Feeding behaviour of wild Asian Elephants (*Elephas maximus*) in the Rajaji National Park

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Abstract: The Asian elephant's (*Elephas maximus*) feeding behaviour with food preferences was studied in Rajaji National Park area between 1999-2006. The major objective of the present study is to document the fodder plant species and their seasonal consumption by elephants. Though elephants consume a variety of plant species in the study area, but their diet mainly consisted of fifty (50) plant species, which are available to them alternately round the year. Alteration between a predominantly browse diet throughout the year with a grass diet during the early dry season was related to the seasonally changing mineral content of grasses. Consumption of tree species (74%) was highest as compared to grasses (14%) and shrubs (8%) but their diet was mainly dependent on availability of seasonal food round the year and on their migration. Elephants extensively feed on *Mallotus phillipinensis*, *Acacia catechu*, *Lagerstroemia parviflora*, *Ehretia laevis*, *Dalbergia sissoo*, *Tectona grandis*, *Zizyphus mauritiana*, *Aegle marmelos* and *Ficus bengalensis* besides, elephants also utilized various grasses and shrubs as their food, which mainly included *Dendrocalamus strictus*, *Helicteres isora*, *Saccharum munja*, *Saccharum spontaneum*, *Cynodon dactylon*, *Desmostachya bipinnata* and *Neyraudia arundinacea*. Elephants sometimes spent long time to feed on some particular plant species like *Dendrocalamus strictus*, *Mallotus phillipinensis* and *Tectona grandis*. Eastern populations of elephants were subjected to feed extremely on *Tectona grandis* and *Holophramitis* spp. whereas currently south-western populations of elephants were not utilizing these species as their food. Crop raiding, which was sporadic during the wet season, gradually increased with more area being cultivated with the onset of monsoon. We propose that this is the first documented study, which has developed a database about the fodder plant species for Asian elephant's survival in north-west India. [The Journal of American Science. 2008;4(2):34-48]. (ISSN 1545-1003).

Keywords: Asian elephant, *Elephas maximus*, feeding behaviour, Rajaji National Park.

Introduction

The Shivalik foothills are one of the world's most spectacular landscapes, encompassing the tall grasslands and the *Shorea robusta* (Sal) forests. This entire belt is a natural home to Asian elephants (*Elephas maximus*) besides many other wild animals like *Panthera tigris* (tiger), *Panthera pardus* (leopard), *Melursus ursinus* (Sloth bear), *Hyaena hyaena* (Hyaena), *Muntiacus muntjak* (Barking deer), *Axis axis* (Spotted deer), *Cervous unicolor* (Sambhar), *Sus scrofa* (Wild boar), *Ophiophagus hannah* (King cobra) etc. This protected area is the western most limit of Asian elephant, tiger and king cobra. The Shivalik landscape is one of the last few places in the world where elephants exist and the region offers an urgent need for conservation. This protected area in India's lesser Himalayan region falls under sub tropical moist deciduous forest type with extensive stands of *Shorea robusta* (Sal), *Mallotus phillipinensis* (Rohini), *Acacia catechu* (Khair), *Adina cordifolia* (Haldu), *Terminalia bellirica* (Bahera), *Ficus bengalensis* (Bar), *Dalbergia sissoo* (Shisham) etc. in its premises besides many other important fodder plant species. From conservation point of view it appears to be India's one of the most successful national park and its management has helped to boost the population of Asian elephant in their natural habitat (Figure 1).

During the recent past extensive lopping and collection of fuelwood by Gujjar (nomadic community) and local people has restricted the regeneration potential of many important fodder plant species. Besides, elephant caused damages has also acted as a barrier to some extent in management related practices. The human population around the Rajaji National Park has doubled during past one decade and

rapid urbanization and industrialization has resulted in the loss of many forestlands to townships and thereby increasing the major problem during the recent past.

Since Independence, forest were cleared and felled and brought under the plough on a large scale. Construction work along with developmental activities like establishment of hydro-electric power plants, irrigation canals and national highways entailed deforestation of large tracts and colonization brought in its wake have resulted in a significant shrinkage in the habitat of wild animals (Singh, 1969). Presently most of the elephant habitats are destructed by various developmental activities or for human needs. There has been a rise in the competition among the same species for the food, shelter and other basic requirements. The status of the elephant in the adjoining countries is equally poor. Nepal, which has the lowest country population, has lost over 80% of its elephant habitat on account of human settlements. Bangladesh, Myanmar, Cambodia, Vietnam, Laos and Sri Lanka are also losing rapidly the natural forest cover, specially the elephant habitats. In Thailand, in spite of the elephant having been a protected species since the 18th century, over exploitation of the habitat and the pressure of human population has made the species highly vulnerable (Daniel, 1996).

The most charismatic among the wild animals of south-east Asia is probably the elephant in India, but somehow this giant Proboscidian is only restricted to only a few of the protected areas. Rapid developmental activities along with the encroachment into the deeper forest regime have made them to survive less, basically due to loss of their natural habitats. On account of their rapidly declining natural habitat and shrinking of migratory routes and feeding grounds the elephant population often scumb to various modes of unnatural deaths like train accidents, electrocution deaths and road accidents, and as a result, their population is falling rapidly. In this situation there is a need for some applied action oriented research studies, which may provide database about ground facts, that will be useful in achieving the goal of biological diversity conservation especially in conserving wildlife species that are categorized under endangered category. The major objective of the present study was to document the fodder plant species and their seasonal consumption by elephants. The study is a part of our long term study on the behavioural biology of Asian elephant in sub tropical moist deciduous forests of India.

