



ISSN: 2141 – 3290
www.wojast.com

DIVERSITY AND DISTRIBUTION OF VASCULAR CRYPTOGAMS IN RELATION TO ELEVATION GRADIENT IN OSOMBA RANGE OF THE CROSS RIVER NATIONAL PARK, CROSS RIVER STATE, NIGERIA.

BASSEY, M. E., ANWANA, E. D., MBONG, E. O., AND UMOH, O. T.

Department of Botany and Ecological Studies,
University of Uyo, Uyo, Akwa Ibom State.

ABSTRACT

Vascular cryptogams also known as Pteridophytes have been found to colonize the lower altitudes of world's tropical forest regions. Hence, a study to establish the relationship existing between elevation gradient and Pteridophytes heterogeneity and distribution within Osomba Range, Cross River State, Nigeria was carried out. In this study, we delineated four elevation classes and enumerated the vascular cryptogam communities found at each level within the range using standard scientific protocol. Shannon-Wiener's (3.434 and 2.833) and Simpson's indices of diversity (0.968 and 0.941) as well as Taxa (31 and 17) assumed a dump bell pattern with peak values associated with the mid-elevation classes (178 -205m and 232 – 240m) respectively. On the contrary, dominance followed an inverted dump bell distribution with its optimum (0.1667 and 0.2500) skewed towards the extreme elevation classes (297 – 295 m and 347- 405 m). Correlation analysis imprinted a significant ($P<0.05$) positive relationship between altitude and dominance (0.867*) but an inverse relationship between elevation and Simpson diversity (-0.867*). 178- 205 m and 232-240 m elevation classes were more comparable with lesser species heterogeneity judging from Bray and Curtis (0.458), Simpson (0.647) and Jaccard (0.297) similarity indices respectively. Conclusively, forty-nine (49) species of vascular cryptogams were identified and their occurrence seemed patchy in distribution along the gradient. This is an indication that elevation is an important factor amongst the suite of ecological drivers which determine the diversity of this critical group of plants. Further investigation on individual species response to ecological gradient is recommended as this will enhance the conservation of these vascular cryptogams within and outside the study area.

INTRODUCTION

Ferns and fern allies otherwise referred to as vascular cryptogams are a unique group of plants which are lower plants and are valuable to man in various ways and find wide application as food, feed, indicators of environmental pollution, pesticide formulation alternatives, bioremediation agents, therapeutic remedies, ornaments, cultural craft components and others. Yet in spite of this, not enough research attention is given to these group of plants compared to spermatophytes within and around the study area. Even on a national level, the diversity of vascular cryptogams across the different ecological zones is not fully covered and the ecological drivers of their distribution is poorly documented. Though it has been established that species richness and distribution tend to align and vary seemingly along environmental gradients in different vegetation formations within the tropics, particularly in the tropical rain forest zones (Ubom *et al.*, 2012; Anwana *et al.*, 2019; Mbong *et al.*, 2020), the specific patterns of species richness variation are still unknown for some locations and vegetation typologies (Tuonisto and Ruokolainen 2002). Notwithstanding, it is very typical to assume that abiotic factors within the environment are being implicated as ecological drivers of diversity and distribution of vegetation assemblages in different areas (Duque *et al.*, 2001; Grandez *et al.*, 2001; Romero-Saltos *et al.*, 2001). Osomba range is a part of the Oban division of Cross River National Park (a protected area) within Akamkpa Local Government of Cross River State. Currently from a reconnaissance survey, Osomba range bears a part of rainforest forest vegetation physiognomy shaped by human disturbances (forest fragmentation, intense agricultural activities and bush burning) and natural influences.

The dominant tree species and their families have been reported for Cross River National Park and its neighboring buffer zones (Aigbe and Omokhua, 2015; Essien *et al.*, 2020). However, these studies only focused on woody tree species leaving out the pteridophytes and lycophytes within the protected area. Also, Nwaka *et al.*, (2022) in their research on pteridophytes diversity of the park only reported six (6) epiphytic ferns in the area and attributed this low diversity to anthropogenic factors. Thus, the scanty literature on pteridophytes and lycophytes within this all-important protected area shows the knowledge gaps on the extant families and species of the park. More so, is the lack of studies on the effect of altitudinal gradient on Pteridophytes and Lycophytes flora. Against this backdrop, our research objectives were to; (1) characterize extant pteridophytes presence within the Osomba mountain range, Cross River National Park (Oban division) and (2) evaluate the effect of elevation on pteridophyte diversity within the study area. Giving that plant environments are rarely homogeneous, especially across spatial and temporal scales, it is therefore logical to query how and to what extent elevation influences the distribution of vascular cryptogams within the study area. Answers to this question we opine are necessary to deepen understanding on ways environmental parameters shapes species composition and distribution, which could be used to enhance their management and conservation.

