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Distribution and sporulation phenology of pteridophytes in Lagos state, Nigeria

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Abstract
The importance of pteridophytes in past and present ecological, environmental and climate monitoring and aerobiology cannot be over-emphasized. Therefore, to provide phenological information on this plant group, a one-year (September 2016 – August 2017) documentation on the floristic composition and sporulation features of pteridophytes in four areas across Lagos State, Nigeria was effectuated using opportunistic sampling method. A total of 11 species belonging to 11 genera and seven families were documented. The richest family was Pteridaceae (four species) and are mostly terrestrial. Statistical analysis revealed positive correlations between: (i) average temperature and sporulation in *A. aureum, C. cornuta* and *P. scolopendria* in Badagry, (ii) temperature and sporulation in *L. microphyllum* in Epe, (iii) temperature and relative humidity and sporulation in *N. biserrata* in Ikorodu and (iv) relative humidity and sporulation in *D. marginalis* in Ikorodu. None of the species encountered was endangered, threatened or vulnerable. Some species sporulated across all sampled locations in some particular months, suggesting that these months represent their peak sporulation period. Based on the sporulation calendar created, we infer that pteridophytes in Lagos State sporulate mostly between the months of April and July. The microenvironment played major roles in the sporulation of all recorded pteridophytes with relative humidity, temperature and rainfall being the determinant meteorological factors.

Keywords: phenology, pteridophytes, sporulation calendar, meteorological data, Lagos, and Nigeria

1. Introduction
Pteridophytes, commonly known as ferns and fern allies belong to the order Filicales and possess greater adaptability to grow under different environmental conditions (including wet and shady) than most typical vascular plants [60, 9, 36, 43]. During the carboniferous period (355 and 290 million years ago), pteridophytes dominated the earth vegetation [46] but presently, pteridophytes diversity are being outnumbered and largely replaced by angiosperms [29]. Despite this, they are still fairly recognized as important members of modern-day vegetation [46]. Past studies have documented and described over 12,000 species of ferns and lycophytes [11, 35, 34]. Globally, pteridophytes are abundant in the tropics and Nigeria is a clear example of such areas with diverse groups [40]. In Africa, few studies have been conducted to document the diversity, phenology, distribution and ecology of pteridophytes flora [8, 26, 21, 7, 48, 1]. Fern species richness, growth and evolutionary processes are driven by climate change [24] (e.g. relative humidity, rainfall, temperature), soil conditions and anthropogenic activities [29] (e.g. forest lands encroachment, industrialization, over-exploitation of natural resources, unplanned developmental activities, urbanization and fire) [28,14, 32]. Conversely, anthropogenic disturbance such as fire increase the distribution of toxic weeds (e.g. *Pteridium;*) [44] and spore germination *P. caudatum* [18].
Previous study [46] reported eight life-form categories; chamaephytes, epiphytes, geophytes, hemicryptophytes, helophytes, hydrophytes, phanerophytes, and therophytes and four major habitats: epiphytic (*Asplenium nidus* L., *Huperzia squarrosa* (G. Forst.) Trevis., *Lepisorus nudus* (Hook.) Ching and *Lygodium* (Burm. F.) Sw.), hydrophytic (*Azolla* Kaulf., *Salvinia* Desv. and *Marsilea* Willd.), lithophytic (*Asplenium ruta muraria* L., *Adiantum venustum* D. Don., *A. capillus-veneris* and *Pteris*, L.) and terrestrial (*Cyclosorus* Ching, *Diplazium* Raddi, *Dryopteris* (Desv.) C. Chr. and *Pteris* Alston) [11, 46]. Pteridophytes checklists have been documented in East Africa (~ 516 species; [29]) and West African countries. Early studies revealed pteridophytes diversity in Zambia (146 species), Tanzania (140 species), [49, 50, 21] and Togo (134 species) [1]. Some of the common species include *Adiantum patens* subsp. *Oatesii*, *Alsophila camerooniana*, *Asplenium aethiopicum*, *Asplenium elliottii*, *Cyathea dregei*, *Diplazium zanzibaricum*, *Dryopteris fadenii*, *Equisetum ramosissimum*, *Isoetes melanotheca Lycopodium verticillatum*, *Lygodium kerstenii*, *Marattia fraxinea*, *Microgramme lycopodiodes*, *Nephrolepis undulata*, *Ophioglossum costatum*, *Pleopeltis macrocarpa. Polystichum wilsonii*, *Pseudolycopodiella affinis*, *Pteris catoptera*, *Ptisana salicifolia*, *Selaginella abyssinica*, *Tectaria gemmifera*, and *Thelypteris dentata*. Pteridophytes species richness has been documented in Benin (42 species) [7], Burkina Faso (25 species) [52], Ghana (165 species) [8] and Nigeria, (165 species) [13].
Evaluation of pteridophytes diversity is limited in Nigeria, despite several ecological survey carried out [37]. Previous works only reported baseline information on the diversity [5, 3] and ethnobotanical uses in Lagos, Southwest Nigeria [37] with no records of the phenology (sporulation period). The importance of phenological information cannot be over-emphasized particularly in the current effort to link disease

occurrence with plants phenological characters as done by [57]. These authors in their attempt to use multi-emergence approach to unravel the spillover of Ebola events across West Africa stressed the relevance of plant phenology data and therefore pleaded for more publication of phenology data in tropical Africa.

