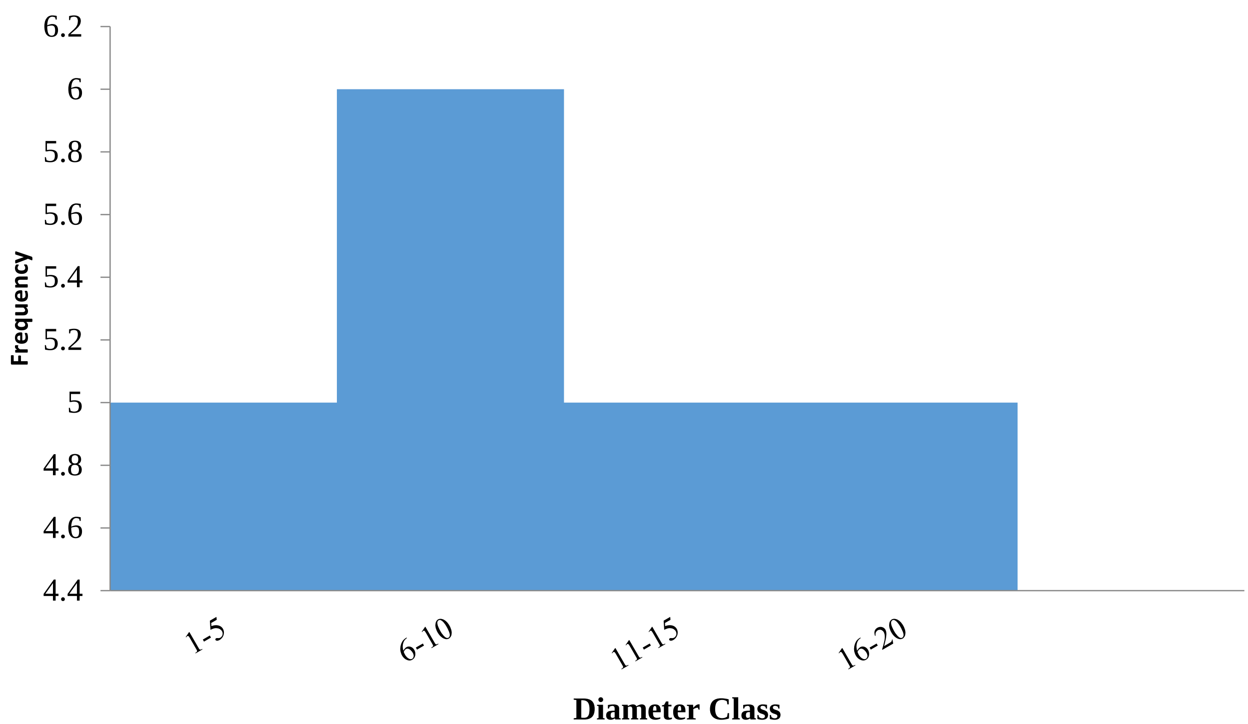

Fig.4a: Diameter class distribution of *Avicennia germinans* in study area

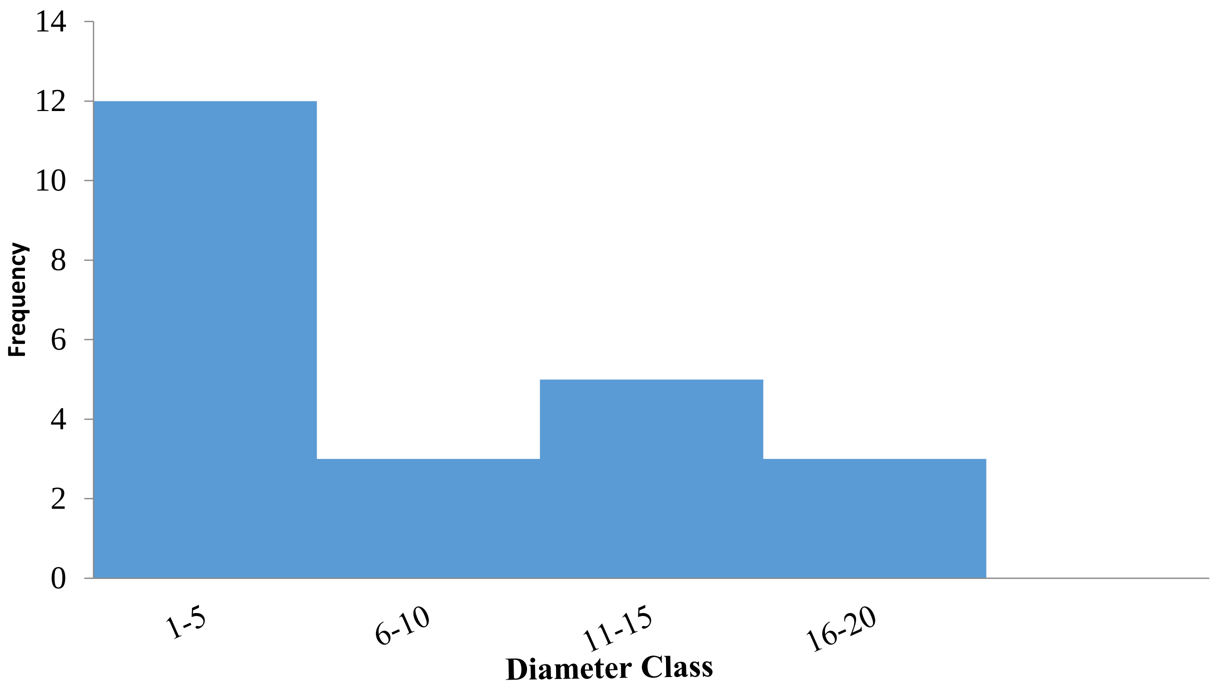

Fig. 4b: Diameter class distribution of Rhizophora mangle in Onne Forest

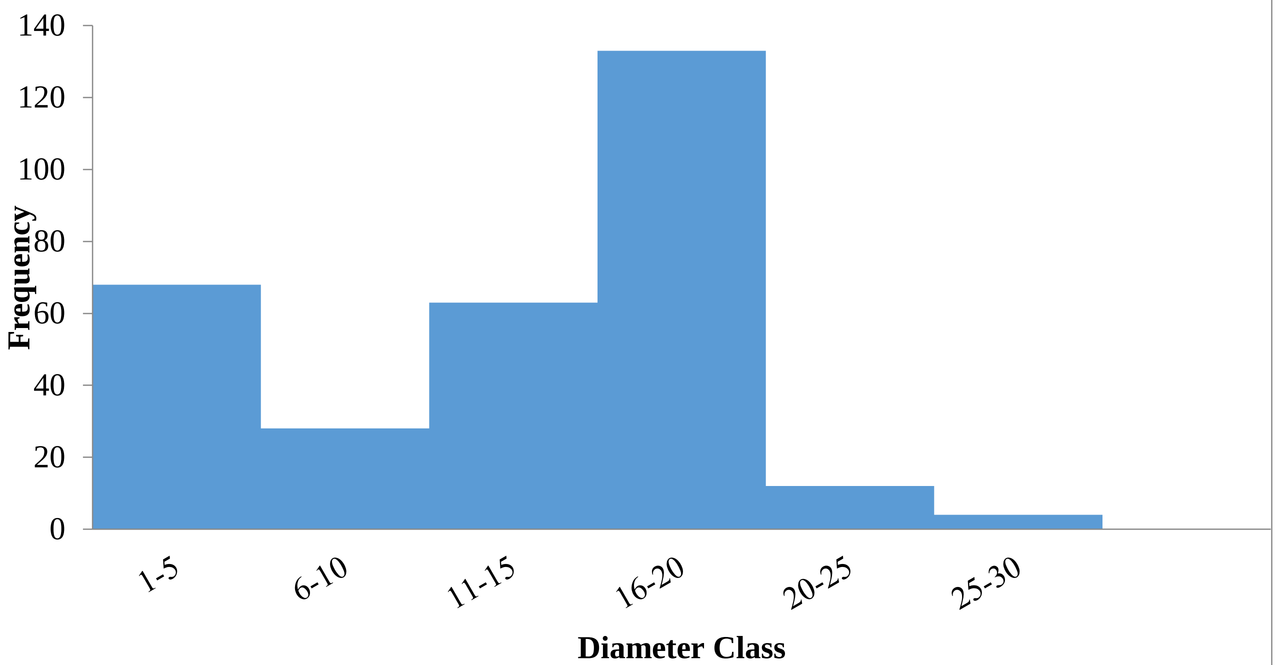

Fig.4c: Diameter class distribution of *Rhizophora racesoma* in Onne Forest

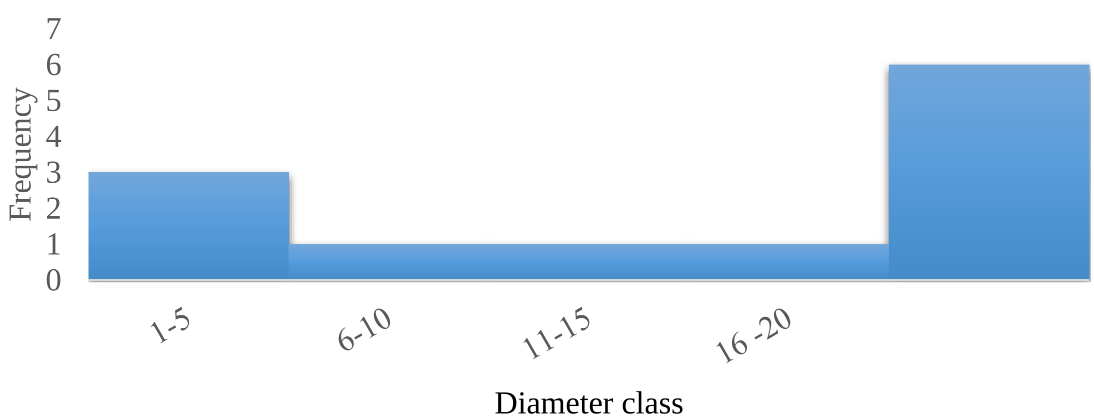

