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Elephant's activities elicited biodiversity disturbance in Omo Biosphere Reserve, Nigeria

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Abstract. Disturbance by herbivores occurs in most of the natural ecosystems and influence species diversity and vegetation structure. This study compares the vegetation of elephant (disturbed) zone (EZ) and non-elephant (undisturbed) zone (NEZ) in the Omo biosphere reserve to assess the effect of elephant browsing on the vegetation. Woody species densities, basal area, importance value and species diversity were determined from twenty sampling plots (20 m x 20 m) established randomly each in the EZ and NEZ. The result of floristic composition shows more species were in the NEZ than EZ. The species diversity reduced by 3.3% in EZ. Sorensen index of similarity of the two communities was 62%. *Celtis zenkeri* (74.75) and *Diospyros dendo* (51.1) dominated the species in the EZ while *Gmelina arborea* (127.35) and *Funtumia africana* (16.63) were the dominant species in the NEZ. Browsing of elephants directly influence species composition, diversity and structure in the forest ecosystem leading to loss of biodiversity.

Key words: bio-conservation, disturbances, diversity, herbivory, vegetation structure, West Africa.

1. Introduction

The disturbance of the biosphere by herbivores occurs in most of the natural ecosystems and influence species richness and the structure of the ecosystem (Moloney & Levin, 1996; Olofsson et al., 2001; Grellmann, 2002; Gandiwa et al., 2011; Mukwashi et al., 2012). Profound disturbances such as browsing, grazing and trampling (especially by large herbivores) are known to reduce plant diversity, alter vegetation structure and eliminate animal species (Petraitis et al., 1989; Pickett & White, 1985; Gandiwa et al., 2011; Mukwashi et al., 2012). At large, elephant browsing contribute immensely to adult tree destruction and changes in natural habitat. In Africa, there is growing concern on the detrimental effects of elephants (*Loxodonta africana* Blumenbach) on vegetation and biodiversity (Cumming et al., 1997; Skarpe et al., 2004; O'Connor et al., 2007; Guldemond & Van Aarde, 2008; Gandiwa et al., 2011). Oftentimes this is caused by increasing elephant populations in protected and bio-conservation areas (Valeix et al., 2007; Van Aarde & Jackson, 2007). Elephants influence forests at two main levels: as opportunistic frugivores, by directly effecting the dispersal and regeneration of certain species; and by trampling, debarking and otherwise disturbing the forest (Hoft & Hoft, 1995; Laws et al., 1970, 1975; Sheil, 1996; Struhsaker et al., 1996). The response of vegetation to elephants is difficult to interpret as drought, fire, disease, other herbivores, and trampling (Guldemond & Van Aarde, 2008, may influence it, all of which independently or in combination could transform woodlands into grasslands (Walker et al., 2004). The interactions between elephant and vegetation has been studied in a broad context (Cumming et al., 1997; Osborn, 2002) and most of these studies focussed on Eastern and Southern Africa whereas in West Africa in particular, surface areas comprising suitable habitats for elephants are dramatically declining due to human activity (habitat fragmentation). Nevertheless, there is a noticeable engagement of West African wildlife managers to assess these threats and to take action towards conserving elephant species for future generations (CMS, 2011).

In 2016, Omo was the only biosphere reserve in Nigeria established under The Man and Biosphere (MAB) programme and was one of 669 biosphere reserves in the world. (UNESCO, 2016). In 2020, three more biosphere reserves were established in Nigeria and four currently operate here as part of the World Network of Biosphere Reserves, comprising over 700 such sites (WNBR, 2022).

However, the reserve has been extensively modified by anthropogenic activities; and now contains only about 0.3% of the original vegetation (Karimu, 1999). In the 1990s, John Thornton of Lagos was impressed by the fact that elephants still survived in the Omo Forest Reserve and he established an elephant research and conservation project (the Nigerian Forest Elephant Wildlife Survey and Protection Group). Afterwards, the NFE project (operating from the Erin Base Camp) established a "Biosphere Extension Area" (BEA) of 142 km^2 and focused on reducing forest conversion and hunting in this area. The BEA had the approval of the state government (Clifford, personal communications, 2017), though it is not clear whether it had full legal status in the sense of a gazetted area. The NFE's research and protection work has lapsed following Thornton's departure from Nigeria, but a conservation education project has continued, sponsored by Paignton Zoo in the U.K., in association with Nigerian Conservation Foundation.

Elephant studies in West Africa were occasional and almost only focused on population dynamics. The detrimental effects that elephants has on vegetation composition and diversity most especially in the forest reserve is scanty in literature and there has been no report for this damage in forest reserves in Nigeria. This study assessed the impact of the elephant activities on the species composition, structure and diversity of vegetation. It is expected that such information will enhance management decisions that will ensure sustainable management of the reserve.

2. Materials and Methods

2. 1. Study Area

The Omo Biosphere Reserve (Nigeria) is located between latitudes 6° 35' to 7° 05' N and longitudes 4° 19' to 4° 40' E in the South-west of Nigeria (Ojo, 2004). It is a lowland rain forest reserve, over 130,000 ha in area, which has been logged at varying intensities since early this century and is now being actively converted into a *Gmelina* pulpwood plantation to feed a nearby mill at Iwopin (Ola-Adams, 1999). However, within the reserve at Etemi Oke, a core area (460 ha) of Strict Nature Reserve or inviolate plot remains, set aside from logging since 1946 (Isichei, 1995; Weeks, 1997). In the Biosphere Reserve, previous report of zones where elephant browse are documented (Emmanuel et al., 2017) and Clifford (personal communications, 2017) conducted a study on the presence of elephants in the Omo Biosphere Reserve and concluded that elephants roam about in some parts of the reserve called 'Elephant Zone' while other parts of the forest without the animal was called 'Non-Elephant Zone' (Fig. 1).

3. Experimental Design

3. 1. Sampling Procedure

Twenty (20) quadrats each of 20 m x 20 m were laid randomly in both the Elephant Zone (EZ) and Non-Elephant Zone (NEZ) across Omo Biosphere Reserve. Geographic coordinates of all the sampling points in both the EZ and NEZ were recorded using a Garmin Extrex GPS. In each plot, complete identification of all plant species of all growth forms (herbs, trees, climbers, shrubs) was done and the woody plants were completely enumerated. Girth at breast height (GBH at 1.3 m) of trees greater than or equal to 3 m high and those <3 m height at midpoint, were measured using a measuring tape. Woody plants were then marked to avoid double counting. Voucher specimens were collected, as well as specimens of species not completely identified in the field. Plants collected were pressed and identified using the Flora of West Tropical Africa (Hutchinson & Dalziel, 1963–‒1972), the Handbook of West African Weeds (Akobundu & Agyakwa, 1998), The World Flora Online (WFO, 2021), and Trees of Nigeria (Keay, 1989) and existing voucher specimens in University of Lagos Herbarium (LUH).

4. 1. Data Analysis

The absolute density of each species, D_i, was calculated as the number of individuals in a unit area:

$$D_i = \frac{n_i}{A}$$

where D_i is the density for species i; n is the total number of individuals counted for species i, and A is the total area sampled.

The frequency for each species was calculated as

$$f_i = \frac{j_i}{k}$$

where f_i is the frequency of species i, j_i is the number of samples taken and k is number of occurrence.