MATERIALS AND METHODS

Study Area

Oban Division protected area situates within longitude 8°20' E and 8°55' E and latitudes 5°00' N and 6°00' N. The area extends up to 742.55km² with rugged and undulating slopes.

Its elevation rises gradually from low river valleys and extends beyond 1,000 meters in its mountainous parts (Jimoh *et al.*, 2012). The area is characterized by a mosaic hilly patches ranging from 100 to over 1,000m. The area records mean monthly relative humidity ranging between 78% in the dry months up to 91% in the wet months and temperatures are generally high all year round with an average of 27°C. The area records an annual rainfall ranging between 2,500mm- 3,000mm (Schmitt, 1996; Aigbe and Omkhua, 2015). Osomba is one of the host communities to the Cross River National Park (hereafter referred to as CRNP), Oban division, located at the foot of the range with a peri-urban population consisting predominantly of farmers, hunters and gatherers.

Vegetation Sampling

Vegetation was sampled using systematic sampling of Ubom *et al.*, (2012). Peculiar to each elevation class, species were sampled in 50 m transect consisting of five (5) 5 m x 5 m quadrats spaced at regular intervals of 5 m. In each quadrat, plants were enumerated and species were properly identified to the species level. Identification of the collected plants were done using Alston (1959), Stanfield and Lowe (1979) and Plants of the World Online (POWO,2020). Voucher specimens of collected samples were deposited in the University of Uyo herbarium (UUYH) for storage. Species distribution was compiled using presence-absence scores for each elevation class and recorded in a field note book. Diversity, Dominance, and the Similarity indices were computed with the Paleontological software (PAST) version 17 (Hammer *et al.*, 2001) according to the methods of Mbong *et al.* (2020).

Diversity indices

The **Shannon - Weiner index (H)** was calculated for each elevation level using the formula.

$$H = -\sum (n_i/N) \log_1 (n_i/N)$$

where: n_i = number of individuals of each species
 N = total number of individuals of all species

The **Simpson index of dominance (D)** was calculated as follows:

$$D = \frac{1}{\sum (n_i/N)^2}$$

Where n_i = number of individuals of each species
 N = total number of individuals of each species.

Also, the Simpsons diversity was calculated as 1- D.

Bruilion = $H = (1/N) \log (N!/IINi!)$
 Where N_i = the number of individuals in the i th species;
 N = the total number of individuals

Menhinick = $D = \frac{S}{\sqrt{N}}$
 Where S = Number of taxa in a sample
 N = square root of the total number of individual organisms (all species) in the sample.

Margelef = $K = \log S / \log N$

Where S is the number of Species;
 N = the total number of individuals in the sample

$$\text{Frequency (\%)} = \frac{n \times 100}{N}$$

Where N = Total Number of quadrat
 n = Number of transect in which species were found

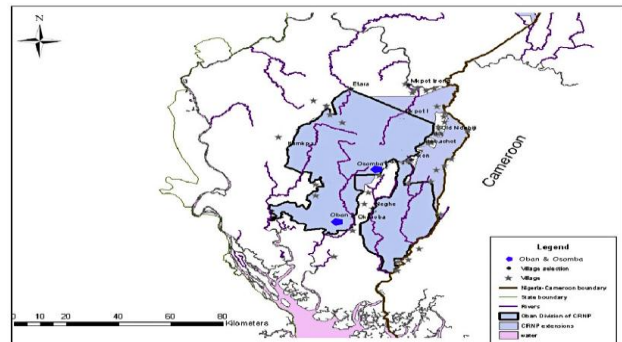


Figure 1: Map showing Study Area (Oban Forest and Osomba village)

