

Report of 2007 field season (Jan to May, 2007) at Brownsberg Nature Park, Suriname to STINASU (Foundation for Nature Conservation in Suriname) and the Research Council of Kent State University

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Introduction: Human and non-human primates represent a small proportion of the total number of seed dispersers in tropical forests, but their relatively large body size and their ability to acquire resources before they are available to other dispersers make them essential players in tropical forest ecologies (e.g., van Roosmalen, 1985; Piperno and Pearsall, 1998). Although humans practicing modern technologies exert considerable control over plant dispersion and reproduction, early humans prior to the advent of agriculture had decidedly less control over plant movement and reproduction (Zeder, 2006). Modeling the kinds of interactions that extant non-human primates have with their plant resources may provide insight into the variability with which humans approached potential food sources. From the perspective of non-human primate feeding ecology, we know a great deal about the feeding habits of most species (see chapters in Campbell et al., 2007), but there has been much less experimental work done on the relationship between primate seed handling and seed survival (Lambert, 2002; Balcomb and Chapman, 2003). The goal of this research was to study seed handling techniques of saki monkeys in Suriname and to examine their interaction with, and possible impact on, seed dispersal and seedling demography. Biogeographical evidence on the extensive overlap of sakis and some genera of the Lecythidaceae plant family suggests that the opportunities for interactions between monkeys and fruit trees has existed for millions of years (Ayres and Prance, unpubl ms; Stevenson, 2001), thus providing an important line of evidence that bridges the present to the past.

Sakis and uacaris (genera *Pithecia*, *Chiropotes*, and *Cacajao*) are among the oldest lineages of primates in South America (Rosenberger 2002; Fleagle and Tejedor, 2002) and today, populations of bearded sakis (*Chiropotes satanas*) and white-faced sakis (*Pithecia pithecia*) are widespread throughout the Guyana Shield. Uninterrupted by drying and forest fragmentation that characterized the Pleistocene-affected habitats of the Amazon Basin, the Guyana Shield served as the dispersal center of many Lecythidaceae species for tens of thousands of years (Mori and Prance, 1987a). Lecythidaceae tree species produce large fruit whose seeds are protected by heavy husks. Seeds are dispersed by gravity or wind through a trap door mechanism at the base of the fruit (Mori, 1987). The brazil nut species (*Bertholletia excelsa*) is the largest and the most heavily used species by humans (Trivedi and Watkinson, 2004), but the family is very diverse and in some plant communities of South America, like the one in Brownsberg Nature Park in Suriname, it is one of the dominant plant families. If we are to find evidence for intensive interaction between non-human primates and their food plants, sakis appear to be the place to look for it. Sakis provide an interesting twist in this story; they are primarily seed eaters or seed predators (van Roosmalen et al., 1988; Kinzey and Norconk, 1990). Thus, if sakis tend their own gardens, it is not clear how they do it.

The goal of this project was to test three hypotheses regarding the influence of saki predation on their food sources. In addition to observing dietary composition of saki diets, we documented fruit production and measured the impacts of pre- and post-dispersal seed predation on seed fate in *L. idatimon*, a common tree found in Brownsberg forests.

The **no-impact or null hypothesis** predicts that sakis have no observable impact (positive or negative) on seed survival. This would be supported if Lecythidaceae trees produce a seasonal abundance of fruit and counteract the effect of seed predation by monkeys and other seed predators (bats, birds, terrestrial mammals).

Ayres and Prance (unpubl ms) suggested that the reduction of the Lecythidaceae fruit crop by sakis at an early stage of their development may cause the plant to divert more resources to remaining fruit. The **pruning hypothesis** predicts that the Lecythidaceae trees that are used heavily by sakis produce larger-than-average seeds, and those seeds when dropped, have higher-than-average seed establishment.

The **diplorchory hypothesis** (*sensu* Vander Wall and Longland, 2004) predicts that only some seeds in multi-seeded Lecythidaceae fruit are ingested by sakis and bearded sakis during feeding, and the rest are dropped intact and available to secondary dispersers, such as scatter-hoarding rodents (e.g., agoutis). Seeds are not expected to be larger as predicted by the pruning hypothesis; rather, the joint activity of more than one seed-disperser/predator affects the spatial distribution of seeds and impacts seed establishment (e.g., Janzen-Connell model) (Janzen, 1970).

Methods: 2007 was the fifth year of primate research at the Brownsberg Nature Park in Suriname, South America. Studies began in 2003 (Norconk, et al., 2003) with a primate census and summer research has continued annually since then.

The 2007 research period was designed specifically to focus on the fruiting of one of the most important fruiting tree families for sakis, the Lecythidaceae. Fruiting of Lecythidaceae trees take place between January and May with flowering peaking in November and December (STINASU; unpubl.). The field season of 2007 was designed to correspond to this fruiting period. M. Norconk was assisted by two volunteer undergraduate students from the US; one from the UK and two undergraduate students from Anton de Kom University. We collected three kinds of data: feeding observations from white-faced and bearded sakis (as well as brown capuchins) by following them from sleeping tree to sleeping tree and documenting feeding behavior; phenological data from Lecythidaceae trees; and hardness data from fruits opened by sakis and capuchins (Table 1).

We collected data using two methods – fruiting abundance of Lecythidaceae trees and feeding activities of primates: 1) we collected fruiting frequency data biweekly on 13 species of Lecythidaceae trees that had been identified and labeled in five diversity (100 x 100m) plant diversity plots set up by ter Steeg et al. (unpubl) in 2003 (Fig 1); 2) we calculated fruit abundance from 14 individual *Lecythis idatimon* (Lecythidaceae) trees from early to late in their fruiting cycles; and 3) we followed two habituated groups of white-faced saki to ascertain their seasonal diet (see Table 1 for specific sampling methods).

