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Vegetation change inferred from the pollen record in recent sediments from around the Lagos-East coastal environment (SW Nigeria)

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ABSTRACT. Recent sediments from the coastal environment of Lagos East, Nigeria, were used to make a palynological reconstruction of the vegetation of the study area and to draw inferences about its palaeoclimate. A total of 8456 palynomorphs were recovered, dominated by pollen grains of Poaceae (13.96%), Cyperaceae (6.23%), *Alchornea cordifolia* Müll-Arg (8.36%) and *Elaeis guineensis* Jacq (2.41%). Others were *Cyclosorus afer* Ching (2.18%), *Rhizophora* sp. (0.45%), *Nephrolepis* sp. (1.03%), *Celtis* sp. (0.25%) and *Pteris* sp. (0.13%). The composition of the recovered palynomorphs suggests that the past vegetation was predominantly a mosaic of freshwater swamp, with open to dry climate, as indicated by the records of Cyperaceae, *Alchornea cordifolia*, *Elaeis guineensis,* Arecaceae, Asteraceae, Acanthaceae and Chenopodiaceae/Amaranthaceae. Radiocarbon dates obtained from two depths (surface and deepest) indicate that the sediments were deposited around the last 103.8 ± 0.4 pMC (percentage Modern Carbon) and 111.9 ± 0.4 pMC, hence in the late Holocene. The study identified fluctuations between wet and dry climatic conditions in the Holocene of this area.

KEYWORDS: pollen, Holocene, vegetation change, south-western Nigeria

INTRODUCTION

Changes in climate are most evidently reflected in vegetation. This is because the vegetation of any area is an integral and basic component of the ecosystem, which is sensitive to change. The distribution pattern of vegetation strongly depends on climatic conditions (Ivanov et al. 2007). According to Sowunmi (1987) there is a close relationship between vegetation and the rest of the environment, particularly climate and soil. Thus the flora of an area generally reflects the major climatic regime of that area. The influence of climate on other components of the environment is so great that every particular climatic zone has its own characteristic vegetation type. Therefore, plants are among the best indicators of environmental and climatic changes. Certain individual assemblages of plants are known to be characteristic of specific ecological zones, and the occurrence of fossils of such ecological indicator species in sediments is taken as a reflection of contemporary environmental conditions. Quantitative analyses of fossil palynomorphs from various layers or horizons of sediments have been used to reconstruct the past vegetation distribution and abundance. (Adekanmbi & Sowunmi 2007, Durugbo et al. 2010, Ige et al. 2011). Information from such studies provides important baseline data for understanding long-term ecosystem dynamics at local, regional or continental scales (Germeraad et al. 1968).

The coastal vegetation of Lagos in south-western Nigeria has been frequently degraded, consequent to which many plant species migrate and become locally extinct. Due to the emphasis on the search for petroleum-indicating fossils, palynological studies have been largely

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confined to the Niger Delta region of Nigeria; hence there is a paucity of published information on the paleovegetation and climatic change in the coastal environment of Lagos. Sowunmi (2004) studied an 11 m long terrestrial core from Ahanve, a village in the western part of the Lagos coastal environment, and reported an abrupt decrease and the subsequent disappearance of *Rhizophora* pollen ca 3109 ± 26 BP during the late Holocene, replaced by freshwater vegetation such as the freshwater grasses *Alchornea cordifolia* and *Elaeis guineensis*. These events were attributed in part to anthropogenic effects, though climate and geomorphology were the main factors said to have influenced Holocene vegetation changes in the area. Orijemie and Sowunmi (2014) also carried out some archaeological and palynological work in the same location and reported a changing vegetation setting. Adekanmbi and Ogundipe (2009) compared pollen and spore assemblages recovered from the shoreline of the floor of the Lagos Lagoon and from off-coast sediments in the hinterland of the same lagoon. They found that the recovered pollen and spores were relatively diverse but that vascular plant pollen was not abundant, corresponding in general to the current vegetation of the studied area. Lezine and Cazet (2005) made a high-resolution pollen study of 69 samples collected from core KW31 off the mouth of the Niger River at the Gulf of Guinea. They suggested that the increase in forest diversity and the expansion of rainforest and secondary forest on the adjoining continent could have arisen from post-glacial warming coupled with an increase in monsoon fluxes over West Africa. They also reported a widespread response of the vegetation to the shift towards aridity at the end of the African Humid Period around 4000 BP. Quaternary studies which tend to reveal the extent of anthropogenic impacts and/or climate change include Adekanmbi (2008), Ige (2009), Njokuocha (2012), Adeonipekun and Olowokudejo (2013), Birks (1993), Adekanmbi et al. (2017) and Adekanmbi & Alebiosu (2017).