Fig.4d: Diameter class distribution of *Nypa fruticans* in Onne Forest

Table 5: Height class of mangrove species in Onne Swamp Forest.

Table 5 and Figure 5 shows the height class distribution of mangrove species in the sampled plots. The result revealed that the mangrove specie with height class of 3-4m were the most prevalent in the sampled area, followed by 1-2m and 5-6m height class.

Table 5: Height class of mangrove species in the study area.

Species	1-2m	3-4m	5-6m	Total
Avicennia africana	6	14	1	21
Rhizophora mangle	10	10	6	26
Rhizophora racemosa	57	205	46	308
Nypa fruticans	2	4		6
Total				361

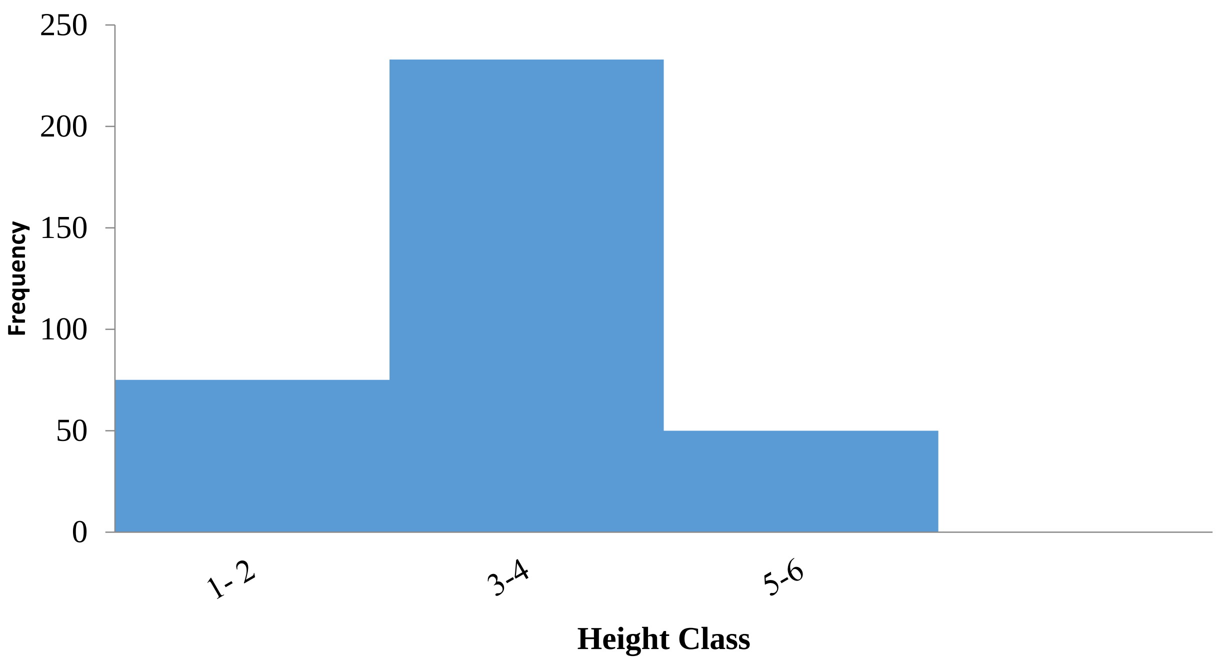

Fig.5: Height class of mangrove species in Onne Swamp Forest

Table 6: Probability Density Function (PDF) of *Avicennia germinans, Rhizophora mangle, Rhizophora racemosa and Nypa fruticans* in Onne Swamp Forest.