Statistical Analysis

Based on the elevation classes, Data on taxa, diversity and dominance values were presented using descriptive statistics. Also, Two-way analysis of variance will be carried out to draw inference on significant differences on species distribution across the distinct elevation groups according to the methods of Ubom (2006) and Okon *et al.* (2019). Pearson correlation coefficients were computed to estimate Vascular cryptogams response or association with topographic heterogeneity using the methods of Mbong *et al.* (2022). The inferential statistics (ANOVA) and correlation coefficients were computed using Statistical package for Social Sciences (SPSS, Version 20.0; IBM Corporation, Armonk USA). Similarity indices for comparing the beta diversity between the plots were computed using Paleontological software (Hammer *et al.*, 2001)

RESULTS AND DISCUSSION

Results

Table 1 reveals the presence and absence scores of 49 species of ferns and fern allies and their distribution across the six elevation classes. Six (6) species (*Bolbitis acrostichoides*, *Bolbitis auriculata*, *Lomariopsis guineensis*, *Oleandra distenta*, *Pteris marginata* and *Pteris milbreadii*) were the most consistent across the slopes with higher relative frequency values (50.0%) whereas twelve (12) species (*Triplophyllum securidiforme*, *Triplophyllum vogelli*, *Triplophyllum jenseniae*, *Thelypteris dentata*, *Tectaria heracleifolia*, *Tectaria fimbriata*, *Selaginella vogelli*, *Pteris atrovirens*, *Nephrolepsis undulata*, *Lygodium smithianum*, *Conniogramme africana* and *Asplenium africana*) had relative frequency values of 33.3%. A total of thirty-one (31) species had a relative frequency value of 16.6 %.

Table 2 shows that the number of taxa found was highest in the 178-205 m elevation class (31 species), and the least within the topmost elevation class 347-405m (4 species).

Species dominance was highest within the topmost elevation class 347-405 m (0.250) but least within the 178-205 m elevation class. Simpson diversity (0.9677 and 0.75), Shannon-Weiner (3.434 and 1.386), Brillion (2.519 and 0.7945), Menhinick (5.568 and 2.000) and Margelef (8.736 and 2.164) indices recorded higher values within the 178-205 m elevation class and least at the 347-405 m respectively.

Tables 3, 4 and 5 reflect an overlap in terms of taxa similarities across elevation gradients. But common to these matrices, 297-295 m elevation recorded no taxa similarity features with 170-175 m and 347-405 m elevation classes respectively.

Table 6 presents a matrix revealing relationships established based on taxa population and distribution indices in relation to elevation gradient. Clearly, the diversity (Shannon = 0.753*) of vascular cryptogams significantly ($P < 0.05$) decreased with increasing elevation while dominance (0.867*) increased significantly with increased elevation within the range.

Discussion

Typically, the present study indicated the presence of 49 species of ferns and fern allies within the Osomba range. This value is high compared to those reported for other ecosystems in previous related studies within and outside Nigeria. For instance, while Bassey (2013) reported 39 species in Akwa Ibom State, Adonipekun *et al.* (2019) reported 11 species in Lagos. Furthermore, Nwaka *et al.* (2022) identified 6 epiphytic ferns in Cross River National Park, whereas Feng *et al.* (2021) reported 32 species for Yuanjiang dry hot valley and Banaticla and Buot, (2005) noted 36 in Luzon Island, Philippines. On the other hand, this value is low compared to 149 species reported by Tuonisto *et al.* (2002) in Yasuni National Park, Amazonia and 86 species reported by Sureshkumar *et al.* (2019) Kolli Hills of the Eastern Ghats, India.

From the results, there is evidence of species selective response and sensitivity to elevation gradients in Osomba range. This is predicated upon the theoretical concept that explains the pattern of species richness and diversity on biotic and abiotic interactive factors, which include competition, historical or evolutionary development, species phenological and adaptation dynamics, environmental gradient, and the nature and intensity of human activities (Zobel, 1997). Specifically, previous studies have confirmed that the abundance and distribution of plants including vascular cryptogams have been shown to oscillate with environmental factors including soil physicochemistry, Temperature, relative humidity, elevation, precipitation in different ecosystems (Zobel, 1997; Tuonisto and Ruokolainen, 2002; Banaticla and Buot, 2005; Mbong *et al.*, 2020). This is clearly exemplified in this research since taxa, dominance and diversity indices differed significantly ($P < 0.05$) between the six elevation classes

