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RESEARCH ARTICLE

Feeding Strategy of François' Langur and White-Headed Langur at Fusui, China

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We investigated the diet of a group of François' langur inhabiting a forest fragment between August 2002 and July 2003 to add to our knowledge of behavior and ecology of this langur. Our objective was to study whether the François' langur would adopt a feeding strategy similar to the white-headed langur in the same nature reserve. Data indicated that a total of 37 plant species were eaten by François' langur; however, only ten species accounted for 90% of the total feeding time. Four species belong to the ten most dominant tree species within the vegetation quadrats. Ninety-four percent of feeding time of François' langur was spent on leaves, whereas the remaining 6% of time was spent on fruits, flowers and twigs. Results also demonstrated that François' langur are similar to white-headed langur in being predominantly folivorous and that Francois' langur adopted a similar strategy to white-headed langur in diet, dietary variation and time spent on feeding. François' langur exhibited a habitat use preference for the middle zone of the forest, whereas the white-headed langur utilized the bottom zone of the forest. Further analysis indicates that human interference and habitat fragmentation caused by agriculture also impact habitat use. Am. J. Primatol. 70:320–326, 2008.

Key words: François' langur (*Trachypithecus francoisi*); white-headed langur (*Trachypithecus luecocephalus*); feeding strategy; diet; habitat use

INTRODUCTION

Feeding strategy is a complex of factors that characterize primates' adaptation to the environment. Fleagle [1988] approximately divided primates into frugivores, folivores and insectivores or faunivores, respectively, according to their diet. The factors of diet, time budget and habitat use vary greatly among the different categories. Even within the Trachypithecus genus, there is wide variation in this folivorous category, for example, the capped langur (*Trachypithecus pileate*) fed on more fruits in summer and more leaves in winter, and had a longer feeding time budget in summer than in winter [Stanford, 1991]. This was different from the white-headed langurs (*Trachypithecus luecocephalus*) that include more leaves in their diets and spent less total time on feeding in summer than in winter [Huang, 2002; Huang et al., 2003a; Li and Rogers, 2004].

The François' langur (*Trachypithecus francoisi*) is an endangered primate species that ranges from the Red River in Vietnam across the Chinese border to as far as the Daming Hills in Guangxi and Xingyi in Guizhou. They are restricted to habitats characterized by karst topography with plentiful cliffs [Groves, 2001] and are considered a limestone langur as is the white-headed langur [Nadler, 2006]. The François' langur is the most northern langur in the world according to Zhang et al. [2002]. Like other primate species, the François' langur exist in a fragmented and isolated condition, and their habitat has been further degraded by deforestation [Hu & Wei, 2002]. The white-headed langur inhabits a triangle area of 200 km^2 within the four counties of Fusui, Chongzuo, Longzhou and Ningming in Southern Guangxi, China (Fig. 1) with a total population of

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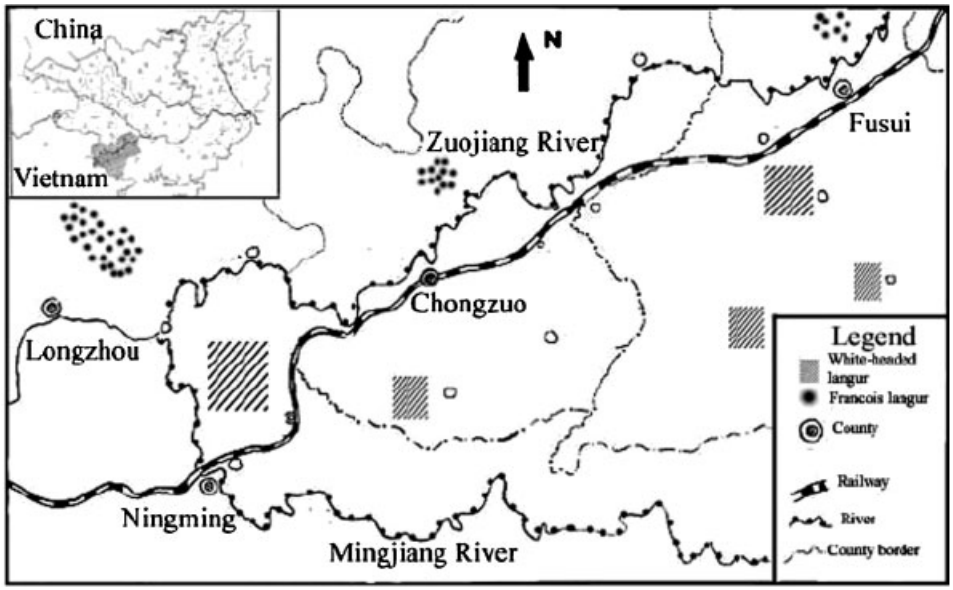

Fig. 1. Distribution of white-headed langur and François' langur in Fusui, Guangxi (scale: 1: 1,300,000).