Methods

Study area

Rajaji National Park [$29^0$15' to $30^0$31' North Latitude, $77^0$52' to $78^0$22' East Longitude] is spread over an area of 820.42 Km^2 in and around the Shivalik foothills, which lies in the lesser Himalayas and the upper Gangetic plains (Figure 2). Spread across Hardwar, Dehradun and Pauri districts of Uttarakhand state, Rajaji National Park (RNP) has been designated as a reserved area for the "Project Elephant" by the Ministry of Environment and Forests, Government of India with the major aim of maintaining the viable population of Asian elephants in their natural habitat. The Shivalik foothills offer the most prominent geomorphic features of this tract. The river Ganges cuts across these hills at Hardwar. The Chilla forest area of the RNP lies to the east of the river Ganges and is attached with the Garhwal Forest Division. The study is ongoing in Hardwar (District-Hardwar), Chilla (District-Pauri) and Motichur (District-Dehradun) forest ranges of the RNP. The altitude lies between 302-1000 m asl. The study site falls in sub-tropical moist deciduous forest type.

Data collection

For studying the feeding behaviour of elephants, the study areas were surveyed in depth for about eight years. All plants on which elephants were observed to feed in the study area were identified either through the flora dictionary or by the help of subject experts (herbarium identification). Some plant species were well-known to us. The majority of plants were collected after observing an elephant feeding on a plant then waiting until the animal had moved away. Besides, elephant's traditional movement tracks along with feeding grounds were searched and observed directly. Different forest blocks of concerned forest ranges were chosen one after another sequentially and searched for elephants for about 10 – 12 hrs. (depending upon weather conditions) in a single day. The observations started at early hours in the morning being the best time to search and observe the elephant in open areas and four hours in the afternoon i.e. before the sunset. Field binocular was also used for observing their feeding behaviour without disturbing the animal

from an adequate and safe distance. The daily record was based on direct sighting of animal's feeding, indirect evidences like feeding sign, footprints impression time and fresh dung piles. The direct sightings were noted in duly prepared proformas, recording the group composition and also the place of sighting, time and vegetation composition. Besides, villagers of adjoining areas, Gujjars (where available), staff of forest department, the researchers from various scientific institutions and non-government organizations and other individuals working in this area, were also interviewed.

Identification of the elephants is important to verify their movement as in the same area there is a possibility that the same group was observed in the different forest beats. Therefore, distinctive features, with certain identification marks of individual elephants were noted like; shape of the ears, tusk size and shape, scars and tubercles on the body, tail length, total number of individuals (all ages separately), body mass and nature of group or solitary bull.

Results

Generally elephants fed in the early hours of the morning and most markedly in the evenings, just before dark. They were observed to feed in mid-day hours in winter but in summer, they rested during midday. It was observed during the study period that sometimes elephants were continuously feeding throughout the night. In summer, they spent their nights in open forest areas and when the day advanced they move towards the denser forest. In evening when the sun begins to set they again came out of the thick forest cover into the open forest areas.

In RNP elephants fed on the tree species like *Mallotus phillipinensis* (Rohini), *Acacia catechu* (Khair), *Dalbergia sissoo* (Shisham), *Tectona grandis* (Teak), *Zizyphus mauritiana* (Ber), *Aegle marmelos* (Bel), *Ficus bengalensis* (Bar), *Ficus glomerata* (Gular), *Grewia oppositifolia* (Bhimal), *Bombax ceiba* (Semal), *Lannea grandis* (Jhingan), *Bauhinia variegata* (Kachnar), *Lagerstroemia parviflora* (Dhauri), *Kydia calycina* (Pula), *Syzygium cumini* (Jamun), *Flacourtia indica* (Kandai) and *Ehretia laevis* (Chamror). Besides elephants also used various grasses and shrubs as their food resources, which included *Dendrocalamus strictus* (Bamboo), *Helicteres isora* (Kapasi), *Saccharum munja* (Pula), *Saccharum spontaneum* (Kans), *Cynodon dactylon* (Doob Grass), *Eulaliopsis binata* (Bhabhar Grass), *Tinospora malabarica* (Giloe) and *Neyraudia arundinacea* (Bichhloo Grass).

A total of 50 plants species were recorded, which were observed to be favourite fodder species for elephants (Table 1). This list has been compiled from the identification of the leaves and fruits directly or taken from those plants that had signs of elephant feeding, and are based on the basis of their vernacular / local names. At the same time data was also collected and documented based on month wise utilization of fodder resources by elephants, which was based on direct observations and indirect evidences of feeding signs observed during the study period (Table 2).

In few of the plant species elephants utilized both leaves and twigs as their fodder for example when they were feeding on species like *Dalbergia sissoo, Acacia catechu, Bombax ceiba, Aegle marmelos, Ficus bengalensis* and *Ougeinia oojeinensis*, they ate different parts of the plant according to various seasons. It was observed from the present investigation that during January to March elephants mainly utilized the bark of different trees (*Shorea robusta, Bauhinia variegata, Mitragyna parvifolia, Schleichera oleosa, Lagerstroemia parviflora, Cordia obliqua, Tectona grandis, Holophramitis* spp. and *Bombax ceiba*) as their food. Elephants prefered to feed extensively on the bark and twigs of *Tectona grandis* at the onset of summer whereas they were observed to eat bark of *Bombax ceiba* tree during very hot season. Barks of the trees were mostly removed with the help of trunk but sometimes were also scrapped by using the tusks in case of bull elephant. Bulls have more options for feeding purpose as compared to cow elephants as sometimes cows could not remove the young and compact bark of trees whereas bulls are very able to remove such barks easily with the help of their tusks.

