

**Winter ecology of the Arunachal macaque *Macaca munzala* in Pangchen Valley, western Arunachal Pradesh.**

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By

**Uttara Mendiratta**

Post-Graduate Programme in Wildlife Biology & Conservation  
Centre for Wildlife Studies

and

National Centre for Biological Sciences  
UAS-GKVK Campus  
Bangalore – 560 065



## Post-Graduate Program in Wildlife Biology and Conservation

National Centre for Biological Sciences, Post Box 6501, GKVK Campus, Hebbal, Bangalore 560 065, INDIA.

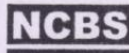
Tel: 91-80-23636421 to 431, Fax: 91-80-23636662, Email: [mso@wcsindia.org](mailto:mso@wcsindia.org) Website: [www.wcsindia.org](http://www.wcsindia.org)

### Declaration

I declare that the thesis entitled "Winter ecology of the Arunachal macaque *Macaca munzala* in the Pangchen Valley, western Arunachal Pradesh" comprises research work done by me under the guidance of Dr Anindya Sinha and co-guidance of Dr Charudutt Mishra. The work is original and has not been done earlier by anyone else. Part of this work, which is related to or similar to work done by other researchers, has been referred to in this thesis at appropriate places. The results presented in this thesis have not been submitted previously to this or any other University for a MSc or any other degree.

Signature of the Guide  
(Anindya Sinha)

Signature of the Candidate  
(Uttara Mendiratta)





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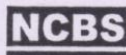
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Tel: 91-80-23636421 to 431, Fax: 91-80-23636662, Email: [mssc@wcsindia.org](mailto:mssc@wcsindia.org) Website: [www.wcsindia.org](http://www.wcsindia.org)

### Certificate

I declare that this thesis entitled "Winter ecology of the Arunachal macaque *Macaca munzala* in the Pangchen Valley, western Arunachal Pradesh" comprises research work carried out by Uttara Mendiratta at the Centre for Wildlife Studies under my guidance and the co-guidance of Dr Charudutt Mishra during the period 2005-2006 for the Degree of Master of Science in Wildlife Biology and Conservation of the Manipal Academy of Higher Education (MAHE). The results presented in this thesis have not been submitted previously to this or any other University for a MSc or any other degree.

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Anindya Sinha, PhD  
National Institute of Advanced Studies  
Indian Institute of Science Campus  
Bangalore



## **SUMMARY**

Production of plant parts in tropical forest is seasonal and the importance of these phenological patterns to primary consumers, such as macaques, is immense. They influence almost all aspects of macaque socio-ecology; importantly the macaque's diet is required to be flexible to accommodate fluctuations in the resource availability. Macaque diets are rarely specialized, however, most species in tropical Asia are highly dependent on fruit through the year. As the one moves away from the tropics towards the temperate zone the habitat becomes more seasonal and the diet has to become more flexible.

The recently described Arunachal macaque lives in subtropical broadleaf forest in high altitudes of upto 3500m. Nothing is known about the ecology or biology of this species. The species is unique in that it is among the minority of macaque species that live in very cold seasonal environments where the energy cost of thermoregulation is high and the availability of food resources is low during winter. This study of the winter ecology of the Arunachal macaque is important not only to understand the newly discovered species but also to better understand the behavioural adaptations of macaques that live in marginal habitats.

This study was carried out in the Pangchen valley of the State of Arunachal Pradesh, India at the altitude of 2180m, the site from where the holotype of the species was photographed. The study was carried out from December 2005 to May 2006. Data on a group of 25 individuals was collected using scan sampling. Data on ranging was recorded using a GPS. Bimonthly monitoring of tagged trees was used to collect data on the phenology. Plots were laid to establish densities of trees in the habitat.

The study period was divided into two seasons – winter (December-February) and post winter (March-May). The differences in activity budget, diet, habitat use, ranging and social interactions were compared between the two seasons, and so was phenology.

The study showed that the macaque group spent more time feeding in the winter as opposed to post winter, while time spent moving was more in post winter. The contrast between the two seasons was exceptionally pronounced in the case of diet. Number of species consumed increased from 18 to 25 while the number of food types rose from 18 to as much as 36. While two species formed 75% of the diet in winter it took more than six individual species to match this percentage in post winter. No one species or food part (leaf, pith or fruit) remained important consistently though the study period. In winter 72% of the feeding time was devoted to feeding on the pith of *Erythrina sp*; this dropped to only 7.8% in post winter. Time spent feeding on leaves increased from 13.2% to 60.7% while that on fruit rose from 1.7% to 18.9%. This change in diet is better understood in the light of the changes in phenology, as overall production of young leaves and fruits were clearly higher in post winter.

The use of habitat also changed from one season to the other. An *Erythrina* dominated forest patch was most extensively used in winter with the group spending as much as 43.2% of the time in this. This percentage of time is much higher than that expected if we consider that the vegetation type covered only 11.5% of the core range. Time spent in open forest increased from 49.8% to 72.7% from winter to post winter. The group did not prefer human dominated habitat in any of the two seasons.

The change in ranging from the early months of the study to the last was conspicuous. The group was seen using much more of the range in the month of May as opposed to

February when they were largely restricted to the *Erythrina* forest. The size of the area used by the group increased from 6.7ha to 18ha from winter to post winter.

The scope for comparing social interactions between winter and post winter was restricted due to low frequency of social interactions. The only aspect of social integration that has been covered by the study is that of frequency of aggression. It was found that the frequency dropped from 0.82/hr in winter to 0.19/hr in post winter.

The results from the study suggest that the Arunachal macaque, like the Japanese, Tibetan and to some extent Taiwanese macaque, has to adapt to high seasonality in its environment. The survival strategy used by the Arunachal macaque to survive winter seems to be one of reducing energy expenditure by spending more time feeding and consuming low nutrient food that is readily available in the habitat. In post winter the macaques show a dramatic changes in their behaviour; time spent moving, diversity of diet, habitat use and ranging go up, which are in accordance with the prediction that these behaviours in winter are governed by scarcity of food and cost of thermoregulation.

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## INTRODUCTION

The genus *Macaca* (Order Primates; Family Cercopithecidae) has the widest distribution for any non-human primate genus (Abegg & Thierry 2002). Macaques have colonized an array of habitats ranging from tropical rain forest to cool temperate forests. The breadth of the adaptability of this genus is distinctly wide.

A majority of primate species, including macaques, are found in the tropical region, (Hill, 1997). Production of new leaves, flowers and fruits in most tropical woody plants happens in bursts and the presence of these in most tropical forest communities is determined by season (van Schaik *et al.*, 1993). The importance of phenological patterns to primate socio-ecology is immense; they influence diet, ranging, habitat use and activity budgets (Ménard, 2004). Adaptations to cope with seasonality become increasingly important as the seasonality becomes more pronounced, as in the case of subtropical and temperate areas. There is also the additional pressure of increased energy expenditure for thermoregulation at low temperatures (Agestsuma, 2000).

Macaque's diets normally consist of an array of food items depending on seasonal availability. Fruits are an important component of the diet of most macaques in tropical Asia. For example the lion-tailed macaque (*Macaca silenus*) and the Sulawesi crested black macaque (*Macaca nigra*) that are tropical rain forest species spent as much as 60% of their feeding time on fruits through the year (Kurup & Kumar, 1993; O'Brien & Kinnaird, 1997). In contrast, macaques in temperate broadleaf and coniferous forests like the Taiwanese macaque (*Macaca cyclopis*) are almost completely folivorous for five months of winter when the availability of fruits is low (Su & Lee, 2001). With increased seasonality in habitat, specialization on fruit decreases further. The Japanese macaque (*Macaca fuscata*) that live in temperate

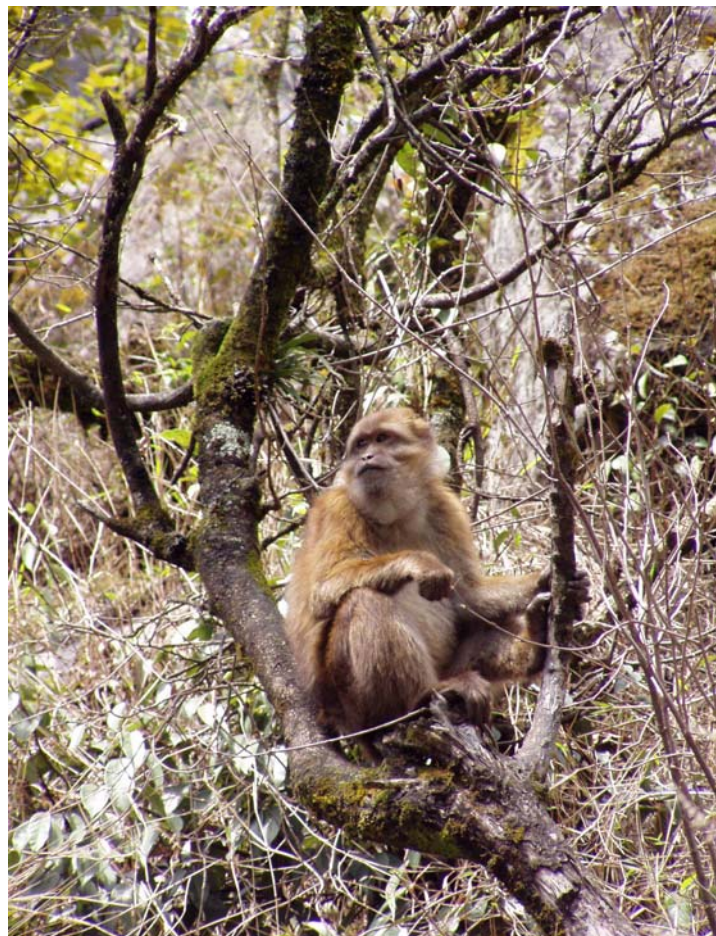
forests do not consume large quantities of fruit and are so flexible in their diet that it has not been possible to assign them to a simple category (Hill, 1997). The above contrasting patterns of feeding ecology are reflected in the time activity budget, ranging and habitat use. Macaques in temperate forests show greater variability in time budget, ranging and habitat use with seasons, compared to those in tropical forests.