To the best of the authors' knowledge, there is no publication on the sporulation periods of the various species of pteridophytes found in Lagos or anywhere in Nigeria. Therefore, the objectives of this study are (i) to document pteridophytes diversity (ferns and allies) in Lagos, South-Western Nigeria and (ii) to provide information on the sporulation phenology of the encountered species. Thus, our results will update the pteridophytes diversity (local, regional and global level), reveal their conservation statuses and newly adds the sporulation phenology.

2. Materials and Methods

2.1 Study area

The study areas were selected based on accessibility and they are geographically located within Latitude 7^0 N and Longitude 3^0 E (Fig. 1; Appendix1). The vegetation and geographic details of the sampled areas are presented in Appendix 1. We randomly established and surveyed four areas (Badagry, Epe, Ikorodu, and University of Lagos [Unilag]) Akoka campus Lagos State, Nigeria for one year (September 2016 – August 2017). The Lagos State climate is a typical tropical climate with two distinct weather conditions; wet season (April to October) and dry season (November to March). In order to have substantial information to assess the pteridophytes sporulation in relation to time/season, we further classified these weather conditions into three subgroups (early, mid and late).

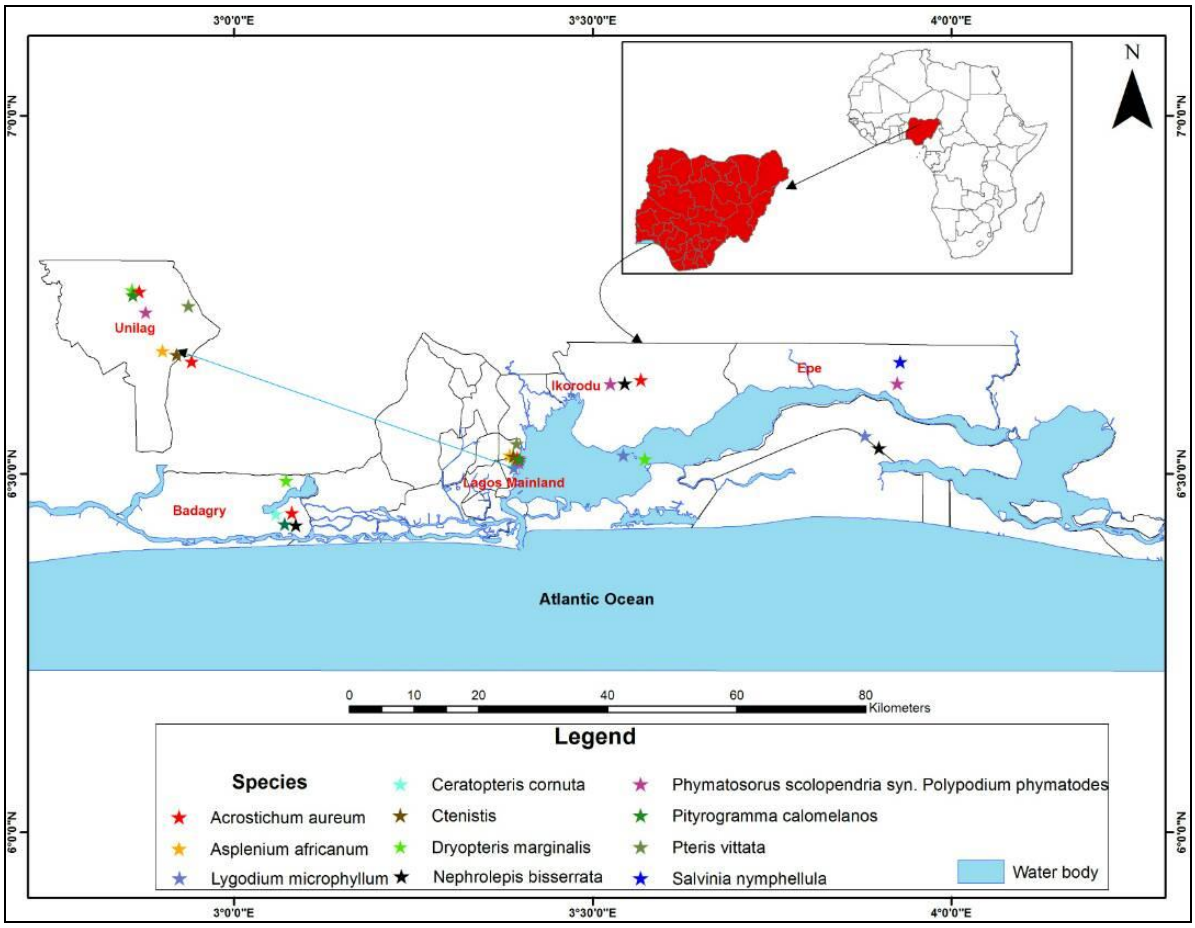

Fig 1: Map of Lagos State showing study locations and pteridophytes distribution at the time of study

2.2 Methods

We surveyed the pteridophytes diversity using Opportunistic sampling method [53]. At every point of occurrence, we permanently marked out this point throughout the study for monthly observations while the coordinates were taken using hand held Global Positioning System (GPS) (Appendix 1). Field identification was aided using relevant floras and manuals including [8, 39]. Instances where on-site assessment was not possible, plant specimens were collected and taken to the Herbarium unit, Department of Botany, University of Lagos for adequate identification. Our study recorded species presence and absence, habitat and sporulation phenology for one year. The conservation statuses of the encountered species were assessed using the International Union for Conservation of Nature web-interface - [51]; (Appendix 2).

2.3 Data analysis