Table 6 presents the result of probability density function (PDF) of *Avicennia germinans, Rhizophora mangle*, *Rhizophora racemosa and Nypa fruticans* in the study area. Also the standard error, maximum and minimum statistics and Weibull models of *each* of the species in the study area with their estimated parameters (Figures 6a-d).

Table 6: Probability Density Function (PDF) of *Avicennia germinans*, *Rhizophora mangle, Rhizophora racemosa and Nypa fruticans* in the study area.

Species	S.E	Min - Max	PDF	Parameters Weibull Models	Estimated x	 b	 y
Avicennia germinans	1.06	10.00 – 18.90	Weibull Weibull (3p)	$F(t) = 1-\exp - \frac{t-ð}{Ɒ}^{\beta}, t \geq ð$ $F(t) = 1-\exp \lambda(t-\tau)\beta, t \geq \tau$	1.6631 1.5312	10.749 9.2812	- 1.4153
Rhizophora mangle	1.39	10.40 -19.70	Weibull Weibull (3p)	$F(t) = 1-\exp - \frac{t-ð}{Ɒ}^{\beta}, t \geq ð$ $F(t) = 1-\exp \lambda(t-\tau)\beta, t \geq \tau$	1.4502 0.7117	7.8808 3.8391	- 2.4
Rhizophora racemosa	0.24	10.10 –28.70	Weibull Weibull (3p)	$F(t) = 1-\exp - \frac{t-ð}{Ɒ}^{\beta}, t \geq ð$ $F(t) = 1-\exp \lambda(t-\tau)\beta, t \geq \tau$	1.6598 3.7488	14.299 22.717	- 8.009
Nypa fruticans	2.11	2.3 - 15.1	Weibull Weibull (3p)	$F(t) = 1-\exp - \frac{t-ð}{Ɒ}^{\beta}, t \geq ð$ $F(t) = 1-\exp \lambda(t-\tau)\beta, t \geq \tau$	1.3217 0.65082	5.661 3.4515	- 2.3

Where S.E = Standard Error, x = location parameter, b = scale parameter and y = shape parameter.

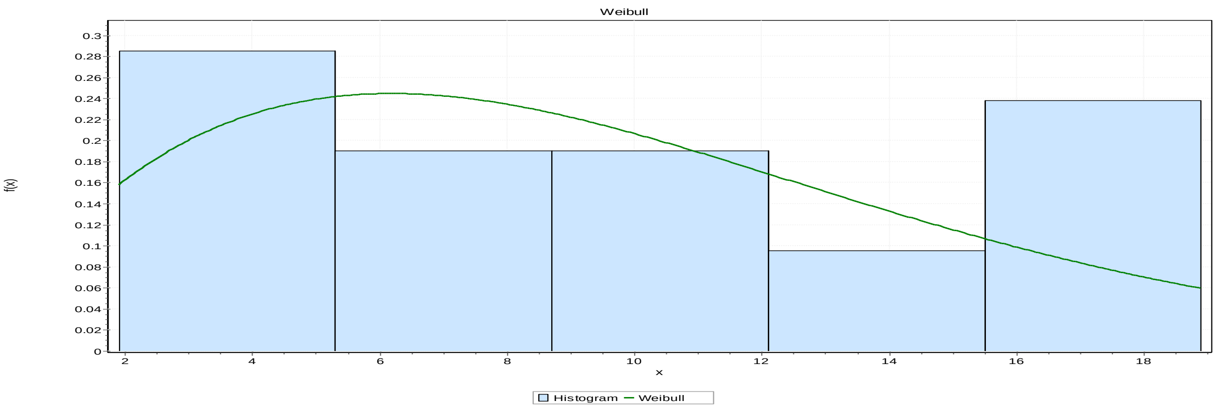

Fig.6a: Weibull parameter of *Avicennia germinans* in the study area.

