
The fruit phenology of *Musanga leo-errerae* and its importance for chimpanzee diet in Kalinzu Forest Uganda

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Abstract

This study reports the rate of fruit phenological pattern of *Musanga leo-errerae* and how it sustains the chimpanzee population better than other fruits in Kalinzu Forest Reserve. We analysed 2635 faecal samples to determine the proportion of *M. leo-errerae* by composition of fruit diet compared with other fruits eaten by chimpanzees. *Musanga leo-errerae* trees were monitored for fruit production between November 2002 and December 2004. *Musanga leo-errerae* fruit production did not vary significantly between months (ANOVA, $F = 2.0$, d.f. = 11, $P = 0.13$). The size of fruit and rate maturation varied with seasons, although fruit production was synchronous and available all year round. From the 2635 faecal samples analysed, 79.2% contained *M. leo-errerae* fruit seed. Chimpanzee diet in Kalinzu is 75% frugivorous, 37.2% of which is solely contributed by *M. leo-errerae* fruit. The continuous availability of *M. leo-errerae* fruit makes it the most important food for chimpanzees in this forest, especially during general fruit scarcity there by joining figs in importance for chimpanzee survival in tropical Africa.

Key words: chimpanzees, diet, fruit phenology, Kalinzu, *Musanga leo-errerae*

Résumé

Cet article rapporte le schéma phénologique du taux de fruits de *Musanga leo-errerae* et comment il sert à la population de chimpanzés mieux que d'autres fruits de la Réserve Forestière de Kalinzu. Nous avons analysé 2635 échantillons fécaux pour déterminer la proportion de *Musanga leo-errerae* dans la composition des fruits mangés par les chimpanzés. La production de fruits des arbres de *M. leo-errerae* a été suivie de novembre 2002 à décembre 2004. La production de fruits de *Musanga leo-errerae* n'a

pas varié significativement au cours des mois (ANOVA, $F = 2,0$; d.f. = 11; $P = 0,13$). La taille des fruits et le taux de maturation variaient avec les saisons, mais la production de fruits était synchrone et les fruits étaient disponibles toute l'année. Sur les 2635 échantillons fécaux analysés, 79,2% contenaient des graines de *Musanga leo-errerae*. Le régime alimentaire des chimpanzés de Kalinzu est frugivore à 75%, 37,2% étant couverts par les fruits de *M. leo-errerae*. La disponibilité permanente des fruits de *M. leo-errerae* en fait la nourriture la plus importante pour les chimpanzés dans cette forêt, spécialement quand les fruits sont rares; ces fruits rejoignent ainsi ceux des figuiers en ce qui concerne l'importance pour la survie des chimpanzés en Afrique tropicale.

Introduction

Musanga leo-errerae has been documented to occur in Ugandan forests like Bwindi impenetrable, Itwara and Kalinzu (Howard, 1991). Studies in Ugandan forests showed figs (Isabirye-Basuta, 1990; Tweheyo *et al.*, 2003) and terrestrial herbaceous vegetation (THV) (Wrangham, Rogers & Isabirye-Basuta, 1993; White *et al.*, 1995) as important food sources of chimpanzees during periods of scarcity. In Kalinzu, however, where figs and THV are also abundant, *M. leo-errerae* has been documented to be a fall back food for chimpanzees (Hashimoto, Furuichi & Tashiro, 2001). The aim of this study was to determine the phenology and extent of importance of *M. leo-errerae* to the chimpanzees of Kalinzu.

Although *M. leo-errerae* is endemic to western Uganda, Thomas (1991) also reported that, in Ituri forest, D.R. Congo, the density of *cercopithecus* monkeys was high in secondary forest in response to continuous fruiting of *Musanga cecropioides*. In Bossou conservation area, Guinea, fruit of *M. cecropioides* and nuts of oil palm were important fallback foods, while figs were one of the main

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foods of chimpanzees (Yamakoshi, 1998). To date, figs have been documented as staple food source for chimpanzees in most tropical forests. It has, however, been documented that other species can be important as diet components of primates because of the low densities and unpredictable fruiting pattern of figs (Gautier-Hion & Michaloud 1989; Tutin *et al.*, 1997). It was also noted that the length and severity of fruit scarcity influence the role of fallback foods, which differs with sites & years (Tutin *et al.*, 1997; Chapman *et al.*, 1999).

