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Research Article

Feeding Ecology of Bonobos (*Pan Paniscus*) Based on Abundance of Plant Food, Displacement and Feeding Time in Luikotale Forest, RDC

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Abstract

This study on bonobo feeding ecology was carried out at the Luikotale field station in the southwest of Salonga National Park, Democratic Republic of Congo. It is based on direct observation of habituated bonobos. The purpose of this study is to understand the factors affecting bonobo ranging using the optimal foraging theory, based on abundance of feeding trees, feeding time, and the fruits and leaves that bonobos consume. We collected 173 plants (26 species, 14 families). From the census, we recorded more than 8 species in Ceasalpiniacea. The top 5 species, *Dialium corbisieri* (20,80%), *Dialium gosweileri* (20,23%), *Annonidium mannii* (16,76%), *Dialium angolense* (6,35%), and *Hymenostegia mundungu* (5,78%) accounted for nearly 70% of feeding trees. Bonobos traveled an average of 1.4±0.54 km per day. They spent 80% of the total feeding time in the 5 trees: *Dialium corbisieri, Treculia africana, Dialium angolense, Dialium gosweleri,* and *Annonidium mannii*. More than 73% of feeding time was conducted in feeding seeds. The average travel distance between feeding trees increases with tree size, and the feeding time increases with density of trees visited. The nutritional analysis showed that *Tabernaemontana crassa* and *Annonidium mannii* are the species with the highest protein values and carbohydrates while *Treculia africana* is the species with the highest protein value and energy. These results suggest the choice of foods by bonobos and their ranging do not correspond well to their optimal energy gains. We also consider the relationship between food types, and protein and carbohydrates composition with body composition and fitness.

Keywords: Optimal foraging theory, Bonobos, Feeding trees, Fruit selectivity rate, Feeding time

Introduction

Feeding ecology is a fundamental interaction between an animal and its environment; most ecological aspects in the wild are related to nutrition. For example, populations dynamics and regulation, mating systems, habitat use, predator-prey interaction. Nutrients, particularly energy composition, sets constraints within which animals must operate [1]. Nutritional ecology is one of the important factors in primate conservation. Protein is an important nutrient when explaining the nutritional ecology of primates, but the protein quality depends on its composition in amino acids [2-4]; because animals find these acids in their plant foods, primates in the wild, like bonobos, place a premium on those foods. These primates need protein, glucids, and fiber for their overall nutritional fitness. For nutritional analysis, the higher the DNF the less digestible the specie [5]. That knowledge allows us to turn toward adequate primate protection and conservation. It also helps us to better understand what kind of meals is linked to primates. According to [6] the author of Optimal Foraging Theory, that "animals seek their food to maximize their contribution of energy per unit of time, and he specifies the behavioral strategy as a decision rule which allows individuals to maximize their fitness". Thus, individuals select resources with a high nutritional and energetic level, or with a chemical composition that is digestible or responding to therapeutic needs. In this theory, animals have time to invest in looking for food, can do it alone or in groups and choose food with high nutritional quality. Also, when animals travel for looking for food, they dip into energy reserves, which must be equitably replaced by foraged foods [7].

Primate nutritional ecology involves interaction between the environment and a primate's nutritional intake, and the individual's resulting physiological state. It is a diverse field that includes physiology [8], morphology [9], ontogeny, growth, development [10], and ecology [11]. Underpinning all aspects of nutritional ecology is the need for individuals to procure appropriate quantities of some of macro- and micro-nutrients from their habitat. There are a number of methodological approaches that can be used more extensively than at present by primate nutritional ecologists attempting to answer questions regarding nutritional goals. Most field studies on the feeding ecology of wildlife are focused on nutrients and the optimization of macro-element intake because habit productivity levels determine the connection between efforts provided per individual for feeding and the nutritionals benefits he gains. Feeding ecology showed that primates prefer, first, vegetal foods because fruits are the principal food of primates. Preliminary study on bonobos by Lomako [12], suggested that bonobos' diet consisted of high levels of macronutrients. That high quality of food was explained by strong selectivity for ripe fruits [12]. The Optimal foraging theory is linked to nutritional aspects of primate foraging because animals develop strategies to acquire more energy than they expend. These strategies could extend feeding time on a Bonobo Feeding Tree (bft), or reduce the distance between two foods, eating foods with high nutritional quality.

In this study, we focused on two factors: feeding time and distance between bonobo feeding trees which modulated the movement pattern of bonobo in the Luikotale forest. The data was collected during the early years of habituation. We recorded feeding time and distance between bonobo feeding trees to determine the most important factor for the basis of bonobo foraging and we analyzed the nutrients to determine the fruit selectivity rate and fruit digestibility rate, which is related to the nutritional quality of a bonobo feeding tree.