Fruits of *Aegle marmelos, Flacourtia indica, Ehretia laevis* and *Zizyphus mauritiana* were consumed by elephants. They often uprooted the plant with the help of the trunk and sometimes with the help of forefoot. Succulent grass species such as *Saccharum munja* and *Saccharum spontaneum* were favoured, although these are not the perennial food resources in the park area. *Tectona grandis* and *Holophramitis* spp. are also important fodder species, which were directly linked with elephant foraging as few of the area comprises of extensive stands of both of these species and currently elephants are utilizing

these food resources in some particular months of the year (from December to June). Direct observations indicated that these species are preferable food item for elephants and it was noticeable that elephants are feeding extensively on these species since last 5-6 years whereas before 2002 elephants were not reported to feed on these species (Figure 3). Only bark of these trees is being utilized by elephants they spent even whole of their day to feed on these species. Elephant induced damages to these species is quite large. Both of these species were planted in few forest pockets sometimes 20 years back to get rid of open damaged forests besides the fact that the regeneration potential of these species is very fast. Extensive feeding was observed on these food resources by elephant in eastern part of river Ganges whereas currently south-western population of elephants were not utilizing these species as their food. Although these plants are not the natural food but now as per the results of our observations these fodder species can be categorized under primary food.

Cordia obliqua, *Holarrhena antidysenterica* and *Mitragyna parvifolia* were also eaten by elephants ocassionally. Generally bark and soft twigs (without leaves) were consumed as food especially during dry periods (April-June). We have described about these important fodder species, which are completely seasonal for the first time and all of these new findings have wider implications in conservation of Asian elephants through habitat improvement and management approaches.

Ranipur, Ravli and Chirak forest beats of the Hardwar forest range are famous for *Dendrocalamus strictus* (Bamboo) and due to the presence of huge amount of bamboo patches elephants have utilized these forest pockets throughout the year before 2002. Since last 3-4 years the regeneration potential of the bamboo is decreasing continuously. Besides, over feeding on bamboo bushes by elephants has led to destruction of this fodder species. Forest fire also restricts the frequent regeneration of bamboo in this area. Besides, few of the villagers also uproot whole of the plant body to fulfill their energy requirements. Our earlier observations review that the declining rate of elephant's population in some particular areas was mainly due to the impact of scarcity of natural water and falling rate of the status of fodder species in the area.

Elephants sometimes spent long time to feed on some particular plant species like *Dendrocalamus strictus* (Bamboo), *Mallotus phillipinensis* (Rohini), *Cynodon dactylon* (Doob grass), *Ficus religiosa* (Pipal), *Saccharum spontaneum* (Kans) and *Saccharum munja* (Sarkanda). The consumption of tree species was highest, followed by few important shrubs and grasses.

Study revealed that the total amount of plant matter removed by the elephants was not fully consumed. In fact a relatively large part was dropped to the ground and left as such, which was sometimes utilized by other herbivores thus representing associational behaviour. The elephants in RNP fed extensively on the mixed vegetation including trees, grasses and shrubs. Although the study area has dominant plant species like *Shorea robusta*, *Mallotus philippinensis*, *Acacia catechu*, *Dalbergia sissoo*, *Terminalia tomentosa*, *Syzygium cumini*, *Ehretia laevis*, *Lagerstroemia parviflora*, *Holarrhena antidysenterica*, *Helicteres isora* and *Lannea coromandelica* besides, few species of *Ficus* and *Zizyphus* are available. The most preferred food item in this area was *Dendrocalamus strictus* (Bamboo) and *Mallotus philippinensis* (Rohini) but elephants used different food resources round the year as per their availability.

Elephants and woody vegetation

We also recorded the damages caused by the elephants in few forest ranges of the park. Elephants sometimes broke entire favourite plants like *Dendrocalamus strictus*, *Aegle marmelos*, *Dalbergia sissoo*, *Tectona grandis*, *Schleichera oleosa*, *Mallotus philippinensis*, *Grewia oppositifolia*, *Garuga pinnata* and *Ehretia laevis* besides, they also peeled off the bark of few plant species like *Bombax ceiba*, *Ficus bengalensis*, *Bauhinia variegata*, *Mitragyna parvifolia*, *Tectona grandis* and *Lagerstroemia parviflora*. The percentage frequencies of the five categories (twig breaking, bark peeling, branch breaking, stem twisting and pushing over) of damages inflicted on the woody vegetation by elephants were observed on several occasions (Figure 4). Out of five categories of damages, twig breaking (40%), and bark peeling (25%) were accounted for highest damage followed by branch breaking (18%), stem twisting (11%) and pushing over (6%). The elephants prefered to feed on soft twigs after removing the leafy portion from it.

Elephant is a wasteful feeder, judging by the amount of vegetation that is not eaten. The pushing over trees enables the animal to have access to the higher branches, which are out of range of its trunk.

Nevertheless, it represents a wasteful mode of feeding. Perhaps, the non-eaten vegetation could form a secondary food source to other herbivores in such cases thus; it is not a waste after all. An abundance of alternative food items (regenerating trees) is perhaps the reason for the low incidence (6%) of pushing over.

