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Biodiversity of Forest Elephants (*Loxodonta Cyclotis*) Diet in the Ogooué Leketi National Park, Congo Brazzaville

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Abstract

The Ogooué Leketi National Park (OLNP) is located within the Batéké-Léconi-Léfini Landscape in the central basin of the Congo River. The Ogooué Leketi Elephant Project (OLEP) area is important for biodiversity conservation from its significant populations of forest species (forest elephant, gorillas, chimpanzees, duikers, monkeys, etc.) combined with savanna species (Grimm's duiker, side-striped jackal, etc). Elephant sign is highest 0.9/km in the northwest of the Landscape in the border area of the Batéké Plateau National Park in Gabon where a number of mineral-rich clearings, or bais, attract forest elephants and others wildlife. Elephants travel a long distance and consume diverse plants and occasionally animals' species from one clearing to others throughout the forest. This paper intends to provide an overall preliminary list of plants consumed by forest elephants across their feeding trials. The results of the study points to the fact that, elephants were found to be feeding on 258 different vegetal species and three animal species recorded from twenty-six elephants feeding trials from March 2013 to December 2014 through different methods. Among these plant species, 156 were identified by us and checked by botanists in both the CERVE at Brazzaville and herbarium of Kinshasa University. Elephants were not only eating plants but they were also consuming occasionally some invertebrate such as bees, termites and ants. An analysis of 53 dung piles revealed that 43 dung piles had traces of 26 species of fruit consumed by elephants while 10 dung piles had no traces of fruits. The OLNP is among the least described protected areas in the Republic of Congo, despite its speculated high potential biodiversity. This lack of ground-truth knowledge is attributed to the status of the protected area that Congolese government classified as park in 2018 after 14 years of existence.

Keywords: Forest elephant feeding; Biodiversity conservation; Ogooué Leketi National Park; Republic of Congo.

1. Introduction

Established in 2004, the Ogooué Leketi National Park (OLNP) was voted by (IUCN 1992) in order to protect rain forest habitat representative of Congo Basin and its diverse wildlife. However, OLNP is among the least described protected areas in the Republic of Congo despite its speculated potential biodiversity. The OLNP (4230 Km^2) is one of the components of the Léconi-Batéké-Léfini Landscape. The Léconi-Batéké-Léfini Landscape (35,350 km^2) is a vast area of forest-savannah mosaic on both sides of the border between Gabon and Congo in Central Africa [1]. It includes, in additional of OLNP, the Léfini Reserve and the Lesio-Louna sanctuary in Congo, the Batéké Plateaux National Park (BPNP) in Gabon, and a large area of unprotected land which connects and surrounds these Parks. Batéké Plateau National Park in Gabon and the FOLNP in Congo together form a transboundary protected area of 6000 km^2. The north western part of the landscape, in Gabon and Congo, is home of a transboundary population of forest elephants (*Loxodonta africana cyclotis*) 0.9 sign/km, as well as numerous other endangered species including western lowland gorillas [2-6] which are also found across the border. The dense forest habitat frequented by forest elephants makes them difficult to study; the best possible

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time to observe them is at forest clearings (bais). Clearings are not only provides an opportunity for the elephants with a source of food which is rich in mineral salts (buried in the soils) [7-9], but, also opens up an avenue for social interaction [10-12]. However, roaming throughout the area, the elephants eat a wide range of vegetal species along with invertebrate species on occasions.

Flore study in this area does not exist except a preliminary list of Botanic Kew Garden/ United Kingdom at the periphery of this area. However, alone study by Mbete, *et al.* [13] on elephant feeding is of significance. The feeding ecology of elephants in forests in Central Africa has been less documented. Studies in West Africa [14-17] and central Africa [18, 19] show that forest elephants have a highly varied diet of leave, bark, wood, roots, and fruit. Elephant feeding lists have been produced from several sites in which 230 species are consumed in Gabon [18] and more than 300 species in Ndoki Forest in Congo [7]. The importance of the vegetative parts of these species has not been quantified since direct evidence is difficult to obtain. Only foods which leave tangible evidence such as seeds in dung piles could help to estimate seasonal consumption of fruit [7, 16, 18, 19] that may influence elephant distribution [16, 19, 20]. Wing and Buss [21] and Chapman, *et al.* [22] confirmed that grasses dominate the diet during the wet period, with browse, wood, and bark becoming increasingly important when rainfall is low. Fruit consumption is less since it is scarce in these habitats. Hence, they are consumed only when they are available. This paper intends to provide an overall preliminary list of the major elephant food components in the OLNP, with emphasis on the conservation status plants consumed by forest elephants across 26 sites. This study has increased our understanding of elephant feeding and provided the most complete coverage of elephant activity yet obtained. Elephant's food in this area is threatened by three Asia logging companies (Taman Industry, Sino Congo Forest and Asian Congo). These companies removed during exploitation some of trees which elephants mostly prefer to eat fruit. These species are *Baillonella toxisperma* and *Okoume klaineana*. As a result of denuding of trees, logging operation and road expansion throughout the region has made easy access to this forest for poaching [23, 24].

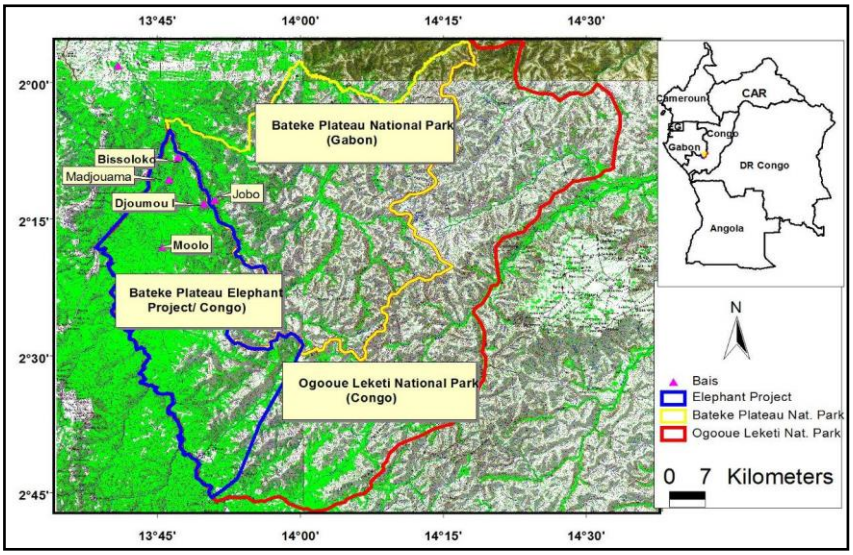
The aim of this study is to provide a non-exhaustive list of the elephant food within Ogooué Leketi National Park in Congo. It will be important to quantify food, and to evaluate feeding success as a basis for determining ecological factors that might influence elephant distribution throughout OLNP habitats. The specific objectives were to: (1) Produce a list of plant species consumed by elephants in the OLNP; (2) Quantify differences in food selection by life form and species; (3) Use these data to show how habitat attributes may be expected to influence forest elephant distribution; (4) Improve our understanding of elephants feeding in the area (numbers of plants species consumed by elephants), and to implement appropriate management decisions.