The Arunachal macaque (*Macaca munzala*) was recently described from remote parts of the State of Arunachal Pradesh, India (Sinha, *et al.*, 2005). The Arunachal macaque occurs at altitudes between 2000m and 3500m in subtropical broadleaved forests with pronounced seasonality, and low winter temperatures. Based on its penile morphology, the species has been placed within the *sinica* group (Sinha *et al.* 2005). Morphologically, the Arunachal macaque shows similarity to the Assamese macaque (*M. assamensis*) and the Tibetan macaque (*M. thibetana*); the two species of the *sinica* group that are geographically closest to it. *M. munzala*, however, differs from these two species in its tail length and in distinctive facial features – a prominent dark crown patch, characteristic facial marks on the temple and forehead, and a pale collar of hair around the neck (Sinha *et al.* 2005). Adult females have prominent facial hair similar to that in Tibetan macaques. Great variability was observed in morphological characters within the species, especially in coloration of fur and facial markings.

The discovery of this new species has raised a lot of curiosity about its biology and ecology. Knowledge of the ecology of this species could greatly help in our understanding of the adaptive abilities of macaques to marginal habitats with harsh



Adult female of the Arunachal *Macaca munzala* at Gorsam village, Tawang.  
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Adult male of the Arunachal *Macaca munzala* at Gorsam village, Tawang.  
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environments that show seasonal fluctuations in food availability. This would also be of great importance to the conservation of this newly described and, possibly endemic species. Little is known about the distribution, biology or ecology of this newly discovered species, making it even more important to study this species and its conservation status.

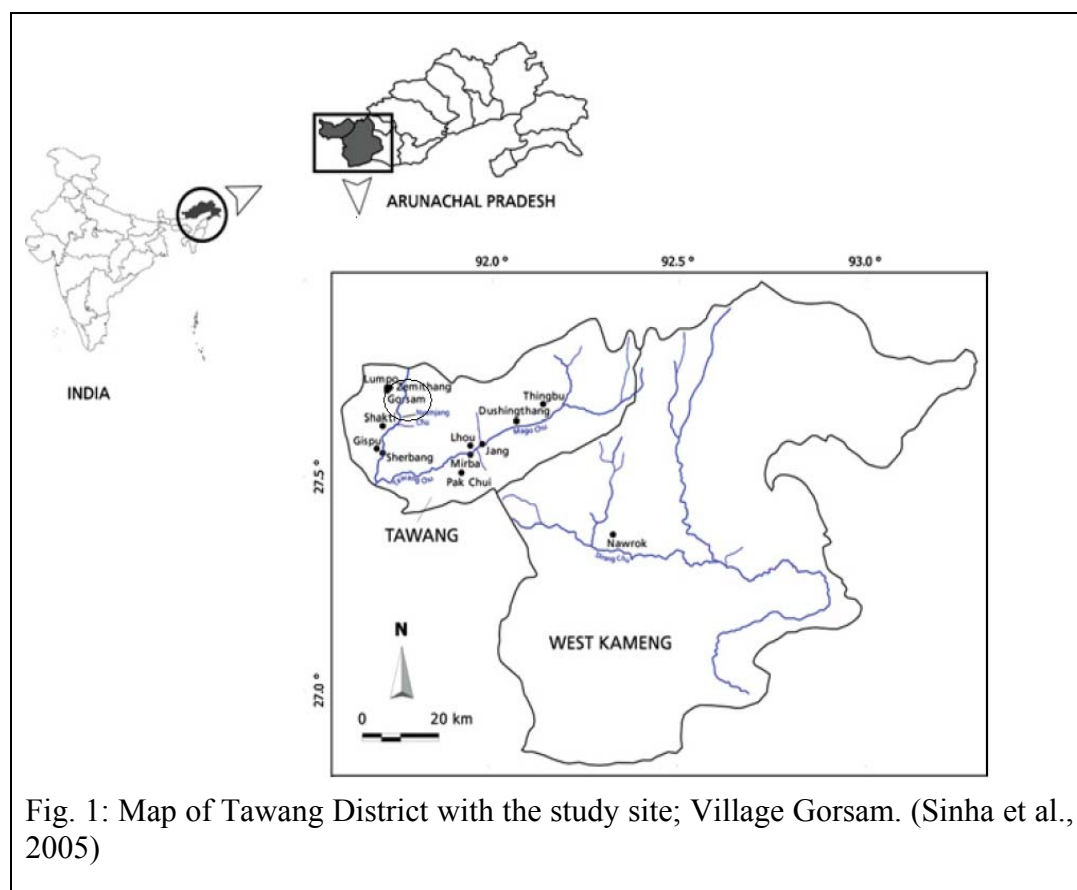
In this study I compare the activity budget, feeding, ranging and habitat use of *the M. munzala* between seasons; winter, when night temperature dropped to  $<0^{\circ}\text{C}$  and post winter, when the maximum temperature was  $>15^{\circ}\text{C}$ . Increase in temperature was accompanied by an increase in precipitation causing an overall increase in productivity of leaf, flower and fruit. The difference in phenology and corresponding increase in availability of food in the seasons has also been examined by this study.

## **STUDY SITE**

The study was carried out from December 2005 to May 2006 in and around the village of Gorsam in Zemithang Circle ( $27^{\circ}42'\text{N}$ ,  $91^{\circ}43'\text{E}$ ), Tawang District, Arunachal Pradesh (Fig. 1). Zemithang, which is situated in the Pangchen Valley, is the site from where the holotype, a male macaque, was photographed on August 20, 2003 (Sinha *et al.* 2005).

The altitude of the study site was 2180 m. The site comprised a mosaic of intact and degraded forest, crop fields, pastures and villages. River Nyamjanmchu runs across the valley and could have potentially acted as an effective barrier to the movement of the macaques; however, the group was seen extensively using the bridges.

Forests in the area were of the subtropical broadleaved category. Most of the dense forest was restricted to the slopes, while land around the village had been converted to fields and pasture. The 170+ human population of village Gorsam and neighboring villages was largely Mompā Buddhist who practiced agriculture and cattle raising. During most of the study months the fields in the area were fallow and it was only in May that crops were being sowed. Conflict between villagers and the macaques is high during the agriculture season. Hunting for meat is rare due to religious taboos.



The more extensively used range of the group consisted mostly of disturbed open forest while it only occasionally used the less disturbed forests. The open forest was



Intensively used range of the study group.



Open forest



Erythrina forest

restricted to areas along the river. Some of the major species in the forest were species of *Salix*, *Prunus*, *Elaeagnus*, *Rhus*, *Dabregeasian* and *Viburnum*. *Erythrina* sp. and *Alnus nepalensis* were common in areas with higher human disturbance. Some patches in the forest were dominated by *Rhododendron spp* and *Quercus sp*.

## **METHODS**

### **Activity budget and diet**

Data on activity budget and diet was collected for a single group of approximately 24 unmarked individuals from December to May 2006. The composition of the study group was approximately five adult females, four adult males, 12 sub-adults and juveniles and two infants, which were born during the study period. The group was observed on approximately 4-5 days over five study sessions.

Data was collected using 5-minute scan sampling at 10-minute intervals. Activity, along with food species and plant parts in case of feeding, was recorded for as many individuals as possible within the 5-min scan. Activities were grouped into one of five main categories:

Feeding – manipulating, placing food in mouth or chewing

Moving – locomotion, including walking, running, climbing, and jumping,

Resting – stationary posture, usually sitting or lying down,

Grooming – allogrooming and autogrooming, and

Other – play, noncopulatory mounting, copulations, aggressive interactions.

A total of 3002 records was made over 448 scans in 112 hours of scan time.