No other palynological work known to the authors has been carried out in coastal areas of Lagos. The present study was aimed at reconstructing the past vegetation and drawing inferences about the palaeoclimate of the coastal environment of Lagos, Nigeria, in the Late Holocene. The findings could be useful to policymakers in formulating active environmental guidelines for conservation and management of coastal environments.

MATERIALS AND METHODS

DESCRIPTION OF STUDY SITE

The study site (6°36′48″N, 3°26′31″E) is located in the Itowolo community, a rural settlement near Ikorodu town. It is located close to one of the outlets of the Ogun River, which serves as a boundary between Ikorodu and

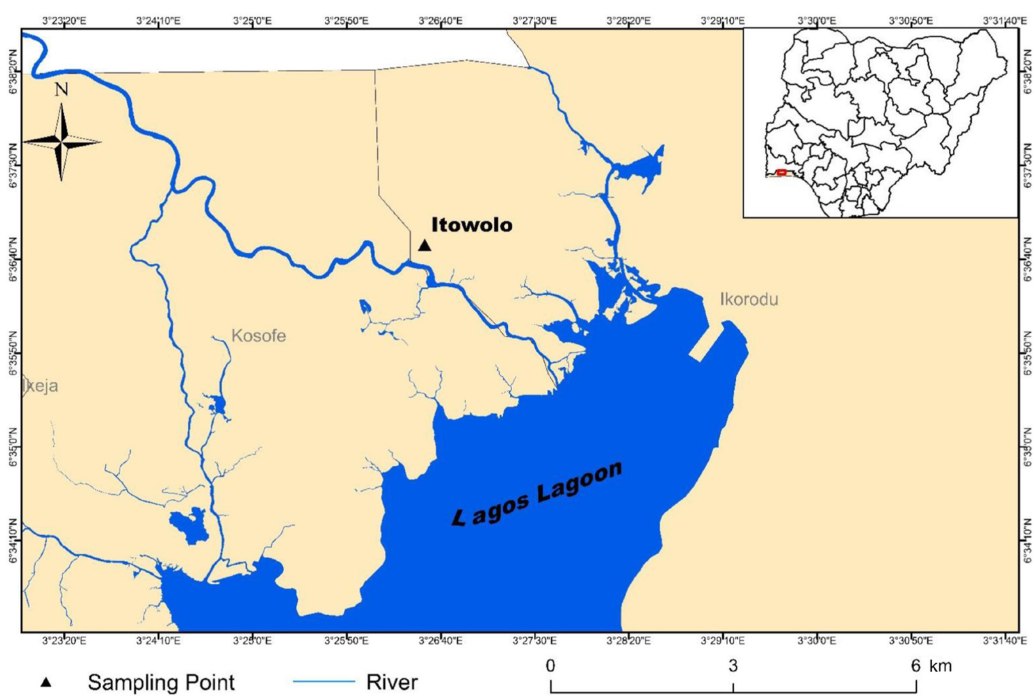

Fig. 1. Study site

Kosofe Local Government Areas of Lagos State (Fig. 1). The climate of the area is tropical wet and dry according to the Köppen climate classification system, with ca 1800 mm mean annual rainfall and 27°C mean annual temperature (Soladoye & Ajibade 2014). The area is dominated by two main seasons (rainy, dry). The rainy season has two wet periods, the first and strongest of them lasting from April to July, and the second, weaker one occurring between September and November. Between these wet periods is a relatively dry period in August and September, commonly referred to as the "August break". The main dry season lasts from December to March and usually brings the harmattan winds from the North-East Trade Winds. The current vegetation is freshwater swamp dominated by *Cyperus* spp. and *Paspalum*. Other species are *Emilia coccinea, Ludwigia erecta, Ageratum conyzoides, Vernonia cinerea, Hallea stipulosa* and *Phyllanthus reticulatus.*

SAMPLE COLLECTION

Seventeen cored sediments samples were collected at 3 cm intervals to a depth of 51 cm using a Russian peat corer and then transferred to sterile sealable sample bags, following the method of Jordan et al. (2010). The location of the sampling point was identified with a GPS and was mapped using Arc GIS software.

PH AND LITHOLOGY

The pH of the sediment samples was determined with a La Motte multi-meter probe (Model HI2550) calibrated against standardized solutions having pH^4 and pH^9. Five grams of each sample were dissolved with distilled water in plastic cups and covered with removable screw caps, transferred to the fumehood, stirred and shaken vigorously. The pH electrode was then inserted into the solution and the values were noted. Lithology was analysed by washing the sediments with distilled water through a 63 µm sieve. The sediments were then oven-dried, examined and described with the aid of a grain size comparator, rock colour chart, stereo binocular microscope and hand lens (40×).

LABORATORY PROCESSING OF SAMPLES

The sediment samples were treated following standard palynological methods of Erdtman (1969) and Faegri and Iversen (1989). These include treatment with hydrofluoric acid (HF) for removal of siliceous material, hydrochloric acid (HCl) for removal of carbonaceous material, a heavy liquid mixture to separate palynomorphs from the sediment, and finally acetolysis to destroy cellulosic material and to darken the palynomorphs for easy identification.

