Feeding flexibility and behavior of young *Prolemur simus* in the fragmented forest of Ambalafary -Eastern Madagascar

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ABSTRACT

An isolated and fragmented site named Ambalafary recently discovered by the NGO The Aspinall Foundation is home to a population of Prolemur simus. Data on the behavior and diet of dyad mother-young Prolemur simus were recorded assuming that at each stage of its development the young consume the same species of plants as his mother and she also share foods to her young . To achieve the objectives, thirteen pairs of individuals Prolemur simus were monitored for an entire year on the site using the "focal animal sampling" method every 5 minutes, including rare events in "ad libitum". As a result, each phase of development corresponds to specific activities for the young: phase 1 (young aged 0 to 2 months) constitutes the exploration phase and the training phase for small jumps. Phase 2 (young aged 3 to 5 months) corresponds to the start of ingestion of solid foods such as buds; young leaves and bamboo shoots (2.5%). For phase 3 (young aged 6 to 8 months) and phase 4 (young aged 9 to 11 months) a food sharing session occurs between mother and young Prolemur simus especially about tough foods. The continuity of the study of the diet of the young proves necessary to better ensure its long-term survival and the survival of the entire population since the site is fragmented and till now it is not yet known the extent to which fragmented habitat can support the population of P. simus in the long term, there is an urgent need to provide data on the diet of Prolemur simus especially for young for effective conservation.

Key words: *Prolemur simus*; lemurs; diet; behaviour, developmental phase, Madagascar

1. INTRODUCTION

When an habitat is fragmented, the quality and quantity of food resources for the animal species found there are also altered (Arrigo-Rodriguez et al., 2006)[1], resulting in nutritional stress for both young and adult individuals. The combination of selective logging, which reduces the density, size and distribution of plants in fragmented forests (Conner et al., 1974))[2], and an unstable season strongly influences plant phenology, including food availability for primate species such as lemurs (Bollen & Donati, 2005))[3] Changing dietary habits by becoming less demanding or more flexible is one of the responses adapted by these lemur species to cope with the temporal and spatial variations to which they are subject (Hemingway & Bynum, 2005))[4]. This dietary flexibility is made

possible by anatomical and physiological adaptations of the body through the mechanism of digestion and mastication (Chivers, 1994; Kizey, 1992)[5][6] or adaptations of the stomach (Chapman & Chapman, 1990)[7].

Prolemur simus, a species of bamboo lemur endemic to eastern Madagascar, feeds mainly on bamboos of the Bambusoidae family (Mutschler &Tan, 2000)[8]. It is known as one of the most flexible-feeding primate species, as it is able to exploit all the bamboo parts it consumes, from shoots to the hardest part of the stem, unlike other bamboo lemurs, which are more selective about the bamboo parts they consume: rarely the stem, but mainly the young leaves and petioles (Tan, 1999; Tan, 2000)[9][10]. Over 90% of the diet of *Prolemur simus* consists of bamboo, but it is the bamboo species consumed that differ from site to site and locality to locality (Tan, 1999; Mihaminekena et al., 2012; Rakotoarinivo et al., 2017)[9][11][12], so the presence of *Prolemur simus* is conditioned by the distribution of bamboo at different altitudes (King et al., 2013) [13]. However, due to the continuous cutting of bamboo (pers obs.) and its excessive use for commercial purposes (Rajaonalison, 2012) [14], the habitat and food resources of *Prolemur simus* are currently endangered, which led the IUCN [15] in 2020 to classify the species as critically endangered, hence the urgency of its conservation.

In same species, food sharing is habitual : food may be transferred between mature individuals or from mature individuals to immatures. So foods habits vary within and between groups of the same species for more reasons such as: interspecific competition or local traditions (Wolovich et al., 2008) [16]. For *Prolemur simus*, the mother-young relationship is very intense (Tan, 1999) [9] and this promiscuity is observed especially when the young are feeding or moving. However, few studies (Tarnaud, 2002) [17] have been able to demonstrate this mother-young *Prolemur simus* relationship when sharing food. The hypothesis to be verified is therefore that there is always a sharing of food between the mother and the young *Prolemur simus* throughout the young's development.

