

**STUDY OF POPULATION, ECOLOGY AND CONSERVATION OF LION-TAILED
MACAQUE *MACACA SILENUS* IN SIRSI-HONNAVARA, WESTERN GHATS,
KARNATAKA**

Thesis submitted to the Bharathiar University in partial fulfillment of the requirements for
the degree of

DOCTOR OF PHILOSOPHY

IN

ZOOLOGY

By

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Coimbatore, INDIA**

December 2015

CERTIFICATE

This is to certify that the thesis, entitled "STUDY OF POPULATION, ECOLOGY AND CONSERVATION OF LION-TAILED MACAQUE *MACACA SILENUS* IN SIRSI-HONNAVARA, WESTERN GHATS, KARNATAKA" submitted to the Bharathiar University, in Partial fulfillment of the requirements for the award of the Degree of **Doctor of Philosophy** in **Zoology** is a record of original research work done by **Mr. K. Santhosh** during the period January 2011 to December 2015 of his research in the Department of Conservation Biology at **Sálim Ali Centre for Ornithology and Natural History, Anaikatty P.O., Coimbatore** under my supervision and guidance and the thesis has not formed the basis for the award of any Degree/Diploma/Associateship/Fellowship or other similar title of any candidate of any University.

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DECLARATION

I, Mr. **K. Santhosh** hereby declare that the thesis, entitled "STUDY OF POPULATION, ECOLOGY AND CONSERVATION OF LION-TAILED MACAQUE *MACACA SILENUS* IN SIRSI-HONNAVARA, WESTERN GHATS, KARNATAKA", submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of **Doctor of Philosophy in Zoology** is a record of original and independent research work done by me during January 2011 to December 2015 under the Supervision and Guidance of **Dr H.N. Kumara** (Senior Scientist), Department of Conservation Biology at **Sálím Ali Centre for Ornithology and Natural History, Anaikatty P.O., Coimbatore** and it has not formed the basis for the award of any Degree/Diploma/Associateship/Fellowship or other similar title to any candidate in any University.

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This is to certify that the Ph.D. candidate **Mr. K. Santhosh** working under my supervision has published research articles in the following peer-reviewed journals

| Journal name | Year | Volume | Pages | Publisher |
|--------------------------------------|-------------|---------------|--------------|----------------------------|
| International Journal of Primatology | 2015 | 36 | 288-310 | Springer |
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| Current Science | 2011 | 101 | 434-439 | Indian Academy of Sciences |

The contents of all these publications incorporate a part of the results presented in his thesis.

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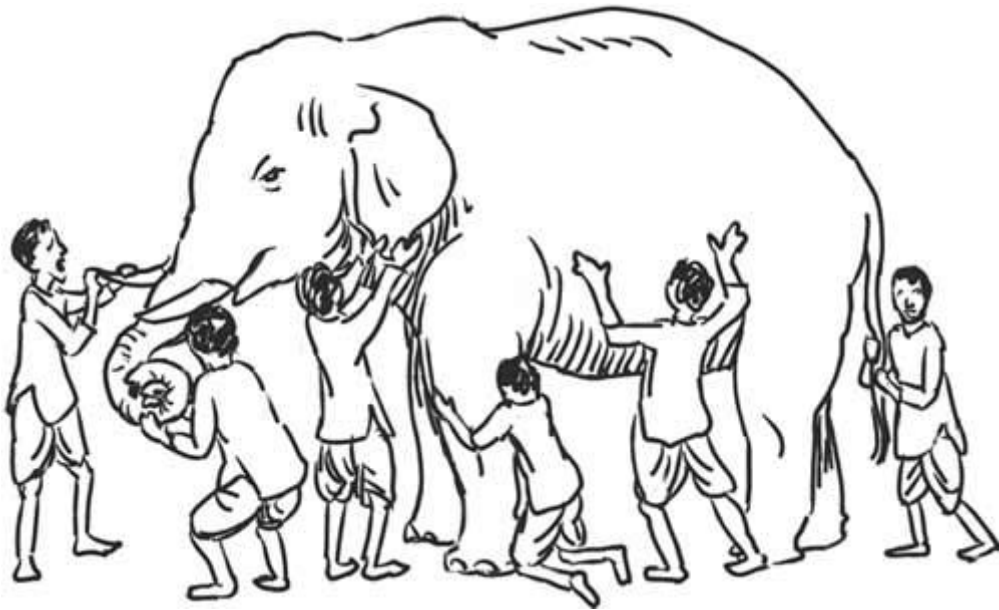
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Dedicated



To everyone solving the jig-saw puzzle of nature...

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Abbreviations

| | |
|--------------|---|
| LTM | Lion-tailed macaque |
| NTFP | Non-Timber Forest Product |
| ACR | Aghanashini Lion-tailed macaque Conservation Reserve |
| IVI | Importance Value Index |
| FIV | Family Importance Value |
| VFC | Village Forest Committee |
| ASTRA | Application of Science and Technology for Rural Areas |

Chapter 1

Introduction

Tropical forests cover only 10% of earth's area but inhabit ~50% of known species and higher number of unidentified species of the globe (Dirzo and Raven 2003). These forests face severe challenge in the recent decades due to everlasting pressure from human activities (Whitmore and Burslem 1998). About 60% of tropical forests were classified as degraded by the year 2000 (ITTO 2002). Degradation of tropical forests are mainly due to land use changes escalated by agricultural expansion, commercial logging and plantations, mining, industrial development and urbanization (Geist and Lambin 2002). Thus, these land use changes are responsible for biodiversity loss (Sala et al 2000). Tropical forests have historically been exploited for sufficing to the needs of development (Gibson et al 2011). This has resulted in elimination of native flora and altering the stand characteristics of the forests (Gadgil and Chandran 1989). These changes have also altered the microclimate (Johns 1985), and thus responsible for colonization of invasive plant species (Malcolm et al 2000). They have rapidly affected the dependent fauna of the area, of especially vertebrates which are highly endemic and habitat specific (Leimgruber et al 2003; Raffaelli 2004).

Mammals are one among the most widely distributed class of vertebrates in the animal kingdom (Wilson et al 1996). Origin of mammals dates back to Cretaceous period about 195 million years ago (Lou et al 2001). Mammals evolved to occupy most of the niches beginning from the Jurassic period (Wyss 2001). Mammals are most prone to be affected from escalating detrimental anthropogenic activities. This is due to habitat loss, fragmentation, and hunting, a primary occupation of humans since Pleistocene epoch (Isaac 1971). Large mammals in particular face the risk of extinctions due to such activities because they are mostly characterized by low densities, large home ranges and relatively lower reproductive turnovers (Kinnaird et al 2003; Leimgruber et al 2003; Raffaelli 2004; Wibisono et al 2011). The ancestral mammals of the Asian region were precursors to terrestrial mammals around the world (Beard 2002). Among all the continents, Asia still

holds high diversity and density of mammals. They presently constitute about 574 species (Nameer 2000) of which 51 species are endemic to India.

Amongst mammals, primates form ideal models for understanding the anthropogenic effects on forests and thus are considered as 'good indicators to general health of rainforest ecosystems' (Oates 1986). In India, 11 species of primates are endemic namely; Lion-tailed macaque *Macaca silenus*, Bonnet macaque *Macaca radiata*, Arunachal macaque *Macaca munzala*, Western grey langur *Semnopithecus achates*, Deccan grey langur *Semnopithecus anchies*, Northern plains grey langur *Semnopithecus entellus*, Black-footed grey langur *Semnopithecus hypoleucos*, Tufted grey langur *Semnopithecus priam*, Nilgiri langur *Trachypithecus johnii*. Some of these endemic primates of the country, macaques in particular face severe threat due to restricted distributions and specialized habitat and diet requirements thus being more sensitive to anthropogenic interventions (Wibisono et al 2011).

Macaques are '*unique among non-human primates for the range of habitats colonized, from continents to islands*' (Abegg and Theirry 2002). One of the oldest of living macaques is lion-tailed macaque is presently a highly threatened species in India. They are believed to have reached Asia from the Indonesian archipelago as the remnants of pre-glacial population (Abegg and Theirry 2002). This is one of the species of macaques of Silenus group from south-east Asia (Tosi et al 2003). Presently, their distribution range is restricted to the evergreen forests of Western Ghats in south India (Molur et al 2003).

Lion-tailed macaque is considered as a flagship species of the rainforests due to its high habitat specificity and distributional status (Kumara and Singh 2004a). In the recent past the population of lion-tailed macaque was known to be contiguous along rainforests from parts of Goa through the stretches of Western Ghats up to southern parts of Tamilnadu (Kumar 2013). Presently, the northern extremity of their distribution has been restricted to the low elevation tropical forests of Aghanashini-Sharavathi valleys (Karanth 1985; Kumara and Singh 2004a). All along their present range their populations have declined, and in some cases they have been exterminated completely in Karnataka (Kumara and Sinha 2009). Their habitats have also been eliminated in many areas especially in the lower

elevations of the Western Ghats (Menon and Bawa 1997). Thus the present ranges of lion-tailed macaques are largely isolated patches throughout the narrow stretches of evergreen forests of Western Ghats. Lion-tailed macaques are distributed in 11 major sub-populations of the south Indian states of Karnataka, Kerala and Tamilnadu (Molur et al 2003). The population of about 3500-4000 individuals of lion-tailed macaques has been estimated (Kumar 1995; Molur et al 2003). They are present in 7 major populations in Kerala and Tamilnadu namely; North of Nilambur, Silent valley-New Amarambalam, Siruvani-Attapadi, Anamalai hills, Munnar forests, Cardamom hills and Ashambu hills containing majority of up to 75% of their total population. In Karnataka, they are distributed in the forests of Aghanashini-Sharavathi valleys, Mookambika-Belthangadi, Charmadi hills and Kodagu forests. Most of these areas are separated from each other either by natural geographical gaps (Palghat gap and Sengottai gap) or by human induced fragmentation by developmental activities, thus making the populations relatively isolated from each other (Molur et al 2003; Kumara and Sinha 2009). Their populations remain challenged majorly because of habitat loss, habitat fragmentation and direct hunting (Kumara and Singh 2004a; 2004b; Kumara and Sinha 2009; Santhosh et al 2013; Umapathy and Kumar 2000) at different sites of their range. In Karnataka, there has been a steady decline of groups, and in some areas they are presently locally extinct (Kumara and Singh 2004a; Kumara and Sinha 2009). Being specialized feeder, habitat specialist, with low population turnover, long inter-birth interval and small remaining wild population they are considered as 'Endangered' (IUCN 2015).

Lion-tailed macaques are characterized by very unique life history parameters as compared to other macaques. Their annual birth rate is up to 0.3 infants per female (Kumar 1987; Joseph 1998) and their inter-birth intervals average about 2.5 years (Kumar 1987). The females attain sexual maturity around 6.6 years and their annual mortality rate is however 0.05 individuals which is the lowest among macaques (Kumar 1987). The group size of lion-tailed macaque vary from 7 – 40 in certain areas (Kumar 1995; Ramachandran and Joseph 2000). The group composition generally constitutes 1-2 males, 6-7 females and immatures. During estrous, females exhibit swelling below their tail during which most copulation occurs (Kumar 2000). The gestation period is about 170 days (Lindburg 2001)

and major birth peak occurring during December to February (Sharma et al 2006) and weaning is observed up to 15 months after birth (Kumar 1987).

The activity budgets of lion-tailed macaque are variable in different areas depending on the quality of habitat and plant species richness in the area (Menon 1993; Menon and Poirier 1996; Roy et al 2011; Umapathy 1998; Umapathy and Kumar 2000). They are specialized feeders highly specific to the phenophase of the plant parts they consume (Kumar 1987). There are variations in food species richness in their diet (Menon 1993; Menon and Poirier 1996; Roy et al 2011; Umapathy 1998; Umapathy and Kumar 2000). They feed on variable number of species in different areas such as in Anamalai hills, Ashambu hills, Silent valley and in southern parts of Sirsi-Honnava forests (Green and Minkowski 1977; Joseph 1998; Kurup and Kumar 1994; Menon 1993; Roy et al 2011; Umapathy 1998). Plant diet however varies at different sites and fruits contribute to the majority of their diet (Menon 1993; Menon and Poirier 1996; Roy et al 2011; Umapathy 1998; Umapathy and Kumar 2000). Rest of their diet however constitutes a variety of invertebrates including insects, caterpillars and opportunistic feeding on frogs, birds, lizards, squirrels and bats (Kumara et al 2001). Their home range is highly dependent on the habitat quality (Green and Minkowski 1977; Kumar 1987).

In the view of increasing pressure on their habitats, there are only a few sites which hold a large and viable population of lion-tailed macaques (Kumara and Sinha 2009). Their populations in forests of Talakaveri Wildlife Sanctuary, Pushpagiri Wildlife Sanctuary, Brahmagiri Wildlife Sanctuary and Kudremukha-Someshwara complex have severely decreased over the years due to hunting and habitat fragmentation (Kumara and Sinha 2009). The Silent valley National Park in Kerala, Kalakkad-Mundanthurai Tiger Reserve and Indira Gandhi Wildlife Sanctuary in Tamilnadu are a few areas having a sizeable population of these macaques (Kumar 2003). Sirsi-Honnava forests revealed a large population (Kumara and Singh 2004a), however they are present in a forest complex with large human population and vast expanses of agriculture lands and hunting pressure (Kumara and Singh 2004a; 2004b). Land use changes have been very pronounced in recent years in these multi-use forests (Kumara et al 2011). People of the area are dependent on the forest on a high number of plant resources for subsistence and livelihood including

Non-Timber Forest Products (Santhosh et al 2013). The area is characterized by unique *Myristica* swamps inhabiting rare flora and fauna. The forests also have mosaics of monoculture plantations regularly harvested by the local forest department for income generation.

The lion-tailed macaque ecology is known from a few locations mostly from the southern Western Ghats (Kumar 1987; Kurup and Kumar 1993; Menon and Poirier 1996; Singh et al 2000). The plant species composition constantly changes for every degree co-ordinate in the Western Ghats (Pascal 1988). It is apparent that the food species of macaques in Sirsi-Honnava forests are different from other studies considering the absence of certain known major food plants. There is an overlap between food plants documented for lion-tailed macaques (Krishnamani and Kumar 2000) and Non-Timber Forest Products of the area. Many food trees listed for lion-tailed macaques (Krishnamani and Kumar 2000) are also considered as trees of Non-Timber Forest Products in the district (Amit and Correa 1997; Rai and Uhl 2004). It is therefore very interesting to study the availability of forest produce and its use by both monkeys and people to understand the impact of Non-Timber Forest Product collection on the ecology of lion-tailed macaques. This is an important landscape for lion-tailed macaques given their population status and high dependency of people on these forests. With an immediate need for protection and on ground conservation of the area there is a need to develop a conservation strategy for this northern-most population of lion-tailed macaque.

Objectives of the present study are:

1. To assess the status of lion-tailed macaques in Sirsi-Honnava forests
2. To study the time-activity budget, resource availability, feeding ecology and ranging behavior of lion-tailed macaques
3. To assess the livelihood options of local people, and to examine the overlap in resource use between humans and lion-tailed macaques
4. Develop a conservation strategy for the lion-tailed macaque population of Sirsi-Honnava forests

Study Area

The Sirsi-Honnavara forests (N 14° 23' - 14° 23' 38"; E 74° 48' - 74° 38') form the part of the Central Western Ghats in the district of Uttara Kannada in the state of Karnataka, South India (Fig. 1.1). The area extends from north of the Sharavathi river in the administrative jurisdiction of Uttara Kannada district covering the taluks of Siddapura, Honnavara and Kumta (Fig. 1.2). The forests of the Sirsi - Honnavara fall under the administrative control of the Kanara Forest Circle. In Sirsi division, majority of the lion-tailed macaque habitat falls under the Kyadgi Forest range and Siddapur forest range. In Honnavara division, the habitat extends to ranges of Gersoppa, Honnavara and Kumta. The area possesses 22 *Biodiversity Hotspots of Hope* of the 50 identified in the state of Karnataka.

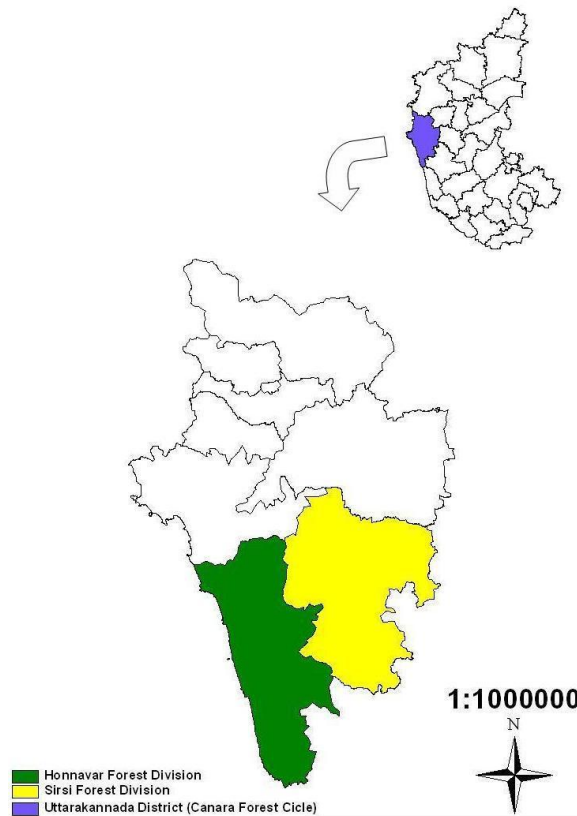


Fig. 1.1 Map of Sirsi and Honnavara forest division in Uttara Kannada district of Karnataka state

Physical Features

Altitude: The Sirsi-Honnava forests are located in the ridge of the Ghats extending in the westerly direction towards the west coast. The altitude varies from 300 m asl to 800 m asl.

Terrain and Slope: The terrain being the part of ridge of the Western Ghats is generally undulating, which forms the primary watershed for the origin of many streams and rivers. The area is densely covered with Southern Tropical Evergreen and Southern Tropical semi-evergreen forests. The terrain is highly undulating, where the slope of the Sirsi-Honnava forests varies from 20% to >35% in general.

Watershed and Catchments: The area is a prime forest dominated watershed which sustains the water resources of the major rivers. The forests in this watershed soak up the heavy rains of the monsoon and contribute to the perennality of many streams. The catchments of the habitat contribute to the Sharavathi and Aghanashini river systems, which are both west flowing, mainly through the streams like Mugthihole and Vatehalla.

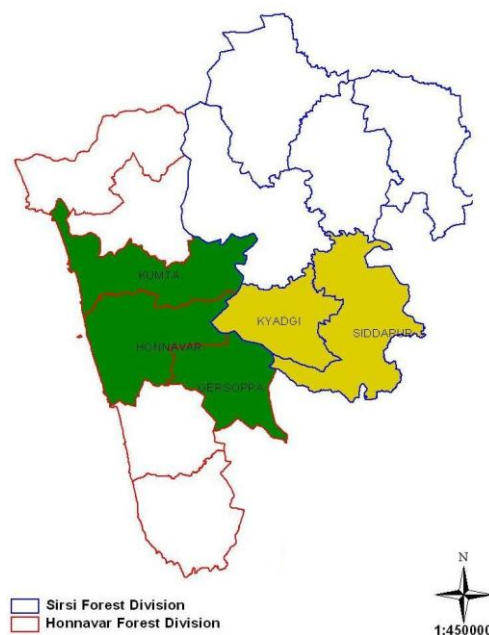


Fig. 1.2 Different ranges of Sirsi-Honnava divisions of Uttara Kannada district of south India

Soil: With the rainfall in excess of 3000 mm, the soils comprise of mainly leached out laterite soils. The fertility of the soil is attributed to the detritus contributed from the forests, the forests not only harvest rain water but also contribute the protection of the soil which if exposed will lead to laterization as in case of exposed slopes forming hard laterite pans. The soils vary from well drained loamy soils to shallow loamy soils. Clayey soils are encountered closer to the river systems, in the ridges gravelly soils are encountered. Rocky and boulder outcrops are encountered in the streams systems.

Temperature and Precipitation: The monthly average temperature ranged from 31°C to 12°C during the study period and the yearly average temperature was about 23°C (Indian Meteorological Department, Bangalore). Though the region receives both the monsoon, the majority of the rainfall is received from the south-western monsoon which is experienced from June to October. Small amount of rainfall is received from the retreating monsoon in November. The dry season is long and will last for more than 6 months, summer showers are received in the month of the April and pre-monsoon showers in the month of May. The mean annual rainfall of the region during the study was about 3000 mm (Fig 1.3)

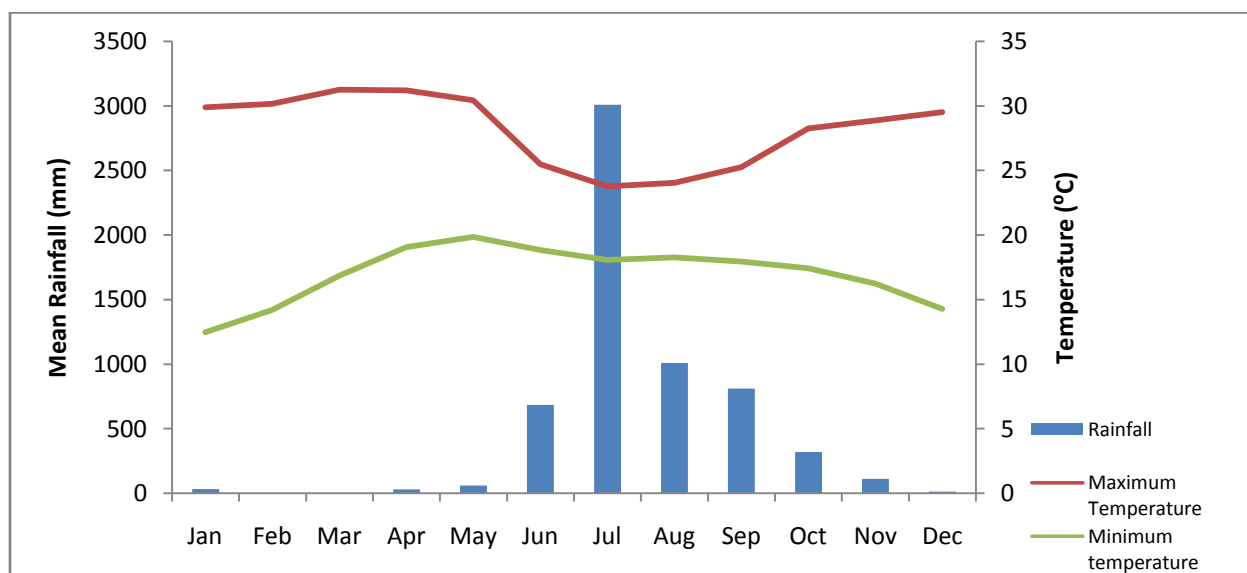


Fig. 1.3 Minimum and Maximum average monthly temperatures and mean annual rainfall during the study period in Sirsi-Honnava forests

Flora and Fauna

Sirsi- Honnavara forests form the northern limit of the evergreen forests of the plains and low elevations (Pascal 1988), with its forests being classified as west coast tropical evergreen forest with low level type flora (Champion and Seth 1968). The vegetation type is *Persea macarantha-Diospyros* spp-*Hologarna* spp. which has been replaced by the dominance of *Dipterocarpus indicus-Diospyros condolleana-Diospyros oocarpa* due to human interference (Pascal 1988).

About 268 species of plants have been documented from the area, which include 116 trees, 14 lianas, 35 climbers, 33 herbs, 59 shrubs, 4 palms, 2 grass and 5 species of orchids. Among them, two species are critically endangered, five species are endangered and 16 species are vulnerable (IUCN, 2015). The region has many *Myristica* swamps which are a home for many endemic plant species. This region harbors many endemic and endangered species, including plants such as *Semecarpus kathalekanensis* (Anacardiaceae), *Madhuca bourdillonii* (Sapotaceae), and *Syzygium travancoricum* (Myrtaceae) (Chandran et al 2008) and also unique *Myristica* swamps (Chandran et al 2008).

Faunal diversity in the region includes 65 species of butterflies, 35 species of amphibians (26 species are endemic to the Ghats), at least 182 species of birds and 33 species of mammals. The major mammal species of the area includes 17 globally threatened large mammals (Kumara and Singh 2004b). Mammals present in the area are gaur *Bos gaurus*, muntjac *Muntiacus muntjak*, Indian chevrotain *Tragulus meminna*, sambar *Cervus unicolor* and wild pig *Sus scrofa*. The primates include Malabar slender loris *Loris lydekkerianus malabaricus*, lion-tailed macaque *Macaca silenus*, bonnet macaque *Macaca radiata*, Hanuman langur *Semnopithecus dussumieri*. The two species of squirrels in the area are Indian giant squirrel *Ratufa indica* and giant flying squirrel *Petaurista petaurista*. The large carnivores in the area include tiger *Panthera tigris*, leopard *Panthera pardus*, wild dog *Cuon alpinus* and Jackal *Canis aureus*. Small carnivores like brown palm civet *Paradoxurus jerdoni*, Asian palm civet *Paradoxurus hermophroditus* and small Indian civet *Vivericula indica* are known to occur in the study site.

Present Management

The region has a strong conservation history; most of the prime relict forests of the region are a result of sacred groves (*kans* and *devarabanas*) by the local community prior to the colonial era. During the colonial period, shift in the focus from protection of these forests to for timber harvesting occurred. Thus, most of the forests have suffered from logging related works even in the sacred groves. Post the colonial period, the department pursued raising of high-value species. The recent the selection felling of softwoods for veneer and matchwood purpose occurred, further degrading the habitat.

The existing Working Plan prescribes the Sirsi-Honnava forests as Protection Working Circle only allowing Non-Timber Forest Produce collections (Saibaba 2002) which lays the foundation for future management of the area on a much intensive conservation oriented scale.

Structure of the thesis

*The thesis is divided into three sections namely; **Population, Ecology and Conservation.***

Chapter 1 deals with the introduction of species in focus and study area. The population section includes **Chapter 2** dealing with status and demography of LTM. Ecology section includes **Chapter 3** dealing with time-activity budget, resource availability, resource utilization and ranging behavior. Conservation section includes **Chapter 4** dealing with mapping of LTM locations, quantifying habitat loss and understanding of local people and their livelihood. **Chapter 5** deals with identifying the issues, initiatives and achievements with conclusions

Chapter 2

Population characteristics of
Lion-tailed macaques in
Sirsi-Honnavara

Introduction

The hill ranges of Western Ghats are present in less than 6% of India's landmass but has more than 30% of all plant and vertebrate species of the country (Das et al 2006) and has been considered as one of the biodiversity hotspots of the world (Myers et al 2000). About 12% of the mammals species present in the Western Ghats are endemic to the area (Das et al 2006). Lion-tailed macaque is one such endangered and endemic primate species restricted to narrow ranges of southern and central Western Ghats (IUCN 2015) isolated into two genetically distinct populations (Ram et al 2015).

Lion-tailed macaques are estimated to be about 3500-4000 individuals present in 49 sub-populations spread out in 8 locations of the Western Ghats (Molur et al 2003). They are distributed in three south Indian states; Kerala, Tamilnadu and Karnataka. Lion-tailed macaque populations of Kerala account to the majority of populations in the wild distributed in 2 major sub-populations. They are present north of Nilambur which have 4-8 groups in a fragmented landscape while the contiguous forests of Silent Valley- New Amarambalam have > 30 groups (Kumar et al 1995). In Tamilnadu, the forests of Siruvani and Attapadi are isolated from others with 4-5 groups while the Anamalai hills inhabit 43-58 groups in highly fragmented forests (Kumar et al 1995). The populations of Munnar and Cardamom hills are also fragmented, inhabiting more than 20 groups. The Kalakkad-Mundanthurai Tiger Reserve, Chenduruny, Neyyara and Peppara forests inhabit >50 groups which is one of the largest of known populations in a very intact forest in Tamilnadu, continuous with fragmented forests in Kerala (Kumar et al 1995). Thus there are only a few populations which inhabit contiguous forests in Kerala and Tamilnadu.

The status of lion-tailed macaque remains threatened in most of the Protected Areas and Reserve Forests of the state Karnataka (Kumara and Sinha 2009). Karanth (1985) reported about 3,000 lion-tailed macaques in 123 groups in forests of Karnataka. Kumara and Singh (2004a) reported a population of 32 groups in the forests of Sirsi-Honnava. The forests of

Bhatkal, Sharavathi, Someshwara and Mookambika showed decrease in the population size, whereas populations of Sakleshpur, Yesalur, Subramanya, Pushpagiri, Makut, Talakavery and Brahmagiri Wildlife Sanctuary showed sharp declines (Kumara and Sinha 2009). Thus, the population of lion-tailed macaques in Karnataka showed decline of about 69%-90% of groups and local extinction in some of the forest areas due to hunting, habitat loss and fragmentation (Kumara and Sinha 2009). The lion-tailed macaque distribution is shrinking in many parts especially in the northern areas of its range (Karanth 1985). Northernmost populations of lion-tailed macaques were earlier reported from Anshi, Kumbaravada, Varalli, Janmane and Honnavara forests (Bhat 1982; Kurup 1978) which are presently locally extinct. Their present northernmost range is parts of Aghanashini-Sharavathi valleys where a large population has been identified (Kumara and Singh 2004a). In this dismal scenario of conservation status of lion-tailed macaque in different ranges of Western Ghats, identification of one of their large population in the forests of Sirsi-Honnavara increased requisite for developing the conservation action plan and proper conservation effort. Kumara and Singh (2004a) reports the presence of anthropogenic pressures like encroachment of forest and valleys for agriculture; developmental activities such as construction of roads, transmission lines, dams, hydel-power plants and local hunting impacting the forests (Kumara and Singh 2004a; b). Further, the area falls under the jurisdiction of 'Reserve Forest' with no legal protection as a Protected Area with high density of people. The present study aims to determine the current status of the population, documenting their demography and highlighting habitat characteristics of the area.

Methods

The survey was carried out using "total count method" (NRC 1981), which is often used for rare and patchily distributed species (White and Edwards 2000; Whitesides 1998). This method increases the probability of seeing the species, but counting the same group twice can be an issue if the group spread is large and they are moving. Double counting was avoided by noting the sighting distance, location, time of the sighting and the direction of movement. The suitable habitat for the lion-tailed macaques was considered based on earlier survey findings and group locations (Kumara and Singh 2004a). Those group

locations were plotted on the map with 2 km radius presuming to be equal to the maximum home range size (5 km²) of a lion-tailed macaque group (Green and Minkowski 1977) around each location points that were mapped and considered those plots as a sampling area. In each such sampling area, predetermined lines were fixed for sampling. The lines were walked 3-4 consecutive days by a team of 3 trained observers. Observers walked parallel to each other by maintaining inter-individual distance of 100 m to get the best sightings of the lion-tailed macaque groups. It was assumed that neither visibility nor detectability factor would bias the data. Since it remained constant throughout the study site, and all the observers were familiar with the species and its habits. The survey was conducted between 05:30 to 12:00 hr and 15:00 to 18:00 hr since the lion-tailed macaques are known to be active and vocalizing throughout the day (Kumar 1987). During the walk, for each sighting of a group, geo-coordinates were recorded using handheld GPS 'Garmin GPS60 and GPS72', group size were recorded generally from "common cross-over points" by spending sufficient time with the group (max. of 30 minutes). Previous studies have documented the home range of a single group to be about 5 km² (Green and Minkowski 1977; Kumar 1987; Umapathy 1998). Each group that was sighted within a range of 1.5 km radius from the other group was considered as the same group, unless the two groups were sighted in a short span of time or the group size and identity of each were confirmed as different. The survey was done in a relatively short period of time, in the pre-monsoon season, to overcome the possible bias caused by changes in ranging distances across seasons. The inter-group distance was extracted on a GIS platform using ArcView3.2. A total of 1,056 km of walk were made for the sampling in Sirsi-Honnava, which include 546, 56, 87 and 354 km in Kyadagi, Siddapura, Honnavara and Gersoppa ranges respectively. Based on the total number of groups sighted, estimated the groups in a particular area were calculated on the basis of location of sighting and group sizes. The groups that were counted completely were used for calculating the average group size, and estimation of population size. Maps were prepared overlaying the macaque sighting locations on vegetation and topography layers for documenting the habitat preference of monkeys.

Results

Population estimation and demography

A total of 49 groups of lion-tailed macaques were sighted with 3 lone males during the survey. The estimated groups for the region was 31 (Table 2.1, Appendix 2.1), which include 15, 2, 1, 2 and 11 groups in Kyadagi, Siddapura, Kumta, Honnavara and Gersoppa ranges respectively (Fig. 2.1). Complete count of the individuals in the group was obtained for 24 groups, which gave a mean group size of 20.5 monkeys/ group (Appendix 2.1). The group size varied between 12 and 35, and ~63 % of the groups had group size between 16 and 25 (Fig. 3). The estimated minimum population size in the study site was 638 monkeys in 31 groups excluding the lone males.

Population status and group size

All the groups remained in the altitudinal range between from 342 m asl to 750 m asl (Fig 2.2). The total geographical area occupied (spatial extant) by lion-tailed macaque is about 32479 ha, which spreads in 28 village boundaries, which include 18 villages of Sirsi and 10 villages of Honnavara divisions (Fig. 2.3). Yet the 85% (27519 ha) of the total geographical area is under forest cover. The forest cover in Sirsi division was 82% and Honnavara division was 86%. The region is characterized by evergreen, semi evergreen, moist deciduous, scrub forests and monoculture plantations, however the lion-tailed macaque groups were predominantly associated with evergreen forests (Fig. 2.4). Though the percent of slope varied in the region, the monkeys were sighted mostly in the area with >35% of slopes (Fig. 2.5).

Discussion

The study shows persistence of large population of lion-tailed macaque in the forests of Sirsi-Honnavara with the estimated population size of 638 individuals in 31 groups. The mean group size was 20.5 individuals per group with birth rate ranging from 0.24-1.00. The groups were sighted between 342-750 msl, primarily showing high preference to evergreen forests and were associated with areas with >35% slope.

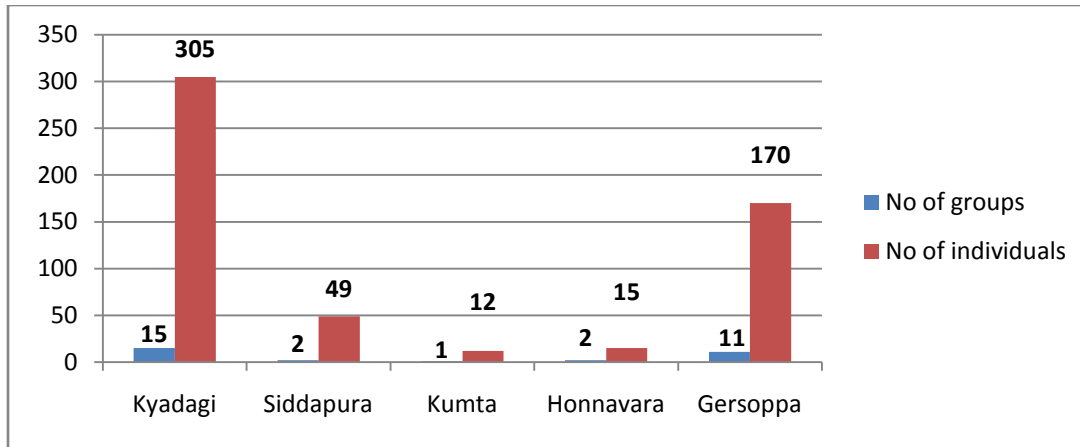


Fig. 2.1 Number of Lion-tailed macaque groups and individuals estimated in different ranges of Sirsi-Honnagara forests

Table 2.1 Effort and details of lion-tailed macaques in different ranges of Sirsi-Honnagara forests

| Range | Distance walked (km) | Number of groups sighted | Number of estimated groups | Number of lion-tailed macaques sighted |
|--------------|----------------------|--------------------------|----------------------------|--|
| Kyadagi | 546 | 27 | 15 | 305 |
| Siddapura | 56 | 2 | 2 | 49 |
| Kumta | 20 | 1 | 1 | 12 |
| Honnavara | 67 | 3 | 2 | 15 |
| Gersoppa | 367 | 16 | 11 | 170 |
| TOTAL | 1056 | 49 | 31 | 551 |

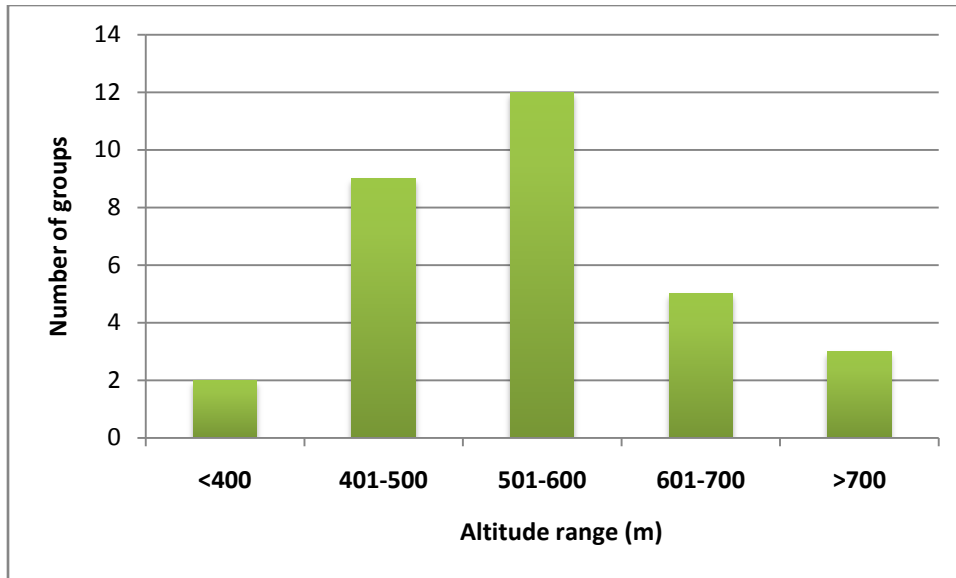


Fig. 2.2 Number of lion-tailed macaque groups at different altitudinal range of Sirsi-Honnavara forests



Fig 2.3 Location of the lion-tailed macaque groups in the forests of Sirsi-Honnavara

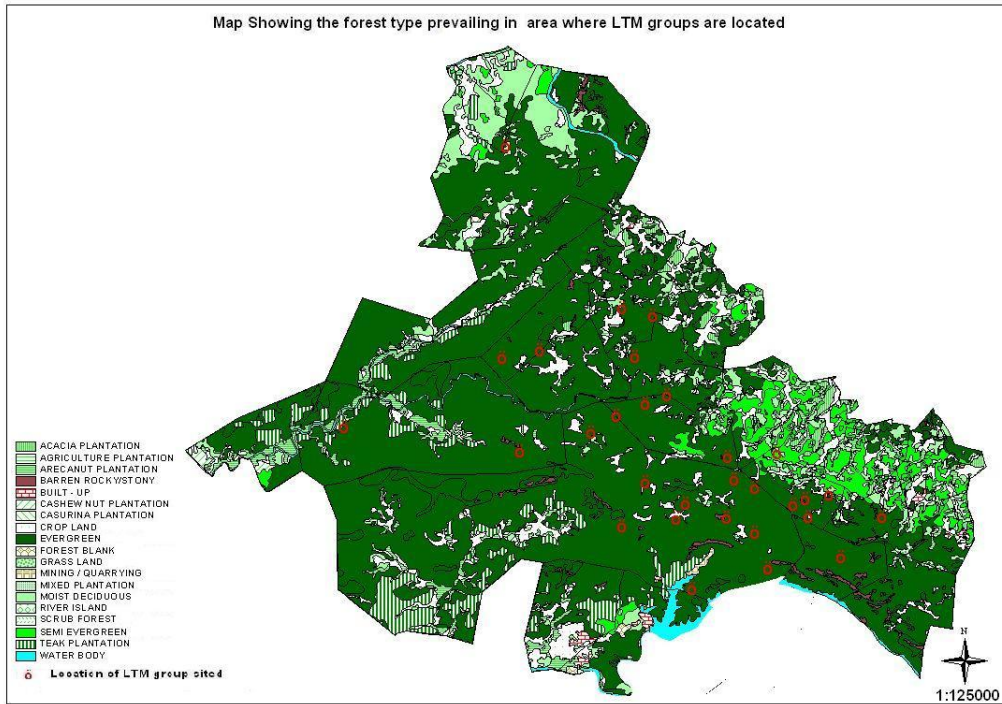


Fig 2.4 The forest types in the region with group locations of lion-tailed macaque

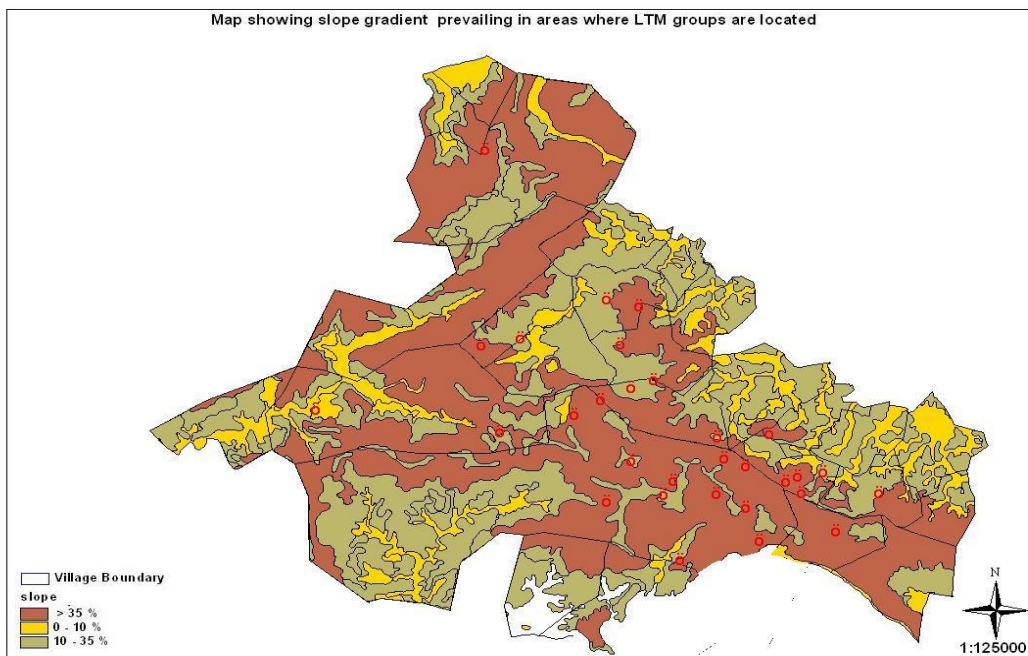


Fig. 2.5 The percent of slope in the region with group locations of lion-tailed macaque

Kumara and Singh (2004a) followed single observer total count technique, but the limitations of this method could have been possibilities of inflated estimate of abundance due to double counting of the same group (Struhsaker 2002). Adapting a conventional line transect technique, found difficult since the terrain of the study site is highly undulating. Thus, multi-observer total count technique was adapted to estimate the abundance of lion-tailed macaques in the study site. However, this technique has a few limitations i.e. it may require many trained observers and does not overcome the problem of changes in group size when social groups are the unit of measure (Struhsaker 2002). To overcome these limitations, we had 3 observers trained each time before the survey to minimize the rate of error in recognizing and locating the lion-tailed macaques. Further, changes in demography and group size was uncommon with lion-tailed macaques in a short period thereby nullifying the rate of error in estimation of abundance.

The present survey demonstrates the persistence of large population of lion-tailed macaques in the forests of Sirsi-Honnavaara which is the northernmost population in its present range of distribution. The mean group size was slightly higher than some of the populations or on par with the known ranges e.g., 16.3 in Indira Gandhi Wildlife Sanctuary (Singh et al 1997), 19.6 in Silent Valley National Park (Joseph and Ramachandran 1998) and 33.2 in Theni (Kumara et al 2011). Sightings of several lone males in the present survey indicate the possible emigration of individuals between the groups ensuring a dynamic gene flow. However, the present mean group size (20.5) is lesser than the earlier survey (24.7) in 2002-2003 (Kumara and Singh 2004a). The difference in the group size between the study periods may be attributed to observer bias or higher level of hunting pressure or mortality of individuals due to anthropogenic reasons like hunting (Kumara and Singh 2004b).

Chapter 3

Resource availability and Resource
use by Lion-tailed macaques

Chapter 3

Resource availability and Resource use by Lion-tailed macaques

The floristic diversity and stand structure contributes largely to the biodiversity of the area and they provide resource and habitat to all the dependent faunal species (Cannon et al 1998). Floristic inventories provide systematic characterization of the forest type and provide insights to the structure of the forest (Pascal and Pelisser 1996; Ayappan and Parthasarathy 1999). Since the plant species composition changes with different latitudes or every degree coordinate (Pascal 1988), it is apparent that even a contiguous forest patch, Sirsi-Honnava forests for instance, remains diverse in structure and composition (Murthy et al 2016). In an area of such high importance, the composition of forests and the status of food plant species of lion-tailed macaques and resource availability need to be studied in the view of dynamic land use change over the years, with large human population dependent on forests. The resource utilization of the monkeys is largely determined by resource availability (Matsuda et al 2009) and plant species richness (Doran-Sheehy et al 2004). In addition to this, inter-group encounters (Watts 2000), terrestriality (Riley 2008), rainfall and seasonality (Baoping et al 2009) also play a determining role. Thus, it is very critical to understand the factors influencing the patterns and seasonal dynamics of home range use and movement of lion-tailed macaques for understanding the ecology of the macaques. The present chapter focuses on vegetation stand structure of vegetation, feeding ecology and ranging pattern of lion-tailed macaque in Sirsi-Honnava forests.