The top, middle and bottom sediment samples were subjected to standard acceleration mass spectrometry (AMS) at Beta Analytic Inc. (Miami, Florida, USA) following the simplified approach to calibrating C^{14} dates of Stuiver and Polach (1977) and Reimer et al. (2013).

IDENTIFICATION OF POLLEN AND PHYTOECOLOGICAL GROUPS

The morphology of the recovered palynomorphs was compared with published description keys for African pollen grains and spores (Sowunmi 1995, 1973, Bonnefille & Riollet 1980, Salard-Cheboldaeff 1990, Willard et al. 2004, Gosling et al. 2013), as well as pollen albums and reference collections in the Laboratory of Paleobotany and Palynology, University of Lagos. Unidentified pollen and spores were recorded as "indeterminate". Photomicrographs of some representative pollen and spores were taken with a Chex DC 5000 camera, Euromex 5.0M pixel digital camera and a Canon DS126181 camera fitted to an Olympus light microscope at 40×. Only pollen grains and spores identified to species, genus or family level, following Moore & Webb (1978), were included in the pollen totals. The pollen spectra include all the palynomorphs recovered from the sediment samples, shown in Table 2. The percentage composition was calculated as the numerical composition of the total of each pollen and spore species in a sample, divided by the pollen total from each depth and multiplied by 100. Pollen zones were recognized based on the changes in the diversity and abundance values of the recovered palynomorphs, calculated by dividing the total for all depths by the totals for particular depths. To construct the pollen zones, all the recovered pollen and spores in the studied core were assigned to phytoecological groups, except for fungal spores, which were over-represented and have no meaningful paleoecological implications beyond indicating wetness. These phytoecological groups are based on the present-day distribution of the variously identified plant taxa, following the works of Hutchinson and Dalziel (1954, 1958), Keay et al. (1959), Sowunmi (1981, 1987), Poumout (1989), Durugbo et al. (2010) and Adeonipekun et al. (2015). The pollen diagram was constructed using Tilia Graph software (Grimm 1991), incorporating the percentage composition of the pollen and spores in the phytoecological groups.

RESULTS AND DISCUSSION

The calibrated AMS ^{14}C dates of the study location (Tab. 1) show well-layered and continuous accumulation of late Holocene sediments.

Table 1. Calibrated AMS ^{14}C dates for the study location

Sample data	Measured radiocarbon dates	Isotope results o/oo	Conventional radiocarbon age
Beta – 456307 Depth 0–3 cm	102.7 ± 0.4 pMC	d13C = –30.3	103.8 ± 0.4 pMC
Beta – 456308 Depth 48–51 cm	111.8 ± 0.4 pMC	d13C = –25.4	111.9 ± 0.4 pMC

Table 2. pH and lithology

Sample depth	pH	Lithological description
0–3 cm	2.62	Mudstone (>65%): Brown, moderately hard, non-fissile Sand (<35%): Light grey, very fine/fine-grained, angular, well sorted
3–6 cm	2.78	Sand (>75%): Light grey, fine/coarse grained, subangular, poorly sorted Mudstone (<25%): Brown, moderately soft, non-fissile
6–9 cm	2.72	Sand (>60%): Light grey, fine-grained, angular, very well sorted Mudstone (<40%): Grey, moderately soft, non-fissile
9–12 cm	2.85	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
12–15 cm	2.32	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
15–18 cm	2.16	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
18–21 cm	2.10	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
21–24 cm	2.23	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
24–27 cm	2.44	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
27–30 cm	2.35	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
30–33 cm	2.38	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
33–36 cm	2.66	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
36–39 cm	2.45	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
39–42 cm	2.40	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted
42–45 cm	2.30	Mudstone (>85%): Dark grey, hard, non-fissile Sand (<15%): Light grey, fine-grained angular, very well sorted
45–48 cm	2.26	Mudstone (>85%): Dark grey, hard, non-fissile Sand (<15%): Light grey, fine-grained angular, very well sorted
48–51 cm	2.49	Mudstone (>70%): Dark grey, hard, non-fissile Sand (<30%): Light grey, fine-grained angular, very well sorted

The pH and lithology of the sediments indicate a generally acidic setting, ranging from pH 2.10 at depth 18–21 cm to 2.85 at depth 9–12 cm (Tab. 2). These values fall within the range considered to be conducive to palynomorph preservation. High alkalinity limits the preservation of pollen grains and spores and has been cited as a major cause of the paucity of pollen in samples (Havinga 1971). The core's layers alternate between mudstone or shales and sand (Tab. 2). The dominance of shales suggests the establishment of mangrove swamp forest during this period of sedimentary deposition. Lithological examination showed light grey, fine-grained, angular and very well sorted sand bodies, pointing to long-distance movement of the deposited sediment. Textural features varying from subangular to rounded, moderately well sorted, with abundant carbonaceous detritus and ferruginous material, indicate that the sand was deposited in terrestrial/freshwater environments.