The aim of the study is therefore to determine the type of behavior and feeding habits of the young *Prolemur simus* throughout its various developmental phases.

The specific objectives will be as follows:

-Know the different activities of the young according to each phase of its development.

-Determine the evolution of the young's diet according to the species and plant parts consumed throughout its different development phases.

-Identify the young's feeding habits

2. METHODOLOGY

2.1 Instantaneous observation

Observations were made every 5 minutes using the "focal animal sampling" method (Altmann, 1974) [18]. This method consists of observing the behavior of mother-young every 5 minutes, and observing rare behaviors and recording them in *ad libitum* (Altmann, 1974) [18], especially when the animal consumes food between the 5-minute time intervals. This method has several advantages, as it allows the observer to focus on all the activities of each member of the mother-young dyad, while recording their interactions. In short, we spent a total of 150 days on the site for the monitoring itself around 1,200 hours.

2.2 Determination of the diet

Each plant species swallowed by the focused animal is equivalent to one consumption. The "feeding" activity is therefore determined by counting the frequency of consumption of the following plant parts: mature leaves; young leaves; fruit; buds; young shoots; stems; flowers. The names of these consumed species are given on site by local patrollers.

2.3 Statistical tests

The tests used are as follows:

Chi two ($\chi 2$) test of independence to study the young *Prolemur simus* general activities and eating habits.

The Wilcoxon (Z) test to study young *Prolemur simus* consumption patterns.

2.4 Reminder

-Phase 1 refers to the first three months of a young *Prolemur simus*'s life, i.e. from birth until it is two months old, from October to December.

-Phase 2 corresponds to the 3rd, 4th and 5th months, i.e. from January to March.

-Phase 3 corresponds to the 6th, 7th and 8th months, i.e. from April to June.

-Phase 4 corresponds to the 9th, 10th and 11th months of the young *Prolemur simus*.

3. RESULTS AND INTERPRETATIONS

3.1 Study of general activities of young *Prolemur simus*

The figure and table below show the activities of the young *Prolemur simus* during all phases. During phase 1, the young *P simus* performs activities such as handling food objects (20%) and locomotion (30%), or moving back and forth on its mother's fur or on a support occupied by the mother. Solid food intake is still absent (0%), and grooming by the mother is 30%. In phase 2, the young is still manipulating objects (20%). Rest is 20%. Other activities are in the order of 10% for grooming received; play (30%) and vocalization at 20%. For phase 3, play and jumping dominate other activities at around 20%. Handling disappeared during phase 3 and phase 4. Thus, according to the Chi two test of independence ($\chi 2=280.55$; ddl=6; $P<0.001$), there is a highly significant difference between the youngs's activities for all phases considered.

Table- 1 : Percentage of activity budget for young *Prolemur simus* durin g each phase

			Activity budget										Total
			Sl	**Frg**	**Pl**	**Loc**	**Manip**	**Mut_gro**	**Rec_gro**	**Clim**	**Sel_gro**	**Voc**	
Phase	Phase 1	Count	2	0	0	3	2	0	3	0	0	0	10
		% within Phase	20,0%	0,0%	0,0%	30,0%	20,0%	0,0%	30,0%	0,0%	0,0%	0,0%	100,0%
	Phase 2	Count	2	0	3	0	2	1	0	0	0	2	10
		% within Phase	20,0%	0,0%	30,0%	0,0%	20,0%	10,0%	0,0%	0,0%	0,0%	20,0%	100,0%
	Phase 3	Count	3	0	3	0	0	1	1	1	0	1	10
		% within Phase	30,0%	0,0%	30,0%	0,0%	0,0%	10,0%	10,0%	10,0%	0,0%	10,0%	100,0%
	Phase 4	Count	1	1	2	0	0	1	0	2	2	1	10
		% within Phase	10,0%	10,0%	20,0%	0,0%	0,0%	10,0%	0,0%	20,0%	20,0%	10,0%	100,0%
Total		Count	8	1	8	3	4	3	4	3	2	4	40
		% within Phase	20,0%	2,5%	20,0%	7,5%	10,0%	7,5%	10,0%	7,5%	5,0%	10,0%	100,0%