2. Material and Methods

2.1. Study Site

This study focused on elephant feeding is mostly concentrated around three clearings viz, Moolo, Madjouama and Bissoloko within the Ogooué Leketi Elephant Project (OLEP) which covers 1,449 km^2 (13°62'-13°96'E; 2°08'-2°76'S) located inside the future Ogooué Leketi National Park (4230 km^2) at the southwest of the Republic of Congo (Fig. 1). Batéké Plateau National Park (BPNP) in Gabon and Ogooué-Leketi National Park (OLNP) in Congo together form a transboundary protected area of 6000 km^2. The BPNP was declared a National Park in 2004; however, the OLNP has been recognised as an important site following the declaration of this area as 'protected area' in 2018 by executing an agreement by the Congolese Government (Mémorundum of 11 February 2004 between WCS Congo and the Ministry responsible of the protected area of Congo).

Figure-1. Study area surveyed within the Batéké Plateau Elephant Project study area



The region of the OLNP is in the lowest platform of the Cuvette Centrale whose major characteristics are flat topography and low altitude (300m) in which two main rivers Ogooué and Leketi flow. The topography rises up eastward reaching approximately 600 to 700 m [25], at which heights the terrain becomes a non-undulating plateau. The habitat is predominated by two biomes the savanna forest mosaic and the mature lowland tropical forest, which

are a part of the large region of guinéo-congolaise flora of sempevirente ombrophile forest [26]. The terra firma forest is characteristically mixed mature forest, in which *Scorodophloeus zenkeri*, *Anonidium mannii*, *Greenwayodendron (Polyalthia) suaveolens*, etc. are the most common plant species. Patches of *Staudtia stipitata* occur in the OLNP although in less extensive unbroken areas [27]. *Marantaceae* stands (e.g. *Haumania danckelmaniana* and *Marantochloa mannii*) are frequent in understories and, in some particular areas of the northern sector, constitute pure monodominant vegetation stands. The climate of the region is sub-equatorial [25] in which the mean temperature is recorded between 24°C-27°C, and the mean annual rainfalls oscillate between 1400-2000 mm [28, 29]. The rainy season is from October to May in a year with a reduced rainfall in January and February. The months between June to September are considered as the dry season. According to the main phytochories of Africa and Madagascar proposed by White [30], Congo Brazzaville is included in the center of endemism Guinea Congolese in the limit of domain low Guinean Atlantic and low Guinean continental [31, 32]. In the Batéké Plateau, there are patches of forest in the savanna. It seems that both deforestation and savanisation existed in conjunction with the sands structure of soils. If the humid climate is susceptible to allow existence of dense forest, the soils structure oriented the vegetation towards savanna [28].

2.2. Methods

It is nearly impossible in the forest habitat to approach an elephant to see what it consumes from a distance of fewer than 10 meters due to thick foliage and poor light. Also, the elephants flee on sighting humans (observers). Thus, we planned to follow known elephants from the clearings through different biotopes to record their food behavior. We are going to use three indirect methods of elephant signs of less than 48 hours: opportunistic observations of the food signs, fresh elephant trails follow, and dung analysis.

2.2.1. Opportunistic Observations

In order to produce a non-exhaustive list of elephant food, it was recorded all signs of less than 48 hours that justified the sign was created by elephants. Leaves signs were associate by elephant fresh footprints digging, or broken vegetation. The nutrition of the bark of trees was distinctive even though the signs date was more than 48 hours. To record the species of the plant consumed (leaf, bark, stems, roots, branches) by the elephant; local trackers were recruited to identify plant species in the local name (Téké and Ndassa). Thereafter, the names were converted into the scientific nomenclature after they are identified and confirmed by the specialist. The preliminary identification of the plant species consumed was made in the field through the botanical materials as Letouzey [33]; White and Abernethy [34]; Nsongola, *et al.* [35].

All known or indeterminate species were collected and kept on a field herbier. This last herbier was brought to the herbarium of the Centre d'Etude sur les Ressources Végétales (CERVE) of Brazzaville (Republic of Congo) and Herbarium of Kinshasa University (Democratic Republic of the Congo) for re-identification of samples. These species were classified in the project herbarium according to their taxonomy which will help the future generation for identification of vegetation.

2.2.2. Fresh Elephant Trails Follows

Fresh elephant trails were followed opportunistically throughout entire area with a minimum of 1km in theory of which 500 meter of every side of the track that joins the Simombondo village and the three clearings of observation. When a fresh elephant trails is discovered, we use the GPS (Global Positionning System) to mark the starting point and the two points of destination as a referencing mark of the itinerary. The distance followed was in theory measured from a topofil (hill top). These trials were noticed across several types of habitats in both forest and savannah that we recorded. The count of the elephants, their age and gender in their respective groups were estimated by the size of their footprints and the number of different sets of prints. We collected all traces of elephant food like leaves, roots, branches, and others.

2.2.3. Dung Analysis

All fresh dung piles that we found from both opportunistically and systematically methods throughout the study area were systematically analyzed. To avoid biasing dung selection during fieldwork, all fresh and intact elephant dung was analyzed in a minimal distance of 2 km. These fresh dungs were analysed according to the methods described by Blake [7] and Mbete, *et al.* [13]. This analysis starts with the measurement (cm) of the diameter of the dung piles. With two sticks of wood, the content of the dung was verified; the nature and the abundance of the components (leaf, fiber, bark/woods, and fruit). The relative abundance of these components was estimated while using the scale of abundance (1 = rare, 2 = few, 3 = common, 4 = abundant). All known seeds were identified in the field whereas unknown seeds were collected and subsequently identified by Nsongola Gilbert of CERVE in Brazzaville. All seeds over 1cm were counted, and for smaller seeds, the relative abundance was estimated following a four-point scale mentioned above. Different components found on the dung piles were grouped into composition macroscopic (the seeds and the rest of the bark and leaves) and microscopic (to appropriate a part of dung or cloths and the other components that we need to see from the optical microscope). The no digestive parts of seeds were identified in the field by using botanical seeds key illustrated by White and Abernethy [34].