For each scan record the individual occurring within 5m of the individual were recorded. *Ad libitum* records of social behavior including fights, copulation, and other behaviors like branch shaking were recorded as and when they were observed. Scan data and *ad libitum* records were used to arrive at a frequency of aggression (events/hr). Aggression was defined as actual fighting, teeth showing, raising eyebrows, staring, chasing (other than in play) and cases of approach-retreat where the retreating animal was in possession of food.

### **Habitat use and ranging**

The habitat type used by the group was recorded for each scan over the study period. GPS (Garmin 72) locations were recorded for the group at regular intervals or if the group moved considerably away from the location of the last recording. GPS was also used for marking the three major habitat types (open forest, *Erythrina* forest and human dominated habitat) and creating a map of the intensively used range of the group. The locations of the group were overlaid on the map of the intensively used habitat of the group to create the home range of the group in each month. Data from the month of December and January were not used since at that time there existed some ambiguity about the identification of the study group. Locations from March and April were combined to create a common range as the group ranged in the same area throughout this period. The polygon for February was created using data from only 22.25 hrs over three days, and for May observations of 23 hrs over two days were used. Observations of 57.25 hrs were used for March and April. Cartalinx (Clark Labs) and MapInfo (MapInfo Corporation) were used to create maps and calculate areas of home ranges.

## **Availability of food**

The phenology of 72-tagged trees, belonging to 24 species including 19 food species, was monitored over the study period. Species were selected based on feeding observations, known potential of the species as food, or abundance. The selected trees were monitored at 15-day intervals. The abundance of young leaves, mature leaves, flower and fruits were independently scored on a scale of 1 to 9. The scores were averaged for each species and then across four sessions and converted into percentages. This gave the availability of food parts on each species in each season. This was multiplied with density of different species in order to estimate abundance of food plant parts for each species.

Vegetation plots of 7m radius were used to estimate the density of food species within the range most extensively used by the group. All trees >12cm in GBH were identified and recorded. A total of 38 plots were laid in the intensively used habitat, which had three distinctly different vegetation types i.e. open forest, *Erythrina* dominated forest and human habitation. The plots covered 2.1% of the intensively used habitat. Number of plots for each habitat type was selected based on proportion of area, use by the group and expected variability of tree species (open forest – 17, *Erythrina* dominated habitat – 10 and human dominated habitat – 11).

## Data Analysis

The time spent on each activity was estimated for each day as:

$$T_a = \frac{1}{S} \sum_{i=1}^S \frac{n_{ai}}{N_i} \times 100$$

Where  $T_a$  = Percentage time spent on activity  $a$  per day,  $S$  = Total number of scans in a day,  $n_{ai}$  = Number of records of activity  $a$ , in scan  $i$ , and  $N_i$  = Total number of records in scan  $i$

Time spent on activity  $a$  in a season was estimated as  $1/D \times T_a$ , where  $D$  is number of days.

The percentage time spent on different species of plant and plant parts was estimated for each season as  $P_a = n_a/N$ ; where  $n_a$  is the number of feeding records on species or part  $a$ , and  $N$  is all feeding records for the season.

The extent of overlap between the two seasons in food species and food type was estimated using Sorensen's quotient of similarity, which was calculated as:  $\frac{2C}{A+B}$

Where  $A$  = Number of food species in winter,  $B$  = Number of food species in post winter and  $C$  = Number of food species common to both seasons

Shannon Weiner Index for diversity and Evenness Index for evenness of diet were used to compare the diet of the group between the two seasons. Shannon Weiner Index was calculated as,  $H' = -\sum p_i^2 \text{Log}(p_i)$  and Evenness Index was calculated as

$J' = \frac{H'}{\text{Log}(S)}$ , where  $p_i$  = Proportion of individuals of species  $I$ , and  $S$  = Total number of species.

The study period was divided into winter (December 2005 to February 2006) and post winter (March to May 2006). Time activity budget, diet, habitat use, ranging, and social interactions of the group were compared between these two seasons. Plant phenology was also compared between the two seasons.

Difference between the two seasons in time spent on an activity was examined using Mann-Whitney U test, with days as samples. Difference between seasons in the use of plant species and parts was examined using Chi square test. Since feeding records made during consecutive scans were not independent, a random sample of 10% of the feeding records for the Chi square test was used. In case of differences between the activity budget of different age and sex classes a random sample of 25% was used. Days in which less than 50 records were made were not included in estimating time budget.

## RESULTS

### Activity budget

Time spent feeding was significantly higher in winter (Mann Whitney  $U=22$ ,  $p=.04$ ) (Fig. 2a). Time spent moving was higher in post winter (Fig. 2b). Time spent on grooming and resting did not change much between the two seasons. (Fig. 2 c&d).

The sequence of activity peaks (activity pattern) during the four quarters of the day (I=0600-0850 hrs, II=0900-1150 hrs, III=1200-1450 hrs and IV=1500 hrs to end) remained consistent through the two seasons for feeding and grooming (Fig 3 a. & b.). While feeding dropped in the second quarter of the day, grooming reached its peak at this time when direct sunlight reached the study site. Moving also followed a similar pattern through the two seasons; except for the last quarter of the day when there was an increase in percentage time spent moving in the post winter season (Fig 3c).

The group in winter would settle down to rest or huddle soon after the sun moved out of the valley. In winter the group rested less in the second and third quarter of the day as opposed to post winter when percentage time spent resting was highest in the second quarter of the day (Fig. 3d). This was also the time when many adults were observed sleeping. This mid-day sleeping was not observed in winter.

Different age-sex classes partitioned their time differently. The activity budget of adult males, adult female and juveniles over the study period differed significantly ( $\chi^2=16.100$ ,  $df=6$ ,  $p=.013$ ). Adult males were feeding more frequently (56.3%), while adult females groomed more frequently (22.1%). Juveniles moved more (24.5%).

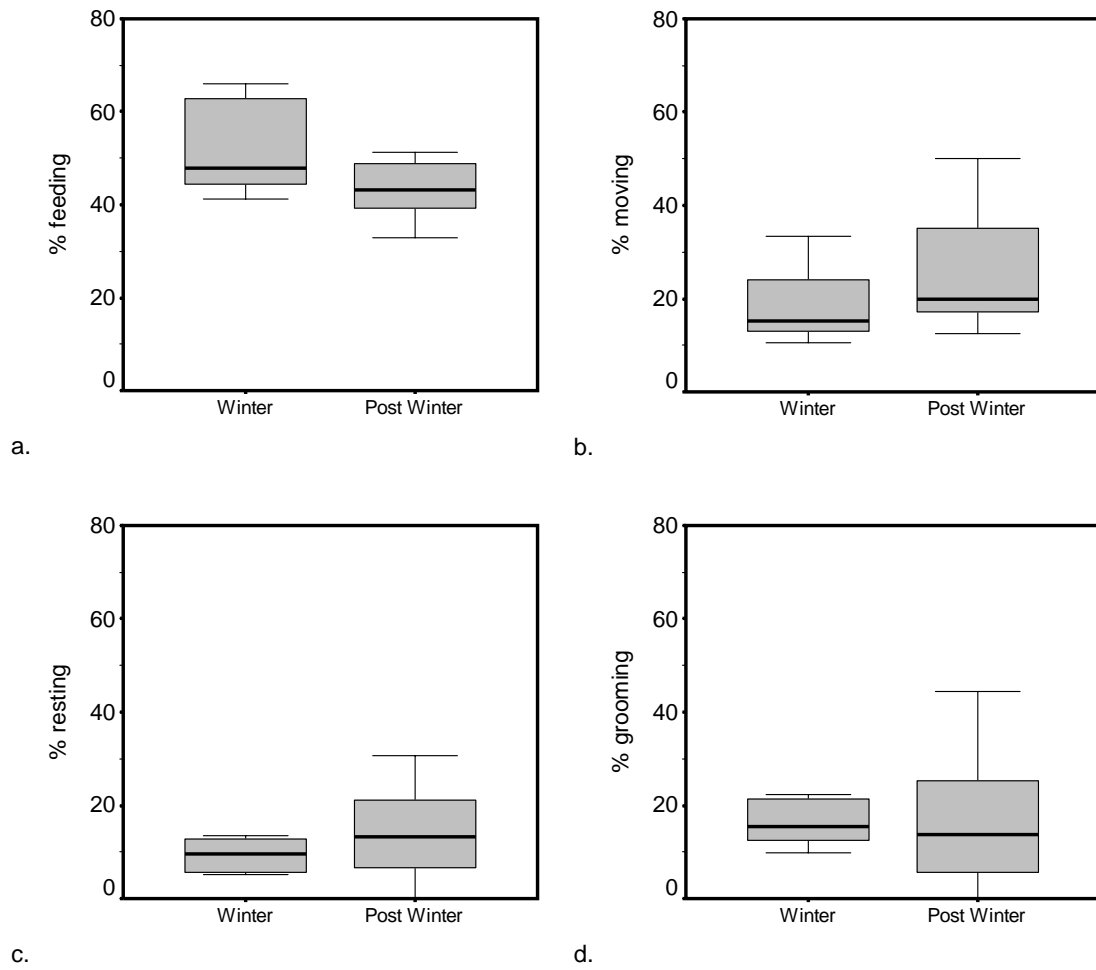


Fig. 2: Box plots of percentage time spent by the group in winter and post winter seasons on (a) feeding (b) moving (c) resting & (d) grooming.