Sl : Sleeping ; Frg : Foraging ; Pl : Playing ; Manip : Manipulation ; Mut_gro: Mutual grooming; Rec_gro: Receiving grooming; Clim: Climbing; Sel_gro: Self grooming; Voc: Vocalization

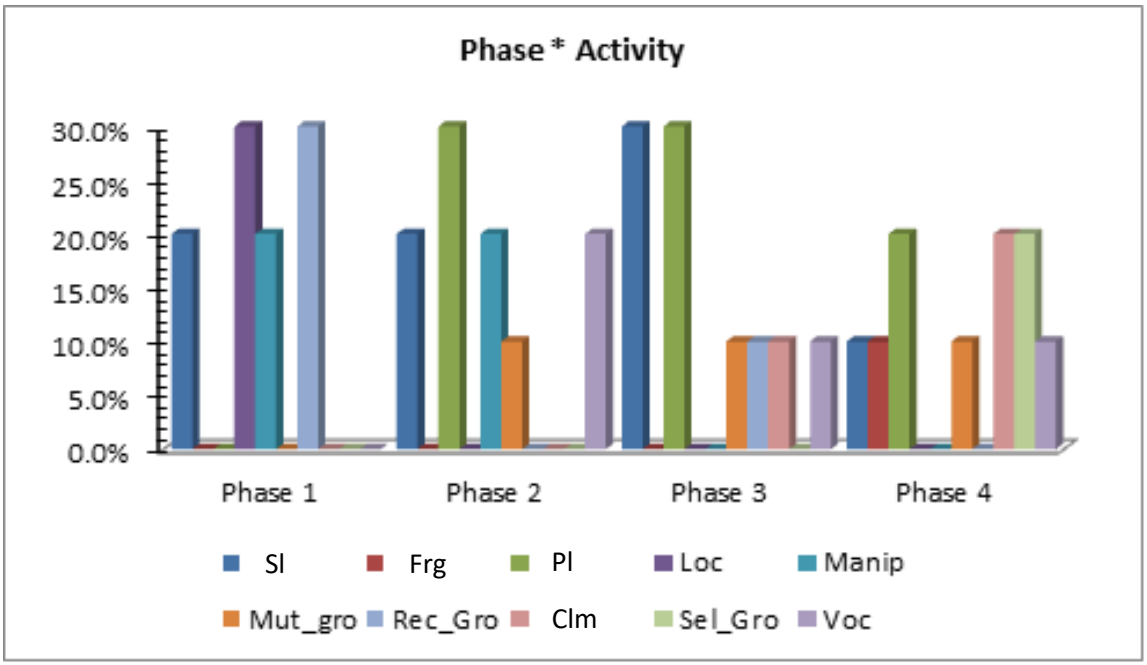

Figure 1 : Histogram showing all types of activity done by young *Prolemur simus*

3.2 Diet of juveniles

The figure and table below show the different plant parts consumed by the young *P simus*. Comparing these plant species, the Chi two test of independence ($\chi 2$=8.36; ddl=3; P=0.03) confirms that there is a significant difference in the plant parts consumed by the young *Prolemur simus* . During phase 1, the young consumes tender plant parts such as young leaves. Its consumption is of the order of 100%. In phase 2, bamboo shoots are consumed the most (68%). In phase 3, it's the consumption of stems or culms that is most pronounced. Finally, in phase 4, bamboo shoots dominated over stalk consumption.