Time-activity budget

Generally elephants became active well before dawn and start their morning activities in the vicinity of the area where they spent night. During hot hours of the day various members of the group retired in available shade, whereas in the wet season they spent more time in feeding related activities. In the afternoon, begin their evening activities, which were quite similar to the morning activities. Evening hour was the time for drinking and bathing especially during summers. The feeding activity during summer was observed to be more in early morning hours and late hours in the afternoon and the mid-day is the time for rest, whereas in winter, feeding activity is near about constant but it is maximum in late evening hours. During the monsoon period, the moving and resting activity generally fluctuate because of slight restriction in movements. Resting during the monsoon largely depends on heavy rains while moving long distances, as at the onset of monsoon elephants show their long-term migration towards upper slopes in some of the areas.

Resting follows the standing of elephants in any shaded area especially in sparse cool shaded trees like *Ficus bengalensis*, *Adina cordiafolia* and *Butea tetrasperma.* Animal spends more time in resting during summer because the mid-day period is too hot and elephants may not tolerate high temperature and direct sun light for a very long time. Whereas during the winter they used open areas for standing and taking the sunbath while feeding activity was also ongoing. In summer season percentage of movement found more due to lack of fodder species and shrinkage of natural water sources. At that time animals have to travel more in search of food and water, while in winter and monsoon there is abundance of fodder species and water within the park area and during that time elephants do not perform very long distances.

The time-activity budget of different seasons during 12 hours of the day (feeding, moving, resting and others) of elephants was observed for two years during the course of this long-term study (Figure 5). Feeding during the winter (11.1 hours), accounted for the highest duration followed by feeding during the summer (10.5 hours) and monsoon (9.1 hours). Movement activity accounted for 1.4 hours (winter), 1.5 hours (summer) and 1.3 hours (monsoon). Fluctuations were observed in resting activity as this largely depended upon season (.4 hours in winter, 2.5 hours in summer and 1.4 hours in monsoon). Apart from this other activities like drinking, bathing, playing etc. accounted for 2.05 hours in winter, 0.4 hours in summer and 3.1 hours in monsoon.

Table 1. Elephant food plant species, their life form and the plant parts eaten in the Rajaji National Park

S. No.	Botanical Name	Vernacular / Local Name	Life forms *	Parts eaten #
1.	*Acacia catechu* (Linn.) Willd.	Khair	T	l, t, b
2.	*Acacia arabica* (Lamk.) Willd.	Babool	T	l, t, b
3.	*Aegle marmelos* Correa.	Bel	T	l, t, f
4.	*Albizzia lebbek* Benth.	Kala siris	T	l, t
5.	*Albizzia procera*, Benth.	Safed siris	T	l, t
6.	*Bauhinia variegata* Linn.	Kachnar	T	l, t, b
7.	*Bauhinia vahlii*, Wight. & Arn.	Maljhan	C	l, t
8.	*Bauhinia malabarica*, Roxb.	Khatua / Amli	T	l, t
9.	*Bombax* ceiba (Linn.) DC.	Semal	T	b
10.	*Bridelia retusa*, (L.) Spr.	Ekdana	T	t
11.	*Cordia obliqua*, Wild	Lassora	T	t
12.	*Cynodon dactylon (*Linn.) Pers.	Doob Grass	G	l, r
13.	*Dalbergia sissoo* Roxb.	Shisham	T	l, t, b

14.	*Dendrocalamus strictus* (Roxb.) Nees.	Bans / Bamboo	S	l, t
15.	*Desmostachya bipinnata*, (L.) Stapf.	Dav / Kush	G	l, r
16.	*Ehretia laevis* (Linn.) Roxb.	Chamror	T	l, t
17.	*Embelica officinalis* Gaertn.	Amla	T	l, t
18.	*Eulaliopsis binata* (Retz.) C.E. Hubbard.	Bhabhar Ghas	G	l, r
-	[Syn. *Ischaemum angustifolium* Hack.]	-	-	-
19	*Ficus bengalensis* Linn.	Bargad / Bar	T	l, t, b
20.	*Ficus glomerata* Roxb.	Gular	T	l, t, b, f
21.	*Ficus religiosa* Linn.	Pipal	T	l, t
22.	*Ficus rumphii*, Bl.	Pilkhan	T	l, t
23.	*Ficus infectoria*, Roxb.	Khabar	T	l, t
24.	*Flacourtia indica* (Burm. F) Merr.	Kandai	T	t, b
25.	*Garuga pinnata* Roxb.	Kharpat	T	l, t
26.	*Grewia oppositifolia*, Roxb.	Bhimal	T	l, t
27.	*Grewia elastica*, Royle	Dhaman	T	t
28.	*Helicteres isora* Linn.	Kapasi	S	l, t
29.	*Holarrhena antidysenterica*, Wall.	Kura	T	t
30.	*Holophramitis* spp. [!]	Kut sagaun	T	l, t, b
31.	*Kydia calycina*, Roxb.	Pula	T	t
32.	*Lagerstroemia parviflora*, Roxb.	Dhauri	T	l, t
33.	*Lannea coromandelica*, (Houtt.) Merr.	Jhinghan	T	l, t
34.	*Mallotus philippinensis* Muell. Arg.	Rohini	T	t
35.	*Mitragyna parvifolia*, Korth.	Phaldu / Kaem	T	b
36.	*Neyraudia arundinacea*, (L.) Hen.	Bichhloo	G	l, r
37.	*Ougeinia oojeinensis*, (Roxb.) Hochr.	Saandan	T	l, t
38.	*Pithecellobium dulce* Benth.	Jangal Jalebi	T	l, t
39.	*Randia dumetorium*, Lamk.	Mainphal	T	t
40.	*Saccharum munja* Roxb.	Phoos / Sarkanda	G	l, r
41.	*Saccharum spontaneum* Linn.	Kans	G	l, r
42.	*Schleichera oleosa*, Willd.	Kusum	T	l, t
43.	*Shorea robusta* Gaertn.f.	Sal	T	b
44.	*Syzygium cumini* (Linn.) Skeels.	Jamun	T	l, t, b
45.	*Terminalia tomentosa*, W.&A.	Sain	T	b
46.	*Tectona grandis*, L. f. [!]	Sagaun/Teak	T	t, b
47.	*Tinospora malabarica*, Miers.	Giloe / Gurch	C	l, t
48.	*Thysanolaena agrostis*, Nees.	Hathi ghas / Pirlu	G	l, r
49.	*Zizyphus mauritiana*, Lam.	Ber / Beri	S	l, t
50.	*Zizyphus xylophyra*, (Retz.) Willd.	Bhander	S	l, t