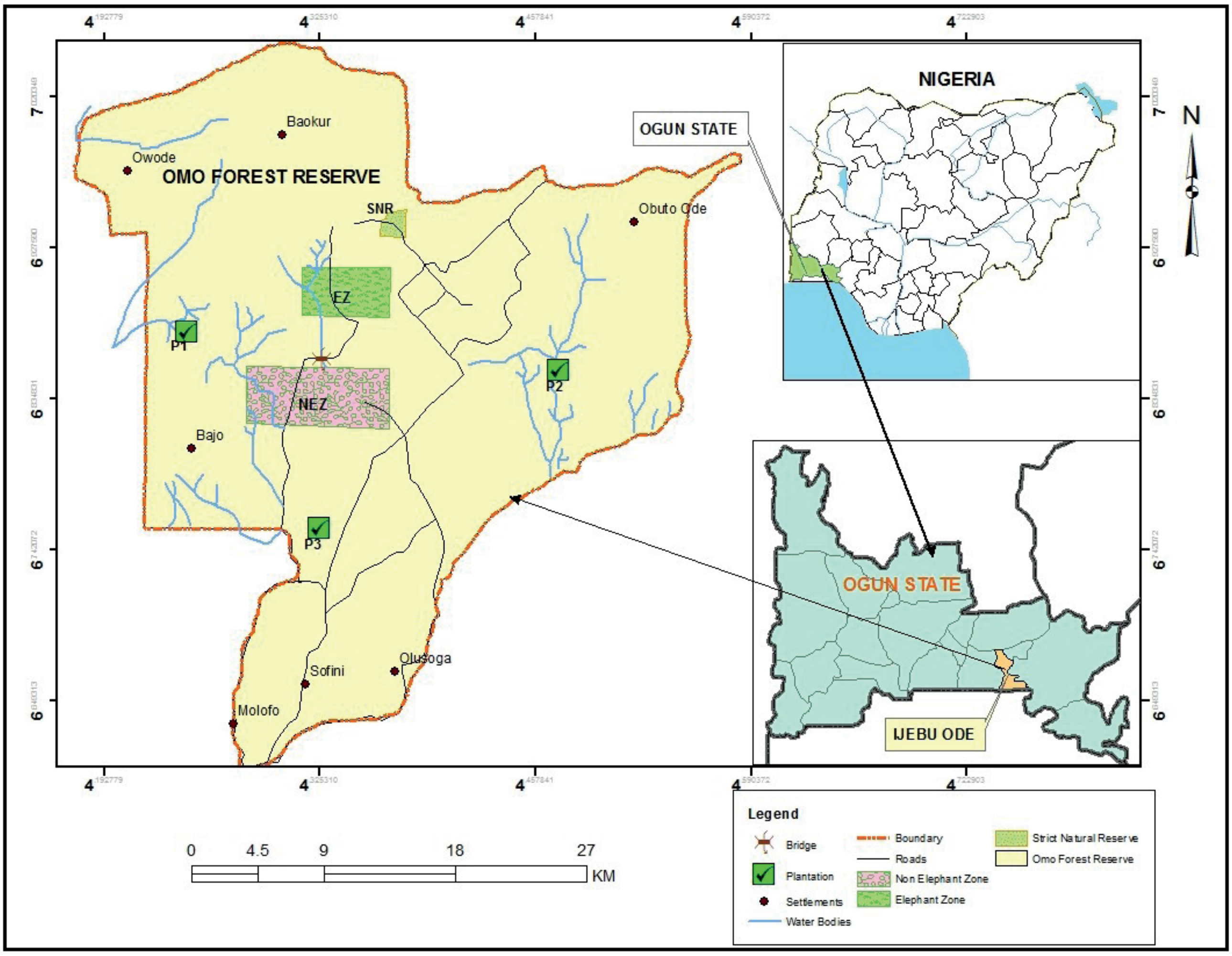

Figure 1. Map of Omo Biosphere Reserve (Nigeria) showing the location of Elephant and Non-Elephant Zone

Species dominance was calculated as basal area of a species. Basal area (BA) was calculated as:

$$\text{Relative Dominance} = \frac{\text{Basal Area per species/family}}{\text{Total Basal Area}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of each species/family}}{\text{Sum of frequency values of all species}} \times 100$$

$$\text{Relative Density} = \frac{\text{Basal Area per species/family}}{\text{Total Basal Area}} \times 100$$

$$BA = (Gbh^2 / 4) \times \pi;$$

where Gbh is girth at breast height and $\pi = 3.14$.

The three relative values were added together to obtain Importance Values (IV) for each species (Kacholi, 2020):

$$IV = R.D + R.F + R.Do\ ,$$

where R.D = Relative Density, R.F = Relative Frequency, and R.Do = Relative Dominance.

Plant species diversity in EZ and NEZ were estimated by various indices. Species richness was estimated using Menhinick index (Menhinick, 1964) following Sugar et al. (2003). Species diversity (a measure of the species richness and species evenness) was calculated using Shannon-Wiener index (H´) as described by Sugar et al. (2003). Species evenness was calculated using Pielou index (Pielou, 1975) as used by Pitchiramu et al. (2008). Sorensen's similarity index (Pielou, 1969) as used to determine the similarity in species composition of both EZ and NEZ.

Similarity Index is expressed as:

$$\mathbf{(CC)} = \frac{2C}{S_{EZ} + S_{NEZ}}\ ,$$

where C is the number of species the two communities have in common, S_{EZ} is the total number of species found in the Elephant Zone, and S_{NEZ} is the total number of species found in Non-Elephant Zone.

5. Results

5. 1. Floristic composition of the elephant and non-elephant zones

The floristic composition of the EZ and NEZ varied considerably. One hundred and eighty-three (183) plant species were encountered in the study area (both the EZ and NEZ) belonging to 71 families, with Rubiaceae being the most represented family in the EZ (10 species), and Apocynaceae, Euphorbiaceae and Sterculiaceae being the most represented families in the NEZ (7 species) (Figs 2 and 3). In terms of growth forms, (75) Trees, (38) Shrubs, (23) Climbers, (6) Epiphytes, (34) Herbs and (7) Ferns were classified in both the EZ and NEZ (Table 1). One hundred and twenty-seven (127) species in 60 families were recorded in the EZ, including (59) Trees, (26) Shrubs, (14) Climbers, (3) Epiphytes, (20) Herbs and (5) Ferns. One hundred and thirty-five (135) species belonging to 62 families were recorded in the NEZ, including (58) Trees, (25) Shrubs, (16) Climbers, (3) Epiphytes, (27) Herbs and (6) Ferns. A total of 81 species in 51 families, representing 44.3% of the enumerated plants were common to both zones. Species belonging to the families of Burseraceae, Polygalaceae, Ampelidaceae, Tiliaceae, Dryopteridaceae, Sapotaceae, Marantaceae, Loranthaceae and Scrophulariaceae were detected only in the EZ; whereas the families of Caricaceae, Compositae, Zingiberaceae, Thelypteridaceae, Hypericaceae, Anacardiaceae, Ochnaceae, Cyperaceae, Musaceae, Malvaceae and Solanaceae were specific to the NEZ (Table 1).

5. 2. Structural characteristics of elephant and non-elephant zones

The result in Table 2 shows that Shannon-Wiener diversity index of the EZ (4.25) was lower than the NEZ (4.39). Species richness of the EZ (127) was also lower than the NEZ (135). However, the number of individuals in the EZ was higher (423) than individuals in the NEZ (338). The Simpson index of diversity of the EZ was 0.70 while that of the NEZ was 0.75. The Sorensen index of similarity of the two communities (EZ and NEZ) was 62%, a clear indication of species differences.

Table 1. List of Plant Species in the Elephant and Non-Elephant Zones

S/N	Species	Family	Growth form						Zones	
			Tr	Sh	Cl	Ep	He	Fe	EZ	NEZ
1	*Acacia ataxacantha* DC.	Mimosaceae			+				+	-
2	*Adenia cissampeloides* (Planch. ex Benth.) Harms	Passifloraceae			+				-	+
3	*Adiantum capillus-veneris* L.	Pteridaceae						+	-	+
4	*Aerangis biloba* (Lindl.) Schltr.	Orchidaceae				+			+	-
5	*Aframomum subsericeum* (Oliv. & Hanb.) K.Schum.	Zingiberaceae					+		+	+
6	*Agelaea hirsuta* De Wild.	Connaraceae		+					+	+
7	*Albizia ferruginea* (Guill. & Perr.) Smith	Mimosaceae	+						+	+
8	*Alchornea cordifolia* (Schum. & Thonn.) Müll. Arg.	Euphorbiaceae		+					-	+
9	*Alstonia boonei* De Wild.	Apocynaceae	+						+	+
10	*Amaranthus Spinosus* Linn.	Amaranthaceae					+		-	+
11	*Anchomanes difformis* (Bl.) Engl.	Araceae					+		+	+
12	*Angylocalyx oligophyllus* (Bak.) Bak. F.	Papilionaceae		+					+	-
13	*Anthocleista procera* var. *umbellata* of A.Chev.	Loganiaceae	+						+	-
14	*Anthocleista vogelii* Planch	Loganiaceae	+						-	+
15	*Anthonotha macrophylla* P.Beauv.	Caesalpiniaceae	+						+	-
16	*Anthurium crystallinum* Linden	Araceae			+				+	-
17	*Anubias lanceolate* N.E.Br.	Araceae					+		+	+
18	*Asplenium formosanum* Baker	Aspleniaceae						+	+	+
19	*Asystasia gangetica* (Linn.) T.Anders	Acanthaceae					+		-	+
20	*Baphia pubescens* Hook. f.	Papilionaceae	+						+	-
21	*Baphia nitida* Load.	Papilionaceae		+					+	+
22	*Barteria nigritiana* Hook. f	Passifloraceae	+						+	-
23	*Blighia sapida* Konig	Sapindaceae	+						-	+
24	*Brachystegia eurycoma* Harms	Caesalpiniaceae	+						+	+
25	*Bridelia micrantha* (Hochst.) Baill.	Euphorbiaceae	+						+	-
26	*Brillantaisia lamium* (Nees) Benth.	Acanthaceae					+		-	+
27	*Bucholzia maritima* (Mart.) Pedersen	Amaranthaceae	+						+	+
28	*Byrsocarpus coccineus* Schum. & Thonn	Connaraceae		+					-	+

Table 1 (continued)