Notably, a Shannon-Wiener Index (H) value of 3.434 reported for vascular cryptogams in this result compares favorably with H value of 3.795 which was recorded by Aibe

and Omokhua, (2015) for tree species in the same ecosystem. This indicates the fact that ferns and fern allies contribute significantly to the ecosystem structure and functions of Osomba range of the CRNP. Obviously, the diversity indices also give an idea of the level of competition going on between species across the elevation classes. Also, as expected, the dominance values of elevation categories fluctuate clearly but inversely with the species richness and diversity indices hence elevation classes with high species diversity synonymously record low Simpson dominance value. Similar observations had been reported for other field studies (Ogbemudia *et al.*, 2014; Anwana *et al.*, 2020). Also, the similarity coefficients also give a basis for the measurement of beta diversity at different altitude levels of the range. Also, while some plots are grossly similar in terms of taxa composition, a coefficient of zero similarity coefficients for specific pair of classes indicates that the areas are not similar.

Again, the overwhelming and high similarity coefficients from the Bray and Curtis, Jaccard and Simpson similarity indices between paired groups is an indication of strong species overlap due to a continuum in vegetation space with the elevation classes seemingly existing as arbitrary but not true boundaries. This further emphasize the distribution of species such *Bolbitis achrostichoides*, *Bolbitis auriculata*, *Tectaria fimbriata*, *Triplophyllum varians* and *Triplophyllum vogelli* which are found on both low and extreme altitude transects. Remarkably, species richness on elevation gradient have been studied widely in different regions and ecosystems but from these, two correlational distribution models have been noted (Sureshkumar *et al.*, 2019). Hence the distribution of plants along environmental gradient either follow a humped (dumb-bell) or monotonic distribution pattern.

The distribution of taxa and the species diversity on the criteria of elevation in Osomba range grossly aligns to the "humped distribution pattern". In line with this taxa, species diversity and richness indices intensify and assume higher values within the mid elevation classes (178 -240m) leaving moderate to low case intensities and observation beyond this range on both sides. This validates the findings of Rahbek (1995) and Grytnes and Beaman (2006). In favor of this pattern, Carpenter (2005) noted that up to about 49% of empirical studies relating plant diversity to elevation gradient as observed from different vegetation assemblages in different parts of the world followed a humped distribution form (Aldasoro *et al.*, 2004; Kluge *et al.*, 2008; Marini *et al.*, 2010). The marked progressive decline beyond the 178-240 elevation classes is noted and well understood. This pattern synchronizes with the observation of Vazquez and Givnish (1998) who recorded progressive monotonic decline in species richness with persisting increase in elevation gradient. From this study, 178 -240m shows the elevation optimum for species diversity and richness beyond which there is progressive decrease in both taxa and diversity.

Table 1: Distribution of Vascular Cryptogams in relation to Elevation Gradient in the Study Area