<700 [Huang et al., 2003b]. The two langurs are allopatrically distributed with the Zuo Jiang River separating the white-headed langur to the south and the François' langur to the north in Fusui Nature Reserve.

The two langurs are close relatives both phylogenetically [Zhang & Ryder, 1998] and taxonomically [Shen & Li, 1982]. They inhabit similar environment, adapt to karst habitat fragments, share a similar climate and exhibit a similar anatomy and ecology. However, the latest documentation indicates that the white-headed langur is a subspecies of the golden-headed langur (*Trachypithecus poliocephalus*) in Vietnam [Brandon-Jones et al., 2004; Groves, 2001], which was proved by molecular evidence [Roos, 2004].

Studies on the white-headed langur feeding strategy indicate that they fed on 50 plant species out of 164 in the habitat and mainly fed on young leaves in 75% of the records [Li et al., 2003]. Huang [2002] found that the white-headed langur fed on 42 plant species out of 213 in a neighboring study site on the same hill groups. In both cases, there is little difference. Both studies indicate that this langur is highly folivorous and spends most of its daytime resting and less time on feeding. The white-headed langur also prefers the bottom zone more than others during feeding [Huang, 2002]. Our research involved investigating whether the François' langur, a close relative of the white-headed langur, would adopt a similar dietary strategy and habitat use as the white-headed langur in the same reserve.

Study Group, Data Collection and Analysis

The Fusui Nature Reserve is located in southern Guangxi, China (22°24′51″-22°36′20″N and 107°23′-107°41′43″E). The topography in this reserve is characterized by steep cliffs with an altitude ranging from 400 to 600 m above sea level. The vegetation is limestone seasonal rainforest [Guangxi Forestry Department, 1993], but it has been destroyed seriously by human activities, such as firewood collection and plantation construction. The flat lands have been used by local people for sugarcane plantations, establishing roads and settlements that fragment the existing forests [Huang et al., 2006; Li & Rogers, 2005].

Rainfall is seasonal with a distinct rainy season between May and September. Annual rainfall averages 1,022 mm. The mean annual temperature is 22.1°C, with temperature peaking in July and August, averaging 28.1°C [Huang, 2002; Huang et al., 2003a]. The rainy season falls between May and September and the dry season is from October to next April according to the rainfall.

Three bisexual François' langur Groups, totaling 23 individuals, inhabit the north of the Fusui Nature Reserve and they are confined to separated hills [Hu & Wei, 2002]. All three groups are 70 km away from the habitat of the white-headed langur. Observations were made on the Zuo Wei Group that inhabits a kart hill fragment completely surrounded by cultivation (Fig. 2). The total area of habitat is approximately 0.5 km^2. The study group consisted of seven individuals, including one adult male, three adult females and three infants [Huang et al., 2006]. In this study, four adult individuals were sampled and a total of 168 hr of feeding were recorded.

Data Collection

We collected systematic feeding data for 11 months from August 2002 to July 2003 over 10 consecutive days in each month. We observed

Fig. 2. The highly fragmented habitat of a group of François' langur (indicating the habitat isolation).

monkeys via binoculars and a spotting scope from a distance of 20–200 m. On each day, the observation session began when the monkeys left the sleeping sites and ended when they returned to the sleeping site. We adopted focal group animal sampling [Altman, 1974], the same method used in case of the white-headed langur [Huang et al., 2003a], to collect data on food item and species, feeding duration, activity time budget and habitat use during feeding day by day. The activities were divided into four general categories: feeding, resting, moving and others. The karst hill habitat was divided into four zones: flat land, bottom, middle and top. The flat land zone was cultivated completely and had never been used earlier. The data on activity rhythm and time budget for this study have been published in Huang et al. [2006].

A study of forest composition was carried out at the onset of the behavioral data collection. Fifteen quadrats measuring 20×20 m were established. Four were in the top zone, five in the middle and six in the bottom zone. We recorded the plant species and individuals measuring ≥ 1.2 cm diameter at breast height in each plot [Li et al., 2003].

Density of agricultural land was estimated on a map of 1:10,000 scale and the number of farmers working in and around the habitat hills was recorded on each observation day.