Methods

Study Site

Fieldwork was conducted at Luikotale, Salonga National Park, and Democratic Republic of Congo (2° 45.610'S, 20°22.723' E) [13], with the annual average temperature between 20,7°C and 26,9°C and rainfall between 1800 and 2000mm [1]. The site is located south of the Lokoro River, close to the border of Salonga National Park, Democratic Republic of Congo [13]. Information on vegetation, forest productivity and climate has been published [14,1] (Figure 1).

Figure 1: Map of study site.

Data Collection

The present study was carried out from direct and indirect observations of food eaten by bonobos (Figure2a and Figure2b). From July to December 2009, bonobos were followed from morning nest to night nest in order to collect and record the samples on and under Bonobos Feeding Trees (bft). Circumference of the feeding trees at breast height (cbh>10Cm) was also measured (Figure 2a).

Bonobos feeding trees were identified by the local name (Nkundo language) with help of local field assistants and information from Luikotale data records [13] we measured the height of tree with an altimeter, the circumference and the diameter of crown of each tree were measured with a ribbon meter. For each feeding scan, we recorded party size that fed on the ground and the canopy, or both. Scientific names were done at the laboratory of Max-Planck-Institute/Institut National de Recherche Biomédicale and at the herbarium of Institut National d'Etude et de Recherche Agronomique, at University of Kinshasa Herbarium (Figure 2b).

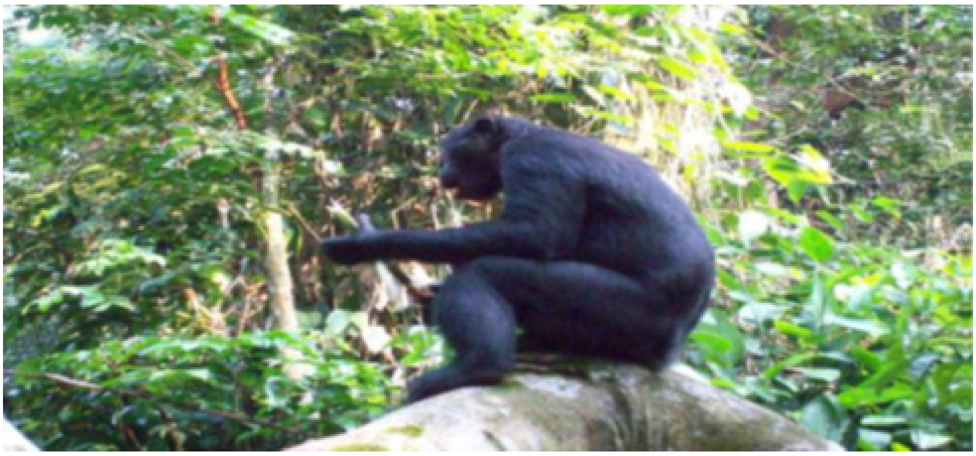

Figure 2a: Bonobos feed Palisota ambigua in the Luikotale forest. (Photo SP Ndimbo).

Figure 2b: Material used in the field study (Photo SP Ndimbo).

For each tree, we also calculated a relative density and volume of the crown using the formula

$$V = \frac{1}{3} \times \pi \times r^2 \times h. = 1/12\pi D^2 H_{tc}.$$

$$(D=2R, R=D/2)$$

Where D means diameter of tree and Htc means Height of Tree Crown. The distance between foods resources were recorded by GPS and the feeding time by scan sampling at 2-min intervals.

After collecting fruits and leaves from the forest, they were sent to Max-Plank-Institute lab at National Institute of Bio-medical Research and to Institut National d'Etude et de Recherches Agronomique/Université de Kinshasa, in Kinshasa, for identification. The abundance of bft was calculated by evaluating the density of each plant consumed, using the formula: Density =Number of tree (Nt)/Km^2. The curve of the frequency was given. Then, we calculated the selectivity rate of bft by the following formula.

Sel: Nt / bftmin

Where Nt mean Number of tree of bft given, and bftmin mean feeding time of the same bonobo feeding tree.