Species	170-175	178-205	232-240	271-279	297-295	347-405	Frequency (%)
<i>Alsophila camerooniana</i> (Hook.) R.M. Tryon	-	+	-	-	-	-	16.6
<i>Arthropteris monocarpa</i> (Cordem.) C.Chr	-	+	-	-	-	-	16.6
<i>Aspleium barteri</i> Hook.	-	+	-	-	-	-	16.6
<i>Asplenium africanum</i> Desv.	-	+	+	-	-	-	33.3
<i>Asplenium cuneatum</i> Lam.	+	-	-	-	-	-	16.6
<i>Asplenium macrophlebium</i> Baker	-	+	-	-	-	-	16.6
<i>Asplenium sandersonii</i> Hook.	-	+	-	-	-	-	16.6
<i>Asplenium subintegrum</i> C.Chr.	-	+	+	-	-	-	33.3
<i>Bolbitis saalicina</i> (Hook.) Ching	-	+	-	-	-	-	16.6
<i>Bolbitis acrostichoides</i> (Afzel.) Ching	-	+	+	-	+	-	50.0
<i>Bolbitis auriculata</i> (Lam.) Alston	-	+	+	-	+	-	50.0
<i>Bolbitis</i> sp.	-	-	-	-	+	-	16.6
<i>Conniogramme africana</i> Hieron	-	+	+	-	-	-	33.3
<i>Hymenophyllum Kuhnii</i> C.Chr.	-	+	-	-	-	-	16.6
<i>Lomariopsis guineensis</i> (Underw.) Alston	-	-	+	+	+	-	50.0
<i>Lomariopsis muriculata</i> Holttum	-	-	-	+	-	-	16.6
<i>Lydodium smithianum</i> C. Presl.	+	+	-	-	-	-	33.3
<i>Microlepia spelunca</i> (L.) T. Moore	-	+	-	-	-	-	16.6
<i>Nephrolepis undulata</i> (Afzel. Ex Sw.) J. Sm.	+	-	-	+	-	-	33.3
<i>Oleandra distenta</i> Kunze	-	+	+	+	-	-	50.0
<i>Phymatosorus scolopendria</i> (Burm. f.) Pic Serm.	-	-	-	-	-	+	16.6
<i>Pityrogramma calomelanos</i> (L.) Link	-	+	-	-	-	-	16.6
<i>Platyterium elephantotis</i> Welw.	-	-	-	+	-	-	16.6
<i>Pteridium aquilinum</i> (L.)Kuhn	+	-	-	-	-	-	16.6
<i>Pteris atrovirens</i> Willd.	+	+	-	-	-	-	33.3
<i>Pteris burtonii</i> Baker	-	+	-	-	-	-	16.6
<i>Pteris linearis</i> Poir	-	+	-	-	-	-	16.6
<i>Pteris marginata</i> Bory	-	-	+	-	-	-	16.6
<i>Pteris mildbraedii</i> Hieron	+	-	+	-	-	+	50.0
<i>Pteris tripartita</i> var. <i>tripartita</i> Sw.	+	+	+	-	-	-	50.0
<i>Selaginella cathedrifolia</i> Spring	-	+	-	-	-	-	16.6
<i>Selaginella kraussiana</i> (Kunze) A. Br.	-	-	+	-	-	-	16.6
<i>Selaginella myosurus</i> (Sw.) Alston	-	+	-	-	-	-	16.6
<i>Selaginella versicolor</i> Spring	+	-	-	-	-	-	16.6
<i>Selaginella vogelii</i> Spring	+	+	-	-	-	-	33.3
<i>Tectaria fimbriata</i> (Willd.) Proctcor &Lourteg	-	+	+	-	+	-	33.3
<i>Tectaria heracleifolia</i> Underw	-	+	+	-	-	-	33.3
<i>Thelypteris dentata</i> (Forssk.) E. P. St. John	+	+	-	-	-	-	33.3
<i>Trichomanes ballardianum</i> Alston	-	-	+	-	-	-	16.6
<i>Trichomanes crispiforme</i> Alston	-	-	+	-	-	-	16.6
<i>Triplophyllum pilosissimum</i> (T. Moore) Holttum	-	+	-	-	-	-	16.6
<i>Triplophyllum batesii</i> Holttum	-	+	-	-	-	-	16.6
<i>Triplophyllum bulchozii</i> (Kuhn) Holttum	-	-	-	-	+	-	16.6
<i>Triplophyllum funestrum</i> (Kunze) Holttum	-	-	-	+	-	-	16.6
<i>Triplophyllum jenseniae</i> (C. Chr.) Holttum	-	+	-	+	-	-	33.3
<i>Triplophyllum protensum</i> (Afzel. ex Sw.) Holttum	-	-	-	+	-	-	16.6
<i>Triplophyllum securidiforme</i> (Hook.) Holttum	-	+	+	-	-	-	33.3
<i>Triplophyllum varians</i> (T. Moore) Holttum	-	+	-	+	-	+	50.0
<i>Triplophyllum vogelii</i> (Hook.) Holttum	-	+	-	-	-	+	33.3

Key: + = Present; - = Absent

Table 2: Vascular Cryptogams Population Dynamics in the Study Area

Altitude Classes	170-175	178-205	232-240	271-279	297-295	347-405
Taxa S	10	31	17	9	6	4
Dominance (D)	0.100	0.032	0.059	0.111	0.167	0.250
Simpson (1-D)	0.9	0.9677	0.9412	0.8889	0.8333	0.75
Shannon (H)	2.303	3.434	2.833	2.197	1.792	1.386
Bruilion	1.51	2.519	1.971	1.422	1.097	0.7945
Menhinick	3.162	5.568	4.123	3.000	2.449	2.000
Margalef	3.909	8.736	5.647	3.641	2.791	2.164

Table 3: Bray and Curtis Similarity Index of Elevation classes in the Study Area

Elevation	170-175	178-205	232-240	271-279	297-295	347-405
170-175	1	0.195	0.222	0.105	0	0.143
178-205		1	0.458	0.150	0.162	0.114
232-240			1	0.153	0.347	0.133
271-279				1	0.095	0.154
297-295					1	0
347-405						1