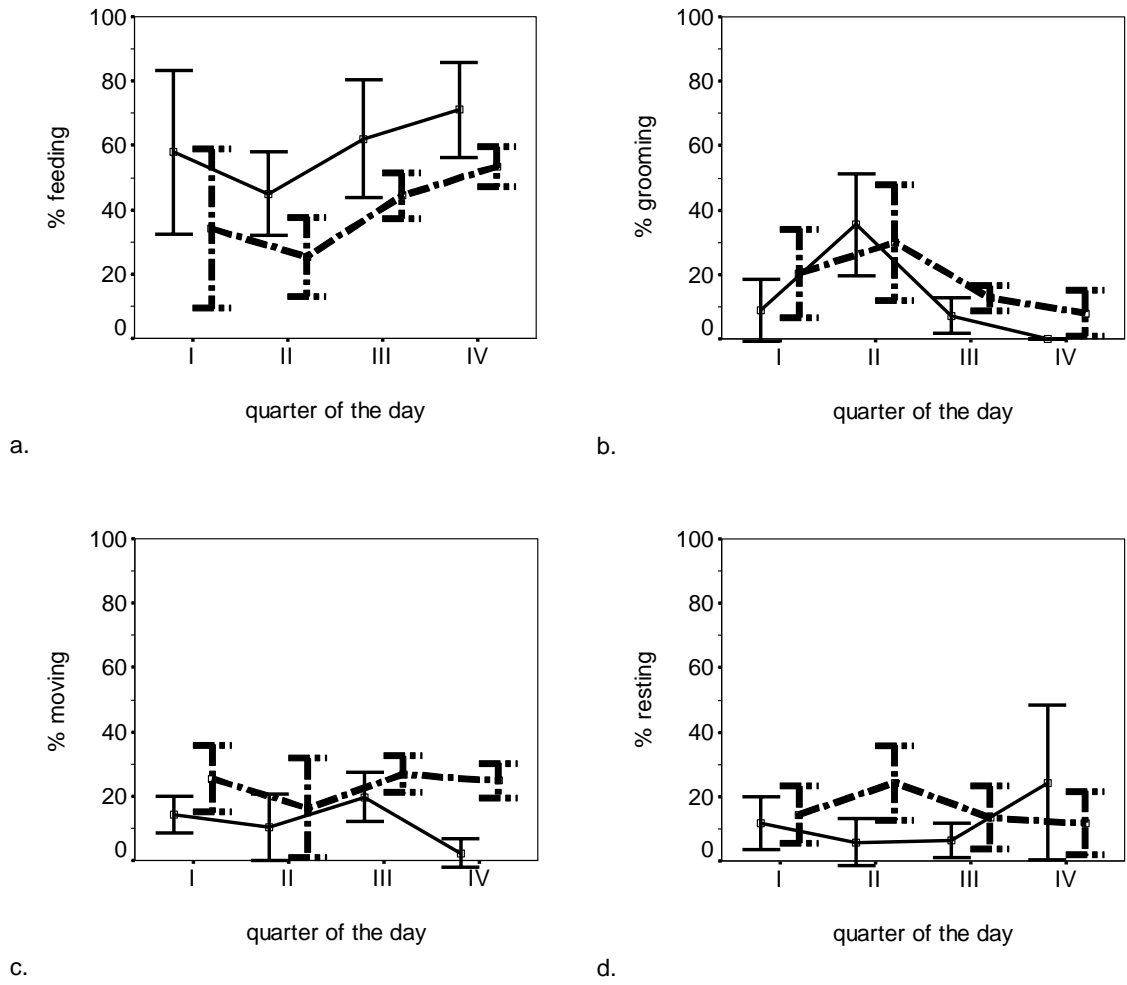


Fig. 3: Percentage time spent by the group during the three quarters of the day on (a) feeding, (b) grooming, (c) moving & (d) resting. (95% CI) — winter; ---- post winter.

## Diet

The group fed on parts of 29 plant species consisting of 14 trees, eight shrubs, five creepers, and two herbs. They also fed on insects and mud. The plant parts that the group fed on included leaf, fruit, pith, flower, and petiole. More than one part of some species was eaten. For example, in winter the pith of *Erythrina spp* was consumed and in post winter young leaves that were just appearing were also added to the diet.

Over the study period, the group spent 44.2% of the feeding time on *Erythrina spp*, 10.5 % on *Mahonia napaulensis*, 6.3% on an *Elaeagnus spp*, 4.8% on a *Salix spp*, 4.7% on *Prunus cerasoides*, 4.5% on *Ficus spp* and 24.9 % on 24 other species, none of which were fed on for more than 3% of the time (Fig. 4a & Table 1). Animal matter formed a negligible proportion of the diet. Thus, six species accounted for 75% of all the feeding time, although they fed on at least 28 species.

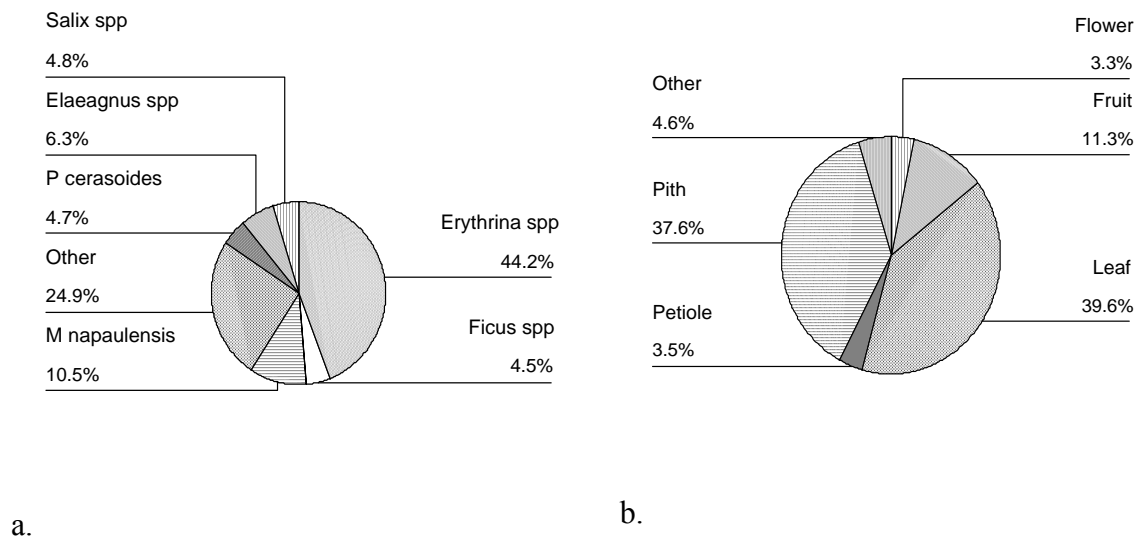


Fig. 4: Percentage time spent on feeding on (a) different species & (b) different plant parts during the entire study period

Of the identified plant parts, the group spent 37.7% of the time feeding on pith (of *Erythrina spp*), 39.4% on leaf (17% mature leaf and 22.2% young leaf), 11.4% on fruit, 3.3% on flower, 3.5% on petiole and 4.9% on others (such as tuber, stem, root and sepal) (Fig. 4b & Table 1).

There was seasonal variation in the proportion of each food type in the diet of the macaques. No one species or food type remained important throughout the study period. There was a highly significant difference between the two seasons in the frequency with which major food species were used ( $\chi^2=37.14$ ,  $df=6$ ,  $p<.001$ ) as well as a difference in the use of plant parts ( $\chi^2=56.55$ ,  $df=5$ ,  $p<.001$ ). (Fig 5a)

The number of food species in winter was 18 and in post winter it was 25. There was a 65% overlap in food species between the two seasons. The group fed on 18 food types in winter and 36 food types in post winter with an overlap of only 48%. Diversity of plant species in the diet during post winter was higher ( $H'=2.526$ ) than that in winter ( $H'=1.081$ ). Diversity of food types in the two seasons showed an even greater difference between the two seasons; winter ( $H'=1.004$ ) and post winter ( $H'=3.049$ ). What is even more striking was the difference in evenness of diet. The diet in the post winter was more diverse not only in the number of species and parts used, but also in the evenness of diet (species,  $E=0.37$  in winter and  $E=0.78$  in post winter; for food types  $E=0.34$  in winter and  $E=0.85$  in post winter). Although the group fed on 18 species in winter, *Erythrina sp.* was the most heavily used. Two species, *Elaeagnus sp.* and *Salix sp.*, which were added to the diet in post winter, accounted for 21.1% of the feeding records in this season. Contribution of other species also went up from 18% to 31.2%. Only two species formed 75% (of which

72.4% was *Erythrina sp.*) of the diet in winter, whereas it took more than six individual species to make up 75% of the diet in post winter.