Pollen grains of Poaceae dominated the total count across the study depths, with 1351 pollen grains representing 13.96% of the count, followed by pollen of Cyperaceae (603, 6.23%), *Alchornea cordifolia* (809, 8.36%) and *Elaeis guineensis* (233, 2.41%) (Tab. 2). Others are *Cyclosorus afer* (211, 2.18%) *Rhizophora* sp. (44, 0.45%), *Nephrolepis* sp. (100, 1.03%), *Celtis* sp. (24, 0.25%), *Pteris* sp. (13, 0.13%), Euphorbiaceae (136, 1.41%), Arecaceae (139, 1.44%), Asteraceae (34, 0.35%), Acanthaceae (35, 0.36%), Chenopodaceae/Amaranthaceae (15, 0.16%), Commelinaceae (22, 0.23%), Sapindaceae (13, 0.13%) and Trilete spores (110, 1.14%). All the identified pollen and spore types and their percentage composition are given in Table 3. The pollen diagram is presented in Figure 1. Plate 1 shows palynomorphs imaged at 400×. Eight phytoecological groups were recognized, based on the present-day vegetation zones of the taxa to which the palynomorphs belong. The phytoecological groups for Itowolo are described as follows:

Table 3. Palynomorphs recovered from the study site, and their percentages

ITOWOLO																				
PALYNOMORPHS/FAMILIES	Depth (cm)																			%
	0–3	3–6	6–9	9–12	12–15	15–18	18–21	21–24	24–27	27–30	30–33	33–36	36–39	39–42	42–45	45–48	48–51	Sum/T	R/Freq	
Acanthaceae	*	*	1	1	1	6	1	2	5	*	2	3	1	3	2	6	1	35	0.78	0.36
Alchornea cordifolia (Euphorbiaceae)	*	*	1	13	59	55	43	61	131	58	61	45	13	73	88	74	34	809	0.89	8.36
Anacardiaceae	*	*	*	*	*	*	*	*	*	*	1	*	*	1	*	*	*	2	0.11	0.02
Annonaceae	*	*	*	*	*	*	*	1	*	*	*	*	*	1	*	*	*	2	0.11	0.02
Apocynaceae	*	*	*	1	*	*	*	*	*	*	1	*	*	*	*	*	*	2	0.11	0.02
Arecaceae	*	*	*	2	5	16	10	11	8	5	13	*	26	18	17	6	2	139	0.78	1.44
Asteraceae	1	*	*	3	2	*	4	4	2	3	9	*	*	*	*	6	*	34	0.56	0.35
Bombacaceae	*	*	*	*	*	*	*	*	5	*	1	*	*	*	*	*	*	6	0.11	0.06
Bromeliaceae	*	*	*	*	*	*	*	*	*	*	*	1	2	*	*	*	*	3	0.11	0.03
Canthium sp. (Rubiaceae)	*	*	*	*	*	*	*	*	*	*	*	1	*	*	*	*	1	2	0.11	0.02
Celtis sp. (Ulmaceae/Cannabaceae)	*	*	*	*	*	*	8	*	3	*	5	*	*	*	*	3	5	24	0.28	0.25
Chenopodiaceae/Amaranthaceae	*	*	*	*	1	*	*	3	8	2	1	*	*	*	*	*	*	15	0.33	0.16
Combretaceae-Melastomataceae	*	*	*	*	*	*	*	1	*	*	*	*	2	*	5	2	*	10	0.22	0.10
Commelinaceae	*	*	*	*	*	*	*	*	*	*	*	6	15	1	*	*	*	22	0.17	0.23
Cyperaceae	5	*	*	2	4	8	8	1	12	11	3	15	28	146	218	95	47	603	0.89	6.23
Drepanocarpus sp. (Fabaceae)	*	*	*	1	*	*	4	*	*	*	*	*	*	*	*	*	*	5	0.11	0.05
Elaeis guineensis (Arecaceae)	1	*	*	1	4	1	*	6	*	*	2	3	20	20	71	59	45	233	0.72	2.41
Euphorbiaceae	*	*	*	2	25	3	*	6	*	8	8	16	25	*	22	13	8	136	0.67	1.41
Ipomoea involucrata (Convolvulaceae)	*	*	*	*	*	*	*	*	*	*	*	1	*	*	*	*	*	1	0.056	0.01
Kigelia africana (Bignoniaceae)	*	*	*	*	*	*	*	*	1	*	*	*	*	*	*	*	*	1	0.056	0.01
Malvaceae	*	*	*	1	3	8	2	2	3	1	1	*	*	*	*	*	*	21	0.44	0.22
Mimosaceae	*	*	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1	0.056	0.01
Nymphaea lotus (Nymphaceae)	*	*	1	*	*	*	*	2	*	1	*	*	*	*	2	1	*	7	0.28	0.07
Onagraceae	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0	0.056	0.00
Parinari sp. (Chrysobalanaceae)	*	*	*	*	*	*	*	*	*	*	*	1	*	*	*	*	*	1	0.056	0.01
Poaceae	3	3	7	12	75	80	*	54	189	35	*	55	62	160	222	274	120	1351	0.89	13.96
Rhizophora sp. (Rhizophoraceae)	4	*	*	*	7	*	1	*	3	6	1	2	8	7	1	1	3	44	0.67	0.45
Rubiaceae	*	*	*	*	*	2	3	*	7	*	*	*	2	2	*	9	1	26	0.39	0.27
Rutaceae	*	*	*	*	*	1	*	*	*	*	*	*	*	*	6	*	1	8	0.17	0.08
Sapindaceae	*	*	*	*	*	*	*	*	*	*	1	*	*	1	6	3	2	13	0.28	0.13
Sapotaceae	*	*	*	*	*	*	*	*	2	*	*	*	*	*	*	*	*	2	0.056	0.02
Solanaceae	*	*	*	*	*	*	*	*	*	*	*	*	*	10	11	5	*	26	0.17	0.27
Spondias mombin (Anacardiaceae)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1	*	1	0.056	0.01
Sygyzium guineense (Myrtaceae)	1	*	*	1	1	*	*	*	1	*	*	*	1	*	*	1	*	6	0.39	0.06
Symphonia globulifera (Clusiaceae/Guttiferae)	*	*	*	*	*	*	*	*	*	*	*	*	3	*	1	2	1	7	0.22	0.07
Tridax procumbens (Asteraceae)	*	*	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1	0.056	0.01