Percentage, species and habitat distribution were calculated using the presence and absence data. We investigated the influence of environmental variables on sporulation periods using three meteorological parameters (rainfall, relative humidity and temperature) downloaded from the public data base [58] from September 2016 – August 2017 (Appendix 3). We conducted four diversity indices (Dominance, Simpson, Shannon – Wieners and Margalef index) and correlation analysis at $p \leq 0.05$ between the environmental variables and sporulation incidences using Pearson Correlation Coefficient (r) incorporated in PA laeontological Statistics (PAST, software version 2.17c, Appendix 4 & 5) [19].

3. Results & Discussion

We documented the sporulation phenology calendar of the encountered pteridophytes in Lagos State (Appendix 5) with a record of a total of 11 species belonging to 11 genera and seven families (Table 1, Appendix 7). Two species (*Dryopteris marginalis* and *Phymatosorus scolopendria*) were recorded in all the locations while six species (*Acrostichum aureum, Asplenium africanum, Ceratopteris cornuta, Pityrogramma calomelanos, Pteris vittata* and *Salvinia nymphellula*) were restricted to single sites each (Table 1). Majority of the species are terrestrial and no endangered or threatened species was encountered in this study.

Table 1: Checklist, distribution and habitats of Pteridophytes in study areas of Lagos State

SN	Species	Family	Badagry	Epe	Ikorodu	Unilag	Habitat	Cons. Status
1.	*Acrostichum aureum* L.	Pteridaceae	+	–	–	+	Terrestrial	LC
2.	*Asplenium africanum* Desv.	Aspleniaceae	–	–	+	–	Epiphytic (*E. guineensis*)	NE
3.	*Ceratopteris cornuta* (P. Beauv.) Le Prieur	Pteridaceae	+	–	–	–	Terrestrial	LC
4.	*Ctenitis* sp.	Dryopteridaceae	–	–	+	–	Terrestrial	NE
5.	*Dryopteris marginalis* (L.) Gray	Dryopteridaceae	+	+	+	+	Terrestrial	NE
6.	*Lygodium microphyllum* (Cav.) R.Br.	Lygodiaceae	–	+	+	+	Climber	LC
7.	*Nephrolepis biserrata* (Sw.) Schott	Nephrolepidaceae	+	+	+	–	Epiphytic (*E. guineensis*)	NE
8.	*Phymatosorus scolopendria* (Burm. fil.) Pichi-Serm. *syn. Polypodium phymatodes*	Polypodiaceae	+	+	+	+	Epiphytic (*E. guineensis*)/ Lithophytic (Concrete)	NE
9.	*Pityrogramma calomelanos* (L.) Link	Pteridaceae	–	–	–	+	Terrestrial	NE
10.	*Pteris vittata* L.	Pteridaceae	–	–	–	+	Lithophytic (Concrete)	LC
11.	*Salvinia nymphellula* Desv.	Salviniaceae	–	+	–	–	Hydrophytic Floating	NE

Key: (-) = Absent, (+) = Present, NE=Not evaluated, LC=Least concern, Cons. Status = Conservation Status