Results:

1. Diet of white-faced sakis was dominated by seeds (64%) during the sample period that consisted of the short dry season and beginning of the long wet season (Table 2). Mesocarp (discarding seeds and pericarp) and arils ranked second and third, respectively (Fig 2). These items were followed by young leaves, flowers, whole fruit (seed included) and termite dirt. The latter may have included dead termites, but no live insects were seen. This proportion of dietary items in the diet is similar to what was documented from Venezuela (Norconk, 1996, 2007, Homburg 1997) and higher than that calculated by Setz (1993). However, total fruit in the diet (i.e., whole fruit, mesocarp, and seeds) exceeds 80% of the diet in all reports.

2. Of the 445 feeding observations, 353 were on identified sources representing 54 species from 27 families (Table 2). Feeding preferences were calculated in two ways: proportion of total number of visits to feeding trees (Table 3) and total time spent feeding (Table 4). Despite the method of calculating feeding tree species rank, two Lecythidaceae tree species (*Gustavia augusta* and *Lecythis idatimon*) were found in the top 5 feeding species. Looking at the distribution of feeding species at the genus level, *Inga* was by far the most important genus with a minimum of 9 species (637 feeding minutes on *Inga* sp: 15.6%). *Inga* sp. seeds were ingested rarely; mesocarp was the primary resource provided by species of this genus.

3. We found wide variation in handling time per fruit, ranging from 0.25 fruit per minute (*Chrysobalanus icaco*) to 16 fruit/flowers per minute (*Casearia rushyane*). Sakis do not avoid fruit that require long handling times, although well protected fruit have a tendency to reduce the number of fruit that can be processed per minute ($r_s = -.50$, $n = 12$ species, ns). Average feeding bout length was positively correlated with total feeding duration/species (Fig 3) and feeding bout length accounted for about 36% of the variance. Other variables contributing to total feeding duration may include number of trees in fruit, size of fruit crop/tree, duration of fruiting cycle and, given the short term of the study, the probability of observing the entire fruiting cycle.

4. Ten Lecythidaceae tree species were monitored for fruiting and flowering during the sample period (Table 5). Most species were in the early stages of fruiting at the first sample period in mid January (14 Jan) and completed fruiting by the last sample day (28 Apr). A wide range of frequencies of Lecythidaceae trees were represented in the plots – five species were represented by fewer than 10 trees. Two plots (AKP and WK) had the highest diversity and number of trees (Table 5). Both AKP and WK plots are on slopes (c. 1 to 3 km below the plateau), compared with PP, KV, and JT that are on the plateau. ter Steeg et al. (2003) noted that these ancient plateaus tend to have thin soils compared to slopes, and deeper soils support larger trees.

5. Of the 10 species monitored for fruiting patterns, two species made up approximately $\frac{3}{4}$ of the sample and had the highest phenology scores: *Lecythis idatimon* ($n = 137$ trees) and *Eschweillera pedicellata* ($n = 152$ trees) (Table 6). There are several possible reasons for low phenology scores for several of the species in this sample. First, it is not uncommon that tropical forest trees fail to produce fruit annually. If these trees reproduced on a supra-annual cycle, 2007 may have been an off year. Second, the trees that did not produce fruit are relatively rare with only one or two trees per $\frac{1}{4}$ ha (in this sample). Tree rarity may result in fewer opportunities for pollination. Unfortunately, we were not present during flowering that probably occurred from October to December, 2006 for many of these species. Mori and Prance (1987b) found a peak in Lecythidaceae flower production in mid November at La Fumée Mountain, French Guiana. Third, several of the trees were included in the sample because they met the minimum cut-off of 10 cm DBH, but small trees of some species may be too young to produce fruit. It is not uncommon to find Lecythidaceae trees of species *Couratari stellata*, *C. multiflora*, and *L. zabucajo* among the largest trees in the forest. These giants are relatively rare however and most of the trees of these species in the plots were smaller than 30 cm DBH. Small trees may still be investing in vegetative growth and not yet mature reproductively. Of the seven *Couratari* spp. trees in the AKP lot, only the two largest (50 cm & 100 cm DBH) produced fruit. The other five *Couratari* trees ranged in size from 12 to 30 cm DBH and may be still immature trees for that species. The two species that were both abundant and big producers (*L. idatimon* & *E. pedicellata*) were clearly productive at a much smaller size (and presumably at a younger age).

However, tree size does not explain why *Gustavia hexapetala* and *Corythophora labriculata* were low producers in our sample. It is not clear why *G. hexapetala* produced so few fruit during the sample period, but we may have missed the fruiting period of both of these trees (Mori and Prance 1987b noted different flowering times for *G. hexapetala* and *G. augusta*). Several *C. labriculata*

trees were flowering in April in the plots and non-plot trees were observed to be fruiting in late April and early May. Interestingly, a congener of *Gustavia hexapetala*, *G. augusta* ranked in the top 5 resources used by white-faced sakis and produced fruit from late January to mid April. Both species of *Gustavia* (and *Corythophora*) are small, understory trees and may be on a different fruiting cycle than most *Couratari*, *Eschweilera*, and *Lecythis* species that range in height from mid-canopy to emergents.

6. Finally, we monitored the entire fruiting cycle of 14 *Lecythis idatimon* trees. For most trees, fruiting peaked from early to mid March, with one tree peaking in February (Fig 7). Larger trees produced more fruit than smaller trees (Fig 8), but we found a large degree of variation in fruit production (average 588 ± 448 fruit; range 86 to 1,587 fruit). Nine of the fourteen trees were clustered within a 50 m radius and 6 of the trees were isolates with no other *L. idatimon* fruiting trees within 100 m. The average DBH was not significantly different between trees in clusters or isolated trees, but isolated trees produced significantly more fruit than the trees in the cluster. Isolated trees also had longer radii (6.3 m vs. 4.7 m) suggesting intraspecific competition may explain lower fruiting abundance in trees that are clustered. Each *L. idatimon* tree in the cluster had at least one other *L. idatimon* tree within 10 meters, thus in several cases tree crowns were nearly touching. The clumping we observed for *L. idatimon* seemed to be rare for other Lecythidaceae tree species with the possible exception of *Gustavia augusta*.