Table 3. Continued

ITOWOLO																				
PALYNOMORPHS/FAMILIES	Depth (cm)																			%
	0–3	3–6	6–9	9–12	12–15	15–18	18–21	21–24	24–27	27–30	30–33	33–36	36–39	39–42	42–45	45–48	48–51	Sum/T	R/Freq	
Typha australis (Typhaceae)	*	*	*	*	*	*	*	*	*	*	*	*	2	*	1	*	*	3	0.11	0.03
pollen indeterminate	1	1	*	*	2	2	1	1	1	*	3	*	1	3	1	*	1	18	0.72	0.19
Ceratopteris sp. (Pteridaceae)	*	*	*	*	*	*	*	*	1	*	*	*	*	*	*	*	*	1	0.056	0.01
Cyclosorus afer (Thelypteridaceae)	1	*	1	1	10	4	16	17	35	8	9	11	*	24	33	23	18	211	0.89	2.18
Dryopteris sp. (Dryopteridaceae)	*	*	*	*	*	*	*	*	1	*	*	1	*	*	*	*	*	2	0.11	0.02
Fungal spores	62	3	*	95	179	354	310	462	191	389	220	400	480	290	250	317	382	4384	0.94	45.31
Lygodium sp. (Schizaeaceae)	1	*	*	*	*	*	*	*	1	*	*	*	*	1	*	*	*	3	0.17	0.03
Nephrolepis sp. (Nephrolepidaceae)	4	*	*	3	1	36	8	*	27	*	1	4	6	*	3	7	*	100	0.67	1.03
Pteridium sp. (Dennstaedtiaceae)	*	*	*	*	*	*	*	2	*	*	*	*	4	3	*	*	*	9	0.22	0.09
Pteris sp. (Pteridaceae)	*	*	*	*	*	*	*	3	2	*	1	1	*	*	4	2	*	13	0.39	0.13
Salvinia sp. (Salviniaceae)	*	*	*	*	*	*	*	*	*	*	*	1	*	*	*	1	*	2	0.17	0.02
Selaginella sp. (Selaginellaceae)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1	*	1	0.056	0.01
Trilete spores	*	*	*	*	*	2	*	3	7	8	11	1	26	20	19	12	1	110	0.67	1.14
Total	84	7	13	139	379	578	419	642	646	535	355	568	727	784	983	924	673			

I. Mangrove/brackish swamp: *Rhizophora* sp.;
II. Freshwater swamp forest: *Symphonia globulifera*, Cyperaceae, *Cyclosorus afer*, Arecaceae and *Nympheae lotus;*
III. Spores: *Pteris* sp., *Nephrolepis* sp., *Ceratopteris* sp., *Lygodium* sp. and Trilete spores;
IV. Rainforest vegetation: Anacardiaceae, Apocynaceae, Bombacaceae, Rutaceae, Combretaceae-Melastomaceae and Mimosaceae;
V. Open forest vegetation: *Elaeis guineensis*, *Alchornea cordifolia*, *Celtis* sp., Malvaceae, Rubiaceae, Commelinaceae, Solanaceae Acanthaceae, Chenopodiaceae/Amaranthaceae Euphorbiaceae and Asteraceae;
VI. Lowland rainforest: *Canthium* sp., Sapotaceae and Sapindaceae;
VII. Savanna: *Sygyzium guineense;*
VIII. Poaceae.