The studies on resource availability were done using two methods. Plot method in which the sampling was done using circular plots along a transect line, within which all the trees with more than 30 cm girth was assessed. The vegetation data was analyzed to obtain the quantitative structure and composition of plant communities in these plots. The method

was very intensive and represented most of the home range of the study groups. Point-centered quarter method in which the area was gridded into 1 km² cells and point-centered quarter method (Cottam and Curtis 1956) was used to assess the overall tree density and food tree density in each grid cell. This method provided a rapid assessment of tree densities at grid level.

For determining the resource use, feeding ecology of lion-tailed macaques was studied using scan sampling method (Altmann 1974), daily path length and ranging pattern was determined by following the groups with hand-held GPS. The inter-group encounters were collected using *ad-libitum* data and rainfall data was collected from Indian Metrological Department records.

3.1 Resource availability in Sirsi-Honnava forests

Introduction

Understanding of diversity of inhabitant species in a given area is pre-requisite for its management and protection (Condit et al 1998). The structure of climax forests worldwide have changed over the past and are continuously changing presently having been replaced by inferior species due to anthropogenic pressure (Parthasarathy 1999). Reduction of forests has been from 1 to 4% annually (Laurance 1999) which may have forced many dependent species to extinction.

The forests of Western Ghats have been highly heterogeneous and complex having varied conditions leading to spatial dynamism in distribution of vegetation (Pascal 1988). The Uttara Kannada district in Karnataka in the central Western Ghats is the most forested area in south India. These forests are under continuous pressure from the past and recent years due to industrial needs, development and rapid urbanization. The areas in and around Sirsi-Honnava are characterized by natural vegetation which includes evergreen, semi-evergreen and moist deciduous forests (Daniels 1989). Species composition in Sirsi-Honnava is expected to vary across latitudes even within a common forest type. Further, Sirsi-Honnava has experienced high degree of selective logging, large scale submergence of forests in water due to dam constructions, loss of forests due to electrical line erections and colonization of people by encroachments in the last six decades (Gadgil and Chandran 1989). In addition to this, inhabitant people also have been highly dependent on these forests for subsistence like water, firewood, non-timber forest products, timber, soil, green manure and dry leaf litter for agriculture. The status of plant species in the study area needs to be investigated to understand their contribution on overall stand structure of the area. The present chapter discusses on vegetation assessment in Hosthota and Chiksuli regions of Sirsi-Honnava forests.

Methods

The floristic assessment was done by laying transects in forest sites belonging to home ranges of lion-tailed macaque study groups in Hothota and Chiksuli which were continuous patch of forests adjacent to each other. On transect line at an interval of 50 m, and 5 m inside from the transect line, circular plots were laid on both sides of transect (Table 3.1.1). In every plot, all living trees with GBH (Girth at breast height) greater than 30 cm (12 inch) was noted down as trees, and those with GBH less than 30 cm was considered as young trees (10-30 cm = juvenile trees). For multi-stemmed trees GBH was separately measured for each stem and was added up. The species identification was done with the help of '*A Field Key to The Trees and Lianas of the Evergreen Forest*' by Pascal and Ramesh (1987). The species which could not be easily identified were collected and identified with from the taxonomists at the college of Forestry, Sirsi.

Table 3.1.1 Sampling efforts for floristic diversity and stand structure in Hothota and Chiksuli

| Study locations | Sampling for Trees | | Sampling for Juveniles | |
|-----------------|-----------------------|-----------|---------------------------------|-----------|
| | No. 10 m radius plots | Area (ha) | No. of 400 m ² plots | Area (ha) |
| Hothota | 132 | 4.14 | 25 | 1.00 |
| Chiksuli | 128 | 4.02 | 25 | 1.00 |

The vegetation data was analyzed to obtain the quantitative structure and composition of plant communities (Table 3.1.2). The vegetation data was tabulated for frequency, density, abundance, relative frequency, relative density, relative abundance, relative dominance, Importance Value Index (IVI) and composition of plant communities, following Curtis and MC Intosh (1950); Philips, (1959) and the Family Importance Value (FIV) was calculated by following Mori and Boom (1983).

Results

A total of 1503 woody plants of 71 species belonging to 57 genera and 32 families, and 1401 woody plants of 73 species belonging to 54 genera and 31 families were recorded in Hosthota and in Chiksuli respectively (Table 3.1.3). The Shannon-Wiener Index values varied from 1.40 in Hosthota to 1.53 in Chiksuli.

Table 3.1.2 Calculations of quantitative structure and composition of plant communities

| Parameters | Formula |
|-------------------------------|---|
| Frequency (%) | (No. of quadrates in which a species occurred/Total no. of quadrates studied) × 100 |
| Abundance | Total number of individuals of the species/No. of quadrates in which the species occurred |
| Density | Total no. of individuals of a given species/Total no. of quadrates examined |
| Relative density | No. of individuals/ No. of individuals of all species |
| Relative abundance | (Abundance of species × 100) / Sum of all Abundances |
| Relative frequency | Number of quadrates occurring/ Total no. of Quadrates |
| Basal area | (GBH in m) ² / 4π |
| Relative Basal area | (Total basal area of Individuals/ Total basal area of all species) × 100 |
| IVI | Relative density + Relative dominance +Relative frequency |
| Family Relative density (%) | (Number of trees in a family/Total number of trees) × 100 |
| Family Relative Diversity (%) | (Number of species in a family/total number of species) × 100 |
| Family Relative Dominance (%) | (Total basal area for all species in a family/Total basal area of all families) × 100 |
| Family Importance Value(FIV) | Σ of Family relative density, diversity and Dominance |
| Species occurrence rate | Species richness / Species density |

Table 3.1.3 Details of species richness, generic richness, familial richness, stand density, basal area, Shannon-Wiener index and Simpson index for study sites

| | Hosthota | Chiksuli |
|-------------------------------------|----------|----------|
| Number of Woody species | 71 | 73 |
| Number of Genera | 57 | 54 |
| Number of Families | 32 | 31 |
| Stand Density(Stems/ha) | 386.50 | 349.30 |
| Basal Area(m²/ha) | 26.50 | 27.10 |
| Shannon-Weiner Index | 1.40 | 1.53 |
| Simpson Index (D) | 0.07 | 0.04 |

Importance Value Index (IVI)

The importance value index for all the woody plants in Hosthota and Chiksuli are provided in Appendices 3.1.1 and 3.1.2. Figure 3.1.1 and 3.1.2 provide the ten most important trees for each study site and their IVI values. The order of highest IVI species in Hosthota was *Knema attenuata* (28.60), *Diospyros sylvatica* (23.90), *Hopea ponga* (19.80), *Holigarna arnottiana* (16.60), *Olea dioica* (14.20) and *Garcinia morella* (13.70) and in Chiksuli was *Olea dioica* (17.90), *Knema attenuata* (15.60), *Aglaia roxburghiana* (14.40), *Garcinia talbotti* (13.00) and *Hopea ponga* (11.90).

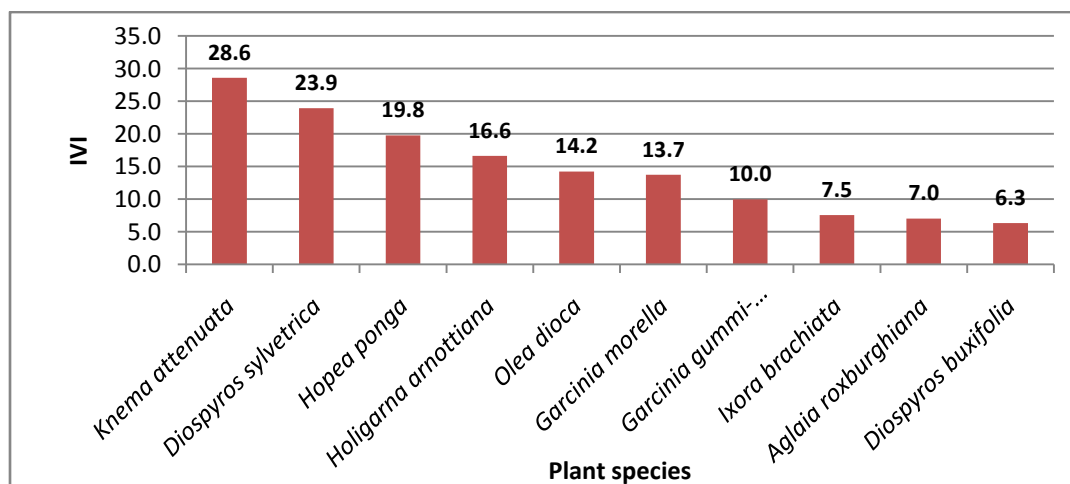


Figure 3.1.1 Importance Value Index (IVI) for top 10 tree species in Hosthota

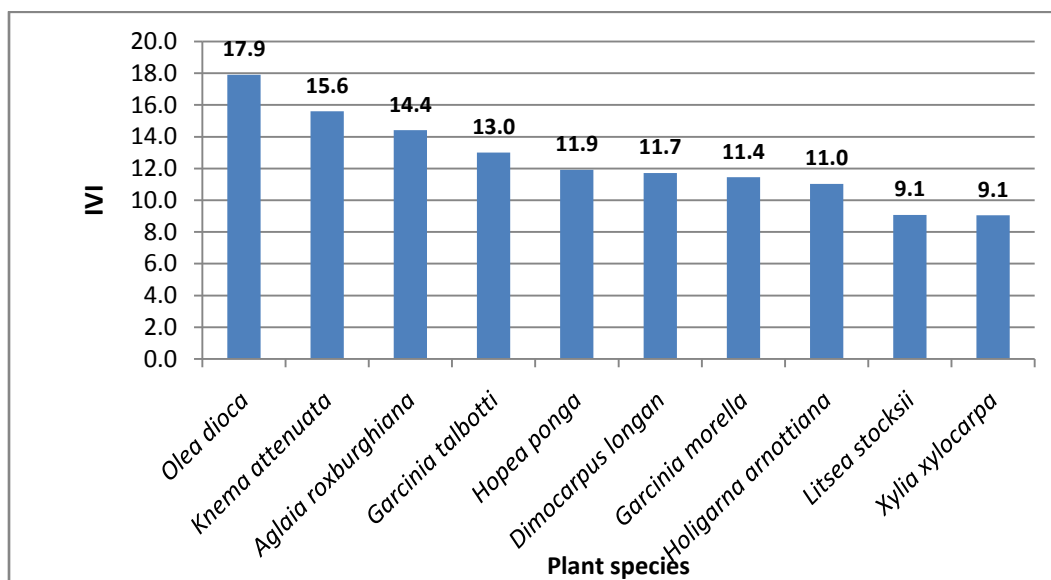


Figure 3.1.2 Importance Value Index (IVI) for top 10 tree species in Chiksuli

Familial composition

Familial importance index for all the study sites are provided in the Appendices 3.1.3 and 3.1.4. The number of families represented in Hosthota was 32 and Chiksuli was 31.

Hosthota: The family Lauraceae was well represented with eight species followed by Clusiaceae, Ebanaceae and Myrtaceae having five species each, and Anacardiaceae, Euphorbiaceae, Moraceae and Sapotaceae having represented by four species each. At the generic level, the most represented family was Lauraceae (N=7), Euphorbiaceae (N=4) and Sapotaceae (N=4). The family Myristicaceae represented by highest number of individuals (N= 254), which is followed by Ebanaceae (N=236), Dipterocarpaceae (N=158) and Clusiaceae (N=157). The maximum basal area was recorded for family Ebanaceae (17.48) followed by Myrtaceae (11.59) and Anacardiaceae (11.44). Of this, Myristicaceae was the dominated family (16.89%) followed by Ebanaceae (15.70%), Dipterocarpaceae (10.51%) and Clusiaceae (10.44%).

Chiksuli: The family Lauraceae represented by eight species, where Moraceae, Clusiaceae, Myrtaceae represented by five species each. At the generic level, family Lauraceae (N=7) dominated followed by Euphorbiaceae (N=4), Flacortiaceae (N=4) and Anacardiaceae (N=4). The family Clusiaceae was well represented by high number of individuals (N=221), which is followed by Lauraceae (N=143), Oleaceae (N=128) and Myristicaceae (N=118). The maximum basal area was recorded for family Moraceae (18.10) followed by Oleaceae (15.40) and Clusiaceae (13.60). Of this, Clusiaceae was the dominated family (15.90%) followed by Lauraceae (10.30%), Oleaceae (9.20%) and Myristicaceae (8.50%).

Stand density and basal area of plant species across different study sites

Stand density and basal area of each species in Hosthota and Chiksuli are provided in Appendix 3.1.5 and 3.1.6 respectively. The order of species that showed highest stand density in Hosthota was *Knema attenuata* (57.38), *Hopea ponga* (38.07) and *Olea dioica* (23.37) and Chiksuli was *Olea dioica* (31.84), *Nathopegia racemosa* (24.88) and *Memycylon malabaricum* (22.89) in Chiksuli. High basal area was recorded for *Diospyros sylvatica* (12.43), *Syzigium gardneri* (10.69) and *Hopea ponga* (9.09) in Hosthota, and *Ficus nervosa* (17.65), *Olea dioica* (15.39) and *Cassine glauca* (5.41) in Chiksuli.

Species-Area curves

The species-area curves plotted for Hosthota and Chiksuli revealed that species increments happened constantly along the curves until the end of sampling, indicating higher sampling effort required to reach the asymptote (Table 3.1.4 and Fig. 3.1.3). Asymptote was not achieved in both the areas indicating the need of more sampling effort. However, it showed negligible difference in estimation value and observed species.

Girth and density class characteristics

The highest stand density and species richness was in the 10-30 cm girth class that gradually tapered down in higher girth classes (Table 3.1.5). Among the 10-30 cm class, Chiksuli showed highest number of individuals (3184 ha⁻¹). Basal area was relatively spread over across different girth classes. However, the basal area in/with 61-120 classes was higher than in any other classes. Further, the trees with greater than 210 cm girth class

showed much higher basal area than in any other girth classes. Higher values of species occurrence were seen in higher girth classes in both the areas. Majority of the tree species remained in their density class $< 20 \text{ ha}^{-1}$, only four to five species of them were in more than 20 ha^{-1} (Table 3.1.6).

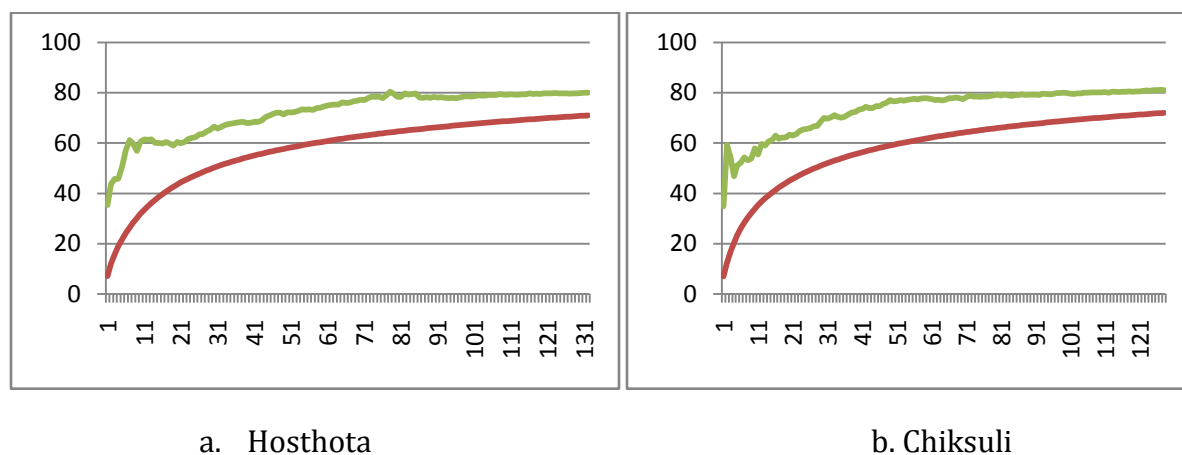


Figure 3.1.3 Species accumulation curve (observed and expected) for study sites

Table 3.1.4 Number of expected and observed species in different sampling sites as predicted by Chao2 Mean and SobsMean

| | Hosthota | Chiksuli |
|------------------|----------|----------|
| Observed | 71 | 72 |
| Estimated | 80 | 81 |

Discussion

The knowledge of stand structure of vegetation of an area contributes largely to the understanding of overall biodiversity parameters as plants provide habitat and food resources to most forest inhabitants (Cannon et al 1998). Stand structure of forests is highly site specific which is decided by the biogeography, human interference and climatic conditions (Whitmore 1998). Thus, the understanding of qualitative and quantitative structural changes across the forest is a critical for management of forests, that too if the forest patch is crucial for the conservation of some important species and having high

human dependence for their livelihood. The forests of Sirsi-Honnava is one of the important and potential sites for conservation of endangered lion-tailed macaque (Kumara and Singh 2004a; b; Santhosh et al 2013), and many other flora and fauna in the central

Table 3.1.5 Stand density, species richness, basal area and species occurrence in different girth classes in the study sites

| Area | Girth class | Stand density | Species richness | Basal area/ha | Species Occurrence rate |
|----------|-------------|---------------|------------------|---------------|-------------------------|
| Hosthota | 10-30 | 1674 | 60 | - | 0.03 |
| | 30-60 | 171.78 | 61 | 2.71 | 0.36 |
| | 61-90 | 86.86 | 51 | 3.68 | 0.59 |
| | 91-120 | 52.35 | 38 | 4.53 | 0.73 |
| | 121-150 | 25.57 | 28 | 3.54 | 1.09 |
| | 151-180 | 32.81 | 18 | 1.87 | 0.55 |
| | 181-210 | 7.24 | 13 | 2.27 | 1.80 |
| | >210 | 9.89 | 19 | 7.77 | 1.92 |
| Chiksuli | 10-30 | 3184 | 63 | - | 0.01 |
| | 30-60 | 168.69 | 62 | 2.62 | 0.37 |
| | 61-90 | 91.06 | 52 | 3.88 | 0.57 |
| | 91-120 | 44.04 | 34 | 3.75 | 0.77 |
| | 121-150 | 19.41 | 20 | 2.78 | 1.03 |
| | 151-180 | 11.69 | 23 | 2.48 | 1.97 |
| | 181-210 | 5.47 | 13 | 1.64 | 2.37 |
| | >210 | 8.96 | 16 | 10.05 | 1.79 |

Table 3.1.6 Species richness of woody plants in different density classes in study sites

| Density Classes | Species Richness | |
|-----------------|------------------|----------|
| | Hosthota | Chiksuli |
| >101 | - | - |
| 100-51 | 1 | - |
| 50-21 | 5 | 4 |
| 20-3 | 13 | 23 |
| <3 | 53 | 46 |
| Total | 72 | 73 |

Western Ghats. Vegetative parameters in the study sites show a great degree of variation within the landscape and that their documentation remains very critical for addressing local issues for management. The species richness in the study sites is much lesser than in the southern Western Ghats (Davidar et al 2005) e.g. 114 species in Sengaltheri forests or 116 species in Kalakad-Mundanthurai Tiger Reserve (Parthasarathy 2001; 1999) and 148 to 153 species in 30 ha of sampling in Vargaliar of Anamalai hills (Ayyappan and Parthasarathy 1999; 2004), however, it is on par with the species richness reported (37 to 63 species) for north of Sirsi-Honnava forest in Uttara Kannada (Bhat et al 2000). The lesser species richness in the central Western Ghats than in the southern Ghats was attributed to changes in the seasonality in addition to variation in the quantity of rainfall (Davidar et al 2005). The stand density of trees (>30 cm) ranged between 318 and 386 stems/ha in the study area, perhaps which is also much lesser than many sites in southern Western Ghats e.g. 851 ha⁻¹ in Sengaltheri (Parthasarathy 2001), 716 ha⁻¹ in Kalakad-Mundanthurai Tiger Reserve (Parthasarathy 1999), 482 ha⁻¹ Courtallam reserve forests (Parthasarathy and Karthikeyan 1997), 583 ha⁻¹ at Kakachi, (Ganesh et al 1996). However, Ayyappan and Parthasarathy, (2004) reported high variation of 273 to 674 stems/ha in Varagaliyar of Anamalai hills. Even within the central Western Ghats, the stem density highly varied from 304 ha⁻¹ in Agumbe (Srinivas 1997) to 635 ha⁻¹ in Uppangala (Pascal and Pelisser 1996), however, 419 ha⁻¹ of mean tree density for a closed canopy evergreen forest of Western Ghats was reported (Ghate et al 1998). The basal area of trees per hectare varied from 21.5 m² to 45.5 m², which is much lower than in southern Western Ghats e.g. 94.6 m² ha⁻¹ in Kalakkad Mundanthurai Tiger Reserve (Parthasarathy 1999) and 55.34 to 78.32 m² ha⁻¹ in Sengaltheri (Parthasarathy 2001). The lesser tree density and basal area in the study sites than in the southern Western Ghats may be due to lesser rainfall and seasonality that vary and variation within the landscape may be due to high exploitation of trees over a period.

Size class distribution indicates the stability of trees in the forest community (Pandey 2006). The higher abundance of plants in lower size classes and gradual tapering across higher size classes in the present study indicates conformity with other regions in the Western Ghats like Sengaltheri (Parthasarathy 2001). The same was true in relationship

between species richness and stand density where highest species richness was in <20 density category across the sites which indicates uniformity in the pattern and existence of disturbance. There were very less individuals across the areas that had a girth >90 cm probably this is due to earlier selective logging (Gadgil and Chandran 1989).

The species like *Knema attenuata*, *Olea dioica*, *Hopea ponga* and *Aglaia roxburghiana* showed high importance value in study area including southern Sirsi-Honnava forests of the same landscape (Roy et al 2010). These species were also indicated as an important food species for primates in the area (Roy et al 2010). Further, the species with high IVI in different season also were important food species in that season for lion-tailed macaque (Roy et al 2010). This indicate that the total species richness is relatively lesser than in the southern Western Ghats, the existing dominant species have become a major food plants for many of the primates in the site, and also contribute to livelihood (as Non-Timber Forest Products and firewood) of local people. The present database indeed helps in deciding the site-specific tree species to bring required management interventions.

3.2 Resource utilization by Lion-tailed macaques in Sirsi-Honnava forests

Introduction

Tropical forests are the species rich ecosystems of the world of which <5% remain protected (Skorupa 1986; Johns 1992). Worldwide, these forests have been highly exploited historically, mostly by selective logging to supply timber for the needs of development (Gibson et al 2011). About 6 million hectare of forest is exploited for logging annually (Asner et al 2005; Foley et al 2007). Timber extractions have thus been a main source of income to many tropical developing countries of the world (Gibson et al 2011; Putz et al 2012). However, timber-harvesting mechanisms in rainforest have never been sustainable for the long-term (Ashton 1984; Johns 1992). In many forest areas, they have eliminated native representative plant populations completely (Gadgil and Chandran 1989). Additionally, logging leads to changes in forest micro-climate (Johns 1985) and rapid colonization of invasive and heliophilous plant species (Malcolm et al 2000; Gadgil and Chandran 1989). This changes the stand structure and species composition of the forest which may lead to local-extinction or sharp decline of some keystone species (Mills et al 1993). This may also alter the abundance of food species and perhaps the resource available for dependent fauna (Morgan et al 2007). In general, logging affects population, behavior, physiology and health of dependant species (Gibson et al 2011). It is especially so with large mammals because of their low densities and specialized habitat requirements (Kinnaird et al 2003; Leimgruber et al 2003; Raffaelli 2004; Wibisono et al 2011). However, the effect of logging on animal populations and their ecology is highly specific to an area and species.

Primates are considered as *'good indicators to general health of rainforest ecosystems'* (Oates 1986). Since most primates are long-living, their responses to changes are slow and hence studies have to be conducted at biologically relevant time-scales (Chapman et al 2000) for systematic understanding the effects of logging on a species. The immediate effect of logging may however be on food availability (Skorupa 1988; Oates 1996); increased frequency of logging may subsequently affect the primate survival in an area.

Although many primates appear to be flexible for logging to a certain degree or adaptable to new conditions with a certain degree of tolerance, by making alterations to their activity pattern and feeding (MacArthur and Pianka 1966; Charnov 1976), they are more vulnerable if they are arboreal, large bodied, fruit specialists with slow reproductive rates and large home ranges (Johns and Skorupa 1987; Symington 1988a; Peres 1994a; Sorenson and Fedigan 2000; Felton et al 2003).

The effect of logging on a primate species is highly variable in relation to their habit, logging intensity and frequency. As a result, primate communities suffer from decrease in nutritional quality and quantity of food resources (Skorupa 1988; Oates 1996). Logging reduces the old-growth trees which constitute important food species (Velho and Krishnadas 2011). For example, logging created permanent loss of food resources of *Ateles chamek* which could not be compensated by feeding on other species (Johns 1988). Logging also altered the resource intake in *Hylobates lar* and *Presbytis melalophos* by increasing folivory (Johns 1986), and increased insect feeding in *Cercopithecus ascanus* (Stickler 2004). *Pongo abelii* were more sensitive for logging, avoided the logged oil palm patches and preferred forest areas (Campbell-Smith et al 2011), where some of the *Pongo* spp. did not alter diversity and proportion of feeding species in their diet after logging (Russon et al 2009), in contrast to this *Macaca nemistrina*, *Cercopithecus* spp., *Lophocebus albigena*, *Cercocebus agilis* showed preference for foraging in logged areas over intact forest (Remis and Robinson 2012). This indicate adaptability to changing resources vary across different species, understanding of this is indeed crucial to develop action plan and manage the species in the wild.

Lion-tailed macaque is a arboreal, medium-sized, fruit specialist species, with large home ranges, and endemic to rain forests of Western Ghats (Umapathy and Kumar 2000; Singh et al 2002; Kumara and Sinha 2009). They have a narrow range of diet because of feeding on specialized resources (Kumar 1995) for which they need to spend large amounts of time and energy in foraging (Townsend et al 2008). The northernmost population of these macaques that is in Sirsi-Honnava forests, which are one of the largest known populations in the wild (Kumara and Singh 2004a; Santhosh et al 2013). These forests of

Sirsi-Honnavara were historically exploited for resources, largely during colonial and post-colonial times (Gadgil and Chandran 1989). This include shifting cultivation by nomadic population, timber supplies to World War II, timber extraction by forest based industries, land use changes by human colonization, hydro-electric projects during the past at different scale within a region (Gadgil and Chandran 1989). Presently, the dependence of people on forests for subsistence has been very apparent (Santhosh et al 2013), thus the area is characterized by differential human interference across the reserve, as certain areas of the reserve are more populated than others (Kumara et al 2011). Hence, these forests have continuously been utilized at variable degrees at several stages, and resulted in loss of evergreen forests at an alarming rate (Kumara et al 2011). Within a study area the selective logging was patchy, and aiming at certain specific plant species over a period of time (Gadgil and Chandran 1989), making the human interference highly dynamic in the area and unique in plant species composition.

The study by Singh and group (Singh et al 2010; Roy et al 2010; 2011) reported resource availability and utilization by lion-tailed macaque at 'Matnigadde' which is located at southern part of the study site 'Sirsi-Honnavara', where I studied two groups of lion-tailed macaques at northern part of the reserve. Although the duration of the study and total effort for each group vary, I used the data for comprehensive understanding of resource availability and resource use in a single patch of forest. The literature reveals that differential exploitation of forest over a period of time in the study site, thus I hypothesize that selective logging has led to a high degree of heterogeneity in the forest structure and plant species composition. For a comprehensive understanding of resource availability and ecology of lion-tailed macaque across different parts of study site, the findings from three groups of lion-tailed macaques are compared in the present chapter.

The ecological responses of lion-tailed macaque in their activity budget, niche breadth, dietary overlap, dietetic diversity, dietetic evenness and food species selectivity are hypothesized if they are specialized or generalized feeder, given the variation in plant species composition across the area is minimal or very high (Table 3.2.1).

Table 3.2.1 The ecological response of lion-tailed macaques in Sirsi-Honnava forests in relation to the degree of specialization given the degree of variation of plant species across the area

| | <i>High Variation in plant species composition</i> | | <i>Low variation in plant species composition</i> |
|--|--|--------------------------|---|
| | <i>Specialized feeder</i> | <i>Generalist feeder</i> | <i>Specialized/Generalist</i> |
| Activity budget variation between groups | High | Low | Least |
| Niche breadth variation between groups | High | Low | Least |
| Dietary overlap variation between groups | Least | High | Highest |
| Dietetic diversity variation between groups | High | Nil | Nil |
| Dietetic evenness variation between groups | Low | High | Highest |
| Food species selectivity variation between groups | High | Low | Nil |

Methods

I selected two groups of lion-tailed macaque located at Hosthota (14° 20' 18.4" N and 74° 40' 13.4" E) and Chiksuli (14° 21' 28.1" N and 74° 40' 38.3" E), with the group size of 29 and 34 respectively (Table 3.2.2). The study groups were followed for 6.96 ± 2.55 SD days/month for a total of 73794.00 minutes (174 days) for Hosthota group and 7.60 ± 3.97 SD days/month for a total of 30407.00 minutes (76 days) for Chiksuli group. Data could not be collected during July, September of 2009; May, July, August of 2010 and March, April of 2011 for Hosthota and June, July, August, October of 2010 and March 2011 for Chiksuli group due to rainfall and high water levels in streams.

The study groups were followed from dawn (ca. 06:00 h) to dusk (ca. 18:30 h), or until the group is lost and could not be relocated. I used group scan-sampling (Altman 1974) to measure the activity budget by conducting group scans on all visible members for duration

of 5 minutes at every 15 minutes (Altman 1974). Activity recorded was passivity (sleeping or sitting for >5s), travel (any movement between trees or on ground excluding movement on the same tree), feed and forage (ingestion and searching for food, handling different plant/animal parts), social (grooming, play, agonistic interactions) and self-directed (auto-grooming and self play). Plant species resources were categorized into the following twelve categories- mesocarp (ripe fruit), mesocarp (partially ripe/ unripe fruit), seed (ripe fruit), seed (partially ripe/ unripe fruit), flower/ inflorescence, aril (ripe fruit), aril (partially ripe/ unripe fruit), shoots (young), shoots (mature), pith, resin/exudates, leaves (young) and leaves (mature). Stand structure and resource availability in Hosthota and Chiksuli are discussed in Chapter 3.1 and Matnigadde in Roy et al (2010).

Table 3.2.2 Demography of study groups of lion-tailed macaque in Sirsi-Honnava

| | Adult male | Adult female | Sub-adult male | Sub-adult female | Juveniles | Infants | Total |
|--------------------|-------------------|---------------------|-----------------------|-------------------------|------------------|----------------|--------------|
| Hosthota | 2 | 16 | 3 | 0 | 5 | 3 | 29 |
| Chiksuli | 2 | 15 | 2 | 0 | 9 | 6 | 34 |
| Matnigadde* | 2 | 7 | 2 | 2 | 6 | 2 | 21 |

* Roy et al (2011)

Analysis

Data on infants (dependent on adults for food and movement) were excluded from analysis. Food types were classified into 3 types based on their origin i.e. plant, animal and fungi. Percent time of activity was calculated as a proportion of certain activity from overall scans and percent feeding as the proportion of feeding from total feeding scans. Each part of a plant species with its phenophase was considered as a unique resource (Roy et al 2011). We combined partially ripe and unripe fruits and young leaves with young stem for our analysis (Roy et al 2011). The major food items were considered as priority only if it occurred in >1% feeding scans.

The scan data was pooled from November- April as dry season and May- October as wet season. It was compared for different activities and feeding on different food types (plant,

fauna and fungi) between the study groups. Before the comparisons, the data was tested for normality, and appropriate parametric or non-parametric statistics were employed. All the analyses were carried out using SPSS v.16.0 (SPSS, Chicago, USA) using the chi-square tests of goodness-of-fit and G-test of independence (Fashing 2001; Mendiratta et al. 2009; Riley 2008).

Niche breadth

The plant species resources which were eaten in >1% feeding scans for the particular season were listed along with their corresponding feeding scans (raw scores) of Hosthota and Chiksuli groups. Levin's standardized measure of niche breadth (Hurlbert 1978) was calculated separately for each season and groups using

$$B_A = \frac{B - 1}{n - 1}$$

where B_A is Levin's standardized niche breadth, B is Levin's measure of niche breadth and n is the number of resources. Levin's measure of niche breadth was calculated using

$$B = \frac{1}{\sum p_j^2}$$

p_j is the proportion of resource j in the diet of the animal species standardized on the scale of 0 to 1 (Hurlbert 1978). The results of Matnigadde group were tabulated (Roy et al 2011) and compared.

Dietetic diversity and evenness

Dietetic diversity was calculated by listing all the plant species eaten in each of the seasons by both the groups with their corresponding feeding scans of all species for that season using Shannon- Wiener index (Magurran 2004)

$$H' = - \sum_{i=1}^R p_i \ln p_i$$

Where H' is diversity, R is total number of species, p_i is the proportion of species belonging to i species.

Similarly, the evenness in diet was calculated for different seasons for both groups using the corresponding feeding scans of all species for that season using Simpson index (Magurran 2004) using the formula,

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right)$$

Where n is total number of individuals of a species and N is total number of individuals of all species. Diversity and evenness were also similarly calculated for Matnigadde group from (Roy et al 2011).

Food species selectivity

The plant species which were eaten in >1% feeding scans for the particular season were used for calculating the plant species preference for feeding against availability for all 3 groups. The data for species availability was obtained from Importance Value Index values of corresponding plant species for Hosthota and Chiksuli areas (Appendix 3.2.2 and 3.2.3) and for Matnigadde group used from Roy et al 2010. The raw scores of feeding scans of particular species were considered as an index for utilization. It was calculated by using Ivlev's electivity index (Ivlev 1961) for determining the dietary selectivity of lion-tailed macaques against plant species availability, using the formula

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where E is the electivity index, r_i is relative abundance of plant resource i in the feeding and p_i is relative abundance of food species available.

Dietary Overlap

Dyadic comparisons were made for dietary overlap between groups using raw scores for feeding. Schoener Overlap Index (Schoener 1974) was used for measuring the dietary proportional similarity between study groups on a scale of 0 to 1. The index was calculated using

$$C = 1 - 0.5 \sum_i |X_i - Y_i|$$

where X_i is the proportion of plant species i in study group X and Y_i is the proportion of plant species i in study group Y .

Dietary dissimilarity

The Importance Value Indices of the food species of each group from respective sites were tabulated and a distance matrix based on Sørensen dissimilarity measure was computed using R package fossil (v 3.2.2: R Development Core team 2015; Vavrek 2011) and a dendrogram was prepared based on similarity distances.

Results

The percent time spent on major activities that include travel, passivity, social, self-directed behavior and feeding-foraging by each group varied significantly across seasons and overall (Table 3.2.3). Time spent on travel and feeding-foraging was 70-80% where the groups spent less time on passivity, social and self-directed behavior. Irrespective of seasons, overall time spent on each major activities differed significantly between the groups (travel: $G=614.58$, $df=2$, $p<0.00$; passivity: $G=36.47$, $df=2$, $p<0.00$; social: $G=278.73$, $df=2$, $p<0.00$; self: $G=104.93$, $df=2$, $p<0.00$ and feeding-foraging: $G=503.29$, $df=2$, $p<0.00$). However, percent time spent on passivity did not differ between the groups during the dry season ($G=7.21$, $df=2$, $p=0.06$), while other activities showed significant difference between the groups (travel: $G=390.39$, $df=2$, $p<0.00$; social: $G=190.39$, $df=2$, $p<0.00$; self: $G=74.71$,

df=2, $p < 0.00$ and feeding-foraging: $G=374.6$, $df=2$, $p < 0.00$). Where percent time spent on all the activities varied significantly between the groups during the wet season (travel: $G=204.80$, $df=2$, $p < 0.00$; passivity: $G=70.20$, $df=2$, $p < 0.00$; social: $G=124.12$, $df=2$, $p < 0.00$; self: $G=22.40$, $df=2$, $p < 0.00$ and feeding-foraging: $G=140.23$, $df=2$, $p < 0.00$).

Table 3.2.3 Percent time spent on major activities by three study groups in Sirsi-Honnava forests

| | Hosthota | | | Chiksuli | | | Matnigadde* | | |
|----------------------------|------------------------------------|------------------------------------|-----------------------------------|----------------------------------|---------------------------------|---------------------------------|----------------------------------|----------------------------------|----------------------------------|
| | Overall N(%) | Dry N(%) | Wet N(%) | Overall N(%) | Dry N(%) | Wet N(%) | Overall N(%) | Dry N(%) | Wet N(%) |
| Total days of observation | 169 | 119 | 50 | 76 | 58 | 18 | Not available | Not available | Not available |
| Total hours of observation | 1196 | 867 | 329 | 507 | 386 | 121 | Not available | Not available | Not available |
| Total Scans | 20115 | 15990 | 4124 | 7518 | 5033 | 2485 | 4410 | 3053 | 1357 |
| Move | 7059 (35.09) | 5652 (35.35) | 1407 (34.12) | 2905 (38.64) | 1825 (36.26) | 1080 (43.46) | 2767 (62.74) | 1894 (62.04) | 873 (64.33) |
| Rest | 2852 (14.18) | 2174 (13.60) | 678 (16.44) | 856 (11.39) | 636 (12.64) | 220 (8.85) | 642 (14.56) | 450 (14.74) | 192 (14.15) |
| Social | 1308 (6.50) | 908 (5.68) | 400 (9.70) | 432 (5.75) | 276 (5.48) | 156 (6.28) | 45 (1.02) | 24 (0.79) | 21 (1.55) |
| Self | 460 (2.29) | 401 (2.51) | 59 (1.43) | 87 (1.16) | 71 (1.41) | 16 (0.64) | 21 (0.48) | 18 (0.59) | 3 (0.22) |
| Feeding and forage | 8435 (41.93) | 6855 (42.87) | 1580 (38.31) | 3238 (43.07) | 2225 (44.21) | 1013 (40.76) | 935 (21.20) | 667 (21.85) | 268 (19.75) |
| χ^2 | 12459.10 , $df=4$, $p=0.00$ | 10478.94 , $df=4$, $p=0.00$ | 2058.36 , $df=4$, $p=0.00$ | 5684.04, $df=0$, $p=0.00$ | 3676.48 $df=4$, $p=0.00$ | 2073.47 $df=4$, $p=0.00$ | 5731.88, $df=4$, $p=0.00$ | 3883.66, $df=4$, $p=0.00$ | 1853.26, $df=4$, $p=0.00$ |

*Roy et al. 2011

All the three groups of lion-tailed macaques largely fed on plant food resources (84.00 % to 91.35%) than faunals (6.81% to 14.00%) and fungi (0.66% to 5.37%), the pattern which remains same across seasons and overall (Table 3.2.4). The overall percent time spent on feeding on plant food resources and faunals did not differ significantly between the groups (plants: $G= 0.82$, $df =2$, $p=0.82$; faunals: $G=8.51$, $df=2$, $p=0.36$), while consumption of fungi varied significantly ($G= 20.58$, $df=2$, $p=0.00$). Where, percent feeding on all the food types

varied significantly between the groups during the dry season (plants: $G=1104.22$, $df=2$, $p=0.00$, faunals: $G=148.12$, $df=2$, $p=0.00$, fungi: $G=65.57$, $df=2$, $p=0.00$). However, percent feeding on plant food resources ($G=1.02$, $df=2$, $p=0.79$) and faunals ($G=12.30$, $df=2$, $p=0.06$) did not vary between groups in wet season, where feeding on fungi ($G=13.75$, $df=2$, $p=0.06$) differed significantly.

Table 3.2.4 Percent time spent on feeding on major food resources by the study groups

| | Hosthota | | | Chiksuli | | | Matnigadde* | | |
|----------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|---------------------------------|---------------------------------|
| | Overall % (N) | Dry % (N) | Wet % (N) | Overall % (N) | Dry % (N) | Wet % (N) | Overall % (N) | Dry % (N) | Wet % (N) |
| Plants | 87.02 (3159) | 86.81 (2487) | 87.83 (671) | 87.68 (1160) | 86.00 (780) | 91.35 (380) | 84.38 (788) | 85.00 (567) | 83.95 (225) |
| Faunals | 9.89 (359) | 10.71 (307) | 6.81 (52) | 11.34 (150) | 13.34 (121) | 6.97 (29) | 13.35 (125) | 11.99 (80) | 14.17 (38) |
| Fungi | 3.09 (112) | 2.48 (71) | 5.37 (41) | 0.98 (13) | 0.66 (6) | 1.68 (7) | 2.27 (22) | 2.99 (20) | 1.86 (5) |
| χ^2 | 4734.22, $df=2$, $p=0.00$ | 3715.58, $df=2$, $p=0.00$ | 1021.18, $df=2$, $p=0.00$ | 1779.65, $df=2$, $p=0.00$ | 1153.89, $df=2$, $p=0.00$ | 631.76, $df=2$, $p=0.00$ | 1109.02, $df=2$, $p=0.00$ | 809.56, $df=2$, $p=0.00$ | 315.14, $df=2$, $p=0.00$ |

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The lion-tailed macaques in Hosthota fed on different food resources from 73 plant species, where it was 45 in Chiksuli and 24 in Matnigadde (Table 3.2.5, Appendix 3.2.1). The priority food species (>1% feeding scans) in Hosthota, Chiksuli and Matnigadde was 17, 19 and 9 respectively, where it varied seasonally in Chiksuli (dry: 13, wet: 18) and Matnigadde (dry: 10, wet: 17). Among plant species, percent feeding on *Caryota urens* was highest in Hosthota and Chiksuli groups (overall: 16.48%; 21.32%; dry season: 17.52%; 17.31%, wet season: 12.07%; 30.05% respectively, Table 3.2.4). Where *Diospyros crumenata* (overall; 21.90%, dry: 28.60%) and *Aglaia roxburghii* (wet: 20.30%) were the most priority species in Matnigadde group, which were absent in the diet of other two groups, however *Caryota urens* remained as one of the priority species in both the seasons and overall. The second most important species in Hosthota, Chiksuli and Matnigadde was *Pandanus tectorius* (9.07%), *Olea dioica* (8.39%) and *Dryptes venusta* (wet: 14.6%) respectively, however, *Pandanus tectorius* (11.13%), *Calophyllum tomentosum* (9.70%) and *Dryptes venusta* (21.00%) were in the dry season, and *Diospyros sylvetrica* (12.17%), *Olea dioica* (12.74%) and *Garcinia gummi-gutta* (16.40%) were in the wet season respectively. Among all the

priority species some of the species were fed by groups in single site viz. *Chilocarpus atrovirens* (5.02%) and *Ficus microcarpa* (1.79%) were fed by only Hosthota group, *Cassine glauca*, *Chrysophyllum lanceolatum*, *Diospyros pruriens*, *Dipterocarpus indicus*, *Ficus callosa*, *Litsea stocksii* were fed by only Matnigadde group. Different resources from these plant species were eaten by the lion-tailed macaques, which shows that mesocarp (ripe and unripe) is the most consumed resource from many plant species in all the study sites (Table 3.2.6).