Discussion:

We have no evidence to support the view that white-faced sakis have either positive or detrimental effects on reproduction of Lecythidaceae trees. We monitored *Lecythis idatimon* intensively through the fruiting cycle and even though this species ranked high in the overall diet, it contributed only 6.6% of the total feeding time. This suggests that saki feeding strategies emphasize diversity of resource use; a strategy that is characteristic of many primates – maximizing nutritional intake and/or minimizing ingestion of toxins.

We cannot exclude the possibility that bearded sakis or uacaris (or other seed predators, e.g., capuchins, and macaws) may severely damage or destroy entire fruit crops of individual trees (see Peres, 1991). We witnessed the effects of bearded sakis feeding on *Couratari stellata* winged seeds during this research period. With one known *C. stellata* tree in fruit in the plot, bearded sakis may have done considerable damage to the fruit crop. However, *C. stellata* produce fruit with at least 30 winged seeds in each pyxidium. To successfully extract the seed embedded in each wing would require more precision and attention to thorough seed extraction than we have witnessed. Thus, some seeds may escape predation suggesting that the diplochory hypothesis may apply in some Lecythidaceae species.

Lecythidaceae fruit vary in several aspects: size of fruit, protection of fruit, number of seeds, method of seed dispersal, size and dispersion of trees, and age at reproductive maturity of trees (Mori, 1987). White-faced sakis and bearded sakis are likely to have different impacts on different species of Lecythidaceae. White-faced sakis form small groups, spend relatively little time feeding at any single resource (average feeding bout was 12.6 minutes), and have a very diverse diet. Seeds do represent the bulk of the diet, but these are procured from many resources each day. Thus the seed predation impact on any single tree is probably small. This is particularly the case for trees like *Lecythis idatimon* that may produce more than 1,500 fruit in a fruiting cycle.

Bearded sakis are a different story. They travel in groups as large as 40 individuals, move through the upper canopy, and probably have a bigger impact on widely dispersed, relatively rare producers like *Couratari stellata*. Given our experience with bearded sakis, they probably locate these trees readily and return to them while the fruit crop is abundant. Even though the pyxidia are drably

colored, *C. stellata* fruit are large (7 to 10 cm long) and are oriented skyward on the apex of the terminal branches to attract the attention of aerial or high-climbing arboreal mammals. Indeed, it is very difficult to monitor phenology of *C. stellata* trees unless there is a good view of the tree crown. Given the ranging patterns of bearded sakis, they may impact the reproductive potential of some Lecythidaceae species, particularly the emergent species, but they probably have little effect on understory species.

White-faced sakis and bearded sakis are likely to serve as both seed predators and seed dispersers for many Lecythidaceae species. Sakis are capable of opening well-protected fruit, but they are unlikely to thoroughly ingest and destroy the seeds of each fruit or have a heavy impact on the seed crop of any particularly individual tree. For some Lecythidaceae species that produce animal dispersed seeds (e.g., *E. pedicellata* and *L. idatimon*), sakis may destroy most seeds from fruit they open. A notable exception for white-faced sakis is the exclusive use of arils in *Gustavia augusta*; all seeds were dropped. Bearded sakis are unlikely to ingest *G. augusta* fruit given that trees are well below the canopy level of the forest, but white-faced sakis may provide an important service for the tree since seeds are indehiscent (Mori and Prance, 1987c) and sakis choose fruit with ripe arils (and probably well-developed seeds). For *Couratari stellata* many winged seeds may be dispersed intact. Thus despite being seed predators, sakis appear to lack the capacity to have widespread adverse effects on the dispersal of Lecythidaceae seeds and may have positive influences on seed dispersal by releasing seeds from well-protected pericarps. The diplorchory hypothesis (sakis working in tandem with agoutis) may have a positive effect on Lecythidaceae reproductive success for some species, but the view that sakis have affected the evolution of this large plant family seems unlikely.

Acknowledgments

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Figure 1. Trail and topographical map of Brownsberg Nature Park. The five diversity plots are denoted by red boxes and all 14 of the *Lecythis idatimon* trees are located within the blue circle. (Map by Evan Bailey)