We also evaluated the correlation between feeding time and distance between bft, density and feeding time, bonobo feeding tree size and density. Due to missing samples, we were able to use only 16 species in our nutritional analysis.

a. Distance Between Bonobo Feeding Trees

The distance between bft is the average of distance between plants. We calculated the sum of all plants for each specie (Smd) and the average of distance per day.

b. Feeding Time

We calculated the feeding time of bonobos using instantaneous party scan sampling at 2-min intervals [15]. Using data from the GPS and we calculated average distances travelled and marked the GPS waypoint.

c. Nutritional Analysis

To complete study of bonobo feeding strategies, samples were lyophilized using Christ ALPHA 1-4 LSC/ALPHA 2-4 lyophilizator before sending them to the Institute for Zoo and Wildlife Research at Berlin (Germany) for nutritional analysis. Macronutrients and energy were evaluated by using the methods described by Hohmann and Ortmann [1,16]. The dry matter (the percentage of forage that is not water) was determined by drying a portion of the sample at 105 °C overnight and weighting it before and after drying. Crude proteins were proportioned by Kjedahl methods [17,18], for this analysis, samples were digested in a mix containing sulfuric acid and a catalyst. A concentrated sodium hydroxide solution was then added, followed by a steam distillation. The distillation is finally titrated with HCl. The amount of acid neutralized is an estimate of the amount of nitrogen in the sample. The lipids were assessed by petroleum ether extraction (soxlhett), the Standard method, consisting of extraction of samples kiln dried with ethyl ether. Calculation was done by the difference in the weights before and after the extraction. The glucids were proportioned from cellulose and hemicellulose using the analysis of fibers by detergent. Detergent fiber Analysis was performed after *Van Soest, et al.,* [19] and provides a rapid stepwise procedure for determining soluble cellular components as well as the soluble cell wall matrix and its major subcomponents: hemicellulose, cellulose, and lignin. Cell contents and soluble components were estimated by boiling the sample in neutral detergent solution. The residue Neutral Detergent Fiber (NDF) contains hemicellulose, cellulose and lignin. The residue Acid Detergent Fiber (ADF) only contains cellulose and lignin. The last step extracts cellulose by acid hydrolysis and burns the sample to ash at 550 °C [1]. Energy content of each sample was determined by bomb calorimetry.

Results

Abundance of Bft Used

Floristic Data:

The floristic data in Table 1 are that of 173 trees collected and belonging to 26 species, 20 genera and 16 families as following: (Table 1).

Table 1: Floristic list of bonobos feeding trees eaten in Luikotale forest from July to December 2009.

Family	Scientific Name	Part Eaten	Local Name (Lokundo)
Annonanceae	*Annonidium mannii* (Oliv.)Engle.&Diels	Seed	Bodzingo
Apocinaceae	*Tabernaemontana crassa* Aschers ex Engl	Leaves	Bonkasa ya dzamba
Cecropiacae	*Musanga cecropioides* R.Br.	Fruits	Botumbe
Chrysobalanaceae	*Parinari excelsa* Sabine	Pulp (mesocarp)	Bodzilo mpongo
Clusiaceae	*Mammea africana* (Sabine)Oliv	Pulp (Mesocarp)	Bokodzi
Ebenaceae	*Diospiros Hoyleana* F.White	Fruits	Ikungu
	D. Melocrpa F.White	Fruits	Manza
Fabaceae/Caesalpinoidae	*Dialium angolensis* Wlw.ex Oliv	Seeds	Maku pembe II
	D. gosweilleri Bak.F	Seeds	Maku pembe I
	D. corbisieri Staner	Seeds	Maku rouge
	Cynometra sessiliflora Hams	Leaves	Eaka
	C. pedicellata De Wild	Pulp (Mesocarp)	Nzau
	Hymenostegia mundungu (Pellegr.) Leonard	Seeds	Botuna
	Scorophleus zenkeri Harms	Seeds	Bopidzi
	Schotia romii De Wild	Leaves	Kfumo
Fabaceae/Mimosoideae	*Parkia bicolor* A. Chev	Seeds	Lomama
Irvingiaceae	*Irvingia gabonsis* (Aub.Lecompte ex O'Rorke) Baill	Pulp (Mesocarp)	Boseki ya pembe
	Klainedoxa gabonensis Pierre & Engl	Pulp (Mesocarp)	Boseki ya moindo
Malvaceae	*Cola chlamydantha* K.Schum	Seeds	Bosekatende
Malvaceae	*Grewia coriacea* Mast	Pulp (Mesocarp)	Bopfumo
Moraceae	*Ficus* sp	Fruits	Lokumo
	Treculia africana Decne	Seeds	Boimbo
Sapindaceae	*Pancovia laurentii*(De Wild.) Gilg. Ex De Wild	Pulp (Mesocarp)	Botende
Sapotaceae	*Chrysophyllum lacourtianum* De Wild	Pulp (Mesocarp)	Bopambu
	Zeyherella longepedicellata	Pulp (Mesocarp)	Ilonge pambu
Vitaceae	*Cissus dinklagei* Gilg	Pulp (Mesocarp)	Botaatata

In this table, according to the number of species in each family, three groups appear: the first group contains the Fabaceae/Caesalpiniaceae family, with 8 species; the second group consists of Ebenaceae, Irvingiaceae, Sapotaceae, and Malvaceae's families with two species each; and the last group consists of Annonaceae, Apocinaceae, Cercropiaceae, Chrysobalanaceae, Clusiaceae, fabaceae/Mimosoideae, Sapindaceae and Vitaceae's families with 1 specie each.