Data Analysis

We summed the feeding time of each plant species in minutes, for the study group, first by month, then by the whole study period, and expressed the annual diet based on feeding time. Food items were counted on a monthly basis. We used the Shannon–Weaver Diversity Index to examine seasonal variation in dietary diversity. The index was calculated as follows: $H' = -\Sigma P_i \ln P_i$, where P_i was the proportion of feeding time of the ith plant species. The Mann–Whitney U-test was used to examine the seasonal variation of monthly diet composition and dietary diversity. A 0.05 significance level was applied.

The feeding time percentage of each month was obtained through the total feeding time on all food items of the month divided by the total observation time in that month. The dominance of each species was calculated using the following formula: relative density+relative frequency+relative coverage [Brower et al., 1990]. The ten most dominant tree species within the quadrats are listed in Table I.

The habitat used in feeding was counted by minutes allowing us to calculate the percentage of time the langur used different zones throughout the total study period.

Total plant species, density of plant species and density of food species in the total study period at each habitat zones were obtained after summing the quadrats data. We analyzed these data to determine the factors that affected the hill zone used by the group.

All research includes data collection and analysis compiled with protocols approved by the appropriate wildlife conservation committee of China and adhered to the legal requirements of China.

RESULTS

During the study period, the langurs were observed to forage on 52 different food items from 37 species. However, a large proportion of the total diet (90%) came from only ten plant species, of which only four species belonged to the most dominant tree species in vegetation quadrats (Tables I and II). Of the 37 plant species eaten, 27 were trees, nine were vines, and one was an epiphyte. Tree species

TABLE I. Number, Density and Dominance of the Ten Most Dominant Tree Species Within in Vegetation Quadrats[a]

Species	Family	Number	Density (individuals/hm^2)	Dominance	Food
Litsea glutinosa	Lauraceae	124	310	1.8304	Yes
Chukrasia cinerascens	Meliaceae	77	192.5	1.1698	Yes
Tilia tuan	Tiliaceae	23	57.5	0.8551	
Breynia frutilosa	Euphorbiaceae	25	62.5	0.8515	
Celtis sinensis	Ulmaceae	30	75	0.7772	
Alchorne trwioides	Euphorbiaceae	30	75	0.7604	
Boniodendron minor	Sapindaceae	19	47.5	0.6367	
Desmos cochinchinensis	Annonaceae	23	57.5	0.5473	Yes
Solanum verbascifolium	Solanaceae	11	27.5	0.5198	
Pistacia weinmannifolia	Anacardiaceae	23	57.5	0.4639	Yes

[a]Species are listed in order of dominance.

TABLE II. List of the Top 10 Food Species in the Fusui Nature Reserve Between August 2002 and July 2003

Species	Family	Life form	Number of month used	%(*F*)
Pittosporum gabratum	Pittosporaceae	Tree	11	23.07
Litsea glutinosa	Lauraceae	Tree	11	22.98
Chukrasia cinerascens	Meliaceae	Tree	11	15.39
Annona glabra	Euphorbiaceae	Tree	9	10.74
Desmos cochinchinensis	Annonaceae	Vine	8	5.88
Pistacia weinmannifolia	Anacardiaceae	Tree	7	2.89
Ficus lacor	Moraceae	Tree	3	2.61
Ficus microcarpa	Moraceae	Tree	3	2.29
Cudrania cochinchinensis	Moraceae	Tree	7	2.28
Polygonum chinense	Rhamnaceae	Vine	4	1.53

%(*F*), percentage of total feeding time.

accounted for 88.8% of the total feeding time, vine for 10.8% and epiphyte for 0.4%.

The langur in the Fusui Nature Reserve spent 10.4% of the daylight hours (minimum in August) and 21.3% (maximum in December) in feeding, which was significant difference [Huang et al., 2006]. Ninety-four percent of their feeding time was used to consume leaves. Fruits, flowers and stems accounted for the remaining 6% of the feeding time (Table III). Eight plant species were used as sources of fruits. Among these, *Polygonum chinense* and *Chukrasia cinerascens* accounted for 69% of feeding time on fruits. Only three plant species were used as source of flowers. *Brooussetia papyrifera* accounted for 57% of feeding time on flowers, *Clematis chinensis* accounted for an additional 39%. In the case of stems, *Litsea glutinosa* and *Annona glabra* accounted for 70% of feeding time.

There was seasonal variation in the feeding time spent on leaves with more time spent in the rainy season and less in the dry season (Mann–Whitney *U*-test: $Z = -2.745$, $P = 0.004$). Conversely, they spent more time feeding on fruits in the dry season than in the rainy season ($Z = -2.616$, $P = 0.009$). Flowers were consumed by langurs only in the dry season months. Although langurs spent more time feeding on twigs in the dry season than in the rainy season, the difference was not statistically significant ($Z = -1.742$, $P = 0.117$).