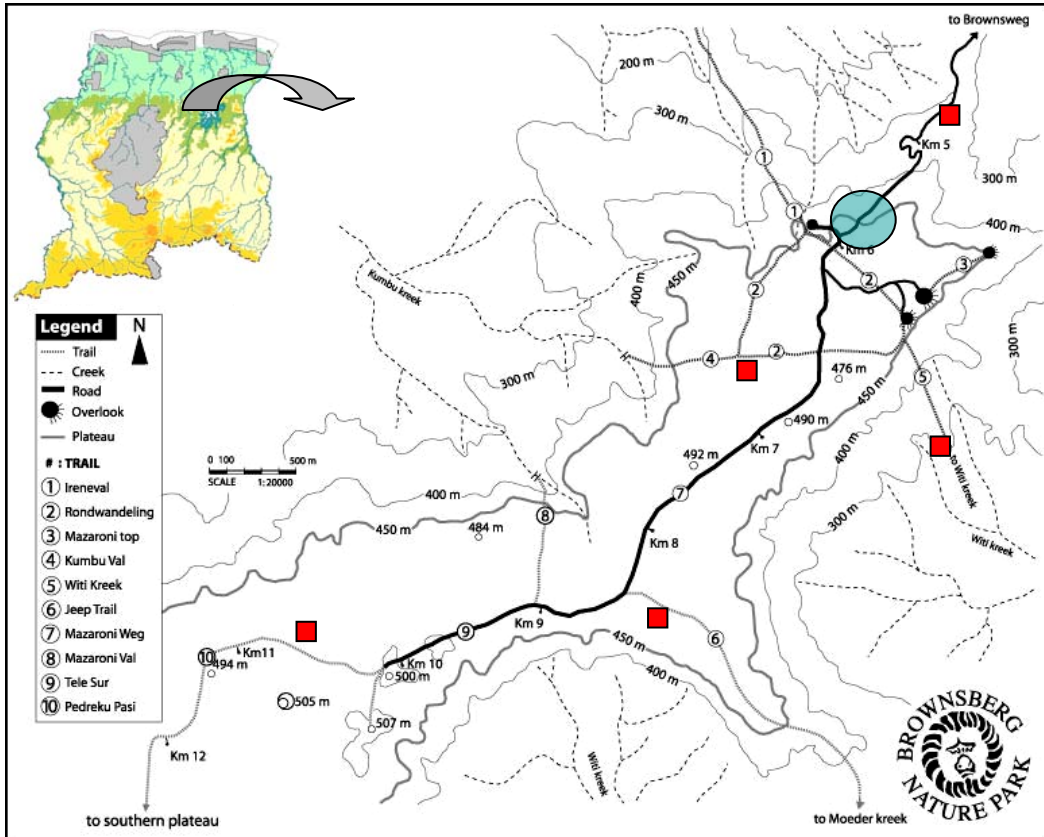


Figure 2. Components in white-faced saki diet, January to April, 2007 (n = 4,065 feeding minutes).

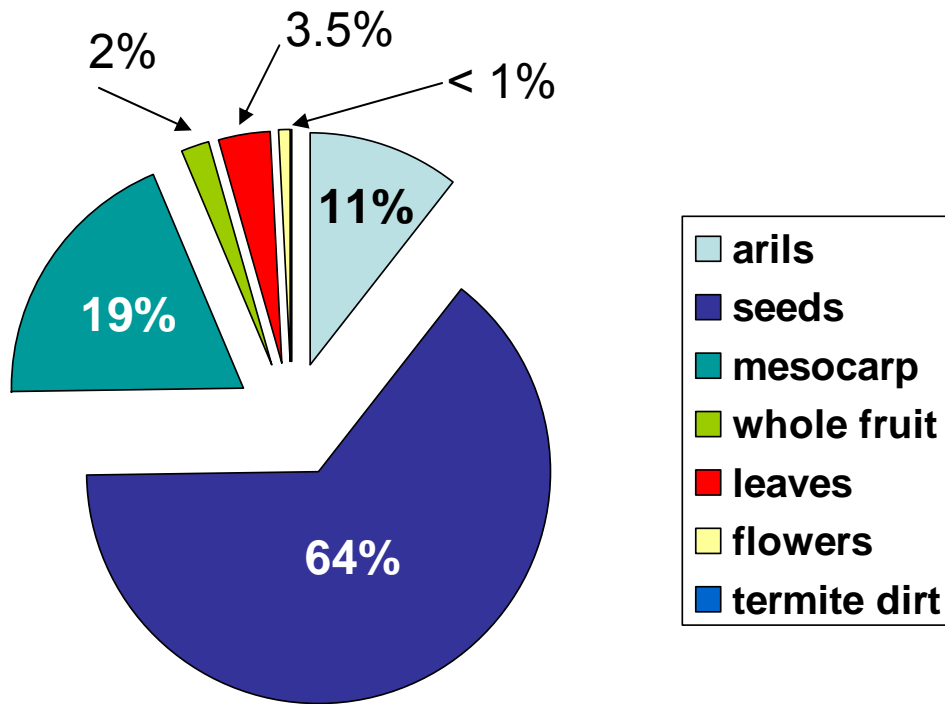


Figure 3. Relationship between feeding bout length and total feeding time per plant species.

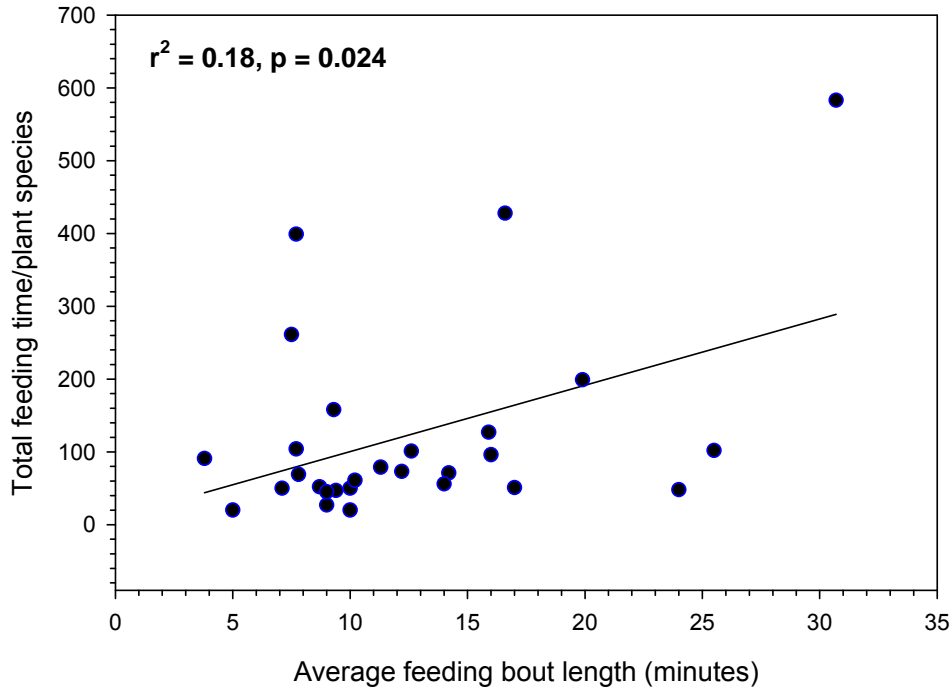


Figure 4a. *Lecythis idatimon* fruit opened by sakis.