	Species	% winter	% post winter	Leaf	Pith	Fruit	Flower	Other
1	<i>Aconogonum molle</i>	2.4	1.0				*	*
2	<i>Artemisia spp</i>	1.2	3.2	*				
3	<i>Dabregeasia longifolia</i>	1.7	0			*		
4	<i>Erythrina spp.</i>	72.0	19.0	*	*			
5	<i>Mysine semisierrata</i>	0.3	0.6			*	*	
6	<i>Ficus spp</i>	0.5	7.9	*				*
7	<i>Gaultheria fragrantissima</i>	0	0.3				*	
8	<i>Juglans regia.</i>	0.7	0					*
9	<i>Mahonia napaulensis</i>	4.1	16.2	*		*	*	
10	<i>Prunus carmesina</i>	0	0.3				*	
11	<i>Prunus cornuta</i>	0	3.7	*			*	
12	<i>Prunus cerasoides.</i>	6.2	4.3	*		*		
13	<i>Rhododendron spp</i>	0.7	0.5					*
14	<i>Rubus ellipticus</i>	0.2	4.9			*	*	
15	<i>Salix sikkimensis</i>	0.5	3.2	*			*	
16	<i>Loranthus spp</i>	0.3	0.6					
17	<i>Leucosceptrum canum</i>	0.7	0					*
18	<i>Todila aculiata</i>	0.3	0.3				*	
20	<i>Herb</i>	0.2	3.0	*				
21	<i>Elaeagnus parvifolia</i>	0	0.5	*		*		
22	<i>Perifloes callosa</i>	0	1.1	*				
23	<i>Litsea spp</i>	0	0.3			*		
24	<i>Coriaria nepalensis</i>	0	1.9			*		
25	<i>Zanthoxylum spp</i>	0	1.0	*				
26	<i>Elaeagnus UI</i>	0	11.9	*			*	
27	<i>Salix UI</i>	0	9.0	*			*	
28	<i>Zingiberacea family</i>	1.2	0.3					*
29	<i>Viburnum spp</i>	0.7	0					*

Table 1: The percentage time, of the total feeding time, spent on different species in winter and post winter and plant part eaten.

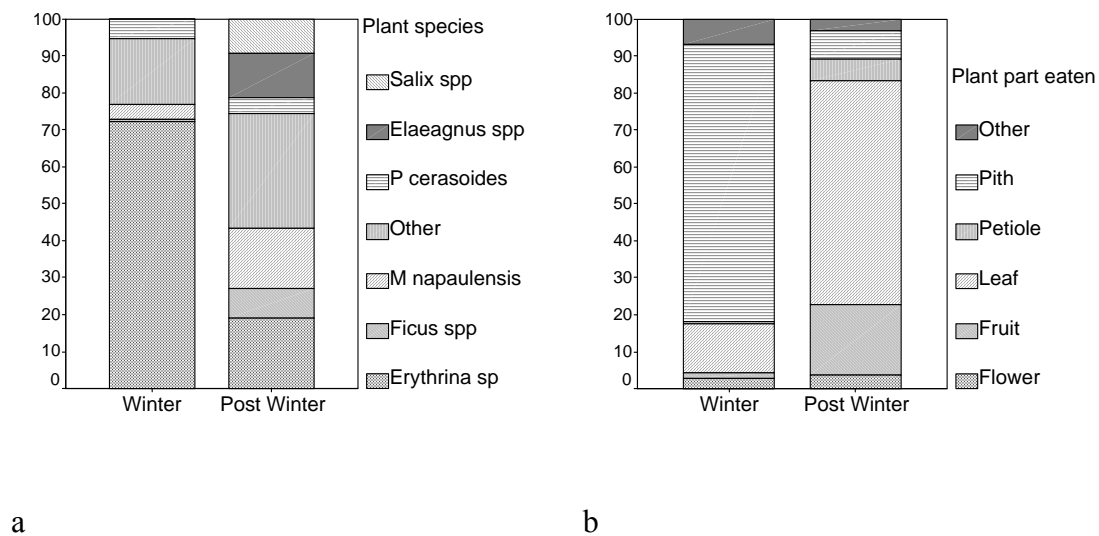


Fig. 5: Percentage time, of the total feeding time, spent on different (a) plant species & (b) plant parts during the two seasons.

Contribution of various plant parts in the diet also showed extreme alterations with the share of pith falling from 75.1% in winter to 7.8% in post winter and the contribution of leaf increasing from 13.2% to 60.7% of the feeding records. Records of feeding on fruit went up from 1.7% to 18.9% (Fig. 5b). Fruiting of *Mahonia napaulensis* and *Rubus ellipticus* in the post winter season contributed largely to this increases in fruit consumption.

### Plant phenology

Data collected from monitoring 72 tagged individuals showed that availability of plant parts - young leaf, mature leaf and ripe fruit, was higher in post winter than in winter (it was same in the case of flower) (Fig. 6).

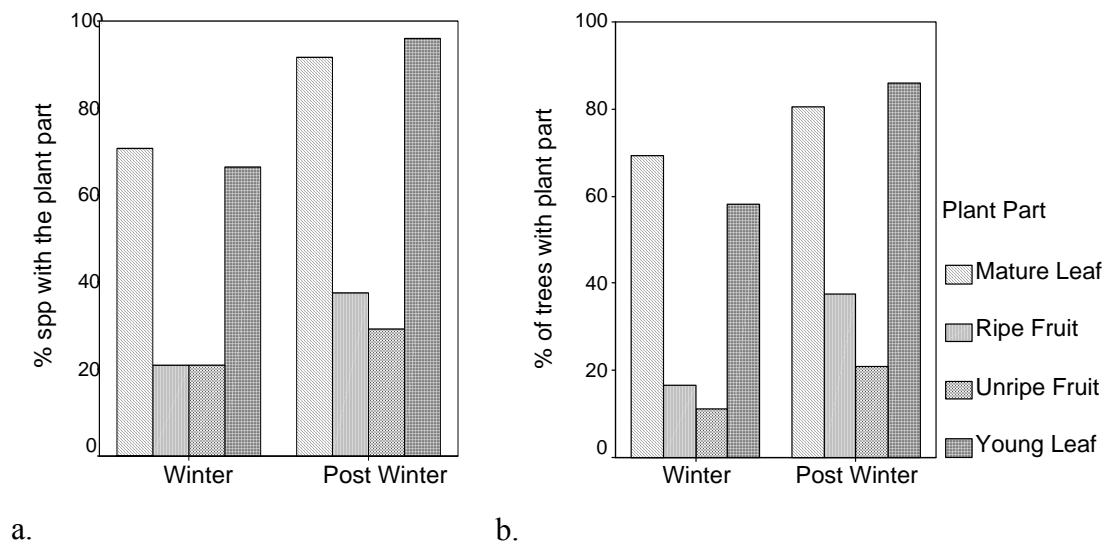


Fig. 6: Percentage of a) species and b) trees with different plant part in post winter and winter.

In most cases the availability of plant parts for each species was higher in post winter. Of the 15 species that showed a difference in mean productivity between seasons, 10 species showed higher productivity in post winter (Fig 6a). Species like *Zanthoxylum spp* and *Gaultheria fragrantissima* had food parts (young leaves and flowers, respectively) only in post winter, while individuals of species like *Erythrina sp.* and *Elaeagnus parvifolia* had a higher percentage of food parts in post winter than winter due to appearance of young leaves and fruits.

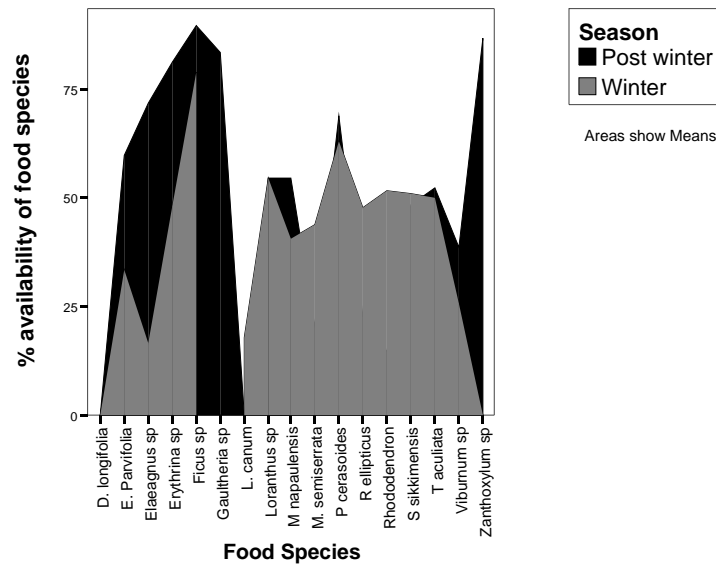


Fig. 7: Percentage availability of plant parts on species in winter and post winter.