Abundance of Bft:

Because we did not use the monthly fruit abundance, rather, we recorded only trees which had a cbh >10 cm (Table 2). Table 2 shows that on 173 trees sampled, 26 were seeds (14, 20%), 143 were mesocarps (78,14%), 11 were leaves (6,01%) and 3 were whole fruits (1,63%). Dialium gosweileri and Annonidium mannii were eaten for about five months, Dialium corbisieri and Scorodopleus zenkeri were eaten for about four months, and Dialium angolense was eaten for about three months; however, the last species were about two or one month's (Table 2).

Table 2: Density of bft eaten by bonobos.

Species	Number of Tree (Nt)	Density of bft Nt/km²	%
Dialium corbisieri Staner	36	0.72	35.66
Dialium gosweileri Bak. F	35	0.7	14.08
Annonidium mannii (Oliv.) Engl.& Diels	29	0.58	9.76
Dialium angolense welw.ex Oliv	11	0.22	10.42
Hymenostegia mundungu (Pellegr.) Leonard	10	0.2	6.62
Scorodophleus zenkeri Harms	9	0.18	2.8
Cissus dinklagei Gilg	5	0.1	4.2
Schotia romii De Wild	5	0.1	1.72
Tabernaemontana crassa Aschers ex Engl	5	0.1	0.87
Chrysophyllum lacourtianum De Wild	4	0.08	1.08
Mammea africana (Sabine)Oliv	4	0.08	1.38
Parinari excelsa Sabine	3	0.06	0.71
Treculia africana Decne	2	0.04	6.47
Ficus sp	2	0.04	0.27
Pancovia laurentii (De Wild.) Gilg. Ex De Wild	2	0.04	0.53
Musanga cercropioides R.Br.	1	0.02	0.02
Irvingia gabonesnis (Aubr.Lecompte ex O'Rorke) Baill	1	0.02	0.23
Klainedoxa gabonensis Pierre & Engl	1	0.02	0.18
Diospiros hoyleana F.White	1	0.02	0.15
Zeyherella longepedicellata	1	0.02	0.38
Grewia coriacea Mast.	1	0.02	0.42
Parkia bicolor A.Chev.	1	0.02	0.67
Cynometra sessiliflora Hams	1	0.02	0.25
Cola chlamydantha K.Schum.	1	0.02	0.71
Diospiros melocarpa F.White	1	0.02	0.1
Cynometra pedicellate De Wild	1	0.02	0.32
Total	**173**	**3.46**	**100**
Standard Deviation		**0.21**	

Concerning the numeric importance of species in Table 2, five species have high number: Dialium corbisieri with 36 trees (20,80%), Dialium gosweileri with 35 trees (20,23%), Annonidium mannii with 29 trees (16,76%), Dialium angolense with 11 trees (6,35%) and Hymenostegia mundungu with 10 trees (5,78%). The cumulative frequency (Figure 3) showed a decreasing curve, it means that species with a high percentage of trees dominated. (Figure 3).

Distance Traveled by Bonobos

During the present study, the total foraging distance covered 82.333km, with an average of 1.4±0.54km per day. Where Dialium corbisieri, Dialium goseilleri and Annonidium mannii were the species for which bonobos traveled the greatest distances (Table 3).

Feeding Time

In general, bonobos spent 73270,80 minutes on all bft collected, with an average of 423,52 minutes per tree. Some of them have occupied the top 5 of food eaten in the study area. We have *Dialium corbisieri* with 2332, 25 minutes (31,84%), *Treculia africana* with 13668 min. (18,65%), *Dialium angolense* with 7795,15 min. (13%), *Dialium gosweileri* with 9561 min. (10,63%) and *Annonidium mannii* with 5256 min. (7,17%). In additional, we calculated the selectivity rate among bonobos feeding trees. It appears that *Treculia africana, Dialium angolense* and *Dialium corbisieri* are the most selective foods that bonobos eat (Table 4). Of the foods eaten, mesocarps represent 64%, leaves represent 20%, and seeds represent 15% (Table 5). The correlation between feeding time and the distance (Figure 3) showed a negative link, that means bonobos reduce the distance between bfts increasing feeding time (i.e they maximize the feeding time by eating in trees in close proximity to one another (Figure 4).