Figure 4b. *Gustavia augusta* fruit opened by sakis; arils are eaten from this plant species.



Figure 4c. *Eschweilera pedicellata* seeds and arils.



Figure 5. Average phenology scores for *Eschweilera pediculata* fruit in all 5 plots over eight sample periods. Phenology scores ranged from 0 to 4. See Table 1 for sample sizes for each plot. Fruiting patterns are shown only for mature fruit. The average phenology score took into account fruit abundance divided by total number of sample trees. By the end of the sample period, almost all trees were at the end of their fruiting period. Abbreviations for plots refer to road or trail designations (see Figure 1): WK = Witi Kreek; AKP = Agwago Kunu Pasi; KV = Kumbu Val; JT = Jeep Trail; PP = Pedreku pasi.

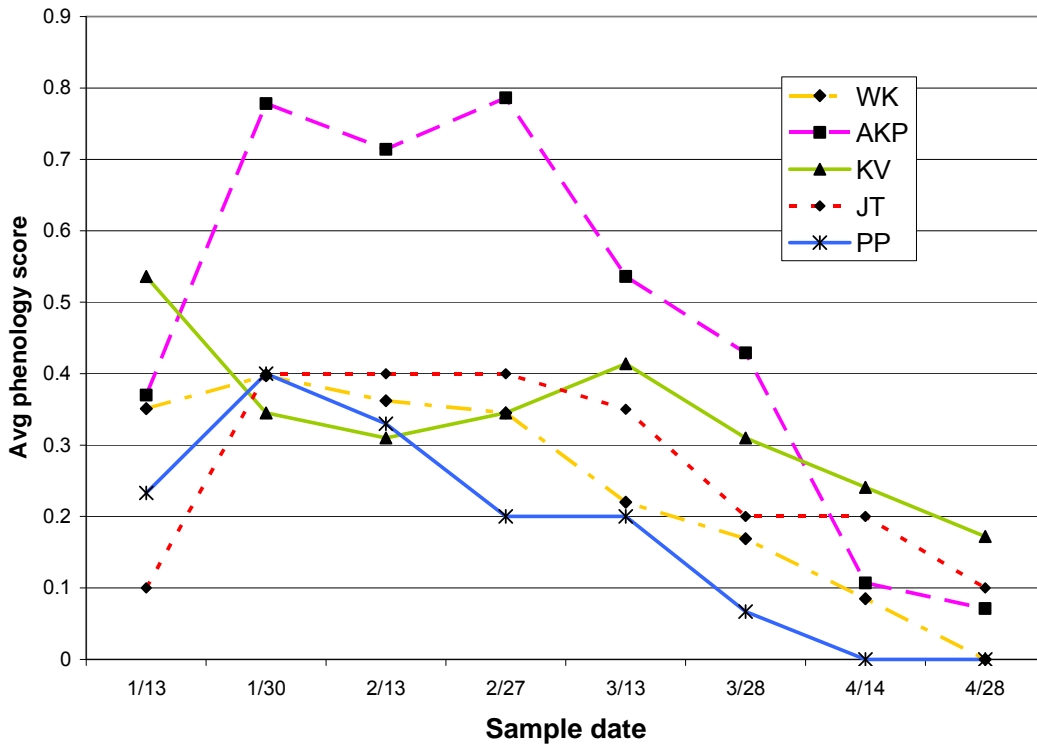


Figure 6. Average phenology scores for *Lecythis idatimon* fruit in all 5 plots over eight sample periods. Phenology scores ranged from 0 to 4. See Table 1 for sample sizes for each plot. Fruiting patterns are shown only for mature (not immature or old) fruit. The average phenology score took into account fruit abundance divided by total number of sample trees. By the end of the sample period, almost all trees had completed their fruiting cycle.