### Density of food plants

Abundance of food plants in the intensively used habitat was calculated using vegetation plots. A total of 346 individual trees of 32 species were sampled in the 38 vegetation plots in three major habitat types (open forest, *Erythrina* dominated forest and human habitation). Of the trees sampled in the vegetation plots 78.32% were food plants

Some common trees in the range were *Erythrina spp*, *Dabregeasia longifolia*, *Viburnum spp* and *Elaeagnus spp*; these were not just abundant in terms of numbers but also occurred in a larger number of plot. This however cannot be used to comment on the distribution pattern of the species in the range. *Erythrina spp*, which was the most common species in the range with 68 individuals in 22 plots was actually

clumped with the 3 ha of *Erythrina* forest plot accounting for 61.8% of all *Erythrina* trees sampled; this was followed by the human habitations that accounted for 29.4% and the open forest only accounted for as little as 8.8%.

Contributions of various species to the overall diet were often disproportional to their relative abundance in the habitat. *Erythrina spp*, which accounted for 44.2% of the feeding time of the group, contributed only 19.5% of the trees in the sampled range, while *Dabregeasia longifolia* that contributed 13.3% of the trees accounted for <3% of the time spent of feeding (Fig. 9). The availability of edible plant parts varied among species. For example, *Salix* and *Elaeagnus* species that were not producing any leaf, flower or fruit during the winter were among the top food species in post winter.

The increase in availability of food plant parts, when multiplied with the density of trees for each species also showed a similar pattern of higher availability in post winter than in winter. Having controlled for densities, the contributions of species to the availability of food can be better understood. *Erythrina spp* and *Elaeagnus parvifolia* still stood out as important sources of food, while *Gaultheria fragrantissima* ceased to contribute significantly due to low densities.

	<i>Species</i>	<i>No. of individual</i>	<i>No. of plots</i>	<i>% of total</i>
1	<i>Alnus nepalensis</i>	11	6	3.18
2	<i>Schima wallichii</i>	1	1	0.29
3	* <i>Dabregeasia longifolia</i>	46	14	13.29
4	* <i>Erythrina spp.</i>	68	22	19.65
5	* <i>Myrsine semiserrata</i>	11	8	3.18
6	* <i>Gaultheria fragrantissima</i>	1	1	0.29
7	* <i>Juglans spp.</i>	6	3	1.73
8	* <i>Mahonia napaulensis</i>	9	5	2.60
9	* <i>Prunus carmesina</i>	4	2	1.16
10	* <i>Prunus cornuta</i>	3	3	0.87
11	* <i>Prunus cerasoides.</i>	12	9	3.47
12	<i>Quercus spp</i>	8	4	2.31
13	* <i>Rhododendron spp</i>	12	4	3.47
14	* <i>Rubus ellipticus</i>	1	1	0.29
15	* <i>Salix sikkimensis</i>	7	3	2.02
16	* <i>Leucosceptrum canum</i>	8	2	2.31
17	* <i>Elaeagnus parvifolia</i>	3	2	0.87
18	<i>Rhus spp</i>	20	11	5.78
19	<i>Ficus UI2</i>	6	6	1.73
20	<i>UI</i>	7	5	2.02
21	* <i>Litsea spp</i>	1	1	0.29
22	<i>Rhus javanica</i>	5	2	1.45
23	<i>Lyonia ovalifolia</i>	5	2	1.45
24	<i>Coriaria nepalensis</i>	1	1	0.29
25	<i>Macaranga spp</i>	6	5	1.73
26	* <i>Zanthoxylum spp</i>	7	5	2.02
27	<i>Salix UII</i>	1	1	0.29
28	<i>Populus cilata</i>	1	1	0.29
29	<i>UI2</i>	4	2	1.16
30	* <i>Elaeagnus UII</i>	32	12	9.25
31	* <i>Salix UI</i>	9	7	2.60
32	* <i>Viburnum spp</i>	30	12	8.67

Table 2 – Species sampled in the vegetation plots with number of individuals sampled, number of plots it was found in and percentage contribution to all trees sampled in the vegetation plots.

(\* Food plants)

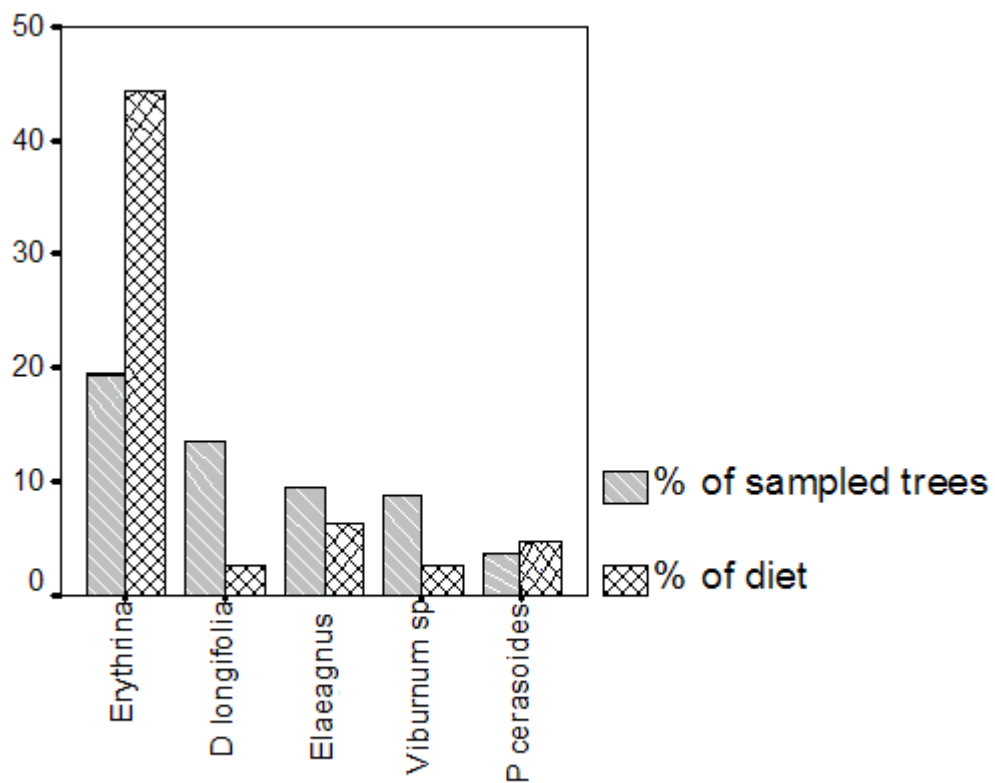


Fig 9: Comparison between the percentage time spent feeding and percentage abundance of the five most common trees in the intensively used range.

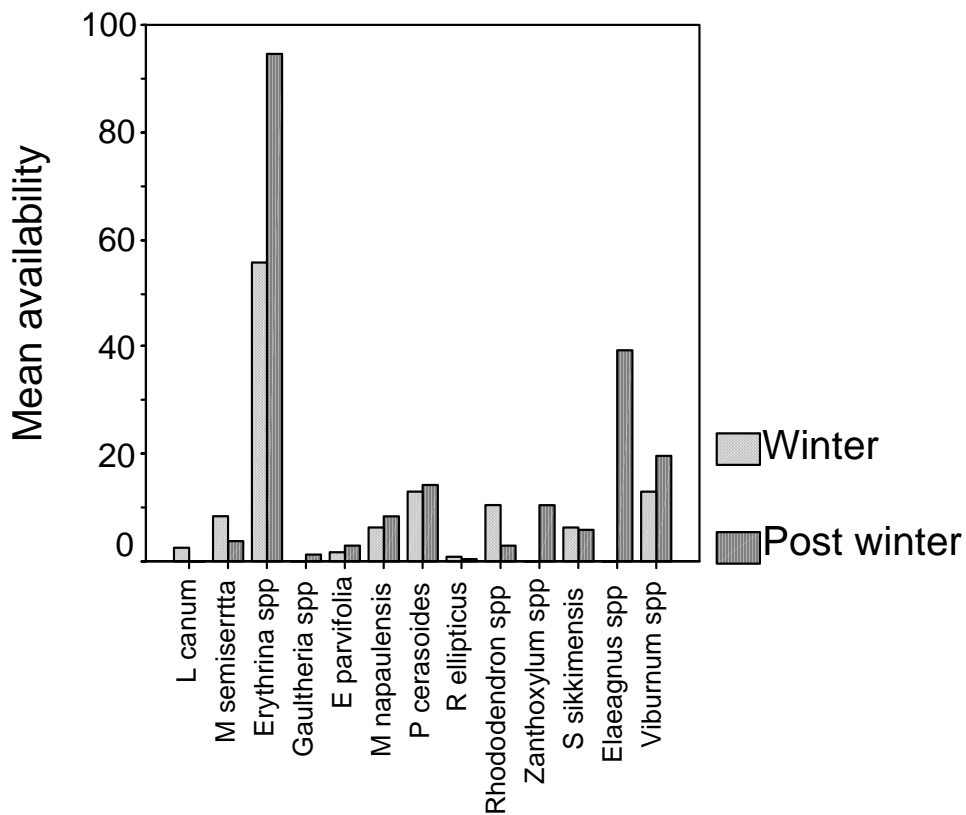


Fig 8: Mean availability of plant parts for each species after controlling for density.