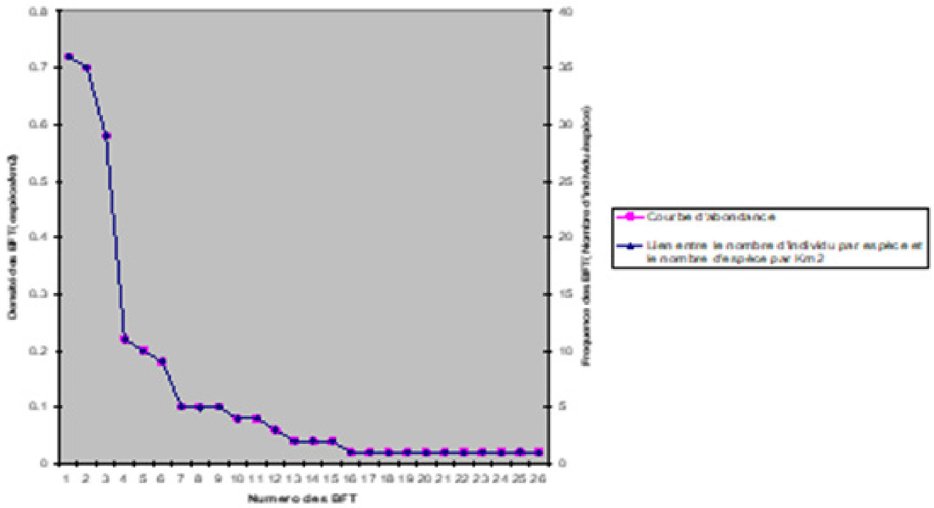

Figure 3: Cumulative frequency of bft.

Table 3: Average distances traveled between bft.

Species Exploited	Nbr of Tree (Nt)	Smd(m)	Avg_Distance(m)
Annonidium mannii (Oliv.) Engl.& Diels	29	15913	568.32±864.98
Chrysophyllum lacourtianum De Wild.	4	5501	1375.25±115.55
Cissus dinklagei Gilg.	5	2453	490.60±276.57
Cola chlamydantha K.Schum.	1	0	0.00±0.00
Cynometra pedicellate De Wild	1	648	648.00±468.00
Cynometra sessiliflora Hams	1	834	834.00±834.00
Dialium angolense welw.ex Oliv.	11	1207	109.72±192.01
Dialium corbisieri Staner	36	22866	635.16±850.90
Dialium gosweileri Bak. F	35	14333	409.51± 591.80
Diospyros hoyleana F. White	1	0	0.00±0.00
Diospyros melocarpa F. White	1	2400	2400.00±2400.00
Ficus sp	2	495	350.00±350.00
Grewia coriacea Mast.	1	743	743.00±525.38
Hymenostegia mundungu	10	2511	251.10±299.02
Irvingia gabonesnis (Aubr.Lecompte ex O'Rorke) Baill.	1	19	19.00±19.00
Klainedoxa gabonensis Pierre & Engl.	1	0	0.00±0.00
Mammea africana	4	1709	427.25±523.64
Musanga cercropioides R.Br.	1	720	720.00±238.07
Pancovia laurentii (De Wild.) Gilg. Ex De Wild	2	16	8.00±7.07
Parinari excelsa Sabine	3	1757	591.66±876.00
Piptadeniastrum africanum	1	2600	2600.00±2600.00
Schotia romii De Wild.	5	1655	331.00±376.26
Scorodophleus zenkeri Harms	9	2216	246.22±238.07
Tabernaemontana crassa Aschers ex Engl.	5	1552	310.40±307.21
Treculia africana	2	167	14.50±28.57
Zeyherella longepedicellata	1	18	18. 00±18.00
Total	**173**	**82333**	**1400.69±542.33**

Note*: Nbre: Number;

Smd: The sum of distances;

avg_distance: Average of distances.

Table 4: Cumulative time of feeding frequency and selectivity rate of bft.