S/N	Species	Family	Growth form						Zones	
			Tr	Sh	Cl	Ep	He	Fe	EZ	NEZ
29	*Caladium bicolor* (Ait.) Vent.	Araceae					+		-	+
30	*Calyptrochilum christyanum* (Rchb. f.) Summerh.	Orchidaceae				+			-	+
31	*Canarium schweinfurthii* Engl.	Burseraceae	+						+	-
32	*Canthium arnoldianum* (De Wild. & Th.Dur.) Hepper	Rubiaceae	+						+	+
33	*Carapa procera* DC	Meliaceae	+						+	+
34	*Carpolobia lutea* G.Don	Polygalaceae		+					+	-
35	*Carica papaya* L.	Caricaceae	+						-	+
36	*Cedrela odorata* L.	Meliaceae	+						+	-
37	*Ceiba pentandra* (L.) Gaertn.	Bombacaceae	+						+	+
38	*Celosia trigyna* L.	Amaranthaceae					+		+	-
39	*Celtis mildbraedii* Engl.	Ulmaceae	+						+	+
40	*Celtis brownii* Rendle	Ulmaceae	+						+	+
41	*Celtis zenkeri* Engl.	Ulmaceae	+						+	+
42	*Centrosema pubescens* Benth.	Papilionaceae			+				-	+
43	*Chassalia kolly* (Schumach.) Hepper	Rubiaceae		+					+	-
44	*Chromolaena odorata* (L.) R.M. King & H.Rob	Compositae		+					-	+
45	*Cissus oreophila* Gilg & Brandt	Ampelidaceae			+				+	-
46	*Citropsis articulata* (Willd. ex Spreng.) Swingle & Kellerman	Rutaceae	+						-	+
47	*Citrus* x *aurantium* L.	Rutaceae		+					+	+
48	*Clausena anisata* (Willd.) Hook. f. ex Benth.	Rutaceae		+					+	+
49	*Cleistopholis patens* (Benth) Engl. & Diels	Annonaceae	+						+	+
50	*Cnestis ferruginea* DC.	Connaraceae		+					-	+
51	*Coffea spathicalyx* K.Schum.	Rubiaceae		+					+	-
52	*Cola nigerica* Brenan & Keay	Sterculiaceae	+						+	+
53	*Cola gigantea* var. *glabrescens* Brenan & Keay	Sterculiaceae	+						+	+
54	*Cola nitida* (Vent.) Schott & Endl.	Sterculiaceae	+						+	+
55	*Colocasia* esculenta (L.) Schott	Araceae			+				-	+
56	*Combretum zenkeri* Engl. & Diels	Combretaceae			+				+	+
57	*Cordia millenii* Bak.	Boraginaceae	+						+	+
58	*Costus afer* Ker-Gawl	Zingiberaceae					+		-	+
59	*Crossandra talbotii* S.Moore	Acanthaceae					+		+	+
60	*Culcasia saxatilis* A.Chev.	Araceae				+			+	+
61	*Culcasia scandens* P.Beauv	Araceae				+			+	-
62	*Culcasia striolata* Engl.	Araceae					+		+	+
63	*Cyathula prostrata* (L.) Blume	Amaranthaceae					+		+	+
64	*Cyclosorus striatus* (Schumach.) Ching	Thelypteridaceae						+	-	+
65	*Dalbergia welwitschii* Baker f.	Papilionaceae	+						+	+
66	*Deinbollia pinnata* Schum. & Thonn.	Sapindaceae	+						+	+
67	*Desmodium laxiflorum* DC.	Papilionaceae					+		+	+
68	*Desplatsia subericarpa* Bocq.	Tiliaceae		+					+	-
69	*Dioscorea alata* L.	Dioscoreaceae			+				+	+
70	*Dioscorea dumetorum* (Kunth) Pax	Dioscoreaceae			+				-	+
71	*Diospyros barteri* Hiern	Ebenaceae		+					+	+
72	*Diospyros crassiflora* Hiern	Ebenaceae	+						+	+
73	*Diospyros dendo* Welw. ex Hiern	Ebenaceae	+						+	+
74	*Diospyros insculpta* Hutch. & Dalziel	Ebenaceae	+						+	+
75	*Diospyros monbuttensis* Gürke	Ebenaceae		+					+	-
76	*Diospyros nigerica* F. White	Ebenaceae	+						+	+
77	*Dissotis rotundifolia* (Sm.) Triana	Melastomataceae					+		-	+
78	*Dracaena ovata* Ker-Gawl.	Agavaceae		+					+	+
79	*Dracaena surculosa* var. *capitata* Hepper	Agavaceae		+					-	+
80	*Dryopteris spinulosa* (O.F. Mull.) Fiori	Dryopteridaceae						+	+	-

Table 1 (continued)

S/N	Species	Family	Growth form						Zones	
			Tr	Sh	Cl	Ep	He	Fe	EZ	NEZ
81	*Drypetes leonensis* Pax	Euphorbiaceae	+						+	-
82	*Elaeis guineensis* Jacq.	Palmae	+						+	+
83	*Entandrophragma angolense* (Welw.) C.DC.	Meliaceae	+						+	-
84	*Erythrina mildbraedii* Harms	Papilionaceae	+						-	+
85	*Ficus exasperata* Vahl	Moraceae	+						+	+
86	*Ficus mucuso* Welw. ex Ficalho	Moraceae	+						+	-
87	*Ficus asperifolia* Miq.	Moraceae		+					+	-
88	*Funtumia africana* (Benth)	Apocynaceae	+						+	+
89	*Garcinia gnetoides* Hutch. & Dalz.	Guttiferae	+						+	+
90	*Geophila repens* (L.) I.M.Johnston	Rubiaceae					+		+	+
91	*Gmelina arborea* Roxb.	Lamiaceae	+						+	+
92	*Gongronema latifolium* Benth.	Asclepiadaceae			+				+	-
93	*Hallea ledermannii* (K.Krause) Verdc.	Rubiaceae	+						-	+
94	*Hallea stipulosa* (DC.) Leroy	Rubiaceae	+						+	-
95	*Harungana madagascariensis* Lam. ex Poir.	Hypericaceae	+						-	+
96	*Hunteria umbellata* (K.Schum.) Hallier f.	Apocynaceae	+						+	-
97	*Icacina tricantha* Oliv.	Icacinaceae		+					+	+
98	*Ipomoea involucrata* var. *saxicola* A.Chev. ex Meeuse	Convolvulaceae			+				+	+
99	*Ipomoea batatas* (L.) Lam	Convolvulaceae			+				-	+
100	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	Irvingiaceae	+						+	+
101	*Isolona campanulata* Engl. & Diels	Annonaceae	+						+	-
102	*Jateorhiza macrantha* (Hook. f.) Exell & Mendonca	Menispermaceae			+				+	+
103	*Khaya ivorensis* A.Chev.	Meliaceae	+						+	-
104	*Landolphia owariensis* P.Beauv	Apocynaceae			+				-	+
105	*Lindmania thyrsoidea* L.B.Sm.	Bromeliaceae					+		+	+
106	*Lannea welwitschii* (Hiern) Engl.	Anacardiaceae	+						-	+
107	*Leptaspis cochleata* Thwaites	Gramineae					+		+	-
108	*Lophira alata* Banks ex Gaertn. F	Ochnaceae	+						-	+
109	*Macaranga barteri* Müll. Arg.	Euphorbiaceae	+						+	+
110	*Maesobotrya barteri* (Baill.) Hutch. var. *barteri*	Euphorbiaceae	+						-	+
111	*Malacantha alnifolia* (Bak.) Pierre	Sapotaceae		+					+	-
112	*Mallotus oppositifolius* (Geisel.) Müll. Arg	Euphorbiaceae		+					+	+
113	*Marantochloa congensis* (K. Schum.) Léonard & Mullend.	Marantaceae					+		+	-
114	*Mariscus alternifolius* Vahl	Cyperaceae					+		-	+
115	*Megaphrynium macrostachyum* (Benth.) Milne-Redh.	Marantaceae					+		+	-
116	*Memecylon afzelii* G. Don	Melastomataceae	+						+	-
117	*Memecylon membranifolium* Hook. f.	Melastomataceae		+					-	+
118	*Mikania cordata* (Burm.f.) B.L.Rob. var. *cordata*	Compositae			+				-	+
119	*Milicia excelsa* (Welw.) C.C.Berg	Moraceae	+						-	+
120	*Mitragyna stipulosa* (DC.) O.Ktze.	Rubiaceae	+						+	-
121	*Momordica charantia* L.	Cucurbitaceae			+				+	-
122	*Momordica foetida* Schum. & Thonn.	Cucurbitaceae			+				-	+
123	*Morinda morindoides* (Bak.) Milne-Redh.	Rubiaceae			+				+	-
124	*Musa paradisiaca* L.	Musaceae					+		-	+
125	*Musanga cecropioides* R.Br.	Urticaceae	+						+	+
126	*Mussaenda arcuata* Lam. ex Poir.	Rubiaceae		+					-	+
127	*Nephrolepis biserrata* (Sw.) Schott	Nephrolepidaceae						+	+	+
128	*Nesogordonia papaverifera* (A.Chev.) R.Capuron	Sterculiaceae	+						-	+
129	*Olax subscorpioidea* Oliv.	Olacaceae		+					+	+
130	*Olyra latifolia* L.	Gramineae					+		+	+
131	*Oplismenus burmannii* (Retz.) P.Beauv.	Gramineae					+		+	-
132	*Oplismenus hirtellus* (L.) P.Beauv.	Gramineae					+		+	+