Table 3.2.5 Percent time spent on plant species in >1% feeding scans by lion-tailed macaque study groups in the forests of Sirsi-Honnava

a. Overall

| Hosthota | | Chiksuli | | Matnigadde | |
|-------------------------------|-----------|---------------------------------|-----------|------------------------------|-----------|
| Overall | % feeding | Overall | % feeding | Overall | % feeding |
| <i>Caryota urens</i> | 16.48 | <i>Caryota urens</i> | 21.32 | <i>Diospyros crumenata</i> | 21.90 |
| <i>Pandanus tectorius</i> | 9.07 | <i>Olea dioica</i> | 8.39 | <i>Drypetes venusta</i> | 14.60 |
| <i>Chilocarpus atrovirens</i> | 5.02 | <i>Ficus nervosa</i> | 6.80 | <i>Garcinia gummi-gutta</i> | 7.20 |
| <i>Psychotria nigra</i> | 4.88 | <i>Calophyllum tomentosum</i> | 6.65 | <i>Caryota urens</i> | 6.90 |
| <i>Olea dioica</i> | 4.00 | <i>Dimocarpus longan</i> | 5.44 | <i>Syzigium gardneri</i> | 6.00 |
| <i>Calophyllum tomentosum</i> | 3.86 | <i>Pandanus tectorius</i> | 4.99 | <i>Aglaiia roxburghii</i> | 5.10 |
| <i>Artocarpus hirsutus</i> | 3.66 | <i>Macaranga peltata</i> | 3.93 | <i>Persea macarantha</i> | 3.90 |
| <i>Mangifera indica</i> | 3.66 | <i>Mangifera indica</i> | 3.40 | Climber | 2.70 |
| <i>Diospyros sylvetrica</i> | 3.42 | <i>Psychotria nigra</i> | 2.87 | <i>Dipterocarpus indicus</i> | 1.90 |
| <i>Aglaiia roxburghii</i> | 2.37 | <i>Artocarpus heterophyllus</i> | 2.80 | | |
| <i>Calamus pseudotenuis</i> | 2.18 | <i>Artocarpus hirsutus</i> | 2.80 | | |
| <i>Nothopegia racemosa</i> | 1.93 | <i>Aglaiia roxburghii</i> | 1.97 | | |
| <i>Ficus microcarpa</i> | 1.79 | <i>Chrysophyllum roxburghii</i> | 1.81 | | |
| <i>Syzygium hemispermicum</i> | 1.68 | <i>Litsea floribonda</i> | 1.66 | | |
| <i>Flacourtia montana</i> | 1.63 | <i>Garcinia gummi-gutta</i> | 1.44 | | |
| <i>Diospyros candolliana</i> | 1.43 | <i>Nothopegia racemosa</i> | 1.21 | | |
| <i>Ficus infectoria</i> | 1.02 | <i>Callicarpa tomentosa</i> | 1.21 | | |
| | | <i>Holigarna arnottiana</i> | 1.13 | | |
| | | <i>Belsmedia whitii</i> | 1.13 | | |
| | | | | | |

b. Dry season

| Hosthota | % feeding | Chiksuli | % feeding | Dry | % feeding |
|-------------------------------|-----------|---------------------------------|-----------|------------------------------|-----------|
| <i>Caryota urens</i> | 17.52 | <i>Caryota urens</i> | 17.31 | <i>Diospyros crumenata</i> | 28.60 |
| <i>Pandanus tectorius</i> | 11.13 | <i>Calophyllum tomentosum</i> | 9.70 | <i>Drypetes venusta</i> | 21.00 |
| <i>Chilocarpus atrovirens</i> | 6.21 | <i>Ficus nervosa</i> | 9.15 | <i>Caryota urens</i> | 5.70 |
| <i>Psychotria nigra</i> | 4.96 | <i>Dimocarpus longan</i> | 7.94 | <i>Persea macarantha</i> | 5.00 |
| <i>Calophyllum tomentosum</i> | 4.85 | <i>Pandanus tectorius</i> | 7.28 | <i>Holigarna grahmii</i> | 3.60 |
| <i>Olea dioica</i> | 4.82 | <i>Olea dioica</i> | 6.39 | <i>Syzigium gardneri</i> | 3.60 |
| <i>Artocarpus hirsutus</i> | 4.40 | <i>Macaranga peltata</i> | 4.52 | Climber | 2.70 |
| <i>Calamus pseudotenuis</i> | 2.69 | <i>Psychotria nigra</i> | 3.86 | <i>Dipterocarpus indicus</i> | 2.70 |
| <i>Nothopegia racemosa</i> | 2.37 | <i>Artocarpus hirsutus</i> | 3.64 | <i>Garcinia gummi-gutta</i> | 2.40 |
| <i>Ficus microcarpa</i> | 2.16 | <i>Chrysophyllum roxburghii</i> | 2.54 | <i>Knema attenuata</i> | 2.10 |
| <i>Flacourtia montana</i> | 2.06 | <i>Mangifera indica</i> | 2.21 | | |
| <i>Syzygium hemispermicum</i> | 1.85 | <i>Artocarpus heterophyllum</i> | 2.09 | | |
| <i>Mangifera indica</i> | 1.43 | <i>Nothopegia racemosa</i> | 1.76 | | |
| <i>Persea macarantha</i> | 1.22 | | | | |
| <i>Ficus infectoria</i> | 1.12 | | | | |
| <i>Diospyros sylvetrica</i> | 1.08 | | | | |
| <i>Madhuca longifolia</i> | 1.01 | | | | |
| | | | | | |

c. Wet season

| Hosthota | % feeding | Chiksuli | % feeding | Wet | % feeding |
|---------------------------------|-----------|---------------------------------|-----------|------------------------------|-----------|
| <i>Caryota urens</i> | 12.57 | <i>Caryota urens</i> | 30.05 | <i>Aglaia roxburghii</i> | 20.30 |
| <i>Diospyros sylvetrica</i> | 12.17 | <i>Olea dioica</i> | 12.74 | <i>Garcinia gummi-gutta</i> | 16.40 |
| <i>Mangifera indica</i> | 12.04 | <i>Aglaia roxburghii</i> | 6.25 | <i>Syzigium gardneri</i> | 10.20 |
| <i>Aglaia roxburghii</i> | 10.47 | <i>Mangifera indica</i> | 6.01 | <i>Caryota urens</i> | 8.20 |
| <i>Psychotria nigra</i> | 4.58 | <i>Litsea floribonda</i> | 5.05 | Climber | 5.60 |
| <i>Diospyros candoliana</i> | 3.80 | <i>Artocarpus heterophyllum</i> | 4.33 | <i>Knema attenuata</i> | 4.70 |
| <i>Knema attenuata</i> | 3.66 | <i>Holigarna arnottiana</i> | 3.61 | <i>Diospyros crumenata</i> | 2.80 |
| <i>Garcinia gummi-gutta</i> | 3.01 | <i>Belsmedia whitii</i> | 3.61 | <i>Diospyros pruriens</i> | 2.40 |
| <i>Vitex altissema</i> | 2.88 | <i>Garcinia gummi-gutta</i> | 3.13 | <i>Dipterocarpus indicus</i> | 2.30 |
| <i>Holigarna arnottiana</i> | 2.36 | <i>Macaranga peltata</i> | 2.64 | <i>Ficus callosa</i> | 2.00 |
| <i>Artocarpus heterophyllum</i> | 2.09 | <i>Callicarpa tomentosa</i> | 2.40 | <i>Cassine glauca</i> | 1.60 |
| <i>Aparosa lindleyana</i> | 1.70 | <i>Ficus nervosa</i> | 1.68 | <i>Litsea stocksii</i> | 1.60 |
| <i>Diospyros buxifolia</i> | 1.44 | <i>Symplocos racemosa</i> | 1.20 | <i>Mangifera indica</i> | 1.60 |
| <i>Pandanus tectorius</i> | 1.31 | <i>Syzygium cumini</i> | 1.20 | <i>Syzygium cumini</i> | 1.60 |
| <i>Syzygium stocksii</i> | 1.31 | | | <i>Cayratia auriculata</i> | 1.20 |
| <i>Syzygium hemispermicum</i> | 1.05 | | | <i>Macaranga peltata</i> | 1.20 |
| <i>Litsea floribonda</i> | 1.05 | | | <i>Persea macarantha</i> | 1.20 |

Table 3.2.6 Percent time spent on plant species resources in >1% feeding scans by lion-tailed macaque study groups during a. overall; b. dry season; c. wet season in the forests of Sirsi-Honnava

a. Overall

| Hosthota | Resource | % Feeding (N) | Chiksuli | Resource | % Feeding (N) | Matnigadde | Resource | % Feeding |
|-------------------------------|-------------------|---------------|---------------------------------|-------------------|---------------|------------------------------|--------------------|-----------|
| <i>Caryota urens</i> | Mesocarp (unripe) | 11.22 (407) | <i>Caryota urens</i> | Mesocarp (Ripe) | 11.34 (150) | <i>Diospyros crumenata</i> | Mesocarp (unripe) | 12.10 |
| <i>Pandanus tectorius</i> | Shoot (mature) | 8.21 (298) | <i>Caryota urens</i> | Mesocarp (unripe) | 9.90 (131) | <i>Diospyros crumenata</i> | Mesocarp (ripe) | 9.80 |
| <i>Caryota urens</i> | Mesocarp (Ripe) | 5.21 (189) | <i>Olea dioica</i> | Mesocarp (Ripe) | 8.09 (107) | <i>Drypetes venusta</i> | Mesocarp (ripe) | 9.10 |
| <i>Psychotria nigra</i> | Mesocarp (Ripe) | 4.38 (159) | <i>Calophyllum tomentosum</i> | Mesocarp (Ripe) | 6.35 (84) | <i>Garcinia gummi-gutta</i> | Mesocarp (ripe) | 7.20 |
| <i>Chilocarpus atrovirens</i> | Mesocarp (Ripe) | 4.38 (159) | <i>Ficus nervosa</i> | Mesocarp (Ripe) | 5.59 (74) | <i>Caryota urens</i> | Mesocarp (unripe) | 6.90 |
| <i>Mangifera indica</i> | Mesocarp (Ripe) | 3.64 (132) | <i>Dimocarpus longan</i> | Flower | 5.44 (72) | <i>Syzygium gardneri</i> | Whole fruit (ripe) | 6.00 |
| <i>Olea dioica</i> | Mesocarp (Ripe) | 3.25 (118) | <i>Pandanus tectorius</i> | Shoot (mature) | 4.69 (62) | <i>Drypetes venusta</i> | Whole fruit (ripe) | 5.50 |
| <i>Diospyros sylvetrica</i> | Mesocarp (Ripe) | 2.56 (93) | <i>Macaranga peltata</i> | Mesocarp (Ripe) | 2.65 (35) | <i>Aglaia roxburghii</i> | Aril (ripe) | 5.10 |
| <i>Aglaia roxburghii</i> | Mesocarp (Ripe) | 2.18 (79) | <i>Psychotria nigra</i> | Mesocarp (Ripe) | 2.65 (35) | <i>Persea macarantha</i> | Mesocarp (ripe) | 2.70 |
| <i>Calophyllum tomentosum</i> | Leaves (young) | 2.12 (77) | <i>Mangifera indica</i> | Mesocarp (Ripe) | 2.57 (34) | <i>Dipterocarpus indicus</i> | Seed (ripe) | 1.90 |
| <i>Artocarpus hirsutus</i> | Mesocarp (unripe) | 1.98 (72) | <i>Artocarpus heterophyllus</i> | Mesocarp (unripe) | 2.04 (27) | Climber | Whole fruit (ripe) | 1.50 |
| <i>Ficus microcarpa</i> | Mesocarp (Ripe) | 1.76 (64) | <i>Artocarpus hirsutus</i> | Mesocarp (unripe) | 1.97 (26) | <i>Persea macarantha</i> | Flower | 1.20 |
| <i>Artocarpus hirsutus</i> | Mesocarp (Ripe) | 1.68 (61) | <i>Chrysophyllum roxburghii</i> | Mesocarp (Ripe) | 1.59 (21) | Climber | Seed (ripe) | 1.20 |
| <i>Calamus pseudotenuis</i> | Shoot (mature) | 1.60 (58) | <i>Callicarpa tomentosa</i> | Mesocarp (Ripe) | 1.06 (14) | | | |
| <i>Nothopegia racemosa</i> | Resin | 1.52 (55) | <i>Litsea floribonda</i> | Mesocarp (Ripe) | 1.51 (20) | | | |
| <i>Flacourtia montana</i> | Mesocarp (Ripe) | 1.46 (53) | <i>Garcinia gummi-gutta</i> | Mesocarp (Ripe) | 1.44 (19) | | | |
| <i>Syzygium hemispermicum</i> | Mesocarp (Ripe) | 1.27 (46) | <i>Aglaia roxburghii</i> | Mesocarp (Ripe) | 1.36 (18) | | | |
| <i>Ficus infectoria</i> | Mesocarp (Ripe) | 1.02 (37) | <i>Ficus nervosa</i> | Mesocarp (unripe) | 1.21 (16) | | | |
| | | | <i>Macaranga peltata</i> | Mesocarp (Ripe) | 1.21 (16) | | | |
| | | | <i>Belsmedia whitii</i> | Mesocarp (Ripe) | 1.13 (15) | | | |
| | | | | | | | | |

b. Dry season

| Hosthota | Resource | % Feeding (N) | Chiksuli | Resource | % Feeding (N) | Matnigadde | Resource | % Feeding |
|-------------------------------|-------------------|---------------|---------------------------------|-------------------|---------------|------------------------------|--------------------|-----------|
| <i>Caryota urens</i> | Mesocarp (unripe) | 12.98 (372) | <i>Calophyllum tomentosum</i> | Flower | 9.26 (84) | <i>Diospyros crumenata</i> | Mesocarp (unripe) | 15.60 |
| <i>Pandanus tectorius</i> | Leaves (mature) | 10.05 (288) | <i>Caryota urens</i> | Mesocarp (unripe) | 8.82 (80) | <i>Diospyros crumenata</i> | Mesocarp (ripe) | 13.00 |
| <i>Chilocarpus atrovirens</i> | Mesocarp (Ripe) | 5.51 (158) | <i>Caryota urens</i> | Mesocarp (Ripe) | 8.49 (77) | <i>Drypetes venusta</i> | Mesocarp (ripe) | 12.20 |
| <i>Caryota urens</i> | Mesocarp (Ripe) | 4.47 (128) | <i>Dimocarpus longan</i> | Flower | 7.94 (72) | <i>Drypetes venusta</i> | Whole fruit (ripe) | 7.40 |
| <i>Psychotria nigra</i> | Mesocarp (Ripe) | 4.36 (125) | <i>Ficus nervosa</i> | Mesocarp (Ripe) | 7.39 (67) | <i>Caryota urens</i> | Mesocarp (unripe) | 5.70 |
| <i>Olea dioica</i> | Mesocarp (Ripe) | 3.98 (114) | <i>Pandanus tectorius</i> | Leaves (mature) | 6.84 (62) | <i>Persea macarantha</i> | Mesocarp (ripe) | 5.00 |
| <i>Calophyllum tomentosum</i> | Leaves (young) | 2.69 (77) | <i>Olea dioica</i> | Mesocarp (Ripe) | 6.06 (55) | <i>Syzigium gardneri</i> | Whole fruit (ripe) | 3.60 |
| <i>Artocarpus hirsutus</i> | Mesocarp (unripe) | 2.51 (72) | <i>Macaranga peltata</i> | Mesocarp (unripe) | 3.86 (35) | <i>Holigarna grahamii</i> | Mesocarp (ripe) | 3.60 |
| <i>Ficus microcarpa</i> | Mesocarp (Ripe) | 2.13 (61) | <i>Psychotria nigra</i> | Mesocarp (Ripe) | 3.75 (34) | <i>Garcinia gummi-gutta</i> | Mesocarp (ripe) | 2.40 |
| <i>Artocarpus hirsutus</i> | Mesocarp (Ripe) | 1.88 (54) | <i>Artocarpus hirsutus</i> | Mesocarp (unripe) | 2.65 (24) | <i>Knema attenuata</i> | Flower | 2.10 |
| <i>Nothopegia racemosa</i> | Resin | 1.85 (53) | <i>Chrysophyllum roxburghii</i> | Mesocarp (Ripe) | 2.21 (20) | Climber | Seed (ripe) | 1.50 |
| <i>Flacourtia montana</i> | Mesocarp (Ripe) | 1.85 (53) | <i>Ficus nervosa</i> | Mesocarp (unripe) | 1.76 (16) | <i>Dipterocarpus indicus</i> | Seed (ripe) | 1.50 |
| <i>Mangifera indica</i> | Mesocarp (Ripe) | 1.40 (40) | <i>Artocarpus heterophyllus</i> | Mesocarp (unripe) | 1.65 (15) | <i>Drypetes venusta</i> | Mesocarp (unripe) | 1.40 |
| <i>Syzygium hemispermicum</i> | Mesocarp (Ripe) | 1.33 (38) | <i>Mangifera indica</i> | Mesocarp (unripe) | 1.21 (11) | Climber | Whole fruit (ripe) | 1.20 |
| <i>Calophyllum tomentosum</i> | Flower | 1.22 (35) | | | | <i>Dipterocarpus indicus</i> | Seed (unripe) | 1.20 |
| <i>Ficus infectoria</i> | Mesocarp (Ripe) | 1.12 (32) | | | | | | |
| <i>Calamus pseudotenius</i> | Shoot (mature) | 1.05 (30) | | | | | | |
| <i>Madhuca longifolia</i> | Flower | 1.01 (29) | | | | | | |

c. Wet season

| Hosthota | Resource | % Feeding (N) | Chiksuli | Resource | % Feeding (N) | Matnigadde | Resource | % Feeding |
|---------------------------------|-------------------|---------------|---------------------------------|-------------------|---------------|------------------------------|----------------------|-----------|
| <i>Mangifera indica</i> | Mesocarp (Ripe) | 12.04 (92) | <i>Caryota urens</i> | Mesocarp (Ripe) | 19.95 (83) | <i>Garcinia gummi-gutta</i> | Mesocarp (ripe) | 16.40 |
| <i>Diospyros sylvetrica</i> | Mesocarp (Ripe) | 12.04 (92) | <i>Olea dioica</i> | Mesocarp (Ripe) | 12.50 (52) | <i>Aglaia roxburghii</i> | Aril (ripe) | 15.60 |
| <i>Aglaia roxburghii</i> | Mesocarp (Ripe) | 10.34 (78) | <i>Caryota urens</i> | Mesocarp (unripe) | 12.26 (51) | <i>Syzigium gardneri</i> | Whole fruit (ripe) | 10.20 |
| <i>Caryota urens</i> | Mesocarp (Ripe) | 8.38 (64) | <i>Mangifera indica</i> | Mesocarp (Ripe) | 6.01 (25) | <i>Caryota urens</i> | Mesocarp (unripe) | 8.20 |
| <i>Caryota urens</i> | Mesocarp (unripe) | 4.19 (32) | <i>Litsea floribonda</i> | Mesocarp (Ripe) | 4.81 (20) | <i>Knema attenuata</i> | Flower | 3.50 |
| <i>Knema attenuata</i> | Mesocarp (Ripe) | 3.66 (28) | <i>Aglaia roxburghii</i> | Mesocarp (Ripe) | 4.33 (18) | <i>Aglaia roxburghii</i> | Mesocarp (unripe) | 3.50 |
| <i>Psychotria nigra</i> | Mesocarp (Ripe) | 3.14 (24) | <i>Belsmedia whitii</i> | Mesocarp (Ripe) | 3.61 (15) | <i>Dipterocarpus indicus</i> | Seed (ripe) | 2.30 |
| <i>Garcinia gummi-gutta</i> | Mesocarp (Ripe) | 3.01 (23) | <i>Garcinia gummi-gutta</i> | Mesocarp (Ripe) | 3.13 (13) | Climber | Whole fruit (ripe) | 2.00 |
| <i>Vitex altissima</i> | Mesocarp (Ripe) | 2.88 (22) | <i>Artocarpus heterophyllus</i> | Mesocarp (unripe) | 2.88 (12) | <i>Ficus callosa</i> | Whole fruit (ripe) | 2.00 |
| <i>Diospyros candoliana</i> | Mesocarp (unripe) | 2.75 (21) | <i>Macaranga peltata</i> | Mesocarp (Ripe) | 2.64 (11) | Climber | Whole fruit (unripe) | 2.00 |
| <i>Aparosa lindleyana</i> | Mesocarp (Ripe) | 1.70 (13) | <i>Holigarna arnottiana</i> | Mesocarp (unripe) | 2.40 (10) | <i>Diospyros crumenata</i> | Mesocarp (unripe) | 1.60 |
| <i>Artocarpus heterophyllus</i> | Mesocarp (Ripe) | 1.44 (11) | <i>Callicarpa tomentosa</i> | Mesocarp (Ripe) | 2.40 (10) | <i>Cassine glauca</i> | Seed (ripe) | 1.60 |
| <i>Holigarna arnottiana</i> | Mesocarp (unripe) | 1.44 (11) | <i>Aglaia roxburghii</i> | Mesocarp (unripe) | 1.92 (8) | Climber | Mesocarp (unripe) | 1.60 |
| <i>Psychotria nigra</i> | Mesocarp (unripe) | 1.44 (11) | <i>Ficus nervosa</i> | Mesocarp (Ripe) | 1.68 (7) | <i>Mangifera indica</i> | Mesocarp (unripe) | 1.60 |
| <i>Syzigium stocksii</i> | Mesocarp (Ripe) | 1.31 (10) | <i>Artocarpus heterophyllus</i> | Mesocarp (Ripe) | 1.44 (6) | <i>Litsea stocksii</i> | Whole fruit (unripe) | 1.60 |
| <i>Pandanus tectorius</i> | Leaves (mature) | 1.18 (9) | <i>Syzigium cumini</i> | Mesocarp (Ripe) | 1.20 (5) | <i>Syzigium cumini</i> | Mesocarp (ripe) | 1.60 |
| <i>Diospyros candoliana</i> | Mesocarp (Ripe) | 1.05 (8) | <i>Holigarna arnottiana</i> | Mesocarp (Ripe) | 1.20 (5) | <i>Diospyros crumenata</i> | Mesocarp (unripe) | 1.20 |
| <i>Syzigium hemispermicum</i> | Mesocarp (Ripe) | 1.05 (8) | <i>Symplocos racemosa</i> | Mesocarp (Ripe) | 1.20 (5) | <i>Persea macarantha</i> | Flower | 1.20 |
| <i>Litsea floribonda</i> | Mesocarp (Ripe) | 1.05 (8) | | | | | | |

| Hosthota | Resource | % Feeding (N) | Chiksuli | Resource | % Feeding (N) | Matnigadde | Resource | % Feeding |
|----------|----------|---------------|----------|----------|---------------|----------------------------|--------------------|-----------|
| | | | | | | <i>Diospyros pruriens</i> | Mesocarp (unripe) | 1.20 |
| | | | | | | <i>Diospyros pruriens</i> | Mesocarp (unripe) | 1.20 |
| | | | | | | <i>Knema attenuata</i> | Aril (ripe) | 1.20 |
| | | | | | | <i>Macaranga peltata</i> | Whole fruit (ripe) | 1.20 |
| | | | | | | <i>Aglaia roxburghii</i> | Aril (unripe) | 1.20 |
| | | | | | | <i>Cayratia auriculata</i> | Mesocarp (ripe) | 1.20 |

The niche breadth of Hosthota group remained almost same across seasons (overall: 0.61; dry: 0.51; wet: 0.50), while Chiksuli group (overall: 0.57; dry: 0.74; wet: 0.45) and Matnigadde group (overall: 0.68; dry: 0.58; wet: 0.41) showed variation between seasons (Table 3.2.7). Overall niche breadth of Matnigadde group (0.68) was relatively higher than the Hosthota (0.61) and Chiksuli groups (0.57). While in dry season, Chiksuli group (0.74) showed higher niche breadth than Matnigadde (0.51) and Hosthota groups (0.51). Niche breadth during the wet season remained in close range with Hosthota group (0.50), Chiksuli group (0.45) and Matnigadde group (0.41). The food species diversity in the diet of lion-tailed macaque remained high in the Hosthota followed by Chiksuli and Matnigadde groups in both the seasons and overall. The food species in the diet of lion-tailed macaque in Matnigadde was more even during both the seasons and overall followed by Chiksuli and Hosthota groups.

Table 3.2.7 Number of feeding scans, species and resources eaten; Niche breadth, Shannon Wiener Index and Simpson Index values of lion-tailed macaque study groups in the forests of Sirsi-Honnava

| | Overall | | | Dry | | | Wet | | |
|---------------------------|----------|----------|------------|----------|----------|------------|----------|----------|------------|
| | Hosthota | Chiksuli | Matnigadde | Hosthota | Chiksuli | Matnigadde | Hosthota | Chiksuli | Matnigadde |
| Number of feeding scans | 3629 | 1323 | 935 | 2865 | 907 | 667 | 764 | 416 | 268 |
| No of species eaten >1% | 17 | 19 | 9 | 17 | 13 | 10 | 17 | 14 | 17 |
| No of resources eaten >1% | 18 | 20 | 12 | 18 | 14 | 15 | 19 | 18 | 24 |
| Niche Breadth | 0.61 | 0.57 | 0.68 | 0.51 | 0.74 | 0.58 | 0.50 | 0.45 | 0.41 |
| Shannon Wiener Index | 1.43 | 1.24 | 0.87 | 1.36 | 1.17 | 0.79 | 1.26 | 1.07 | 0.92 |
| Simpson Index (D) | 0.07 | 0.10 | 0.17 | 0.08 | 0.09 | 0.23 | 0.08 | 0.15 | 0.09 |

Note: Matnigadde: Roy et al (2011)

Ivlev electivity index indicates that the *Caryota urens* was the highly preferred plant species by all the groups (both seasons and overall), where *Mangifera indica* and *Calophyllum tomentosum* were preferred by Hosthota and Chiksuli groups. The other preferred plant species by Hosthota group include *Ficus infectoria*, where *Artocarpus heterophyllus* and *Ficus nervosa* were by Chiksuli group. Matnigadde group highly preferred *Diospyros crumenata*, *Drypetes venusta* and *Dipterocarpus indicus* and *Persea macarantha* among the other species (Table 3.2.8).

Table 3.2.8 Highly preferred species and their Ivlev values from >1% feeding scans of lion-tailed macaque study groups during a. overall; b. dry season; c. wet season in the Sirsi-Honnava forests

a. Overall

| Hosthota | Ivlev index | Chiksuli | Ivlev index | Matnigadde | Ivlev Index |
|-------------------------------|-------------|---------------------------------|-------------|------------------------------|-------------|
| <i>Ficus infectoria</i> | +1.00 | <i>Artocarpus heterophyllus</i> | +1.00 | <i>Drypetes venusta</i> | +0.69 |
| <i>Caryota urens</i> | +0.85 | <i>Caryota urens</i> | +0.91 | <i>Diospyros crumenata</i> | +0.66 |
| <i>Calophyllum tomentosum</i> | +0.44 | <i>Ficus nervosa</i> | +0.55 | <i>Caryota urens</i> | +0.28 |
| <i>Ficus microcarpa</i> | +0.35 | <i>Calophyllum tomentosum</i> | +0.50 | <i>Persea macarantha</i> | +0.23 |
| <i>Mangifera indica</i> | +0.27 | <i>Chrysophyllum roxburghii</i> | +0.34 | <i>Garcinia gummi-gutta</i> | +0.13 |
| <i>Artocarpus hirsutus</i> | +0.19 | <i>Mangifera indica</i> | +0.31 | <i>Dipterocarpus indicus</i> | +0.08 |
| <i>Syzizium hemispermicum</i> | +0.10 | <i>Artocarpus hirsutus</i> | +0.21 | <i>Aglaiia roxburghii</i> | -0.35 |
| <i>Diospyros candolliana</i> | -0.14 | <i>Macaranga peltata</i> | +0.21 | <i>Syzizium gardneri</i> | -0.38 |
| <i>Nothopegia racemosa</i> | -0.20 | <i>Olea dioica</i> | -0.21 | <i>Holigarna grahmii</i> | -0.53 |
| <i>Flacourtia montana</i> | -0.29 | <i>Dimocarpus longan</i> | -0.21 | <i>Knema attenuata</i> | -0.74 |
| <i>Aglaiia roxburghii</i> | -0.32 | <i>Callicarpa tomentosa</i> | -0.31 | | |
| <i>Olea dioica</i> | -0.40 | <i>Litsea floribonda</i> | -0.52 | | |

| Hosthota | Ivlev index | Chiksuli | Ivlev index | Matnigadde | Ivlev Index |
|-----------------------------|-------------|-----------------------------|-------------|------------|-------------|
| <i>Diospyros sylvetrica</i> | -0.64 | <i>Nothopegia racemosa</i> | -0.54 | | |
| | | <i>Belsmedia whitii</i> | -0.54 | | |
| | | <i>Garcinia gummi-gutta</i> | -0.62 | | |
| | | <i>Aglaia roxburghiana</i> | -0.68 | | |
| | | <i>Holigarna arnottiana</i> | -0.75 | | |

b. Dry season

| Hosthota | Ivlev index | Chiksuli | Ivlev index | Matnigadde | Ivlev Index |
|-------------------------------|-------------|---------------------------------|-------------|------------------------------|-------------|
| <i>Ficus infectoria</i> | +1.00 | <i>Artocarpus heterophyllus</i> | +1.00 | <i>Drypetes venusta</i> | +0.72 |
| <i>Caryota urens</i> | +0.85 | <i>Caryota urens</i> | +0.81 | <i>Diospyros crumenata</i> | +0.68 |
| <i>Calophyllum tomentosum</i> | +0.51 | <i>Ficus nervosa</i> | +0.45 | <i>Persea macarantha</i> | +0.25 |
| <i>Ficus microcarpa</i> | +0.42 | <i>Calophyllum tomentosum</i> | +0.42 | <i>Dipterocarpus indicus</i> | +0.15 |
| <i>Artocarpus hirsutus</i> | +0.24 | <i>Chrysophyllum roxburghii</i> | +0.24 | <i>Caryota urens</i> | +0.08 |
| <i>Syzizium hemispermicum</i> | +0.12 | <i>Artocarpus hirsutus</i> | +0.04 | <i>Garcinia gummi-gutta</i> | -0.48 |
| <i>Madhuca longifolia</i> | -0.10 | <i>Macaranga peltata</i> | -0.01 | <i>Holigarna grahmii</i> | -0.50 |
| <i>Nothopegia racemosa</i> | -0.12 | <i>Mangifera indica</i> | -0.19 | <i>Syzizium gardneri</i> | -0.64 |
| <i>Flacourtia montana</i> | -0.20 | <i>Dimocarpus longan</i> | -0.31 | <i>Knema attenuata</i> | -0.83 |
| <i>Mangifera indica</i> | -0.21 | <i>Olea dioica</i> | -0.56 | | |
| <i>Persea macarantha</i> | -0.26 | <i>Nothopegia racemosa</i> | -0.61 | | |
| <i>Olea dioica</i> | -0.34 | | | | |
| <i>Diospyros sylvetrica</i> | -0.88 | | | | |

c. Wet season

| Hosthota | Ivlev index | Chiksuli | Ivlev index | Matnigadde | Ivlev Index |
|---------------------------------|-------------|---------------------------------|-------------|------------------------------|-------------|
| <i>Caryota urens</i> | +0.82 | <i>Artocarpus heterophyllus</i> | +1.00 | <i>Garcinia gummi-gutta</i> | +0.48 |
| <i>Mangifera indica</i> | +0.72 | <i>Caryota urens</i> | +0.91 | <i>Cayratia auriculata</i> | +1.00 |
| <i>Aglaia roxburghiana</i> | +0.43 | <i>Mangifera indica</i> | +0.41 | <i>Syzizium cumini</i> | +0.51 |
| <i>Artocarpus heterophyllus</i> | +0.40 | <i>Diospyros candolliana</i> | -0.08 | <i>Caryota urens</i> | +0.34 |
| <i>Diospyros candolliana</i> | +0.37 | <i>Diospyros buxifolia</i> | -0.15 | <i>Diospyros pruriens</i> | +0.23 |
| <i>Syzizium stocksii</i> | +0.25 | <i>Aparosa lindleyana</i> | -0.15 | <i>Aglaia roxburghii</i> | +0.17 |
| <i>Vitex altissemma</i> | +0.03 | <i>Vitex altissemma</i> | -0.17 | <i>Dipterocarpus indicus</i> | +0.16 |
| <i>Diospyros sylvetrica</i> | -0.08 | <i>Syzizium stocksii</i> | -0.19 | <i>Mangifera indica</i> | +0.01 |
| <i>Syzizium hemispermicum</i> | -0.09 | <i>Diospyros sylvetrica</i> | -0.20 | <i>Ficus callosa</i> | -0.05 |
| <i>Litsea floribonda</i> | -0.30 | <i>Syzizium hemispermicum</i> | -0.23 | <i>Syzizium gardneri</i> | -0.14 |
| <i>Aparosa lindleyana</i> | -0.31 | <i>Aglaia roxburghiana</i> | -0.39 | <i>Litsea stocksii</i> | -0.17 |
| <i>Garcinia gummi-gutta</i> | -0.33 | <i>Litsea floribonda</i> | -0.44 | <i>Diospyros crumenata</i> | -0.27 |
| <i>Diospyros buxifolia</i> | -0.45 | <i>Knema attenuata</i> | -0.51 | <i>Persea macarantha</i> | -0.35 |
| <i>Holigarna arnottiana</i> | -0.62 | <i>Holigarna arnottiana</i> | -0.61 | <i>Cassine glauca</i> | -0.41 |
| <i>Knema attenuata</i> | -0.65 | <i>Garcinia gummi-gutta</i> | -0.44 | <i>Macaranga peltata</i> | -0.42 |
| | | | | <i>Knema attenuata</i> | -0.61 |

The overall dietary overlap between Hosthota-Chiksuli groups was higher (0.63) than Chiksuli-Matnigadde groups (0.13) and Hosthota-Matnigadde groups (0.13). The dietary overlap during the dry season between Chiksuli-Matnigadde groups (0.00) and Hosthota-Matnigadde groups (0.09) was lesser than in Hosthota-Chiksuli groups (0.41). During the wet season, the dietary overlap between the study groups remained in the range of 0.41-0.49 (Table 3.2.9).

Table 3.2.9 Schoener's Overlap index values of diet of lion-tailed macaque study groups in the forests of Sirsi-Honnavaara

| | Schoener's Overlap Index C | | |
|-----------------------------|-------------------------------|------|------|
| | Overall | Dry | Wet |
| Hosthota- Chiksuli | 0.63 | 0.41 | 0.49 |
| Chiksuli-Matnigadde | 0.13 | 0.00 | 0.41 |
| Hosthota- Matnigadde | 0.13 | 0.09 | 0.41 |

The dissimilarity between Hosthota-Chiksuli was least (0.03) as compared to Hosthota - Matnigadde (0.24) and Chiksuli-Matnigadde (0.23; Fig 3.2.1; Appendix 3.2.2. and 3.2.3).

Discussion

The degree of dietary specialization of lion-tailed macaques in Sirsi-Honnavaara was explored. Although, the pattern of time activity remained same between the groups, Matnigadde group spent more time on travel than on feeding. Plant origin food, mesocarp in particular is the major part of the lion-tailed macaque diet in all the study groups. Chiksuli group ate fewer fungi than other two groups, however, percent feeding on all the food type varied between the groups in dry season, where only feeding on fungi by Hosthota was more than other groups in wet season. Although niche breadth varied narrowly in both seasons, it was overall higher in Matnigadde, where Chiksuli during dry

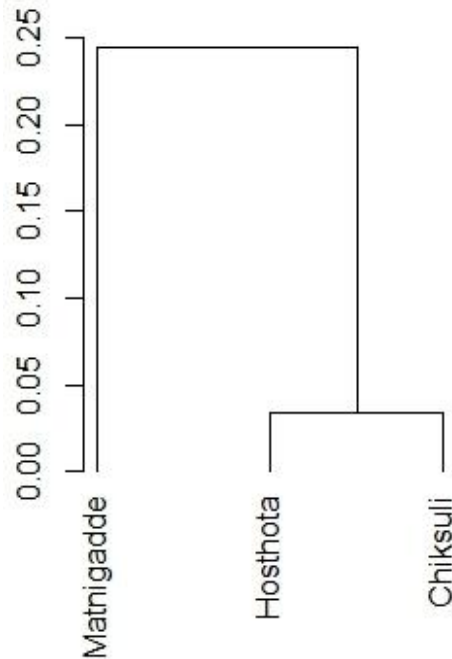


Fig 3.2.1 Dendrogram of Sørensen dissimilarity measure of food species composition of lion-tailed macaque groups from the respective study sites

and Hosthota during wet season. Hosthota group showed more species diversity and less evenness in the diet. *Caryota urens* was the most fed and priority species for all the groups, where *Diospyros crumenata* and *Dryptes venusta* were highly fed and priority species for Matnigadde group. The dietary overlap between Hosthota and Chiksuli group was higher than other combinations.

The plant species composition changes across latitudes in Western Ghats (Pascal 1988). Thus, the dependent fauna naturally depends on the local food species of the area, however, if some food species are widely distributed such species will be most preferred by animals e.g. *Cullinea exharillata* distributed south of Brahmagiri forests in Karnataka to southern tip of the Ghats, further about 70% of the total population of lion-tailed macaque inhabit in the same forests and their most preferred and fed species is same (Kumar 1987; Kurup and Kumar 1993; Singh et al 2000; Sushma and Singh 2006; Joseph and Ramachandran 1996). However, north of Brahmagiri, in the absence of *Cullinea exharillata*,

the preferred species by lion-tailed macaque was expected to be different, to be according to the local species composition. The northern most population of lion-tailed macaque inhabit forests of Sirsi-Honnava in the central Western Ghats is also one of the largest known population in the wild, where the habitat has witnessed variation in species composition by removal of timber species, selective retention of fruiting trees and non-timber forest products. This has alleviated the dynamism and high variation in vegetation composition and stand structure in Sirsi-Honnava. As I hypothesized, food species composition varied highly between northern (Hosthota and Chiksuli) and southern sites (Matnigadde), and accordingly the findings show that the monkeys exhibit variability in activity pattern and species preference in feeding.

The difference in time spent on travel and feeding is apparent between Matnigadde and Hosthota-Chiksuli groups. Matnigadde showed relatively lower food species diversity in their diet (0.87) and higher evenness (0.17), thus they travelled more (62.74) and spent less time on feeding-foraging (21.20) than Hosthota and Chiksuli groups. Conversely, Hosthota and Chiksuli showed relatively higher food species diversity (1.43; 1.24) and lower evenness (0.07; 0.10) hence travelled less and spent more time on feeding-foraging from several food resources and plant species. Further, the time spent on travel by Matnigadde group is much higher than in other sites e.g. 15.00% in Anakunthi-Varagaliar (Kurup and Kumar 1993), 34.00% in Puthuthotam estate (Menon and Poirier 1996), 43.60% in Andiparai (Singh et al 2000). Since the other indices are not available from these sites, conclusion for the differences could not be attributed to these parameters. However, the difference in the time spent on feeding and travel between the groups is indeed due to variation in the food species composition, availability and distribution escalated by logging. Different species of primates have shown differential response to logging in their time activity e.g. *Pongo abelli* showed higher travel and decreased passivity in logged area (Hardus et al 2012); *Cercopithecus ascanius* showed less feeding and increased resting and movement in logged area (Strickler 2004) and *Trachypithecus leucocephalus* showed increased feeding and decreased play in logged habitat (Li and Rogers 2004).

Few plant species like *Diospyros crumenata* and *Dryptes venusta* formed major proportion of diet in Matnigadde but were absent in Hosthota and Chiksuli sites. While *Chilocarpus atrovirens*, *Diospyros sylvatica*, *Psychotria* spp., *Pandanus* sp. and *Calamus* spp. was major food species in the northern groups, it was not recorded in Matnigadde. Consumption of *Garcinia gummi-gutta* during the wet season in Matnigadde (16.40%) was higher than Hosthota (3.01%) and Chiksuli (3.13%) while its IVI did not vary across sites. It is one of the major Non-timber Forest Product in the area. High competition exists for its collection due to their high economic dependence during the wet season (Rai 2003). The human population around Hosthota and Chiksuli sites is higher than in Matnigadde and thus, their collection between sites may be variable. The high variation in *Garcinia gummi-gutta* consumption between northern and southern sites probably due to relative difference in harvest of fruits by local people. Thus, the difference in consumption of *Garcinia gummi-gutta*, *Diospyros crumenata*, *Dryptes venusta*, *Chilocarpus atrovirens* and *Diospyros sylvatica* are due to availability in particular sites.

Some of the widely used species like are *Cullinea exharillata* are absent in the area and *Artocarpus hirsutus*, *Artocarpus heterophyllus*, *Ficus* spp. are very low in densities. The variations of these species due to natural and anthropogenic interference have certainly affected the food diet composition of the monkeys in the region. *Caryota urens* was the most widely eaten species among the study groups consumed throughout the year. While, it was a priority food in both seasons in northern groups, it ranked fourth for Matnigadde group although the availability of the species was relatively higher. Although, the fruits are available throughout the year, it may not provide complete nutritional requirement for the monkeys. Thus, Hosthota and Chiksuli groups might have been compelled to feed on *Caryota urens* in the absence of other preferred food species. Thus, the relative difference in feeding of *Caryota urens* may be due to lower food profitability than availability. These findings are similar to differential use of *Acacia collinsii* fruits by *Cebus capucinus* (Chapman and Fedigan 1990) and *Rothmannia decaryi* fruits by *Propithecus verreauxi* (Richard 1977) irrespective of their higher abundance due to food profitability.

Table 3.2.10 Stand density status of historically extracted species, recent timber species and present NTFP species with their current status in Sirsi-Honnava forests as compared with Gadgil and Chandran (1989)

| Name of the species | Density(Trees/ha) | |
|---|----------------------------|----------------|
| | Gadgil and Chandran (1989) | Present status |
| Stand density decreased | | |
| <i>Artocarpus lakoocha</i> * | 2.00 | 0.00 |
| <i>Calophyllum polyanthum</i> ** | 18.00 | 0.00 |
| <i>Caryota urens</i> ** | 4.00 | 0.72 |
| <i>Garcinia indica</i> * | 1.00 | 0.00 |
| <i>Garcinia morella</i> * | 49.00 | 20.96 |
| <i>Myristica dactyloides</i> * | 11.00 | 2.17 |
| <i>Myristica malabarica</i> * | 9.00 | 1.69 |
| <i>Vitex altissema</i> ** | 13.00 | 4.82 |
| <i>Canerium strictum</i> * | 1.00 | 0.00 |
| <i>Ficus nervosa</i> " | 1.00 | 0.00 |
| Stand density increased | | |
| <i>Aparosa lindelana</i> ^ | 0.00 | 6.27 |
| <i>Careya arborea</i> ~ | 0.00 | 0.72 |
| <i>Cassine glauca</i> ~ | 1.00 | 2.89 |
| <i>Diospyros angustifolia</i> ^ | 0.00 | 1.45 |
| <i>Diospyros buxifolia</i> ^ | 0.00 | 7.71 |
| <i>Diospyros montana</i> ^ | 0.00 | 0.72 |
| <i>Garcinia gummi-gutta</i> * ^^ | 1.00 | 14.22 |
| <i>Holigarna arnottiana</i> ^ | 4.00 | 26.75 |
| <i>Ixora brachiata</i> ^ | 1.00 | 9.16 |
| <i>Lageostromia microcarpa</i> ** ~ | 0.00 | 1.20 |
| <i>Macaranga peltata</i> ^ | 1.00 | 2.17 |
| <i>Pterospermum reticulatum</i> ~ | 0.00 | 6.02 |
| Stand density unaltered | | |
| <i>Artocarpus heterophyllus</i> ** " | 0.00 | 0.00 |
| <i>Callophyllum apetalum</i> ** " | 0.00 | 0.00 |
| <i>Dipterocarpus indicus</i> " | 0.00 | 0.00 |
| <i>Ficus asperima</i> " | 0.00 | 0.00 |
| <i>Ficus microcarpa</i> " | 0.00 | 0.00 |
| *NTFP; ^^ Selective retention ; ^Heliophilous evergreens; ~Deciduous species; " Species exploited beyond recovery; **Timber | | |

Gadgil and Chandran (1989) report the stand densities of plant species logged within few hundred meters around Hosthota and Chiksuli sites. Comparing the findings of present study, plant densities of some important food species logged for soft-wood timber in the past show high declines. For e.g. *Artocarpus heterophyllus*, *Ficus* spp., *Dipterocarpus indicus* and *Callophylum* spp. were exploited beyond recovery (Table 3.2.10); *Myristica* spp., *Canerium strictum* and *Vitex altissemia* were probably depleted due to logging and over harvesting by people. However, higher stand densities were recorded for opportunistic heliophilous evergreen species like *Aparosa lindleyana*, *Diospyros* spp., *Holigarna arnottiana*, and *Macaranga peltata*; deciduous species like *Lagerstroemia microcarpa* and *Pterospermum reticulatum*. These factors are major drivers for heterogeneity in resource availability for the lion-tailed macaque in Sirsi-Honnava. The impacts of such depletion on overall ecology of forest, and for dependent species in particular is however alarming.

Lion-tailed macaques being habitat specialist and selective feeder have shown a certain degree of dietary flexibility and adaptation to the local food resources in Sirsi-Honnava. However, a continued change on long term may affect their population size, age structure and demography (Umapathy and Kumar 2000). In the background of evergreen forests of the area reducing at a rapid rate (Kumara et al 2011), continued pressure may lead to fragmentation of the habitat and decline of lion-tailed macaque population. Management policies prioritizing habitat restoration may be immediately required along with measures for halting habitat fragmentation. The present study however provides site specific plant species restoration for restoring degraded areas to near-natural forests.

3.3 Ranging behavior and resource use by Lion-tailed macaques

Introduction

An understanding of the ecological requirements of a species and its behavioural adaptations to ecological changes is essential to understand its ability to adapt to such changes (Chapman and Rothman 2009; Sinha 2005; Strier 2008) and to design effective conservation strategies (Twinomugisha and Chapman 2007). Animals typically move within an established range to harvest food from the habitat and tend to move in ways that maximizes their nutrient uptake or minimizes energy used (Pyke 1984; Rode et al 2006). Ecological factors including seasonal changes, rainfall, food availability, food distribution, inter-group encounters and degree of terrestriality affect daily path length (DPL) and home range use in primates. Anthropogenic forces such as habitat alteration, hunting or provisioning may also influence movement patterns and home range use (Sinha and Mukhopadhyay 2013).