Three pollen zones (I, II, III) were recognized for this study site, each pollen zone starting with a major high abundance and ending with another major high abundance. Pollen zones I and II were characterized by the presence of two paleoclimatic zones or cycles (wet, dry) (Fig. 2). Pollen zone III had only one paleoclimatic cycle. Below the recognized pollen and paleoclimatic zones are discussed from the oldest to the youngest sections.

Zone III (51–30 cm, 1480 BP). This deepest section of the studied core has only one paleoclimatic cycle. The recovered pollen assemblage is characterized by the dominance of freshwater swamp species including *Alchornea cordifolia*, Arecaceae, Cyperaceae, the palm *Elaeis guineensis, Rhizophora* sp., *Symphonia globulifera*, *Cyclosorus afer* and trilete spores, which suggests that the corresponding period (1480 BP) was dominated by wet climate that encouraged the growth of sedges in marshes. The highest palynomorph count (983) was recorded at 45–42 cm. The sample from 48–45 cm showed the highest palynomorph diversity (25). The dominance of mudstone with <30% sand content is largely responsible for the good preservation of palynomorphs. Predominantly wet climate is inferred for this zone due to the preponderance of freshwater swamp elements, confirming findings reported by Sowunmi (1987).

Zone II (30–15 cm, 740 BP). In this zone the highest count (646) and highest diversity (24) were recorded from 27–24 cm. This pollen