Table 1 (continued)

S/N	Species	Family	Growth form						Zones	
			Tr	Sh	Cl	Ep	He	Fe	EZ	NEZ
133	*Palisota hirsuta* (Thunb.) K.Schum.	Commelinaceae					+		+	+
134	*Panicum maximum* Jacq.	Gramineae					+		-	+
135	*Phragmanthera incana* (Schum.) Balle	Loranthaceae				+			+	-
136	*Phyllanthus amarus* Schum. & Thonn.	Euphorbiaceae					+		-	+
137	*Phyllanthus muellerianus* (O.Ktze.) Exell	Euphorbiaceae		+					+	-
138	*Phyllanthus pentandrus* Schum. & Thonn.	Euphorbiaceae					+		-	+
139	*Picralima nitida* (Stapf) T.Durand & H.Durand	Apocynaceae	+						+	+
140	*Piper guineense* Schum. & Thonn.	Piperaceae			+				+	+
141	*Piptadeniastrum africanum* (Hook. f.) Brenan	Mimosaceae	+						-	+
142	*Pleiocarpa pycnantha* (K.Schum.) Stapf var. *tubicina*	Apocynaceae	+						+	+
143	*Plukenetia conophora* Müll. Arg.	Euphorbiaceae			+				+	-
144	*Polystachya paniculata* (Sw.) Rolfe	Orchidaceae				+			-	+
145	*Pouzolzia guineensis* Benth.	Urticaceae					+		-	+
146	*Psychotria insidens* Hiern	Rubiaceae		+					+	-
147	*Psychotria nigerica* Hepper	Rubiaceae		+					+	+
148	*Pteris semipinnata* L.	Pteridaceae						+	+	+
149	*Pteris togoensis* Hieron	Pteridaceae						+	+	+
150	*Pterocarpus mildbraedii* Harms	Papilionaceae	+						+	+
151	*Pycnanthus angolensis* (Welw.) Warb.	Myristicaceae	+						+	+
152	*Rauvolfia vomitoria* Afzel.	Apocynaceae		+					+	+
153	*Ricinodendron heudelotii* (Baill.) Pierre ex Pax	Euphorbiaceae	+						+	+
154	*Rinorea dentata* (P.Beauv.) O.Ktze.	Violaceae		+					+	-
155	*Rinorea ilicifolia* (Welw. ex Oliv.) O.Ktze.	Violaceae		+					-	+
156	*Sabicea calycina* Benth	Rubiaceae		+					-	+
157	*Sarcocephalus diderrichii* De Wild. & Th. Dur.	Rubiaceae	+						+	-
158	*Secamone afzelii* (Schultes) K. Schum	Asclepiadaceae		+					+	+
159	*Setaria chevalieri* Stapf	Gramineae					+		-	+
160	*Sida acuta* Burm. F	Malvaceae		+					-	+
161	*Smilax anceps* Willd.	Smilacaceae			+				+	+
162	*Solanum erianthum* D.Don	Solanaceae		+					-	+
163	*Spathodea campanulata* P.Beauv	Bignoniaceae	+						+	+
164	*Sphenocentrum jollyanum* Pierre	Menispermaceae		+					+	+
165	*Sterculia rhinopetala* K.Schum.	Sterculiaceae	+						+	+
166	*Strychnos innocua* Delile	Loganiaceae		+					+	-
167	*Strychnos spinosa* Lam.	Loganiaceae		+					+	-
168	*Synedrella nodiflora* Gaertn.	Compositae					+		-	+
169	*Tabernaemontana pachysiphon* L.	Apocynaceae	+						+	-
170	*Terminalia ivorensis* A.Chev.	Combretaceae	+						+	-
171	*Terminalia superba* Engl. & Diels	Combretaceae	+						+	+
172	*Thaumatococcus daniellii* (Benn.) Benth.	Marantaceae					+		+	-
173	*Theobroma cacao* L.	Sterculiaceae	+						-	+
174	*Thonningia sanguinea* Vahl	Balanophoraceae					+		+	+
175	*Trema orientalis* (L.) Blume	Ulmaceae	+						-	+
176	*Trichilia heudelotii* Planch. ex Oliv.	Meliaceae	+							+
177	*Triclisia gilletii* (De Wild.) Staner	Menispermaceae			+				-	+
178	*Triclisia* sp.	Menispermaceae			+				+	+
179	*Triplochiton scleroxylon* K.Schum.	Sterculiaceae	+						-	+
180	*Urena lobata* L.	Malvaceae		+					-	+
181	*Veronica abyssinica* Fres.	Scrophulariaceae					+		+	-
182	*Voacanga africana* Stapf	Apocynaceae	+						+	+
183	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	Rutaceae	+						+	+
Total			75	38	23	6	34	7	127	135

Note: Tr – Tree; Sh – Shrub; Cl – Climber; Ep – Epiphyte; He – Herb; Fe – Fern; EZ – Elephant zone; NEZ – Non-elephant zone.