The species diversity indices were high for all the locations especially Unilag (Simpson = 0.7635, Shannon – Wieners = 1.564 and Margalef = 1.313; Appendix 4). Two locations had highest percentage species occurrence (27.27 %, 6 species in Ikorodu and Unilag) (Fig. 2). *Nephrolepis bisserata* was recorded in three locations (Badagry, Epe and Ikorodu). Similarly, we encountered *L. microphyllum in* three locations (Epe, Unilag and Ikorodu) while *A. aureum* occurred in two locations (Badagry and Unilag). Five species; *S. nymphellula* (Epe), *C. cornuta* (Badagry), *P. vittata* (Unilag), *A. africanum* (Ikorodu) and *Ctenitis* sp. (Ikorodu) occurred in one location only. Similarly, two locations (Ikorodu and Unilag) had highest pteridophytes family richness (22.78 %, 5 species.). Family Pteridaceae had the highest species (4), followed by Dryopteridaceae, Aspleniaceae, Polypodiaceae, Lygodiaceae and Nephrolepidaceae (Figs. 2 & 3). The survey revealed six habitats; (i) terrestrial [46%], (ii) epiphytic [18%], (iii) epiphytic and lithophytic [9%], (iv) lithophytic [9%], (v) climber [9%], and (vi) Hydrophytic (floating) [9%] (Table 2).