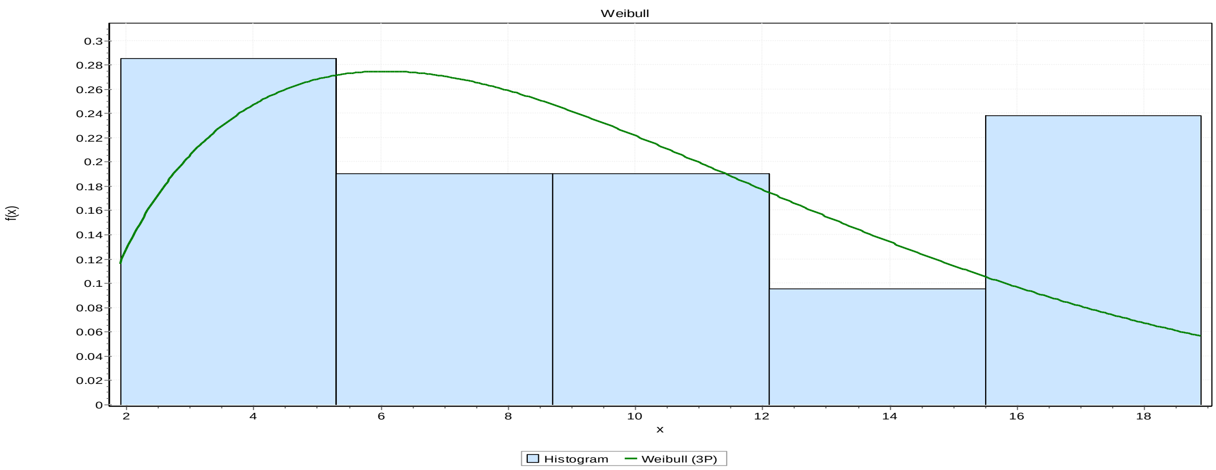

Fig.6a: Weibull (3p) parameter of *Avicennia germinans* in the study area.

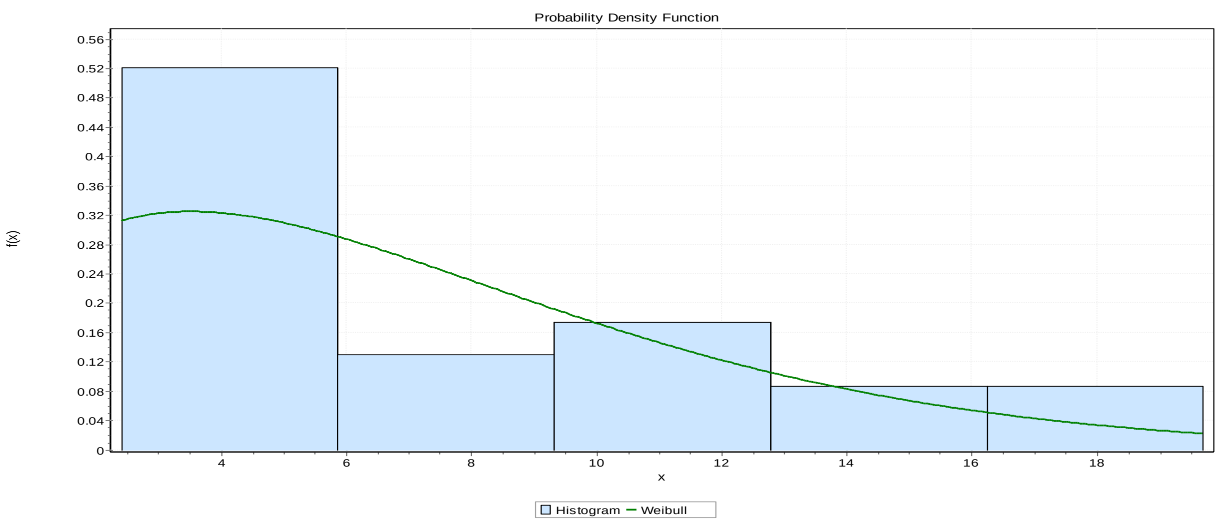

Fig.6b: Weibull parameter of *Rhizophora mangle* in the study area.