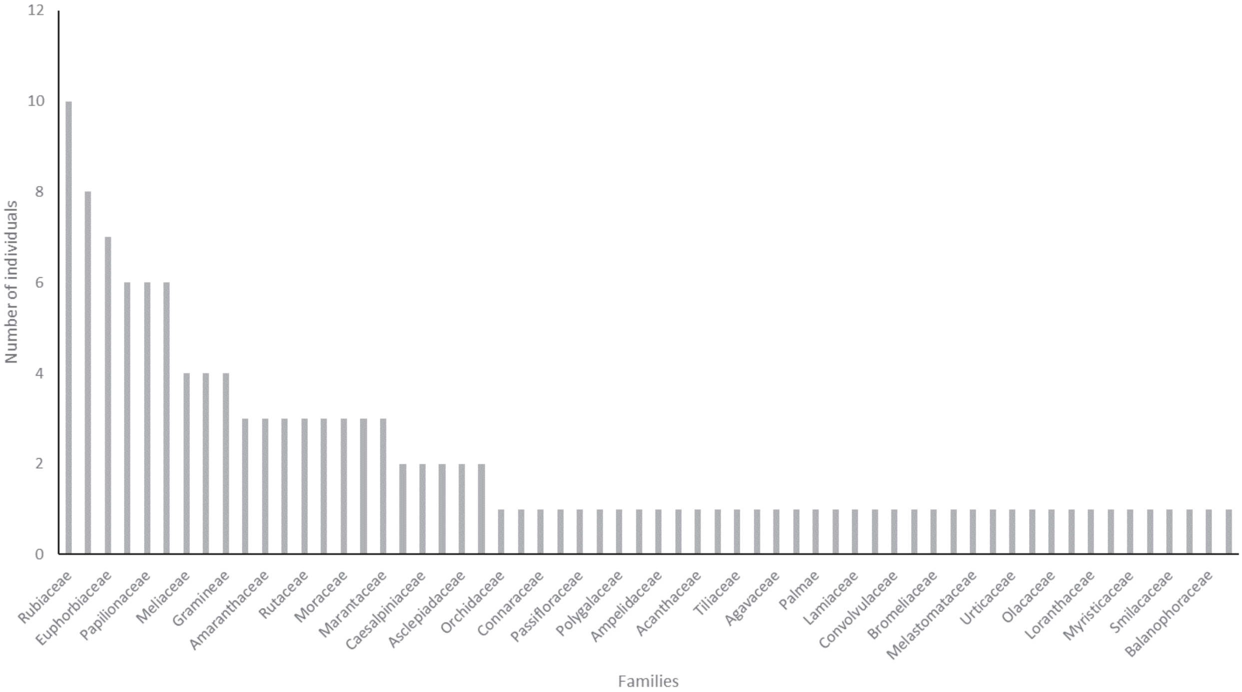

Figure 2. Family Distribution of Species encountered in the Elephant Zone

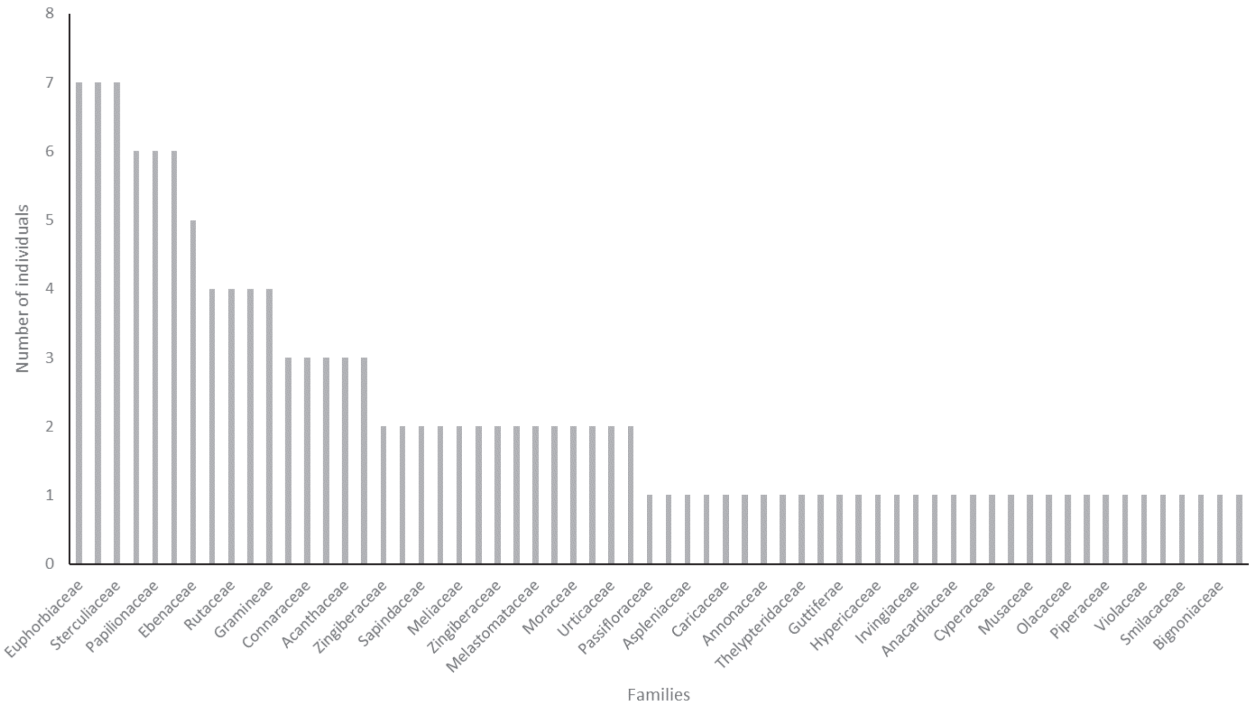

Figure 3. Family Distribution of Species encountered in the Non-Elephant Zone

Table 2. Alpha and Beta Diversity indices of Elephant and Non-Elephant zones

Parameters	EZ	NEZ
Species Richness	127	135
Number of individuals	423	338
Simpson index of diversity	0.70	0.75
Shannon Weiner index of diversity	4.25	4.39
Sorenson index similarity	0.62	

Note: EZ – Elephant Zone; NEZ – Non Elephant Zone.

The girth size distribution of woody species in both zones differ (Fig. 4). In the EZ, there were more individuals with small girth size classes of 0-50 cm, 51-100 cm, 101-150 cm and 151-200 cm than in the NEZ while the number of individuals with large girth size class of 201-250 cm in the NEZ was higher than the EZ. In general, the number of individuals increases as the girth size declines; indicating that there are few individuals with large girth size.

Girth size distribution of woody species in the EZ and NEZ shows that the EZ has higher number of small girth sizes distribution compared to the NEZ (Fig. 4). Sparse undercover and close dense canopy cover together with large number of trees and shrubs characterizes the EZ. In contrast, a denser undercover and sparse canopy cover with large amounts of herbs and climbers characterizes the NEZ.

The species dominance based on the species importance value was different in both communities. In the EZ, the 5 most dominant species based on the high Species importance value was *Celtis zenkeri* (74.75), *Diospyros dendo* (51.1), *Cleistopholis patens* (21.62), *Sarcocephallus didderichii* (11.12) and *Spathodea campanulata* (10.66) while in the NEZ the most dominant species are *Gmelina arborea* (127.35), *Funtumia africana* (16.63), *Diospyros dendo* (15.79), *Brachystegia eurycoma* (11.85) and *Irvingia gabonensis* (9.21) (Tables 3 and 4).

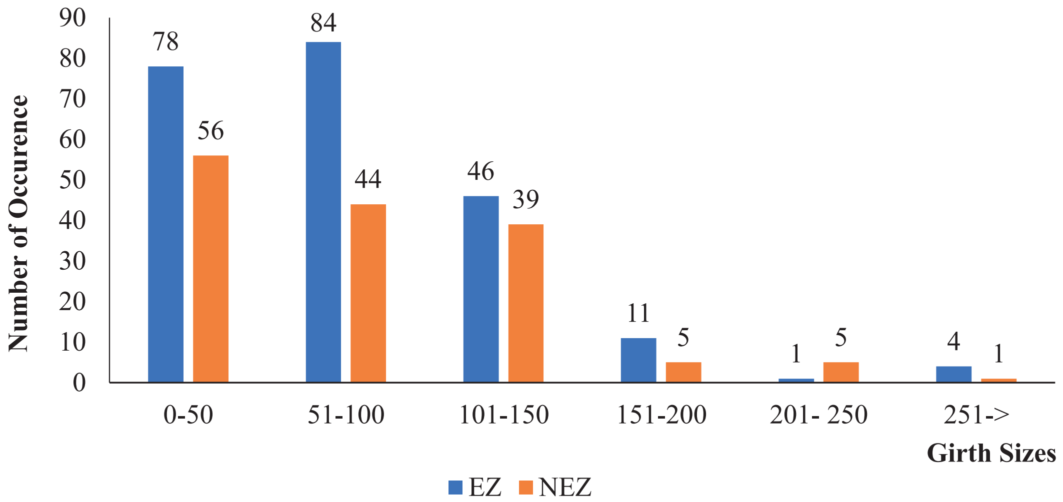

Figure 4. Distribution of Girth Sizes in both the Elephant Zone and Non-Elephant Zone

Table 3. Structural Analysis of woody species in Elephant Zone

S/N	Plants Species	Density	R.De	R.F	R.Do	Imp. Value
1	*Celtis zenkeri* Engl.	0.95	16.88	11.03	46.84	74.75
2	*Diospyros dendo* Welw. ex Hiern	1.025	19.55	7.58	23.97	51.1
3	*Cleistopholis patens* (Benth) Engl. & Diels	1.025	6.66	4.82	10.14	21.62
4	*Sarcocephalus didderichii* De Wild. & Th. Dur.	0.05	4.44	3.44	3.239	11.119
5	*Spathodea campanulata* P.Beauv.	0.25	2.66	4.13	3.868	10.658
6	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	0.15	2.66	4.13	1.013	7.803
7	*Funtumia africana* (Benth)	0.175	3.11	4.13	0.312	7.552
8	*Ceiba pentandra* (L.) Gaertn	0.1	1.77	2.75	2.963	7.483
9	*Drypetes leonensis* Pax	0.15	2.66	3.44	0.963	7.063
10	*Terminalia ivorensis* A.Chev.	0.15	2.66	2.75	1.639	7.049
11	*Baphia nitida* Harms	0.15	2.66	4.13	0.116	6.906
12	*Cola nigerica* Brenan & Keay	0.2	3.55	2.75	0.475	6.775

Table 3 (continued)