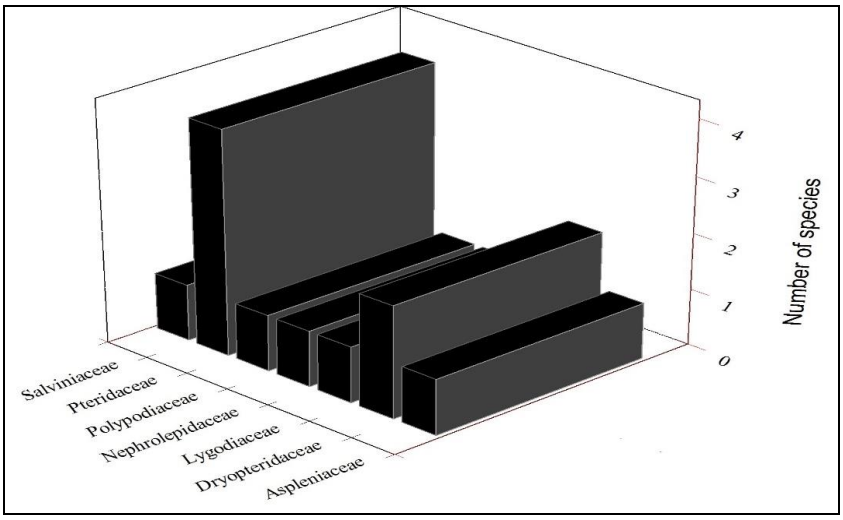

Fig 2: Summary of family distribution with their species across the study areas

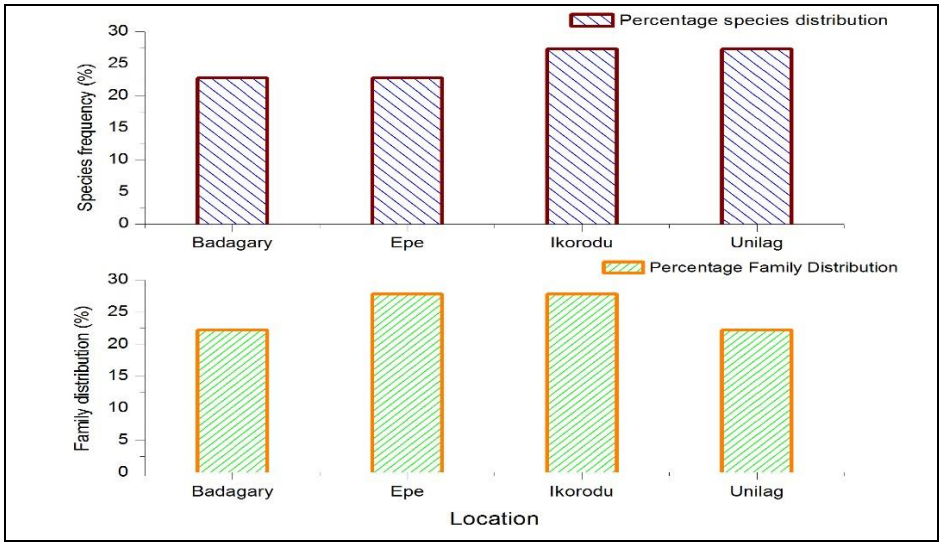

Fig 3: Percentage species and family distribution per location

The sporulation periods of these species vary accordingly (Figs. 4 and 5, & Appendix 6). Our Pearson's analyses revealed moderate to strong positive correlations (0.5 – 0.9) between sporulation incidence and the environmental parameters (Appendix 4). In Badagry, *A. aureum* sporulation incidence correlated positively with rainfall, relative humidity and temperature (~ 0.7, 0.5 and 0.8 respectively) while sporulation in *P. scolopendria* correlated positively with temperature (~ 0.8). For N.biserrata and C. cornuta, sporulation incidence in these two species strongly correlated positively with rainfall (~0.7) and temperature (~0.9) respectively. In Epe, positive correlation was observed between sporulation incidence in *L. microphylum* and rainfall (~0.6) as well as temperature (~0.8). In Ikorodu, the sporulation incidence of *D. marginalis* correlated positively with rainfall (~ 0.5) while the sporulation incidences in *A. africanum*, *D. marginalis and N. biserrata* correlated positively with relative humidity (~ 0.5, 0.99 and 0.8 respectively). Similarly, positive correlations was established between *Ctenistis* sp., *D. marginalis N. biserrata, and* temperature (~ 0.5, 0.7 and 0.9 respectively). In Unilag, *L. microphylum* sporulation incidence correlated positively with rainfall (0.9) while three species correlated positively with relative humidity (~ 0.7 [*P. vittata*], 0.7 [*D. marginalis] and* 0.8 [*P. calomelanos*]). Only *P. calomelanos* showed a positive correlation with temperature (~ 0.9) in this location.

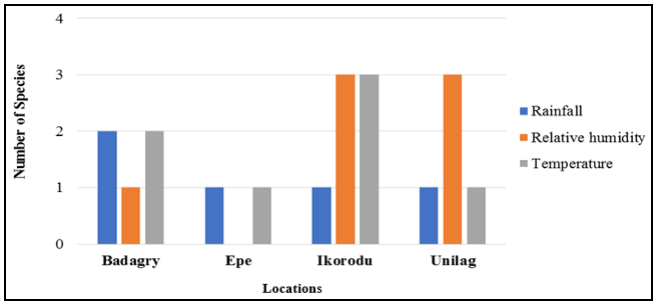

Fig 4: Number of species that correlated with environmental factors based on their sporulation periods

Phenology of Sporulation

Sporulation of Pteridophytes encountered in Epe study area

Five species distributed to five genera and five families were encountered. It was observed that *D. marginalis* started sporulating from December (early dry season) – May (mid wet season). *N. biserrata* sporulated from September (late wet season) – June (mid wet season). Also, the sporulating period recorded for *P. scolopendria* was from March (late dry season) – December (early dry season) while *L. microphyllum* sporulated from January (dry season) to August (wet season). However, *S. nymphellula* emerged in the beginning of wet season (March) and no sporulation was observed till the end of the study.

Sporulation of Pteridophytes encountered in Ikorodu study

Six species distributed into six genera and five families were encountered. It was observed that *L. microphyllum* started sporulating from December (early dry season) – April (early wet season). However, there was no record of *L. microphyllum* from May (mid wet season) to August (wet season) because the site where it was earlier recorded had been cleared before the sampling of these months. *D. marginalis* sporulated from February (dry season) to August (wet season). Furthermore, the sporulation period recorded for *N. bisserata* was from February (dry season) to April (early wet season), with another short sporulation period recorded in August. *P. scolopendria* sporulated from September (late wet season) – November (early dry season) and this was followed by a period of non-sporulation for four months before resumption of sporulation from April (early wet season) to August (wet season). *A. africanum* and *Ctenitis* sp. sporulated almost all year round except within the months of March (late dry season) – April (early wet season) and December (early dry season) – January (dry season) respectively.

Sporulation of Pteridophytes encountered in Badagry study area

We documented a total of five species distributed into six genera and four families. The sporulation period for *D. marginalis* was November (start of dry season) – April (early wet season). We observed two sporulation periods in *A. aureum*; (i) November – February (dry season) and (ii) May (mid wet season) – August (wet season). *N. bisserata* sporulated during the harmattan period in January through to August (wet season). *P. scolopendria* sporulated during

the months of June – August (wet season). Occurrence of sporulation in *C. cornuta* was established during the dry season of December through the early wet season in April.

Sporulation of Pteridophytes encountered in Unilag study area

Six species distributed into six genera and four families were encountered. The sporulation of *D. marginalis* was observed from March (late dry season) – July (wet season). On the other hand, *A. aureum* sporulated in two periods viz (i) September – January and (ii) May (mid wet season) – August (wet season) respectively. Occurrence of two species were not detected (*P. vittata* and *P. calomelanos*) between September and December, until January onward. The sporulation period of *P. vittata* was recorded from May (mid wet season) – August (wet season) while *P. calomelanos* sporulated within April (early wet season) and July (wet season). *P. scolopendria* was observed to have sporulated from September (late wet season) – December (early dry season), followed by a period of non-sporulation for five months. This was later followed by a period of sporulation from June to August (wet season).