The effects of season on primate movement vary with different species (Chapman 1988; Fleury and Gautier-Hion 1999; Hoffman and O’Riain 2011; Porter et al 2007; Volempeno et al 2011). In *Rhinopithecus bieti*, it varies at different sites (Grueter et al 2008; Kirkpatrick 1998; Xiang 2005). Home range decreased in summer in *Colobus satanas* (Fleury and Gautier-Hion 1999), *Cebus capucinus* (Chapman 1988) and *Papio ursinus* (Hoffman and O’Riain 2011). Finally, seasonal variation in rainfall does not influence movement and home range use in some species (Baoping et al 2009; Grueter et al 2008; Riley 2008).

An early compilation of data across species showed increased DPL and home range use with increased food availability (Harvey and Clutton-Brock 1981). Similar findings have been reported for individual species since. For example, DPL increased with food availability in *Propithecus diadema* (Irwin 2007), *Gorilla gorilla* (Doran-Sheehy et al 2004), *Atelus belzebuth* (Suarez 2006) and *Papio hamadryas* (Swedell 2002). Home range use increased with food availability in *Pygathrix roxellena* (Li 2001), *Rhinopithecus bieti* (Li and Zhao 2005), *Nasalis larvatus* (Matsuda et al 2009) and *Atelus belzebuth* (Suarez 2006).

Inter-group encounters may influence DPL and home range use because the animals may avoid encounters with conspecifics by altering the movement patterns in its home range. For example, DPL increased with inter-group encounters in *Gorilla gorilla* (Watts 2000).

Terrestriality may influence DPL and home range use because terrestrial animals may move horizontally more than vertically in the habitat. The effect of terrestriality on home range use is not well studied in primates, but DPL is positively influenced by the degree of terrestriality in *M. tonkeana* (Riley 2008). In addition to altering the availability, amount and distribution patterns of food resources, anthropogenic habitat modifications often simulate 'resource-scarce' ecological conditions (Struhsaker 1997). This requires the affected species to adopt appropriate strategies to cope with the changing ecological regimes. Selective logging negatively influences primate movement (Johns 1986). There is a negative influence of logging on home range use. For example, *Hylobates lar*, *Presbytis melalophos*, *Atelus paniscus* and *Lagothrix lagotricha* show decreased movement and habitat use in logged forests, perhaps as a mechanism to conserve energy in a resource-poor habitat (Johns 1986; Johns and Skorupa, 1987).

Macaques are some of the most ecologically adaptable and evolutionarily successful primates, occupying a variety of habitats, ranging from broad-leaved rainforests through dry scrub jungles to human habitations (Fooden 1982; Richard et al 1989; Thierry et al 2004). However, some macaque species are more ecologically restricted. For example, the lion-tailed macaque (*M. silenus*) is endemic to the evergreen forests of the Western Ghats mountains of western India. Lion-tailed macaques live in social groups with a mean group size of 16-33 individuals depending on the population (Kumara and Singh 2004a; Kumara et al 2011, 2014; Ramachandran and Joseph 2001; Singh et al 2002). The forests of Sirsi-Honnava in the central Western Ghats harbour the largest viable population of lion-tailed macaques (Kumara and Singh 2004a; Kumara and Sinha 2009; Santhosh et al 2013). The area receives a high amount of rainfall, mostly from the south west monsoon. These forests sustain a high human density and concomitant agriculture, resulting in a gradual conversion of evergreen forests to degraded forests (Kumara et al 2011), and have been

exposed to severe selective logging in the past, leading to an uneven distribution of many plant species (Gadgil and Chandran 1989).

The relationship between daily movement patterns and home range use and seasonality, rainfall, availability of fruiting trees, food plant species richness, terrestriality, and rates of inter-group encounters in lion-tailed macaques were examined. The predictions were that the DPL and home range use would be higher during dry season than in wet season because of high degree of selective feeding during periods of high diversity of resources (Kumar 1987). Rainfall and intensity of inter-group encounters were expected to have negative influence on DPL because rainfall may restrict the movement of the monkeys in the canopy, and inter-group encounters may alter the movement of the monkeys to be restricted to core area of their home range due to competition. DPL would increase with higher fruit availability because although lion-tailed macaques can adapt to feed on novel food resources (Singh et al 2002), as they are specialized feeders (Kumar 1987) and highly selective in harvesting fruits when in plenty (Krishnadas et al 2011). As overexploitation of the forest has created high habitat heterogeneity and lowered canopy contiguity (Kumara et al 2011), increased use of lower strata and the ground, and a decrease in DPL in comparison to un-logged forests were predicted. Tree density was used as an indicator of canopy continuity and the density of fruit trees as an indicator of resource availability. Both overall tree density and fruit tree density were predicted to be positively related to habitat use because lion-tailed macaques move through the canopy to optimize foraging on fruiting trees in their home range. However, as fruits are an important food resource, and fruit trees have an uneven distribution due to selective logging in the past, fruit tree density was predicted to positively influence over overall tree density.

Methods

Study site and group

The details of the study area are given in Chapter 1. Mean annual rainfall in the study area was $6391.40 \pm \text{SD } 485.10$ mm (www.imd.gov.in), distributed principally across the wet season, from June to November (Fig. 3.3.1). One lion-tailed macaque group (Hosthota group) located between $14^{\circ}20'18.4''$ N and $74^{\circ}40'13.4''$ E was selected for the study. I did

not collect data during July and September of 2009; July, August, October of 2010 and March 2011 due to high rainfall and high water levels in streams. Details of Hosthota group parameters are given in the previous chapter.

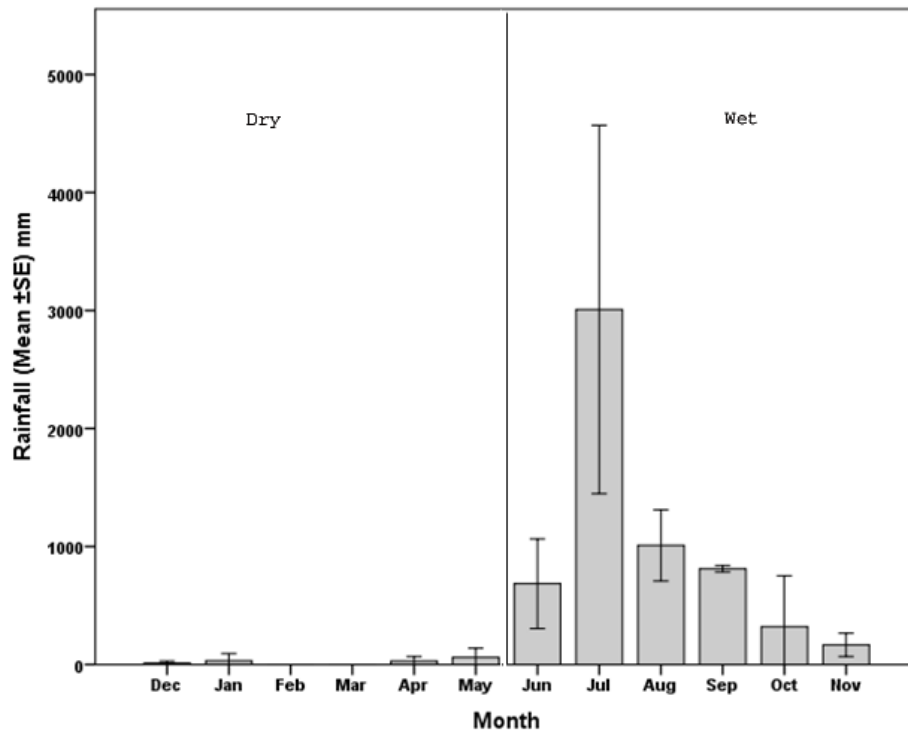


Fig. 3.3.1 Mean total monthly rainfall (mm) from Dec 2008 to May 2011 at Nilkunda, 15 km north of the study site (www.imd.gov.in)

Ranging patterns and DPL

The study group followed from dawn (c.06:00) to dusk (c.18:30), or until the group was lost and could not be relocated. During group follows, I recorded geo-coordinates at the approximate centre of the group (Kumar 1987) using a handheld GPS (GPSMAP 76CSx, Garmin, Kansas City) at 30 min intervals.

During group follows I recorded the mean distance between the farthest individuals at regular intervals on two perpendicular axes. The mean diameter of group spread was $70 \pm \text{SE } 15$ m, from which the mean group-spread area as 0.38 ha (range: 0.23 to 0.57 ha) was

calculated. Rounding the upper limit to the nearest integer, one hectare as a grid cell size was chosen for the complete home range of the group. Although grid analysis is considered to be conservative, it has been used for continuous group follows (Grueter et al 2009) and to record feeding and resource availability data spatially (Twinomugisha and Chapman 2007). Moreover, widely used estimators such as kernel and maximum convex polygon can be unreliable and inaccurate for home range shapes that are concave and perforated (Downs and Horner 2008), as in the present study. Location points were used to plot a cumulative curve of grid use by adding a new grid cell the first time it was used. The number of location points accumulated in each grid cell was used as an indicator of the intensity of home range use.

Feeding ecology

The methodology used for the data collection is as explained in the previous chapter. I recorded the plant species and parts consumed using binoculars (Olympus 8-16 X 40 ZOOM DPS I) during scan sampling. For the present chapter, four categories of plant parts: fruit (mesocarp, seed, aril or whole fruit), flower (whole flower, pollen or nectar), stem-leaves (young offshoots, young stem or tender parts of mature stem) and resin (exudates and latex oozing from bark) were considered for our analysis. Data on immature animals dependent on adult individuals were excluded and the food tree species that were eaten most (n=20) separately for the dry and wet seasons were listed.

Inter-group encounters

When another macaque group was encountered while following the study group, *ad libitum* data on the distance at which the study group appeared to notice the other group, geo-coordinates of the centre of the group, the closest distance between the two groups, the type of interaction, and the response of both the groups to the encounter were collected. Inter-group encounter was recorded when two groups came into visual or auditory contact (determined by calls by the focal group members and a search in the forest for another group) within 50 m (Kumara et al 2014). The geo-coordinates of such inter-group encounters were noted.

Rainfall

Rainfall data was obtained for the study period from the Indian Meteorological Department station at Nilkunda (15 km north of the study site) (Fig 3.3.1).

Tree density

Point-centered quarter method (Cottam and Curtis 1956) was used to assess the overall tree density and food tree density in each grid cell. Tree species which appeared in >1% of the feeding scans were considered as food trees. In each one hectare grid cell, five equi-distance points on a digitized map were plotted and the corresponding points on the ground were located. From the five points all four quarters for the nearest tree and the nearest food tree with ≥ 30 cm diameter at breast height were assessed. The overall tree density and fruit tree density for each grid cell was calculated. Plant species eaten in each month from feeding scans were listed and summed to obtain the density of these species on monthly fruit tree density values. These density values were used as an indicator of monthly fruit tree density.

Data analysis

DPL data for days with a minimum of nine hours observation ($n=121$) were only used. Day follows with more than nine hours of data were not statistically different from full (12 hour) days ($t = 0.50$, $df=26$, $p=0.31$), because monkeys spent time in close proximity to the sleeping tree during the early morning and late evening. All the data was used for other analyses. The mean total rainfall during the dry season (December to May) was $131 \pm SD 133$ mm and during the wet season (June to November) it was $5999 \pm SD 838$ mm for the study period.

The data for normality was tested and was employed for parametric or non-parametric statistics, as appropriate, for analyses using SPSS v.16.0 (SPSS, Chicago, USA). Scan data from June to November (wet season) and December to May (dry season) was compared for feeding on different resources. The percentage of major food type eaten (plant, fauna and fungi) was calculated based on overall feeding scans for the dry and wet seasons. Similarly,

the percentage of fruits, flowers, stem-leaves and resins eaten by seasons were calculated based on plant feeding scans. The percentage time spent indifferent activities in the two seasons was compared using the chi-square test of goodness-of-fit and G-test of independence (Fashing 2001; Mendiratta et al 2009; Riley 2008). The percentage use of different food tree species from group scans were calculated and compared the seasons. For analyses of fruit tree density, the first 20 woody species were listed by priority in plant feeding scans, which contributed 70% of the macaques' plant diet. The percentage of each species in the diet was calculated based on total plant feeding scans and explored the diversity of food species consumed using the Shannon-Weiner Index. Height data was categorized as "ground-lower stratum" (<1.5 m), "tree trunk-medium stratum" (1.5 -7 m) "canopy - upper stratum" (>7 m). Ground-lower stratum data was used to measure terrestriality because lion-tailed macaques use climbers, bushes, stumps and dead logs to forage on the ground. The percent use of ground-lower stratum between seasons and across months was calculated using the chi-square test of goodness-of-fit.

Movement data was recorded every day from the GPS, connected sequential location points, and the minimum total distance across all the points was considered as DPL. The mean monthly DPL across seasons was calculated using ANOVA. The relationship between monthly rainfall, number of food tree species fed on and the number of fruiting trees density in each month, number of inter-group encounters, terrestriality, and the mean monthly DPL were tested using Pearson product-moment correlations. Bonferroni and Holm-Bonferroni corrections (Abdi 2007; Armstrong 2014) was applied using R package (v. 3.10-1.1). Critical significance level for multiple comparison for DPL was 0.01 ($\alpha = 0.05$, 95% confidence limit) while for home range use it was 0.02 ($\alpha = 0.05$, 95% confidence limit).

To calculate grid cell use, the percentage of total location points recorded and classified in each grid (overall, and in the dry and wet seasons) into five intensity levels (<0.35%, 0.36-0.65%, 0.66-1.00% and >1.00%). The percentage was calculated as the number of observations within a grid cell in proportion to the total observations made during dry and wet seasons and overall and plotted these on a gridded map to represent home range use

visually (Kinnaird 1990; Riley 2008). Finally, the number of entries in each grid cell was related to overall tree density, number of food tree species and food tree density using Pearson product-moment correlations.

Results

Food resource use

A total of 19,236 individual scans in 3,296 scan sessions was collected with a mean of 5.9 individuals per scan (range: 1-9, except one occasion when 17 individuals were recorded when they were moving on ground in an open area) during 1230 h of observation, which include 3,388 individual feeding scans. The lion-tailed macaques fed more on plant food resources (88.2%) than on faunal (8.8%) or fungal resources (2.9%; $\chi^2 = 4616.1$, $df = 2$, $p < 0.001$), and only the percentage time spent feeding on fungi differed between the dry and wet seasons (Table 3.3.1, Appendix 4.3.1). Among plant resources, the overall percentage time spent feeding on fruits (71.9%) was significantly greater than that on stem-leaves (22.3%), resins (2.0%) and flowers (3.8%; Chi-square test, $\chi^2 = 3809.5$, $df = 3$, $P < 0.001$) and this was true in both seasons (Dry season: $\chi^2 = 2525.9$, $df = 3$, $p < 0.001$; Wet season: $\chi^2 = 1466.6$, $df = 3$, $p < 0.001$). Percent time spent feeding on fruits in the dry season was significantly lower than that of the wet season where feeding on stem-leaves and resins were significantly higher than the wet season (Table 3.3.1, Appendix 4.3.1).

Although the lion-tailed macaques fed on 73 species of plants, only 27 of these, including six shrubs (*Pandanus tectorius*, *Psychotria nigra*, *Calamus pseudotenuis*, *Calamus thwaitesii*, *Psychotria flavida*, *Psychotria dalzelli*) and one climber (*Chilocarpus atrovirens*), constituted major food resources for our study group and formed part of its diet in at least one month (Table 3.3.2). 17 plant species comprised 70% of the diet during the dry season while only four species, *Caryota urens* (Aracaceae), *Diospyros sylvatica* (Ebanaceae), *Psychotria nigra* (Rubiaceae) and *Aglaia roxburghiana* (Meliaceae), constituted this percentage in the wet season (Table 3.3.2).

Table 3.3.1 Percentage feeding on different food resources by the study group of lion-tailed macaques in Sirsi –Honnava forests

| Food category | Dry season | Wet season | |
|---------------------------|--|--|----------------------------|
| Total feeding scans | N = 2577 | N = 811 | |
| Plants | 90.0 (N= 2319) | 82.6 (N=670) | G = 3.9, df = 2, p =0.14 |
| Fauna | 8.2 (N=213) | 10.7 (N=87) | G = 4.2, df = 2, p =0.12 |
| Fungi | 1.7 (N=45) | 6.7 (N= 54) | G = 42.6, df = 2, p<0.01 |
| | $\chi^2 = 3743.6$, df = 2, p < 0.001 | $\chi^2 = 888.3$, df = 2, p < 0.001 | |
| Total plant feeding scans | N = 2320 | N = 670 | |
| Fruits | 67.0(N= 1554) | 89.0 (N= 596) | G = 33.3, df = 2, p<0.01 |
| Flowers | 3.9 (N= 91) | 3.4 (N=23) | G = 0.3, df = 2, p=0.84 |
| Stem-leaves | 26.7 (N=620) | 6.9 (N=46) | G = 117.6, df = 2, p <0.01 |
| Resins | 2.4 (N=55) | 0.7 (N=5) | G = 8.4, df = 2, p<0.05 |
| | $\chi^2 = 2525.90$, df = 3, p < 0.001 | $\chi^2 = 1466.63$, df = 3, p < 0.001 | |

The lion-tailed macaques spent $23.9 \pm SE 3.9$ percent of their overall time in the lower stratum of the vegetation or on the ground (Fig. 3.3.2) and while this differed across the months of the study period ($\chi^2 = 4109.45$, df = 23, P < 0.001), it did not vary between the dry ($28.5 \pm 4.53\%$) and wet seasons ($14.0 \pm 6.3\%$) ($\chi^2 = 3743.9$, df = 1, P < 0.001). The diversity of the food plants used was higher in the dry season ($H' = 0.7 \pm SE 0.0$) than in the wet season ($H' = 0.5 \pm SE 0.1$).

Table 3.3.2 Overall and seasonal use of major food plant species by the study group of lion-tailed macaques in Sirsi-Honnava forests

| Woody plants | Family | Percentage: Overall | Percentage: Dry season | Percentage: Wet season | Density per hectare |
|--|---------------|---------------------|------------------------|------------------------|---------------------|
| Total number of plant feeding scans | | 3388 | 2577 | 811 | |
| <i>Caryota urens</i> | Aracaceae | 15.08 | 9.22 | 35.37 | 0.72 |
| <i>Artocarpus hirsutus</i> | Moraceae | 5.02 | 6.47 | 0.00 | 3.86 |
| <i>Olea dioica</i> | Oleaceae | 4.85 | 6.25 | 0.00 | 23.37 |
| <i>Calophyllum tomentosum</i> | Clusiaceae | 4.68 | 5.82 | 0.75 | 1.45 |
| <i>Diospyros sylvatica</i> | Ebanaceae | 4.15 | 1.34 | 13.88 | 44.58 |
| <i>Aglaia roxburghiana</i> | Meliaceae | 2.88 | 1.21 | 8.66 | 9.40 |
| <i>Ficus microcarpa</i> | Moraceae | 2.37 | 2.97 | 0.30 | 0.24 |
| <i>Nothopegia racemosa</i> | Anacardiaceae | 2.31 | 2.89 | 0.30 | 4.82 |
| <i>Flacourtia montana</i> | Flacortiaceae | 2.01 | 2.59 | 0.00 | 4.82 |
| <i>Ficus infectoria</i> | Moraceae | 1.24 | 1.38 | 0.75 | 0 |
| <i>Knema attenuata</i> | Myristicaceae | 1.04 | 0.86 | 1.64 | 57.35 |
| <i>Garcinia gummi-gutta</i> | Clusiaceae | 1.04 | 0.43 | 3.13 | 14.22 |
| <i>Madhuca longifolia</i> | Sapotaceae | 0.97 | 0.26 | 3.43 | 0.96 |
| <i>Artocarpus heterophyllus</i> | Moraceae | 0.87 | 0.65 | 1.64 | 0.48 |
| <i>Holigarna grahami</i> | Anacardiaceae | 0.80 | 1.03 | 0.00 | 1.93 |
| <i>Ficus nervosa</i> | Moraceae | 0.80 | 1.03 | 0.00 | 0 |
| <i>Vitex altissima</i> | Verbenaceae | 0.77 | 0.04 | 3.28 | 4.82 |
| <i>Macaranga peltata</i> | Euphorbiaceae | 0.77 | 0.99 | 0.00 | 2.17 |
| <i>Diospyros buxifolia</i> | Ebanaceae | 0.77 | 0.91 | 0.30 | 7.71 |
| <i>Belsmedia whitii</i> | Lauraceae | 0.37 | 0.47 | 0.00 | 2.41 |
| Shrubs and Climber | | | | | |
| <i>Pandanus tectorius</i> | Pandanaceae | 10.77 | 12.93 | 3.28 | |
| <i>Psychotria nigra</i> | Rubiaceae | 5.28 | 3.45 | 11.64 | |
| <i>Calamus pseudotenuis</i> | Aracaceae | 2.64 | 3.36 | 0.15 | |
| <i>Calamus thwaitesii</i> | Aracaceae | 0.90 | 0.99 | 0.60 | |
| <i>Psychotria flavida</i> | Rubiaceae | 0.37 | 0.04 | 1.49 | |
| <i>Psychotria dalzelli</i> | Rubiaceae | 0.90 | 1.03 | 0.45 | |
| <i>Chilocarpus atrovirens</i> | Apocynaceae | 5.79 | 7.03 | 1.49 | |
| Other species | | 29.90 | 31.90 | 23.55 | |
| Total | | 100 | 100 | 100 | |

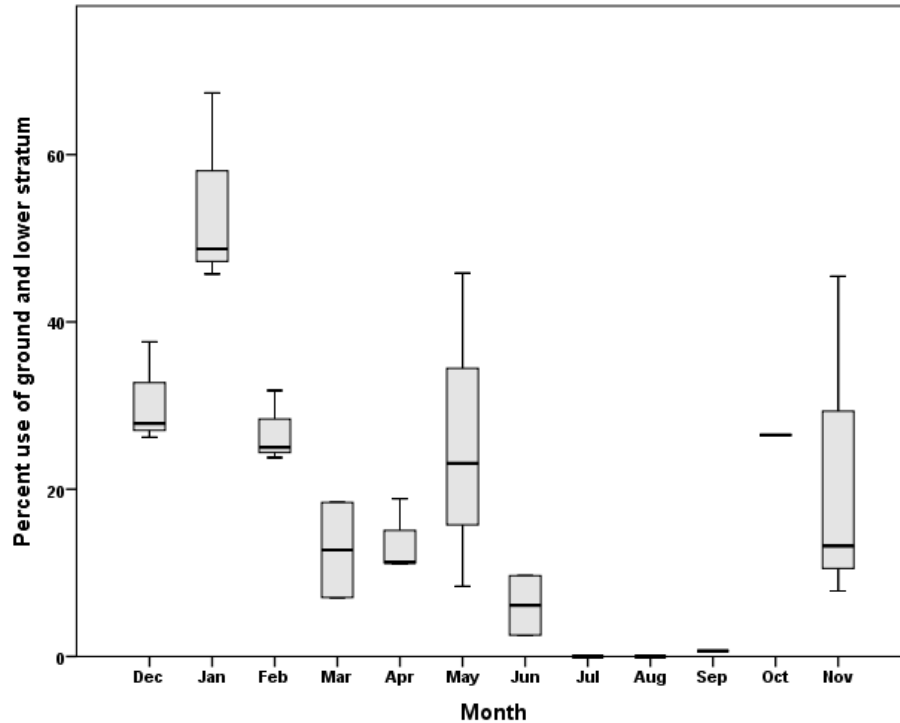


Fig. 3.3.2 Ground or lower strata use by lion-tailed macaques in Sirsi-Honnava forests. Boxes represent 25th and 75th quartiles, horizontal lines within the boxes represent median and whiskers represent the range

Daily path length

The DPL of the study group ($n=121$ days) ranged 301 -3240 m, with 80% falling between 500 and 1500 m. Mean monthly DPL varied significantly with month (ANOVA, $F_{10, 110} = 9.5$, $p < 0.001$; Fig. 3.3.3) and the overall mean monthly DPL was $1185.2 \pm SE 38.9$ m. Approximately 55% of the DPL during the wet season was < 1000 m while $< 25\%$ of DPL in the dry season was < 1000 m (Fig. 3.3.4). The mean monthly DPL during the dry season ($1306.4 \pm SE 47.4$ m, $n=81$ days) was significantly greater than that in the wet season ($939.8 \pm SE 49.4$ m, $n=40$ days; $t = 4.8$, $df = 119$, $P < 0.001$).

The mean monthly DPL was negatively correlated with monthly rainfall (Pearson's product-moment correlation, $r = -0.5$, $df = 22$, $p < 0.01$) but positively correlated with fruit tree density ($r = 0.6$, $df = 22$, $p = 0.01$). The inter-group encounter rate in the study site was

0.008 \pm SD 0.01 per hour ($n=15$ encounters). The mean monthly DPL was however, not significantly correlated with the inter-group encounter rate ($r = 0.1$, $df = 22$, $p = 0.522$), number of plant species eaten ($r = 0.2$, $df = 22$, $p = 0.662$) or the extent of terrestriality ($r = -0.0$, $df = 22$, $P=0.973$). Although, fruit tree density was positively correlated with the mean monthly DPL, the density of fruit-bearing tree species fed on in the dry season (12 species, 95.2 trees ha^{-1}) was significantly lower than that in the wet season (8 species, 132.5 trees ha^{-1} ; G-test of independence, $G = 30.6$, $df = 2$, $p < 0.001$).

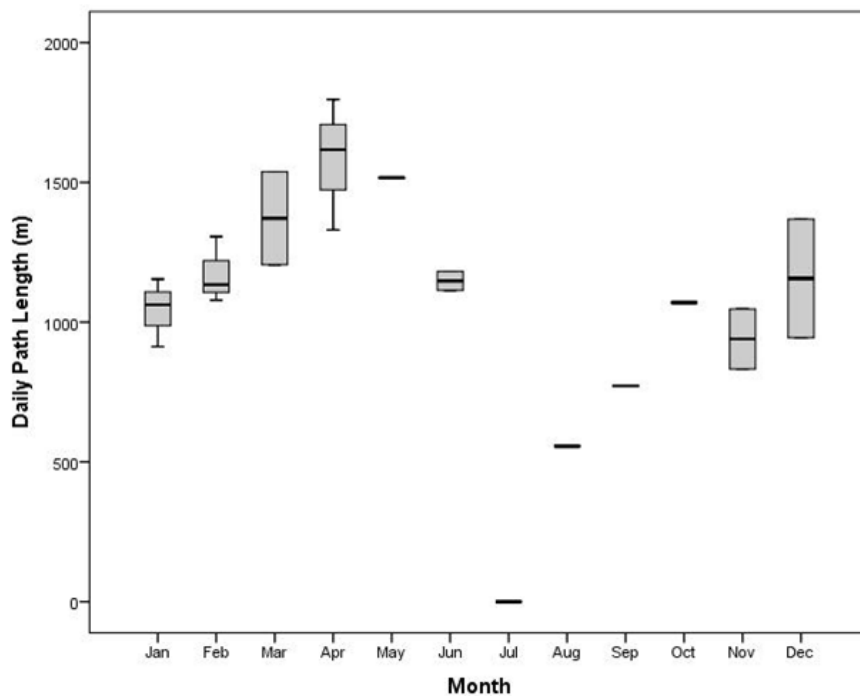


Fig. 3.3.3 Variation in daily path length displayed by lion-tailed macaques in Sirsi-Honnava forests. (Box represents 25th and 75th quartile, horizontal line within the box represents median and whiskers represent the range)

The adjusted p values for the correlation between DPL and rainfall (adjusted $p = 0.05$), overall tree density (adjusted $p = 0.01$), food plant species richness (adjusted $p = 1.00$),

ground-lower stratum use (adjusted $p = 1.00$) and rates of inter group encounter (adjusted $p = 1.00$) were not significant.

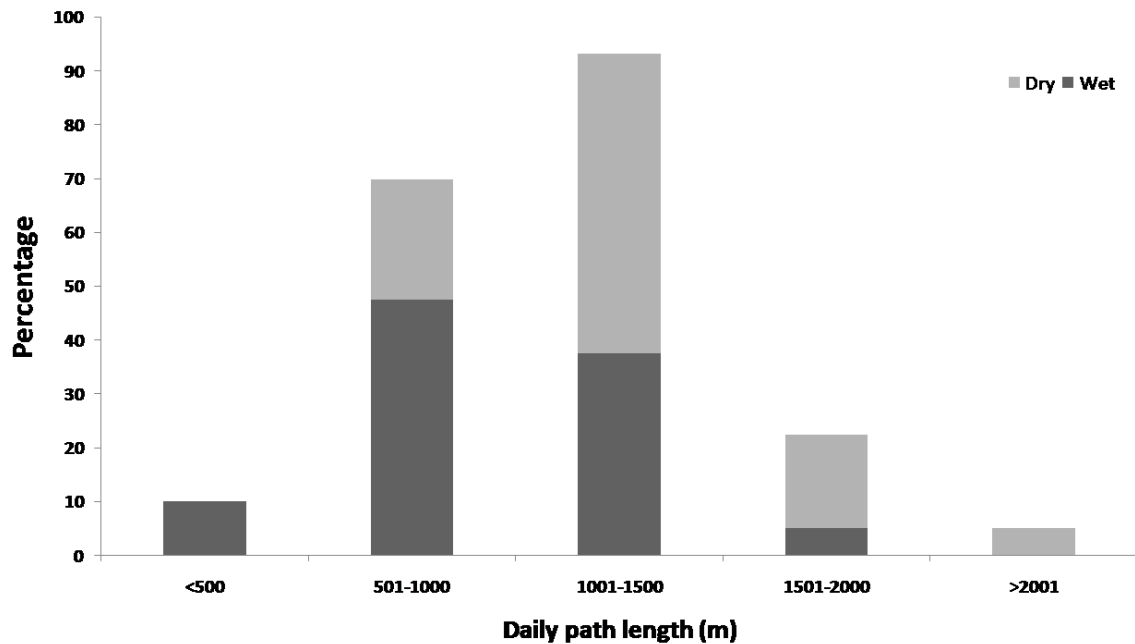


Fig. 3.3.4 Overall and season-wise percentage distribution of daily path length exhibited by study group of lion-tailed macaques in Sirsi-Honnava forests (Wet season $N = 40$, Dry season $N = 81$, Overall $N = 121$)

Home range use

The lion-tailed macaques entered a total of 318 grid cells over the study period with a mean of $2.1 \pm SE 0.2$ ($n=154$ days) grid cells per day. Although, the overall accumulation curve appeared to be asymptotic, macaques entered 11 new grid cells at the end of the study (Fig. 3.3.5). Some grid cells were consistently used intensively (Fig. 3.3.6). The intensity of grid cell use was positively correlated with the overall tree density ($r = 0.1$, $df = 285$, $p < 0.05$) and fruit tree density ($r = 0.2$, $df = 285$, $p < 0.001$) across the study period,

where fruit species richness was not correlated with intensity of grid use ($r = -0.037$, $df = 285$, $p = 0.53$).

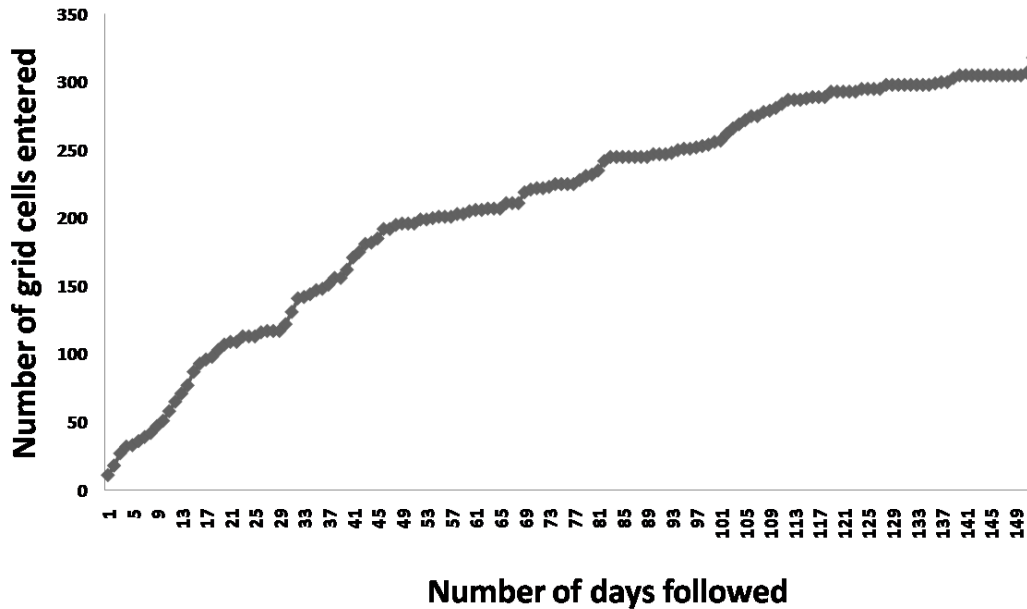


Fig. 3.3.5 Cumulative curve of the number of new grid cells entered each day by the study group of lion-tailed macaques in Sirsi-Honnavaara forests

Similarly, the intensity of grid use in the dry season was positively correlated with fruit tree density ($r = 0.1$, $df = 266$, $p < 0.05$) and overall tree density ($r = 0.1$, $df = 266$, $p < 0.05$). During the wet season fruit tree density was positively correlated with grid cell use ($r = 0.4$, $df = 132$, $p < 0.01$) but total tree density was not correlated with grid cell use ($r = 0.04$, $df = 132$, $p = 0.61$). The fruit species richness was not correlated with intensity of grid use in dry or wet season (Dry season $r = -0.03$, $df = 266$, $p = 0.64$; Wet season $r = 0.15$, $df = 132$, $p = 0.08$). Overall grid use was significantly correlated with fruit tree density (adjusted $p = 0.0009 < 0.016$) but was not correlated with total tree density (adjusted $p = 0.05$) and food plant species richness (adjusted $p = 0.00$). During the dry season, total tree density (adjusted $p = 0.12$), fruit tree density (adjusted $p = 0.21$) and food plant species richness (adjusted $p = 0.92$) and during the wet season, total tree density (adjusted $p = 0.15$), fruit

tree density (adjusted $p=0.04$) and food plant species richness (adjusted $p=1.00$) were not significantly correlated with DPL.

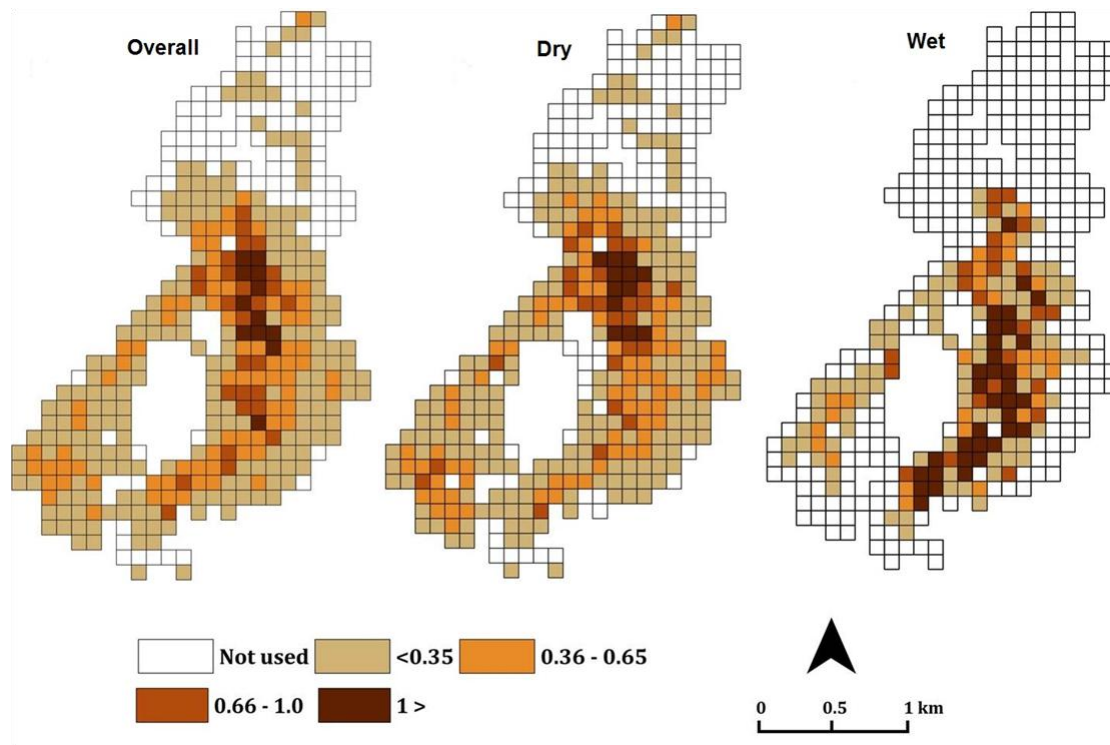


Fig. 3.3.6 Percentage use of grid cells by the study group of lion-tailed macaques in Sirsi-Honnava forests overall, and during the dry and wet seasons

Discussion

The spatial and temporal availability of food resources was correlated with home range use and DPL of lion-tailed macaques in our study area. Lion-tailed macaques fed on 73 plant species, among which 27 were major food species. The consumption of plant resources and faunals did not vary with month or season, although fungi consumption varied significantly across months and seasons. The diversity of food resources used in the dry season was higher than in the wet season. Although the ground use varied across months, it did not differ with season. The mean monthly DPL was higher in the dry season than in the wet season. The mean monthly DPL was positively correlated with fruit tree density and negatively correlated with rainfall, while the intensity of grid cell use in the home range was positively correlated with fruit tree density.

The relationship between DPL and the availability of fruit trees in each month and with decreasing rainfall reflects that found in other specialist frugivores, such as *Nomascus concolor* (Fan and Jiang 2008), *Lagothrix lagotricha* (Stevenson 2006), *M. fuscata* (Tsuji and Takatsuki 2009; Wada and Tokida 1981), *M. fascicularis* (van Schaik et al 1983) and *M. munzala* (Mendiratta et al 2009, Table 3.3.3). In contrast, DPL decreased with increased food tree density and food availability in *M. fuscata* and *M. nigra* (Maruhashi et al 1998; O'Brien and Kinnaird 1997). This was due to lower home range use because of increased food density, leading to lower inter-feeding bout distance.

Table 3.3.3 Relationship of different covariates on day path length (or movement) and home range use in different macaque species from different studies

| Species | Study site | Variable | Effect* | Variable | Reference |
|----------------------------|---------------------------------------|---|---------|---|---------------------------|
| <i>Macaca fascicularis</i> | Ketambe, Indonesia | Movement | + | Food availability | Van Schaik 1983 |
| <i>Macaca sylvanus</i> | Ghomaran and Moyan mountains, Morocco | Home range size and use | + | Habitat with food availability, Conspecific competition | Mehlman 1989 |
| | --- | Home range size | - | Food availability, vegetation | --- |
| <i>Macaca silenus</i> | Varagaliar in Anamalais, India | Movement | NE | Food availability | Kurup and Kumar 1993 |
| <i>Macaca nigra</i> | Sulawesi, Indonesia | DPL | - | Fruit availability | O'Brien and Kinnaird 1997 |
| <i>Macaca tonkeana</i> | Lore Lindu National Park, Sulawesi | DPL | NE | Rainfall and temperature | Riley 2008 |
| <i>Macaca fuscata</i> | Shiga heights, Japan | Home range use | + | Food availability, vegetation | Wada and Ichiki 1980 |
| | --- | Home range use | - | Presence of conspecific group | --- |
| | Shiga heights, Japan | Movement | + | Food availability | Wada and Tokida 1981 |
| | --- | Habitat use | + | Density of feeding trees | |
| | Yakushima island, Japan | Home range size and daily travel length | - | Density of feeding trees | Maruhashi et al 1998 |
| | --- | Home range use | + | Patchy food distribution, Conspecific competition | --- |
| | Kinkazan island, Japan | Home range use | + | Food availability | Tsuji and Takatsuki 2009 |
| <i>Macaca munzala</i> | Tawang, India | Movement | + | Food availability | Mendiratta et al 2009 |

*+: positive correlation; -: negative correlation; NE: no effect

Of the 73 species of plants consumed, 69 species were used in the dry season as opposed to only 36 species in the wet season. The negative correlation between DPL and rainfall may be due to more selective and extensive searching for specific fruits in the dry season characterized by higher density of fruiting trees and significantly greater food species diversity. Although this may not be cost effective, nevertheless it would balance their diet by feeding on combinations of different food types (Gaulin and Gaulin 1982; Johns 1986). Conversely, the monthly rainfall did not influence DPL in *M. tonkeana*, although the montane forests of Lore Lindu National Park in Indonesia received high monthly rainfall (Riley 2008). Heavy rain during the wet season may limit the movement of lion-tailed macaques in the canopy to a large extent. The relatively lower DPL during the wet season may also be due to their spending prolonged periods of time in resource-rich areas with a high abundance of certain food species. Support for this possibility comes from the fact that four food species, *Caryota urens*, *Diospyros sylvatica*, *Psychotria nigra* and *Aglaia roxburghiana*, alone accounted for more than 75% of the diet of our study group in this season. This focus on relatively restricted, resource-rich areas in the wet season may obviate the need for extensive travel during heavy rain. An earlier study reported that lion-tailed macaques consumed a relatively greater number of food plant species in the wet season than in the dry season in the same landscape (Singh et al 2010), however, they reported that niche breadth was significantly lower in the wet season, which matches our observations. Lion-tailed macaques fed on less abundant fleshy fruits of relatively high quality during a period of fruit scarcity in the dry season in the Silent Valley National Park of Kerala state (Krishnadas et al 2011). However, another study found no effect of food availability on movement of lion-tailed macaques in the Varagaliyar area of the Anamalai Hills of Tamil Nadu state (Kurup and Kumar 1993). Differences in seasonal patterns of resource use between sites and across landscapes may largely be influenced by the density, distribution and phenology of locally available food tree species and this may, in turn, lead to the observed variability in DPL across these populations. Such differential impact of food availability on DPL is also reported for *M. fuscata* (Maruhashi et al 1998; Wada and Tokida 1981).

Lion-tailed macaques generally harvest their food vertically rather than horizontally (Joseph and Ramachandran 2001; Sushma 2004). I predicted that use of the ground or lower stratum for feeding would correlate with home range use and DPL, due to increased vertical exploration of habitat and decreased horizontal (spatial) movement. The study group fed on shrubs on the ground-lower strata which varied across months. However, it did not influence the mean monthly DPL similar to *M. tonkeana* (Riley 2008). Variability in strata use in these two species may be related to habitat quality and to optimize foraging opportunities.

Although our study area had a >30 groups of lion-tailed macaques (Kumara and Singh 2004a; Santhosh et al 2013), and our study group had four adjacent groups, the number of observed inter-group encounters were low (Kumara et al 2014) and encounters did not appear to influence the DPL of the study group. Defense of a territory to defend access to food resources from conspecific groups may also influence home range use and DPL. The intensity of interactions may depend on the density of groups and value attached to the defended resources, in addition to group characteristics such as size, and the number of males and receptive females in a group (Isbell 1991; Koenig 2002; Sterck et al 1997; van Schaik 1989; Wrangham 1980). I predicted that inter-group encounters would be negatively correlated with DPL in lion-tailed macaques. In *M. sylvanus*, conspecific competition was linked to food availability, home range size and home range use (Mehlman 1989). Similarly, patchy food distribution and high conspecific competition were linked to home range use (Maruhashi et al 1998), and home range use decreased with increased presence of conspecific groups in *M. fuscata* (Wada and Ichiki 1980), due to lesser food density associated with harsh climatic conditions making the groups shift from their main home ranges leading to high overlap in the home ranges. In our study area, uniform rainfall pattern in the entire habitat and relatively lesser density of lion-tailed macaques, led to less overlap in home range and low inter-group encounters (Kumara et al 2014).

Two plant species, *Caryota urens* and *Diospyros sylvatica*, contributed about 50% of lion-tailed macaque plant diet in the wet season whereas their dry season diet was more diverse. They also had low mean DPL and used resource rich forest patches during the wet

season. Spatial use of the habitat was more highly influenced by fruit tree density than any other factors over the entire study period and particularly during the wet season. Similarly, habitat use in *M. fuscata* in different sites in Japan was highly influenced by the density of feeding trees and availability of food (Tsuji and Takatsuki 2009; Wada and Ichiki 1980; Wada and Tokida 1981, Table 3.3.3). Fruits account for 93.3% (Umapathy and Kumar 2000), 57.7% (Kumar 1987), 59.5% (Singh et al 2000) and 81.2% (Sushma and Singh 2006) of the diet of lion-tailed macaques in different fragments of Anamalai hills. Lion-tailed macaques also feed on specific phenophases (Krishnadas et al 2011), reinforcing the importance of the fruits in their diet. Their spatial movement is highly determined by the availability of fruiting trees in its habitat (Kurup and Kumar 1993; Krishnadas et al 2011).