The change in densities and fruiting patterns could be affected by anthropogenic activities, hence a strong implication to forest management. Management of forest reserves in Uganda focuses on timber provision and a plan is underway to increase logging of timber to make it financially viable (Plumptre, Cox & Mugume, 2003). The management policies lack information on the functional role of the nontimber trees like *M. leo-errerae*. This study provides information on the biological role of such species in conservation of biodiversity for policy makers to make informed decisions about conservation of the endangered chimpanzee in particular and wildlife in general, especially in forests like Kalinzu that is under logging pressure and lots of indiscriminate, illegal uses.

Materials and methods

Study site

Kalinzu Forest Reserve lies in south-western Uganda ($0^{\circ}17'S$ and $30^{\circ}07'E$) at an altitude of 700–1840 m above sea level (Howard, 1991; Hashimoto, 1995). The Kalinzu Forest borders the Maramaganbo forest and the two form one continuous forest ecosystem with Kalinzu forming a pocket on the rift valley escarpment and Maramaganbo on the rift valley floor. Kalinzu forest reserve is classified as a medium altitude moist evergreen forest with tree species considered endangered like *Entandrophragma angolense*, *Lova swynnertonii*, *Chlorophora excelsa* and *Cordia milleni*. Twelve species of large mammals of which six are diurnal primates have been recorded (Howard, 1991). Primates include *Pan troglodytes*, *Papio anubis*, *Colobus guereza*, *Cercopithecus ascanius*, *Cercopithecus lhoesti* and *Cercopithecus mitis*. Other mammals like elephants, *Loxodonta africana* and buffaloes, *Syncerus caffer* were also recorded by Howard, but are presently scarce (Hashimoto *et al.*, 2001).

Fruit phenology of *Musanga leo-errerae* and other fruit trees

Thirty trees of *M. leo-errerae* were randomly chosen on the transects to monitor the fruiting pattern. For each fruit monitoring session, at 15-day interval, we recorded the number of young and ripe fruit in the tree above a 2×2 m horizontal area using four grades; 0, 1–4, 5–9 and ≥ 10 that culminated into fruit frequency scores of 1, 3, and 9 respectively. Sixty-four trees of other major fruit species eaten by chimpanzees were also monitored for fruit production for comparison. Secondly, *M. leo-errerae* inflorescences were randomly sampled in each tree canopy and were visited twice a week, in each visit, the presence or absence of the inflorescence sheath, number of fruits uncovered after the falling of the sheath, and the sequential diameter of the fruit until ripening were noted. Using a ladder to reach each inflorescence, the number of fruits was physically counted. The diameter of fruits was also measured using calipers.

Fruit availability

From October 2002 to November 2004, a fruit census or counting of fallen fruit was conducted on each of ten transects, every 15 days. We defined a fruit cluster as an aggregation of fallen fruit found within 2 m of each side of a transect that had fallen from one tree. When there was a large contiguous cluster of fruit that came from several trees of the same species, we divided the cluster by the number of fruiting trees. Thus, the number of clusters matched with the number of fruiting trees that dropped fruit within the census belt. The tree species, the number of fruit in each cluster and whether the fruit would be ripe or unripe (determined by majority) was recorded. The numbers of fruit in each cluster was grouped as 1–4, 5–9, or >10 . Because modal numbers of fruit for these grades were 2–3, 7–8, and about 20, we assigned a frequency score of 1, 3, or 9 respectively to a cluster of each grade. Then, we determined a fruit availability index (FAI) from the total frequency score of clusters per hectare. FAI includes chimpanzee foods only (Furuichi, Hashimoto & Tashiro, 2001), unless otherwise mentioned.

Faecal analysis

We also analysed dung samples to compute the proportion of *M. leo-errerae* fruit in chimpanzee diet as compared to other fruits, which were also recorded. Chimpanzee dung

was collected in plastic bags and washed using a laboratory sieve. A total of 2635 fresh faecal samples were analysed. Each faecal sample was marked and all seeds from different fruit species in each sample were separated from each other and from other components of the faeces. Percentage occurrence of *M. leo-errerae* seed in comparison with other species was computed. Figs seeds' were taken as one in the analysis because they could not be differentiated to individual species.

Data analysis

Spearman's correlation coefficient was used to find the correlation between fruiting of *M. leo-errerae* and rainfall and the relationship between its abundance and its consumption. The *T*-test was used to test the significance between the consumption of *Musanga* fruit and other fruits put together, and the significance between fruit availability of *Musanga* and total fruit abundance of all the other fruits.