Sporulation patterns of the encountered Pteridophytes in Lagos State

The study revealed the variation patterns in the sporulation periods of the encountered pteridophytes with locations (Table 2 & Appendix 6). Details of these species are given below.

***Acrostichum aureum* L.**

Habitat: Mangrove swamps and salt marshes

Sporulation period and comments: Two sporulating periods were established for *A. aureum* i.e. November – January and May–August (Appendix 6). In the months of March and April, *A. aureum* did not sporulate in the sampling locations they occurred.

***Asplenium africanum* Desv.**

Synonyms: *A. guineense* K. Schum., *A. sinuatum* P. Beauv. and *A. venosum* Hook

Habitat: Epiphytic

Sporulation period and comments: Two sporulation periods were indicated for this species. The first occurred from September - February while the second occurred from May to August (Appendix 6). *A. africanum* recorded no sporulation in March and April, a period that coincides with the end of the dry season and the beginning of the wet season but with very high temperature.

***Ceratopteris cornuta* (P. Beauv.) Le Prieur**

Habitat: Terrestrial (aquatic and marshy ecosystems)

Sporulation period and comments: Sporulation in this species was observed from the months of December through April, suggesting that *C. cornuta* matures and prepares for sporulation during the wet season; then at the onset of the harmattan period, it begins to sporulate.

***Ctenitis* sp. C. Chr. ex C. Chr.**

Habitat: Terrestrial (less marshy ecosystem in disturbed secondary forest)

Sporulation period and comments: This species has two sporulation periods annually: the first occurs from September to November and the second from February to August (Appendix 6). *Ctenitis* did not sporulate in December - January, a period that coincides with the peak of the dry season with relatively low temperature.

***Dryopteris marginalis* (L.) Gray**

Synonyms: *Nephrodium marginale* (L.) Michx., *Polypodium marginale* L.

Habitat: Terrestrial (in a marshy/aquatic ecosystem)

Sporulation period and comments: This species started sporulating in Lagos from November to August across all locations (Appendix 6). Although overlapping of sporulation months was observed for *D. marginalis*, it sporulated simultaneously across all locations in March and April. There fore these months, March and April most likely represent its peak sporulation period.

***Lygodium microphyllum* (Cav.) R. Br.**

Synonyms: *Lygodium, scandens* Auct., *L. scandens* var. *microphyllum* (Cav.) Luerss., *Ophioglossum filiforme* Roxb.

Habitat: Climbing fern in a moist forest

Sporulation period and comments: We observed simultaneous sporulation in *L. microphyllum* in Epe, Ikorodu and Unilag from January to April (Appendix 6), suggesting that this represents the peak sporulation period for this species. We cannot assert that the sporulation period of this species extends beyond April because the sampling location in Ikorodu was cleared in May, hence, our inability to make observation on its sporulation status for the months of May through August. However, based on the observation of the sporulation pattern of this species, we infer that *L. microphyllum* started sporulating in December. Meanwhile, observation of this fern still continues so as to fill in the gap in subsequent studies.

***Nephrolepis biserrata* (Sw.) Schott**

Synonyms: *Aspidium acuminatum* Willd., *Lepidoneuron punctulatum* (Poir.) Fée, *Nephrolepis acuta* (Schkuhr) C. Presl, *Polypodium punctulatum* Poir.

Habitat: Epiphytic (growing on *Elaeis guineensis* tree)

Sporulation period and comments: This species sporulated all-round the year in Lagos, although, it does not sporulate in some locations at certain periods of the year (Appendix 6). Nonetheless, *N. biserrata* sporulated simultaneously across all locations where it was found from February – April. These months most likely represent its peak sporulation period.

***Phymatosorus scolopendria* (Burm. fil.) Pichi-Serm.**

Synonyms: *Aglaomorpha colopendria, Polypodium phymatodes, Microsorum scolopendria*

Habitat: Epiphytic (growing on *E. guineensis*) and also litholitic.

Sporulation period: Simultaneous sporulation for this species was observed in the months of June – August. This suggests that this period represents the peak sporulation period (Appendix 6). Double sporulation periods were observed for this species in Epe, Ikorodu, and Unilag except Badagry. The months of January and February were established as a non-sporulation period for *P. scolopendria.* This species is commonly referred to as the golden rod fern or wart fern.