The number of plant species eaten by langurs in each month varied from five species in September to 16 species in November, with an average of 10.6 species monthly (Table III). The langurs used more plant species as foods in the dry season than in the rainy season (Mann–Whitney *U*-test: $Z = -2.659$, $P = 0.004$). Among all food species, only three (10.8% of 37 food species), namely *Pittosporum gabratum*, *L. glutinosa*, *C. cinerascens*, *A. glabra*, were used by langurs in $\geq$9 to 12 months, and four (10.8% of 37 food species) were used in $\geq$5 and $\leq$8 months. The remainder was used in $\geq$1 and $\leq$4 months (78.4% of 37 food species).

The mean monthly dietary diversity of the Franç ois' langur was 1.83 (Table III). Similarly, the dietary diversity was lowest in September (1.08), and highest in November (2.30). Compared with the rainy season, the dietary diversity was significantly higher in the dry season ($Z = -2.373$, $P = 0.017$). Significant and negative correlations were found between the monthly feeding time for leaves and the number of

TABLE III. Monthly Number of Food Species, Dietary Diversity and Percentage of Feeding Time Devoted to Different Plant Items From August 2002 to July 2003

Month	Food species	Diversity index	Leave	Fruit	Flower	Stem
August, 2002	6	1.22	100.0	0	0	0
September, 2002	5	1.08	99.3	0	0	0.7
October, 2002	13	2.09	92.1	6.2	1.7	0
November, 2002	16	2.30	86.3	13.7	0	0
December, 2002	15	2.26	93.0	7.0	0	0
January, 2003	15	2.23	90.1	2.0	1.5	6.4
March, 2003	11	1.80	89.9	1.2	2.5	6.4
April, 2003	10	1.79	92.1	2.2	0.0	5.7
May, 2003	7	1.70	97.8	0	0	2.2
June, 2003	8	1.72	100.0	0	0	0
July, 2003	10	1.91	98.5	1.3	0	0.2
Average	10.6	1.83	94.5	3.1	0.5	2.0

plant species consumed each month (Spearman Rank correlation coefficient $r_s = -0.792$, $n = 11$, $P < 0.004$) as well as dietary diversity ($r_s = -0.702$, $n = 11$, $P < 0.016$). Conversely, the feeding time for fruits was found to be associated positively with the number of plant species each month ($r_s = 0.893$, $n = 11$, $P < 0.001$) and with the monthly dietary diversity ($r_s = 0.903$, $n = 11$, $P < 0.001$).

Thirty-seven food species were located in different zones of the habitat. Seventeen food species were found in all three zones, 11 in two zones and nine were found in only one zone. The bottom zone had 31 species (83.4%), which held the richest food diversity. The middle zone had 27 species (72.9%), whereas the top zone had 22 species (59.5%). Compared with the middle and top zones, the bottom zone had the highest density of food species with 2,320 individuals/ha, whereas the middle and top zones had 2,260 and 1,330 individuals/ha, respectively.

The middle zone accounted for 66.1% (54.9–80.1%) of the entire feeding time, whereas the bottom and top zones had 18.6% (4.1–36.2%) and 15.3% (6.1–26.5%), respectively, a significant difference (Kruskal–Walls H-test, $K = 21.509$, $P < 0.001$; Fig. 3). This result indicated that François' langurs used different zones and their use of the middle zone was significant.

The flat land around this langur habitat is cultivated completely and planted with sugarcane, sesame and other crops (Fig. 2). It was accounting for 53% of the area. Farmers working in the field were counted on each observation day with an average of 16.2 persons working around (Table IV).

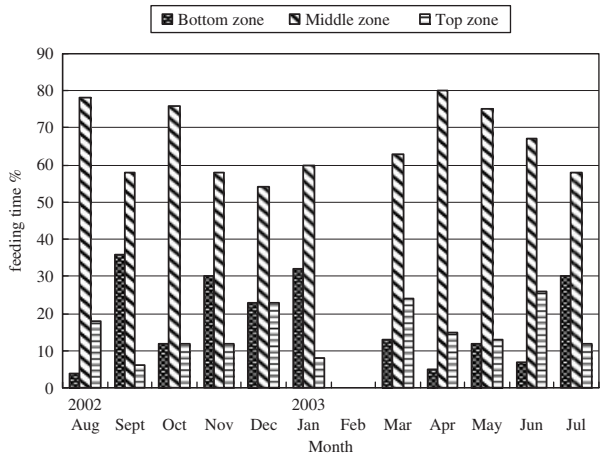

Fig. 3. Monthly feeding time spent at different zones by François' langur.