S/N	Plants Species	Density	R.De	R.F	R.Do	Imp. Value
13	*Alstonia boonei* De Wild.	0.1	1.77	2.75	0.644	5.164
14	*Ricinodendron heudelotii* (Baill.) Pierre ex Pax	0.1	1.77	2.75	0.509	5.029
15	*Cordia millenii* Bak.	0.1	1.77	2.06	0.256	4.086
16	*Diospyros nigerica* F.White	0.1	1.77	2.06	0.138	3.968
17	*Desplatsia subericarpa* Bocq.	0.075	1.33	2.06	0.573	3.963
18	*Terminalia superba* Engl. & Diels	0.075	1.33	2.06	0.203	3.593
19	*Hunteria umbellata* (K.Schum.) Hallier f.	0.05	0.88	2.06	0.107	3.047
20	*Musanga cecropioides* R.Br	0.075	1.33	1.37	0.316	3.016
21	*Entandrophragma angolense* (Welw.) C.DC.	0.05	0.88	1.37	0.221	2.471
22	*Diospyros monbuttensis* Gürke	0.05	0.88	1.37	0.198	2.448
23	*Celtis brownii* Rendle	0.05	0.88	1.37	0.196	2.446
24	*Khaya ivorensis* A.Chev.	0.05	0.88	1.37	0.165	2.415
25	*Ficus mucuso* Welw. ex Ficalho	0.05	0.88	1.37	0.129	2.379
26	*Macaranga barteri* Müll. Arg.	0.05	0.88	1.37	0.118	2.368
27	*Celtis mildbraedii* Engl.	0.05	0.88	1.37	0.079	2.329
28	*Pycnanthus angolensis* (Welw.) Warb.	0.05	0.88	1.37	0.057	2.307
29	*Diospyros insculpta* Hutch. & Dalziel	0.05	0.88	1.37	0.029	2.279
30	*Carapa procera* DC	0.05	0.88	1.37	0.005	2.255
31	*Anthonotha macrophylla* P.Beauv.	0.075	1.33	0.68	0.066	2.076
32	*Ficus exasperata* Vahl	0.025	0.44	0.68	0.102	1.222
33	*Canarium schweinfurthii* Engl.	0.025	0.44	0.68	0.075	1.195
34	*Brachystegia eurycoma* Harms	0.025	0.44	0.68	0.068	1.188
35	*Albizia ferruginea* (Guill. & Perr.) Benth.	0.025	0.44	0.68	0.039	1.159
36	*Diospyros crassiflora* Hiern	0.025	0.44	0.68	0.037	1.157
37	*Canthium arnoldianum* (De Wild. & Th. Dur) Hepper	0.025	0.44	0.68	0.017	1.137
38	*Barteria nigritiana* Hook. f	0.025	0.44	0.68	0.014	1.134
39	*Cedrela odorata* L.	0.025	0.44	0.68	0.013	1.133
40	*Dioscorea alata* L.	0.025	0.44	0.68	0.012	1.132
41	*Hallea stipulosa* (DC.) Leroy	0.025	0.44	0.68	0.011	1.131
42	*Mitragyna stipulosa* (DC.) O.Ktze.	0.025	0.44	0.68	0.011	1.131
43	*Bucholzia maritima* Mart.	0.025	0.44	0.68	0.011	1.131
44	*Baphia pubescens* Hook f.	0.025	0.44	0.68	0.007	1.127
45	*Cola nitida* (Vent.) Schott & Endl.	0.025	0.44	0.68	0.007	1.127
46	*Sterculia rhinopetala* K.Schum.	0.025	0.44	0.68	0.005	1.125
47	*Rauvolfia vomitoria* Afzel.	0.025	0.44	0.68	0.003	1.123
48	*Garcinia gnetoides* Hutch. & Dalz.	0.025	0.44	0.68	0.001	1.121
49	*Zanthoxylon zanthoxyloides* (Lam.) Zepern. & Timler	0.025	0.44	0.68	0.020	1.140
50	*Anthocleista vogelii* Planch.	0.025	0.44	0.68	0.020	1.120

Note: R.De – Relative Density; R.F – Relative Frequency; R.Do – Relative Dominance; Imp. Value – Importance Value.

Table 4. Structural Analysis of woody species in Non-Elephant Zone

S/N	Plants Species	Density	R.De	R.F	R.Do	Imp. Value
1	*Gmelina arborea* Roxb.	1.3	29.53	12.26	85.56	127.35
2	*Funtumia africana* (Benth)	0.26	6.04	8.49	2.103	16.633
3	*Diospyros dendo* Welw. ex Hiern	0.28	7.38	7.54	0.866	15.786
4	*Brachystegia eurycoma* Harms.	0.2	4.69	4.71	2.453	11.853
5	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	0.17	4.02	3.77	1.423	9.213
6	*Celtis zenkeri* Engl.	0.14	3.35	3.77	1.07	8.19
7	*Celtis brownie* Rendle	0.07	3.35	3.77	0.428	7.548
8	*Musanga cecropioides* R.Br.	0.11	2.68	3.77	0.78	7.23

Table 3 (continued)

S/N	Plants Species	Density	R.De	R.F	R.Do	Imp. Value
9	*Ceiba pentandra* (Linn.) Gaertn.	0.11	2.68	3.77	0.539	6.989
10	*Cleistopholis patens* (Benth) Engl. & Diels	0.11	2.68	3.77	0.493	6.943
11	*Cordia millenii* Bak.	0.09	2.01	2.83	1.101	5.941
12	*Albizia ferruginea* (Guill. & Perr.) Benth.	0.09	2.01	2.83	0.644	5.484
13	*Ricinodendron heudelotii* (Baill.) Pierre ex Pax	0.09	2.01	1.88	1.369	5.259
14	*Tabernaemontana pachysiphon* L.	0.03	2.01	2.83	0.163	5.003
15	*Alstonia boonei* De Wild.	0.07	1.34	2.83	0.18	4.35
16	*Diospyros insculpta* Hutch. & Dalziel	0.09	2.01	1.88	0.069	3.959
17	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	0.07	1.34	1.88	0.096	3.316
18	*Cola nigerica* Brenan & Keay	0.07	1.34	1.88	0.033	3.253
19	*Baphia nitida* Lodd.	0.07	1.34	1.88	0.028	3.248
20	*Terminalia superba* Engl. & Diels	0.07	1.34	0.94	0.17	2.45
21	*Canthium arnoldianum* (De Wild. & Th.Dur.) Hepper	0.07	1.34	0.94	0.02	2.3
22	*Pycnanthus angolensis* (Welw.) Warb.	0.07	0.67	0.94	0.088	1.698
23	*Cola gigantea* var. glabrescens Brean & Keay	0.03	0.67	0.94	0.088	1.698
24	*Diospyros nigerica* F.White	0.03	0.67	0.94	0.039	1.649
25	*Anthocleista vogelii* Planch.	0.03	0.67	0.94	0.027	1.637
26	*Trichilia heudelotii* Planch. ex Oliv.	0.03	0.67	0.94	0.026	1.636
27	*Pterocarpus milbraedii* Harms	0.03	0.67	0.94	0.019	1.629
28	*Nesogordonia papaverifera* (A.Chev.) R.Capuron	0.03	0.67	0.94	0.018	1.628
29	*Hallea stipulosa* (DC.) Leroy	0.03	0.67	0.94	0.014	1.624
30	*Rauvolfia vomitoria* Afzel.	0.03	0.67	0.94	0.014	1.624
31	*Diospyros crassiflora* Hiern	0.03	0.67	0.94	0.014	1.624
32	*Piptadeniastrum africanum* (Hook. F.)	0.03	0.67	0.94	0.01	1.62
33	*Cola nitida* (Vent.) Schott & Endl.	0.03	0.67	0.94	0.01	1.62
34	*Macaranga barteri* Müll. Arg.	0.03	0.67	0.94	0.009	1.619
35	*Spathodea campanulata* P.Beauv	0.03	0.67	0.94	0.008	1.618
36	*Voacanga africana* Stapf	0.03	0.67	0.94	0.007	1.617
37	*Celtis mildbraedii* Engl.	0.03	0.67	0.94	0.006	1.616
38	*Bucholzia maritima* Mart.	0.03	0.67	0.94	0.005	1.615
39	*Milicia excelsa* (Welw.) C.C. Berg	0.03	0.67	0.94	0.005	1.615
40	*Maesobotrya barteri* (Baill.) Hutch.	0.03	0.67	0.94	0.004	1.614
41	*Ficus exasperata* Vahl	0.03	0.67	0.94	0.004	1.614
42	*Harungana madagascariensis* Lam. ex Poir.	0.03	0.67	0.94	0.002	1.612
43	*Triplochiton scleroxylon* K.Schum.	0.03	0.67	0.94	0.002	1.612
44	*Hallea ledermannii* (K.Krause) Verdc.	0.03	0.67	0.94	0.001	1.611

Note: R.De – Relative Density; R.F – Relative Frequency; R.Do – Relative dominance; Imp. Value – Importance Value.

6. Discussion

In this study we showed that species composition of the EZ is lower than the NEZ. This observation agrees with other studies and in general, elephants are known to be physical ecosystem engineers with an ability to directly or indirectly control the availability of resources to other organisms (Cowling & Kerley, 2002). In research carried out by Pamo and Tchamba (2001), elephants were shown to have varying effects on the vegetation; they can cause detrimental changes to some species, at the same time increasing the abundance of other species. However, the findings of reduced woody species in elephant zone contradicts the observation of Midgley et al. (2005) that reported that the density of woody plants increased with elephant defoliation which was attributed to the removal of the canopy allowing coppicing to occur. This difference in the number of species is likely to result from elephant browsing since this is the key active parameter allowing differentiation between both locations.

Clegg (2008) reported the impact by elephants on woody vegetation being greatest when their feeding involves breaking branches, debarking stems, or toppling, pollarding or uprooting whole plants, and less when trunk loads of leaves are stripped without breaking branches. This observation supports the findings of our study on reduced species diversity and floristic composition reduction in the elephant browsing location. The browsing of elephant was the major disturbance that cause the loss of species diversity and this might have caused the breaking of branches, debarking stems and even uprooting of whole plants, which has further aggravated the loss of biodiversity in the forest reserve.