The number of food species reported for different populations of the macaque varies by site, with 80 species in Silent Valley National Park, Kerala state (Joseph and Ramachandran 2001), 73 species recorded in the current study at the northern segment of Sirsi-Honnava, 40-50 species in different forest fragments of the Indira Gandhi Wildlife Sanctuary in the Anamalai Hills of Tamil Nadu state (Sushma and Singh 2006; Umapathy and Kumar 2000) and 24 plant species in the southern forests of Sirsi-Honnava, just south of our study site (Singh et al 2010). The two most important food tree species (*C. urens* and *D. sylvatica*) that I identified in this study were not part of the major plant food species reported for any of the other populations (Joseph and Ramachandran 2001; Singh et al 2010; Sushma and Singh 2006; Umapathy and Kumar 2000). The fruits and flowers of *Cullinea exharillata*, which are a major food resource for lion-tailed macaques in the southern Western Ghats, are absent in the forests north of the Brahmagiri Wildlife Sanctuary in the central Western Ghats (Kumara and Singh 2004b) including our study area. The major food species of the study population differed highly even within its narrow range in the forests of Sirsi-Honnava, varying from *D. crumenata*, *Dryptes venusta*, *Garcinia gummi-gutta*, *C. urens* and *Syzigium gardneri* in the south (Singh et al 2010) to *C. urens*, *D. sylvatica*, *Aglaia roxburgiana*, *Artocarpus hirsutus*, *Ficus microcarpa* and *Flacourtia montana* in the north at the present study site. It is thus clear that different populations of lion-tailed macaques depend on different food resources and that variability in feeding ecology is strongly dependent on the food species available. Detailed knowledge of the

important food species in each area is therefore crucial for understanding the ecology of the different populations, especially from the perspective of phenotypic plasticity and local adaptation. Such knowledge also assists the management of specific microhabitats and their components as these are the major determinants of home range use by these Endangered macaques.

Selective logging in the study area may have altered the local plant species composition and contributed to the feeding ecology of the lion-tailed macaques. In addition, many other anthropogenic activities have led to thinning and degrading of the habitat (Gadgil and Chandran 1989; Kumara et al 2011). As a strategy for management this information may be used for planning on management actions and initiatives.

Chapter 4

Exploring the human dominated
landscape of Sirsi-Honnagara

The evergreen forests of Western Ghats are reducing drastically leading to change in the species composition and vegetation characteristics (Parthasarathy 1999). Being one of the hotspots of the world (Myers et al 2000), it possesses a range of endemic species and a large forest dependent population (Cincotta et al 2000). Many of the anthropogenic activities have led to extinction of a large number of endemic species of an area or made them isolated and restricted in distribution.

The major challenges to biodiversity in the Western Ghats are the loss of suitable habitats and their fragmentation. However, the rate of fragmentation is variable in different regions of Western Ghats is in relation with the density of people in the area. The area faces challenges from local people's dependence on a wide array of resources including timber. In addition to dependence on forests for timber, about 130 species of Non-timber Forest Products are being extracted in the country (Hegde et al 2000). The income generated from Non-timber Forest Products is estimated to be twice as compared to that of timber (Murthy et al 2005). In Sirsi-Honnava forests, local people collect Non-timber Forest Products as an integral part of life with the yearly income highly dependent on it. These forests are highly bio-diverse and inhabit a large number of endemic and endangered species. In this background, there is an immediate need to quantify the extent of habitat loss over time and evaluate the status of these forests. It is also critical to understand the extent of dependence of people on the forest in relation to livelihood and economy.

The following chapters 4.1 and 4.2 deals with the quantification of land use changes over the years and describes the characteristics of local people, their livelihood and dependence on forests of Sirsi-Honnava.

4.1 Land Cover Change in Sirsi-Honnava forests

Introduction

The primary forests of Asia, particularly those of the Western Ghats in southwestern peninsular India, are disappearing at an alarming rate due to anthropogenic activities and are undergoing a change in land-use patterns, including being replaced by forests comprising inferior secondary species (Parthasarathy 1999). The Western Ghats, however, also has a high human density (Cincotta et al 2000). Although these hills have been inhabited for several thousands of years (Chandran 1997), the forests of the Western Ghats are declining drastically and have undergone severe fragmentation in recent years due to a high degree of exploitation (Menon and Bawa 1997). Such fragmentation or the complete loss of habitats and other anthropogenic activities have led to the local extinction of many species or caused them to be presently restricted in their distribution to isolated and threatened patches.

Sirsi-Honnava forests inhabit a high human density with extensive areas under agriculture, posing high anthropogenic pressures on the forests. Such pressures on the forest have led to drastic land use changes in the area. There is a need to understand the land use changes happening in the forests at different periods. I attempted to evaluate the forest status in the study area using a temporal series of satellite images. Such satellite images are crucial in providing a temporal window on recent changes in the land use changes in the forest cover, particularly in an area where the difficult terrain prevents extensive ground-truthing of potential habitat loss and fragmentation.

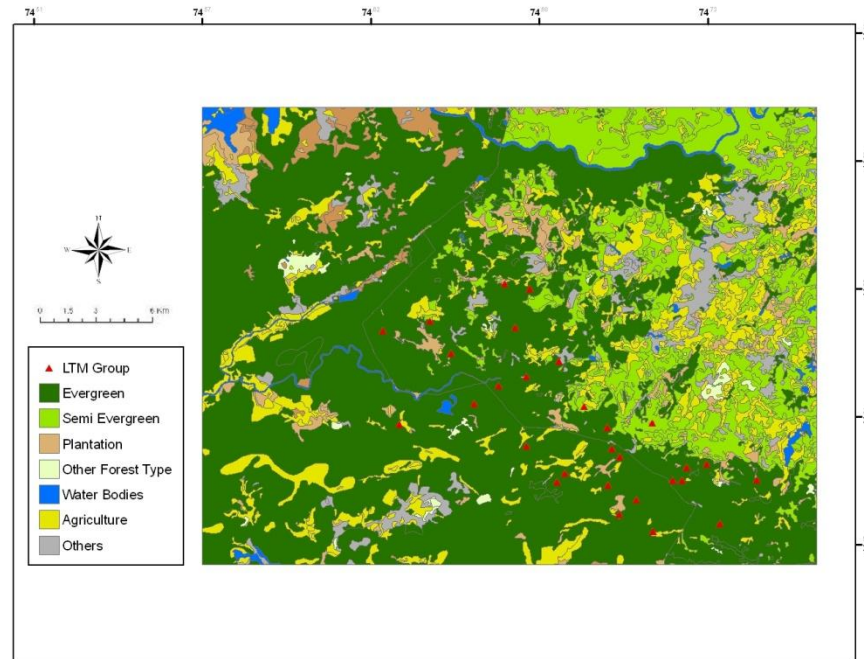


Fig. 4.1.1 Vegetation map of the study area showing the locations of lion-tailed macaque groups in Sirsi-Honnavaara

Methods

A general land-use/land-cover map of the area was extracted by digitizing toposheet number 48 1/11 (Survey of India 1979) to derive the vegetation cover of the area (Figure 4.1.1). Further verification was carried out by repeated field visits for ground truthing. The vegetation cover of the area could be classified into five thematic classes on the basis of a comparison with the classified images of the vegetation map produced by Pascal (1988), and this classification was supported by the geo-coordinates directly obtained from the field. These thematic classes could be grouped and broadly categorized under evergreen forests, semi-evergreen forests, plantations (including *Acacia* species, *Casuarina* species, *Eucalyptus* species, bamboo and teak, *Tectona grandis*), other forest types (including scrub jungles and grasslands), water bodies, agricultural fields (including areca nut and paddy, the two major crops in the area) and other areas (including barren land and built-up areas). I selected the Landsat 7 images of the year 1989 and 2000, given the preference of these images in the study of the environment (Tucker and Maxwell 1976), and selected subsets of the images to match our study area. The acquisition dates for the images were

November 1989 and March 2000 respectively. The problem of differences being generated in vegetation cover on these acquisition dates due to varying climatic conditions was overcome by the geo-coordinates collected from the field during the classification process. A supervised classification was carried out, using the software ERDAS, to obtain a classified map of the land-use/land-cover over a span of 11 years from 1989 to 2000. Five distinct classes could be derived from homogeneous areas for which detailed descriptions on vegetation were available in the thematic map, and these were chosen for the supervised classification (Figure 4.1.1). These consisted of (i) evergreen forests (including evergreen and semi-evergreen forests); (ii) plantations (including those of areca nut, *Acacia*, *Casuarina*, bamboo, *Eucalyptus* and teak); (iii) paddy fields; (iv) *Byana* (grasslands, degraded forests, barren and built-up land), and (v) water bodies (rivers and streams). The parametric rule for the supervised classification used for all images was the maximum likelihood method, which exhibits sensitivity to variation in the quality of the training data (Campbell 2007). A minimum of 40 and a maximum of 80 signature sets were collected from the field for each of the five thematic classes using a handheld GPS (Garmin 76CSx). The chosen thematic classes were identified as relevant for quantifying the range of vegetation types and the associated habitat of the lion-tailed macaque across space and time.

The area under each thematic class was calculated to get the extent of change in the respective habitat type from 1989 to 2000. The areas (in km²) for all the classes were extracted for both the years and the same data were used to determine the intrinsic rate of change (r) in each forest type between the years using the formula:

$$N_t = N_0 e^{rt}$$

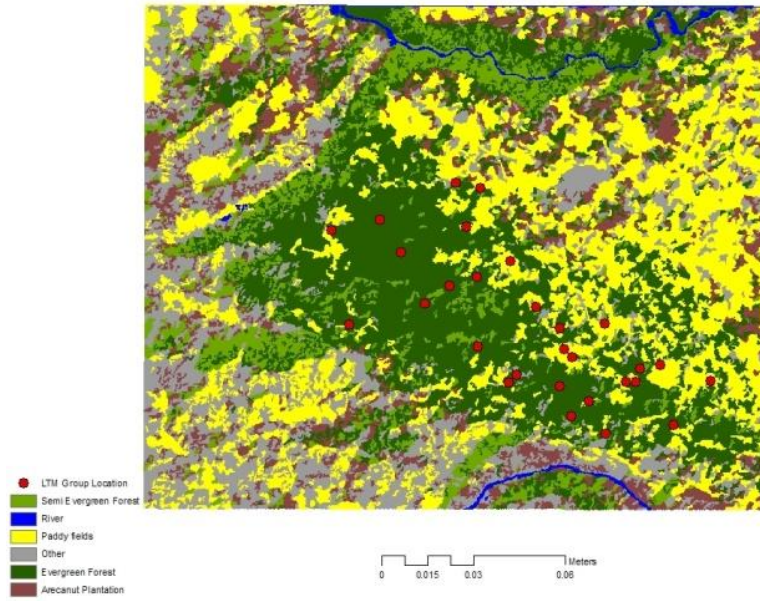
in which r is calculated from the available study years N , and t is the number of years between the study period. Geo-coordinates were recorded for every sighting of lion-tailed macaque troops during the surveys in the study area. These coordinates were then overlaid on the land-use/ land-cover map to determine the habitat association of the species, and the classified images were visually interpreted to examine the qualitative changes and the

magnitude of such change in the land-use patterns within the habitat of the lion-tailed macaque.

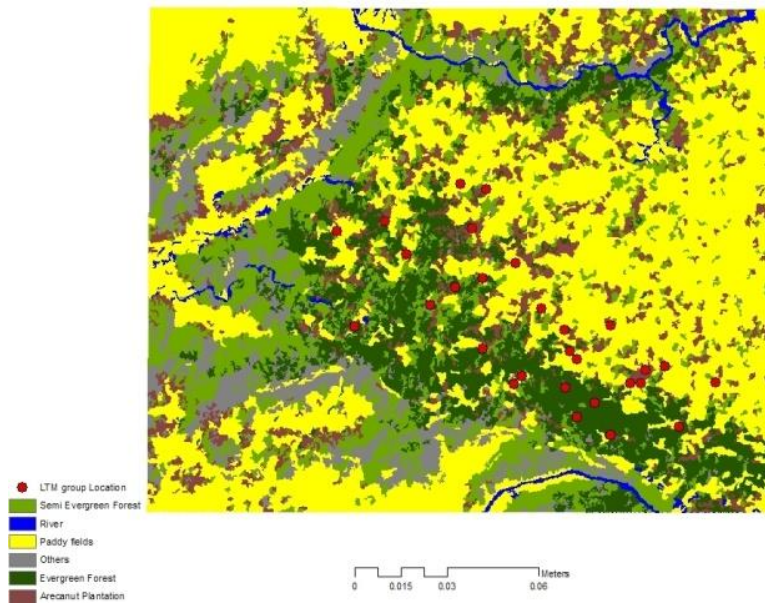
Results

Analysis of the habitat preference of the lion-tailed macaque population, was obtained by mapping the observed troop locations on the vegetation cover map of the Sirsi– Honnavara. It indicated that virtually all troops, except three, were located in continuous evergreen forests (Figure 4.1.1). The three exceptional troops were mapped to the eastern limit of the population in areas that were richer in agricultural land, plantations and other forest types.

The supervised classified images of 1989 and 2000 (Figure 4.1.2) clearly depict a significant increase in open areas over the 11 years; these images, however, indicate a greater degree of change shown by the thematic vegetation cover map (Figure 4.1.1). The wet evergreen forests in this region exhibit a major decline of about 11.5% in these intervening years (Figure 4.1.3), a change at a rate of about 1.9% per year (intrinsic rate of change, $r = -0.019$; Figure 4.1.4). The area under all other forest types appears to have slightly increased during the same period, although it is significant that the maximum increase has been in grasslands/degraded forests (Figure 4.1.3). The evergreen forests, preferred by lion-tailed macaques, are still continuous in their distribution in the western part of the region, but there have been major changes in the eastern parts which now appear as a narrow strip covered principally by other forest types.



a.



b.

Fig. 4.1.2 Classified images of the study area from a. 1989 and b. 2000 with sightings of lion-tailed macaque groups in Sirsi-Honnava forests

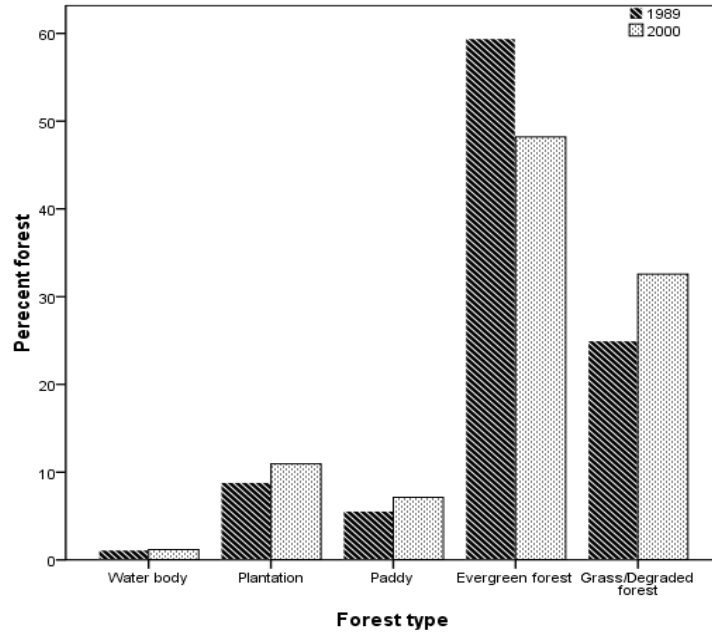


Fig 4.1.3 Status of different forest types during 1989 and 2000

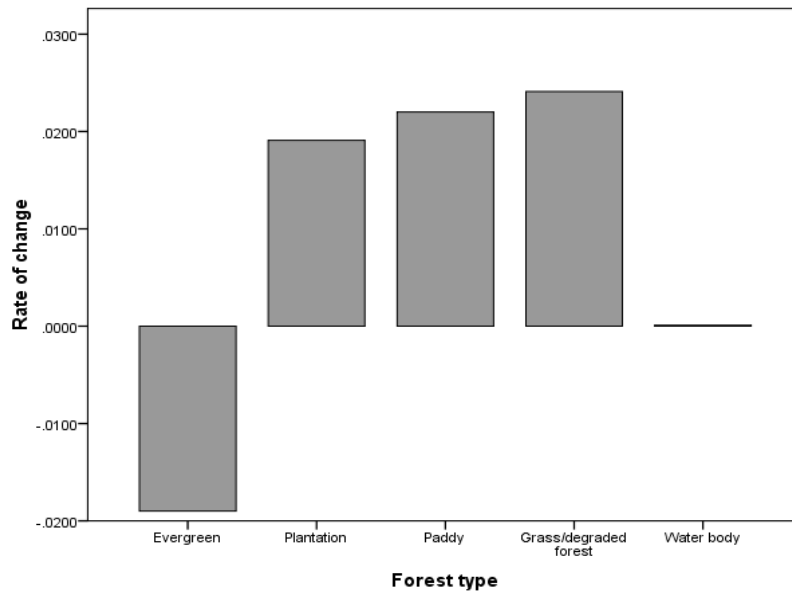


Fig 4.1.4 Intrinsic rate of change (r) in the area under different forest types between 1989 and 2000

Discussion

The rate of deforestation in the Western Ghats has been estimated to be about 0.57% annually during the period 1920–1990 (Menon and Bawa 1997). The estimate of annual decline in natural forest cover in different regions of the Western Ghats, however, remains highly variable, as, for example, 0.90% in some parts of Kerala and 0.28% in others between 1961 and 1988 (Prasad et al 1998); 0.33% in the Agastyamalai region from 1920 to 1990 (Ramesh et al 1997), and up to 1.84% in some districts of Tamil Nadu and Kerala (Jha et al 2000).

In the present estimate, the annual loss of evergreen forests in Sirsi– Honnavara was about 1.9%, which is on par with the highest decline reported for any part of the Western Ghats (Jha et al 2000). An important reason for this may be the fact that the forests of Sirsi– Honnavara do not fall under the Indian protected area network, and further there is a high density of humans (~46 people/km²) spread out in about 29 villages (Santhosh et al 2013). Most of the local people in the study area are agriculturists and the expansion of agricultural land is almost invariably mediated by the illegal encroachment of forest land. Although the collection of non-timber forest produce by the local people is legal, uncontrolled timber and firewood extraction continues unabated in these forests. Leaf litter is regularly collected from the forest floor during the dry season, whereas green manure is made by extracting the foliage from the undergrowth and also by lopping tree branches during the wet season.

The collected leaf litter and green manure are then mixed with cow dung and used as manure for agriculture. As such activities keep escalating in an ever-increasing human population; the already threatened forests near human settlements are made even more fragile (Chittibabu and Parthasarathy 2000). These anthropogenic factors have collectively contributed to the rapid loss of evergreen forests and the concomitant increase in degraded forests or grasslands over the last decades.

Land-cover change and habitat loss can have drastic impacts on any species. Habitat specialists, such as many arboreal mammalian species, are usually more severely affected by such changes than are more resilient species that are able to adapt and survive better under these adverse conditions. Fragmented habitats, particularly evergreen forests, usually tend to be biologically impoverished and, in general, support a relatively lesser number of habitat specialists (Harrison and Bruna 1999). The lion-tailed macaque is one such habitat specialist found in this region and the Sirsi– Honnavara population marks the northernmost limit of its distribution range. Although the macaque population of Sirsi– Honnavara does not face much hunting pressure, the extensive habitat loss documented in this study can lead to severe population fragmentation. Kumara and Sinha (2009) have pointed out that most lion-tailed macaque populations in the wild, including those in southern Karnataka, are depleted in troops, and many troops have highly skewed sex ratios. The Sirsi–Honnavara population has thus been considered as one of the largest and most important populations of the species over its entire distribution range (Kumara and Singh 2004). It is thus considered that habitat protection and restoration of the evergreen forest to be of highest priority in this region and additionally advocate the enforcement of conservation action, particularly through legal action against forest encroachment and extraction of timber to restrain further loss of evergreen forests. Any developmental activities like dam construction or road development should also be carefully considered as they can significantly enhance habitat fragmentation. The forests of Sirsi–Honnavara are a treasury of the endemic flora and fauna of the Western Ghats, many of which are today severely endangered, though the official status of the region is that of a Reserve Forest. A new species of frog, *Philautus neelanethrus*, has been recently discovered (Gururaja et al 2007), and a few critically endangered tree species are also reported from this region (Mesta et al 2008). This area is also characterized by *Myristica* swamps, a unique habitat for many endemic plant species, including the recently discovered tree, *Semecarpus kathlekanensis* (Chandran et al 2008; Gururaja et al 2007). The conservation, restoration and management of the evergreen forests of Sirsi–Honnavara are of critical importance in order to protect the biodiversity of the region and ensure the continued survival of several unique endemic species, including the largest population of lion-tailed macaque.

4.2 The local people and livelihood patterns

Introduction

Humans were basically hunters and gatherers much before they became agriculturists, and thus forest products make an important contribution to subsistence and market economies even today. Significance of forests in India is so prominent that it is estimated ~ 50 million people depend on it directly for livelihood (Hegde et al 1996). Several thousands of species of Non-Timber Forest Products are collected worldwide (Myers 1988) and in India about 3000 species yield Non-Timber Forest Products (Saulei and Aruga 1994). The human density in Uttara Kannada district is the lowest in the country (Census of India 1991) and it has the largest forest cover (76%) in the state (Bhat et al 2003). About 130 species of Non-Timber Forest Products are collected by people to varying extents in the district (Hegde et al 2000). Significance of Non-Timber Forest Product collection in the district can be realized by the fact that the income is nearly twice as compared to timber collection (Murthy et al 2005). In the district, many low income class people lead their livelihood using forest products and most communities have a tendency to collect forest produce (Gaonkar et al 1998; Hegde et al 2000; Rai 2003; Rai and Uhl 2004). Thus Non-Timber Forest Product collection has been an integral part of their life system and its collection is extensive. Unsustainable collection of Non-Timber Forest Products from crucial trees can deplete resources for its dependents on the long run. Extensive loss of important species due to faulty harvesting mechanisms (Parameswarappa 1992; Murthy et al 2005) indeed serves as warnings for policy makers.

The study area harbor high density of people and large extents of agricultural land, which is also indeed high biodiversity area. The present chapter documents the interaction of people with forest thus indicating their dependence on livelihood and economy. It also attempts to study harvesting mechanisms, rate of extraction and utilization over time and seasons indicating trends and patterns of use and yield for managing resources for administrators ensuring long term survival of Non-Timber Forest Products for its dependents.

Study area

About 12 villages were selected in and around the Hosthota and Chiksuli areas (Table 4.2.1). These villages were spread out in the forest area with agriculture fields. Houses in these villages surrounded the forests. 73 households (94 % of the total households in the focal villages) were selected from these villages to understand their socio-economic status and to monitor the Non-Timber Forest Products collection and use.

The major ethnic communities in the region are *Naika*, *Vokkaliga gowda*, *Harijans* and *Brahmins* who own either legal or acquired lands and practice traditional rain dependent agriculture. They depend on forests for a wide array of resources including leaf-litter, green manure, firewood, water and Non-Timber Forest Products. Major crops of the area include areca and paddy for which they use 'organic manure' prepared locally by mixing leaf litter, green manure and cow dung.

Methods

The structured questionnaire (Appendix 4.2.1 and 4.2.2) was used to collect the data on their socioeconomic status and Non-Timber Forest Products related aspects. To begin with one time data collection on socio-economic information and family details (family members, land and livestock holding, education, and livelihood aspects) were collected using questionnaire-1. At the end of each fourth month (the months were divided into three categories- Monsoon: June-Sept, Post-monsoon: Oct-Jan and summer: Feb-May), people were interviewed to collect the data on Non-Timber Forest Products collection using questionnaire-2. The data was collected on species collected, harvesting technique, quantity extracted, distance travelled and number of individuals from family involved in collection. In addition to this, data on market dynamics of Non-Timber Forest Products trading was also collected. Man days were calculated by mathematical multiplication of number of harvesters in a family and number of days involved in the harvest.

Five hypotheses were developed for factors that determine increased harvests at individual household level and Generalized Linear Model (Nelder and Wederburn, 1972) was applied. The criteria assumed were: i. Increase in number of people and man-days, ii. Increase in

number of people only, iii. Increase in number of people and distance walked, iv. Increase in Man days and v. Increase in distance walked.

Table 4.2.1 Table showing the number of households interviewed for Non-Timber Forest Products collection in the study area

| Village | Total households | Households interviewed |
|-------------|------------------|------------------------|
| Surgaal | 30 | 28 |
| Gurkodu | 3 | 2 |
| Kerekuli | 8 | 8 |
| Dyavingundi | 2 | 2 |
| Naaginmane | 5 | 5 |
| Kaanmane | 2 | 2 |
| Bolumane | 2 | 2 |
| Melinmane | 16 | 14 |
| Heggar | 5 | 5 |
| Kadlimane | 3 | 3 |
| Huthgaar | 1 | 1 |
| Kumrithota | 1 | 1 |
| Total | 78 | 73 |

Results

The human population in 12 villages was 317 in 78 households, including 102 men, 109 women and 73 children; however, the data collected was on 73 households for the present study. Their major livelihood sources include income from agriculture, Non-Timber Forest Products collection, daily wages and business (Fig.4.2.1). The large part of their livelihood was dependent on agriculture (67.68%) than from Non-Timber Forest Products (13.40%) or daily wages and business (18.91%) (Fig.4.2.1). Areca (*Areca catechu*), vanilla (*Vanilla planifolia*) and pepper (*Piper nigrum*) were the major cash crops and paddy (*Oryza sativa*) was a major cultivation for the domestic purpose. Income from Non-Timber Forest

Products noticeably varied between the study years i.e. 4, 10,650 INR in 2008, 4, 56,941 INR in 2009, and 2, 64,832 INR in 2010 averaging to 3, 77,474 INR (Fig. 4.2.2).

Non-Timber Forest Products were collected from a total of 15 species including honey from *Apis cerana* in the study area. During the wet season, the major Non-Timber Forest Products extracted was from *Garcinia gummi-gutta* and *Garcinia indica*, while *Myristica spp.*, and *Cinnomomum malabathrum*, honey, *Piper nigrum*, *Calamus spp.*, *Mangifera indica*, *Garcinia morella*, *Callophylum apetalum* and *Artocarpus lakoocha* during dry season (Table 4.2.2). Two species of *Calamus* were extracted all through the year irrespective of seasons. Among them, largely Non-Timber Forest Products was extracted from seven species (Fig. 4.2.3). *G. gummi-gutta* (91.78%) was the most widely collected species followed by *M. malabarica* (41.09%), *M. dactyloides* (38.35%), Honey (15.06%), 2 species of *Calamus* (6.84%) and *G. indica* (1.36%). Harvesters sometimes resorted to destructive harvesting practices by either cutting the branches of trees or wholly cut the resourceful tree for quick and increase harvests. Collection of *E. scandens*, *G. morella* and *C. apetalum* seeds were absent during the study period, while fruits of *Mangifera indica*, *Piper nigrum* and *A. lakoocha* were done in relatively smaller amounts. Information could not be obtained on extraction of *C. malabathrum* leaves and resin of *C. strictum* since people were refused to share information.

Harvesting and processing mechanism of Non-Timber Forest Products

Garcinia gummi-gutta:

Local people use different strategies to harvest *Garcinia gummi-gutta* fruits from forests and backyards or around their farmlands. People wait for the fruits to mature on trees which are claimed to be their own i.e. in backyard or around farmlands; on the other hand the unripe fruits are harvested from the forest. The date of harvest of fruits from the forest is decided upon from village meetings headed by only representatives of the village, and accordingly people venture out to the forest all at the same day. The date of collection is highly variable every year and it is based on demand and price of the product in the market. If prices are high for dried fruits in a particular year, the tendency of people is towards quicker and maximized collections even though in unripe condition. *Garcinia*

gummi-gutta is extracted by climbing trees or by collection of fallen fruits. The fruits are plucked down using 'dhotee' (a long stick with a hook at the end). There have been instances where fruiting trees that are far from settlements have seen to be cut down for facilitating quicker harvests. The fruits from backyards are left to completely ripen, fall and collected from ground. Once the fruits are carried back to houses, they are cut, deseeded and dried in an open oven fuelled by fire wood over night until the greenish yellow fruit dries and turns blackish completely. The seeds are also air-dried to extract oil.

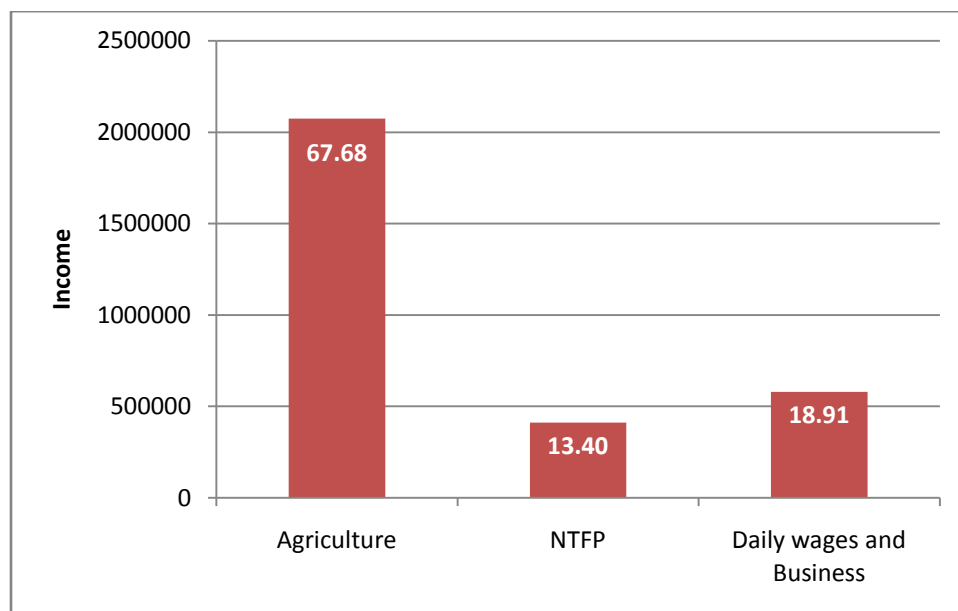


Figure 4.2.1 Overall income of people from different sources in 73 households during 2008

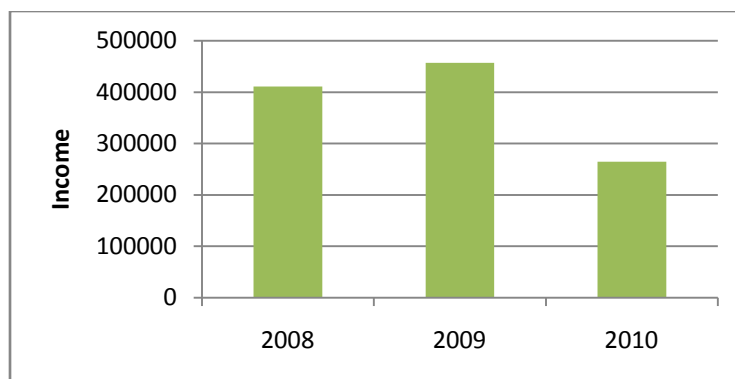


Figure 4.2.2 Income from Non-Timber Forest Products to people of study villages during the study period (2008-2010)

Table 4.2.2 Non-Timber Forest Products collected in the study area, part used and season of collection by people during the recent years

| Vernacular name | Latin name | Part used by people | Collection season |
|-----------------|-------------------------------|---------------------|-------------------|
| Uppage | <i>Garcinia gummi-gutta</i> | Fruits and seeds | Monsoon |
| Rampathre | <i>Myristica malabarica</i> | Aril | Post-monsoon |
| Sannapathre | <i>Myristica dactyloides</i> | Aril | Post-monsoon |
| Kalu menasu | <i>Piper nigrum</i> | Seeds | Summer |
| Dalchinni | <i>Cinnomomum malabathrum</i> | Leaves, buds, bark | Post-monsoon |
| Halbettha | <i>Calamus spp.</i> | Mature stem | All through |
| Handibettha | <i>Calamus spp.</i> | Mature stem | All through |
| Maavu | <i>Mangifera indica</i> | Unripe fruits | Summer |
| Arsnalli | <i>Garcinia morella</i> | Fallen seeds | Summer |
| Muruglu | <i>Garcinia indica</i> | Mature fruits | Monsoon |
| Babbi | <i>Callophyllum apetalum</i> | Fallen seeds | Summer |
| Vaate | <i>Artocarpus lakoocha</i> | Unripe fruit | Summer |
| Rala dhoopa | <i>Canerium strictum</i> | Sap | All through |
| Kanabe/Ganape | <i>Entada scandens</i> | Seeds | Post-Monsoon |
| Jenu thuppa | <i>Apis cerana</i> | Honey, larvae, eggs | Summer |

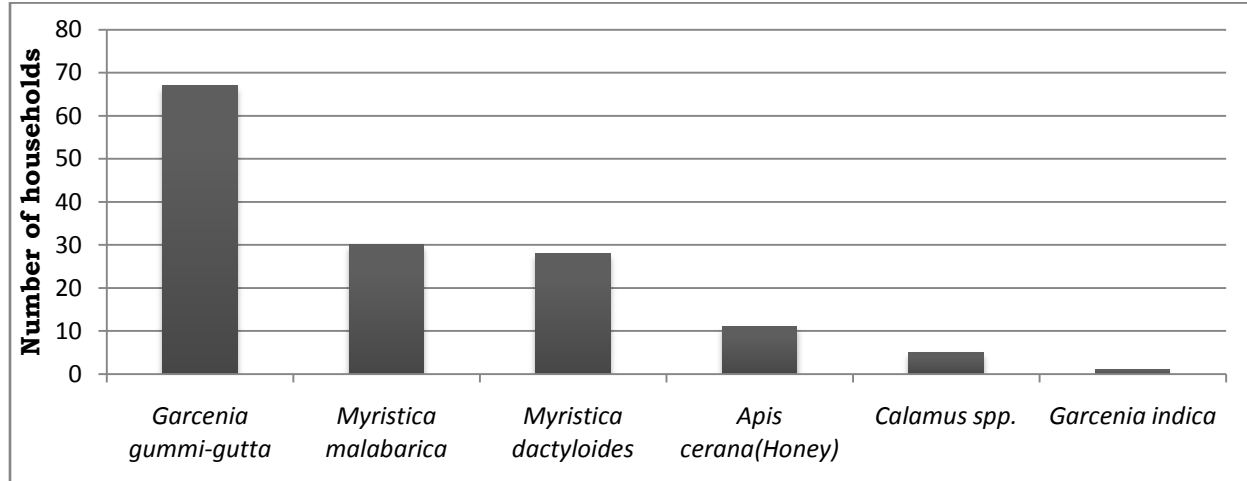


Figure 4.2.3 Number of households that extracted specific Non-Timber Forest Products in the study area

Myristica spp.

Two species of *Myristica* i.e. *M. malabarica* and *M. dactyloides* are harvested between December and February. People make small teams of two to three individuals to search for fruiting trees and walk long distances (upto 10 km). Mostly unripe fruits are harvested, and harvest is by climbing the tree and using *dhotee*. Lopping of branches and cutting of trees to harvest this fruit are however not uncommon. The aril part of the fruit is extracted by breaking the fruits, and aril is separated from the seeds and dried for a day in shade, and taken care to retain appropriate moisture for gaining more weight during marketing. Though there is the knowledge among extractors that aril of ripe fruits weigh more than the ones of unripe fruits, the former is extracted due to competition.

Calamus spp.

Two species of *Calamus* (*C. twaitessi*, *C. pseudotenuis*) are present in the study area; local people harvest both the species. Thorny stems of *Calamus* are cut carefully and de-thorned in the forest, slit into half and sliced off its surfaces, and carried back home. The thin sliced

Calamus are then dried in sun light for couple of hours and these flexible stems are woven to make attractive products of utility such as baskets of different sizes.

Artocarpus lakoocha

The unripe fruits from *Artocarpus lakoocha* are used as souring agent in the local food-recipe. The fruit is extracted using *dhotee* by climbing the tree. The unripe fruits are brought back home chopped into small pieces, mixed with common salt as a mode of preservation and dried in direct sun light. The processed fruits are stored in air tight containers.

Garcinia morella

The fallen seeds of *Garcinia morella* are ground collected from the forest floor. Seeds are washed with water, cleaned and dried to extract the oil. Extraction is usually done in homes or in a local refinery mill. Purified oil is not consumed as food due to its bitter taste but used as fuel for lighting lamps for daily use and religious purposes.

Honey (*Apis cerana indica*)

Usually harvesters enter the forest very early in the morning and locate the hives by observing bee movements against the angle of sunlight. Honey is collected only of *Apis cerana indica* by smoking through the entrance of the hive and extracting the combs. The combs with honey are squeezed and raw honey is collected in containers. Hives with larvae and eggs are consumed directly and is considered delicacy. During the process of collection, extractors take care to not dismantle the crevices of the hive for the bees to construct the hives in the same place successfully in the coming years. Some harvesters make small parties to the forest and may sometimes camp over night as they go for long distances specifically searching for previously extracted crevices or tree holes which they claim to go year after year to same places for extraction.

Other Non-Timber Forest Products

Pepper is extracted by plucking the fruits from the creepers by climbing the corresponding trees. The harvested fruit is dried in sunlight for about a week and marketed. Mango unripe

fruits which are used at households for domestic consumption are mostly found in 'bettas' or backyards of houses. Fruits are plucked in unripe condition and stored in concentrated salt solution for preservation. Fruits of *Garcinia indica* are used as a souring agent in food. The dried ripe fruits which are dried are used as a medicine and flavoring agent in food.

Factors affecting the income from Non-Timber Forest Products

Some criteria that helped maximizing the income from the Non-Timber Forest Products extraction among people in the study area were considered, and GLM model was used to find what has influenced people to get high income (Table 4.2.3). The most parsimonious GLM model was the increase in number of people going for harvest in the family and number of days (Man days) of harvest maximizing the income from Non-Timber Forest Products.

Table 4.2.3 Table showing the descriptions of assumptions for GLM model and their respective values

| Criteria | AIC | Δ_i | wi |
|---|-------|------------|---------|
| Increase in number of people and man days | 296.9 | 0 | 0.5877 |
| Increase in number of people | 298.4 | 1.52 | 0.2744 |
| Increase in number of people and distance walked | 300.0 | 3.21 | 0.1179 |
| Increase in man-days | 303.7 | 6.77 | 0.0198 |
| Increase in distance walked | 319.7 | 20.83 | 0.00002 |

Discussion

The collection of Non-Timber Forest Products by human's dates back to historical times (Moegenburg 2002; Posey 1982). Conservation of forests through Non-Timber Forest Products management has been stressed in recent years and has been considered seriously (Hiremath 2004). However, the challenge lies in assessment and quantification of benefits from Non-Timber Forest Products, to lead them to a socially and ecologically viable use for

the purpose of livelihood and development of dependent people (Saulei and Aruga 1994). Markets locally and globally remain unstable along with variations in Non-Timber Forest Products productivity where harvesters and their dependents get lower incomes (Arnold and Perez 2001; Gopalakrishnan et al 2005; Mahapatra et al 2005; Rai and Uhl 2004). Non-Timber Forest Products collection also positively contributes to sustainable forest management by providing monetary incentives to economically weaker communities (Peters et al 1989; Shahabuddin and Prasad 2004; Kaushal and Melkani 2005; Mahapatra et al 2005).

Agriculture is considered as a backbone of India and it is known that Non-Timber Forest Products collection does not compete with agriculture in a country where major economy depends on it (Sharma 1992). In India, there are about 15,000 plant species out of which nearly 3000 species (20%) yield Non-Timber Forest Products (Maithani 1994). In the country, sustainable Non-Timber Forest Products collection and its management with better markets have been promoted as a strategy to increase the economy of dependent people and also help conservation of wildlife (Hiremath 2004; Mahapatra and Mitchell 1997; Mahapatra et al 2005; Shaanker et al 2004a, 2004b; Shanker et al 2005).

In Uttara Kannada district, earlier studies indicate that Non-Timber Forest Products were extracted from 59 different species which are used for food, household articles, fencing, medicinal uses and commercial purposes (Murthy et al 2005). In the recent years at the study site people collected 15 Non-Timber Forest Products but during the study period it was reduced to only 7 species. Though the demand for all Non-Timber Forest Products were the same in the market, the resource availability probably played a major role in deciding the quantity of collection which varied from 91.70% (*Garcinia gummi-gutta*) to 1.36% (*Garcinia indica*). In the present study, findings suggest that *Garcinia gummi-gutta* was the most widely extracted Non-Timber Forest Products in the recent years due to continual demand from pharmaceutical industries. Dried rind of *Garcinia gummi-gutta* is an additive and fish preservative (Samarajeewa and Shanmugapirabu, 1983) whose demand in market increased due to Hydroxy citric acid discovery for management of obesity (Majeed et.al., 1994; Sergio, 1988). In case of *Myristica malabarica* (n=30) and *Myristica dactyloides* (n=28) the demand for the product was such that the extractions

happened much before the ripening of fruits due to competition among harvesters in addition to destructive harvesting practices. The dried aril of *Myristica* spp. is a chief constituent of Indian soups as spice, and also an additive in the Indian culinary. Although it was observed the collection of *Cinnamomum malabathrum* and *Canarium strictum* took place, the quantification of this was not possible because of their rarity and ban on extraction of these species. The rest of the Non-Timber Forest Products like *Piper nigrum*, *Mangifera indica*, *Garcinia morella*, *Callophyllum apetalum*, *Artocarpus lakoocha*, *Entada scandens* had no extractions during the study thus details into their harvest mechanism are not discussed.

The present study indicates that if the people possessed time and labor required for collection of any commercial Non-Timber Forest Products, they would maximize their income if the opportunity arised. Increase in effort of distance walked for harvest showed no significance to the income obtained. This was probably due to: *a.* the intense competition for harvesting that exists during a short period of time, *b.* the resource although evenly distributed, people walking longer distances had less chance of maximizing their harvest due to ease of access for that area by nearby villagers who also compete to maximize their income, and *c.* Some of the Non-Timber Forest Products like *Garcinia gummi-gutta* which need quick processing in the given weather conditions making distance a limiting factor for increased harvesting because of several trips harvester has to make to and fro from the harvesting tree to processing place.

In most Non-Timber Forest Products species the predictive ability of yield is difficult to determine as it shows a significant difference in yield between two consecutive years due to environmental attributes (Bhat et al 2003) leading to changes in income from Non-Timber Forest Products. When the Non-Timber Forest Product resources are sparse, price shoots up and vice versa. This was exactly the case in the present study where the quantity of production, harvest and associated income which varied across years. Thus it can be ascertained that Non-Timber Forest Products is a good part of income locally and play an important part in livelihood. Although the income from Non-Timber Forest Products are not the highest compared to agriculture, they provide financial support for livelihoods continuously all throughout the year in smaller amounts in contrast to agriculture which

benefits only once annually. The income from agriculture did not influence Non-Timber Forest Products collections in the area. Banning and implementation of stringent rules against Non-Timber Forest Products collection without proper scientific understanding may bring about socio-economic crisis. This may adversely affect the chain of events associated with Non-Timber Forest Products trade and alleviate black market influence leading to loss of many important species of Non-Timber Forest Products. A system to ensure proper monitoring of Non-Timber Forest Products collection keeping long term incentives to people are strongly required.

Chapter 5

The road to conservation: Issues,
Initiatives, Achievements
& Conclusions

Chapter 5

The Road to Conservation: Issues, Initiatives, Achievements and Conclusions

Sirsi-Honnavaara forests are a home to about 658 individuals of lion-tailed macaques in ~30 groups in an area covering about 300 km². It is a viable population present in contiguous evergreen forest thus enabling a sustained gene flow within the population. The present findings received a widespread support from activists, environmental groups, Non-Governmental Organizations and local administrators. The area which was under a 'Reserve Forest' from the colonial times was notified as a protected area. This was a first step towards conservation of lion-tailed macaque habitat in Sirsi-Honnavaara. The area is also occupied by a human population numbering about 15,000 people largely practicing agriculture. They are dependent on these forests for timber, water, soil, leaf-litter, green manure and Non-Timber Forest Products. The evergreen forest which also inhabits a good number of endemic species has been decreasing in recent decades. The long-term ecology study throws light on resource availability and resource utilization by the macaques. The species of priority and important Non-Timber Forest Products for people generated was shared with the forest managers. The species in common need for both the macaques and local people are considered as priority species and raised in nurseries for restoring in degraded areas on ground. Thus, it highlights the need for large scale restoration for degraded parts of evergreen forests. The study documents the dependence of people on the forests by providing strategies for sustainable alternatives to the existing system. The present study provides means and measures to use local people as an active part in conservation of the area by providing incentives for sustenance and livelihood. It develops a model for sustainable harvest and marketing of Non-Timber Forest Products. It stresses the need to establish a multi-stakeholder society to manage the marketing of all Non-timber Forest Products.

The study highlights the presence of certain issues such as fragmentation by developmental activities and the need and importance of precise mapping of the area. It highlights the implementation of sustainable low input agriculture system to decrease the pressure on forest resources. Additionally it stresses the need of large scale restoration of degraded

areas into near-natural forest for the long-term survival of all the endemic, endangered flora and fauna keeping lion-tailed macaques as a flagship species.

The following chapters enunciate the means by which the scientific information on status and ecology of lion-tailed macaques and socio-economic data led to the road towards 'on ground' conservation.