Table- 2 : Plant parts eaten by young *Prolemur simus* during each phase

			Alimentation						Total
			Culm	Dry petiole	Young leaves	Ripe fruit	Shoots	Mature leaves	
Phase	Phase 1	Count	0	0	2	0	0	0	2
		% within Phase	0%	0%	100%	0%	0%	0%	100%
	Phase 2	Count	0	4	0	2	21	4	31
		%within Phase	0%	13%	0%	6%	68%	13%	100%
	Phase 3	Count	96	0	0	0	0	0	96
		% within Phase	100%	0%	0%	0%	0%	0%	100%
	Phase 4	Count	347	0	0	0	8	0	355
		% within Phase	98%	0%	0%	0%	2%	0%	100%
Total		**Total count**	**443**	**4**	**2**	**2**	**29**	**4**	**484**
		% within Phase	**92%**	**1%**	**0%**	**0%**	**6%**	**1%**	**100%**

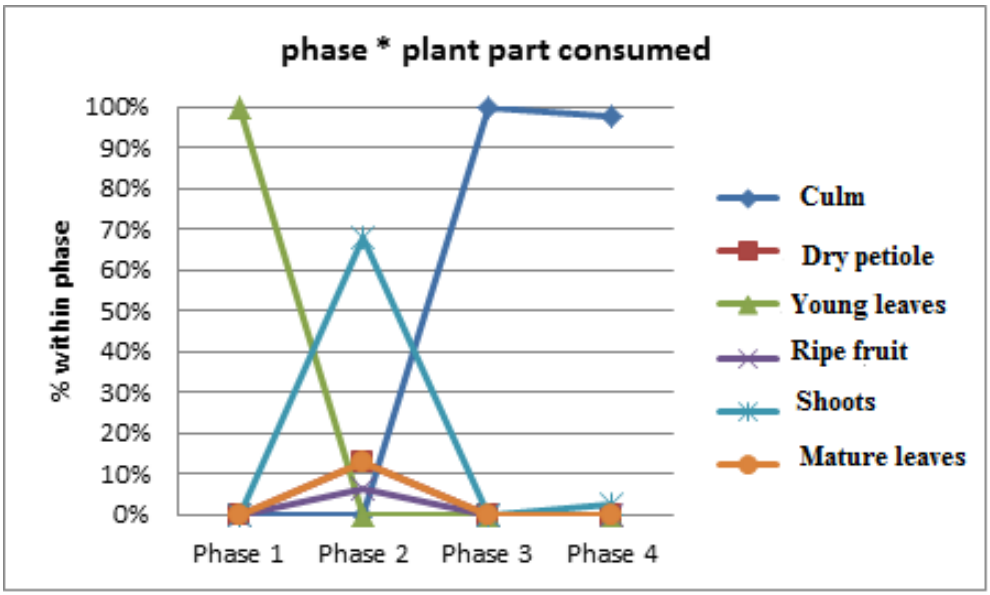

Figure 2 : Curve showing the percentage of plant parts eatne by young *Prolemur simus*

3.3 Sharing food session

The frequency of sharing food, including bamboo stalks, is shown in the figure below. In phase 1, mother and young do not yet share food. In phase 2, sharing between mother and young begins at around 40%, as the young begin to ingest solid food. In phase 3, the frequency of sharing and non-sharing is identical. Finally, in phase 4, the frequency of sharing and non-sharing is always the same for both mother and young. Moreover, a significant difference in the frequency of sharing and non-sharing between mother and young was statistically demonstrated (Wilcoxon Test: Z=-20.80; P<0.001). In other words, the mother agrees to share her food with her youngs when he's still very young. But the older the young, the more the *Prolemur simus* mother reduces the amount of food she gives her young.