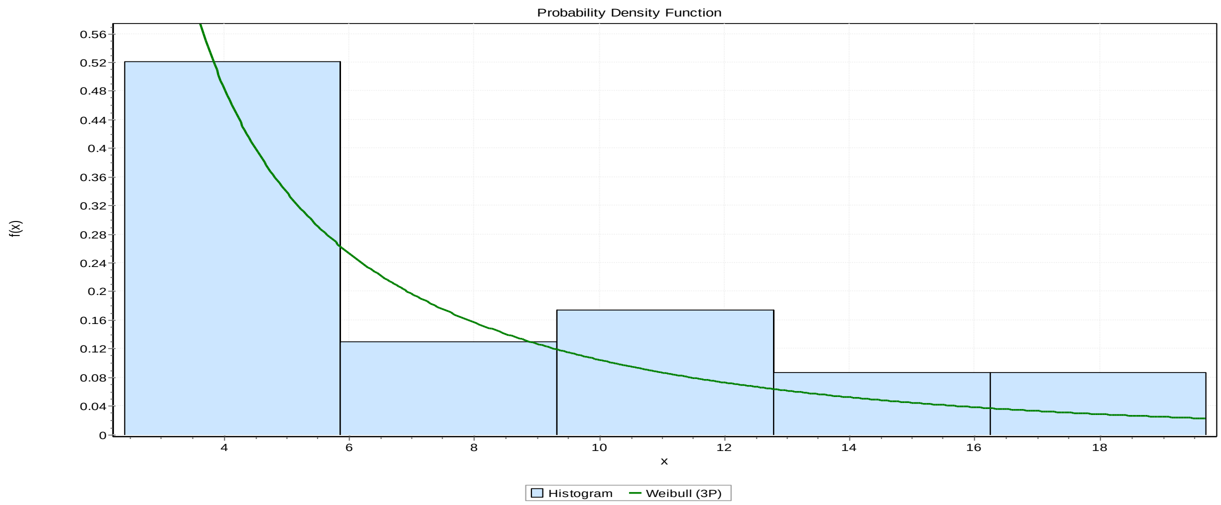

Fig.6b: Weibull (3p) parameter of *Rhizophora mangle* in the study area.

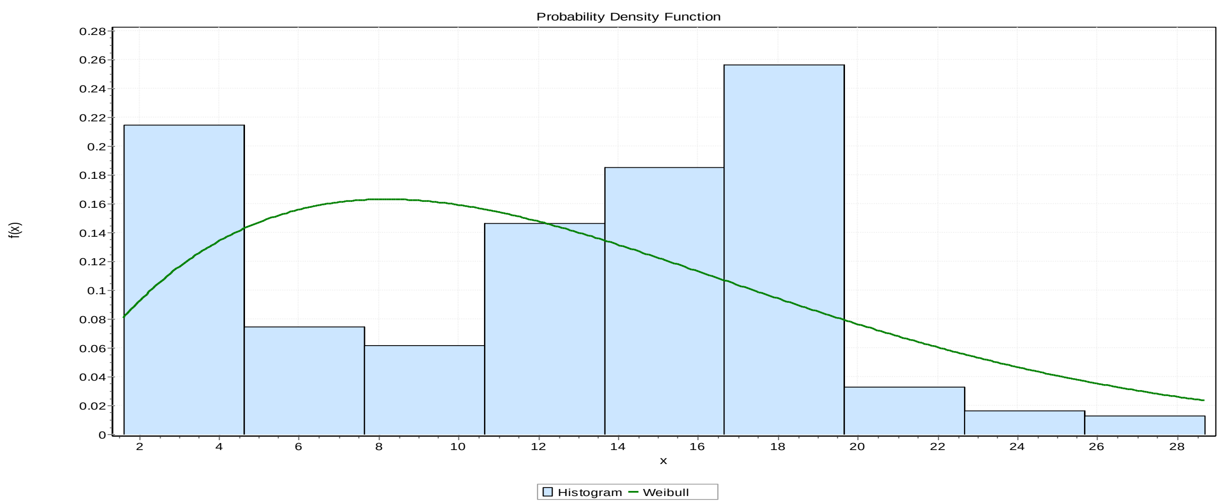

Fig.6c: Weibull parameter of *Rhizophora racemosa* in the study area.