N	Scientific Name	n	Nt	bftmint(min)	BFTmin_avg(min)	Sélectivité Rate (Nt/bftmin)
1	*Annonidium mannii* (Oliv.)Engl.& Diels	28	29	5256	181.24±212.62	0.0055
2	*Chrysophyllum lacourtianum* De Wild.	4	4	792	198.00±193.44	0.0051
3	*Cissus dinklagei* Gilg.	4	5	2032	406.4±414.58	0.0025
4	*Cola chlamydantha* K. Schum.	1	1	340	340.00±340.00	0.0029
5	*Cynometra sessiliflora* Hams	1	1	120	120.00±120.00	0.0083
6	*C. pedicellata* De wild	1	1	168	168.00±168.00	0.006
7	*Dialium angolense* Welw. Ex Oliv.	11	11	7795.15	708.65±770.51	0.0014
8	*D. corbisieri* Staner	38	36	23332.25	648.12±774.39	0.0015
9	*D. gosweileri* Bak.F	37	35	9561	273.17±454.28	0.0037
10	*Diopyros hoyleana* F. White	1	1	112	112.00±112.00	0.0089
11	*D. melopcarpa* F. White	1	1	10	10.00±10.00	0.1
12	*Ficus* sp	2	2	150	75.00±97.58	0.0133
13	*Grewia coriacea* Mast.	2	1	176	176.00±176.00	0.0057
14	*Hymenostegia* mundungu	10	10	4788	478.80±771.82	0.0021
15	*Irvingia gabonensis* (aubr. Lecompte ex O'Rorke) Baill.	1	1	154	154.00±154.00	0.0065
16	*Klainedoxa gabonensis* Pierre & Engl.	1	1	108	108.00±108.00	0.0093
17	*Mammea africana*	4	4	687	171.75±89.84	0.0058
18	*Musanga cecropioides* R.Br.	1	1	2	2.00±2.00	0.5
19	*Pancovia laurentii*(De Wild.) Gilg. Ex De Wild	2	2	261	130.50 ±65.76	0.0077
20	*Parinari excelsa* Sabine	3	3	546	182.00±153.01	0.0055
21	*Parkia bicolor*	1	1	140.4	140.40±140.40	0.0071
22	*Schotia romii* De Wild.	5	5	512	102.40±83.79	0.0098
23	*Scorodophleus zenkeri* Harms	9	9	1764	196.00±223.86	0.0051
24	*Tabernamontana crassa* Aschers ex Engl.	5	5	508	101.60±163.37	0.0098
25	*Treculia africana*	5	2	13668	6834.00±9562.91	0.0001
26	*Zeyherella longepedicellata*	1	1	288	288.00±288.00	0.0035
	Total	**179**	**173**			**0.7371**

Note*:

N=Observation number per species.

Nt: Number of trees.

bftmint: Cumulative time of the consumption of bonobos feeding tree.

avgmin: Average of time of consumption of bonobos feeding time.

Nt/bftmint: Selectivity rate of bonobos feeding time.

Table 5: Frequency of plant part eaten.

	Part Eaten (%)				
Species	Seeds	Pulp (Mesocarp)	Leaves	Wole Fruits	Total
Annonidium mannii (Oliv.)Engl.& Diels	0(0)	28(100)	0(0)	0(0)	28
Chrysophyllum lacourtianum De Wild.	0(0)	4(100)	0(0)	0(0)	4
Cissus dinklagei Gilg.	0(0)	5(100)	0(0)	0(0)	5
Cola chlamydantha K. Schum.	1(100)	0(0)	0(0)	0(0)	1
Cynometra pedicellata De Wild	1(100)	0(0)	0(0)	0(0)	1
Cynometra sessiliflora Hams	0(0)	0(0)	1(100)	0(0)	1
Dialium angolense Welw. Ex Oliv.	0(0)	11(100)	0(0)	0(0)	11
D. corbisieri Staner	0(0)	36(100)	0(0)	0(0)	36

D. gosweileri Bak.F	0(0)	15(38,46)	24(61,54)	0(0)	39
Diopyros hoyleana F. White	0(0)	0(0)	0(0)	1(100)	1
D. melopcarpa F. White	1(100)	0(0)	0(0)	0(0)	1
Ficus sp	0(0)	2(100)	0(0)	0(0)	2
Grewia coriacea Mast.	0(0)	1(100)	0(0)	0(0)	1
Hymenostegia mundungu	10(100)	0(0)	0(0)	0(0)	10
Irvingia gabonensis (aubr. Lecompte ex O'Rorke) Baill.	0(0)	1(100)	0(0)	0(0)	1
Klainedoxa gabonensis Pierre & Engl.	0(0)	1(100)	0(0)	0(0)	1
Mammea africana	0(0)	4(100)	0(0)	0(0)	4
Musanga cecropioides R.Br.	1(100)	0(0)	0(0)	0(0)	1
Pancovia laurentii(De Wild.) Gilg. Ex De Wild	0(0)	0(0)	0(0)	2(100)	2
Parinari excelsa Sabine	0(0)	3(100)	0(0)	0(0)	3
Parkia bicolor	1(100)	0(0)	0(0)	0(0)	1
Schotia romii De Wild.	0(0)	0(0)	5(100)	0(0)	5
Scorodophleus zenkeri Harms	9(100)	0(0)	0(0)	0(0)	9
Tabernamontana crassa Aschers ex Engl.	0(0)	0(0)	5(100)	0(0)	5
Treculia africana	2(100)	0(0)	0(0)	0(0)	2
Zeyherella longepedicellata	0(0)	1(100)	0(0)	0(0)	1
Total	**26(14,77)**	**112(63,64)**	**35(19,89)**	**3(1,70)**	**176**