### Habitat use

Time spent in various habitat types in the range i.e. in the open forests, *Erythrina* dominated forest and human habitation, also varied with change in diet and productivity of the tree species. Open forest constituted around 45.5% of the intensively used range. Time spent by the group in the open forest in winter was 49.8% and in post winter 72.7%. Of the three identified vegetation types in the core habitat the open forest represented the maximum number of food species and

individual trees. Plots in this vegetation type included trees of 30 species of which 18 were food species. Moreover, 56.7% of all food trees sampled throughout the habitat were in this vegetation type, and three in every four trees within this habitat type was a food tree.

*Erythrina* forest covered only 11.5% of the core range, but in winter the groups spent as much as 43% of their time in this forest; this proportion dropped to 25% in post winter. This forest had 17 species of trees of which 11 were food species. As many as 83.5% of the trees within this habitat were food trees, primarily due to dominance of *Erythrina sp*, which formed 39% of all trees in the patch.

The open forest and the *Erythrina* forest patch were surrounded by human dominated habitat with large pasture area next to the open forest and some human settlements within and around the *Erythrina* patch. Although large in its spread (43%), the human dominated habitat was only rarely used by the group and held little importance with only 8 tree species and 10% of all food trees present here. The group spent as little as 7% of their time here in winter and this dropped further to 2.2% in post winter.

The relative preferences for the three forest types are evident, when time spent by the group in them is compared with that expected, based on the relative proportion of area and trees. In winter the group spent 43.2% of their time in *Erythrina* forest, more than expected on the basis of its relative area i.e. 11.5% of all area (Fig 10a) and percentage of food trees in the habitat i.e. 33.3% of all food trees (Fig 10b). Similar deviations from the expected share of time that the group was expected to spend in the three habitat types based on the actual area and number of food trees is given in Fig 10. These deviations varied in the two seasons reflecting preferences for habitat types.

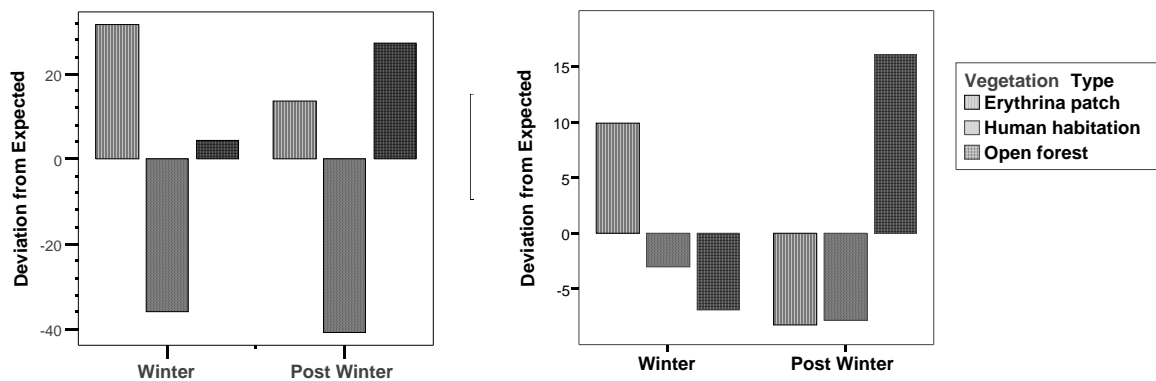


Fig. 10: Deviation from the expected time spent in the three vegetation types in winter and post winter based on a) percentage area covered by the habitat type and b) percentage of food trees present in the habitat type.

Deviations from the expected were greater when comparing expected values based on area covered by the habitat type, than those based on number of food trees present. Time spent by the group in human habitation was below expected in both cases. *Erythrina* forest and open forest were preferred in both seasons. Use of the *Erythrina* patch post winter was due to the feeding on *Mahonia napaulensis*, which formed 23.5% of the feeding in March. Although *Mahonia napaulensis* was not common in the *Erythrina* patch, feeding on the few available plants was extensive.

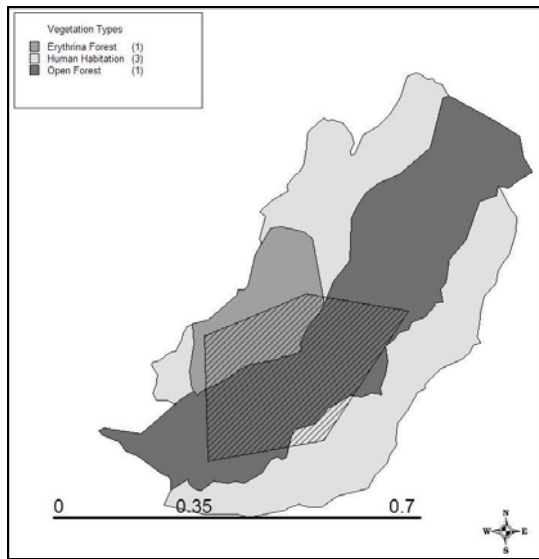
There was a striking difference between the two seasons in the number of food trees and the time spent in a habitat (Fig 10b). In winter, time spent in open forest was

below expected while time spent in *Erythrina* was above expected. This trend was reversed in the post winter. The switch from an *Erythrina* dominated diet to a more diverse diet including young leafs, fruits and flowers of various species would explain this reversal in trend.

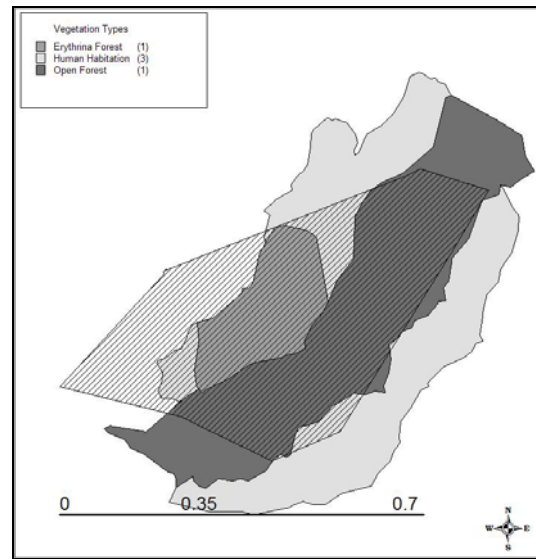
### **Ranging**

Along with the shift in habitat preference from *Erythrina* forest to open forest, came the shift in ranging patterns. The group was seen using a larger area in the post winter months (March, April and May) than in winter months (January and February) (Fig. 11). In February the group remained mostly spread over the *Erythrina* patch and the open forest patch (Fig. 11a); in March and April they were recorded in the open forest more often (Fig. 11b); and in May the group was not recorded from the *Erythrina* patch at all and was instead recorded moving way out of what had been identified as the intensively used range of the group.

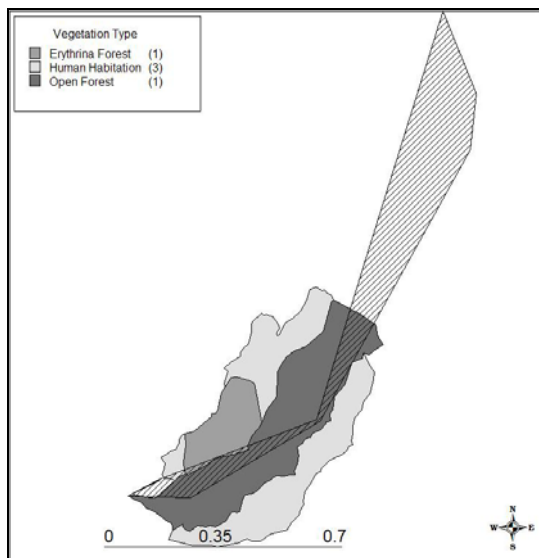
The total size of the range in the study period was 54.7 ha; the size of their range in February was 6.67 ha, for March/April it was 18.71 and for May it was 16.9 ha. The area of the range in May was less than that for March/April, however, the actual linear distance covered by the group was greater (Fig 11c).



a.



b.



c.



d.

Fig. 11: Polygon joining the outermost locations recorded for the group during the months of (a) February, (b) March & April, (c) May and (d) Feb-May. The points have been overlaid on the map of the intensively used habitat with the three major vegetation types shaded in greys. (Scale in Km)

## **Social interactions**

Social interactions were analysed only to test the hypothesis that feeding on clumped and scarce resources during the lean period of winter would be expected to decrease the distance between individuals and increase frequency of aggressive interactions. Although the distance between individuals in January showed a higher percentage of individuals in the 0-1m and 2-3m distance classes while in May the percentage of individuals in >5m was the highest, the pooled data for the seasons did not show much variation in nearest neighbors.