Furthermore, the consequences of feeding and foraging behaviour of elephant populations are important for woody species diversity, most importantly when developing conservation management options (Wiseman et al., 2004). Elephants feed for about 16 hours daily, with peaks in the morning, afternoon, and around midnight. An elephant's diet requirement is complete with forest-edge and woodland, and these habitats provide the elephants with valuable shades (Croze, 1974). The presence of *Desplatsia subericarpa* Bocq., *Dioscorea alata* Linn. and *Tabernaemontana pachysiphon* Linn in the EZ as parts of elephants diets might be one of the factors encouraging the presence and browsing of elephant in the EZ. Alexandre (1978) reported that elephants in Africa eat abundant of the above plants fruit when available. According to Danquah (2016), elephants can spread seeds far from the parent tree up to 57 kilometres. However, the extent to which elephants contribute to the long-term survival of some plants species through their role as dispersers can equally be considered (Clifford, personal communications).

The higher Shannon-wiener index of diversity of NEZ translates to high species diversity in the zone. This agrees with Young and Swiacki (2006) who stated that diversity was made up of the variety of species present and the relative abundance of those species. The higher the value, the higher the diversity (Ojo, 2004) and elephants have the tendency of causing loss of biodiversity.

Utilization of plants by elephants can alter the vertical structure of the woody plant community, commonly manifested as reduced tree density and increased shrub density (Leuthold, 1977). Persistent browsing may trap plants in more accessible size-classes (Jachmann & Bell, 1985; Mapaure & Mhlanga, 2000), although Lewis (1991) argues that such shrublands are unstable, prone to crashes when nutrients are eventually depleted under persistent utilization by elephants. The intensity of habitat uses by elephants and the emergent spatial patterns of change in vegetation, reflect the distribution of elephants across the heterogeneous forest landscape (van Wyk & Fairall, 1969; Thomson, 1975; Swanepoel & Swanepoel, 1986; Steyn & Stalmans, 2001).

The consequences of elephants' presence in the ecosystem or under semi-artificial conditions such as in fenced reserves may therefore have implications, both positive and negative, on biodiversity. Structural changes in woodland can benefit from smaller browsers by increasing availability of food and cover (van Wyk & Fairall, 1969; Lawton & Gough, 1970). Mwalyosi (1990) also argues that canopy thinning of woodland by elephants is a positive phenomenon that increases gap dynamics, landscape diversity, and browsing productivity. Lock (1993) attributes increase in woody plant cover and species diversity to a decline in elephant populations.

Intrinsically, elephant dominance has conservation implications due to their impact on other species, especially when occurring at relatively high densities (Laws, 1970; Cumming et al., 1997; Western & Maitumo, 2004; Wiseman et al., 2004). Under such conditions, their foraging and feeding habits may reduce tree densities, transform forests and intact woodlands into mixed woodlands and even grasslands (Dublin et al., 1990; Lock, 1993; Barnes et al., 1994; Leuthold, 1996; Ben-Shahar, 1998; Trollope et al., 1998; Van de Vijver et al., 1999; Eckhardt et al., 2000; Mosugelo et al., 2002). The resultant effect of such selective feeding and conversion may be associated with changes in abundance-incidence and rank-abundance functions that describe woody plant communities.

The Nigerian rainforest is dominated by members of Sterculiaceae, Moraceae, Ulmaceae, Meliaceae families (Isichei, 1995), which agrees with our findings. Species belonging to families such as Sterculiaceae, Moraceae, Ulmaceae, Meliaceae were parts of the most present to both zones, although the number of families in the NEZ were slightly higher than that in EZ (Table 1). The result of Sorenson's coefficient revealed that species in the two zones is slightly different. This difference may be attributed to the activities of elephants in the EZ.

7. Conclusion

This study reported the influence of elephants on vegetation structure and species diversity which showed that elephant activities, most especially browsing habit, can alter the composition of species, structure of the vegetation and the diversity of tree dominant ecosystems leading to loss of biodiversity, thus demanding strict conservation strategies in the management of the reserve. Therefore, we conclude that the presence and browsing of elephants can alter the floristic composition, structure and diversity of plant species.

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References

Akobundo I.O. & Agyakwa C.W., 1998, A Handbook of West African Weeds, 2nd Edition. International Institute of Tropical Agriculture, Ibadan.

Alexandre D.-Y., 1978, Le role disseminateur des elephants en foret de Taï, Cote-d'Ivoire. Rev. Ecol. (Terre Vie) 32: 47–72.

Barnes R.F.W., Barnes K.L. & Kapela E.B., 1994, The long-term impact of elephant browsing on baobab trees at Msembe, Ruaha National Park, Tanzania. African Journal of Ecology 32: 177–184.

Ben-Shahar R., 1998, Elephant density and impact on Kalahari woodland habitats. Transactions of the Royal Society of South Africa 53: 149–156.

Clegg B.W., 2008, Habitat and diet selection by the African elephant at the landscape level: a functional integration of multi-scale foraging processes. PhD Thesis, University of the Witwatersrand, Johannesburg. https://core.ac.uk/download/pdf/39666647.pdf

CMS, 2011. Convention sur espèces migratrices. Deuxième réunion des stagiaires du mémorandum d'accord concernant les mesures de conservation en faveur des populations Ouest-Africaines de l'Eléphant d'Afrique (Loxodonta africana). PNUE/CMS/WAE2/Inf.2 juin 2011, Niamey, Niger, 45pp.

Cowling R. & Kerley G.I.H., 2002, Impacts of elephants on the flora and vegetation of subtropical thicket in the Eastern Cape, [in;] Elephant conservation and management in the Eastern Cape: Workshop Proceedings, p. 55–72, Terrestrial Ecology Research Unit, University of Port Elizabeth, Port Elizabeth, South Africa, Report (No. 35).

Croze H., 1974, The Seronera Bull Problem I. The Elephants. East African Wildlife Journal 12: 1–27. http://dx.doi.org/10.1111/j.1365-2028.1974.tb00104.x

Cumming D.H.M., Brock-Fenton M., Rautenbach I.L., Taylor R.D., Cumming G.S., Cumming M.S., Dunlop J.M., Ford A.G., Hovorka M.D., Jonhstohn D.S., Kalcounis M., Malangu Z. & Portfors C.V.R., 1997, Elephants, Woodlands and Biodiversity In Southern Africa. South African Journal of Science 93: 231–236.

Danquah E., 2016, Spatial Distribution of Elephants versus Human and Ecological Variables in Western Ghana. Advances in Ecology Article ID 8038524

Dublin H.T., Sinclair A.R.E. & McGlade J., 1990, Elephants and fire as causes of multiple stable states in the Serengeti-Mara woodlands. Journal of Animal Ecology 59: 1147–1164.

Eckhardt H.C., van Wilgen B.W. & Biggs H.C., 2000, Trends in woody vegetation cover in the Kruger National Park, South Africa, between 1940 and 1988. African Journal of Ecology 38: 108–115.

Emmanuel O., Onyewen T., Egbe S., Omonu C., Bowkett A.E., Francis L., Morakinyo T., Hall P., Adepoju A., Onoja J. & Karunwi A., 2017, First photographs of chimpanzees in the Omo Forest Reserve, Nigeria. Oryx 51(3): 395–396.

Gandiwa E., Magwati T., Zisadza P., Chinuwo T. & Tafangenyasha C., 2011, The impact of African elephants on *Acacia tortilis* woodland in northern Gonarezhou National Park, Zimbabwe. Journal of Arid Environments 75(9): 809–814.

Grellmann D., 2002, Plant responses to fertilization and exclusion of grazers on an arctic tundra heath. Oikos 98: 190–204. doi: 10.1034/j.1600-0706.2002.980202.x

Guldemond R. & Van Aarde R., 2008, A Meta-Analysis of the Impact of African Elephants on Savanna Vegetation. Journal of Wildlife Management 72(4): 892–899. https://doi.org/10.2193/2007-072

Hoft H. & Hoft M., 1995, The differential effects of elephants on rain forest communities in the Shimba hills, Kenya. Biological Conservation 73: 67–79.

Hutchinson J. & Dalziel J.M., 1963–1972, Flora of West Tropical Africa. Vol. I–III.

Isichei A.O., 1995, Omo Biosphere Reserve, Current Status, Utilization of Biological Resources and Sustainable Management (Nigeria). Working Papers of the South-South Cooperation Programme on Environmentally Sound Socio-Economic Development in the Humid Tropics. UNESCO, Paris.

Jachmann H. & Bell R.H.V., 1985, Utilisation by Elephants of Brachystegia Woodlands of Kasungu National Park, Malawi. African Journal of Ecology 23: 245–258. http://dx.doi.org/10.1111/j.1365-2028.1985.tb00955.x

Kacholi D.S., 2020, Density and Aboriginal Uses of Wild Tree Species in Milawilila Forest Reserve in Morogoro Region, Tanzania. Tanzania Journal of Science 46(1): 85–100.

Karimu S.A., 1999, The role of surrounding communities on the management of Omo Forest Reserve. Consultant Report for FORMECU, June 1999, 47 pp.