The unknown seeds were dried and placed in a small plastic bag for their identification by the botanists later in the laboratory. The partially digested matters were dried and kept in a plastic bag for their identification in the laboratory.

2.2.4. Statistical Analysis

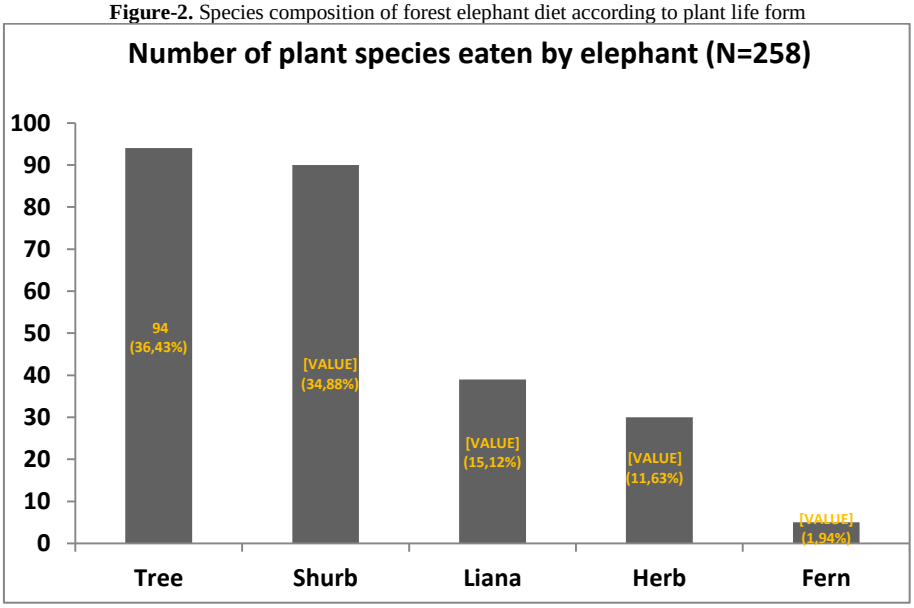
A percentage table was built for each of the analysis of these trees as food species selection by Batéké elephants, the plant part selection by a life form, and the number of fruit in the diet was determined. However, an appropriate statistical test was performed for the seasonal consumption of fruit species. The computer program SPSS.16 was used to carry out all the statistical analyses and tests. We conducted Pearson chi-squared test to assess the number of seeds of each species contained in each dung pile per month year of record. To understand if there is seasonality in the elephants feeding fruit throughout the years, a non-parametric statistical test of Mann Whitney was performed for these two variables (season and number of seeds within the dung piles). For these two last statistical tests, a significantly difference is observed if the output of the test has a P values less than 0.05. We examined the relationships between fruit species recorded across month years during the time of the study. We assess the correlation between fruit species and monthly rainfall to establish the relationships between these two variables. The results are presented as below.

3. Results

3.1. Food Species Selection by Batéké Elephants

As results of this survey, elephants consumed in one hand two hundred and fifty-eight different plant parts of plant species in which 198 plants identified were classified in 66 families. These plant parts included leaves, bark, wood, stems, roots, and fruits. Among these species, 60 plant species different have not yet identified even by botanist in the CERVE in Brazzaville and herbarium of Kinshasa University (DRC). It has also been recorded in other hand three invertebrate (insects), bee, ant and termite which were grouped in two families Apidae and Termitidae. Results included here are restricted to all species consumed by elephants. Elephants consume diverse plants part basically leaves, followed by woods (small trunks, branches and terminal twigs), roots and sometimes tuber. Leaf foods were most diverse from 94 trees species (36%), 90 Shurbs species (35%), followed by 39 species of lianas (15%), 30 species of herbs (12%) and 5 species of fern (2%) of the total number of food species in the diet (Fig. 2).

Figure-2. Species composition of forest elephant diet according to plant life form



3.2. Plant Part Selection by Life Form

Elephants selected more in theirs diet leaves from trees and shrubs in similar proportions (84.4% and 89.4%) than herb (55.3%) and lianas (33.3%) (Table 1). However, woody material (leaf+branch, leaf+bark and leaf+root) was selected more heavily from lianas (58.8%) than trees (7.5%). In one occasion, elephants ate heavily leaves, removed all bark, pull out tree and ate roots of *Petersianthus macrocarpum* (Fig.3a). May be this plant keeps some medical virtues that we need to explore in the future. Butterflies preferred in the right season to lay eggs in this tree which will after metamorphose become caterpillar then butterflies.

Table-1. Parts of plant eaten by plants from biological type

Plant part and Animal	Trees	Shrubs	Fen	Herb	Lianas	Animal
Bark	5.8	0.4				
Leaf	84.4	89.4		55.3	33.3	
Leaf+Branch/ Leaf+Bark/Leaf+Root	7.5	9.7		44.0	58.8	
Fruit	0.3					
Nut	0.3					
Root	1.0				2.9	
Stem	0.3				4.9	
Tuber				0.6		

Whole Plant			100.0			
Bees+Termites+Ants	0.3	0.4				100.0
Total (%)	100	100	100	100	100	100

It was often apparent that elephants strongly selected liana wood because of the high water content in the trunks (e.g. *Eresmopatha, Laccosperma*). Elephants tended to select trunks for only a few species of tree. Fruit and nut tree were less selected with each 0.3% of records. It was difficult to know if elephants ate fruit because all the contained is ingurgitate and the evidence of elephant action is through the remaining materials or when elephants vomiting under the fruiting tree. Fruit species registered in the field are *Baillonella toxisperma* and *Tridesmosternon omphalocarpoides*. The only nut that we collected was from *Sclerosperma mannii*. Root and stem of plant were selected most of time for trees and lianas. Elephants selected more than once the tuber of *Anchomanes difformis* (0.6%). The whole plant had been selected for the fern (100%).