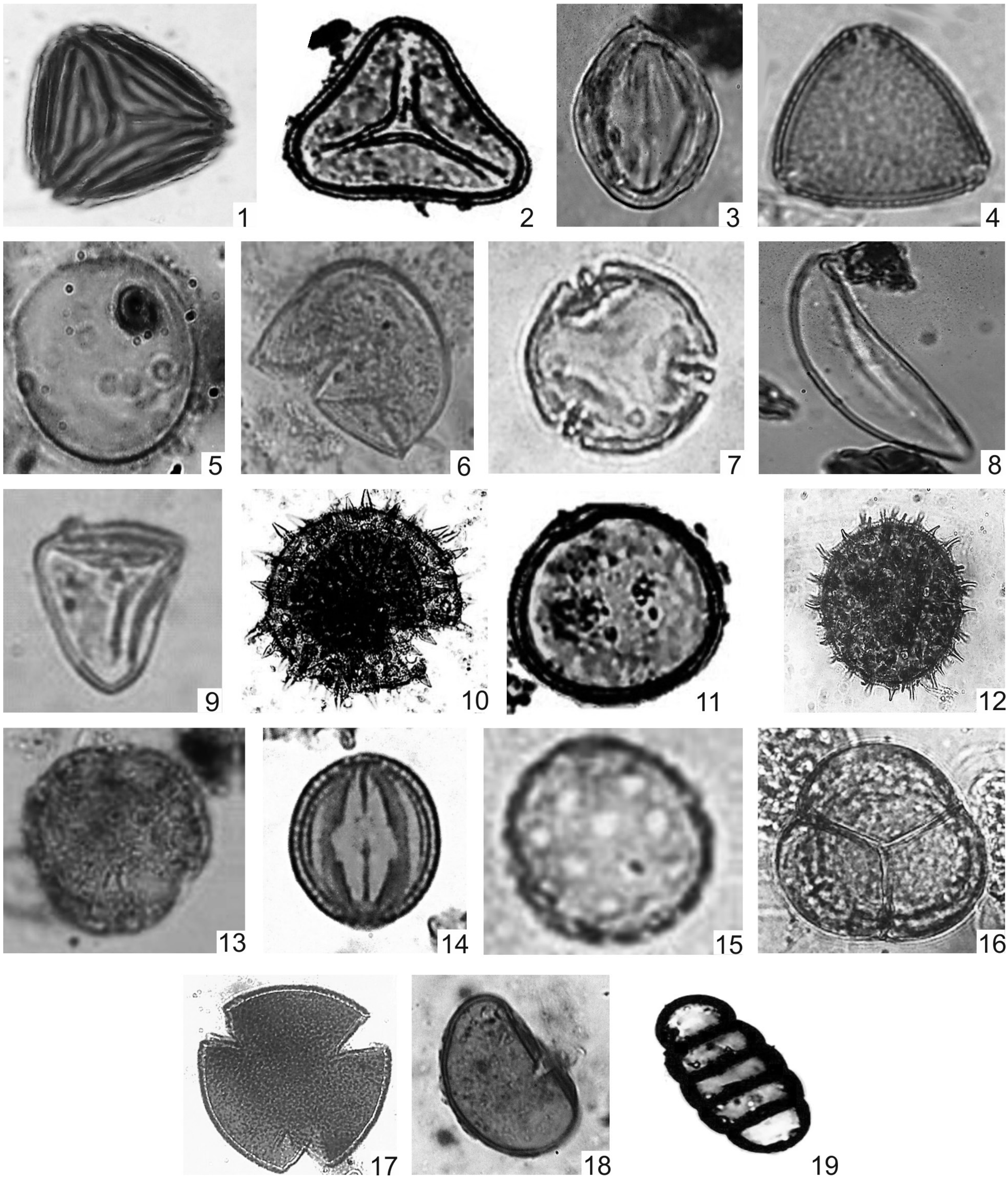

Plate 1. Photomicrograph of some recovered palynomorphs from the study site (400×). **1** – *Ceratopteris* sp., **2** – *Elaeis guineensis*, **3** – *Pteris* sp., **4** – *Syzyguim guineense*, **5, 6** – Poaceae, **7** – *Alchornea cordifolia*, **8** – Arecaceae, **9** – Cyperaceae, **10** – Malvaceae, **11** – Solanaceae, **12** – Asteraceae, **13** – *Euphorbia heterophylla*, **14** – Euphorbiaceae, **15** – Chenopodiaceae/Amaranthaceae, **16** – *Gardenia imperialis*, **17** – *Kigelia africana*, **18** – *Nephrolepis* sp., **19** – fungal spores

zone had two paleoclimatic cycles, suggesting cycles of dry and wet periods. There is a set of common records of pollen of Asteraceae, Acanthaceae, Amaranthaceae, Malvaceae, *Cyclosorus afer* and *Celtis* sp., indicating dry climate. Another set of pollen of the freshwater species *Alchornea cordifolia,* Arecaceae, Cyperaceae, *Rhizophora* sp., Euphorbiaceae and *Nephrolepis* sp., and the sparse occurrence of oil palm *Elaeis guineensis* pollen, indicated wet climate for this depth. The pollen assemblages in this zone suggest a dry and wet climate for the last 740 years, inferred from the preponderance of the recorded palynomorphs. In an analysis of core samples from four different communities of the Niger Delta, Nigeria, Sowunmi (1987)