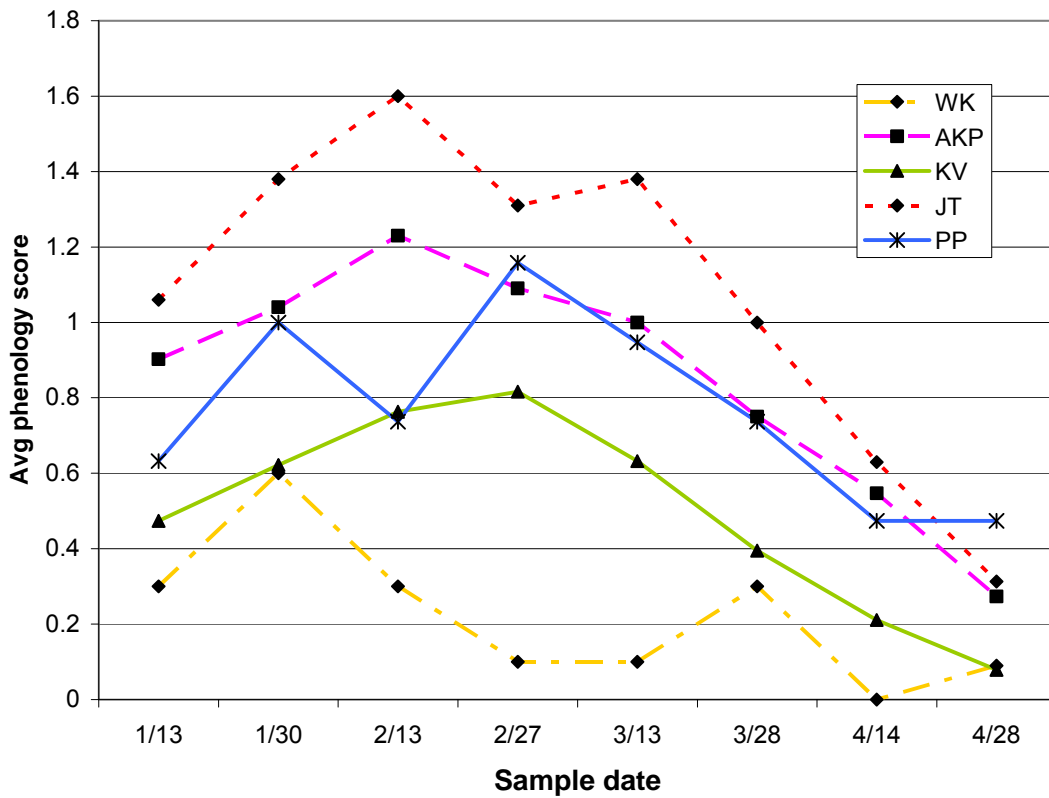


Figure 7. Fruiting cycles of 14 *Lecythis idatimon* trees and the total number of fruit produced during each sample period.

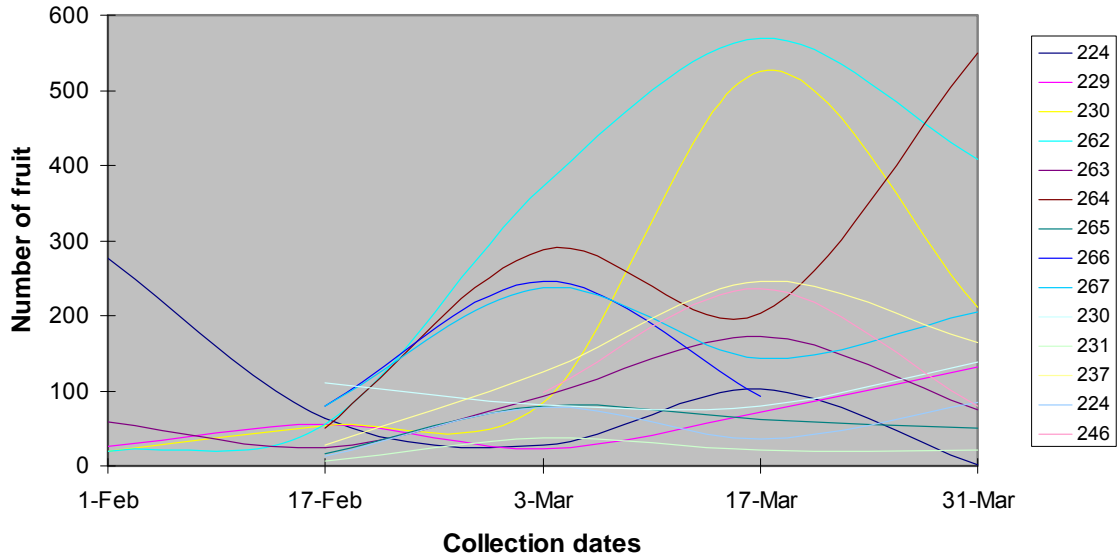


Figure 8. Although all trees were productive and at least 10 cm DBH (diameter at breast height), there was a positive relationship between fruit crop size and tree size.

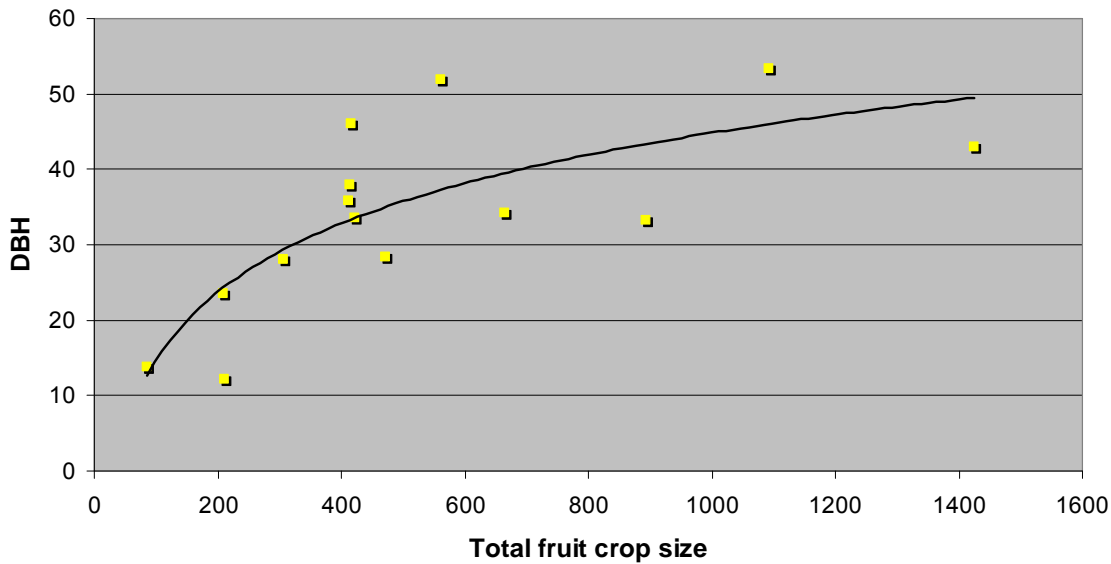


Table 1. Sampling methods for phenological and primate behavioral study.