Table 4: Jaccard Similarity Index of Elevation classes in the Study Area

Elevation	170-175	178-205	232-240	271-279	297-295	347-405
170-175	1	0.108	0.125	0.056	0	0.077
178-205		1	0.297	0.081	0.088	0.061
232-240			1	0.083	0.210	0.050
271-279				1	0.071	0.083
297-295					1	0
347-405						1

Table 5: Simpson's Similarity Index of Elevation classes in the Study Area

Elevation	170-175	178-205	232-240	271-279	297-295	347-405
170-175	1	0.400	0.300	0.111	0	0.25
178-205		1	0.647	0.333	0.500	0.500
232-240			1	0.222	0.667	0.25
271-279				1	0.167	0.25
297-295					1	0
347-405						1

Table 6: Correlating Elevation gradient and Pteridophyte community indices in the Study Area

	Elevation	Taxa	Dominance	Simpson	Shannon	Bruilion	Menhinick	Margalef
Elevation	1	-.598	.867*	-.867*	-.753	-.732	-.674	-.631
Taxa		1	-.824*	.823*	.956**	.967**	.990**	.998**
Dominance			1	-.999**	-.951**	-.938**	-.892*	-.854*
Simpson				1	.951**	.938**	.892*	.854*
Shannon					1	.999**	.987**	.971**
Bruilion						1	.993**	.980**
Menhinick							1	.997**
Margalef								1

*Correlation is significant at the 0.05 level (2-tailed);

**Correlation is significant at the 0.01 level (2-tailed)

Clearly, this decline gives room to increasing dominance by few elevations' tolerant species. The preferential exclusion of most species beyond the elevation optimum further confirms the postulations of Shelford's law of tolerance (Allabay, 2015) while species dominance within this transect lends credence to the Darwinian evolution theory. Clearly, these observations may be explained on the premise of environmental challenges and species tolerance limits (Spasojevic et al., 2014). Possibly beyond the elevation optimum there may exist unfavourable environmental

conditions such as low relative humidity, rapid leaching of soil nutrients along steep slopes, reduced canopy cover, intense solar radiation and strong dry wind which serve as environmental challenges. Hence, the species with most efficient adaptive strategies thrives, reproduce and dominate within the seemingly difficult habitat conditions associated with the extreme elevation classes to the exclusion of other less adaptive species.

In a related study, Tuonisto and Poulsen (2000) noted that the amount of topographic heterogeneity within transects correlated strongly and significantly even at local scales with density of individuals, species richness indices even at the local scale. In this study, since transects were altitude biased, it is logical not to undermine the strong significant correlation coefficients between the elevation classes, Dominance ($r=0.867^*$) and diversity ($r=-0.867^*$) the elevation classes as seen from the correlation matrix. On the whole the matrix interprets that unrestricted progression in elevation gradient within the range unilaterally reduces vascular cryptogams richness and diversity along the range and increase the dominance trend within the extreme elevation classes. This is concurrent with the views of previous researchers (e.g., Vazquez and Givnish 1998).

CONCLUSION

With reference to the diversity and distribution of ferns and fern allies in Osomba mountain range, varied distinct patterns were found in association to topography. Clearly the area has a rich diversity for these species. Taxa seemed to increase steadily from the low lying terrain towards the mid elevation classes (170-240 m) where peak value for taxa was achieved. Beyond this ambience taxa showed a monotonous pattern, with sharp decline in diversity. The topographic heterogeneity at the intermediate levels secured an ecological optimum for Shannon-Weiner, Simpson, Bruilion, Margalef and Menhinick indices of diversity and richness. Also, Bray and Curtis, Simpson and Jaccard beta diversity indices indicated similarities which showed an overlap in taxa distribution at different elevation intensities with exceptions at 297-295m that had no similarities with 170-175m and 347-405m. This overlap is more obvious and prominent judging from the relative frequency scores of species including those of, *Bolbitis achrostichoides*, *Bolbitis auriculata*, *Lomariopsis gguineensis*, *Oleandra distenta*, *Tectaria fimbriata*, *Triplophyllum varians* *Triplophyllum vogelli*, *Pteridium aquilinum* and *Pteris tripartita*. From this research we conclude that topographic heterogeneity is a complex gradient which clearly influences the diversity and distribution of vascular cryptogams across the range. Further investigation on individual species response to ecological gradient is recommended as this will enhance the conservation of these ferns and other associated species within and outside the study area.