5.1 Notification of Protected area

The confirmation of one of the largest populations of the endangered macaques in Sirsi-Honnavara forests needed immediate intervention from the government. The area being increasingly exploited for multiple purposes by local people and other stake holders also needed immediate reviewing. Thus as a first step towards conservation, a map was developed by connecting all the outermost groups by plotting all the sighted groups on the village map of the study area. All the forests of villages within and associated to the polygon were considered as a '**core area**' (Fig. 5.1.1). Further the forests of the villages boarding outwardly to the core area were considered as '**buffer area**'. The buffer region includes forests of 35 village areas. Since the river Sharavathi acts as a barrier for the lion-tailed macaque population to move further south, the river was considered as a southern boundary to develop protected area.

The proposal was submitted by the local forest department to the state government with all the required facts and figures extracted from the present study. Since the area inhabited a large human population with large expanses of agricultural lands and local people highly dependent on the forests, making a Conservation Reserve was more suitable than other types of protected areas. A government order was passed on 13 June 2011 to notify an area of 299.52 sq km as "**Aghanashini Lion-tailed macaque Conservation Reserve**" (Fig 5.1.2).



Fig. 5.1.1 Core and buffer area for proposed protected area

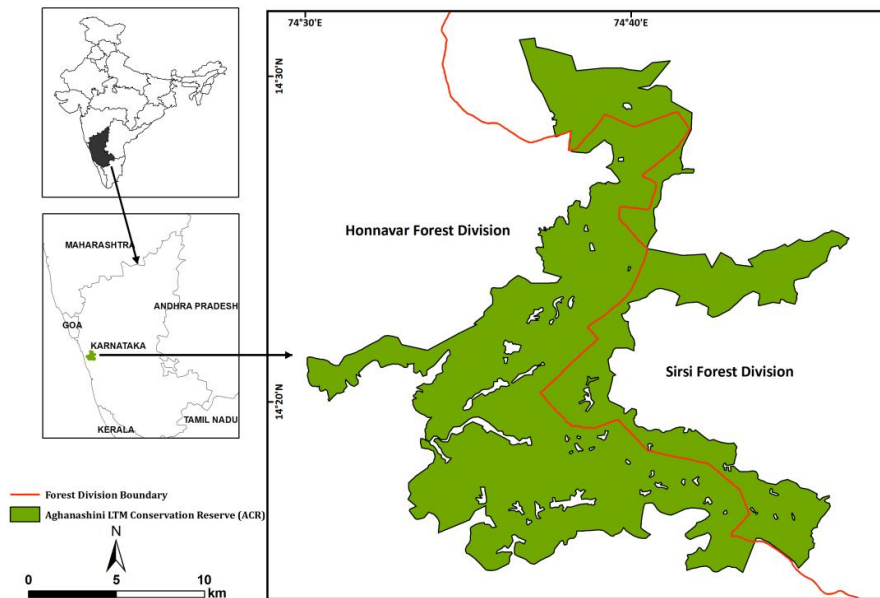


Figure 5.1.2 Map of the newly notified Aghanashini lion-tailed macaque Conservation Reserve in the central Western Ghats of Karnataka State

Table 5.1.1 Geographical area and forest cover are projected for each village with in the lion-tailed macaque habitat (Extracted from Forest Department records)

| Division | Range | Village | Total geographical Area (ha) | Forest Cover (Ha) | Forest Cover (%) |
|-------------|----------------------|---------------|------------------------------|-------------------|------------------|
| Sirsi | Kyadgi | Bilegod | 763.53 | 585.69 | 0.77 |
| | Kyadgi | Nirgod | 618.28 | 581.93 | 0.94 |
| | Kyadgi | Kodigadde | 845.04 | 742.36 | 0.88 |
| | Kyadgi | Kaunsale | 673.81 | 535.41 | 0.79 |
| | Kyadgi | Dodmane | 284.96 | 204.12 | 0.72 |
| | Kyadgi | Kudegod | 726.12 | 639.23 | 0.88 |
| | Kyadgi | Kible | 614.12 | 449.07 | 0.73 |
| | Kyadgi | talekeri | 767.30 | 684.28 | 0.89 |
| | Kyadgi | Danmav | 956.34 | 742.94 | 0.78 |
| | Kyadgi | Sutlamane | 459.37 | 410.97 | 0.89 |
| | Kyadgi | Vajgod | 401.55 | 296.00 | 0.74 |
| | Kyadgi | Keremane | 537.25 | 414.99 | 0.77 |
| | Kyadgi | Hukali | 584.96 | 495.43 | 0.85 |
| | Kyadgi | Alvalli | 673.39 | 468.25 | 0.70 |
| | Siddapur | Malemane | 653.06 | 580.31 | 0.89 |
| | Siddapur | Hejni | 941.53 | 810.79 | 0.86 |
| | Honnavara | Kyadgi | Kudgund | 399.63 | 308.68 |
| Kyadgi | | Masalmakki | 37.65 | 31.56 | 0.84 |
| Kumta | | Soppinhosalli | 380.20 | 281.61 | 0.74 |
| Kumta | | Mudanhalli | 377.25 | 291.44 | 0.77 |
| Kumta | | Medni | 3087.70 | 2868.54 | 0.93 |
| Honnavar | | Hirebail | 2290.99 | 2011.80 | 0.88 |
| Honnavar | | Jankadkal | 2932.07 | 2597.39 | 0.89 |
| Gersoppa | | Mahime | 7502.29 | 6726.93 | 0.90 |
| Honnavar | | Gundbal | 822.56 | 640.31 | 0.78 |
| Gersoppa | | Hulegar | 977.24 | 653.92 | 0.67 |
| Gersoppa | Honnehali kabinnakal | 895.81 | 582.45 | 0.65 | |
| Gersoppa | Heggargadde | 2275.39 | 1883.51 | 0.83 | |
| Grand Total | | | 32479.39 | 27519.91 | 0.85 |

5.2 Resource overlap between lion-tailed macaque and local people, and its conservation implications

Introduction

Dependence of people on forest resources dates back to historical times (Ticktin 2004). Even today people residing in-and-around forests have a great dependence on forests for subsistence (Bawa and Godoy 1993). Large amount of time and labor is invested for collecting resources in the forest which is indeed a profession of some inhabitants (Gubbi et al 1998). People have evolved improvised strategies for increased harvesting over the years and thus, are gradually gaining upper hand on resources that are of commercial importance (Kuipers 1997; Lange 1998). Though, globally there has been a leading concern on the impacts of Non-Timber Forest Products collections on the ecosystem (Bawa 1992; Bhatnagar 2002; Lambert 1998; Shankar et al 1996, 1998; Ticktin 2004; Vasquez and Gentry 1989), studies on impact of Non-Timber Forest Products collection on dependent fauna and ecosystem is scanty. In some instances, these resources have been over-exploited leading to many ecological effects like hampered productivity, decreased density and regeneration of respective species (Cunningham 2001; Peters 1994). In India, commercially valuable resources in the forest have been exploited to such an extent that the adverse ecological impacts on the species itself have been obvious (Murali et al 1996; Negi 2003; Shankar et al 1998). On the other hand, animals dependent on these food resources have had to adapt to changing environment leading to irreversible changes in its ecology, physiology and behaviour. Ticktin (2004) stresses the impact of Non-Timber Forest Product extractions may happen at many levels from individuals, population, community and ecosystem.

To a habitat specialist animal, these changes on long term might have an impact on the population dynamics, which can also lead to decline in the population size. As some of the food species are critical at particular season, long term changes might irreversibly affect the ecological chain of many fauna dependent on them. It is indeed important to understand the resource utilization by people and dependent fauna keeping sustainability

on long term into consideration, as there is a global demand for natural products from forests due to its various uses in medicine, crafts and culinary (Rai and Uhl 2004).

Results

During the study, various Non-Timber Forest Products were extracted from a total of 15 tree species (Table 5.2.1), among them, 11 species were used as food by lion-tailed macaque. The details of Non-Timber Forest Products species and parts collected and preference by lion-tailed macaques are summarized in Table 5.2.1. Among them, only seven species have a large overlap in utilization by people and lion-tailed macaques viz. *Garcinia gummi-gutta*, *Myristica malabarica*, *Myristica dactyloides*, *Calamus pseudo-tenuis*, *Calamus twaitessi*, *Mangifera indica* and *Artocarpus lakoocha*.

Garcinia gummi-gutta constituted (Hosthota: 0.77%; Chiksuli: 1.44%) overall time spent on feeding by lion-tailed macaque was one of the most widely consumed resource during wet season (Hosthota: 3.01%; Chiksuli: 3.13%). On the other hand it was the most extracted Non-Timber Forest Products among all the Non-Timber Forest Products extracted from the region.

Myristica malabarica and *Myristica dactyloides* did not constitute any proportion of lion-tailed macaque diet, however while it showed high extraction by people. *Calamus pseudo-tenuis* (Overall, Hosthota: 2.18%; Chiksuli: 0.45%) and *Calamus twaitessi* (Overall, Hosthota: 0.72% Chiksuli: 0.60) were the next most widely eaten Non-Timber Forest Product species which had notable extractions by people. Fruits of *Mangifera indica* (Overall, Hosthota: 3.66%; Chiksuli: 3.40%), *Piper nigrum* (Overall, Hosthota: 0.52%; Chiksuli: 0.30%) and *A. lakoocha* (nil) were extracted in negligible amounts. During the study period, Honey of *Apis cerana* and fruits of *Garcinia indica* did not contribute to diet of lion-tailed macaque while their extractions by people contributed to their income by 15.06% and 1.36% respectively.

Table 5.2.1 Non-Timber Forest Products parts and phenophase preference by lion-tailed macaques and people in the study area during the study period

| Non-Timber Forest Products species | Season of collection | Part preferred | | Phenophase preferred | |
|------------------------------------|----------------------|-----------------------|----------------|------------------------------|------------------------|
| | | LTM | People | LTM | People |
| <i>Garcinia gummi-gutta</i> * | July-Aug | Mesocarp | Rind and seeds | Ripe fruits | Unripe and Ripe fruits |
| <i>Myristica malabarica</i> * | Dec-Feb | Aril | Aril | Ripe fruit | Unripe fruit |
| <i>Myristica dactyloides</i> * | Dec-Feb | Aril | Aril | Ripe fruit | Unripe fruit |
| <i>Calamus pseudo-tenuis</i> .* | All through | Stem, Fruit | Mature stem | Not specific | Not specific |
| <i>Calamus. twaitessi</i> * | All through | Stem, Fruit | Mature stem | Not specific | Not specific |
| <i>Piper nigrum</i> * | Jan-Apr | Young shoots, Fruits | Seeds | Young leaves, Unripe Fruit | Ripe fruits |
| <i>Cinnamomum malabathrum</i> * | Dec-Mar | Young shoots | Mature leaves | Young leaves | Mature leaves |
| <i>Mangifera indica</i> * | Mar-Jun | Fruit | Fruit | Unripe, ripe fruits | Unripe fruits |
| <i>Artocarpus lakoocha</i> * | Mar-May | Fruit | Fruit | Ripe/Unripe fruits | Unripe fruits |
| <i>Calophyllum apetalum</i> * | Aug-Oct | Young stem, leaves | Fallen Seeds | Unripe Fruits, Mature leaves | Ripe, Fallen fruits |
| <i>Garcinia indica</i> | Jul-Aug | - | Ripe fruits | - | Ripe fruits |
| <i>Garcinia morella</i> | May-Jun | - | Fallen seeds | - | Ripe fallen fruits |
| <i>Entada scandens</i> | Oct-Jan | - | Seeds | - | Fallen ripe fruits |
| <i>Canarium strictum</i> | All through | - | Exudates | - | Not specific |
| Honey* (<i>Apis cerana</i>) | Apr-May | Larva, Eggs and Honey | Honey | - | - |

*Food of lion-tailed macaques

Discussion

Though the diet of lion-tailed macaques include various resources from 73 and 45 plant species from Hosthota and Chiksuli respectively, only a few species contributed to the majority of their diet. On the other hand, partial livelihood of local people (~14% of their total annual income) also depends on various Non-Timber Forest Products from about 14 species of plant species and honey. Among 14 plant species, seven of them are food for lion-tailed macaques, however, only five species of them are the major common resources used by both lion-tailed macaques and local people i.e. *Garcinia gummi-gutta*, *M. malabarica*, *M. dactyloides*, *Calamus pseudo-tenuis* and *Calamus twaitessi*. Contribution of other species (*Mangifera indica*, *Piper nigrum* and *Artocarpus lakoocha*) either to local people or to the diet of lion-tailed macaque is negligible, thus it can be considered that the impact on feeding ecology of lion-tailed macaque may be insignificant. However, extraction of Non-Timber Forest Products from those five common species may have notable impacts on feeding ecology of lion-tailed macaque.

Along with lion-tailed macaques, many other mammal species also depend on fruits or seeds of *G. gummi-gutta* which include brown palm civet (*Paradoxurus jerdoni*), Asian palm civet (*Paradoxurus hermaphoditus*), Hanuman langur (*Semnopithicus* sp.), bonnet macaque (*Macaca radiata*), Malabar giant squirrel (*Ratufa indica*) and flying squirrel (*Petaurista philippensis*) (Rai 2003). If fruits of *G. gummi-gutta* are harvested at proper time (ripe fruit) or if picked up on ground during natural fall, it will not have any competition between dependent fauna and people (Rai 2003). Early harvests not only hamper the feeding ecology of these animals but may have long term detrimental effects on regeneration of the species. Though the fruits of *G. gummi-gutta* do not form any proportion in the diet of lion-tailed macaque in other regions of the Western Ghats may be due to absence of the species or may be due to availability of many other food species (Kumar 1985; Ramachandran and Joseph 2000; Singh et al 2001; Sushma 2004; Umapathy and Kumar 2000), but, the fruits of *G. gummi-gutta* constitute a large proportion in the diet of lion-tailed macaque during wet season in the study area. Thus, it has a negative impact on feeding ecology of lion-tailed macaque in the area in the long run considering the high demand for the fruits of *G. gummi-gutta* in the market, quantity of extraction by people, and improper harvesting techniques.

In case of *Myristica* spp., would have formed an important food resource for the lion-tailed macaque, but early extractions resulted in non availability of resource during the preferred phenophase (ripe fruit) for lion-tailed macaque. This is because extractions have all happened during unripe fruit stage. *M. dactyloides* constitute 0.06% of the total diet of lion-tailed macaque in Silent Valley National Park (Ramachandran and Joseph 2000) probably because of relatively lesser Non-Timber Forest Products extraction in Silent Valley National Park due to better protection and lesser human enclaves in it. This may have probably facilitated substantial resource for lion-tailed macaque diet compared to Sirsi-Honnava forests.

Although few families extract *Calamus*, their collections and dependence remains constant all throughout the year. Kumar (1985) reported that even rare extractions also may drastically alter food resource use by lion-tailed macaque in Anamalai hills. Though the skill of making baskets remains with very less number of people, utility of *Calamus* spp. is very high in every household due to their dependency on agriculture. Similarly interactions with people reveal that previously *Piper nigrum* was collected in considerable quantity in the past. But in the recent time, according to people, the fall in the quantity of harvest was due to cutting up of most climbers for quicker and easier harvesting. Similarly, decline in *Artocarpus heterophyllus* trees over a few decades were probably due to its high extraction for its timber value. The high extraction was due to aesthetic value and long-lasting nature of the wood was valued for making artistic frames for doors and windows (Green and Minkowski 1974; Ramachandran and Joseph 2000; Umapathy and Kumar 2000; Singh et al 2001) due to selective logging.

The reduction in number of species collected by people by over the years may not only be due to fall of market value but also due to decline of some of the species by over exploitation. I presume that many other species like *Canarium strictum*, *Cinnamomum malabathrum* and *Artocarpus heterophyllus* have all been severely depleted or locally endangered due to the same phenomenon. Taking into account the findings of present study it can be said that impact of collections may notably affect the feeding of lion-tailed macaques. There is an increasing need to strike a balance between resource partitioning between humans and lion-tailed macaque keeping long term into consideration.

Sustainability in resource extraction needs to be urgently addressed as a strategy in management policy. Stringent monitoring of extractions during harvest seasons by forest department along with revisions in tendering process needs to be taken up. Incentives to people for sustainable harvesting by establishment of multi-stakeholder society constituting all stake-holders might eliminate middle-men factor benefiting harvesters as well as ensuring sustainability of resources.

5.3 Model for sustainable harvesting of Non-Timber Forest Products

Introduction

Village Forest Committees (VFC) were formed by the Government of India in 1988 on the priority of managing forests with the association of local community who share the resources with the forest department. The decisions regarding the management of forests are jointly taken by local people and forest department. Presently some VFCs are also collecting the rind of *Garcinia gummi-gutta* and auctioning, but it has not been taken up on large scale. There are many criteria set by the government for constituting VFCs which includes the percent of forest cover and minimum number of households in the village. These are not met by many of the villages which have excluded them from VFC establishment.

The process of existing marketing of *Garcinia gummi-gutta* is that the tenders are issued from the forest department on bi-yearly basis. The harvesters are expected to sell their produce only to the agents of the bidder either in villages or through VFC. The produce which is marketed through this channel is considered 'legal' by the government. In some cases, the agents of the middle men from neighboring areas involve in collection of the produce by increasing the buying prices and luring the harvesters. They establish themselves in the trade by providing loan to harvesters and buy the produce in exchange for money lent. They mostly reside at towns by opening inlets in the market during the harvest season. They sometimes send agents to villages to buy the produce directly from harvesters. Additionally, harvesters also exchange their produce with fish, lime and blankets at their door step. All these modes of selling are considered as 'illegal' or black market sale by the forest department.

Although, some of the interventions to reduce the firewood usage were conceived by people for drying the fruits and streamlining of the marketing of the dried fruits, they have not been implemented on large scale in the area. Application of Science and Technology for Rural Areas (ASTRA) from Indian Institute of Science designed the driers and disseminated

information locally through Technology Demonstration Center in Sirsi. Training was given to people on the details of manufacturing and distributed locally by trained people for fuel efficient drying of materials of which most were used for only agricultural purposes. It has also been distributed locally by organizations and government departments with subsidy but it has all been on experimental basis. The effectiveness of ASTRA driers are not well realized by local people. Thus there are less than 10 ASTRA ovens installed in the study area presently. Added to this fact, cost of ASTRA driers varies from 35,000 INR to 1,30,000 INR (525 to 1950 USD) based on the quantity output produced. This remains out of reach for even average income households. Some of the organizations installed few community ovens in few villages, which were also monitored to understand the sharing oven between many households. Attempts to extract juice from *Garcinia gummi-gutta* fruits and supply to the industry have also failed for the reasons of its decomposition in the weather condition and concerns over transportation.

Aghanashini Lion-tailed macaque Conservation Reserve was considered as a critical habitat and declared as a protected area by the state government of Karnataka. The purpose of notification was to “protect, propagate and develop” this habitat for the inhabiting endangered and endemic flora and fauna keeping lion-tailed macaque as a flagship species. With the high overlap of resource use between humans and lion-tailed macaque, sustainability in resource extraction is postulated as a management strategy in view of long term benefits for both. The present chapter provides the model for processing and marketing of *Garcinia gummi-gutta* rind. It presents the summary of interviews with all stakeholders in the view of reducing the pressure on forest, considering the interests of sustained harvester’s income. The possibilities and potential of different models for sustainable harvesting, marketing of *Garcinia gummi-gutta* and the interventions required from the governance and stakeholders are discussed.

Methods

The identified households (N=73) for the long-term monitoring of Non-Timber Forest Products collection and their livelihood in the study site were revisited. Data collection on

livelihood, agricultural land holdings, yearly income, and quantity of harvests and marketing of those Non-Timber Forest Products from those households were continued.

Questionnaire survey was carried out for households that fell under three VFC jurisdiction (N=31) for opinion on VFC functioning mechanism, advantages and limitations of VFC mediated *Garcinia gummi-gutta* trade, knowledge and preference of ASTRA ovens and their willingness and conditions to use the oven in the future. Additionally, questionnaire survey was carried out for two deputy range officers of the forest department handling VFC mediated auctions (N=10). Information was collected on the challenges faced during auctioning of *Garcinia gummi-gutta* and the expected interventions required from higher officials for achieving expected results. Questionnaire survey was carried out for ASTRA oven users of the area (N=14) and information was collected on purpose of installations, usage, fuel wood efficiency for drying *Garcinia gummi-gutta* and the overall advantages and drawbacks of ovens.

Personal meetings were held with the concerned officials of leading industries (N=3) that use the *Garcinia gummi-gutta* rind as a raw material about value addition and marketing the products made of *Garcinia gummi-gutta*. Data on their perspectives of *Garcinia gummi-gutta* marketing, challenges and limitations in the existing mechanism and its mitigation was also collected. Detailed discussions were held and inputs collected on the possibilities of streamlining the trade of *Garcinia gummi-gutta*.

Existing and suggested strategies for harvesting-marketing of the *Garcinia gummi-gutta*:

*Existing marketing dynamics of *Garcinia gummi-gutta**

The mechanism of marketing of the products in the study area is enunciated Fig. 5.3.1. The harvesters from the villages with VFC sell the produce through VFC (55.00% of households) and through intermediaries at villages (45.00% of households). On the other hand, harvesters in a villages without VFC sell the produce directly to the bidder or through the village intermediaries (100.00% of households) or sometimes directly to the shops in nearby town. A small part of the produce reaches the market for domestic consumption.

Majority reaches the supplier who does the value addition by extracting Hydroxy Citric Acid and sells it to the industry. Some industries have their own supply unit present internally while others get from external suppliers.

Limitations of present harvesting, role of VFC, tenders and industry

Harvesting

An average of ~ 8 million kg/year of firewood is used to dry the rind in the study area, since majority of harvesters are using traditional open fire oven .24.00% of harvest from the forests is unripe fruits in villages without awareness as compared to villages with awareness (13.63%, This is probably due to intense competition for getting higher harvests due to inconsistent market prices). Harvesters cannot take the produce at large scale to nearby town expecting higher prices. The products will be confiscated at forest check posts for illegal trading with black market (Forest Department Sources). Interaction with local people confirmed that storage of produce at households is risky due to fungal infestation and loss in gross rind weight during the high humid conditions.

Village Forest Committees (VFC):

Since the tendering happens separately for VFC area and non-VFC area, bidders do not show interest in VFC tenders due to relatively less produce collected by VFC in comparison with non-VFC area as opined by the forest personnel on ten VFCs. Among three VFCs monitored, auctioning has never happened in one VFC, and in other two VFCs it was irregular. One of the deputy range officer opines that there is a need for de-centralizing the auctions to the range offices for effective management of auction. 12 members belonging to 2 VFCs expressed that the functioning of VFC is not transparent while 8 members informed it is transparent. The other 10 members of other VFC opined that there are no VFC mediated auctions. One of the deputy range officer representing managing 5 VFC opines that there is no consistent for the price in all the areas.

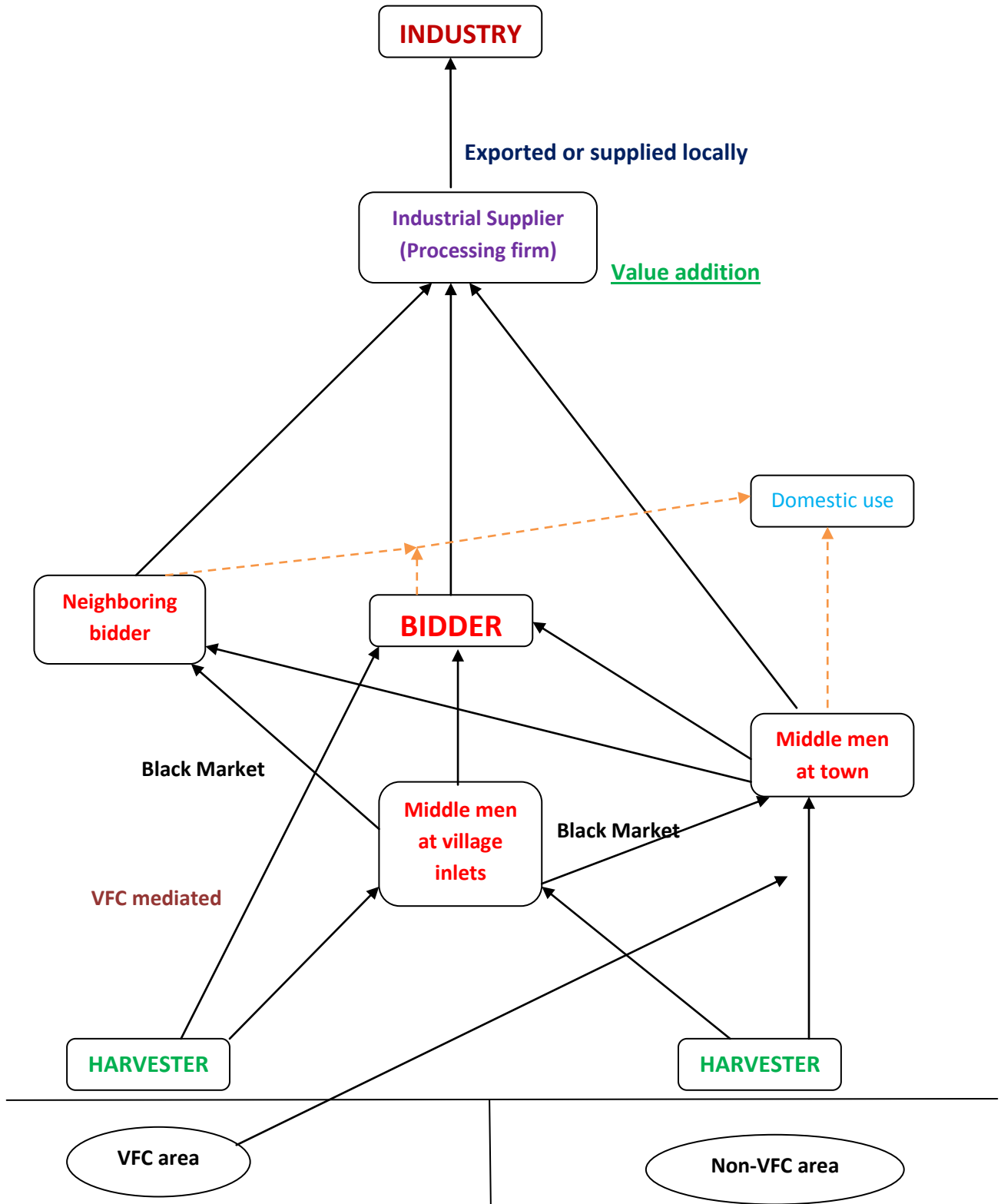


Figure 5.3.1 Existing mechanism of marketing of *Garcinia gummi-gutta*

Both the forest department personnel admit that VFCs do not prioritize the implementation of sustainable harvesting techniques by harvesters. It was observed that tendering did not happen during our study period for some of the VFCs and forest ranges at right time. This triggered the black market operations to monopolize on trading. Miscommunication exists between local people in VFC and forest department in some of the area creating friction between the two. People sampled from two VFC opine that regular meetings are not held through the VFC. 3 VFCs among the sample do not have seed money to buy products on daily basis from harvesters. Among 10 VFC sampled, one of the VFC expressed that they were unable to compete with open market and convince harvesters to sell products through them. VFCs cannot be established in many villages, as they do not qualify the basic criteria for VFC establishment. Therefore, there are a large number of villages harvesting *Garcinia gummi-gutta*, which do not come under VFC.

Tenderers

There is no tenural security for buying products, due to uncertainty of winning the tender repeatedly. Thus, they do not stress on the need of sustainable harvesting by harvesters (Rai and Uhl 2004). The prices fixed for different quality products vary only marginally. The prices fixed for the product varies across years and multiple times in the same season (95.65% households). Tenderers have information of both the productivity from the forest and the projected demand from the industry in a particular year, which turns out to be advantageous for them (Rai and Uhl 2004). Some tenderers in the past have done adulterations by adding salt, sand and iron filings to the dried rind for increasing the weight of the product as opined by one of the industry.

Industry

Industries are highly dependent on suppliers for the raw material. They incur loss in buying adulterated products. The cost of production regularly varies due to instability in the market which implies on the selling price affecting their margin. This makes them susceptible to fluctuations in market. All of the industries sampled opine that they cannot take part in VFC auctions and win tenders competing with others.

Possible mitigation of limitations

Usage of ASTRA ovens reduces the fuel consumption to less than one fourth of consumption from traditional oven (Hegde and Vasudeva 2010). The fuel wood can be further reduced by using dry agricultural biomass for processing which is available in abundance. Among the interviewed oven users, 61.00% of them used it to process *Garcinia gummi-gutta* rind of whom all users confirmed that their fuel wood usage has gone down to less than 4 kg to dry a unit kg of dry rind. Additionally, they claimed it to be multipurpose (63.00%), with less smoke (38.00%), with no fire accidents (38.00%), ease in processing (38.00%), good quality product produced (25.00%) and more value for the product in market (13.00%). Most households are willing to buy ASTRA driers (96.77%) if given in subsidized rate with the facility of installment paying. Community driers were not successful for drying *Garcinia gummi-gutta* as none of the families agreed that they could share it equally with other families during harvest season. This was because of the short time available for processing the rind due to high competition.

57.14% of the people of villages doing VFC mediated marketing have the opinion that VFC marketing is advantageous due to high financial security. Thus it confirms that some people have confidence towards the potential of VFC. There is a need to convince harvesters towards timely and sustainable harvests by meetings by VFC. In areas where VFCs are not established, forest department personnel around harvest season need to initiate meetings. The frequency of untimely fruit harvest and unsustainable practices of harvesting can be lowered by forest department with the support of VFC by effective scrutiny and monitoring of harvests. Regular meetings need to happen to bridge the gap between forest department and people.

An auction for produce from all the VFCs of the range needs to happen at one instance in a particular place. This will not only increase the quantity auctioned but also increases the buyer's interest in VFC auction. This may lead to constancy and regularity in auction every year.

There is an urgent need to install VFCs in maximum number of villages possible. In places where it cannot be installed, nearest VFC need to take up the responsibility to collect the produce. Following this, capacity building of all VFCs is one of the most critical steps in sustainable harvest mechanism. Most villages lack common warehouses for storing their forest products. The present priorities of VFCs of the area need to be critically analyzed and needed interventions are to be taken up to bring transparency. The absence of seed money for many of the already installed VFCs is however a serious drawback for smooth functioning. There is a need to win the confidence of harvesters, especially the ones with low income towards the possibilities of VFC marketing. A prompt business initiative by the VFC such as immediate payment in exchange of received harvest is a simple, yet effective way to achieve success.

There is a need for consulting the industry by the forest department for initiating negotiations for direct sale of products eliminating the middle men. Industries are open for entering a memorandum of understanding (one of the industries) with the VFC groups (need to constitute a cooperative society) for constantly buying products. Necessary administrative interventions need to be addressed.

Based on our interaction with local people, resource personnel and forest department we developed two models for sustainable extraction and marketing of *Garcinia gummi-gutta* namely: **1. Harvester- VFC-Industry model** and **2. Harvester- VFC processing-Industry model**

1. The harvester from VFC area sells his products to the VFC. All neighboring villages which do not fall in the jurisdiction of VFC also sell to the nearest VFC. The VFC maintains a separate account for the villages of non-VFC area. One time tender is given after stocking of all the produce in the administrative range. Produce is sold directly to the industry for the negotiated price. The rest of the produce is auctioned to suppliers who quote the highest price for the product (Fig 5.3.2).
2. The mechanism of selling by the harvester is similar to previous model except that the value addition is done by processing firms co-operatively mediated by VFC and forest department and sold to the industry through the proper channel (Fig 5.3.3).

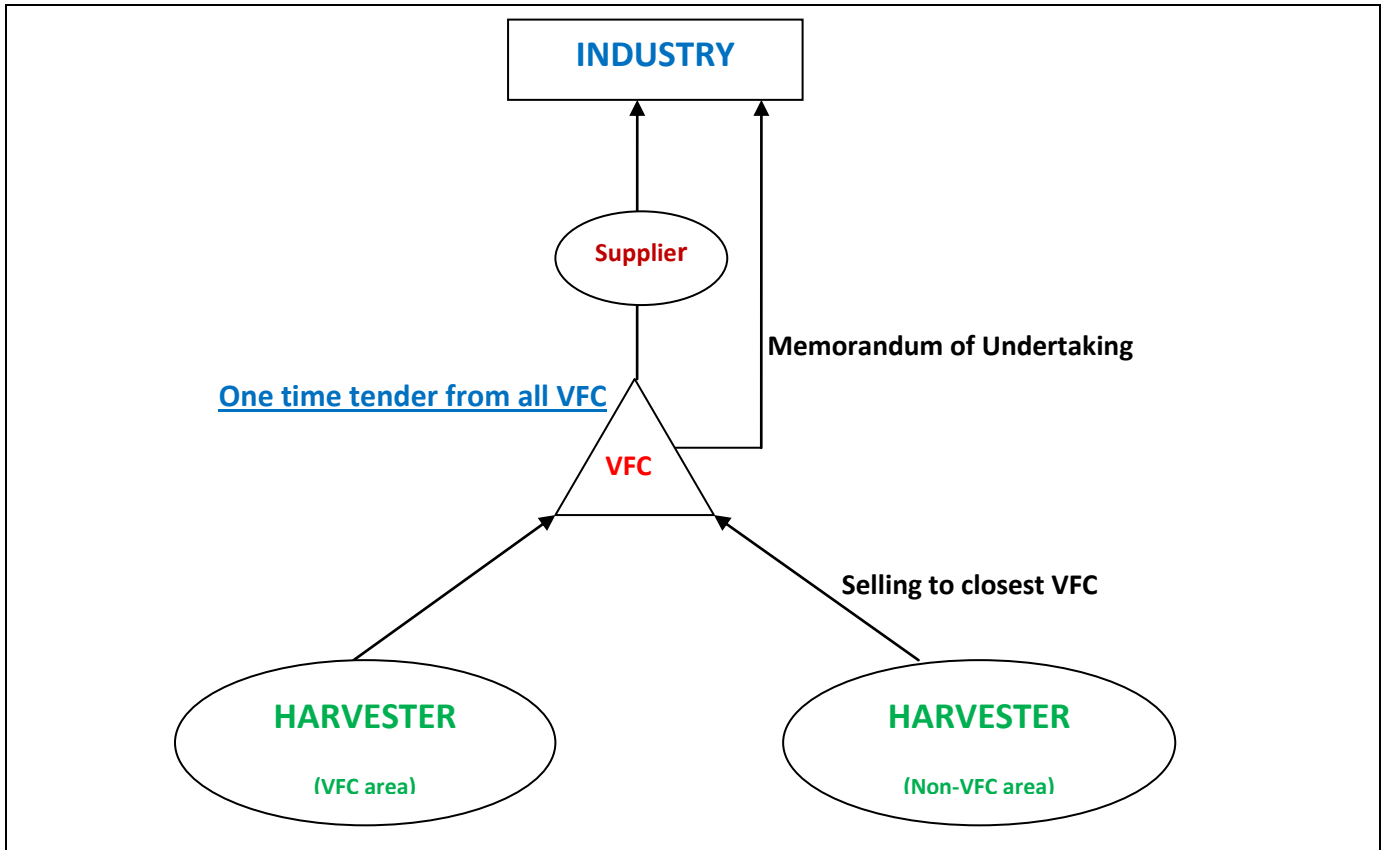


Fig 5.3.2 Flowchart of harvester-VFC-Industry model

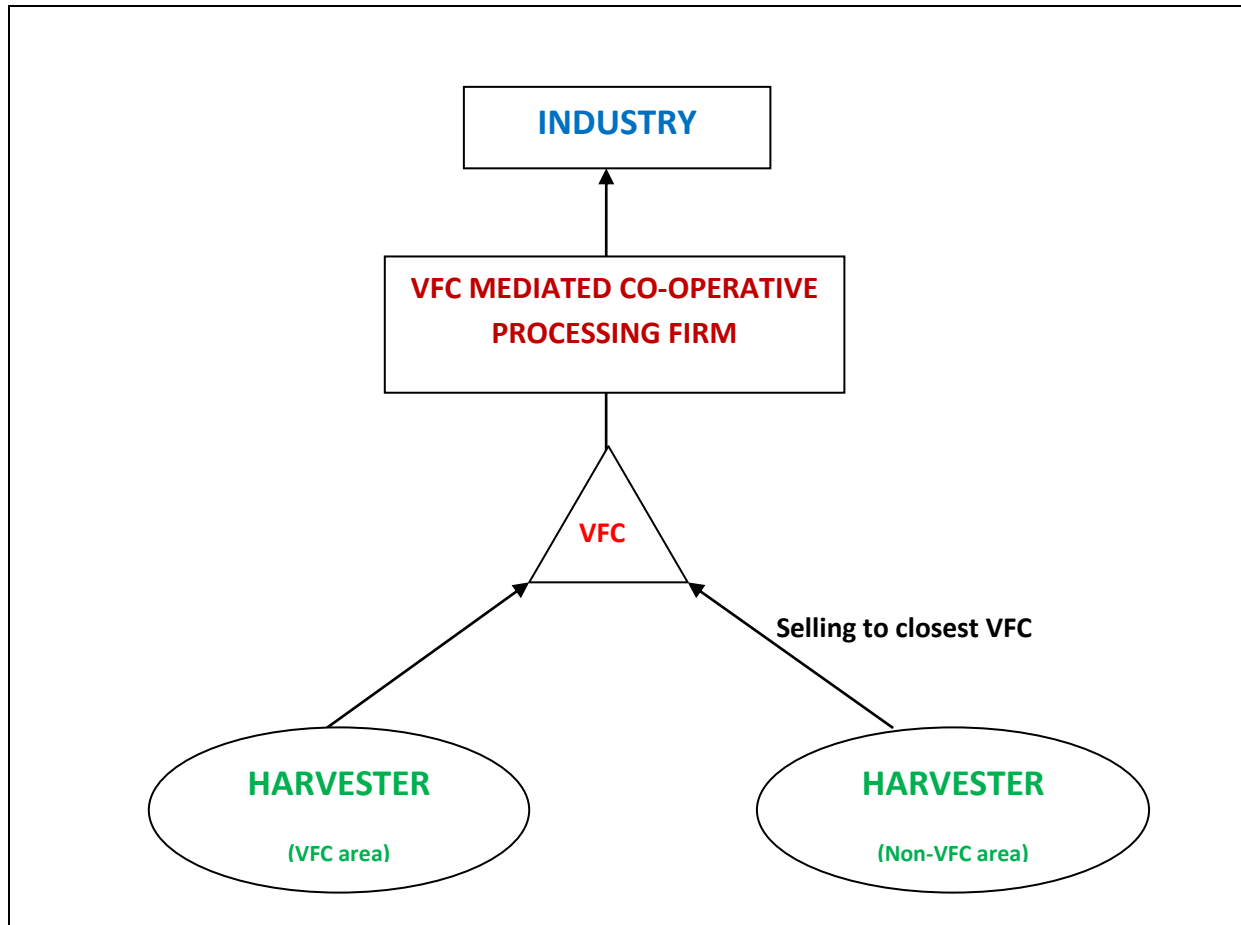


Fig 5.3.3 Flowchart of Harvester-VFC processing-Industry model

Other issues and suggestions for conservation

The formation of Aghanashini-Lion-tailed macaque Conservation Reserve was a first step towards the protection of the area. However, there are several issues in the area; of which the most critical issues have been discussed in the previous chapters and enumerated overleaf. The most important being, streamlining the harvesting to ensure right time and method of harvesting of non-timber forest products. Distribution and usage of fuel efficient

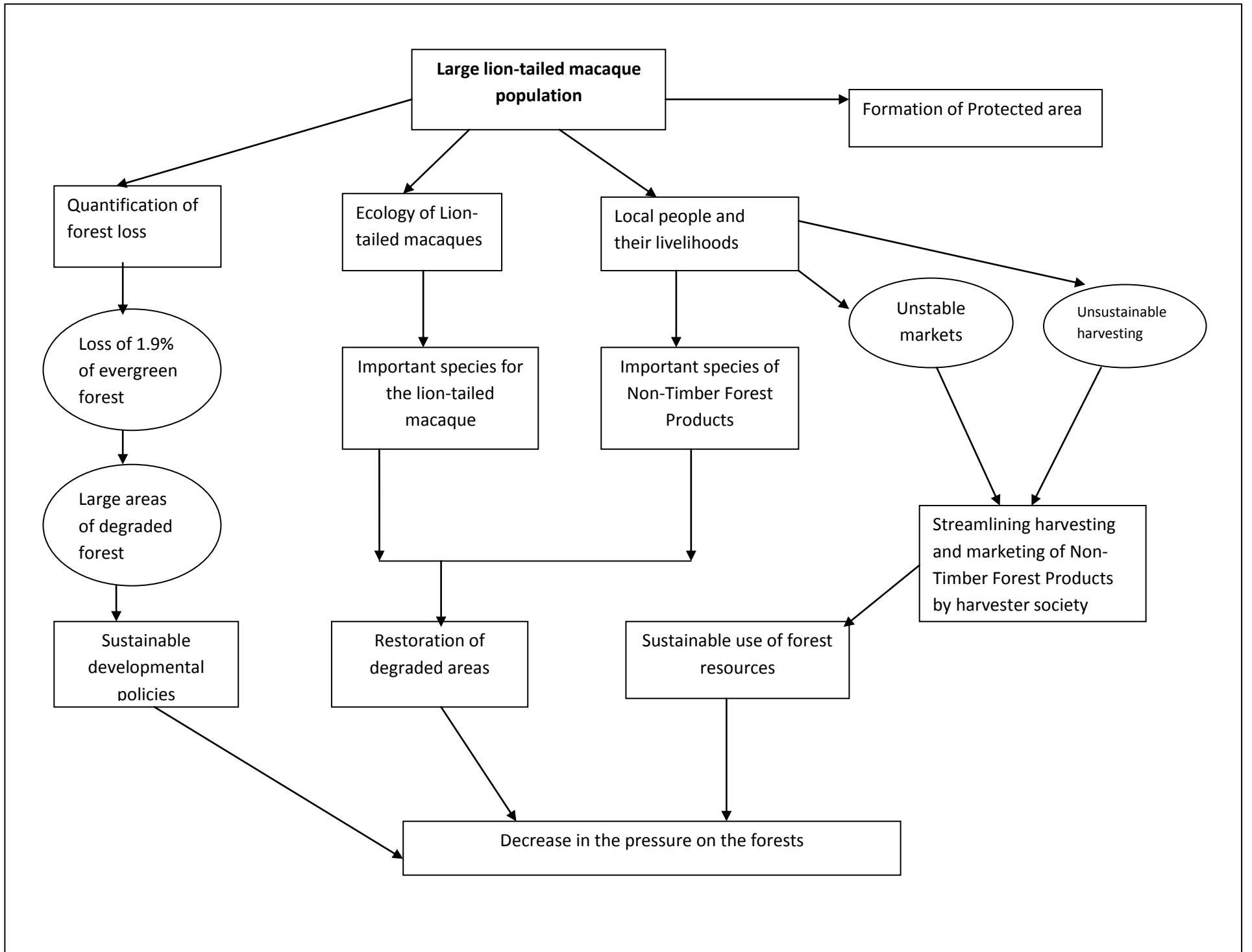
driers for processing of *Garcinia gummi-gutta* is also critical. Formation of multi-stakeholder society to monitor and market non-timber forest products will ensure sustainability and quality of products.

However, other important conservation issues that need attention in the future are listed. Firstly, it is very critical to map the reserve entirely covering all the forest types, agricultural lands, corridors, grasslands and degraded forests. This information helps to identify and prioritize areas for restoration of the habitat. The plant species important for both lion-tailed macaques and people may however be used for restoration.

Secondly, there is a need to study the different types of agricultural practices and influence the people to take up Low Input Sustainable Agriculture which helps to reduce the dependence of resources from the forest.

Lastly, the developmental policies by the government on housing, roads and electrification have been very detrimental to the habitat. Most of these schemes are allotted at the *panchayat* level which is the local administrative body. The families are encouraged to increase their households by breaking into smaller nuclear families. This is because of the benefit from freebies such as free rations for cereals, fuel and sugar in addition to free houses and roads. There is a need to relook at these schemes to suit the local conditions which can be well accommodated with the habitat. However, the challenge remains in bringing all stakeholders under one roof to resolve these critical issues.

The flow chart illustrated below gives a comprehensive information research findings and conservation activity in the area. Thus, it can be concluded that the area hold a high potential for survival of a large number wildlife species along with restoring the interests and economy of local people, administrators and forest department. In which case, the Aghanashini-Lion-tailed macaque Conservation Reserve may become a model area for showing conservation success for the country.