Frequency of events of aggression, however, did show a difference in the two seasons. The frequency of aggression dropped considerably from 0.82/hr in winter to 0.19/hr in post winter. A total of 42 events of aggression were recorded during the study period. Of these 26 records were from winter (31.75 scan hrs) and 16 from post winter (80.25 scan hrs). The frequency of aggressive events was high in winter i.e. 1.26/hr in January and 0.63 in February. A frequency only of 0.13/hr was observed in May, and 0.2/hr in April and 0.26/hr in March.

## DISCUSSION

### Diet

The phenology reflected a marked seasonality in food availability in the environment. Winter as opposed to post winter was the time of food scarcity for the study group with availability of food such as fruit and young leaves being at its lowest. This was also the time when the energy requirements for thermoregulation were highest for the monkeys. Agetsuma's lab study (2000) suggests that macaques need the least energy at ambient temperatures of 29°C; night temperatures at the study site were <0°C during winter. Agetsuma's study further shows that not only are macaques expected to increase energy intake, they are expected to take in more low quality food at lower temperatures. Selection of food would change with temperature in response to changing energy requirements for thermoregulations; having exhausted all high quality food the monkeys would continue to feed on low quality food to make up for the increased energy requirement (Agetsuma, 2000). This would explain the high intake of low nutrient food like pith and high feeding rate in the winter. In the winter season when young leaf and fruit are low in abundance or absent the *Macaca munzala*'s diet consisted of a large percentage of *Erythrina* pith.

The high consumption of pith, which accounts for 75% of the feeding time in winter, is perhaps unique to the species. This is possibly similar to the adaptation by the Japanese macaques (*M. fuscata*) in the high altitude zone that consume large quantities of high fiber food in the form of mature leaves (Hanya *et al.*, 2003). Feeding on fiber-rich food rises from 2-20% of the feeding time in the tropics to >30% in the temperate regions (Hanya, 2003). Like in the case of the Japanese macaque, the seasonal diet of the Arunachal macaque is restricted by availability. This

also led to high variability and flexibility in their diet. Staple food varied considerably between the two seasons; pith in winter and leaf in post winter. Similar variation in food types between seasons has been reported not only for the Japanese macaque in cold temperate forest (Hill, 1997) but also for the Barbary macaques in deciduous oak forest of Algeria (Ménard & Vallet, 1996).

Macaque species of tropical Asia such as the lion-tailed macaque (*M. silenus*) (Kurup and Kumar, 1993), bonnet macaque (*M. radiata*) (Ali, 1986) and Sulawesi crested black macaque (*M. nigra*) (Su & Lee, 2001) are predominantly frugivorous. Species in marginal habitats away from the tropics are likely to face a season in which fruits are at extremely low density or totally absent from the environment. This leads to a large seasonal turnover of species and food types in the diet depending on availability. Due to this variability the diet of the Japanese macaque cannot be placed under any category (Hill, 1997). The Taiwanese macaque (*Macaca cyclopis*) that inhabits broadleaf and coniferous forests, although classified as frugivorous (Ménard, 2004), is almost completely folivorous for five months of winter when the availability of fruits is low (Su & Lee, 2001).

For the Arunachal macaque the diet in winter was largely dependent on pith of *Erythrina spp*, the fact that feeding on pith dropped drastically in post winter suggests that this was not preferred food and was used only as fallback food by the species to help it survive the low resource months of winter. In post winter, the diet shifted to one of leaves, especially young leaves. Post winter also saw a major increase in the diversity of species in the diet. It has been suggested that a similar increase in diet diversity that coincides with increased consumption of young leaves for the Japanese

macaque may be due to synchronous production of young leaves in spring (Hill, 1997).

### **Activity budget**

Seasonal shifts in activity budgets are well demonstrated and common explanations for the shift have been listed by O'Brien and Kinnaird (1997) as (i) fluctuation in food resources; as food availability declines the monkeys must spend more time foraging and feeding to meet energy requirements and (ii) change in climatic conditions: like high mid-day temperatures in the case of most tropical macaques. Cases where seasonality causes little or no changes in time budget of primates have also been reported (Richard, 1978; Watts, 1988 in Overdroff, 1996).

The Arunachal macaque spent a significantly higher percentage of time feeding in the winter. Agetsuma (1995) found a positive correlation between increase in feeding time and feeding on mature leaves for the Japanese macaque. It was argued that when feeding on mature leaves the monkeys have to eat for longer durations in order to get the required energy since leaves tend to contain more fiber and less energy than other food types. This possibly holds true for the Arunachal macaque too, since it needs to meet increased requirement for energy for thermoregulation using low nutrition food like pith.

Time spent moving was observed to be higher in the post winter season. A similar patten of lower percentage of time spent moving in winter as opposed to spring has been reported for the Tibetan macaque (*M. thibetana*) and the Japanese macaque (*M. fuscata*) (Zhao, 1999; Hill, 1997). This seasonal change in the activity budget can be

accounted for by food availability factors and also (low) temperature (Hanya, 2004). For the Japanese macaques, Hanya found that when the temperature was low, the macaques decreased travelling and feeding time; when the feeding rate of available foods was slow, they spent more time feeding; when high-quality foods were abundant, they decreased feeding time. The decrease in time spent moving and feeding was explained by the logic of energy conservation by endothermal animals under severe thermoregulation cost (Hanya, 2004). Although the Arunachal macaque did not decrease feeding time this can be explained by the high handling time of *Erythrina* pith. Hanya's observations can also explain the drop in feeding time in post winter for the Arunachal macaque. Even for the Barbary macaque, great monthly variations in foraging effort and other activities were observed and it was seen that when resource availabilities were maximal, foraging effort was low (Ménard & Vallet, 1997)

An overlap in increase in fruit eating at the end of post winter coincided with reduced percentage time spent feeding and this may be explained by the fact that when high nutrient food is available the group could afford to decrease intake of food. Pigtail and longtailed macaque species, which have been categorized as the most frugivorous by Ménard (2004), spent least time feeding and foraging and the maximum time moving and as compared to other species. In the case of *M. nigra* we find that groups with larger proportion of primary forest spent the least time feeding, most of which was on fruits (O'Brien and Kinnaird, 1997)

## **Ranging and habitat use**

Seasonal changes in food availability are also expected to cause a change in parameters such as day foraging ranges, travel-speed, time allocation to moving and searching, number of feeding patches visited and seasonal home ranges (Di Fiore, 2003).

Ranging, as measured by day range length, in some cases increases in regions of low resource availability (Struhsaker 1967). A study of the winter range utilization in Japanese macaques (*M. fuscata*) also suggests that the per capita range area increases as the quality of the habitat becomes poorer (Furuichi et al. 1982). Many primary consumers depend on certain plant products, keystone resources that act as mainstays during periods of scarcity (van Schaik *et al.*, 1993). These may be distributed in patchy clumps. This would require increase in time spent moving and more range covered. Contrary to these, the Arunachal macaque shows a reduction in time spent moving and in the area used by the group in winter; of the range used in winter was restricted to the areas where *Erythrina spp* was in highest densities. The Tibetan macaque showed similar ranging in winter, where it used small parts of its range that were not extensively used in other months of the year (Zhao, 1999). This behaviour has also been attributed to the macaque's winter strategy of maximizing foraging efficiency by selectively denuding certain plants that are available at this time, and minimizing the distance travelled, reducing expenditure of energy (Raemakers, 1980; Zao, 1999); this could well be true for the *M. munzala* also.

The proportion of time spent by the group in the various habitat types reflects the preferences and food availability in these habitat types. The density of foods trees alone cannot explain the preferences to a habitat. The actual phenology of the species

in the two seasons had to do a lot with the group spending more time in one habitat as opposed to another. The preference for the *Erythrina* patch in winter can be explained by the fact that many food species (*Prunus spp*, *Elagaeanus spp*, *Salix spp* and *Rubus spp*) that provided the young leaf, flower and fruit in the post winter season were mostly leafless or at least non-productive in the winter season. It is reasonable to argue that the rare and patchy availability of food in winter in the open forest could not support feeding by the entire group. The *Erythrina* patch with large number food trees provided the groups with large quantities of clumped food (*Erythrina* pith).

## **CONCLUSION**

The strategy used by the Arunachal macaque to survive winter seems to be one of spending more time feeding and consuming low nutrient food that is readily available in the habitat in order to reduce energy expenditure. In this, it is perhaps similar to the Japanese, Tibetan and to some extent Taiwanese macaque, which have to adapt to high seasonality in their environment. Post winter, the species shows major change in its behaviour; time spent moving, diversity of diet, habitat use and ranging go up, which are in accordance with the prediction that these behaviour in winter are governed by scarcity of food and cost of thermoregulation.

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