Figure-3.(a) Petersianthus macrocarpum rest of food; (b) Rest of elephant feeding the honey bees; (c) Rest of elephant feeding ants; (d) Rest of elephant feeding termites

However, elephants selected occasionally some invertebrate found either on tree, shrub and termite nest. More than one occasion elephants break the trunk of tree to retrieve honey made by bees (Fig. 3b). Some ants were seen on ground in which shrub was broken and leaves not eaten. Elephants selected ants from their home nest (Fig. 3c) in addition to vegetable resources that they collected throughout the area. Following the same observation, we thought that elephant is eating accidentally the young leaves of *Bateria fustiloides* in which it selected more the ants than leaves.

In an old death tree with termite nest, elephants broke the nest and ate termites (Fig. 3d). This study confirmed previous observation in which elephants ate extremely feeding bouts on the pith of large *Raphia spp*. Palms or *Elaeis guineensis* (oil palms), and food intake was often exceptionally high to eat larvae of coleopteran.

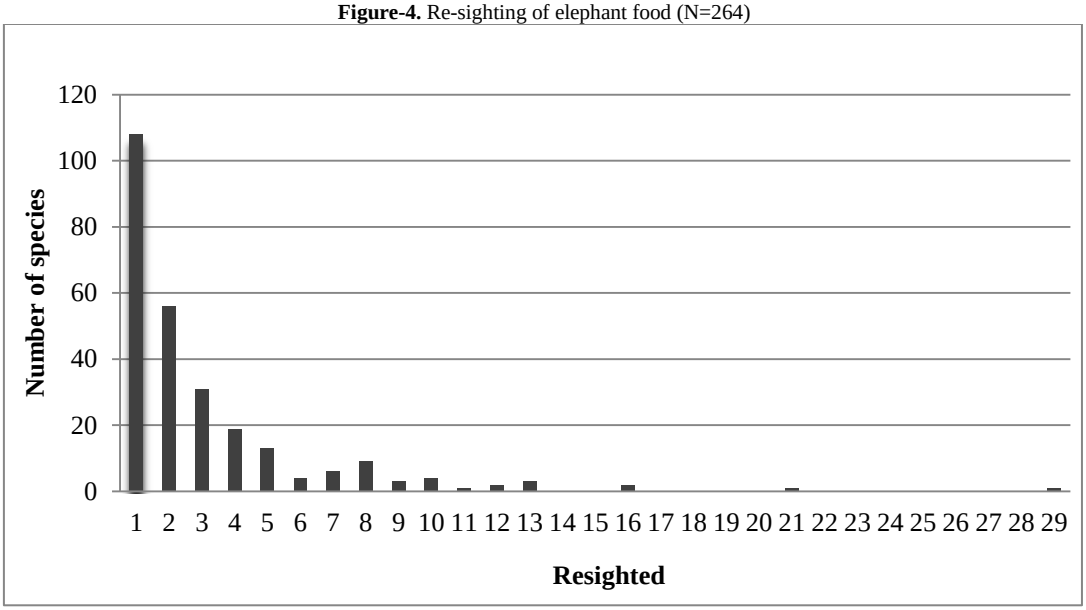
From the 261 species of plant and animals, it was counted a total of 258 species of plant recorded on the elephants feeding trials and 03 species of invertebrates. Among them 10 top most recorded plant species represent 19.1% are listed in the table 2. However, *Grossera macrantha* (29) and *Strombosiopsis tetandra* (21) were most re sighted species from the total record. These species were followed by *Dicellandra sp* and *Staudtia kamerunensis* with each 16 records, the remaining of species were less represented (until 11) as shown in the table 2 and Figure 4.

Table-2. Top 10 most important food species by in all elephant trials

Species	**N**	**Frequency (%)**
Grossera macrantha Pax	29	3.6
Strombosiopsis tetrandra Engl.	21	2.6
Dicellandra sp	16	2.0
*Staudtia kamerunensis var. gabonensis (*Warb.*)* Fouilloy	16	2.0
Costus sp	13	1.6

Palisota ambigua (P.Beauv.) C.B.Clarke	13	1.6
Trachyphrynium braunianum (K. Schum.) Baker	13	1.6
Aframomum laurentii (De Wild. & T.Durand) K.Schum.	12	1.5
Harungana madagascariensis Lam. ex Poir.	12	1.5
Dialium pachyphyllum Harms	11	1.3
Top 10 as % of total species		19.1
N species		261
N records		815

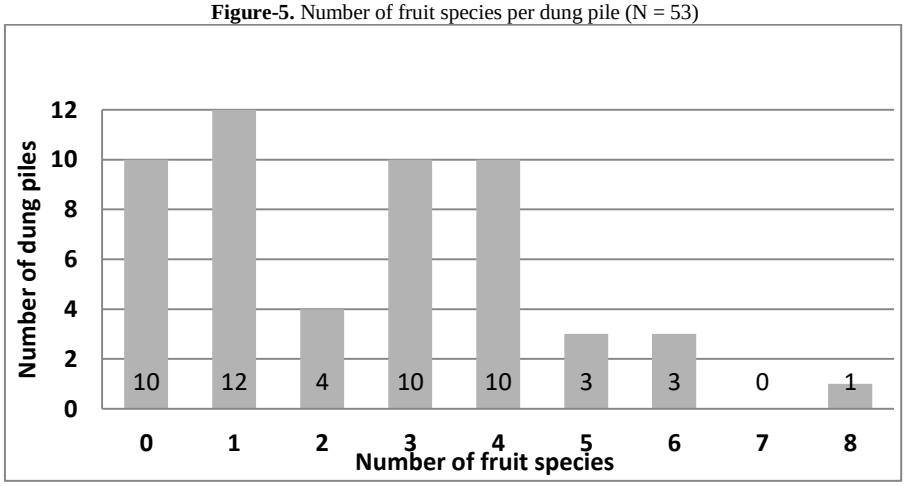
Figure-4. Re-sighting of elephant food (N=264)



3.3. Fruit in the Diet

A total of 53 dung piles were analyzed over two years from March 2013 to December 2014 in the Ogooué Leketi Elephant project area. The composition of these elephant dung piles was dominated by fibrous material from leaves, wood, roots and stems consumed. At least, 26 species of fruit were consumed from 16 families known (Table 3). Among these 53 dung piles analyzed 10 dungs have no seeds in which diet were almost composed by fibrous materials. Twelve dungs piles have one fruit rest, 20 dungs piles have respectively three and four fruit species. Six dung piles got five and six fruit species, four dung piles contained two species and then, only one dung piles got 8 fruit species as shown in the figure 5.