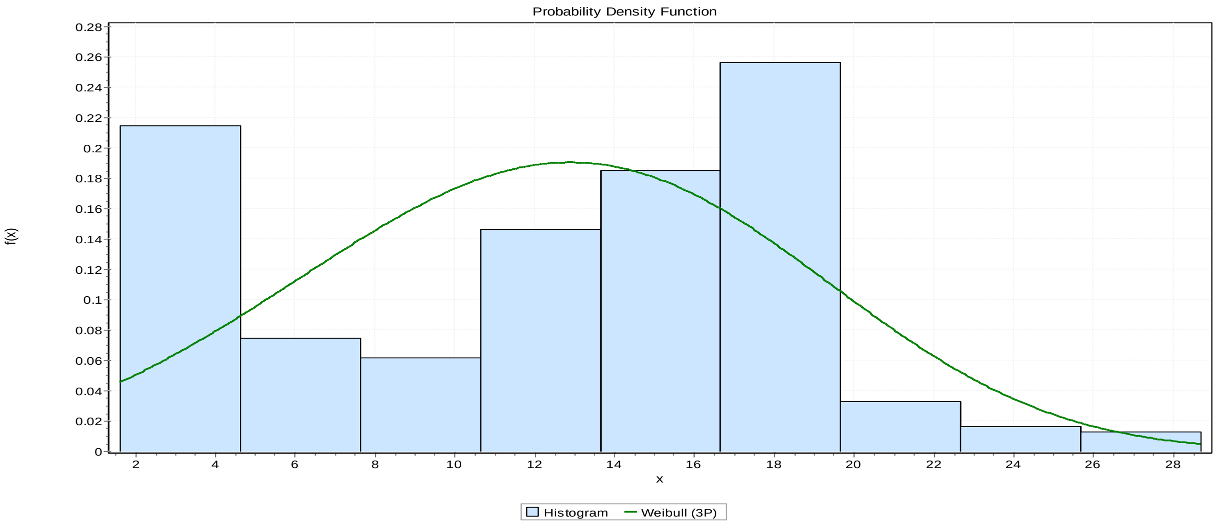

Fig.6c: Weibull (3p) parameter of *Rhizophora racemosa* in the study area.

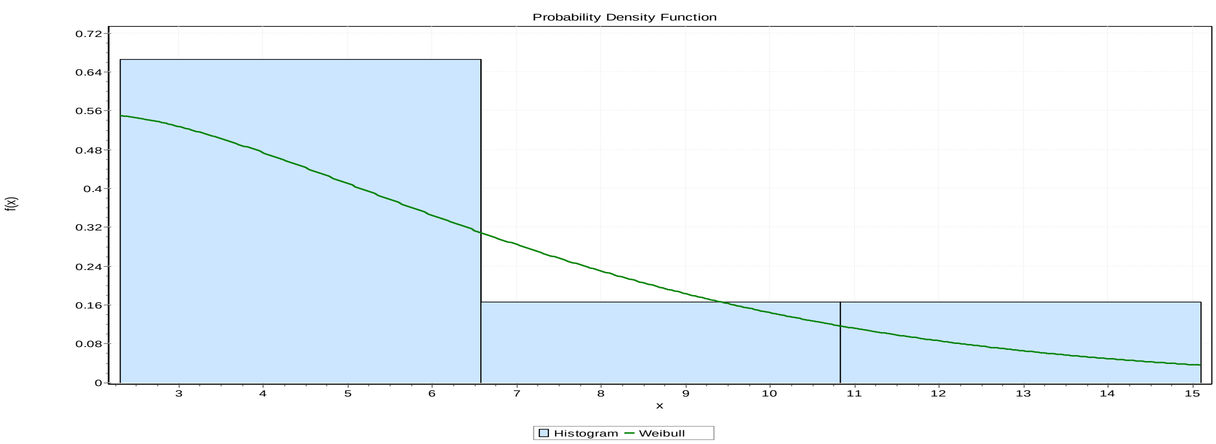

Fig.6d: Weibull parameter of *Nypa fruticans* in the study area.