[*] T – Tree, S – Shrub, G – Grass, C - Climber

[#] l – leaves, t – twigs (twigs are generally eaten by removing the leafy portion from it), b – bark, r – root, f – fruits

[!] Present mainly in adjoining areas of forest rest houses and field sub-stations.

Table 2. Month - wise utilization of fodder resources by elephants in the Rajaji National Park area

Botanical Name	Vernacular Name	Winter					Summer				Rainy		
		Oct.	Nov.	Dec.	Jan,	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Acacia catechu (Linn.) Willd.	Khair	-	✓	✓	-	✓	✓	✓	✓	-	✓	-	-
Acacia arabica (Lamk.) Willd.	Babool	✓	-	-	-	-	-	-	-	-	-	-	✓
Aegle marmelos Correa.	Bel	✓	-	-	-	✓	✓	✓	✓	✓	-	-	✓
Albizzia lebbek Benth.	Kala siris	-	-	-	-	-	✓	✓	✓	-	-	-	-
Albizzia procera, Benth.	Safed siris	-	-	-	-	✓	✓	✓	-	-	-	-	-
Bauhinia variegata Linn.	Kachnar	-	-	-	-	✓	✓	✓	✓	-	-	-	-
Bauhinia vahlii, Wight. & Arn.	Maljhan	-	-	✓	✓	-	✓	✓	✓				
Bauhinia malabarica, Roxb.	Khatua	-	-	-	-	✓	✓	✓	-	-	-	✓	✓
Bombax ceiba (Linn.) DC.	Semal	✓	-	-	-	-	✓	✓	✓	✓	-	-	✓
Bridelia retusa, (L.) Spr.	Ekdana	-	✓	-	-	-	-	-	-	-	-	-	-
Cordia obliqua, Wild	Lassora								✓				
Cynodon dactylon (Linn.) Pers.	Doob ghas	-	-	-	✓	✓	✓	✓	-	-	-	-	✓
Dalbergia sissoo Roxb.	Shisham	✓	-	-	-	✓	✓	✓	✓	✓	✓	-	✓
Dendrocalamus strictus (Roxb.) Nees.	Bans	✓	✓	-	-	✓	✓	-	-	-	✓	✓	✓
Desmostachya bipinnata, (L.) Stapf.	Dav	✓	✓	-	-	-	✓	✓	✓	-		✓	✓
Ehretia laevis (Linn.) Roxb.	Chamror	-	✓	✓	✓	✓	✓	-	-	-	-	-	-
Embelica officinalis Gaertn.	Amla	-	-	-	✓	✓	✓	✓	-		-	-	-
Eulaliopsis binata (Retz.) C.E.	Bhabhar	✓	✓	-	-	-	✓	-	-	-	-	✓	✓
Ficus bengalensis Linn.	Bargad	-	-	-	-	✓	✓	✓	✓	✓	✓	✓	✓
Ficus glomerata Roxb.	Gular	✓	-	-	-	-	✓	✓	✓	-	-	-	-

Ficus religiosa Linn.	Pipal	-	✓	✓	-	-	✓	✓	✓	✓	✓	-	-
Ficus rumphii, Bl.	Pilkhan	-	-	✓	-	-	✓	✓	-	-	-	-	-
Ficus infectoria, Roxb.	Khabar	-	-	✓	-	✓	✓	-	-	✓	✓	✓	-
Flacourtia indica (Burm. F) Merr.	Kandai							✓	✓	✓			
Garuga pinnata Roxb.	Kharpat	-	✓	✓	-	✓	✓	-	-	-	-	✓	✓
Grewia oppositifolia, Roxb.	Bhimal	-	✓	-	✓	✓	✓	-	-	-	-	-	-
Grewia elastica, Royle	Dhaman	-	✓	-	✓	✓	-	-	-	-	-	-	-
Helicteres isora Linn.	Kapasi	✓	-	-	-	-	-	-	✓	✓	✓	✓	✓
Holarrhena antidysenterica, Wall.	Kura	-	-	-	-	✓	✓	-	-	-	-	-	-
Holophramitis spp. [!]	KutSagaun	-	-	-	✓	✓	✓	✓	✓	-	-	-	-
Kydia calycina, Roxb.	Pula	-	-	-	✓	✓	✓	✓	-	-	-	-	
Lagerstroemia parviflora, Roxb.	Dhauri	-	-	✓	✓	✓	✓	✓	✓	-	-	-	-
Lannea coromandelica, (Houtt.) Merr.	Jhingan	✓	✓	-	-	✓	✓	✓	-	-	-	✓	✓
Mallotus philippinensis Muell. Arg.	Rohini	-	-	-	✓	✓	✓	✓	✓	✓	✓	-	-
Mitragyna parvifolia, Korth.	Phaldu	-	-	-		✓	✓	-	-	-	-	-	-
Neyraudia arundinacea, (L.) Hen.	Bichhloo	✓	-	-	-	-	-	-	-	-	✓	✓	✓
Ougeinia oojeinensis, (Roxb.) Hochr.	Saandan	✓	✓	✓	✓	✓	-	-	-	-	-	✓	✓
Pithecellobium dulce Benth.	Jangal jelebi	-	✓	-	✓	✓	-	-	-	-	-	-	-
Randia dumetorium, Lamk.	Mainphal	-	-	✓	✓	-	-	-	✓	-	-	-	-
Saccharum munja Roxb.	Phoos	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-
Saccharum spontaneum Linn.	Kans	-	-	✓	✓	✓	✓	✓	-	-	-	-	-
Schleichera oleosa, Willd.	Kusum	✓	-	-	-	✓	✓	-	-	-	✓	-	✓
Shorea robusta Gaertn.f.	Sal	-	-	✓	✓	✓	✓	-	-	-	-	✓	-