Figure-5. Number of fruit species per dung pile (N = 53)



The most represented family is the Sapotaceae, which accounted for 15.0% of all fruit records in dung piles and comprised 2 species especially *Chrysophyllum africanum* and *Omphalocarpum procera*. The Caesalpiniaceae family was next most common with 10.7% of fruit records was represented only by *Bobgunnia fistuloides (*syn. *Swartzia fistuloides*), followed by the Phyllanthaceae and Putranjivaceae with 4.65% (1 species each). The top ten families accounted for 72.1% of all fruit remains recorded, and 5% of other families was less represented. Ten dung piles have not fruits represented 7.1% of record and the undetermined families represent 15.7% (Table 3).

Table-3. Families of fruit within the dung piles

Family	Frequency	%dung piles	% species
Sapotaceae	21	15.0	39.6
Leguminosae	24	17.1	45.3
Euphorbiaceae	13	9.3	24.5
Rubiaceae	11	7.9	20.8
Annonaceae	10	7.1	18.9
Irvingiaceae	10	7.1	18.9
Moraceae	5	3.6	9.4
Malvaceae	4	2.9	7.5
Apocynaceae	3	2.1	5.7
Pandaceae	3	2.1	5.7
Cucurbitaceae	1	0.7	1.9
Marantaceae	1	0.7	1.9
Lamiaceae	1	0.7	1.9
Zingiberaceae	1	0.7	1.9
No fruit	10	7.1	18.9
Unkwon	22	15.7	41.5
Record	140	100	
N	53		
Group	17		

The most recorded seeds in dung piles were Annonaceae family represented by *Anonidium mannii*, found in 26.3% of all dung piles, followed by Phyllanthaceae (15.1%) especially represented by *Uapaca heudelotii* and Putranjivaceae (2.5%: *Drypetes gosweilleri*). The third most represented family is Irvingiaceae 17.5% with three species *Irvingia tenuinucleata* (syn. *Irvingia wombulu:* 12.1%), *I. gabonensis* (3.0%) and *Klainedoxa gabonensis* (2.5%). Others families and unknown species were less represented as shows in the table 4.

Table-4. Plant families with fruit remains found in dung piles

Family	Species	Seeds	% record
Annonaceae	*Anonidium mannii* (Oliv.) Engl. & Diels	252	26.3
Phyllanthaceae	*Uapaca heudelotii* Baill.	145	15.1
Putranjivaceae	*Drypetes gossweileri* S.Moore	24	2.5
Irvingiaceae	*Irvingia tenuinucleata* Tiegh.	116	12.1
	Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	29	3.0
	Klainedoxa gabonensis Pierre	23	2.4
Leguminosae	*Tetrapleura tetraptera* (Schum. & Thonn.) Taub.	65	6.8
	Bobgunnia fistuloides (Harms) J.H.Kirkbr. & Wiersema	63	6.6
Pandaceae	*Panda oleosa* Pierre	54	5.6
Rubiaceae	*Breniana brieyi*	49	5.1
Malvaceae	*Duboscia macrocarpa* Bocq.	35	3.7
Urticaceae	*Myrianthus arboreus* P.Beauv.	3	0.3
Moraceae	*Treculia africana* Decne. ex Trécul	16	1.7
Sapotaceae	*Omphalocarpum procerum* P.Beauv.	12	1.3
	Chrysophyllum africanum A.DC.	5	0.5
Marantaceae	*Haumania danckelmaniana* (J.Braun & K.Schum.) Milne-Redh.	12	1.3
Cucurbitaceae	*Cucurbita sp.*	5	0.5
Zingiberaceae	*Aframomum laurentii* (De Wild. & T.Durand) K.Schum.	3	0.3
Apocynaceae	*Landolphia sp.*	2	0.2
Lamiaceae	*Vitex sp*	1	0.1
	Inc1	7	0.7
	Inc2	12	1.3
	Inc3	14	1.5
	Inc4	3	0.3
	Inc5	6	0.6
Unkwon	Inc6	2	0.2
Record		958	100.0

3.4. Seasonal Consumption of Fruit by Species

From the 26 elephant trials followed, 26 fruit species were identified within 54 dung piles analysed. Only two species *Omphalocarpum procera* and *Swartia fustiloides* were recorded in 15 dung piles. This record has been followed by *Breniana brieyi* in 11 dung piles and *Anonidium mannii* within 10 dung piles. The majority of species were present less than 10 times. The number of seed recorded in each dung pile by month year was not significant

(Pearson Chi-Square χ^2 = 2.609, df = 273, P = 0.691 NS). Some fruit species consistently found in the diet were also consumed in higher quantities in some months than others. Two clear outliers in this general trend (Fig. 6) were *Anonidium mannii* and *Irvingia tenuinucleata* (syn: *Irvingia wombulu*), which were consumed in few months, the maximum presence of seeds in dung piles for a single month was extremely high (142 and 115 seeds respectively). Both these species had discrete temporal fruiting periods with high forest wide abundance. Data from these two years record by season show that there is no regular pattern on number of fruit species from the dung piles. The high number of seeds was recorded the first year in March 2013 and November 2013, and the second year only in June 2014 as shown in the figure 7.