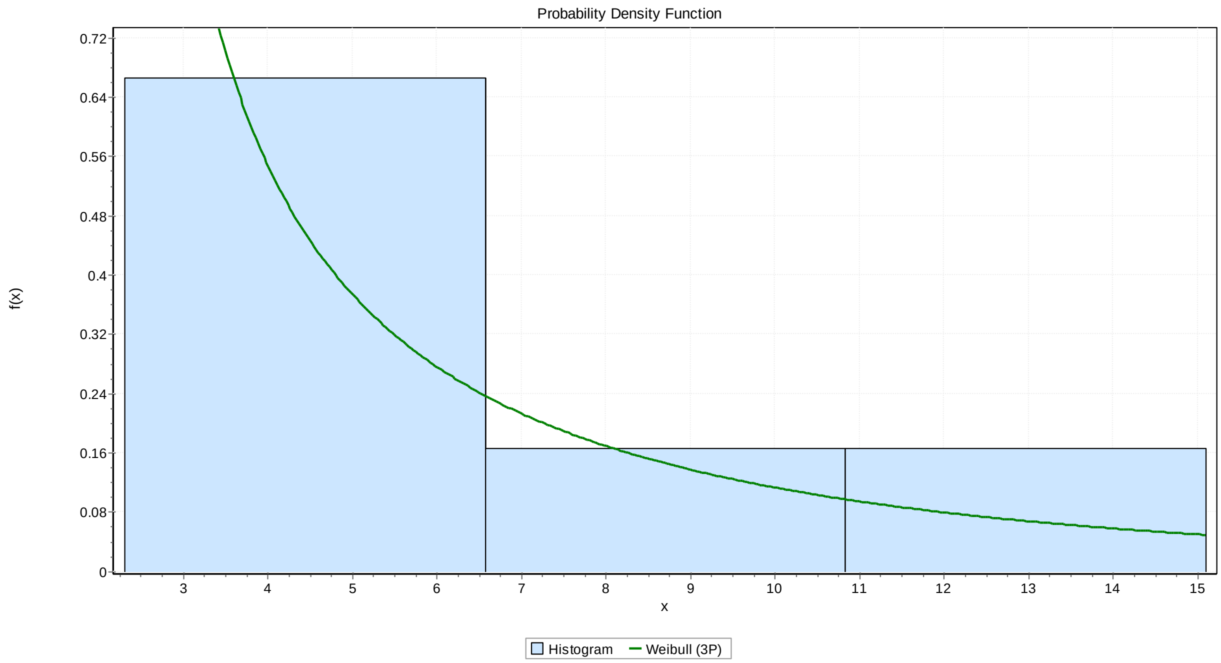

Fig.6d: Weibull (3p) parameter of *Nypa fruticans* in the study area.

Table 7: Goodness of fit for *Avicennia germinans, Rhizophora mangle, Rhizophora racemosa* and *Nypa fruticans* in Onne Swamp Forest.

Table 7 presents the result of goodness of fit for *Avicennia germinans, Rhizophora mangle, Rhizophora racemosa* and *Nypa fruticans* in the study area. The results reveal statistics and rank of different goodness of fit of the two Weibull parameters in each of the species in the sampled plots.

Table 7: Goodness of fit for *Avicennia germinans, Rhizophora mangle, Rhizophora racemosa* and *Nypa fruticans* in the study area.

Species	Weibull Parameters	Goodness of Fit Parameters					
		Kolmogorov Smirnov (K_S)		Anderson Darling (H_A)		Chi-Squared (R^2)	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
Avicennia germinans	Weibull	0.11182	10	0.29879	5	2.2643	42
	Weibull 3p	0.11362	11	0.34346	10	1.5762	36
Rhizophora mangle	Weibull	0.20969	22	0.95457	14	5.2608	40
	Weibull 3p	0.16523	6	2.8092	38	1.581	19
Rhizophora racemosa	Weibull	0.15311	14	12.287	17	174.82	20
	Weibull 3p	0.14541	10	9.3678	5	117.27	5
Nypa fruticans	Weibull	0.26221	29	0.57754	25	N/A	N/A
	Weibull 3p	0.15906	2	3.5752	51	N/A	N/A

CONCLUSION

This study has shown how Onne Swamp Forest of FRIN has high mangrove species diversity, although there is huge trace of exploitation which has reduced mangrove species diversity in the study zone. *Rhizophora racemosa* was the dominant species in the study area. However, species richness for

Avicennia germinans, Rhizophora mangle and *Nypa fruticans* were poor, which may be attributed to uncontrolled exploitation for the commercial purpose and livelihood support. There are notable degree of correlation between the growth variables of the species which have made the study area a species diversity hotspot in the Niger Delta. The basal area per hectare observed in Onne Swamp Forest of FRIN was lesser than the figure tabulated for a well-managed forest in Nigeria. It is recommended that the conservation effort of the Onne FRIN Station be more intensified.

Contribution of Authors:

Okedimma, F.C.: Primary data collection, analysis and, initial draft production

Oyebade, B.A.: Project conceptualization, supervision and, data management & interpretation

Eguakun, F.S.: Project conceptualization and supervision

Ezenwaka, J.: General coordination, quality check, botany of mangrove and, final editing

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