REFERENCES

Adeonipekun, P. A., Oyebanji, O., Adebayo, M. B. and Bamigbade, O. S. (2019). Distribution and sporulation phenology of pteridophytes in Lagos State, Nigeria. *International Journal of Botany Studies*, 4(2): 72-80.

Aigbe, H. I. and Omokhua, G. E (2015) Tree Species Composition and Diversity in Oban Forest Reserve, Nigeria. *Journal of Agricultural Studies*, 3(1): 10-24.

Aldasoro J. J, Cabezas, F. and Aedo, C. (2004). Diversity and distribution of ferns in sub-Saharan Africa, Madagascar and some islands of the South Atlantic. *Journal of Biogeography*, 31:1579-1604.

Allabay, M. (2015). *A Dictionary of Ecology*. Oxford University Press. Fifth Edition p. 287.

Anwana, E. D., Mbong, E. O. and Etim, N. (2020). Trends in Macrophyte Diversity in Anthropogenic Perturbed Lentic Ecosystems within Uyo Metropolis. *Journal of Environmental and Waste Management*, 7 (1): 339-344.

Banaticla, M. C. N. and Buot Jr. I. E. (2005) Altitudinal Zonation of Pteridophytes on Mt. Banahaw de Lucban, Luzon Island, Philippines. *Plant Ecology*, 180(2): 135-151.

Bassey, M. E. (2013). *Introductory Pteridology*, Uyo: Modern Business Press, 96p.

Carpenter C. (2005). The environmental control of plant species density on a Himalayan elevation gradient. *Journal of Biogeography*, 32 (6): 999-1018.

Duque, A., M., Sanchez, J., Cavelier, J. F., Duivenvoorden, I M, A, Mima, J., and Ma Tap A. (2001). Relación bosque-ambiente en el Medio Caquetd, Amazonia colombiana. In: J. E Duivenvoorden, H. Balslev, J. Cavelier, C. Grinda, H. Tuomisto, and R. Vdencia (Eds.). *Evaluacion de recursos forestales no maderables en la Amazonia noroccidental*, IBED, Universiteit van Amsterdam, Amsterdam, The Netherlands. pp. 99-129.

Essien, I. I., Ogbemudia, F. O and Ezekiel, A. G. (2020). Soil-Woody Plant Relationship in Oban Forest Reserve, Akamkpa, Cross River State. *Asian Journal of Research in Botany*, 4(4): 38-52.

Feng-Chun Y, Chaya S., Jing-Xin L., Hua-Ping H., Jian-Yong, G., Ye, L., Xiao-Ye, M., Hui-Ting W., Jun, Z., Ming-F, Y., Suthathong, H. and Kritana, P. (2021). How fern and fern allies respond to heterogeneous habitat — a case in Yuanjiang dry-hot valley. *Communicative and Integrative Biology*, 14(1): 248-260.

Grandez, C., Gar, A., Duque, A. and Duivenvoorden, J. F. (2001). La composición florística de 10s bosques en las cuencas de 10s rios Ampiyacu y Yaguasyacu (Amazonia peruana). In: J. E Duivenvoorden, H. Balslev, J. Cavelier, C. Grinda, H. Tuomisto, and R. Valencia (Eds.). *Evaluacion de recursos forestales no maderables en la Amazonia noroccidental*, IBED, Universiteit van Amsterdam, Amsterdam, The Netherlands. pp. 163-176

Grytnes JA, and Beaman J. H. (2006). Elevational species richness patterns for vascular plants on Mount Kinabalu, Borneo. *Journal of Biogeography*, 33:1838-1849.

Hammer, O., Harper, D.A.T., and Ryan, P.D. (2001). PAST: Paleontological statistics software package for Education and Data analysis. *Palaeontologia Electronica*, 4(1): 1-9.

Hutchinson, J. and Daziel, J. M. (1958). *Flora of West Tropical Africa*. Volume 1, Part 2. Crown Agents for Overseas Government and Administrations, Millbank, London 828pp.

Jimoh S. O., Adesoye P. O., Adeyemi A. A. and Ikyaagba E. T., (2012). Forest Structure Analysis in the Oban Division of Cross River National Park, Nigeria. *Journal of Agricultural Science and Technology*, B2: 510-518.