Results

Fruit phenology monitoring of *M. leo-errerae* showed that fruit is available throughout the year. The sheath that encloses the bud develops and falls off three times a month on average. It reveals young leaves and fruits ranging from six to sixteen on each branchlet that grow to maturity roughly within 29 days. Therefore, almost every week young fruit is uncovered on every inflorescence. The rate of fruit production is higher in the dry season than in the wet season (Fig. 1). Fruit matures and ripens very rapidly in the major dry season of May–August. Although the rate of fruit production is high, these fruits are smaller in diameter than those produced during the wet season. The increase in diameter is the highest during September–October producing much bigger fruits, therefore, compensating for the smaller number of fruits per branchlet. The big and more durable fruit crops occur in the long wet season. The small, abundant but also durable fruit crops were found in the short wet season. In the major dry season, there are small quick-maturing fruits with relatively high numbers per branchlet that decline in subsequent months. The census of fruits on each inflorescence revealed that the maximum number of fruits occurred in the habitat-wide low fruiting season of January–April and the least during September–October in each calendar year, although this may vary annually depending on the monthly amount of rainfall.

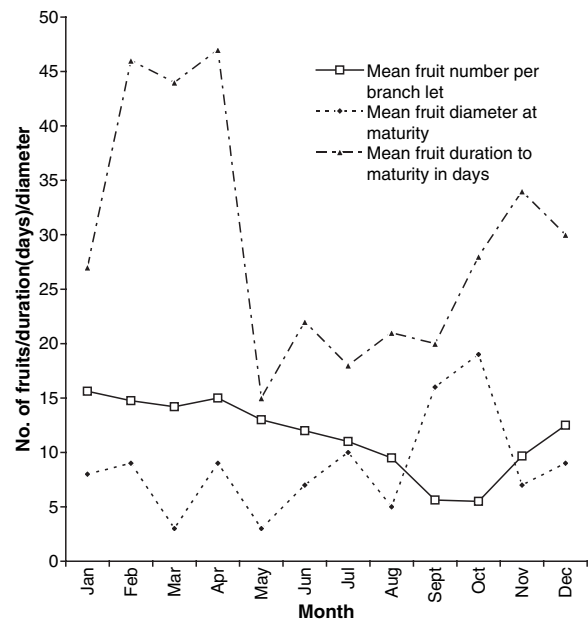


Fig 1 Monthly variation in number, size and duration of fruit crop of *Musanga leo-errerae*

Availability and abundance of fruit eaten by chimpanzees fluctuated both annually and seasonally. A seasonal difference was observed in a number of tree species in-fruit with the wet season ($n = 11$) offering more fruiting tree species than the dry season ($n = 4$). The difference between fruit abundance of all fruits from November (68%), the month with the highest, and that from July (46%) the month with the least, was 22%. The difference in fruit abundance of fruits eaten by chimpanzees between the lowest in July and the highest in September was 10%. *Musanga leo-errerae* fruited all year round (Fig. 2). The fruit abundance of *M. leo-errerae* was not the highest, but it was consumed more than other species (Fig. 3). There was a positive correlation between FAI of *M. leo-errerae* and rainfall ($r = 0.603$).

Of the total fruit diet (75%), *M. leo-errerae* contributed 37.2%, *Ficus* contributed 26% leaving only 11.8% as contribution by other fruit species like *Myrianthus holstii*, *Landolphia dawei*, *Pseudospondias microcarpa*, *Celtis durandii*, *Drypetes bipidensis*, *Craterispermum laurinum*, *Uvariopsis congensis* and *Bielshmidia ugandensis*. When statistically tested, *Musanga* fruit abundance was significantly higher than all other fruit abundance ($P = 0.053$; $t = -2.034$). In terms of frequency of occurrence in chimpanzees diet, *M. leo-errerae* was the highest in (76.2%; $n = 2007$) in all faecal samples ($n = 2635$), followed by *Ficus* (65%;