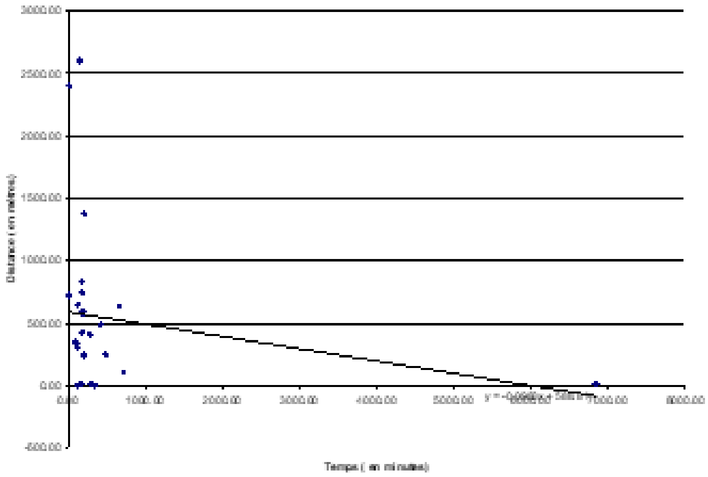

Figure 4: Correlation between feeding time and distance.

Analysis of Nutrients

Leaves, seeds, pulp (mesocarps) and whole fruits of 16 bfts were used for nutritional analysis and the results are in the (Table 6). In this table, the top five of species which have more proteins are: *Dialium corbisieri, Tabernaemontana crassa, Annonidium mannii, Cissus dinklagei*, and *Treculia africana*.

Table 6: Nutritionals values of bft.

Species	Protein (mg/g)	Glucid (mg/g)	Cellulose%	Hemicellulose %	Energy (kJ/g)	NDF %	ADF %	ADL %	DM (%)
Annonidium mannii (Oliv.) Engl.& Diels	115.9	177.68	12.31	6.455	16.86	20.685	14.23	1.925	1.2
Cissus dinklagei Gilg.	106.15	123.8	6.44	2.81	15.64	10.85	8.03	1.59	3.69
Dialium corbisieri Staner	145.7	104.35	8.1	23.35	16.32	31.965	8.61	0.51	1.8
Dialium gosweileri Bak. F	5.18	195.72	6.75	7.13	17.01	13.91	6.78	0.03	2.32
Diospyros hoyleana F. White	62.63	20.4	18.2	19.7	12.5	50	30.4	12.1	1.9

Diospyros melocarpa F. White	51.5	104.4	28.43	13.16	15.91	42.255	29.095	0.665	3.4
Ficus sp	68.4	16.59	23.43	16.53	17.98	56.64	40.11	16.68	2.1
Gambeya lacourtiana (De Wild.) Aubr. & Pellegr.	59.55	121.25	5.475	7.88	19.69	14.335	6.46	0.98	14.8
Grewia coriacea Mast.	80.2	36.76	19.88	7.79	16.09	32.81	25.02	5.14	6.55
Klainedoxa gabonensis Pierre & Engl.	23.05	146.74	8.05	7.55	17.43	16.61	9.06	1.02	0.3
Mammea africana	42.9	150.325	7.26	4.62	18.76	12.28	7.67	0.41	8.8
Musanga cercropioides R.Br.	85.3	127.6	7.615	8.105	17.16	22.735	14.625	7.01	1.8
Pancovia laurentii (De Wild.) Gilg. Ex De Wild	65.5	199.83	3.955	2.81	14.61	6.855	4.055	0.1	0.5
Parinari excelsa Sabine	82.3	0.91	15.74	15.49	32.65	50.3	34.81	19.07	2.76
Tabernaemontana crassa Aschers ex Engl.	125.2	321.92	6.08	7.64	13.5	14.575	6.935	0.85	5.2
Treculia africana	106.9	99.51	18.46	9.09	17.77	31.45	22.36	3.9	12.5

Note*: ADF: Acid Detergent Fiber; NDF: Neutral Detergent Fiber; ADL: Lignine Detergent Acide; DM: Dry Mater; %: Percentage.