Syzygium cumini (Linn.) Skeels.	Jamun	-	-	-	✓	✓	-	-	✓	✓	✓	-	-
Terminalia tomentosa, W.&A.	Sain	-	-	-	-	-	✓	-	-	-	-	✓	-
Tectona grandis, L. f. [!]	Sagaun	-	-	-	✓	✓	✓	✓	-	-	-	-	-
Tinospora malabarica, Miers.	Giloe	✓	✓	✓	-	-	✓	✓	✓	✓	-	-	-
Thysanolaena agrostis, Nees.	Hathi ghas	-	✓	✓	✓	✓	✓	-	-	-	-	-	-
Zizyphus mauritiana, Lam.	Ber	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
Zizyphus xylophyra, (Retz.) Willd.	Beri	-	✓	✓	✓	✓	-	-	-	-	-	-	-

✓ When elephants were observed to fed on above mentioned fodder resources [based on direct and indirect observations].
[!] Plantation present mainly in buffer / outer areas of forest.

Figure 1. Baby elephants with their mother in Rajaji.

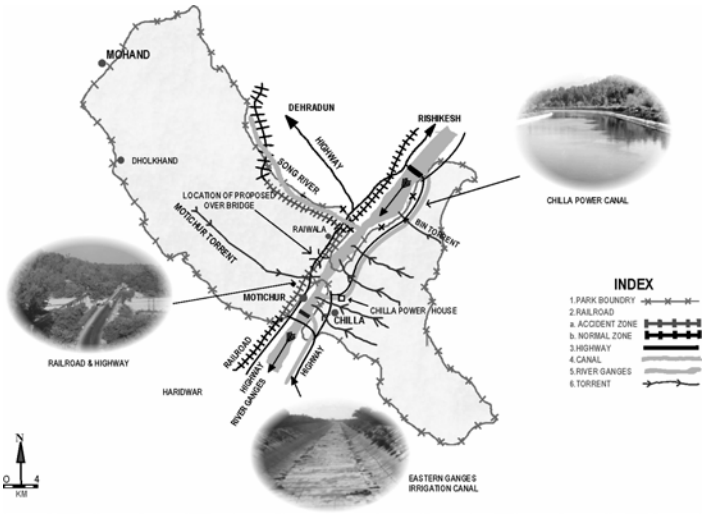

Figure 2. Map of the study area.

Figure 3. A cow elephant feeding on *Tectona grandis* in Rajaji National Park.

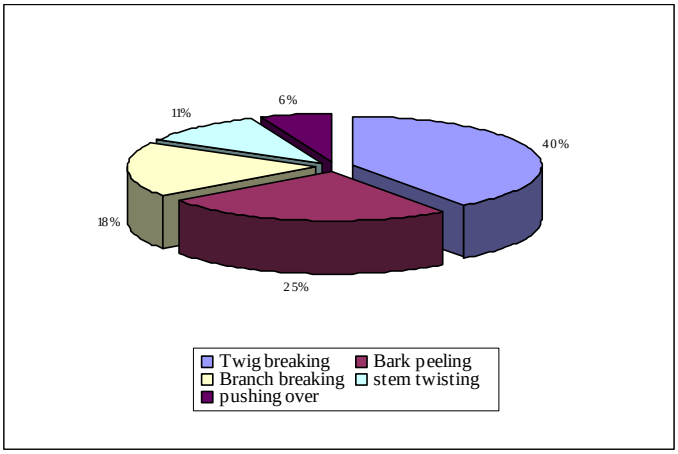

Figure 4. Relative frequencies of the various elephant-induced damages observed in the woody vegetation (n = 108 days).