Table- 3 : Frequency of food sharing between mother-young during phase 3 and phase 4

Cross tab Phase * Acquisition_Aliment					
			Acquisition_Aliment		Total
			AP	SP	
Phase	Phase 1	Count	10	0	10
		% within phase	100.0%	0.0%	100.0%
	Phase 2	Count	6	4	10
		% within phase	60.0%	40.0%	100.0%
	Phase 3	Count	5	5	10
		% within phase	50.0%	50.0%	100.0%
	Phase 4	Count	5	5	10
		% within phase	50.0%	50.0%	100.0%
Total		Total count	26	14	40
		% within phase	65.0%	35.0%	100.0%

AP : Absence of sharing food session ; SP : Presence of food sharing session

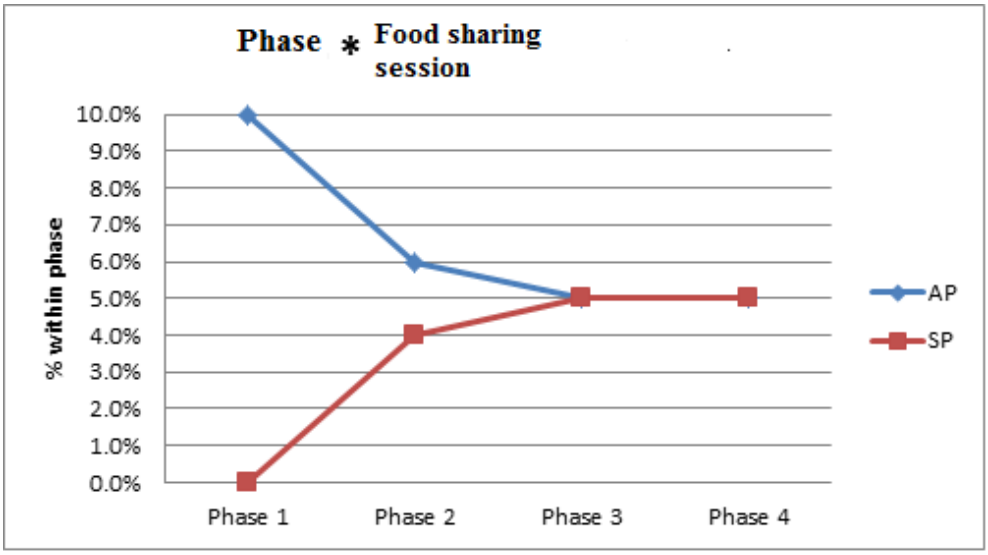

Figure 3 : Curve showing food sharing and non food sharing session between mother-young *Prolemur simus*

4.CONCLUSIONS

A recently discovered isolated site in the Brickaville district of the Atsinanana region, named Ambalafary, has been chosen for a study on the development of a species of bamboo-eating lemur called *Prolemur simus*. The aim is to ensure the long-term conservation and survival of this species, and at the same time to better manage the *Prolemur simus* population living in this site, given its fragmentation and isolation. As a result:

For all behavioral activities of the young, each developmental phase corresponds to specific activities such as resting, jumping on trees and manipulating objects. The ingestion of solid food is not yet observed, while an increase in the frequency of mother-young body contact and care of the young is also observed.

As far as diet is concerned, the young begins to eat solid foods from phase 2 onwards (3 to 5 months), although the frequency of consumption is low as it is still supplemented by a milk diet, compared with the frequency of consumption in other phases such as phase 3 or phase 4. For phase 2, the plant parts most appreciated by young are those that are softest to swallow, such as buds, shoots and young leaves.

During phase 3 (6 to 8 months) and phase 4 (9 to 11 months), a food-sharing session is observed between the *Prolemur simus* mother and her young, especially for foods that require a great deal of physical effort to obtain, such as extracting pith from bamboo culms. The rate of this sharing is higher when the young is between 3 to 5 months. So the *P simus* mother helps her young when the latter is still very young.

5. REFERENCES

[1]. Arrigo-Rodriguez V., Mandujano S., 2006. Forest fragmentation modifies habitat quality for *Alouatta palliata*. Int J Primatol 27 : 1079-1096.

[2]. Connor E F, Mc Coy ED. 1974. The statistics and biology of the species area relationship. Am Nat 113: 791-833

[3]. Bollen A, Donati G. 2005. Phenology of the littoral forest of Sainte Luce , southeastern Madagascar. Biotropical, 37: 32-43.