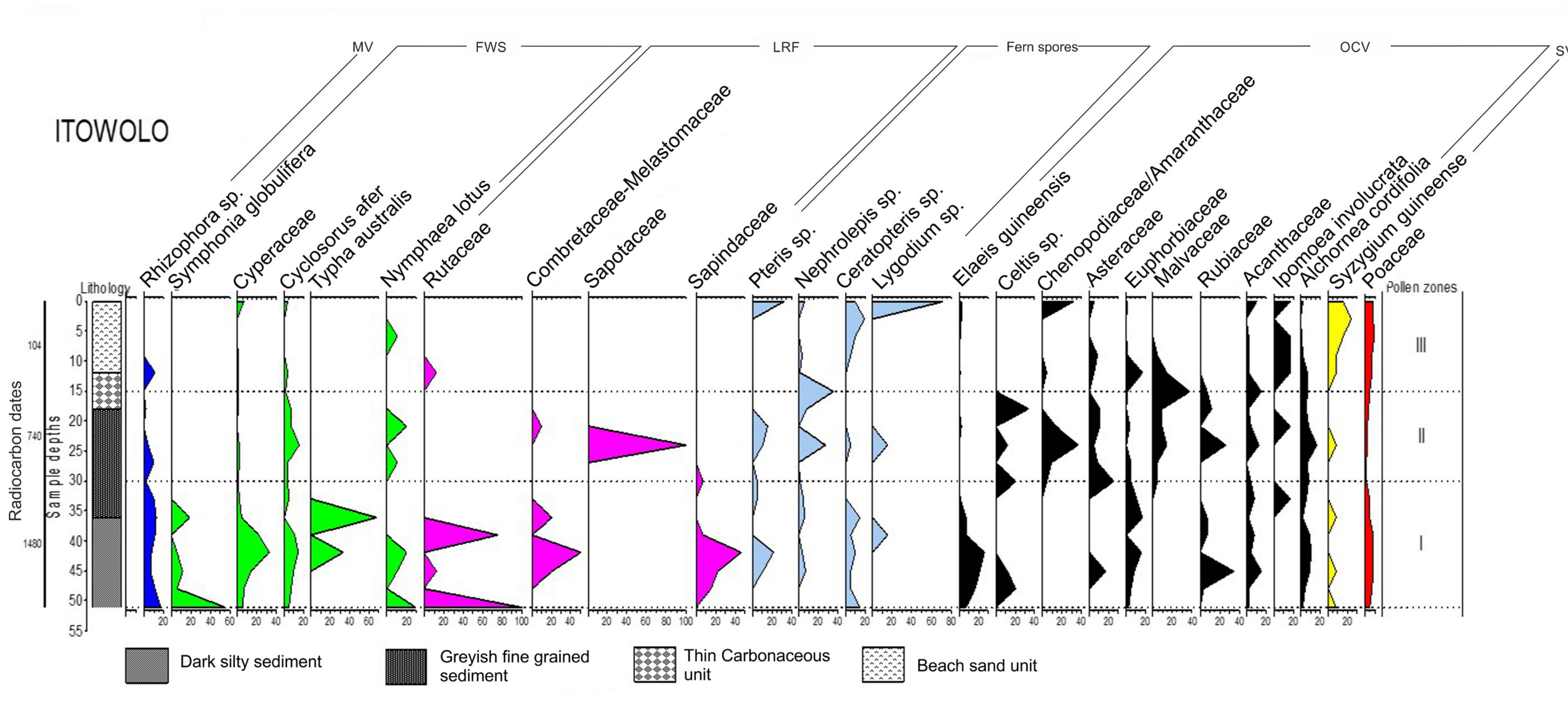

Fig. 2. Pollen diagram depicting variation of phytoecological groupings and paleoclimate. MV: mangrove vegetation; FWS: freshwater swamp; LRF: lowland rainforest; OCV: open coastal vegetation; SV: savanna

found that the reduction in forest species and a concomitant expansion of savanna was due to adverse dry climatic conditions. The dominance of open-vegetation species in our investigation, such as *Cyclosorus afer, Celtis* sp., *Alchornea cordifolia,* Arecaceae, Cyperaceae, *Rhizophora* sp., Euphorbiaceae and *Nephrolepis* sp., can be attributed to the prevalence of farming activity in the coastal zone of Lagos. The alternation of sand and mudstone in the lithological profile also supports the inference of dry and wet paleoclimate.

Zone I (15–00 cm, 104 BP). This is the youngest section of the studied site. The pollen zone consists of two paleoclimatic cycles, suggesting another dry and wet paleoclimatic regime. The analysis yielded palynomorph counts that were appreciable but lower than those of the underlying sections. The recovered pollen and spores that characterized the dry paleoclimatic cycle included Poaceae, Asteraceae and Acanthaceae, known to be indicators of dry climate. The recovered wet-paleoclimate indicator species include *Alchornea cordifolia*, Euphorbiaceae, *Elaeis guineensis, Cyperus* sp., *Cyclosorus afer* and the fern *Nephrolepis* sp. The lithology was mostly sandy at 0–3 cm and 6–9 cm; this may have affected the pollen preservation and hence led to the low counts. An alternating dry and wet climate is inferred for this section due to the absence of common freshwater elements, namely Arecaceae.

PALEOCLIMATIC INFERENCE

The preponderance of mangrove, freshwater swamp, rainforest and lowland rainforest species (Fig. 2) is suggestive of a humid climate. However, periods of dry climate were sandwiched in between, inferred from the presence of Poaceae, *Sygyzium guineensis* and open-vegetation species (Poumot 1989, Oboh et al. 1992, Morley 1995, Durugbo et al. 2010). Also, the sediments were deposited during a prevailing wet/humid climate, indicated by the moderately abundant records of mangrove pollen types, which include *Rhizophora* sp., coupled with the high occurrence of *Elaeis guineensis*. These findings confirm those of Sowunmi (1987), who noted that the earlier association of pollen of *Elaeis guineensis* (oil palm) with wet climatic conditions is influenced by the proliferation and association of other Palmae pollen (Arecaceae) as well as *Alchornea cordifolia*, *Symphonia globulifera, Nymphaea lotus* and *Cyperus* sp., which represent wet environments. In addition, the moderate to high occurrence of dry-climate indicator pollen or palynomorphs in this study area, which include Poaceae, Asteraceae and Acanthaceae within different intervals, suggests that during the last 1480 years the Lagos coastal environment has been under a predominantly warm-humid climate.

CONCLUSION

The findings from this investigation reveal a consistent fluctuation and alternation between wet and dry paleoclimatic phases in the late Holocene. The fluctuation in the vegetation of the studied site is evidenced by the records of the different phytoecological groups, made up of mostly open-vegetation species. Human activity and environmental factors have been the cause. Most of the original plants, which include *Rhizophora* sp., *Symphonia globulifera,* Cyperaceae, *Cyclosorus afer* and Arecaceae, have migrated or disappeared, becoming extinct due to the heavy influence of humans during the Holocene, and have been replaced by open forest vegetation, notably *Alchornea cordifolia* and Poaceae. This succession is an ongoing phenomenon in the region. The mangrove and freshwater ecosystems continue to be depleted by human activity in the Lagos coastal environment of Nigeria. Better conservation strategies are needed to prevent their complete extinction and to save them for future generations.

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