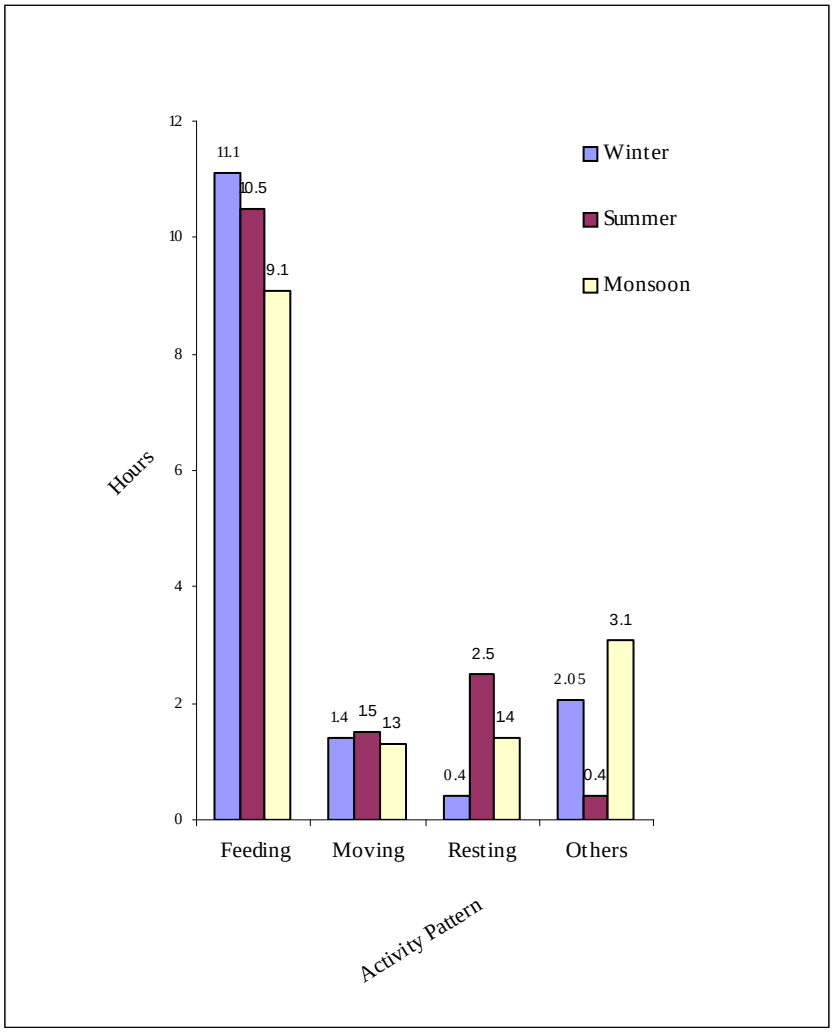

Figure 5. Comparative time-activity budget for different activities in different seasons

Discussion

The study enumerated 50 plant species in the diet of elephants in RNP. The bulk of the diet in number of species and quantities eaten came from twigs, bark, fruits and leaves. Though study area comprises of 128 tree species, 63 shrub and herb species, 33 climber species, 1 bamboo species and 37 grass species but out of total recorded fodder plant species (50), trees represented 74% of the species that elephants fed followed by 14% (grass species), 8% (shrub species) and 4% (climber species).

Elephants are known to feed on a wide variety of plant species. Research on forest elephant feeding ecology in Nouabale – Ndoki National Park in northern Congo has shown that elephants have a general diet comprising more than 350 species (Blake, 2002). A preliminary study on elephant's habitat in the RNP area has pointed out that 30 plant species were present in this area, which are being utilized by

elephants (Williams, 2002). A study on Asian elephant's foraging behaviour in southern India pointed out that elephants consumed at least 112 plant species and 85% of their diet consisted of only 25 species (Sukumar, 1990). During the dry season, 18 species of flowering plants were found to be eaten by the elephants in the Manas National Park (Lahkar et al., 2007). Another study on the conservation of Asian elephant in Bangladesh indicated that 143 plant species were present in Chunati Wildlife Sanctuary, out of which only 17 species were utilized by elephants that represents only 12% of the total local plant species (UCN Report). Similarly, a study on the diet and foraging ecology of the Asian elephant was conducted in the Shangyong National Natural Reserve, Xishuangbanna, China and pointed out that 106 plant species were eaten by elephants as their food (Chen et al., 2006).

RNP area falls under sub-tropical moist deciduous forest type and hence one can assume that in RNP, elephants eat seasonal food resources to provide the necessary range of nutrients. There is a distinct difference in the quantity and number of fruit species eaten seasonally by elephants and this influences elephant's feeding behaviour. As fruits abundance (*Aegle marmelos*, *Zizyphus mauritiana*, *Syzygium cumini* and *Ehretia laevis*) increases during various seasons, therefore, elephants consumed the available fruits round the year. During this period, they are probably less attracted to other sources of food.

Elephants use the soft twigs of the trees by removing the leafy portion from it; bark from woody plant is often ripped off for feeding purpose. Since bark is rich in calcium, elephants would select this resource, which is sometimes essential for the favourable growth of skeleton and for the tusks in males. A study was also conducted on the debarking behaviour of elephants in southern India, which shows that maximum number of debarked trees was from dry deciduous forests (Vanaraj, 2001). Comparatively captive elephants were observed having better health and grow faster than wild elephants, owing to better plane of nutrition and decreased parasitism. In the wild, a mature elephant will spend as many as 18 hours per day feeding, consuming as much as 280 kilograms of food. Obviously the food consumed in the wild is low in nutrients and high in fiber (John and Subramanian, 1991).