Appendices

Appendix 2.1. Details of lion-tailed macaque group sightings in Sirsi-Honnava forests

| Group ID | PROBABLE GROUP | GROUP SIZE | LAT-LONG |
|----------|----------------------|------------|----------------------------|
| HV1 | Sannmanegudde | 6+ | N14°18'48.1" E74°39'24.5" |
| HV2 | Maavinamarada savalu | 9+ | N14°20'14.8" E74°37'35.5" |
| KU1 | Hirebylu | 12 | N14°24'18.5" E74°37'8.3" |
| KD1 | Hoskaanu | 17 | N14°21'4.2" E74°40'30.5" |
| KD2 | Krishnaghatta | 24 | N14°21'10.9" E74°40'0.8" |
| KD3 | Hosathota | 17 | N14°20'18.4" E74°40'13.4" |
| KD4 | Sarvan thota | 20 | N14°19'9.2" E74°39'53.6" |
| KD5 | Appae gadde sirlu | 30 | N14°20'26.8" E74°38'31.8" |
| KD6 | Dasur | 26 | N14°19'19.9" E74°40'26.4" |
| KD7 | Kudegodu | 22 | N14°19'38.0" E74°41'5.2" |
| KD8 | Hapregoli | 15 | N14°18'25.0" E74°42'56.4" |
| KD9 | Kalegadde | 20 | N14°18'19.8" E74°42'3.0 " |
| KD10 | Galmav | 15 | N14°17'54.5" E74°42'8.5" |
| KD11 | Suthlumane | 19 | N14°17'36.4" E74°44'0.9" |
| KD12 | Doddgudde kaanu | 19 | N14°17'31.9" E74°43'37.2" |
| KD13 | Kotegudda | 17 | N14°17'16.9" E74°43'32.0" |
| KD14 | Hukkali | 22 | N14°17'17.6" E74°45' 0.7" |
| KD15 | Tormai | 21 | N14°18'44.5" E74°41' 35.1" |
| KD16 | Hegdegadde halla | 1 | N14°19'48.1" E74°38'57.0" |
| SD1 | Malemane | 35 | N14°17'16.7" E74°43'20.4" |
| SD2 | Kathlekaanu | 14 | N14°16'25.4" E74°44'16.9" |
| GR1 | Hasuvalli | 7+ | N14°18'55.22" E74°34'28.0" |
| GR2 | Kodgi-Kerigadde | 25 | N14°18'23.4" E74°37'55.5" |
| GR3 | Kendikuli | 9+ | N14°17'57.5" E74°40'26.9" |
| GR4 | Mahime | - | N14°17' 16.7" E74°43'20.4" |
| GR5 | Sasiguli-A | 13 | N14°17'15.1" E74°41'3.2" |
| GR6 | Sasiguli_B | 33 | N14°17'25.2" E74°41'12.7" |
| GR7 | Dundmav-A | 14 | N14°17'11.1" E74°42'3.6" |
| GR8 | Dundmav-B | 23 | N14°17'45" E74°42'17.5" |
| GR9 | Matnigadde | 21 | N14°16'53.9" E74°42'38.9" |
| GR10 | Vatehalla | 17+ | N14°16'15.72" E74°42'56.8" |
| GR11 | Vatehalla | 1 | N14°16'15.72"E74°42'56.8" |
| GR12 | Vatehalla | 1 | N14°16'15.72" E74°42'56.8" |
| GR13 | Water falls | 6+ | N14°16'36.4" E74°42'17" |

HV-Honnava; KU-Kumta; KD-Kyadagi; SD-Siddapura; GR-Gersoppa; + indicates incomplete group size

Appendix 3.1.1 Density and Important Value Index (IVI) for woody plants in Hosthota area.

| Name of the species | Family | N | No. of plots | GBH (m) | F | A | D | RF | RA | RD | BA | IVI |
|---------------------------------|------------------|-----|--------------|---------|------|-----|-----|-----|-----|------|------|------|
| <i>Knema attenuata</i> | Myristicaceae | 238 | 93 | 153.2 | 70.5 | 2.6 | 1.8 | 9.8 | 2.9 | 15.8 | 8.9 | 28.6 |
| <i>Diospyros sylvetrica</i> | Ebanaceae | 185 | 87 | 154.6 | 65.9 | 2.1 | 1.4 | 9.2 | 2.4 | 12.3 | 12.4 | 23.9 |
| <i>Hopea ponga</i> | Dipterocarpaceae | 158 | 58 | 116.2 | 43.9 | 2.7 | 1.2 | 6.1 | 3.1 | 10.5 | 9.1 | 19.8 |
| <i>Holigarna arnottiana</i> | Anacardiaceae | 111 | 70 | 100.8 | 53.0 | 1.6 | 0.8 | 7.4 | 1.8 | 7.4 | 9.7 | 16.6 |
| <i>Olea dioica</i> | Oleaceae | 97 | 54 | 90.9 | 40.9 | 1.8 | 0.7 | 5.7 | 2.1 | 6.5 | 9.0 | 14.2 |
| <i>Garcinia morella</i> | Clusiaceae | 87 | 59 | 39.4 | 44.7 | 1.5 | 0.7 | 6.2 | 1.7 | 5.8 | 1.5 | 13.7 |
| <i>Garcinia gummi-gutta</i> | Clusiaceae | 59 | 42 | 38.5 | 31.8 | 1.4 | 0.4 | 4.4 | 1.6 | 3.9 | 2.7 | 10 |
| <i>Ixora brachiata</i> | Rubiaceae | 38 | 36 | 17.1 | 27.3 | 1.1 | 0.3 | 3.8 | 1.2 | 2.5 | 0.7 | 7.5 |
| <i>Aglaia roxburghiana</i> | Meliaceae | 39 | 25 | 25.3 | 18.9 | 1.6 | 0.3 | 2.6 | 1.8 | 2.6 | 1.3 | 7.0 |
| <i>Diospyros buxifolia</i> | Ebanaceae | 32 | 27 | 36.6 | 20.5 | 1.2 | 0.2 | 2.9 | 1.4 | 2.1 | 4.4 | 6.3 |
| <i>Syzigium gardneri</i> | Myrtaceae | 28 | 25 | 44.0 | 18.9 | 1.1 | 0.2 | 2.6 | 1.3 | 1.9 | 10.7 | 5.8 |
| <i>Aparosa lindelana</i> | Euphorbiaceae | 26 | 21 | 16.4 | 15.9 | 1.2 | 0.2 | 2.2 | 1.4 | 1.7 | 0.9 | 5.4 |
| <i>Pterospermum reticulatum</i> | Sterculiaceae | 25 | 14 | 18.3 | 10.6 | 1.8 | 0.2 | 1.5 | 2.0 | 1.7 | 1.6 | 5.2 |
| <i>Vitex altissema</i> | Verbenaceae | 20 | 18 | 32.0 | 13.6 | 1.1 | 0.2 | 1.9 | 1.3 | 1.3 | 5.2 | 4.5 |
| <i>Flacourtia montana</i> | Flacortiaceae | 20 | 18 | 16.1 | 13.6 | 1.1 | 0.2 | 1.9 | 1.3 | 1.3 | 0.9 | 4.5 |
| <i>Nathopegia racemosa</i> | Anacardiaceae | 20 | 15 | 10.8 | 11.4 | 1.3 | 0.2 | 1.6 | 1.5 | 1.3 | 0.6 | 4.4 |
| <i>Litsea stocksii</i> | Lauraceae | 19 | 16 | 13.3 | 12.1 | 1.2 | 0.1 | 1.7 | 1.4 | 1.3 | 0.8 | 4.3 |
| <i>Symplocos racemosa</i> | Symplocaceae | 19 | 14 | 13.4 | 10.6 | 1.4 | 0.1 | 1.5 | 1.6 | 1.3 | 0.9 | 4.3 |
| <i>Artocarpus hirsutus</i> | Moraceae | 16 | 14 | 13.2 | 10.6 | 1.1 | 0.1 | 1.5 | 1.3 | 1.1 | 1.3 | 3.9 |
| <i>Lopopetalum whitianum</i> | Celastraceae | 12 | 8 | 18.4 | 6.1 | 1.5 | 0.1 | 0.8 | 1.7 | 0.8 | 3.7 | 3.4 |
| <i>Memecylon malabaricum</i> | Melastomaceae | 12 | 11 | 5.4 | 8.3 | 1.1 | 0.1 | 1.2 | 1.2 | 0.8 | 0.2 | 3.2 |
| <i>Eleocarpus serratus</i> | Urticaceae | 12 | 11 | 6.0 | 8.3 | 1.1 | 0.1 | 1.2 | 1.2 | 0.8 | 0.2 | 3.2 |
| <i>Cassine glauca</i> | Celastraceae | 12 | 12 | 17.0 | 9.1 | 1.0 | 0.1 | 1.3 | 1.1 | 0.8 | 3.4 | 3.2 |
| <i>Mangefera indica</i> | Anacardiaceae | 12 | 12 | 8.2 | 9.1 | 1.0 | 0.1 | 1.3 | 1.1 | 0.8 | 0.5 | 3.2 |
| <i>Litsea floribonda</i> | Lauraceae | 12 | 11 | 9.6 | 8.3 | 1.1 | 0.1 | 1.2 | 1.2 | 0.8 | 0.8 | 3.2 |
| <i>Persia macarantha</i> | Lauraceae | 11 | 10 | 18.0 | 7.6 | 1.1 | 0.1 | 1.1 | 1.3 | 0.7 | 2.9 | 3.0 |
| <i>Actinodaphne hookeri</i> | Lauraceae | 10 | 8 | 6.8 | 6.1 | 1.3 | 0.1 | 0.8 | 1.4 | 0.7 | 0.4 | 2.9 |
| <i>Belsmedia whitii</i> | Lauraceae | 10 | 9 | 7.6 | 6.8 | 1.1 | 0.1 | 1.0 | 1.3 | 0.7 | 0.7 | 2.9 |
| <i>Diospyros candolliana</i> | Ebanaceae | 10 | 9 | 6.6 | 6.8 | 1.1 | 0.1 | 1.0 | 1.3 | 0.7 | 0.4 | 2.9 |
| <i>Dimocarpus longan</i> | Sapindaceae | 10 | 8 | 5.8 | 6.1 | 1.3 | 0.1 | 0.8 | 1.4 | 0.7 | 0.3 | 2.9 |
| <i>Mimusops elengi</i> | Sapotaceae | 10 | 9 | 9.1 | 6.8 | 1.1 | 0.1 | 1.0 | 1.3 | 0.7 | 0.7 | 2.9 |
| <i>Macarange peltata</i> | Euphorbiaceae | 9 | 7 | 5.4 | 5.3 | 1.3 | 0.1 | 0.7 | 1.5 | 0.6 | 0.3 | 2.8 |
| <i>Xantolis tomentosa</i> | Sapotaceae | 4 | 2 | 2.1 | 1.5 | 2.0 | 0.0 | 0.2 | 2.3 | 0.3 | 0.1 | 2.8 |
| <i>Myristica dactyloides</i> | Myristicaceae | 9 | 8 | 6.1 | 6.1 | 1.1 | 0.1 | 0.8 | 1.3 | 0.6 | 0.5 | 2.7 |
| <i>Holigarna grahmi</i> | Anacardiaceae | 8 | 7 | 7.4 | 5.3 | 1.1 | 0.1 | 0.7 | 1.3 | 0.5 | 0.7 | 2.6 |
| <i>Tabernamontana heyinana</i> | Apocynaceae | 8 | 8 | 3.3 | 6.1 | 1.0 | 0.1 | 0.8 | 1.1 | 0.5 | 0.1 | 2.5 |
| <i>Aalsea daphni</i> | Lauraceae | 2 | 1 | 3.0 | 0.8 | 2.0 | 0.0 | 0.1 | 2.3 | 0.1 | 0.4 | 2.5 |
| <i>Chrysophyllum roxburghii</i> | Sapotaceae | 6 | 5 | 4.7 | 3.8 | 1.2 | 0.0 | 0.5 | 1.4 | 0.4 | 0.3 | 2.3 |

| Name of the species | Family | N | No. of plots | GBH (m) | F | A | D | RF | RA | RD | BA | IVI |
|---------------------------------|----------------|---|--------------|---------|-----|-----|-----|-----|-----|-----|-----|-----|
| <i>Myristica malabarica</i> | Myristicaceae | 7 | 7 | 4.4 | 5.3 | 1.0 | 0.1 | 0.7 | 1.1 | 0.5 | 0.3 | 2.3 |
| <i>Diospyros angustifolia</i> | Ebanaceae | 6 | 5 | 2.4 | 3.8 | 1.2 | 0.0 | 0.5 | 1.4 | 0.4 | 0.1 | 2.3 |
| <i>Callophylum tomentosum</i> | Clusiaceae | 6 | 5 | 9.2 | 3.8 | 1.2 | 0.0 | 0.5 | 1.4 | 0.4 | 1.4 | 2.3 |
| <i>Lageostromia microcarpa</i> | Lythraceae | 5 | 4 | 7.3 | 3.0 | 1.3 | 0.0 | 0.4 | 1.4 | 0.3 | 0.9 | 2.2 |
| <i>Caryota urens</i> | Aracaceae | 3 | 2 | 2.6 | 1.5 | 1.5 | 0.0 | 0.2 | 1.7 | 0.2 | 0.2 | 2.1 |
| <i>Careya arborea</i> | Aracaceae | 3 | 2 | 1.5 | 1.5 | 1.5 | 0.0 | 0.2 | 1.7 | 0.2 | 0.1 | 2.1 |
| <i>Syzizium hemispermicum</i> | Myrtaceae | 3 | 2 | 3.7 | 1.5 | 1.5 | 0.0 | 0.2 | 1.7 | 0.2 | 0.4 | 2.1 |
| <i>Cinnamomum malabathrum</i> | Lauraceae | 4 | 4 | 2.1 | 3.0 | 1.0 | 0.0 | 0.4 | 1.1 | 0.3 | 0.1 | 1.8 |
| <i>Garcinia talbotti</i> | Clusiaceae | 4 | 4 | 4.2 | 3.0 | 1.0 | 0.0 | 0.4 | 1.1 | 0.3 | 0.8 | 1.8 |
| <i>Maduca longifolia</i> | Sapotaceae | 4 | 4 | 3.3 | 3.0 | 1.0 | 0.0 | 0.4 | 1.1 | 0.3 | 0.2 | 1.8 |
| <i>Carallia brachiata</i> | Rhizophoraceae | 3 | 3 | 1.3 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 0.0 | 1.7 |
| <i>Diospyros montana</i> | Ebanaceae | 3 | 3 | 2.4 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 0.2 | 1.7 |
| <i>Neolitsia zeylanica</i> | Lauraceae | 4 | 5 | 2.7 | 3.8 | 0.8 | 0.0 | 0.5 | 0.9 | 0.3 | 0.2 | 1.7 |
| <i>Canthium dicoccum</i> | Rubiaceae | 4 | 5 | 2.0 | 3.8 | 0.8 | 0.0 | 0.5 | 0.9 | 0.3 | 0.1 | 1.7 |
| <i>Homelium zeylanicum</i> | Flacortiaceae | 3 | 3 | 1.2 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 0.0 | 1.7 |
| <i>Canerium strictum</i> | Burseraceae | 2 | 2 | 2.0 | 1.5 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.2 | 1.5 |
| <i>Chukrasia tabularis</i> | Liliaceae | 2 | 2 | 4.0 | 1.5 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.7 | 1.5 |
| <i>Artocarpus heterophyllus</i> | Moraceae | 2 | 2 | 1.7 | 1.5 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.1 | 1.5 |
| <i>Syzizium laetum</i> | Myrtaceae | 2 | 2 | 0.9 | 1.5 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.0 | 1.5 |
| <i>Syzygium cumini</i> | Myrtaceae | 2 | 2 | 4.1 | 1.5 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.7 | 1.5 |
| <i>Callicarpa tomentosa</i> | Verbinaceae | 2 | 2 | 0.8 | 1.5 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.0 | 1.5 |
| <i>Drypetes confertifolius</i> | Euphorbiaceae | 1 | 1 | 1.0 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.1 | 1.3 |
| <i>Callophylum apetalum</i> | Clusiaceae | 1 | 1 | 0.1 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.3 |
| <i>Sterculia guttata</i> | Sterculiaceae | 1 | 1 | 0.8 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.1 | 1.3 |
| <i>Ficus microcarpa</i> | Moraceae | 1 | 1 | 4.7 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 1.8 | 1.3 |
| <i>Steriospermum personatum</i> | Bignonianaceae | 1 | 1 | 1.7 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.2 | 1.3 |
| <i>Euodia lunu-ankenda</i> | Rutaceae | 1 | 1 | 0.5 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.3 |
| <i>Syzygium sp.</i> | Myrtaceae | 1 | 1 | 1.4 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.2 | 1.3 |
| <i>Albizia lebbbeck</i> | Mimosaceae | 1 | 1 | 1.9 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.2 | 1.3 |
| <i>Prunus ceylanica</i> | Rosaceae | 1 | 1 | 1.5 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.2 | 1.3 |
| <i>Glochidion velutinum</i> | Euphorbiaceae | 1 | 1 | 0.4 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.3 |
| <i>Hydnocarpus pentandra</i> | Flacortiaceae | 1 | 1 | 1.8 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.2 | 1.3 |
| <i>Artocarpus lakoocha</i> | Moraceae | 1 | 1 | 0.7 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.3 |
| <i>Polyanthia fragrens</i> | Anonaceae | 1 | 2 | 0.9 | 1.5 | 0.5 | 0.0 | 0.2 | 0.6 | 0.1 | 0.1 | 0.8 |

N- Number of Individuals, GBH- Girth at Breast Height, F-Frequency, A-Abundance, D-Density, RF-Relative Frequency, RA-Relative Abundance, RD- Relative Density, BA-Basal Area, IVI-Importance Value Index

Appendix 3.1.2 Density and Important Value Index (IVI) for woody plants in Chiksuli area.

| Name of the species | Family | N | No. of plots | GBH (m) | F | A | D | RF | RA | RD | BA | IVI |
|---------------------------------|------------------|-----|--------------|---------|------|-----|-----|-----|-----|-----|------|------|
| <i>Olea dioica</i> | Oleaceae | 128 | 57 | 135.7 | 44.5 | 2.2 | 1.0 | 6.4 | 2.4 | 9.1 | 15.4 | 17.9 |
| <i>Knema attenuata</i> | Myristicaceae | 100 | 60 | 76.3 | 46.9 | 1.7 | 0.8 | 6.7 | 1.8 | 7.1 | 5.4 | 15.6 |
| <i>Aglaia roxburghiana</i> | Meliaceae | 92 | 54 | 67.3 | 42.2 | 1.7 | 0.7 | 6.0 | 1.8 | 6.6 | 5.0 | 14.4 |
| <i>Garcinia talbotii</i> | Clusiaceae | 89 | 36 | 72.6 | 28.1 | 2.5 | 0.7 | 4.0 | 2.6 | 6.4 | 5.6 | 13.0 |
| <i>Hopea ponga</i> | Dipterocarpaceae | 79 | 34 | 59.2 | 26.6 | 2.3 | 0.6 | 3.8 | 2.5 | 5.6 | 4.4 | 11.9 |
| <i>Dimocarpus longan</i> | Sapindaceae | 72 | 43 | 43.5 | 33.6 | 1.7 | 0.6 | 4.8 | 1.8 | 5.1 | 2.6 | 11.7 |
| <i>Garcinia morella</i> | Clusiaceae | 73 | 37 | 37.0 | 28.9 | 2.0 | 0.6 | 4.1 | 2.1 | 5.2 | 1.6 | 11.4 |
| <i>Holigarna arnottiana</i> | Anacardiaceae | 64 | 44 | 45.2 | 34.4 | 1.5 | 0.5 | 4.9 | 1.5 | 4.6 | 3.0 | 11.0 |
| <i>Litsea stocksii</i> | Lauraceae | 52 | 33 | 34.4 | 25.8 | 1.6 | 0.4 | 3.7 | 1.7 | 3.7 | 2.0 | 9.1 |
| <i>Xylia xylocarpa</i> | Fabaceae | 54 | 18 | 38.0 | 14.1 | 3.0 | 0.4 | 2.0 | 3.2 | 3.9 | 2.8 | 9.1 |
| <i>Diospyros candolliana</i> | Ebanaceae | 51 | 31 | 37.1 | 24.2 | 1.6 | 0.4 | 3.5 | 1.8 | 3.6 | 2.6 | 8.9 |
| <i>Garcinia gummi-gutta</i> | Clusiaceae | 45 | 35 | 34.7 | 27.3 | 1.3 | 0.4 | 3.9 | 1.4 | 3.2 | 2.8 | 8.5 |
| <i>Litsea floribonda</i> | Lauraceae | 40 | 25 | 31.5 | 19.5 | 1.6 | 0.3 | 2.8 | 1.7 | 2.9 | 2.7 | 7.4 |
| <i>Pterospermum reticulatum</i> | Sterculiaceae | 37 | 20 | 21.2 | 15.6 | 1.9 | 0.3 | 2.2 | 2.0 | 2.6 | 1.1 | 6.8 |
| <i>Nathopegia racemosa</i> | Anacardiaceae | 27 | 23 | 13.6 | 18.0 | 1.2 | 0.2 | 2.6 | 1.3 | 1.9 | 0.6 | 5.7 |
| <i>Belsmedia whitii</i> | Lauraceae | 24 | 23 | 21.3 | 18.0 | 1.0 | 0.2 | 2.6 | 1.1 | 1.7 | 1.9 | 5.4 |
| <i>Symplocos racemosa</i> | Symplocaceae | 23 | 15 | 11.0 | 11.7 | 1.5 | 0.2 | 1.7 | 1.6 | 1.6 | 0.5 | 4.9 |
| <i>Ixora brachiata</i> | Rubiaceae | 21 | 17 | 9.5 | 13.3 | 1.2 | 0.2 | 1.9 | 1.3 | 1.5 | 0.4 | 4.7 |
| <i>Mimusops elengi</i> | Sapotaceae | 21 | 17 | 16.2 | 13.3 | 1.2 | 0.2 | 1.9 | 1.3 | 1.5 | 1.6 | 4.7 |
| <i>Myristica dactyloides</i> | Myristicaceae | 17 | 13 | 11.7 | 10.2 | 1.3 | 0.1 | 1.5 | 1.4 | 1.2 | 0.8 | 4.1 |
| <i>Diospyros angustifolia</i> | Ebanaceae | 16 | 16 | 8.3 | 12.5 | 1.0 | 0.1 | 1.8 | 1.1 | 1.1 | 0.4 | 4.0 |
| <i>Holigarna grahmi</i> | Anacardiaceae | 16 | 16 | 11.4 | 12.5 | 1.0 | 0.1 | 1.8 | 1.1 | 1.1 | 0.8 | 4.0 |
| <i>Euodia lunu-ankenda</i> | Rutaceae | 15 | 11 | 1.3 | 8.6 | 1.4 | 0.1 | 1.2 | 1.5 | 1.1 | 1.3 | 3.8 |
| <i>Vitex altissema</i> | Verbenaceae | 14 | 9 | 19.8 | 7.0 | 1.6 | 0.1 | 1.0 | 1.7 | 1.0 | 2.8 | 3.7 |
| <i>Macaranga peltata</i> | Euphorbiaceae | 14 | 10 | 7.7 | 7.8 | 1.4 | 0.1 | 1.1 | 1.5 | 1.0 | 0.4 | 3.6 |
| <i>Xantolis tomentosa</i> | Sapotaceae | 14 | 12 | 10.2 | 9.4 | 1.2 | 0.1 | 1.3 | 1.2 | 1.0 | 0.7 | 3.6 |
| <i>Maduca longifolia</i> | Sapotaceae | 3 | 1 | 2.6 | 0.8 | 3.0 | 0.0 | 0.1 | 3.2 | 0.2 | 0.2 | 3.5 |
| <i>Eleocarpus serratus</i> | Urticaceae | 13 | 12 | 6.5 | 9.4 | 1.1 | 0.1 | 1.3 | 1.2 | 0.9 | 0.3 | 3.4 |
| <i>Syzizium hemispermicum</i> | Myrtaceae | 12 | 10 | 9.0 | 7.8 | 1.2 | 0.1 | 1.1 | 1.3 | 0.9 | 0.8 | 3.3 |
| <i>Callicarpa tomentosa</i> | Verbinaceae | 12 | 11 | 5.1 | 8.6 | 1.1 | 0.1 | 1.2 | 1.2 | 0.9 | 0.2 | 3.2 |
| <i>Callophylum tomentosum</i> | Clusiaceae | 11 | 11 | 21.4 | 8.6 | 1.0 | 0.1 | 1.2 | 1.1 | 0.8 | 3.6 | 3.1 |
| <i>Ficus nervosa</i> | Moraceae | 9 | 8 | 22.9 | 6.3 | 1.1 | 0.1 | 0.9 | 1.2 | 0.6 | 17.7 | 2.7 |
| <i>Artocarpus hirsutus</i> | Moraceae | 8 | 7 | 5.6 | 5.5 | 1.1 | 0.1 | 0.8 | 1.2 | 0.6 | 0.4 | 2.6 |
| <i>Flacourtia montana</i> | Flacortiaceae | 6 | 4 | 3.1 | 3.1 | 1.5 | 0.0 | 0.4 | 1.6 | 0.4 | 0.1 | 2.5 |
| <i>Mangifera indica</i> | Anacardiaceae | 8 | 8 | 3.2 | 6.3 | 1.0 | 0.1 | 0.9 | 1.1 | 0.6 | 0.1 | 2.5 |
| <i>Glochidion velutinum</i> | Euphorbiaceae | 5 | 3 | 4.3 | 2.3 | 1.7 | 0.0 | 0.3 | 1.8 | 0.4 | 0.4 | 2.5 |

| Name of the species | Family | N | No. of plots | GBH (m) | F | A | D | RF | RA | RD | BA | IVI |
|---------------------------------|---------------|---|--------------|---------|-----|-----|-----|-----|-----|-----|-----|-----|
| <i>Steriospermum personatum</i> | Bignoniaceae | 2 | 1 | 1.1 | 0.8 | 2.0 | 0.0 | 0.1 | 2.1 | 0.1 | 0.1 | 2.4 |
| <i>Memecylon malabaricum</i> | Melastomaceae | 7 | 7 | 2.7 | 5.5 | 1.0 | 0.1 | 0.8 | 1.1 | 0.5 | 0.1 | 2.3 |
| <i>Neolitsia zeylanica</i> | Lauraceae | 6 | 5 | 3.0 | 3.9 | 1.2 | 0.0 | 0.6 | 1.3 | 0.4 | 0.1 | 2.3 |
| <i>Cinnamomum malabathrum</i> | Lauraceae | 7 | 7 | 3.3 | 5.5 | 1.0 | 0.1 | 0.8 | 1.1 | 0.5 | 0.1 | 2.3 |
| <i>Syzizium laetum</i> | Myrtaceae | 7 | 7 | 2.6 | 5.5 | 1.0 | 0.1 | 0.8 | 1.1 | 0.5 | 0.1 | 2.3 |
| <i>Actinodaphne hookeri</i> | Lauraceae | 6 | 6 | 3.1 | 4.7 | 1.0 | 0.0 | 0.7 | 1.1 | 0.4 | 0.2 | 2.2 |
| <i>Tabernamontana heyinana</i> | Apocynaceae | 6 | 6 | 2.2 | 4.7 | 1.0 | 0.0 | 0.7 | 1.1 | 0.4 | 0.1 | 2.2 |
| <i>Casearia beddomi</i> | Flacortiaceae | 6 | 6 | 3.1 | 4.7 | 1.0 | 0.0 | 0.7 | 1.1 | 0.4 | 0.2 | 2.2 |
| <i>Syzygium gardneri</i> | Myrtaceae | 6 | 6 | 10.8 | 4.7 | 1.0 | 0.0 | 0.7 | 1.1 | 0.4 | 2.8 | 2.2 |
| <i>Homelium zeylanicum</i> | Flacortiaceae | 5 | 4 | 2.8 | 3.1 | 1.3 | 0.0 | 0.4 | 1.3 | 0.4 | 0.1 | 2.1 |
| <i>Sterculia guttata</i> | Sterculiaceae | 4 | 3 | 3.7 | 2.3 | 1.3 | 0.0 | 0.3 | 1.4 | 0.3 | 0.3 | 2.0 |
| <i>Cassine glauca</i> | Celastraceae | 4 | 3 | 11.4 | 2.3 | 1.3 | 0.0 | 0.3 | 1.4 | 0.3 | 5.4 | 2.0 |
| <i>Persia macarantha</i> | Lauraceae | 5 | 5 | 5.2 | 3.9 | 1.0 | 0.0 | 0.6 | 1.1 | 0.4 | 0.7 | 2.0 |
| <i>Aparosa lindelana</i> | Euphorbiaceae | 4 | 4 | 2.2 | 3.1 | 1.0 | 0.0 | 0.4 | 1.1 | 0.3 | 0.1 | 1.8 |
| <i>Diospyros buxifolia</i> | Ebanaceae | 4 | 4 | 6.7 | 3.1 | 1.0 | 0.0 | 0.4 | 1.1 | 0.3 | 1.2 | 1.8 |
| <i>Callophylum apetalum</i> | Clusiaceae | 3 | 3 | 2.1 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 0.1 | 1.6 |
| <i>Canerium strictum</i> | Burseraceae | 3 | 3 | 4.2 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 0.5 | 1.6 |
| <i>Alsea daphni</i> | Lauraceae | 3 | 3 | 3.2 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 0.3 | 1.6 |
| <i>Lageostromia microcarpa</i> | Lythraceae | 3 | 3 | 6.0 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 1.0 | 1.6 |
| <i>Nothapodytes nimmoniana</i> | Icacinaceae | 3 | 3 | 1.1 | 2.3 | 1.0 | 0.0 | 0.3 | 1.1 | 0.2 | 0.0 | 1.6 |
| <i>Caryota urens</i> | Aracaceae | 2 | 2 | 1.8 | 1.6 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.1 | 1.4 |
| <i>Canthium dicocum</i> | Rubiaceae | 2 | 2 | 1.3 | 1.6 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.1 | 1.4 |
| <i>Diospyros sylvetrica</i> | Ebanaceae | 2 | 2 | 1.0 | 1.6 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.0 | 1.4 |
| <i>Syzygium cumini</i> | Myrtaceae | 2 | 2 | 3.1 | 1.6 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.4 | 1.4 |
| <i>Terminalia bellarica</i> | Combretaceae | 2 | 2 | 3.7 | 1.6 | 1.0 | 0.0 | 0.2 | 1.1 | 0.1 | 0.5 | 1.4 |
| <i>Ficus microcarpa</i> | Moraceae | 1 | 1 | 0.6 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.2 |
| <i>Chrysophyllum roxburghii</i> | Sapotaceae | 1 | 1 | 1.6 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.2 | 1.2 |
| <i>Celtis tetandra</i> | Ulmaceae | 1 | 1 | 0.6 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.2 |
| <i>Terminalia paniculata</i> | Combretaceae | 1 | 1 | 1.6 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.2 | 1.2 |
| <i>Careya arborea</i> | Aracaceae | 1 | 1 | 0.8 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.2 |
| <i>Syzygium caryphyllatum</i> | Myrtaceae | 1 | 1 | 1.2 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.1 | 1.2 |
| <i>Sapium insigne</i> | Euphorbiaceae | 1 | 1 | 1.2 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.7 | 1.2 |
| <i>Alstonia scholaris</i> | Apocynaceae | 1 | 1 | 0.5 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.2 |
| <i>Myristica malabarica</i> | Myristicaceae | 1 | 1 | 0.5 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.2 |
| <i>Hydnocarpus pentandra</i> | Flacortiaceae | 1 | 1 | 0.9 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.1 | 1.2 |
| <i>Artocarpus lakoocha</i> | Moraceae | 1 | 1 | 0.6 | 0.8 | 1.0 | 0.0 | 0.1 | 1.1 | 0.1 | 0.0 | 1.2 |
| <i>Ficus asperima</i> | Moraceae | 1 | 2 | 0.8 | 1.6 | 0.5 | 0.0 | 0.2 | 0.5 | 0.1 | 0.1 | 0.8 |

N- Number of Individuals, GBH- Girth at Breast Height, F-Frequency, A-Abundance, D-Density, RF-Relative Frequency, RA-Relative Abundance, RD- Relative Density, BA-Basal Area, IVI-Importance Value Index

Appendix 3.1.3 Contribution of species richness, generic richness, Family relative density, Family relative diversity, Basal Area, Family relative dominance and Family importance Value in Hothota area

| Family | Species Richness | Generic richness | No. of individuals | Family Relative density | Family Relative diversity | Basal area | Family Relative dominance | Family Importance Value |
|------------------|------------------|------------------|--------------------|-------------------------|---------------------------|------------|---------------------------|-------------------------|
| Ebanaceae | 5 | 1 | 236 | 15.7 | 7.0 | 17.4 | 16.1 | 38.8 |
| Myristicaceae | 3 | 2 | 254 | 16.9 | 4.2 | 9.5 | 8.8 | 29.9 |
| Anacardiaceae | 4 | 3 | 151 | 10.0 | 5.6 | 11.4 | 10.5 | 26.2 |
| Clusiaceae | 5 | 2 | 157 | 10.5 | 7.04 | 6.4 | 5.9 | 23.4 |
| Lauraceae | 8 | 7 | 72 | 4.9 | 11.2 | 6.8 | 5.7 | 21.8 |
| Myrtaceae | 5 | 1 | 36 | 2.4 | 7.0 | 11.9 | 11.0 | 20.4 |
| Dipterocarpaceae | 1 | 1 | 158 | 10.5 | 1.4 | 9.0 | 8.3 | 20.3 |
| Oleaceae | 1 | 1 | 97 | 6.4 | 1.4 | 9.0 | 8.3 | 16.1 |
| Celastraceae | 2 | 2 | 24 | 1.6 | 2.8 | 7.0 | 6.5 | 10.9 |
| Moraceae | 4 | 2 | 20 | 1.3 | 5.6 | 3.1 | 2.8 | 9.8 |
| Euphorbiaceae | 4 | 4 | 37 | 2.4 | 5.6 | 1.2 | 1.1 | 9.2 |
| Verbenaceae | 2 | 2 | 22 | 1.4 | 2.8 | 5.1 | 4.7 | 9.0 |
| Sapotaceae | 4 | 4 | 24 | 1.6 | 5.6 | 1.3 | 1.2 | 8.4 |
| Flacortiaceae | 3 | 3 | 24 | 1.6 | 4.2 | 1.1 | 1.0 | 6.8 |
| Rubiaceae | 2 | 2 | 42 | 2.7 | 2.8 | 0.7 | 0.6 | 6.2 |
| Meliaceae | 1 | 1 | 39 | 2.5 | 1.4 | 1.3 | 1.2 | 5.2 |
| Sterculiaceae | 1 | 2 | 26 | 1.7 | 1.4 | 1.6 | 1.4 | 4.6 |
| Symplocaceae | 1 | 1 | 19 | 1.2 | 1.4 | 0.8 | 0.8 | 3.4 |
| Aracaceae | 2 | 2 | 6 | 0.4 | 2.8 | 0.2 | 0.2 | 3.4 |
| Lythraceae | 1 | 1 | 5 | 0.3 | 1.4 | 0.9 | 0.8 | 2.5 |
| Urticaceae | 1 | 1 | 12 | 0.8 | 1.4 | 0.2 | 0.2 | 2.4 |
| Melastomaceae | 1 | 1 | 12 | 0.8 | 1.4 | 0.2 | 0.1 | 2.3 |
| Sapindaceae | 1 | 1 | 10 | 0.6 | 1.4 | 0.2 | 0.2 | 2.3 |
| Liliaceae | 1 | 1 | 2 | 0.1 | 1.4 | 0.6 | 0.6 | 2.1 |
| Apocynaceae | 1 | 1 | 8 | 0.5 | 1.4 | 0.1 | 0.1 | 2.0 |
| Burseraceae | 1 | 2 | 2 | 0.1 | 1.4 | 0.1 | 0.1 | 1.7 |
| Bignoniaceae | 1 | 1 | 1 | 0.1 | 1.4 | 0.2 | 0.1 | 1.6 |
| Mimosaceae | 1 | 1 | 1 | 0.1 | 1.4 | 0.2 | 0.1 | 1.6 |
| Rosaceae | 1 | 1 | 1 | 0.1 | 1.4 | 0.1 | 0.1 | 1.6 |
| Rhizophoraceae | 1 | 1 | 3 | 0.2 | 1.4 | 0.04 | 0.04 | 1.6 |
| Anonaceae | 1 | 1 | 1 | 0.1 | 1.4 | 0.06 | 0.1 | 1.5 |
| Rutaceae | 1 | 1 | 1 | 0.1 | 1.4 | 0.01 | 0.01 | 1.4 |

Appendix 3.1.4 Contribution of species richness, generic richness, Family relative density, Family relative diversity, Basal Area, Family relative dominance and Family importance Value in Chiksuli.

| Family | Species Richness | Generic richness | No. of individuals | Family Relative density | Family Relative diversity | Basal area | Family Relative dominance | Family Importance Value |
|------------------|------------------|------------------|--------------------|-------------------------|---------------------------|------------|---------------------------|-------------------------|
| Clusiaceae | 5 | 2 | 221 | 15.9 | 6.8 | 13.6 | 12.6 | 35.4 |
| Lauraceae | 8 | 7 | 143 | 10.3 | 10.9 | 7.9 | 7.3 | 28.6 |
| Moraceae | 5 | 2 | 20 | 1.4 | 6.8 | 18.1 | 16.7 | 25.0 |
| Oleaceae | 1 | 1 | 128 | 9.2 | 1.3 | 15.3 | 14.1 | 24.8 |
| Myristicaceae | 3 | 2 | 118 | 8.5 | 4.1 | 6.1 | 5.7 | 18.3 |
| Anacardiaceae | 4 | 3 | 115 | 8.3 | 5.4 | 4.4 | 4.0 | 17.8 |
| Ebanaceae | 4 | 1 | 73 | 5.2 | 5.4 | 4.1 | 3.8 | 14.6 |
| Myrtaceae | 5 | 1 | 28 | 2.0 | 6.8 | 4.1 | 3.8 | 12.7 |
| Meliaceae | 1 | 1 | 92 | 6.6 | 1.3 | 4.9 | 4.5 | 12.6 |
| Dipterocarpaceae | 1 | 1 | 79 | 5.7 | 1.3 | 4.4 | 4.0 | 11.1 |
| Sapotaceae | 4 | 1 | 21 | 1.5 | 5.4 | 2.7 | 2.5 | 9.5 |
| Sapindaceae | 1 | 1 | 72 | 5.2 | 1.3 | 2.6 | 2.4 | 8.9 |
| Euphorbiaceae | 4 | 4 | 24 | 1.7 | 5.4 | 1.5 | 1.4 | 8.6 |
| Fabaceae | 1 | 1 | 54 | 3.9 | 1.3 | 2.7 | 2.5 | 7.8 |
| Verbenaceae | 2 | 2 | 26 | 1.8 | 2.7 | 2.9 | 2.7 | 7.3 |
| Flacortiaceae | 4 | 4 | 18 | 1.3 | 5.4 | 0.4 | 0.4 | 7.2 |
| Sterculiaceae | 2 | 2 | 41 | 2.9 | 2.7 | 1.4 | 1.3 | 7.0 |
| Celastraceae | 1 | 1 | 4 | 0.2 | 1.3 | 5.4 | 4.9 | 6.6 |
| Rubiaceae | 2 | 2 | 23 | 1.6 | 2.7 | 0.4 | 0.3 | 4.7 |
| Combretaceae | 2 | 2 | 3 | 0.2 | 2.7 | 0.7 | 0.6 | 3.6 |
| Rutaceae | 1 | 1 | 15 | 1.0 | 1.3 | 1.2 | 1.1 | 3.6 |
| Symplocaceae | 1 | 1 | 23 | 1.6 | 1.3 | 0.4 | 0.4 | 3.4 |
| Apocynaceae | 2 | 2 | 7 | 0.5 | 2.7 | 0.1 | 0.1 | 3.3 |
| Aracaceae | 2 | 2 | 3 | 0.2 | 2.7 | 0.1 | 0.1 | 3.1 |
| Urticaceae | 1 | 1 | 13 | 0.9 | 1.3 | 0.2 | 0.2 | 2.5 |
| Lythraceae | 1 | 1 | 3 | 0.2 | 1.3 | 0.9 | 0.9 | 2.4 |
| Burseraceae | 1 | 1 | 3 | 0.2 | 1.3 | 0.5 | 0.4 | 2.0 |
| Melastomaceae | 1 | 1 | 7 | 0.5 | 1.3 | 0.1 | 0.07 | 1.9 |
| Icaciniaceae | 1 | 1 | 3 | 0.2 | 1.3 | 0.03 | 0.03 | 1.6 |
| Bignonianaceae | 1 | 1 | 2 | 0.1 | 1.3 | 0.05 | 0.05 | 1.5 |
| Ulmaceae | 1 | 1 | 1 | 0.1 | 1.3 | 0.03 | 0.03 | 1.4 |

Appendix 3.1.5 Stand density of plant species across different study sites

| Name of the species | Density (Trees/ha) | |
|---------------------------------|--------------------|----------|
| | Hosthota | Chiksuli |
| <i>Knema attenuata</i> | 57.35 | 2.24 |
| <i>Hopea ponga</i> | 38.07 | 3.48 |
| <i>Olea dioica</i> | 23.37 | 31.84 |
| <i>Garcinia morella</i> | 20.96 | 22.14 |
| <i>Diospyros sylvetrica</i> | 44.58 | 1.99 |
| <i>Aglaia roxburghiana</i> | 9.40 | 1.49 |
| <i>Nathopegia racemosa</i> | 4.82 | 24.88 |
| <i>Holigarna arnottiana</i> | 26.75 | 0.75 |
| <i>Memecylon malabaricum</i> | 2.89 | 22.89 |
| <i>Ixora brachiata</i> | 9.16 | 3.98 |
| <i>Garcinia gummi-gutta</i> | 14.22 | 0.25 |
| <i>Litsea stocksii</i> | 4.58 | 9.20 |
| <i>Vitex altissemma</i> | 4.82 | 17.91 |
| <i>Symplocos racemosa</i> | 4.58 | 1.74 |
| <i>Diospyros candolliana</i> | 2.41 | 0.0 |
| <i>Caryota urens</i> | 0.72 | 19.65 |
| <i>Aparosa lindelana</i> | 6.27 | 6.72 |
| <i>Eleocarpus serratus</i> | 2.89 | 11.19 |
| <i>Myristica dactyloides</i> | 2.17 | 0.25 |
| <i>Callophylum apetalum</i> | 0.24 | 18.16 |
| <i>Pterospermum reticulatum</i> | 6.02 | 0.75 |
| <i>Holigarna grahmi</i> | 1.93 | 0.25 |
| <i>Ficus microcarpa</i> | 0.24 | 15.92 |
| <i>Actinodaphne hookeri</i> | 2.41 | 9.95 |
| <i>Neolitsia zeylanica</i> | 0.96 | 12.94 |
| <i>Belsmedia whitii</i> | 2.41 | 1.49 |
| <i>Macaranga peltata</i> | 2.17 | 5.97 |
| <i>Steriospermum personatum</i> | 0.24 | 12.69 |
| <i>Diospyros buxifolia</i> | 7.71 | 0.75 |
| <i>Sterculia guttata</i> | 0.24 | 13.43 |
| <i>Cassine glauca</i> | 2.89 | 3.73 |
| <i>Xantolis tomentosa</i> | 0.96 | 3.98 |
| <i>Litsea floribonda</i> | 2.89 | 0.25 |
| <i>Dimocarpus longan</i> | 2.41 | 0.0 |
| <i>Flacourtia montana</i> | 4.82 | 2.99 |
| <i>Cinnamomum malabathrum</i> | 0.96 | 5.72 |
| <i>Mimusops elengi</i> | 2.41 | 0.25 |
| <i>Chionanthus malabaricus</i> | 0.0 | 1.00 |
| <i>Syzizium stocksii</i> | 0.0 | 0.0 |
| <i>Garcinia talbotti</i> | 0.0 | 1.49 |
| <i>Mangifera indica</i> | 2.89 | 0.75 |
| <i>Diospyros angustifolia</i> | 1.45 | 0.0 |
| <i>Persea macaranga</i> | 2.65 | 3.48 |
| <i>Artocarpus hirsutus</i> | 3.86 | 2.74 |
| <i>Syzygium sp.</i> | 0.24 | 0.0 |
| <i>Glochidion velutinum</i> | 0.24 | 0.50 |
| <i>Canarium strictum</i> | 0.48 | 5.22 |
| <i>Ficus asperima</i> | 0.0 | 4.23 |
| <i>Eleocarpus serratus</i> | 0.0 | 0.0 |
| <i>Syzygium gardneri</i> | 6.75 | 0.50 |
| <i>Diospyros buxifolia</i> | 0.0 | 0.0 |
| <i>Euodia lunu-ankenda</i> | 0.24 | 5.22 |
| <i>Diospyros angustifolia</i> | 0.0 | 0.25 |
| <i>Chrysophyllum roxburghii</i> | 1.45 | 3.48 |
| <i>Myristica malabarica</i> | 1.69 | 0.50 |
| <i>Canthium dicoccum</i> | 0.96 | 2.99 |
| <i>Lopopetalum whitianum</i> | 2.89 | 0.0 |
| <i>Syzygium cumini</i> | 0.48 | 1.24 |

| Name of the species | Density (Trees/ha) | |
|---------------------------------|--------------------|----------|
| | Hosthota | Chiksuli |
| <i>Gymnocranthera canarica</i> | 0.0 | 0.0 |
| <i>Tabernamontana heyinana</i> | 1.93 | 0.0 |
| <i>Syzizium laetum</i> | 0.48 | 1.49 |
| <i>Lageostromia microcarpa</i> | 1.20 | 0.50 |
| <i>Saraca asoka</i> | 0.0 | 0.0 |
| <i>Tabernamontana heyinana</i> | 0.0 | 3.23 |
| <i>Alsea daphni</i> | 0.48 | 1.49 |
| <i>Callophylum tomentasum</i> | 1.45 | 0.25 |
| <i>Callicarpa tomentosa</i> | 0.48 | 0.25 |
| <i>Bishopia javanica</i> | 0.0 | 0.0 |
| <i>Casearia beddomi</i> | 0.0 | 1.74 |
| <i>Syzizium hemispermicum</i> | 0.72 | 0.75 |
| <i>Careya arborea</i> | 0.72 | 1.24 |
| <i>Flacortia sp.</i> | 0.0 | 0.0 |
| <i>Terminalia paniculata</i> | 0.0 | 1.74 |
| <i>Diospyros montana</i> | 0.72 | 0.0 |
| <i>Syzizium laetum</i> | 0.0 | 0.0 |
| <i>Celtis tetandra</i> | 0.0 | 1.99 |
| <i>Homelium ceylanicum</i> | 0.0 | 0.0 |
| <i>Buchnanian lanzan</i> | 0.0 | 0.0 |
| <i>Syzygium caryophyllatum</i> | 0.0 | 0.0 |
| <i>Homelium zeylanicum</i> | 0.72 | 1.00 |
| <i>Carallia brachiata</i> | 0.72 | 0.0 |
| <i>Terminalia paniculata</i> | 0.0 | 0.0 |
| <i>Polyanthia fragrens</i> | 0.24 | 0.0 |
| <i>Xylia xylocarpa</i> | 0.0 | 1.49 |
| <i>Maduca longifolia</i> | 0.96 | 0.50 |
| <i>Ficus nervosa</i> | 0.0 | 0.0 |
| <i>Terminalia tomentosa</i> | 0.0 | 0.0 |
| <i>Chionanthus malabaricus</i> | 0.0 | 0.0 |
| <i>Nothapodytes nimmoniana</i> | 0.0 | 0.25 |
| <i>Artocarpus lakoocha</i> | 0.24 | 0.25 |
| <i>Terminalia bellarica</i> | 0.0 | 0.25 |
| <i>Sapium insigne</i> | 0.0 | 1.00 |
| <i>Syzygium caryophyllatum</i> | 0.0 | 1.00 |
| <i>Leea indica</i> | 0.0 | 0.0 |
| <i>Polyanthia fragrens</i> | 0.0 | 0.0 |
| <i>Garcinia talbotti</i> | 0.96 | 0.0 |
| <i>Pittosporum floribundam</i> | 0.0 | 0.0 |
| <i>Chukrasia tabularis</i> | 0.48 | 0.0 |
| <i>Ficus nervosa</i> | 0.0 | 0.0 |
| <i>Alstonia scolaris</i> | 0.0 | 0.75 |
| <i>Mastixia arborea</i> | 0.0 | 0.0 |
| <i>Trichilia connaroides</i> | 0.0 | 0.0 |
| <i>Artocarpus heterophyllus</i> | 0.48 | 0.0 |
| <i>Melia dubia</i> | 0.0 | 0.0 |
| <i>Drypetes confertifolius</i> | 0.24 | 0.0 |
| <i>Trichilia connaroides</i> | 0.0 | 0.0 |
| <i>Ixora nigricans</i> | 0.0 | 0.0 |
| <i>Ficus nervosa</i> | 0.0 | 0.50 |
| <i>Hydnocarpus pentandra</i> | 0.24 | 0.25 |
| <i>Aglaia sp.</i> | 0.0 | 0.0 |
| <i>Canthium angustifolium</i> | 0.0 | 0.0 |
| <i>Canthium dicoccum</i> | 0.0 | 0.0 |
| <i>Dipterocarpus indicus</i> | 0.0 | 0.0 |
| <i>Eleagnus conferta</i> | 0.0 | 0.0 |
| <i>Mastixia arborea</i> | 0.0 | 0.0 |
| <i>Albizia lebbeck</i> | 0.24 | 0.0 |
| <i>Prunus ceylanica</i> | 0.24 | 0.0 |