Fig 2 Monthly availability of fruits eaten by chimpanzees in Kalinzu Forest

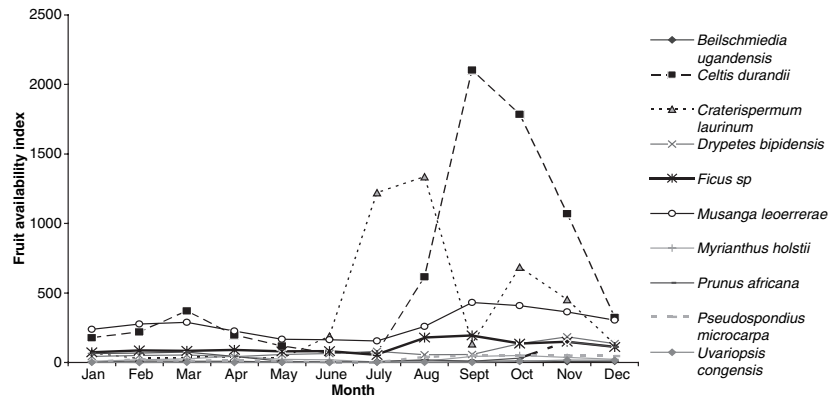
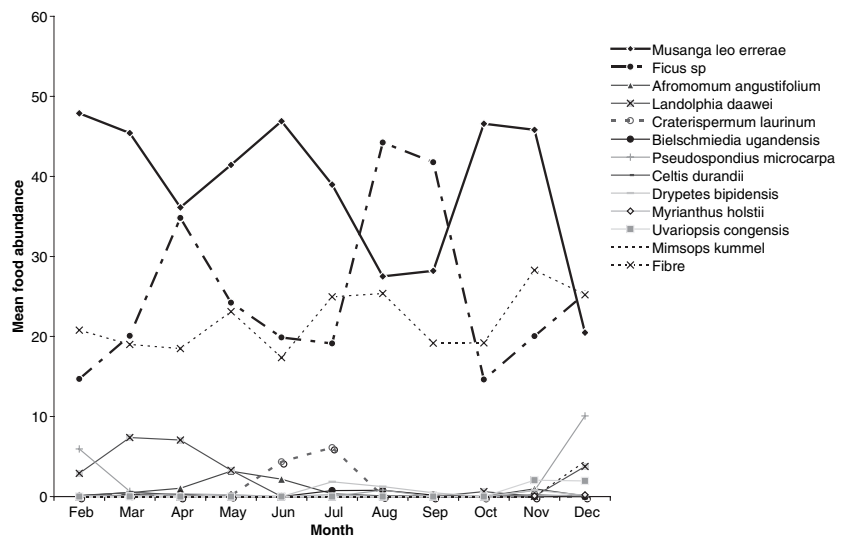


Fig 3 Monthly consumption of fruit and fibre (leaf) by chimpanzees in Kalinzu forest based on faecal analysis



n = 1714). The rest of the fruit species occurred in <25% of the total faecal samples. When ranked as ‘top four’ in chimpanzee faeces, *M. leo-errerae* occurred in all the 26 months of study in Kalinzu forest (Table 1). *Musanga leo-errerae* fruit was more abundant in both duration and quantity and was much higher in the months of general fruit scarcity, February and July. There was no correlation between the abundance of *M. leo-errerae* fruit and its occurrence in faecal samples ($r = 0.153$, $P = 0.456$).

Discussion

In *Musanga*, the type of inflorescence ensures continued growth and production of fruit throughout the year. A preliminary study by Hashimoto *et al.* (2001) also recorded a similar trend. The fall of the spathe results in the uncovering of young fruit on each inflorescence. The ants

of genus *Azteca* found in the internodes of *Musanga* stem may also play a big role in pollination. Phenology survey indicated that the number of fruit per branch let on the inflorescence was the highest in the short dry season in the months of January–March. During this time however, the fruits took the longest time to mature; therefore, the fruit crop was available for a longer period, as different branches would be at different ripening stages. The number of fruits per branchlet reduced from 15 in April to 11 in August. The quick maturity of the fruits compensated the reduction in number of fruits.

The number of fruits per branchlet was the lowest in September and October where the fruit number reduced to almost five fruits per branchlet. Fruit diameter at maturity was, however, the highest during these months; the few fruits present in these months were the largest, i.e. size compensated for the decrease in fruit number, and these