[4]. Hemingway C A,& Bynum, N. 2005. The influence of seasonality on primate diet and ranging. In D.K. Brockman & C.P. van Schaik (Eds). Seasonality in primates: Studies of living and extinct human and non human primates (pp 57-104). Cambridge: Cambridge University Press.

[5]. Chivers D J. 1994. Fuctionnal anatomy of the gastrointestinal tract. In G Davis & J. Oates (Eds), Colobine monkeys : Their ecology, behaviour and evolution (pp 205-228). Cambridge: Cambridge University Press

[6]. Kinzey, W. G. 1992. Dietary and dental adaptations in the Pitheciinae. American Journal of Physical Anthropology, 88 : 499-514.

[7]. Chapman C A, Chapman L J, Wrangham R, Hunt K, Gebo D et al. 1992. Estimators of fruit abundance of tropical trees: Biotropica 24: 527-531

[8]. Mutschler T. & C.L. Tan 2003. Hapalemur, bamboo of gentle lemurs. In : The Natural History of Madagascar, S M Goodman and J. Benstead (eds), pp 1324-1329. University of Chicago Press, Chicago.

[9]. Tan, C. L. 1999. Group composition, home range size, and diet in three sympatric bamboo lemur species (genus *Hapalemur*) in Ranomafana National Park, Madagascar. *International Journal of Primatology* 20: 547–566.

[10]. Tan, C. L. 2000. Behavior and ecology of three sympatric bamboo lemur species (genus *Hapalemur*) in Ranomafana National Park, Madagascar. Ph.D. Thesis, State University of New York, Stony Brook

[11]. Mihaminekena, T.H., Ravaloharimanitra, M., Ranaivosoa, P., Ratsimbazafy, J. & King, T. (2012). Abondance et conservation de *Prolemur simus* dans les sites de basse altitude de Sahavola et Ambalafary, District de Brickaville. *Lemur News,* 16, 11–15

[12]. Rakotoarinivo, T.H., Ravelojaona, R., Razafindramanana, J. & Ratsimbazafy, J. (2017).Etude préliminaire du rythme d'activité et de l'écologie de deux groupes de *Prolemur simus* dans la forêt dégradée de Vohitrarivo, District d'Ifanadiana. *Lemur News*, 20, 19–24.

[13]. King, T., Randrianarimanana, H.L.L., Rakotonirina, L.H.F., Mihaminekena, T.H., Andrianandrasana, Z.A., Ratolojanahary, M., Randriahaingo, H.N.T., Ratolojanahary, T., Rafalimandimby, J., Bonaventure, A., Rajaonson, A., Ravaloharimanitra, M., Rasolofoharivelo, M.T., Dolch, R. & Ratsimbazafy, J.H. (2013). Large-culmed bamboos in Madagascar: Distribution and field identification of the primary food sources of the Critically Endangered greater bamboo lemur *Prolemur simus*. *Primate Conservation*, 27, 33–53.

[14]. Rajaonalison, F. 2012. Caractérisation des propriétés physiques des bambous dans la région Atsiananana. Mémoire d'ingéniorat. Sciences Agronomiques option Eaux et Forêts. 65p+Annexe

[15]. IUCN. 2020. The IUCN Red List of Threatened Species. Version 2020-2. Available at: www.iucnredlist.org. (Accessed: 13 June 2020).

[16]. Wolovich, C.K. ; Perera-Rodriguez, J.P. ; Fernandez-Duque, E. 2008. Food transfers in young and mates in wild Owl,Monkeys (Aotus azarai) . American Journal;of Primatology 70: 211-221.

[17]. Tarnaud, L. 2002. L'ontogenèse du comportement alimentaire du primate *Eulemur fulvus* en forêt sèche (Mayotte, archipel des Comores) en relation avec le lien mère-jeune et la disponibilité des ressources alimentaires : Thèse de doctorat, Université de Paris 5-René Descartes

[18]. Altmann, J. 1974. Observational study of behaviour : sampling methods. Behaviour 49: 227-267