***Pteris vittata* L.**
Synonyms: *Pteris costata* Bory, *P. diversifolia* Sw. *P. ensifolia* Poir., *P. inaequilateralis* Poir.
Habitat: Lithophytic (rooted in between concrete crack and concrete structures)
Sporulation period and comments: This species started sporulating in Lagos from May to August in Unilag (Appendix 6). Its occurrence was not noted until January, thus between September and December, there was no observation. The May – August sporulation may not be the real period because between September and December what the picture was could not be ascertained. Surprisingly however, in the following year outside the study period, sporulation was observed in February up to early April. Further observation is needed to conclude more accurately on the sporulation phenology of this plant.

***Salvinia nymphellula* Desv.**
Habitat: Hydrophytic (Free aquatic)
Sporulation period and comments: From September – February, there was no occurrence of this plant and when eventually encountered, it did not sporulate throughout the sampling period (Appendix 6). There is a need to monitor this species more closely in order to delineate more accurately its sporulation period.

***Pityrogramma calomelanos* (L.) Link**
Synonym
Acrostichum austroamericana, A. calomelanos, A. ochracea , A. calomelas

Habitat: Terrestrial
Sporulation period and comments: From September to December, there was no occurrence of this plant species (Appendix 6). However, in January, it was encountered but not sporulating. In April, it began sporulating and this lasted only for four months.

Table 2: Sporulation Calendar of all encountered Pteridophytes in Lagos State, Nigeria Green = Sporulating; Red = Present but not sporulating; White = Inconclusive

Species/Months	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
D. marginalis												
A. aureum												
C. cornuta												
P. scolopendria												
N. biserrata												
A. africanum												
Ctenitis sp.												
L. microphylum												
P. vittata												
Pityrogramma calomelanos (L.) Link												
S. nymphellula												

The current record has shown the diversity of pteridophytes in Lagos State as well as documenting their distribution, habitat and abundance. High diversity and species richness in Ikorodu and Unilag compared to Badagry and Epe were recorded. This clearly points to the fact that Ikorodu still has a good biodiversity potential. The high diversity of pteridophytes in Unilag is somewhat expected because of conservation efforts of the institution, which enabled the preservation of many ecological systems with lush vegetation. In the present work more taxa (11 species) were recorded compared to five taxa recorded in previous study by [5]. The results of the present study could not confirm the presence of two species (*Salvinia natans* and *Pteridium aquilinum*) previously recorded in the wetland of Ibeju-Lekki, an area not too far from Epe in Lagos by [4]. Likewise, *Nephrolepis biserrata* and *Ctenitis* sp. were present within the Unilag campus but absent from our mapped locations. In spite of these additional six species, it is clear that some pteridophytes were still by-passed in the present study. The selection criterion for the study locations (based on easy accessibility) maybe an important factor that determined the pteridophytes diversity documented. It is therefore recommended that subsequent work should move into the inner parts of visited vegetation to ascertain more accurately the pteridophytes distribution, abundance and diversity.

The diversity and habitats of the species encountered are not different from past records by previous workers as reported for *A. aureum* (mangrove ecosystem, [2, 25, 5, 38]), *P. vittata* (lithophytic, [59]), and *P. scolopendria* (epiphytic on trees, [20]). *P. scolopendria* grows naturally on palm trees or wood in wet forest areas or in secondary forest but can be cultivated as a potted plant [39]. Also, *A. africanum*, *S. nymphellula*, and *C. cornuta* are found in similar habitat reported by earlier workers [54, 6, 22]. This indicates the endemism of pteridophytes to specific microhabitats [31, 42] hence making protection of these microhabitats highly imperative. The health status of each habitat is directly proportional to the conservation and diversity of the species [46, 56, 12].

Heterogeneity in pteridophytes community can also be attributed to environmental variation and gradient, edaphic factors, water availability, historical factors, dispersal rate, niche and anthropogenic factors [23, 27, 61]. Ecological factors influencing pteridophytes distribution within the tropical zone in Africa are fire, moisture, soil conditions and human activity and in certain instances, temperature [28]. Other environmental factors that significantly influence pteridophytes distribution include soil moisture, photoperiod and habitat specificity (biotic and abiotic) [56, 31, 15, 16, 10]. Similarly, the sporulation phenology is also dependent on these factors. This is evident and supported by the results from this work.

Phenological study of the sporulation of the encountered taxa also indicates the need for a longer observation period and higher frequency of visits. This is because the sporulation period of one of the monitored pteridophytes was not recorded probably due to the shorter sporulation period than what our monthly visit could capture. This may be responsible for the non-capturing of the sporulation in *Salvinia nymphelluna* which was by-passed; hence, there is need for extensive monitoring period. We observed that the sporulation features of each species were influenced by their micro-environment. This is evident in the differential sporulation periods recorded in the four areas studied. These micro-environmental factors are meteorological and edaphic as well as anthropogenic. Statistical analysis revealed varying correlations between meteorological parameters and sporulation incidences of the encountered pteridophytes (Appendix 3). Environmental parameters; Temperature (*A. aureum, L. microphyllum, C. cornuta, N. biserrata* and *P. scolopendria*), rainfall and relative humidity (*D. marginalis, N. biserrata and P. calomelanos*) play significant roles in the sporulation incidence of the encountered pteridophytes. This suggests that temperature, rainfall and relative humidity, determine the sporulation period within the studied area.