Present study revealed that tree species consist of major food for elephants and their diet is dependent on their migration and movement related activities. Study further indicated that few of the fodder species are common throughout the year while few are only available to elephants in particular season of the year. Present investigation suggested that widely distributed species were utilized throughout the year whereas altitude-wise distributed species were utilized in particular months during seasonal movement. For example elephants generally feed on *Saccharum munja* and *Saccharum spontaneum* when their movement is towards lower areas and *Neyraudia arundinacea* is utilized especially during monsoon season when their movement is towards upper slopes i.e. in Rawasan and Pulani forest beat. *Mallotus phillipinensis* is commonly eaten from the onset of summer whereas elephants start feeding on *Dalbergia sissoo* from February onwards. Elephants were observed most markedly to feed on *Dendrocalamus strictus* from July to December whereas *Ficus* species were most favourable food item and elephants utilize these resources in most of the months in a year. Elephants feed extensively on large number of food resources during March, April and May months when they are performing their longer movements within and outside (adjoining reserve forests) from the park area basically in search of water. Availability of fresh water further ensures the presence of elephants in any particular area.

During the past six years, we have made extensive studies on different fodder resources and observed that only few populations of the elephants were observed to feed on *Tectona grandis* and *Holophramitis* spp. species, whereas in few of the areas elephants are not utilizing both of these species as their food. Eastern part of the RNP area comprises of Chilla and Gohri forest range whereas south-western portion consists of Kansro, Motichur, Hardwar, Beribara and Dholkhand forest ranges. There is complete isolation between western and eastern components of an internal ecological unit mainly because of presence of Army dump, various villages, shrines, Ganga canal, hydro-electric power plant, national highways and railway track in between these two forest zones. Ongoing anthropogenic activities inside and peripheral to the protected forests are another major obstacle in these corridors.

The motor roads, which are adjacent to the forests like Hardwar-Dehradun National Highway, BHEL roads etc. have heavy traffic pressure. As per a preliminary study, the average number of vehicles passing on Dehradun-Hardwar road per day is 7,929 and all the wild animals, including elephants, are not in a position to cross this track at any time due to the presence of heavy traffic (Singh and Sharma, 2001).

Same situation is with other corridors present adjacent to the RNP area. Kotdwar – Lansdowne road runs parallel to the river Kho and crosses the Rajaji-Corbett corridor, the major movement track of northwestern elephant population between the Yamuna and river Sharda. This road serves as the major transport link between Pauri town and Kotdwar area. The presence of traffic on the road, construction of steep retaining walls and the presence of human population along the entire corridor area have almost restricted the migration of elephants (Johnsingh and Williams, 1999).

Crop raiding by elephants is a common phenomenon in adjoining areas of the RNP. Indigenous villages are situated around various forest ranges of the park and grow many potential cash crops to enrich their economy. The major cash crops are *Saccharum officinarum* (Sugarcane), *Oryza sativa* (Paddy), *Triticum* spp. (Wheat) and *Zea mays* (Maize) and few cultivators also grow fruit yielding species in their fields like *Musa paradisiaca* (Banana) and *Mangifera indica* (Mango). Elephants traditionally often leave the forest to feed in nearby villages, usually during nights. Even before 1998 elephants were reported to be raiding fields but their outside movement was more common from 2001 (Joshi at el., 2001). Currently the raids have become more frequent and the number of complaints by farmers has increased.

Elephant's movement towards outside areas is more common between November to February. During monsoon period only few elephants are found in these areas, which are mainly loners. Depredation of sugarcane took place throughout the year but was highest between November to February. The raiding group size also differs as per different seasons. During November to February group size is larger between 2 - 14 elephants than in the other seasons. Crop depredation pattern and season coincide with human deaths in the area. The peak depredation period is between the months of October to March during which time human deaths by elephants are also very high. Movement of elephants was noted outside of the park area generally in the late evening hours and in the night, but occasionally, it was also reported after mid-day. According to a long term preliminary study in southern India raiding was at peak during October mainly by bulls and to a lesser extent by herds (Sukumar, 1989). Stray behaviour among elephants has been more common from last two years as compared to previous years as they are making their tendency to feed on the cultivated crops (Joshi and Joshi, 2001).

It has been observed that the elephants enter in villages after sunset and re-enter the park area before dawn. In few of the places their village leaving time is 2 to 3 hours after dawn. In many places a same herd was reported continuously for about 14-15 days. A surprising thing was that only identified bull elephants and groups were reported to move outside of the conservation area. A study pointed out that most of the incidents of raiding were found to be in late evening hours or during night period (Nair, 1990) whereas another study indicated that raids by elephants were the results of either solitary individual (adult males) or small groups (Santiapillai and Suprahman, 1986).

Conclusion

The feeding habits of elephants show a great variance with respect to the seasons, availability of natural water and traditional movements. Elephants of RNP are well adapted to feed on seasonal fodder species present round the year in this hilly track, which lies in Shivalik foothills. The RNP has been intensively logged during the past few years as the result of which many of the original sub-tropical moist deciduous forest cover has disappeared and what are left today are large areas of annual or evergreen trees and extensive stands of Sal (*Shorea robusta*). From the point of elephant conservation, RNP is a rich habitat but is under biotic pressure mainly due to the traditional lopping of trees by Gujjars in few of the forest ranges (where they still exist) as Gujjar rehabilitation programme is still ongoing in the RNP area. Therefore, in few of the areas elephant are utilizing all the forest compartments frequently to fulfill their routine requirements. Other major factors are agricultural expansion peripheral to the different forest ranges and increasing number of anthropogenic and developmental activities. Study indicated that 50 plant species were consumed by elephants as their food but it has been suggested that different populations of elephants in the same forest stretch use some separate and specific fodder species (as having different geological conditions) hence more information is needed on their feeding biology to properly develop management strategies for their conservation. The RNP is one of the finest of the few remaining examples of the exceedingly diverse and productive lesser Himalayan eco-systems. Therefore, management practices are needed to conserve the elephants' habitat for their long-term survival.

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