DISCUSSION

Many studies have documented that the variations of dietary richness are related to differences in vegetation richness among habitats [Bicca-Marques, 2003; Li et al., 2003; Pinto & Setz, 2004]. In this study, 37 plant species were consumed by the François' langur during the 11-month study, whereas the white-headed langur used a similar number of plant species as food [42 species, Huang, 2002; 50 species, Li et al., 2003].

In this study, François' langurs fed more on leaves, had fewer food items and less dietary diversity in the rainy season, whereas in the dry season they foraged less on leaves, and ate more food items with more dietary diversity. This was also the case for the white-headed langur. Time spent on feeding ranks second after resting, which is the feature of folivorous primates [Huang et al., 2006; Li et al., 2003]. More than 90% of feeding time was spent consuming leaves, which demonstrates that the François' langur is a highly folivorous primate similar to the white-headed langur [Huang, 2002; Li et al., 2003]. Therefore the more leaves in diet, the lesser the time spent on feeding. The richness of leaves in the rainy season, when there is less availability of fruits and flowers, simplified the diet

TABLE IV. The Percentage of Cultivated Land and Karst Hill, Daily Human Occurrence in the Habitat of White-headed Langur and Francois Langur in Fusui Nature Reserve, China

Species	Percentage of agriculture (%)	Percentage of karst hill (%)	Daily human occurrence	Resources
White-headed langur	21	79	4	Huang [2002]
François langur	53	47	16.2	This study

composition. It forces the langur to consume more leaves, which contributed to the reduction in the time spent on feeding and increased the time spent resting. Other folivorous primates also exhibit dietary changes following seasonal variations in food availabilities [Strier, 1999]. Thus, as expected, lower availability of food increased dietary diversity, similar to that reported for other primate species such as *Lophocebus albigena* [Poulsen et al., 2001], *Macaca fuscata* [Hill, 1997], *Cercocebus albigena* [Olupot et al., 1997] and howler monkeys [Bicca-Marques, 2003]. This evidence demonstrates that François' langurs adopt a similar feeding strategy, diet composition and variation and feeding time budget as the white-headed langur.

Plant species do not grow evenly in all three zones in karst environment owing to the difference in water, soil and other factors [Xu, 1993]. Thus, the food species vary. The bottom zone has the advantage of the richest soil and water [Jiang, 1996]; therefore, it has the highest diversity of plant species and food species. In the white-headed langur's habitat, species density was 9,226 individuals/ha and food density reached up to 3,212 individuals/ha [Huang, 2002]. In the François' langur's habitat, the bottom zone also had the highest food density. In this case, both the white-headed langur and the François' langur spent most of their feeding time in the bottom zone. This is the case for the white-headed langur, because it used 65.05% of feeding time in the bottom zone, and 22.45 and 12.5% in the middle and top zones, respectively [Huang, 2002]. However, the François' langur preferred the middle zone the most and spent 66.1% of feeding time in this zone, with only 18.6% in the bottom zone where there is more richness of food species. What factors contribute to the difference in zone use? Compared with that of the white-headed langur, we found that there are some differences including density of karst hills and cultivation land, and degree of human activity (Table IV). In other words, habitat fragmentation and human interference may contribute to this difference. In less fragmented habitats, agricultural land (flat land) is less common and there are fewer people working in the field, the vegetation is better and the white-headed langurs naturally select the best food patch to feed on. On the contrary, the habitat of the François' langur is different, it has more cultivated flat land and more people working in the field. A study of François' langur in the Longgang Nature Reserve, where flat land zone is covered with natural vegetation, documented that the Franç ois' langur used the flat land zone and bottom zone more than the other zones [Zhou, 2005]. It is clear that the degradation of the vegetation and frequent human occurrence and interference may force the François' langur Group in Fusui to withdraw from the prime bottom zone and move to the second best zone to feed.

Conclusion

François' langur in a highly fragmented habitat in Fusui foraged on 37 plant species with 90% on ten tree species. Dietary variation between the rainy and dry season was significantly different, more items in dry season and less in rain season. This feeding strategy is similar to that of the white-headed langur in the same nature reserve. The François' langur feeding time spent on different hill zones was different from that of the white-headed langur, which preferred the middle zone with the richest food diversity rather than the bottom zone. The heavy human interference including cultivation and chopping in this highly fragmented habitat contributes to this difference.

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