Type of monitoring	Sampling strategy
Phenology	All Lecythidaceae trees in five plots were identified and tagged for biweekly analysis of fruiting status. The crown of each tree was scanned with binoculars and given a score using a logarithmic scale where 0 = no visible fruit, 1 = 1 - 10 fruit or flowers; 2 = 10 - 100; 3 = 100 - 1000; 4 = 1000 to 10,000; 5, 10,000 fruit or flowers (Korine et al., 2000; Ganzhorn, 2003).
Collection of feeding samples	Primate groups were followed from sleeping tree to sleeping tree. Feeding data collection consists of: 1- time in (first individual into tree) and time out (last individual out of tree); 2- tree number; 3- tree species (if known) & tree tagged for later measurement; 4- estimate of fruit abundance (using the scale described in phenological sampling methods); 5- estimates of handling time and within-tree search time [using a stop watch, split times will calculate a) handling time (beginning with reaching for or removing a fruit, preparing it for ingestion, and ingesting it] and b) duration between ingestion of one fruit and reaching for the next fruit]; if multiple fruits are removed at once and ingested, the total time is divided by the number of fruit ingested and the bout is calculated as handling time; 6- collection of fruit and seeds for identification, wet weight, dimensions (length & width), puncture resistance of pericarp and crushing resistance of seeds using a Rimac® soil tester with a pin apparatus (1mm diameter) attached to the tester to measure puncture resistance; 7- voucher specimens of seeds collected, dried, and deposited at the National Herbarium of Suriname.

Table 2. List of plant foods ingested by white-faced sakis from January to April, 2007, ranked by genus. Relative feeding frequency refers to the number of visits to each species; total feeding minutes was calculated as group minutes (time leaving tree – time entered tree); average feeding minutes per feeding bout; handling time = duration from reaching for a fruit, processing it and reaching for another fruit.

<i>Plant species</i>	<i>Plant family</i>	<i>Relative feeding frequency</i>	<i>Habit</i>	<i>Part eaten</i>	<i>Total feeding minutes</i>	<i>Avg feeding min/bout</i>	<i>Handling time frt/min</i>
<i>Abuta sp.</i>	Menispermaceae	20	liana/shrub	seeds & mesocarp	104	7.7	1.76
<i>Amphizoma glabra</i>	Hippocrateaceae	6	high climbing liana	seeds & mesocarp	45	9.0	2.00
<i>Bellucia grossularioides</i>	Melastomataceae	1	tree		2		
<i>Carpotroche surinamensis</i>	Flacourtiaceae	1	small tree	seed & aril	1		
<i>Casearia rushyane</i>	Flacourtiaceae	5	small tree	flowers & seeds	102	25.5	16.00
<i>Cheiloclinium hippocrateoidea</i>	Hippocrataceae	2		seeds & mesocarp	17		
<i>Chrysobalanus icaco</i>	Chrysobalanaceae	3	tree	seeds & mesocarp	56	14.0	0.25
<i>Chrysophyllum cuneifolium</i>	Sapotaceae	2	tree	seeds & mesocarp	39		0.87
<i>Clusia grandiflora</i>	Guttiferae	2	liana	seeds	36		
<i>Clusia scrobiculata</i>	Guttiferae	6	liana	seeds	52	8.7	
<i>Cnestidium guianense</i>	Connaraceae	2	high climbing liana	seeds & arils	8		4.00
<i>Conceveiba guianensis</i>	Euphorbiaceae	6	tree	seeds	71	14.2	2.80
<i>Davilla rugosa</i>	Dilleniaceae	3	high climbing liana	seeds & arils	48	24.0	
<i>Drypetes variabilis</i>	Euphorbiaceae	7	small tree	seeds	50	7.1	
<i>Eschweilera pedicellata</i>	Lecythidaceae	2	tree	seeds	33		0.66
<i>Guarea grandifolia</i>	Meliaceae	1	small tree	seeds	14		
<i>Guarea kunthiana</i>	Meliaceae	3	small tree	seeds	20	10.0	6.80
<i>Gurania subumbellata</i>	Curcurbitaceae	11	shrub	seeds & mesocarp	127	15.9	4.00
<i>Gustavia augusta</i>	Lecythidaceae	26	small tree	arils	428	16.6	0.37
<i>Heteropsis flexuosa</i>	Araceae	6	high climbing liana	seeds & mesocarp	61	10.2	
<i>Hyeronima alcorneoides</i>	Euphorbiaceae	3	tree	seeds & arils	27	9.0	
<i>Inga acrocephala</i>	Fabaceae	6	tree	mesocarp	73	12.2	
<i>Inga alba</i>	Fabaceae	8	tree	mesocarp & some seeds	79	11.3	0.86
<i>Inga cayennensis</i>	Fabaceae	2	tree	mesocarp	35		
<i>Inga rubiginosa</i>	Fabaceae	6	tree	mesocarp	20	5.0	0.55
<i>Inga sp.</i>	Fabaceae	31	tree	mesocarp	399	7.7	0.39
<i>Inga sp. 2</i>	Fabaceae	6	tree	mesocarp	96	16.0	0.92
<i>Inga sp. 3</i>	Fabaceae	2	tree	mesocarp	18		0.57
<i>Inga sp. 4</i>	Fabaceae	2	tree	mesocarp	18		
<i>Inga splendens?</i>	Fabaceae	2	tree	mesocarp	46		
<i>Inga thibaudiana</i>	Fabaceae	2	tree	mesocarp	46		0.27