Table 1 Monthly records of fruit species as 'top four' from faecal analysis

Species	Family	Life form	Faecal samples with seed		No. month recorded as top 4	
			Mean monthly %	Total faeces	No.	%
<i>Musanga leo-errerae</i>	<i>Urticaceae</i>	Tree	76.5	2007	25	100
<i>Ficus</i> sp	<i>Moraceae</i>	Tree	66.4	1714	25	100
<i>Afromomum angustifolium</i>	<i>Zingiberaceae</i>	Herb	20	500	19	76
<i>Landolphia dawei</i>	<i>Apocynaceae</i>	Tree	26.4	330	8	32
<i>Phytolacca dodecandra</i>	<i>Phytolaccaceae</i>	Shrub	16.9	125	4	16
<i>Pseudospondias microcarpa</i>	<i>Anacardiaceae</i>	Tree	20.7	178	3	12
<i>Myrianthus holstii</i>	<i>Moraceae</i>	Tree	6.8	46	3	12
<i>Celtis durandii</i>	<i>Ulmaceae</i>	Tree	6.1	70	3	12
<i>Bielschmiedia ugandensis</i>	<i>Lauraceae</i>	Tree	2.7	38	2	8
<i>Craterispermum laurinum</i>	<i>Rubiaceae</i>	Tree	22.3	212	2	8
<i>Drypetes bipindensis</i>	<i>Euphobiaceae</i>	Tree	11.3	69	2	8
<i>Solanum terminale</i>	<i>Solanaceae</i>	Shrub	5.5	22	2	8
<i>Uvariopsis congensis</i>	<i>Annonaceae</i>	Tree	7.6	12	1	4
<i>Monodora myristica</i>	<i>Annonaceae</i>	Tree	8.7	29	1	4
<i>Mimusops bagshawei</i>	<i>Sapotaceae</i>	Tree	18.9	21	1	4

bigger fruits matured in 25–35 days. The fruits thus stayed long on the branch. Fruit size in *M. leo-errerae* was, therefore, influenced by the rainfall and temperature patterns. The fruit size was almost constant except in months of scarcity when fruit sizes were the least, but the biggest fruit occurred during the months of heavy rainfall. Fruit ripening seemed to be affected by temperature changes, ripening faster in the dry season than in the wet season. High temperatures probably ensured faster ripening, hence production of the preferred ripe fruit for chimpanzees to eat. As the phenology of *Musanga* trees in Kalinzu was not synchronized, fruit was available throughout the study area. Chimpanzees preferred *M. leo-errerae* to other fruits during the high fruiting season and depended more on *Musanga* during the low fruiting season.

General fruiting patterns were distinctly seasonal, with different peaks in both ripe and unripe fruit production. In Kalinzu forest, a higher number of species fruited during the wet season than during the dry season indicating that rainfall is one of the major factors that influences fruiting. Muhanguzi *et al.* (2003), also indicated that the monthly number of species that fruited in each forest condition was significantly related to monthly rainfall. The fruit tree species eaten by chimpanzees that fruited during the wet season did not greatly influence fruit abundance. Chimpanzees relied on them when they are abundant, but they did not play a significant role as the difference between periods of abundance and periods of scarcity was small.

Chapman, Wrangham & Chapman (1994) also documented similar seasonal patterns in plant part production in Kibale forest with almost the same altitude as that of Kalinzu and where climate is similarly seasonal. *Musanga leo-errerae*, on which chimpanzees depended mostly, did not show this varied seasonality, although there was an increase in its fruit production with rainfall. The lack of correlation between FAI and occurrence of fruit seed in faeces of *M. leo-errerae* suggests that chimpanzees actively search for this fruit; it is not opportunistically consumed. Therefore, the length of the fruiting period of such a species plays an important role in survival of chimpanzees in Kalinzu where only a limited number of species offer ripe fruit at the same time in both the dry and the long rainy seasons.

Fruit production constitutes the major food sources for frugivorous primates, and its abundance and seasonal availability may have great influences on the density of these primates (Oates *et al.*, 1990). Chimpanzees shifted ranging accordingly as evidenced by the location of faecal samples collected. Where the perennial fruit tree genera of *M. leo-errerae* occurred in the greatest density is where chimpanzees ranged most.

The relationship between fruit abundance of major fruit species and their consumption by the chimpanzees continued to show that *M. leo-errerae* out-competed the rest as it ranked topmost in the 'top four' species in chimpanzee diet. The fruit abundance of *M. leo-errerae* species was not

the highest, but it was consumed more than other fruit species. The other eleven fruit species occurred in less than 20% as the 'top four' in chimpanzee faeces. This does not mean that they were not important in chimpanzee diet, but that they might either be rare or absent most of the time or bear fruit at the same time as other fruits of high value. Other studies, with different methods, confirmed that *Musanga* is an important food source for both *Cercopithecines* and chimpanzees in Kalinzu (Tashiro, Furuichi & Hashimoto, 1999; Furuichi *et al.*, 2001). The densities of *Cercopithecine* species are strongly affected by the presence or absence of *Musanga* trees because of their small home range. *Musanga* trees form large clumps in their ranges and produce fruit continuously. *Musanga* may not affect chimpanzees' density that much, because they have a larger range but chimpanzees were reported to change their ranging patterns to utilize *Musanga* fruit (Tashiro *et al.*, 1999). This means that *Musanga* will be even more important to chimpanzees as their home range reduces as a result of forest fragmentation.