Figure-6. Number of seeds within the dung piles

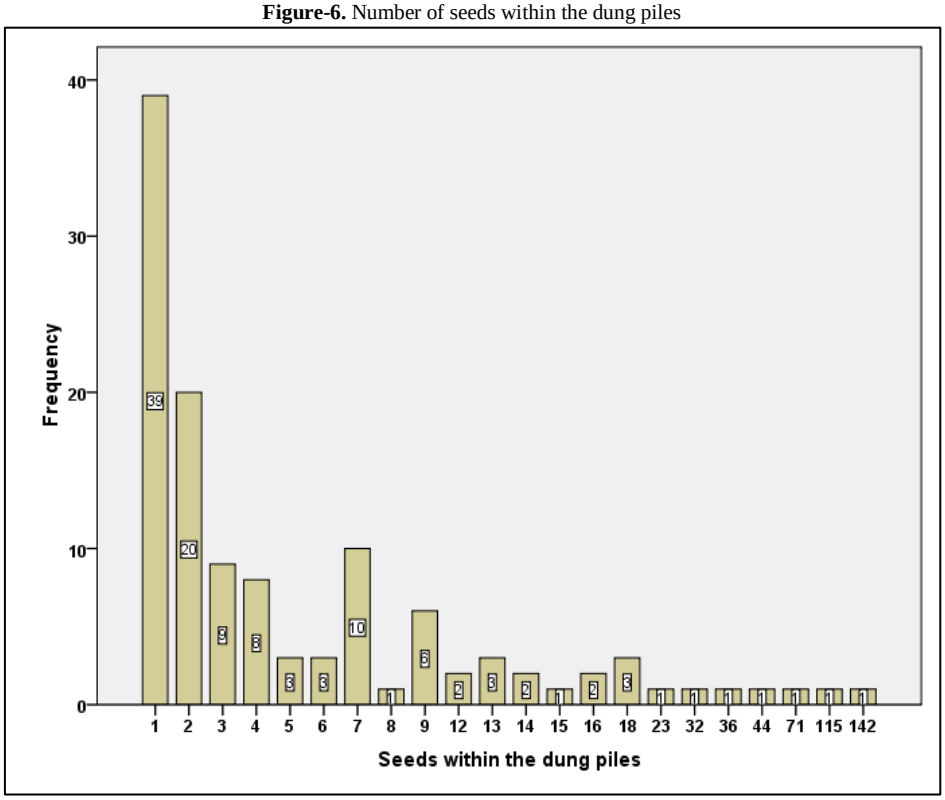
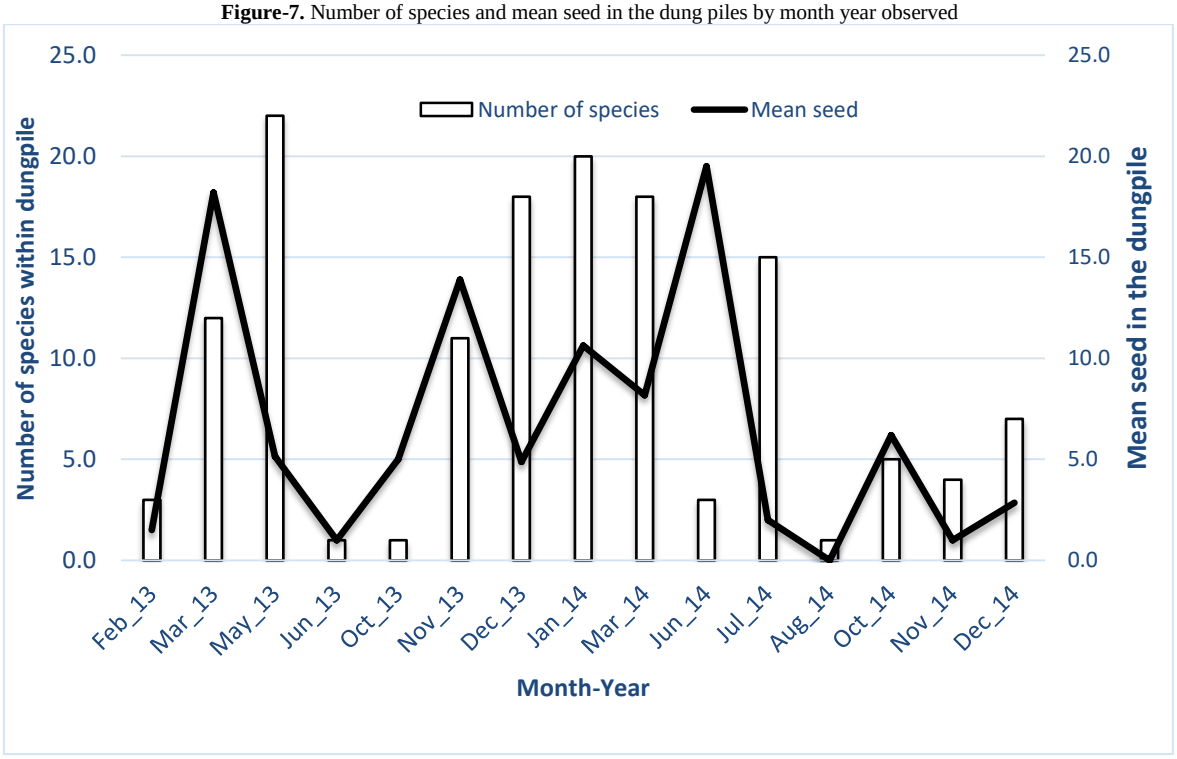
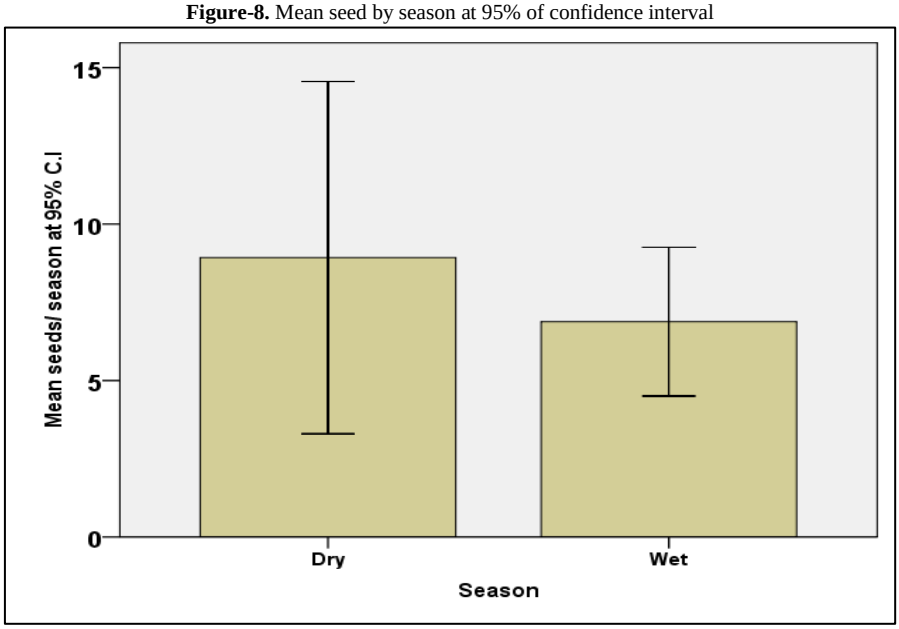


Figure-7. Number of species and mean seed in the dung piles by month year observed



Roughly, there is seasonality in the fruit species counted in the dung piles during these two years (Mann Whitney test U=1.87, p=0.03). Although the slight trend is that elephants consume more fruit species during the dry season (56.47%) than the wet season (43.53%) (Fig. 8).