[33] in their phenological study of *Acrostichum danaeifolium* at a mangrove site in Mexico, recorded positive correlations between fertility in *A. danaeifolium* and mean temperature and precipitation. Hence, fertile leaf fronds were observed between the rainy period of April and August. Results from our work for this same genus also support this as fertile leaf fronds of *Acrostichum* were also observed to be sporulating during the rainy season (May – August) except for the month of April where it was not sporulating. We also recorded positive correlations between sporulation incidences of *Acrostichum* in Badagry and mean temperature (Appendix 3, Table 1). We suspect that the agreeing pattern in these results, asides the parameters previously mentioned, could be attributed to the similarity in the environment where these species were recovered: both sites sit close to a brackish-water lagoon. Sporulation in majority of the pteridophytes from the Satara district in India was also observed to occur during months of high precipitation (June to August) [41], this result also corroborates our finding. Although [28] noted that temperature plays a little role in influencing pteridophytes distribution across tropical Africa, rather we observed here that temperature played a huge role in sporulation in Nigeria.

While some of these taxa sporulated in the wet season, some others sporulated also in the dry season. Generally, the dry season sporulation was only significant in *Dryopteris, Ceratopteris, Lygodium* and *Nephrolepis* with records of their peaks in this season. Wet season sporulation was significant in *A. aureum* and *P. scolopendria*. *Asplenium* and *Ctenitis* sporulated almost throughout the year except two months each in the dry season; March – April, and December – January respectively. Due to the reason earlier adduced for *Pteris vittata,* the restriction of its sporulation to the wet season may be incorrect. All these variations confirm the impact of the various micro-environmental factors [17]. The overall implication of these is the fact that aerobiological records of pteridophytes spores in any locality must be clearly recognized as such and be cautiously applied on regional basis. This is because the relatively heavy weight of these spores will limit their aerodynamism and combined with the micro-environmental factors make them more of a local phenomenon than regional.

Based on the sporulation period of the various encountered pteridophytes species per location, a single sporulation calendar was developed (Table 2). The relative frequency of sporulation incidences in all species was used to harmonize the data from each location, with 75 % being the benchmark for drawing conclusions on the likelihood of a single species sporulating in a given month. This means that there is a high probability for a species to sporulate in a particular month if it is found sporulating in three out of the four locations studied in that month. Overall, we were able to establish the sporulation period for ten species. One species (*S. nymphellula*) was inconclusive because we did not come across any of its sporulating species within the period of our studies. This suggests that without a continuous visit onsite, it will be difficult to forecast the sporulation period of these species as their sporulation may be dependent on sharp responses to changes in micro-environmental factors, such as soil, light intensity, pH, and other meteorological parameters. Out of the ten species whose sporulation periods were recorded, seven sporulated from the months of May to June while six of these species sporulated in April and July respectively. Simultaneous sporulation among species was observed majorly in the months of April through July. Given that these were the months in which most of the encountered pteridophytes species sporulated, we therefore infer that pteridophytes sporulate in Lagos State mostly from April to July.

It is important to report that no endangered, threatened or vulnerable species was encountered during this study however, attention should be given to their conservation because they play substantial roles in the aquatic ecosystem maintenance apart from their usefulness to man. [30] have highlighted a wide range of uses of pteridophytes. According to [55], *P. vittata* serves as pollution control and can be used for phytoremediation [55] while *P. calomenalos* has been reported to cure kidney related problems. Finally, we consider the results of this work as major contributions to existing knowledge on the phenology of the different pteridophytes encountered and the first of such in Nigeria to the best of the authors' knowledge.

4. Conclusion

This study recorded eleven species belonging to ten genera and seven families within the four sampled locations viz Epe, Ikorodu, Badagry and Unilag. The Ikorodu and Unilag locations recorded the highest diversity of pteridophytes thereby giving credence to the fact that Ikorodu still has a high biodiversity conservation potential. Recorded sporulation periods of the various pteridophytes encountered varied throughout the year and across locations. While some species were found to be sporulating at the offset of dry season, others were found to have sporulated at the beginning of the wet season. Some species sporulated across all sampled locations in some particular months, suggesting that these months represent their peak sporulation period. The microenvironment plays a major key in the sporulation of all recorded pteridophytes with relative humidity, temperature and rainfall as determinant meteorological factors across Lagos State.

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