<i>Iryanthera sagotiana</i>	Myristicaceae	5	tree	arils	47	9.4	
<i>Lacunaria crenata</i>	Quiinaceae	1	tree	seeds	1		
<i>Lecythis corrugata</i>	Lecythidaceae	5	tree	seeds	50	10.0	
<i>Lecythis idatimon</i>	Lecythidaceae	39	tree	seeds	261	7.5	0.60
<i>Licania densiflora</i>	Chrysobalanaceae	2	tree	seeds	7		
<i>Mabea piriri</i>	Euphorbiaceae	17	small tree	seeds	158	9.3	1.25
<i>Manilkara bidentata</i> ssp 1 or 2	Sapotaceae	1	tree	seeds	1		
<i>Miconia tomentosa</i>	Melastomataceae	12	small tree	whole	69	7.8	8.60
<i>Nectandra</i> or <i>Ocotea</i> ?	Lauraceae	1	small tree	seeds	1		
<i>Passiflora glandulosa</i>	Passifloraceae	1	liana	seeds & mesocarp	7		
<i>Passiflora</i> sp	Passifloraceae	1	liana	seeds & mesocarp	7		
<i>Paullinia tricornis</i>	Sapindaceae	2	liana	seeds	20		
<i>Paullinia venosa</i>	Sapindaceae	2	liana	seeds	12		
<i>Pausandra martinii</i>	Euphorbiaceae	31	small tree	seeds	91	3.8	1.56
<i>Pourouma guianensis</i>	Cecropiaceae	2	tree	mesocarp	23		
<i>Rourea frutescens</i>	Connaraceae	10	liana	seeds & arils	199	19.9	15.00
<i>Saccoglottis cydonioides</i>	Humiriaceae	1	tree	mesocarp	1		
<i>Salacia multiflora</i>	Celastraceae	2	liana	seeds & mesocarp	17		
<i>Simarouba amara</i>	Simaroubaceae	19	tree	seeds	583	30.7	6.30
<i>Tetragastris panamensis</i>	Burseraceae	3	tree	mesocarp	51	17.0	
<i>Tomovita brevistaminea</i> ?	Clusiaceae	1	tree	seeds	16		
<i>Tontelea coriacea</i>	Hippocrataceae	6	high climbing liana	mesocarp	101	12.6	
<i>Vochysia guianensis</i>	Vochisiaceae	2	tree	seeds	32		

Table 3. Feeding species ranked by the number of visits to trees. These 10 plant species represented 61.5% of the total number of identified plants used for feeding during the study period (n = 351).

Rank	Plant species	Plant family	Relative feeding frequency
1	<i>Lecythis idatimon</i>	Lecythidaceae	39
2	<i>Inga sp.</i>	Fabaceae	31
3	<i>Pausandra martinii</i>	Euphorbiaceae	31
4	<i>Gustavia augusta</i>	Lecythidaceae	26
5	<i>Abuta sp.</i>	Menispermaceae	20
6	<i>Simarouba amara</i>	Simaroubaceae	19
7	<i>Mabea piriri</i>	Euphorbiaceae	17
8	<i>Miconia tomentosa</i>	Melastomataceae	12
9	<i>Gurania subumbellata</i>	Curcubitaceae	11
10	<i>Rourea frutescens</i>	Connaraceae	10

Table 4. Feeding species ranked by total feeding minutes, representing 62.7% of the total feeding minutes (n = 3,926) on identified feeding sources.

Rank	Plant species	Plant family	Total feeding minutes
1	<i>Simarouba amara</i>	Simaroubaceae	583
2	<i>Gustavia augusta</i>	Lecythidaceae	428
3	<i>Inga sp.</i>	Fabaceae	399
4	<i>Lecythis idatimon</i>	Lecythidaceae	261
5	<i>Rourea frutescens</i>	Connaraceae	199
6	<i>Mabea piriri</i>	Euphorbiaceae	158
7	<i>Gurania subumbellata</i>	Curcubitaceae	127
8	<i>Abuta sp.</i>	Menispermaceae	104
9	<i>Casearia rushyane</i>	Flacourtiaceae	102
10	<i>Tontelea coriacea</i>	Hippocrataceae	101

Table 5. Tree species, number of stems sampled in each of the 5 diversity plots, and average DBH of trees.

<i>Lecythidaceae species</i>	<i>JT</i>		<i>KV</i>		<i>PP</i>		<i>AKP</i>		<i>WK</i>		
	DBH	n	DBH	n	DBH	n	DBH	n	DBH	n	
<i>Corythophora labriculata</i>	13.2	4	16.9	7			12.6	4	12.0	16	31
<i>Couratari multiflora</i>					11.5	1	26.9	3			4
<i>Couratari stellata</i>	32.1	7	24.0	1	20.7	1	39.8	4	37.5	19	32
<i>Eschweilera pedicellata</i>	26.4	20	22.8	31	20.4	15	25.1	28	22.5	58	152
<i>Gustavia hexapetala</i>	11.7	1					14.3	12	12.9	10	23
<i>Lecythis chartaceae</i>	19.6	4	56.0	1							5
<i>Lecythis corrugata corrugata</i>	16.7	1					10.9	1			2
<i>Lecythis idatimon</i>	24.0	18	16.5	38	20.7	19	17.8	52	16.9	10	137
<i>Lecythis poiteau</i>							30.8	2	17.0	1	3
<i>Lecythis zabucajo</i>			23.5	4	114.0	1			32.7	2	7
Total trees		55		82		37		106		116	396

Table 6. Summary of phenology scores for each tree species in each plot. Scores were calculated by taking the maximum phenology score for each tree (e.g., 1, 2, 3, or 4) and multiplying by a weighting factor: $\sum (x*y)$, where x = the phenology score and y = the weighting factor. The weighting factor = 1 for phenology score 1, 2 for 2, 3 for 3 and 4 for 4.

	<i>JT</i>	<i>KV</i>	<i>PP</i>	<i>AKP</i>	<i>WK</i>	sum of rows
<i>Corythophora labriculata</i>	6	4	0	5	4	19
<i>Couratari multiflora</i>	0	0	0	4	0	4
<i>Couratari stellata</i>	1	0	0	3	5	9
<i>Eschweilera pedicellata</i>	12	30	11	45	51	149
<i>Gustavia hexapetala</i>	1	0	0	4	3	8
<i>Lecythis chartaceae</i>	2	0	0	1	2	5
<i>Lecythis corrugata</i>	0	0	0	1	0	1
<i>Lecythis idatimon</i>	38	49	33	95	10	225
<i>Lecythis poiteau</i>	0	0	0	2	0	2
<i>Lecythis zabucajo</i>	0	1	0	0	0	1