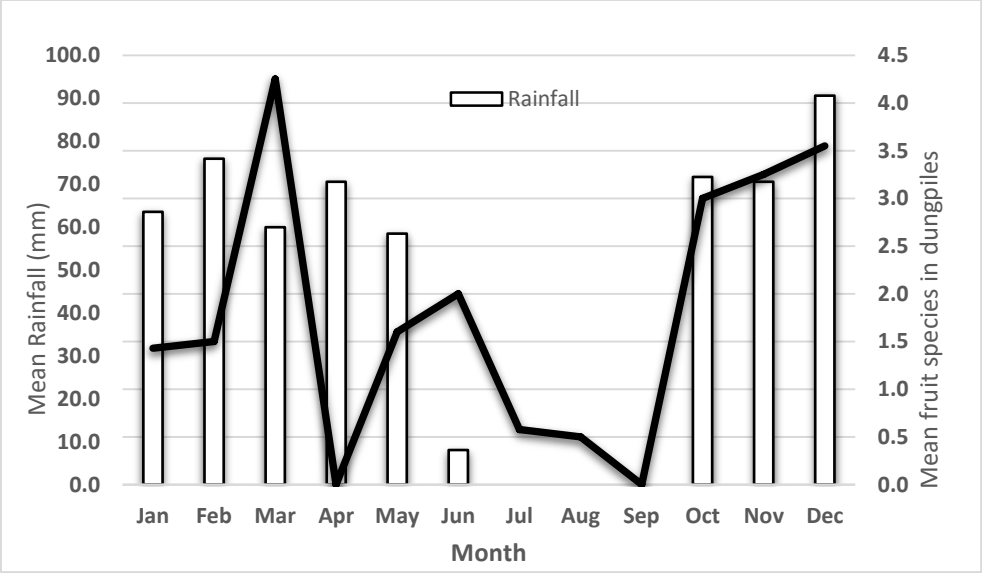
Figure-8. Mean seed by season at 95% of confidence interval



3.5. Elephant Fruit Preferences

Elephants showed strong preferences for some fruit species and avoidance of others. The extensive coverage of the survey nevertheless suggested that these species were strongly preferred. Four species (*Anonidium mannii*, *Uapaca heudoloti*, *Omphalocarpum procerum*, *Bobgunnia fistuloides*) were recorded in dung for more seasons than they were recorded on the feeding trials, which indicates that their preferences indices may be underestimates. *Anonidium mannii* was the most preferred species recorded 15 times. *Uapaca heudoloti* was observed in dung during 4 surveys and recorded in 7 dung piles. The distribution of this species must be extremely patchy, since it is one of the rarest elephant fruit trees in the Batéké forest. *Omphalocarpum procerum* fruits were also rarely seen on the ground, though this tree is considerably more common than *Bobgunnia fistuloides (*syn. *Swartzia fistuloides*).

Figure-9. Mean fruit species in dung piles by rainfall each year



According to the rainfall data collected in the MPD station from 2013 to 2014. The mean rainfall shows that there is no rain during the large dry season from June to September during these two years. Meanwhile, the maximum rainfall is 90 mm noticed in December (Fig. 9). The mean fruit species in the dung piles shows roughly the same pattern with no significance correlation (Spearman's Rank Correlation Rho = 0.522, N = 12, P=0.082) with the mean of rainfall, thus fruit species found in the diet were also consumed in higher quantities in some months than others.

4. Discussion

Forest elephant in this study area is feeding in total of 258 plant species and three animal species reported from the feeding trials. This number is lower than would be expected as main elephants feeding species in the region of Batéké Plateau. It has been mentioned the first time the presence of invertebrate in the elephants feeding selection. Comparing these data with Gretchen [7, 36], we found in common 52 species that elephants at Batéké are eating. Gretchen study was carried out in the Batéké Plateau National Park in Gabon and Blake study held in The Nouabale

Ndoki National Park in Congo. Preliminary reports of Botanic Kew Garden carried out in the same area close to Ogooué Rivers indicate high plant species diversity. This last study was held in both savanna and forest areas through the forest-savannah ecotone which exhibit higher plant species [37]. Among different tree species recorded on the feeding trials, four have a high commercial value and posted to the international wood market (Chudnoff 1984): (1) *Okoume klaineana*, (2) *Baillonella toxisperma*, (3) *Staudtia stipitata*, (4) *Piptadeniastrum africanum*.

However, in this area logging had especially exploited *Okoumea klaineana*. Furthermore, three Asiatic logging companies that exploited in this area have no management plan and lead to major habitat destructions. It is known that, logging creates roads which encourage poachers that used artificial bridge to cross river with their motorbike [38]. These poachers dwell even in their camp as results to increase levels of illegal hunting within the park. Lawlessness has been a negative impact in the surviving of elephants from severe threats as illegal killing for ivory and bush meat and habitat conversion [39]. According to the diet composition of African elephants, the savannah elephants are eating a limited number of plants from grasses and occasionally fruit, though a species list of all foods was not given. It has shown from these studies that savannah elephants selected less than 100 species [40-45]. This low diversity of foods is probably a reflection of low plant species diversity of grassland habitats. However when savannah elephants have access to rainforest with highest vegetation diversity [46], dietary increases to nearly 200 woody plants [15-17, 21]. Furthermore, forest elephants ate at least 304 food items from 230 plant species in 52 families [7, 18]. This study recorded 258 plant species grouped in 66 families from the feeding trials. Beside of plant species, elephants selected occasionally three invertebrate (bee, ant and termite) from two families. This invertebrate consummation means that elephants increase the animal protein needs. This is why; elephants are almost destroying the young tree of *Barteria* that contained the ants and several trees of *Raphia sp* and *Elais guinensis* just to catch coleopteran larvae which are on it. In the same vision, elephants have seen to eat termite soil for minerals [9] in the north of Congo. Actually, these elephants need clays that they eat termited soil and also termite for animal protein matter. Fruit species found in 54 dung piles were represented by 26 plant species grouped in 16 families. It is difficult to compare and contrast diet lists across forest sites since the duration and intensity of research has varied between sites. Some studies run for less than 17 months [15-17] to more than 24 months [7, 18].