The top five of species with 53.7% of glucids is *Tabernaemontana crassa, Pancovia laurentii, Dialium gosweileri, Annonidium mannii* and *Mammea africana*. The top five energetic species were: *Parinari excelsa, Chrysophyllum lacourtianum, Mammea africana, Ficus sp.,* and *Treculia africana*. The nutrient quality is given by the proportion of Prot/NDF following *Rogers, et al.,* while the digestibility rate is given by the difference between NDF-ADF, *Wasserman, et al.,* and *Chapman, et al.,* (Table 7).

Table 7: Digestibility and nutritional rate of some bft.

Species	NADF-ADF	Prot/NDF
Annonidium mannii (Oliv.) Engl.& Diels	6,45	5.6
Chrysophzllum lacourtianum	7,87	4.15
Cissus dinklagei Gilg.	2,82	9.78
Dialium corbisieri Staner	23,35	4.55
Dialium gosweileri Bak. F	7,13	0.37
Diospyros hoyleana F.White	19,6	1.25
Diospyros melocarpa F.White	13,16	1.21
Ficus sp	16,53	1.2
Grewia coriacea Mast.	7,79	2.44
Klainedoxa gabonensis Pierre & Engl.	7,55	1.38
Mammea africana	4,61	3.49
Musanga cercropioides R.Br.	8,11	3.75
Pancovia laurentii (De Wild.) Gilg. Ex De Wild	2,8	9.55
Parinari excelsa Sabine	15,49	1.63
Tabernaemontana crassa Aschers ex Engl.	7,64	8.59
Treculia africana	9,09	3.39

Discussion

Here we considered this optimal foraging theory to understanding the feeding strategies behavioral of bonobos in Luikotale forest. This study is interested in demonstrating the modulating factors in animal behavioral.

Abundance

Our investigation showed that all species were not eaten at the same time by bonobos, nor in the same month. Also, the Fabaceae/ceasalpinaceae family with eight species eaten, had the resources available for bonobo according to phenology observation (Hohmann, in press) in the period of study. According to previous studies on Herbaceous Terrestrial Vegetation (HTV) [20-25], bonobos' diet constituted of 55% fruits (mesocarps and seeds) and 14% leaves [26]. This conforms to our results, which have given a cumulative 80% fruits, and 20% leaves. However, we had collected data only on trees with a cbh<10Cm because it was difficult to measure smaller plants.

Distance Traveled

With the average distance of 1.4±0.54Km traveled for feeding, optimal foraging of bonobos depends of distance. They travel throughout much of the day looking for food. But at the moment of our study, they moved in and outside of site area; then, we could not follow them outside. That is why we have the distance traveled only inside.

Feeding Time

The results showed that bonobos spent more time feeding on Treculia africana than other species and that it has a high selectivity rate and high level of fiber ratio. It means that selectivity rates depend on feeding time. More species given are selective, the more bonobos spend time on. The great proportion of monocarps in diet of bonobos showed that they often eat this part of the plant. We showed that bonobos decrease the distance between bfts in which they spend more time to feed. This corresponds to the optimal foraging theory, which stipulates that animals maximize their feeding time by reducing the distances between trees [11]. In addition, they reduce their feeding time when the density (or abundance) of bfts increases. These results are in accordance with Optimal Foraging Theory, which stipulates that feeding time can increase when looking to the advantage of the food source. We showed that abundance, distance and feeding time would be one of the important selection factors of feeding strategy of bonobos.

Nutritional Analysis

Our results showed that five species have both high levels of the Difference between Neutral Detergent Fiber and Acid Detergent Fiber, and high proportions of protein by NDF, meaning that these plants have a high nutritional quality and are highly digestible. Bonobos choose foods with higher selectivity rate, there by acquiring higher nutritional quality and higher digestive level. *Emlen, et al., MacArthur, et al.,* and *Pianka*, *et al.,* in 1996, established for the first time the optimal theory of foraging strategy suggesting seeking the optimal prey with the least possible stress [27,28]. Individuals able to exploit their food resources in the most efficient manner have a higher survival rate, and thus better fitness. Natural selection is going to benefit them, hence their interest in adopting the best foraging strategy. The theory of optimal foraging strategy has helped to explain the strategies used by bonobos in their choice of optimal foods. In this study, we showed that the choice of foods by bonobos is motivated by the nutrient quality of food, which influences their selectivity rate. Also, according to digestibility and nutritional rates, bonobos have to travel looking for the best quality of foods. When they find it, more time is spent eating; but when the foods or their quality are not enough, they travel to other food patches or other sorts of foods [29-35].

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Conflict of Interest

None.

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