- Kluge, J., Bach K. and Kessler M. (2008). Elevational distribution and zonation of tropical pteridophyte assemblages in Costa Rica. *Basic and Applied Ecology*, 9:35-43.
- Marini, L., Bona, E., Kunin, W. E. and Gaston, K. J. (2010). Exploring anthropogenic and natural processes shaping fern species richness along elevational gradients. *Journal of Biogeography*, 38:78-88.
- Mbong, E. O., Ogbemudia F. O., George, U. U and Okon, J. E. (2022). Modeling growth response of *Cucumis sativus* L. growing under spent engine oil contamination stress in an Ultisol. *International Journal of Applied Research*, 8(4): 150-154
- Mbong, E. O., Osu, S. R., Uboh, D. G. and Ekpo, I. (2020). Abundance and distribution of Species in relation to soil Properties in Sedge-dominated Habitats in Uyo Metropolis, Southern Nigeria. *Global Journal of Ecology*, 5(1): 24 -29.
- Nwaka, C. L.; Akwaji, P. I.; Edu, E. A.; Okoh, T.; Egbe, A. E. (2022). Diversity Of Epiphytic ferns in the cross river national park, Akamkpa, Nigeria as indicators of forest disturbance. *Scientific Report in Life Sciences*, 3(2): 32-51.
- Ogbemudia, F. O., Anwana, E. D., Mbong E. O. and Joshua, E. E. (2014). Plant Diversity Status and Soil Physicochemistry in a Flood Plain. *International Journal of Research*, 1(10): 1977 – 1985.
- Okon O. G., Okon I. E., Mbong, E. O. and Eneh G. D. O. (2019). Mitigation of salt induced stress via arbuscular mycorrhizal fungi (*Rhizophagus irregularis*) inoculation in *Cucurbita maxima* Duch. *International Journal of Molecular Biology*, 4(1):30–36.
- POWO (2023). *Plants of the World Online*. powo.science.kew.org DOA 28/4/23.
- Rahbek C. (1995). The elevational gradient of species richness: a uniform pattern? *Ecography*, 18:200-205.
- Romero-saltos, H., R. Valencia, and Ma, M. J. (2001). Patrones de diversidad, distribucion y rareza de plantas leiosas en el Parque Nacional Yasuni y la Reserva ktica Huaorani, Amazonia ecuatoriana. In: J. F. Duivenvoorden, H. Balslev, J. Cavellier, C. Grinda, H. Tuomisto, and R. Valencia (Eds.). *Evaluacion de recursos forestales no maderables en la Amazonia noroccidental*, pp. 131-162. IBED, Universiteit van Amsterdam, Amsterdam, The Netherlands.
- Sanfield, D.P. and Lowe, J. (1979). Numerical Key to the Nigerian Genera of Ferns and Fern –Allies. *Personal Communication*
- Schmitt K. (1996). Zoological survey of the Oban division of Cross River National Park. Oban Hill programme, Calabar. Pp 21.
- Spasojevic, M. J., Grace, J. B., Harrison, S. and Damschen, E. I. (2014). Functional Diversity supports the physiological tolerance hypothesis for plant species richness along climatic gradients. *Journal of Ecology*, 102: 447–455.
- Sureshkumar, J., Ayyanar, M. and Silambarasan, R. (2019). Pteridophyte Species Richness along Elevation Gradient in Kolli Hills of Eastern Ghats, India. *Journal of Pacific Biodiversity*, 13(1): 96 – 106.
- Tuomisto, H. and Ruokolainen, K. (2002) Distribution and Diversity of Pteridophytes and Melastomataceae along Edaphic Gradients in Yasuni National Park, Ecuadorian Amazonia. *Blotroplca*, 34(4): 516-533.
- Ubom R.M. (2006) *Biometry*. Uyo. Abams Publisher Pg. 27.
- Ubom, R. M., Ogbemudia, F. O. and Benson, K.O. (2012). Soil vegetation relationship in freshwater swamp forest. *Scientific Journal of Biological Sciences*, 1(2): 43-51.
- Vazquez, J. A., and Givnish, T. J. (1998). Altitudinal gradients in Tropical Forest Composition, Structure and Diversity in the Sierra de Manantlan. *Journal of Ecology*, 86: 999-1020.
- Zobel M. (1997). The relative role of species pools in determining plants species richness: an alternative explanation of species coexistence. *Trends in Ecology and Evolution*, 12:266e269