Keay R.W.J., 1989, Trees of Nigeria. Clarendon Press, Oxford. doi: 10.1111/j.1756-1051.1991.tb01411.x

Laws R.M., 1970, Elephants as agents of habitat and landscape change in East Africa. Oikos 21: 1–15.

Laws R.M., Parker I.S.C. & Johnstone R.C.B., 1970, Elephants and Habitats in North Bunyoro, Uganda. East African Wildlife Journal 8: 163–180.

Laws R.M., Parker I.S.C. & Johnstone R.C.B., 1975, Elephants and their habitats. Clarendon Press, Oxford.

Lawton R.M. & Gough M., 1970, Elephants or Fire: Which to Blame? Oryx 10(4): 244–248.

Leuthold W., 1977, African Ungulates. Springer-Verlag, Berlin.

Leuthold W., 1996, Recovery of woody vegetation in Tsavo National Park, Kenya, 1970-94. African Journal of Ecology 34: 101–112.

Lewis D.M., 1991, Observations of tree growth, woodland structure and elephant damage on Colophospermum mopane in Luangwa Valley, Zambia. African Journal of Ecology 29(3): 207–221. doi: 10.1111/j.1365-2028.1991.tb01003.x

Lock J.M., 1993, Vegetation change in Queen Elizabeth National Park, Uganda: 1970-1988. African Journal of Ecology 31: 106–117.

Mapaure I. & Mhlanga L., 2000, Patterns of elephant damage to Colophospermum mopane on selected islands in Lake Kariba, Zimbabwe. Kirkia 17: 189–198.

Menhinick E.F., 1964, A comparison of some species-individuals diversity indices applied to samples of field insects. Ecology 45: 859–861.

Midgley G., Chapman R. & Hewitson B., 2005, A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape. Unpublished document.

Moloney K.A. & Levin, S.A., 1996, The effects of disturbance architecture on landscape-level population dynamics. Ecology 77: 375–394.

Mosugelo D.K., Moe S.T., Ringrose S. & Nelleman C., 2002, Vegetation changes during a 36-year period in northern Chobe National Park, Botswana. African Journal of Ecology 40: 232–240.

Mwalyosi R.B.B., 1990, Decline of Acacia tortilis in Lake Manyara National Park, Tanzania. African Journal of Ecology 25: 51–53.

Mukwashi K, Gandiwa E, Kativu S., 2012, Impact of African elephants on Baikiaea plurijuga woodland around natural and artificial watering points in northern Hwange National Park, Zimbabwe. International Journal of Environmental Sciences 2: 1355–1368.

O'Connor M.I., Bruno J.F., Gaines S.D., Lester S.E., Halpern B.S., Kinlan B.P. & Weiss J.M., 2007, Temperature control of larval dispersal and implications for marine ecology, evolution, and conservation. Proceedings of the National Academy of Sciences USA, 104: 1266–1271. doi: 10.1073/pnas.0603422104

Ojo L.O., 2004, The fate of a tropical rainforest in Nigeria: Abeku sector of Omo Forest Reserve. Global Nest 6(2): 116–130.

Ola-Adams B.A., 1999, Biodiversity Inventory of Omo Biosphere Reserve, Nigeria. Country Report on Biosphere Reserves for Biodiversity Conservation and Sustainable Development in Anglophone Africa (BRAAF) Project, 351 pp.

Olofsson J., Kitti H., Rautiainen P., Stark S. & Oksanen L., 2001, Effects of summer grazing by reindeer on composition of vegetation, productivity and nitrogen cycling. Ecography 24: 13–24.

Osborn F.V., 2002, Capsicum oleoresin as an elephant repellent: field trials in the communal lands of Zimbabwe. Journal of Wildlife Management 66: 674–677.

Pamo E.T. & Tchamba M.N., 2001, Elephants and vegetation change in the Sahelo-Soudanian region of Cameroon. Journal of Arid Environments 48(3): 243–253.

Petraitis P.S., Latham R.E. & Niesenbaum R.A., 1989, The maintenance of species diversity by disturbance. The Quarterly Review of Biology 64: 393–418.

Pitchairamu C., Muthucherian K. & Siva N., 2008, Floristic inventory and quantitative analysis of tropical deciduous forest in Piranmalai Forest, Eastern Ghats, Tamil Nadu, India. Ethnobotanical Letters 12: 204–216.

Pickett S.T.A. & White P.S., 1985, The ecology of natural disturbance and patch dynamics. Academic Press, Orlando.

Pielou E.C., 1969, An Introduction to Mathematical Ecology. Wiley and Sons, New York.

Pielou E.C., 1975, Ecological Diversity. John Wiley and Sons, New York.

Sheil D., 1996, Species richness, forest dynamics and sampling: questioning cause and effect. Oikos 76: 587–590.

Skarpe C., Aarrestad P.A., Andreassen H.P., Dhillion S.S., Dimakatso T., du Toit J.T., Halley D.J., Hytteborn H., Makhabu S., Mari M., Marokane W., Masunga G., Modise D., Moe S.R., Mojaphoko R., Mosugelo D., Motsumi S., Neo-Mahupeleng G., Ramotadima M., Rutina L., Sechele L., Sejoe T.B., Stokke S., Swenson J.E., Taolo C., Vandewalle M. & Wegge P., 2004, The return of the giants: Ecological effects of an increasing elephant population. Ambio 33: 276–282.

Steyn A. & Stalmans M., 2001, Selective habitat utilisation and impact on vegetation by African elephant within a heterogeneous landscape. Koedoe 44(1): 95–103.

Struhsaker T.T., Lwanga J.S. & Kasenene J.M., 1996, Elephants, selective logging and forest regeneration in the Kibale Forest, Uganda. Journal of Tropical Ecology 12: 45–64.

Sugar R., Raghubanshi. A.S. & Singh. J.S., 2003, Tree Species Composition, Dispersion, and Diversity along a disturbance gradient in dry tropical forest region of India. Forest Ecology and Management 186(1–3): 61–71.

Swanepoel C.M. & Swanepoel S.M., 1986, Baobab damage by elephant in the middle Zambezi, Valley, Zimbabwe. African Journal of Ecology 24(2): 129–132. doi: 10.1111/j.1365-2028.1986.tb00352.x

Thomson P.J., 1975, The role of elephants, fire and other agents in the decline of a *Brachystegia boehmii* woodland. Journal of the Southern African Wildlife Management Association 5: 11–18.

Trollope W.S.W., Trollope L.A., Biggs H.C., Pienaar D. & Potgieter A.L.F., 1998, Long-term changes in the woody vegetation of the Kruger National Park, with special reference to the effects of elephants and fire. Koedoe 41: 103–112.

UNESCO, 2016, About the Man and the Biosphere Programme (MAB). Available at: http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/man-and-biosphereprogramme/about-mab/ [Accessed on: June 11 2021].

Valeix M., Fritz H. & Dubois S., 2007, Vegetation structure and herbivore abundance over a period of increasing elephant abundance in Hwange National Park, Zimbabwe. Journal of Tropical Ecology 23: 87–93. doi:10.1017/S0266467406003609

Van Aarde R.J. & Jackson T.P., 2007, Megaparks for metapopulations: addressing the causes of locally high elephant numbers in southern Africa. Biological Conservation 134: 289–297. doi: 10.1016/j.biocon.2006.08.027

Van de Vijver C.A.D.M., Foley C.A. & Olff H., 1999, Changes in the woody component of an East African savanna during 25 years. Journal of Tropical Ecology 15: 545–564.

Van Wyk P. & Fairall N., 1969, The influence of the Africal elephant on the vegetation of the Kruger National Park. Koede 9: 57–95.

Walker B., Holling C.S., Carpenter S.R. & Kinzig A., 2004, Resilience, adaptability and transformability in social-ecological systems. Ecology and Society 9(2): 5. http://www.ecologyandsociety.org/vol9/iss2/art5/

Weeks M.R., 1997, Enumeration Survey of the Omo Forest Reserve Biosphere Extension Area. The Nigerian Forest Elephant (NFE) Forest Inventory Final Report. Erin Camp: NFE and Wildlife Survey and Protection Group.

Western D. & Maitumo D., 2004, Woodland loss and restoration in a savanna park: a 20-year experiment. African Journal of Ecology 42: 111–121.

Wiseman R., Page B.R. & O'Connor T.G., 2004, Woody vegetation change in response to browsing in Ithala Game Reserve, South Africa. Southern African Journal of Wildlife Research 34: 25–37.

WFO, 2021, The World Flora Online. http://www.worldfloraonline.org/ [Accessed: 31 December, 2021].

WNBR, 2022, World Network of Biosphere Reserves. UNESCO, The MAB programme. https://en.unesco.org/biosphere/wnbr [Accessed July 5, 2022].

Young S. & Swiacki L.N., 2006, Surveying the forest biodiversity of Evansburg State Park: Plant community classification and species diversity assessment. Int. J. Bot. 2: 293–299.