This study spent only 14 months over 2 years data collection in which field mission were not standardized suggesting the actual number of food species consumed lower than the current list indicates. According to the plant part selection by life form, trees (36%) and shrubs (35%) were the most heavily browsed, though effort in habitat was different. The Liana (15%) is also preferred by elephants because of the high quantity of water. Almost during the dry season, elephants diet is basically composed more by herbs (12%) that are available throughout the forest habitat. Although that fern (2%) are very rare in the forest habitat, elephants ate them when available.

The most dominant species in the diet along the feeding trials were *Grossera macrantha* (29) and *Strombosiopsis tetandra* (21) from the total record. It is probable that elephant's usually detected preferred species even if the forest is very thick. These species are more used by elephants may be for their availability in the habitats and also they are eating them intentionally. Herbs constitute a small proportion of diet never exceeding 13% of feeding events, and were an insignificant part of the diet in the mixed terra firma forests. Finally, ferns (Pteridophytes), which are generally rare in the Batéké forest except in highly localised patches in deep swamp, never constituted more than 3% of food selection. Again, these results are difficult to compare with those from studies in savannahs because of elephant feeding behavior and habitat. However, Tchamba [45] claimed that diet selection of elephants in the savannahs of Cameroon is strongly influenced by habitat type. In the same time, Blake [7] thought that in mixed vegetation elephants ate grass 7 times more frequently than plentiful browse items. Field [47], used time spent feeding on each plant life form as a measure of frequency of selection found that a considerable variation with rainfall and habitat. During the dry season elephant ate grass over 90% of time whereas in the wet season grass feeding decreased from 40% of the diet [41]. Grass was rarely fed by elephant in Ndoki forest, but was readily consumed during the dry season a long of rivers [7]. Across all plant life forms, leaves constituted over 80% of feeding events, being highest in shrubs, and when leaves and wood (terminal twigs) are combined. These two plant parts accounted for over 90% of feeding signs from trees and shrubs. Considerably more wood from trunks was consumed for lianas than trees, suggesting that liana wood was softer and contained more liquid than the wood of trees. Lianas of several genera (e.g. *Cissus*, *Landolphia*) contain copious quantities of water, which are used as a water source by human. Elephants frequently masticated on the stems of these plants, spitting out the fibers when the liquid was spent.

It has been found in this study that elephants prefer bark feeding of large trees as mentioned by White, *et al.* [18] in Gabon. However, Short [16] found that bark was relatively infrequently selected by elephants in Ghana. Furthermore, in Ndoki Forest, bark made up 25% of feeding events on trees and 7% for lianas [7]. Roots of tree and herbs were a minor part of the diet. It has been seen that elephant heavily ate all life form of *Petersianthus macrocarpum*. We thought that elephants are eating some species to resolve other matter as disease. However, humans drunk the stem bark of *Petersianthus macrocarpum* against malaria, hemorrhoids [48], incurable ulcerate wound, boils and pain [49, 50]. Furthermore, analgesic effects of ellagic acid which is responsible for the antinociceptive effects have been demonstrated in experimental models of pain [51, 52].

The selection of plant parts from herbs and ferns was also dominated by leaf and leaf+stem feeding, also all the plant especially for the ferns. It is established that forest elephants are highly frugivorous compared to savannah elephants [7, 14, 17-19]. Wing and Buss [21] and Chapman, *et al.* [22] showed that savannah elephants ate abundant fruits when available in forest. White, *et al.* [18], found that elephants in the Lopé Reserve ate 72 fruit species present in 82% of dung piles. Powell [19], identified 93 species of germinating seedlings in dung piles. Blake [7] found that elephants consumed at least 96 fruit species in 94.4% of dung piles. This study confirmed that forest elephants are frugivorous in which fruit species have been found in 54 dung piles were represented by 26 plant

species grouped in 16 families. The data show that some species of fruit heavily consumed provide elephants with indispensable items in the diet, such as *Anonidium mannii, Omphalocarpum procera, Uapaca heudolotti, Irvingia wombulu* and *Swartzia fustiloides*. Elephants in Batéké area are opportunistic for certain fruit species. The majority of fruit species were recorded in dung in just one or two months of the study. The wide range of species consumed allows elephants to exploit at least some fruit throughout the year. Rainfall was a good predictor of both the numbers of species consumed per month, and the number of species per dung pile. Thus, in low rainfall periods elephants must increase their consumption of browse to compensate deficit of fruit availability. Given the spatial distribution is determined from the fruit-rich versus browse-rich areas across the Batéké forest.

5. Conclusion Suggestions

The results of the present study revealed that:

- Batéké elephants had the most diverse diet from vegetable and animal. Batéké elephants ate a variety of plant foods including leaves, bark, wood, stems, roots, and fruits. A minimum of 261 species (258 plant species and 03 animal species), from 68 families, involving 815 plant parts were consumed throughout the elephants feeding trials. Beside of these plants elephants ate occasionally three invertebrates (ant, bee and termite). Trees and shrubs accounted for the majority of food species (36% and 35% respectively). Lianas made up 15% of species. Herbs and ferns were less recorded respectively (12% and 2%). Leaves were the most frequently consumed items and also the most diverse, with at least 588 plants recorded as food. Barks from 23 tree and liana species were also consumed.
- The remains of at least 26 species of fruit from 16 families were identified from dung piles. Fruit remains were recorded in 81% of 54 dung piles analysed over nearly two years. Species of both Sapotaceae and Caesalpiniaceae were recorded in over 10% of dung piles (15.0% and 10.7% respectively). Three seeds of fruit were more recorded as *Anonidium mannii* (26.3%), *Uapaca heudelotii* (15.1%) and *Irvingia wombulu* (12.1%) that elephants preferred more than others. Fruit consumption was low during dry period but became a major part of the diet as fruit availability in forest increased. It has been shown that number of fruit species per dung pile, and the total number of fruit species consumed per month, were significantly positive correlated with rainfall.

Strong conservation measures are needed to save what is can be saved. More research is needed to fully document the biodiversity of the Ogooué Leketi National Park, especially detailed botanical studies in the all area.

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