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References

- CHAPMAN, C.A., WRANGHAM, R.W. & CHAPMAN, L.J. (1994) Indices of habitat wide fruit abundance in tropical forest. *Biotropica* **26**, 160–171.
- CHAPMAN, C.A., WRANGHAM, R.W., CHAPMAN, L.J., KENNARD, D.K. & ZANNE, A.E. (1999) Fruit and flower phenology at two sites in Kibale National Park, Uganda. *J. Trop. Ecol.* **15**, 189–211.
- FURUICHI, T., HASHIMOTO, C. & TASHIRO, Y. (2001) Seasonal changes in habitat use by chimpanzees in the Kalinzu forest, Uganda: extended application of marked nest census method. *Int. J. Primatol.* **22**, 913–928.
- GAUTIER-HION, A. & MICHALOUD, G. (1989) Are figs always key stone resources for tropical frugivorous vertebrates? A test in Gabon. *Ecology* **70**, 1826–1833.
- HASHIMOTO, C. (1995) Population census of the chimpanzees in the Kalinzu forest Uganda: comparison between methods with nest counts. *Primate* **36**, 477–488.
- HASHIMOTO, C., FURUICHI, T. & TASHIRO, Y. (2001) Fruit availability and habitat use by chimpanzees in the Kalinzu forest, Uganda. Examination of fall back foods. *Int. J. Primatol.* **22**, 929–945.
- HOWARD, P.C. (1991) *Nature Conservation in Uganda's Tropical Forest Reserves*. IUCN, Gland, Switzerland and Cambridge.
- ISABIRYE-BASUTA, G. (1990) *Feeding Ecology of Chimpanzees in the Kibale Forest, Uganda. Understanding Chimpanzees*. Harvard University Press, Cambridge.
- MUHANGUZI, H.D.R., OBUA, J., ORYEM-ORIGA, H. & VETAAS, O.R. (2003) Tree fruiting phenology in Kalinzu Forest, Uganda. *Afr. J. Ecol.* **41**, 171–178.
- OATES, J.F., WHITESIDES, G.H., WATERMAN, P.G., GREEN, S.M., DASILVA, G.L. & MOLE, S. (1990) Determinants of variation in tropical rain forest primate biomass: new evidence from west Africa. *Ecology* **71**, 328–343.
- PLUMPTRE, A.J., COX, D. & MUGUME, S. (2003) *The Status of Chimpanzees in Uganda*. Albertine Rift Technical report series No. 2. Wildlife Conservation Society, Kampala, Uganda.
- TASHIRO, Y., FURUICHI, T. & HASHIMOTO, C. (1999) A preliminary report of the feeding ecology of chimpanzees in Kalinzu Forest reserve, Uganda: faecal analysis and habitat use. *Primate Res.* **15**, 179–185.
- THOMAS, S.C. (1991) Population densities and pattern of habitat use among anthropoid primates of the Ituri forest Zaire. *Biotropica* **23**, 68–83.
- TUTIN, C.E.G., REBECCA, M.H., WHITE, L.J.T. & HARRISON, M.J.S. (1997) The primate community of the Lope reserve, Gabon: diets, responses to fruit scarcity, and effects on biomass. *Am. J. Primatol.* **42**, 1–24.
- TWEHEYO, M. & LYE, K.A. (2003) Phenology of figs in Budongo forest, Uganda and its importance for chimpanzee diet. *Afr. J. Ecol.* **41**, 306–316.
- WHITE, L.J.T., ROGERS, M.E., TUTIN, C.E.G., WILLIAMSON, E.A. & FERNANDEZ, M. (1995) Herbaceous vegetation in different forest types in Lope Reserve, Gabon: implications for key stone food availability. *Afr. J. Ecol.* **33**, 124–141.
- WRANGHAM, R.W., ROGERS, M.E. & ISABIRYE-BASUTA, G. (1993) Ape food density in the ground layer in Kibale. *Afr. J. Ecol.* **31**, 49–57.
- YAMAKOSHI, G. (1998) Dietary responses to fruit scarcity of wild chimpanzees at Bossou, Guinea: possible implications for ecological importance of tool use. *Am. J. Phys. Anthropol.* **106**, 283–295.

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