Appendix 3.1.6 Basal area of plant species across different study sites

| Name of the species | Basal Area | |
|---------------------------------|------------|----------|
| | Hosthota | Chiksuli |
| <i>Actinodaphne hookeri</i> | 0.40 | 0.15 |
| <i>Aglaiia roxburghiana</i> | 1.33 | 4.97 |
| <i>Aglaiia</i> sp. | 0.0 | 0.0 |
| <i>Albizia lebbeck</i> | 0.21 | 0.0 |
| <i>Alsea daphni</i> | 0.37 | 0.31 |
| <i>Alstonia scholaris</i> | 0.0 | 0.01 |
| <i>Aparosa lindelana</i> | 0.90 | 0.10 |
| <i>Artocarpus heterophyllus</i> | 0.10 | 0.0 |
| <i>Artocarpus hirsutus</i> | 1.26 | 0.40 |
| <i>Artocarpus lakoocha</i> | 0.03 | 0.02 |
| <i>Belsmedia whitii</i> | 0.70 | 1.86 |
| <i>Bishopia javanica</i> | 0.0 | 0.0 |
| <i>Buchnanania lanzan</i> | 0.0 | 0.0 |
| <i>Callicarpa tomentosa</i> | 0.02 | 0.18 |
| <i>Callophylum apetalum</i> | 0.00 | 0.14 |
| <i>Callophylum tomentosum</i> | 1.41 | 3.56 |
| <i>Canerium strictum</i> | 0.17 | 0.51 |
| <i>Canthium angustifolium</i> | 0.0 | 0.0 |
| <i>Canthium dicoccum</i> | 0.07 | 0.06 |
| <i>Carallia brachiata</i> | 0.04 | 0.0 |
| <i>Careya arborea</i> | 0.08 | 0.04 |
| <i>Caryota urens</i> | 0.18 | 0.12 |
| <i>Casearia beddomi</i> | 0.0 | 0.15 |
| <i>Cassine glauca</i> | 3.43 | 5.41 |
| <i>Celtis tetandra</i> | 0.0 | 0.03 |
| <i>Chionanthus malabaricus</i> | 0.0 | 0.0 |
| <i>Chrysophyllum roxburghii</i> | 0.34 | 0.19 |
| <i>Chukrasia tabularis</i> | 0.65 | 0.0 |
| <i>Cinnamomum malabathrum</i> | 0.09 | 0.13 |
| <i>Dimocarpus longan</i> | 0.29 | 2.60 |
| <i>Diospyros angustifolia</i> | 0.08 | 0.39 |
| <i>Diospyros buxifolia</i> | 4.38 | 1.20 |
| <i>Diospyros candolliana</i> | 0.43 | 2.57 |
| <i>Diospyros montana</i> | 0.16 | 0.0 |
| <i>Diospyros sylvetrica</i> | 12.43 | 0.03 |
| <i>Dipterocarpus indicus</i> | 0.0 | 0.0 |

| Name of the species | Basal Area | |
|--------------------------------|------------|----------|
| | Hosthota | Chiksuli |
| <i>Drypetes confertifolius</i> | 0.08 | 0.0 |
| <i>Eleagnus conferta</i> | 0.0 | 0.0 |
| <i>Eleocarpus serratus</i> | 0.22 | 0.27 |
| <i>Euodia lunu-ankenda</i> | 0.01 | 1.26 |
| <i>Ficus asperima</i> | 0.0 | 0.05 |
| <i>Ficus microcarpa</i> | 1.75 | 0.02 |
| <i>Ficus nervosa</i> | 0.0 | 17.65 |
| <i>Flacortia sp.</i> | 0.0 | 0.0 |
| <i>Flacourtia montana</i> | 0.90 | 0.14 |
| <i>Garcinia gummi-gutta</i> | 2.70 | 2.80 |
| <i>Garcinia morella</i> | 1.49 | 1.61 |
| <i>Garcinia talbotti</i> | 0.84 | 5.57 |
| <i>Glochidion velutinum</i> | 0.01 | 0.35 |
| <i>Gymnocranthera canarica</i> | 0.0 | 0.0 |
| <i>Holigarna arnottiana</i> | 9.74 | 2.99 |
| <i>Holigarna grahmi</i> | 0.65 | 0.76 |
| <i>Homelium zeylanicum</i> | 0.03 | 0.14 |
| <i>Hopea ponga</i> | 9.09 | 4.40 |
| <i>Hydnocarpus pentandra</i> | 0.21 | 0.05 |
| <i>Ixora brachiata</i> | 0.65 | 0.36 |
| <i>Ixora nigricans</i> | 0.0 | 0.0 |
| <i>Knema attenuata</i> | 8.87 | 5.38 |
| <i>Lageostromia microcarpa</i> | 0.92 | 0.98 |
| <i>Leea indica</i> | 0.0 | 0.0 |
| <i>Litsea floribonda</i> | 0.80 | 2.66 |
| <i>Litsea stocksii</i> | 0.83 | 2.01 |
| <i>Lopopetalum whittianum</i> | 3.66 | 0.0 |
| <i>Macaranga peltata</i> | 0.26 | 0.38 |
| <i>Maduca longifolia</i> | 0.21 | 0.19 |
| <i>Mangifera indica</i> | 0.50 | 0.10 |
| <i>Mastixia arborea</i> | 0.0 | 0.0 |
| <i>Melia dubia</i> | 0.0 | 0.0 |
| <i>Memecylon malabaricum</i> | 0.20 | 0.08 |
| <i>Mimusops elengi</i> | 0.74 | 1.61 |
| <i>Myristica dactyloides</i> | 0.46 | 0.80 |
| <i>Myristica malabarica</i> | 0.26 | 0.01 |
| <i>Nathopegia racemosa</i> | 0.55 | 0.58 |
| <i>Neolitsia zeylanica</i> | 0.17 | 0.13 |
| <i>Nothapodytes nimmoniana</i> | 0.0 | 0.03 |

| Name of the species | Basal Area | |
|---------------------------------|------------|----------|
| | Hosthota | Chiksuli |
| <i>Olea dioica</i> | 9.02 | 15.39 |
| <i>Persia macarantha</i> | 2.92 | 0.71 |
| <i>Pittosporum floribundam</i> | 0.0 | 0.0 |
| <i>Polyanthia fragrens</i> | 0.06 | 0.0 |
| <i>Prunus ceylanica</i> | 0.19 | 0.0 |
| <i>Pterospermum reticulatum</i> | 1.57 | 1.10 |
| <i>Sapium insigne</i> | 0.0 | 0.72 |
| <i>Saraca asoka</i> | 0.0 | 0.0 |
| <i>Sterculia guttata</i> | 0.05 | 0.34 |
| <i>Steriospermum personatum</i> | 0.21 | 0.05 |
| <i>Symplocos racemosa</i> | 0.89 | 0.48 |
| <i>Syzigium cumini</i> | 0.68 | 0.43 |
| <i>Syzigium gardneri</i> | 10.69 | 2.75 |
| <i>Syzizium hemispermicum</i> | 0.40 | 0.79 |
| <i>Syzizium laetum</i> | 0.02 | 0.07 |
| <i>Syzizium stocksii</i> | 0.0 | 0.0 |
| <i>Syzygium caryphyllatum</i> | 0.0 | 0.11 |
| <i>Syzygium sp.</i> | 0.16 | 0.0 |
| <i>Tabernamontana heyinana</i> | 0.10 | 0.06 |
| <i>Terminalia paniculata</i> | 0.0 | 0.20 |
| <i>Terminalia tomentosa</i> | 0.0 | 0.0 |
| <i>Terminelia bellarica</i> | 0.0 | 0.54 |
| <i>Trichilia connaroides</i> | 0.0 | 0.0 |
| <i>Vitex altissema</i> | 5.17 | 2.80 |
| <i>Xantolis tomentosa</i> | 0.05 | 0.74 |
| <i>Xylia xylocarpa</i> | 0.0 | 2.75 |

Appendix 3.2.1 List of food species of Hosthota and Chiksuli study groups with overall% feeding values

| | Hosthota (% feeding) | Chiksuli (% feeding) |
|---------------------------------|---------------------------------|---------------------------------|
| <i>Actinodaphne hookeri</i> | 0.19 | 0.23 |
| <i>Aglaiia roxburghiana</i> | 2.37 | 1.97 |
| <i>Aparosa lindleyana</i> | 0.44 | 0.00 |
| <i>Artocarpus heterophyllus</i> | 0.72 | 2.80 |
| <i>Artocarpus hirsutus</i> | 3.66 | 2.80 |
| <i>Asparagus racemosus</i> | 0.06 | 0.00 |
| <i>Atlantia racemosa</i> | 0.06 | 0.00 |
| <i>Belsmedia whitii</i> | 0.30 | 1.13 |
| <i>Calamus pseudotenuis</i> | 2.18 | 0.45 |
| <i>Calamus twaitessi</i> | 0.72 | 0.60 |
| <i>Callicarpa tomentosa</i> | 0.69 | 1.21 |
| <i>Calophyllum apetalum</i> | 0.06 | 0.00 |
| <i>Calophyllum tomentosum</i> | 3.86 | 6.65 |
| <i>Canthium angustifolium</i> | 0.03 | 0.00 |
| <i>Canthium dicoccum</i> | 0.19 | 0.00 |
| <i>Carissa spinarum</i> | 0.14 | 0.23 |
| <i>Caryota urens</i> | 16.48 | 21.32 |
| <i>Chilocarpus atrovirens</i> | 5.02 | 0.00 |
| <i>Chrysophyllum roxburghii</i> | 0.28 | 1.81 |
| <i>Desmos lawii</i> | 0.03 | 0.00 |
| <i>Dimocarpus longan</i> | 0.06 | 5.44 |
| <i>Diospyros buxifolia</i> | 0.63 | 0.08 |
| <i>Diospyros candolliana</i> | 1.43 | 0.15 |
| <i>Diospyros sylvatica</i> | 3.42 | 0.38 |
| <i>Eleocarpus serratus</i> | 0.06 | 0.00 |
| <i>Ficus infectoria</i> | 1.02 | 0.00 |
| <i>Ficus microcarpa</i> | 1.79 | 0.00 |
| <i>Ficus nervosa</i> | 0.66 | 6.80 |
| <i>Flacourtia montana</i> | 1.63 | 0.08 |
| <i>Garcinia gummi-gutta</i> | 0.77 | 1.44 |
| <i>Garcinia morella</i> | 0.14 | 0.00 |
| <i>Garcinia talbotti</i> | 0.06 | 0.00 |
| <i>Gnetum ula</i> | 0.14 | 0.30 |
| <i>Holigarna arnottiana</i> | 0.94 | 1.13 |
| <i>Holigarna grahami</i> | 0.61 | 0.68 |
| <i>Hopea ponga</i> | 0.08 | 0.00 |

| | Hosthota (% feeding) | Chiksuli (% feeding) |
|--------------------------------|-------------------------|-------------------------|
| <i>Ixora brachiata</i> | 0.06 | 0.00 |
| <i>Knema attenuata</i> | 0.85 | 0.08 |
| <i>Leea indica</i> | 0.11 | 0.45 |
| <i>Lophopetalum wightianum</i> | 0.00 | 0.15 |
| <i>Litsea floribonda</i> | 0.33 | 1.66 |
| <i>Macaranga peltata</i> | 0.63 | 3.93 |
| <i>Madhuca longifolia</i> | 0.80 | 0.30 |
| <i>Mangifera indica</i> | 3.66 | 3.40 |
| <i>Mastixia arborea</i> | 0.03 | 0.00 |
| <i>Melastoma malabathricum</i> | 0.28 | 0.08 |
| <i>Memecylon malabaricum</i> | 0.22 | 0.00 |
| <i>Mimusops elangi</i> | 0.17 | 0.00 |
| <i>Myristica dactyloides</i> | 0.06 | 0.00 |
| <i>Nothopegia racemosa</i> | 1.93 | 1.21 |
| <i>Nothopoditis nimmoniana</i> | 0.11 | 0.15 |
| <i>Olea dioica</i> | 4.00 | 8.39 |
| <i>Pandanus tectorius</i> | 9.07 | 4.99 |
| <i>Persea macarantha</i> | 0.96 | 0.00 |
| <i>Pinanga dicksonii</i> | 0.69 | 0.23 |
| <i>Piper nigrum</i> | 0.52 | 0.30 |
| <i>Piper sp.</i> | 0.03 | 0.00 |
| <i>Pothos scandens</i> | 0.77 | 0.15 |
| <i>Psychotria dalzelli</i> | 0.74 | 0.00 |
| <i>Psychotria flavida</i> | 0.30 | 0.15 |
| <i>Psychotria nigra</i> | 4.88 | 2.87 |
| <i>Salacia oblonga</i> | 0.61 | 0.00 |
| <i>Smilax zeylanica</i> | 0.17 | 0.08 |
| <i>Symplocos racemosa</i> | 0.14 | 0.38 |
| <i>Syzizium cumini</i> | 0.00 | 0.38 |
| <i>Syzizium gardneri</i> | 0.17 | 0.00 |
| <i>Syzizium hemispermicum</i> | 1.68 | 0.08 |
| <i>Syzizium stocksii</i> | 0.94 | 0.60 |
| <i>Syzygium caryophyllatum</i> | 0.03 | 0.00 |
| <i>Trichilia connaroides</i> | 0.08 | 0.00 |
| Unknown Climber | 0.08 | 0.00 |
| Unknown Grass | 0.03 | 0.00 |
| <i>Vitex altissema</i> | 0.63 | 0.08 |
| <i>Ziziphus rugosa</i> | 0.25 | 0.00 |
| <i>Ziziphus sp.</i> | 0.11 | 0.00 |

Appendix 3.2.2. Importance Value Index of food species of lion-tailed macaque study groups in Sirsi-Honnava forests as compared with Roy et al 2010

| Plant species | Family | Importance Value Index | | |
|--------------------------------------|------------------|------------------------|----------|------------|
| | | Hosthota | Chiksuli | Matnigadde |
| <i>Actinodaphne hookeri</i> | Lauraceae | 2.94 | 2.16 | 3.11 |
| <i>Aglaia roxburghii</i> | Meliaceae | 7.02 | 14.41 | 19.69 |
| <i>Aporosa lindleyana</i> * | Euphorbiaceae | 5.37 | 1.80 | 1.16 |
| <i>Artocarpus heterophyllus</i> | Moraceae | 1.49 | 0.00 | 0.00 |
| <i>Artocarpus hirsutus</i> | Moraceae | 3.85 | 2.57 | 2.89 |
| <i>Belsmedia whitii</i> | Lauraceae | 2.89 | 5.39 | 0.00 |
| <i>Callicarpa tomentosa</i> | Verbinaceae | 1.49 | 3.25 | 2.12 |
| <i>Calophyllum apetalum</i> * | Clusiaceae | 1.32 | 1.61 | 0.00 |
| <i>Calophyllum tomentosum</i> | Clusiaceae | 2.30 | 3.08 | 0.00 |
| <i>Canthium dicoccum</i> * | Rubiaceae | 1.71 | 1.43 | 0.36 |
| <i>Caryota urens</i> | Aracaceae | 2.13 | 1.43 | 5.55 |
| <i>Cassine glauca</i> *** | Celastraceae | 3.21 | 2.04 | 5.23 |
| <i>Chrysophyllum lanceolatum</i> *** | Sapotaceae | 0.00 | 0.00 | 1.45 |
| <i>Chrysophyllum roxburghii</i> | Sapotaceae | 2.30 | 1.25 | 0.00 |
| <i>Dimocarpus longan</i> | Sapindaceae | 2.94 | 11.72 | 12.49 |
| <i>Diospyros buxifolia</i> | Ebanaceae | 6.34 | 1.80 | 0.00 |
| <i>Diospyros candolliana</i> | Ebanaceae | 2.89 | 8.85 | 0.00 |
| <i>Diospyros crumenata</i> *** | Ebanaceae | 0.00 | 0.00 | 6.28 |
| <i>Diospyros pruriens</i> *** | Ebanaceae | 0.00 | 0.00 | 1.95 |
| <i>Diospyros sylvetrica</i> | Ebanaceae | 23.94 | 1.43 | 0.00 |
| <i>Dipterocarpus indicus</i> *** | Dipterocarpaceae | 0.00 | 0.00 | 2.28 |
| <i>Drypetes venusta</i> *** | Euphorbiaceae | 0.00 | 0.00 | 3.84 |
| <i>Eleocarpus serratus</i> * | Urticaceae | 3.21 | 3.42 | 2.99 |
| <i>Ficus callosa</i> *** | Moraceae | 0.00 | 0.00 | 2.86 |
| <i>Ficus microcarpa</i> * | Moraceae | 1.32 | 1.25 | 0.00 |
| <i>Ficus nervosa</i> | Moraceae | 0.00 | 2.73 | 6.63 |
| <i>Flacourtia montana</i> | Flacortiaceae | 4.50 | 2.47 | 2.06 |
| <i>Garcinia gummi-gutta</i> | Clusiaceae | 9.97 | 8.49 | 7.92 |
| <i>Garcinia morella</i> * | Clusiaceae | 13.71 | 11.44 | 3.69 |
| <i>Garcinia talbotti</i> * | Clusiaceae | 1.83 | 13.01 | 3.65 |
| <i>Holigarna arnottiana</i> | Anacardiaceae | 16.60 | 11.03 | 0.79 |
| <i>Holigarna grahmi</i> | Anacardiaceae | 2.58 | 3.99 | 12.44 |
| <i>Hopea ponga</i> | Dipterocarpaceae | 19.76 | 11.91 | 15.77 |
| <i>Ixora brachiata</i> * | Rubiaceae | 7.54 | 4.71 | 2.74 |
| <i>Knema attenuata</i> | Myristicaceae | 28.60 | 15.61 | 25.10 |
| <i>Litsea floribonda</i> | Lauraceae | 3.21 | 7.35 | 1.07 |
| <i>Litsea stocksii</i> *** | Lauraceae | 4.31 | 9.07 | 3.12 |
| <i>Macaranga peltata</i> | Euphorbiaceae | 2.81 | 3.61 | 4.01 |

| Plant species | Family | Importance Value Index | | |
|--------------------------------|---------------|------------------------|----------|------------|
| | | Hosthota | Chiksuli | Matnigadde |
| <i>Mangifera indica</i> | Anacardiaceae | 3.21 | 2.53 | 2.16 |
| <i>Memecylon malabaricum</i> * | Melastomaceae | 3.21 | 2.35 | 0.00 |
| <i>Mimusops elengi</i> * | Sapotaceae | 2.89 | 4.71 | 3.55 |
| <i>Myristica dactyloides</i> * | Myristicaceae | 2.73 | 4.06 | 2.77 |
| <i>Nothapodytes nimmoniana</i> | Icaciniceae | 0.00 | 1.61 | 0.00 |
| <i>Nothopegia racemosa</i> | Anacardiaceae | 4.44 | 5.75 | 3.26 |
| <i>Olea dioca</i> | Oleaceae | 14.22 | 17.89 | 15.53 |
| <i>Persea macrantha</i> | Lauraceae | 3.05 | 4.95 | 3.45 |
| <i>Symplocos racemosa</i> | Symplocaceae | 4.30 | 4.95 | 2.84 |
| <i>Syzygium gardneri</i> | Myrtaceae | 5.79 | 2.16 | 18.75 |
| <i>Syzygium hemispermicum</i> | Myrtaceae | 2.13 | 3.25 | 0.00 |
| <i>Syzygium cuminii</i> | Myrtaceae | 1.49 | 1.43 | 0.73 |
| <i>Vitex altissema</i> | Verbenaceae | 4.50 | 3.66 | 1.84 |

* Exclusive food species of Hosthota group; *** Exclusive food species of Matnigadde group

Appendix 3.2.3 . Frequency, density and Importance Value Index of priority food species (> 1%) of lion-tailed macaque study groups in Sirsi-Honnava forests as compared with Roy et al 2010

| | Hosthota | | | Chiksuli | | | Matnigadde | | |
|---------------------------------|-----------|---------|-------|-----------|---------|-------|------------|---------|-------|
| | Frequency | Density | IVI | Frequency | Density | IVI | Frequency | Density | IVI |
| <i>Aglaia roxburghii</i> | 18.94 | 0.30 | 7.02 | 42.19 | 0.72 | 14.41 | 100.00 | 20.40 | 19.69 |
| <i>Artocarpus heterophyllus</i> | 1.52 | 0.02 | 1.49 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| <i>Artocarpus hirsutus</i> | 10.61 | 0.12 | 3.85 | 5.47 | 0.06 | 2.57 | 60.00 | 1.80 | 2.89 |
| <i>Belsmedia whittii</i> | 6.82 | 0.08 | 2.89 | 17.97 | 0.19 | 5.39 | 0.00 | 0.00 | 0.00 |
| <i>Callicarpa tomentosa</i> | 1.52 | 0.02 | 1.49 | 8.59 | 0.09 | 3.25 | 50.00 | 1.60 | 2.11 |
| <i>Calophyllum tomentosum</i> | 3.79 | 0.05 | 2.30 | 8.59 | 0.09 | 3.08 | 0.00 | 0.00 | 0.00 |
| <i>Caryota urens</i> | 1.52 | 0.02 | 2.13 | 1.56 | 0.02 | 1.43 | 90.00 | 4.10 | 5.54 |
| <i>Cassine glauca</i> | 9.00 | 1.30 | 3.20 | 2.30 | 0.00 | 2.00 | 80.00 | 3.20 | 5.22 |
| <i>Chrysophyllum roxburghii</i> | 3.79 | 0.05 | 2.30 | 0.78 | 0.01 | 1.25 | 0.00 | 0.00 | 0.00 |
| <i>Dimocarpus longan</i> | 6.06 | 0.08 | 2.94 | 33.59 | 0.56 | 11.72 | 100.00 | 10.80 | 12.48 |
| <i>Diospyros candolliana</i> | 6.82 | 0.08 | 2.89 | 24.22 | 0.40 | 8.85 | 0.00 | 0.00 | 0.00 |
| <i>Diospyros crumenata</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 40.00 | 2.20 | 6.28 |
| <i>Diospyros pruriens</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 50.00 | 1.20 | 1.94 |
| <i>Diospyros sylvatica</i> | 65.91 | 1.40 | 23.94 | 1.56 | 0.02 | 1.43 | 0.00 | 0.00 | 0.00 |
| <i>Dipterocarpus indicus</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 | 2.30 | 2.28 |
| <i>Dryptes venusta</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 | 3.60 | 3.84 |
| <i>Ficus infectoria</i> | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| <i>Ficus microcarpa</i> | 0.76 | 0.01 | 1.32 | 0.78 | 0.01 | 1.25 | 0.00 | 0.00 | 0.00 |
| <i>Ficus nervosa</i> | 0.00 | 0.00 | 0.00 | 6.25 | 0.07 | 2.73 | 60.00 | 1.20 | 6.62 |
| <i>Flacourtia montana</i> | 13.64 | 0.15 | 4.50 | 3.13 | 0.05 | 2.47 | 60.00 | 0.80 | 2.06 |
| <i>Garcinia gummi-gutta</i> | 31.82 | 0.45 | 9.97 | 27.34 | 0.35 | 8.49 | 100.00 | 5.70 | 7.91 |
| <i>Holigarna arnottiana</i> | 53.03 | 0.84 | 16.60 | 34.38 | 0.50 | 11.03 | 20.00 | 0.20 | 0.79 |
| <i>Holigarna grahamii</i> | 5.30 | 0.06 | 2.58 | 12.50 | 0.13 | 3.99 | 100.00 | 10.40 | 12.43 |
| <i>Knema attenuata</i> | 70.45 | 1.80 | 28.60 | 46.88 | 0.78 | 15.61 | 100.00 | 29.50 | 25.10 |
| <i>Litsea floribunda</i> | 8.33 | 0.09 | 3.21 | 19.53 | 0.31 | 7.35 | 20.00 | 0.90 | 1.06 |
| <i>Macaranga peltata</i> | 5.30 | 0.07 | 2.81 | 7.81 | 0.11 | 3.61 | 70.00 | 3.60 | 4.00 |
| <i>Mangifera indica</i> | 9.09 | 0.09 | 3.21 | 6.25 | 0.06 | 2.53 | 60.00 | 0.90 | 2.15 |
| <i>Nothopegia racemosa</i> | 11.36 | 0.15 | 4.44 | 17.97 | 0.21 | 5.75 | 80.00 | 2.10 | 3.25 |
| <i>Olea dioica</i> | 40.91 | 0.73 | 14.22 | 44.53 | 1.00 | 17.89 | 100.00 | 10.30 | 15.53 |
| <i>Persea macarantha</i> | 7.58 | 0.08 | 3.05 | 3.91 | 0.04 | 1.98 | 60.00 | 1.40 | 3.44 |
| <i>Syzigium gardneri</i> | 18.94 | 0.21 | 5.79 | 4.69 | 0.05 | 2.16 | 100.00 | 8.30 | 18.74 |
| <i>Syzigium hemispermicum</i> | 1.52 | 0.02 | 2.13 | 7.81 | 0.09 | 3.25 | 0.00 | 0.00 | 0.00 |

Appendix 3.3.1. Effort, scan details, percent feeding, mean monthly food type and plant parts consumed by lion-tailed macaques

| | | | | | Overall feeding* | | | | | | Overall plant feeding** | | | |
|-------------------|-------------------------|--------------|---------------|-------------|------------------|----------------|-----------|---------------|-----------|---------------|---------------------------|---------------------------|-------------------------|-------------------------|
| | | | | | Plant | | Faunals | | Fungi | | Fruit | Stem-leaves | Resin | Flower |
| | Number of days observed | Total scans | Feeding scans | Plant scans | % feeding | Mean \pm SE | % feeding | Mean \pm SE | % feeding | Mean \pm SE | Mean \pm SE | Mean \pm SE | Mean \pm SE | Mean \pm SE |
| Dry season | 104 | 15032 | 2577 | 2319 | | | | | | | | | | |
| Dec-08 | 10 | 1322 | 308 | 265 | 84.3 | 25.8 \pm 3.7 | 9.1 | 2.8 \pm 0.7 | 6.5 | 2.0 \pm 0.7 | 12.1 \pm 1.8 (N=121) | 12.9 \pm 2.4 (N=129) | 1.0 \pm 0.5 (N=10) | 0.5 \pm 0.4 (N=5) |
| Jan-09 | 10 | 1324 | 195 | 173 | 93.2 | 18.1 \pm 2.5 | 6.2 | 1.2 \pm 0.3 | 0.5 | 0.1 \pm 0.1 | 8.9 \pm 2.3 (N=89) | 7.4 \pm 1.7 (N=79) | 0.0 \pm 0.0 (N=0) | 0.6 \pm 0.3 (N=5) |
| Feb-09 | 1 | 60 | 12 | 11 | 91.6 | 11 | 8.3 | 1 | 0.0 | 0 | (N=0) | (N=4) | (N=2) | (N=5) |
| Mar-09 | 8 | 1216 | 88 | 69 | 82.5 | 8.7 \pm 1.2 | 16.2 | 1.7 \pm 0.4 | 1.2 | 0.1 \pm 0.1 | 7.0 \pm 1.3 (N=56) | 1.2 \pm 0.6 (N=10) | 0.0 \pm 0.0 (N=0) | 0.4 \pm 0.3 (N=3) |
| Apr-09 | 10 | 1936 | 302 | 273 | 91.0 | 27.3 \pm 5.3 | 9.0 | 2.7 \pm 0.9 | 0.0 | 0.0 \pm 0.0 | 26.8 \pm 5.3 (N=268) | 0.5 \pm 0.3 (N=5) | 0.0 \pm 0.0 (N=0) | 0.0 \pm 0.0 (N=0) |
| May-09 | 5 | 571 | 82 | 78 | 95.1 | 15.6 \pm 3.1 | 4.9 | 0.8 \pm 0.4 | 0.0 | 0.0 \pm 0.0 | 15.6 \pm 3.1 (N=78) | 0.0 \pm 0.0 (N=0) | 0.0 \pm 0.0 (N=0) | 0.0 \pm 0.0 (N=0) |
| Dec-09 | 10 | 1320 | 269 | 244 | 91.4 | 24.5 \pm 3.5 | 6.0 | 1.6 \pm 0.4 | 2.6 | 0.7 \pm 0.3 | 12.3 \pm 2.9 (N=123) | 12.1 \pm 2.3 (N=121) | 0.0 \pm 0.0 (N=0) | 0.0 \pm 0.0 (N=0) |
| Jan-10 | 10 | 1278 | 247 | 213 | 87.3 | 21.4 \pm 3.7 | 11.8 | 2.9 \pm 0.5 | 0.8 | 0.2 \pm 0.2 | 12.3 \pm 3.9 (N=123) | 6.9 \pm 1.4 (N=69) | 2.1 \pm 0.7 (N=21) | 0.0 \pm 0.0 (N=0) |
| Feb-10 | 7 | 804 | 124 | 116 | 87.7 | 16.6 \pm 3.8 | 12.3 | 2.3 \pm 0.5 | 0.0 | 0.0 \pm 0.0 | 10.4 \pm 2.5 (N=73) | 5.7 \pm 1.6 (N=40) | 0.4 \pm 0.3 (N=3) | 0.0 \pm 0.0 (N=0) |
| Mar-10 | 5 | 508 | 116 | 133 | 97.3 | 26.6 \pm 3.7 | 2.6 | 1.0 \pm 0.3 | 0.0 | 0.0 \pm 0.0 | 19.8 \pm 3.6 (N=99) | 3.4 \pm 1.1 (N=17) | 0.2 \pm 0.2 (N=1) | 3.2 \pm 1.6 (N=16) |
| Apr-10 | 5 | 671 | 76 | 68 | 90.8 | 13.6 \pm 2.2 | 7.9 | 1.2 \pm 0.4 | 1.3 | 0.2 \pm 0.2 | 12.6 \pm 2.6 (N=63) | 1.0 \pm 0.6 (N=5) | 0.0 \pm 0.0 (N=0) | 0.0 \pm 0.0 (N=0) |
| May-10 | 1 | 140 | 17 | 16 | 94.1 | 16 | 0.0 | 0 | 5.8 | 1 | (N=10) | (N=3) | (N=3) | (N=0) |
| Dec-10 | 4 | 655 | 129 | 107 | 87.6 | 28.0 \pm 3.8 | 12.4 | 4.0 \pm 1.5 | 0.0 | 0.0 \pm 0.0 | 22.2 \pm 3.9 (N=84) | 4.2 \pm 2.5 (N=17) | 1.5 \pm 0.6 (N=6) | 0.0 \pm 0.0 (N=0) |
| Jan-11 | 5 | 943 | 199 | 153 | 79.2 | 30.8 \pm 5.6 | 15.2 | 0.6 \pm 1.3 | 5.6 | 2.2 \pm 1.0 | 8.2 \pm 1.5 (N=41) | 13.2 \pm 3.2 (N=66) | 1.8 \pm 0.9 (N=9) | 7.4 \pm 5.1 (N=37) |
| Feb-11 | 5 | 656 | 119 | 114 | 97.4 | 22.8 \pm 4.3 | 2.6 | 0.6 \pm 0.4 | 0.0 | 0.0 \pm 0.0 | 8.2 \pm 1.5 (N=44) | 13.2 \pm 3.2 (N=51) | 0.0 \pm 0.0 (N=0) | 7.4 \pm 5.1 (N=19) |

| | Overall feeding* | Overall plant feeding** | | | | | | | | | | | | |
|-------------------|-------------------------|-------------------------|---------------|-------------|-------------|-----------|-----------|----------|-----------|----------|----------------------|-------------------|------------------|-------------------|
| | Plant | Faunals | Fungi | Fruit | Stem-leaves | Resin | Flower | | | | | | | |
| | Number of days observed | Total scans | Feeding scans | Plant scans | % feeding | Mean ±SE | % feeding | Mean ±SE | % feeding | Mean ±SE | Mean ±SE | Mean ±SE | Mean ±SE | Mean ±SE |
| Apr-11 | 3 | 668 | 119 | 117 | 98.3 | 39.0±11.0 | 1.7 | 0.7±0.3 | 0.0 | 0.0±0.0 | 38.0±11.1 (N=114) | 1.0±0.6 (N=3) | 0.0±0.0 (N=0) | 0.0±0.0 (N=0) |
| May-11 | 5 | 960 | 175 | 169 | 97.7 | 33.8±3.6 | 1.7 | 0.6±0.2 | 0.6 | 0.2±0.2 | 32.6±3.8 (N=163) | 1.2±0.5 (N=6) | 0.0±0.0 (N=0) | 0.0±0.0 (N=0) |
| Wet season | 37 | 4204 | 811 | 670 | | | | | | | | | | |
| Jun-09 | 6 | 402 | 88 | 75 | 85.2 | 12.5±5.0 | 1.1 | 0.2±0.2 | 13.6 | 2.0±1.6 | 12.3±4.9 (N=74) | 0.2±0.2 (N=1) | 0.0±0.0 (N=0) | 0.0±0.0 (N=0) |
| Aug-09 | 2 | 88 | 34 | 33 | 97.1 | 16.5±8.5 | 0.0 | 0.0±0.0 | 2.9 | 0.5±0.5 | 16.0±9.0 (N=32) | 0.5±0.5 (N=1) | 0.0±0.0 (N=0) | 0.0±0.0 (N=0) |
| Oct-09 | 8 | 1012 | 172 | 119 | 68.6 | 14.7±1.6 | 18.6 | 4.0±1.0 | 12.8 | 2.6±1.0 | 12.5±1.4 (N=100) | 2.0±0.6 (N=16) | 0.4±0.2 (N=3) | 0.0±0.0 (N=0) |
| Nov-09 | 10 | 1413 | 244 | 199 | 81.9 | 19.3±3.8 | 14.8 | 3.6±0.8 | 3.3 | 0.8±0.3 | 16.1±2.9 (N=161) | 1.5±0.6 (N=15) | 0.0±0.0 (N=0) | 2.3±1.1 (N=23) |
| Jun-10 | 4 | 488 | 70 | 64 | 91.4 | 16.0±2.4 | 7.1 | 1.2±0.5 | 1.4 | 0.2±0.2 | 14.7±3.3 (N=59) | 0.7±0.5 (N=3) | 0.5±0.5 (N=2) | 0.0±0.0 (N=0) |
| Sep-10 | 5 | 465 | 128 | 118 | 93.0 | 23.6±6.5 | 5.5 | 1.4±0.5 | 1.6 | 0.6±0.4 | 23.6±6.4 (N=118) | 0.0±0.0 (N=0) | 0.0±0.0 (N=0) | 0.0±0.0 (N=0) |
| Nov-10 | 2 | 336 | 75 | 62 | 82.6 | 31.0±2.0 | 8.0 | 3.0±2.0 | 9.3 | 3.5±2.5 | 26.0±4.0 (N=52) | 5.0±2.0 (N=10) | 0.0±0.0 (N=0) | 0.0±0.0 (N=0) |

* corresponding to column 4 of the table ** corresponding to column 5 of the table

Mean ±SE provided above are group-scans per day

Bibliography

Bibliography

- Abdi, H. (2007). The Bonferonni and Šidák corrections for multiple comparisons. *Encyclopedia of measurement and statistics*, 3, 103-107.
- Abegg, C., & Thierry, B. (2002). Macaque evolution and dispersal in insular south-east Asia. *Biological Journal of the Linnean Society*, 75, 555-576.
- Altmann, J. (1974). Observational study of behavior: sampling methods. *Behaviour*, 49, 227-267.
- Amit, M., & Correa, M. (1997). Uttara Kannada an evaluation of the first phase of work on non timber forest produce in support of the KFD/DFID Western Ghats forestry project, Oxfam (India) trust, New Delhi.
- Armstrong, R.A. (2014). When to use the Bonferroni correction. *Ophthalmic and Physiological Optics*, doi: 10.1111/opo.12131
- Arnold, J.E.M., & Perez, M.R. (2001). Can non-timber forest products match tropical forest conservation and development objectives? *Ecological Economics*, 39, 437-447.
- Ashton, P. S. (1984). Biosystematics of tropical forest plants: a problem of rare species. In *Plant biosystematics* Eds . Grant, W.F.
- Asner, G. P., Knapp, D. E., Broadbent, E. N., Oliveira, P. J., Keller, M., & Silva, J. N. (2005). Selective logging in the Brazilian Amazon. *Science*, 310, 480-482.
- Ayyappan, N. & Parthasarathy, N. (1999). Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagaliar, Anamalai, Western Ghats, India. *Biodiversity and Conservation*, 8, 1533-1554.
- Ayyappan, N. & Parthasarathy, N. (2004). Short-term changes in tree populations in a tropical evergreen forest at Varagaliar, Western Ghats, India. *Biodiversity and Conservation*, 10, 1843-1851.
- Baoping, R., Ming, L., Yongcheng, L., & Fuwen, W. (2009). Influence of day length, ambient temperature, and seasonality on daily travel distance in the Yunnan snub-nosed monkey at Jinsichang, Yunnan, China. *American Journal of Primatology*, 71, 233-241.
- Bawa, K.S. & Godoy, R. (1993). Introduction to case studies from South Asia. *Economic Botany*, 47, 248-250.
- Bawa, K.S. (1992). The Riches of Tropical Forests: Non-Timber Products. *Trends in Ecology and Evolution*, 7, 361-63.

Beard, C. (2002). East of Eden at the Paleocene/Eocene boundary. *Science*, 295, 2028-2029.

Bhat, D.M., Naik, M.B., Patagar, S.G., Hegde, G.T., Kanade, Y.K., Hegde, G.N., Shastri, C.M., Shetti, D.M. & Furtado, R.M. (2000). Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. *Current Science* 79, 975-985.

Bhat, P.R., Murali, K.S., Hegde, G.T., Shastri, C.M., Bhat, D.M., Murthy, I.K., & Ravindranath, N.H. (2003). Annual variation in non-timber forest product yield in the Western Ghats, Karnataka, India. *Current Science*, 85, 1350-1355.

Bhatnagar, P. (2002). Conservation and Trade of Medicinal Herbs: A Study of Safed Musli (*Chlorophytum* spp.) in Madhya Pradesh. *Sustainable Forestry*, 7, 11-14.

Caldecott, J. O. (1986). *An ecological and behavioural study of the pig-tailed macaque*. Basel: S. Karger, pp 262

Campbell, J.B. (2007) *Introduction to Remote Sensing*, Taylor & Francis, New York, 4th edition.

Campbell-Smith, G., Campbell-Smith, M., Singleton, I., & Linkie, M. (2011). Apes in space: saving an imperilled orangutan population in Sumatra. *PLoS One*, 6, e17210.

Cannon, C.H., Peart, D.R. & Leihton, M. (1998). Tree species diversity in commercially logged Bornean rain-forest. *Science* 28, 1366-1368.

Census of India. (1991). District Profile 1991: Karnataka. New Delhi: Office of the Registrar General and Census Commissioner.

Champion, H.G., & Seth, S.K. (1968). *A revised survey of forest types of India* (p. 404) Nasik, Government of India press.

Chandran, M.D.S., Mesta, D.K., Rao, G.R., Ali, S., Gururaj, K.V., & Ramachandra T.V. (2008). Discovery of two critically endangered tree species and issues related to relic forests of the Western Ghats. *The Open Conservation Biology Journal*, 2:1-8.

Chandran, M.S. (1997). On the ecological history of the Western Ghats. *Current Science*, 73, 146-155.

Chapman, C. (1988). Patterns of foraging and range use by three species of neotropical primates. *Primates*, 29, 177-194.

Chapman, C. A., & Fedigan, L. M. (1990). Dietary differences between neighboring *Cebus capucinus* groups: local traditions, food availability or responses to food profitability?. *Folia Primatologica*, *54*, 177-186.

Chapman, C. A., Balcomb, S. R., Gillespie, T. R., Skorupa, J. P., & Struhsaker, T. T. (2000). Long-term effects of logging on African primate communities: a 28-year comparison from Kibale National Park, Uganda. *Conservation Biology*, *14*, 207-217.

Chapman, C.A., & Rothman, J.M. (2009). Within-species differences in primate social structure: Evolution of plasticity and phylogenetic constraints. *Primates*, *50*, 12-22.

Charnov, E. L. (1976). Optimal foraging, the marginal value theorem. *Theoretical population biology*, *9*, 129-136.

Chittibabu, C.V., & Parthasarathy, N. (2000). Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. *Biodiversity & Conservation*, *9*, 1493-1519.

Cincotta, R.P., Wisnewski, J., & Engelman, R. (2000). Human population in the biodiversity hotspots. *Nature*, *404*, 990-992.

Condit, R. (1996). Defining and Mapping vegetation types in megadiverse tropical forests. *Trends in Ecology and Evolution* *11*, 4-5.

Condit, R., Hubbell, S.P., La Frankie, J.V., Sukumar, R., Manokaran, N., Foster, R.B. & Ashton, P.S. (1996). Species-area and species-individual relationships for tropical trees a comparison of three 50 ha plots. *Journal of Ecology* *84*, 549-562.

Condit, R., Sukumar, R., Hubbell, S.P. & Foster, R.B. (1998). Predicting population trends from size distributions: a direct test in a tropical tree community. *The American Naturalist* *152*, 495-509.

Cottam, G., & Curtis, J.T. (1956). The use of distance measures in phytosociological sampling. *Ecology*, *37*, 451-460.

Cunningham, A.B. (1993). *African Medicinal Plants Setting Priorities at the Interface between Conservation and Primary Healthcare*. People and Plant Working Paper1 . UNESCO, Paris, France.

Cunningham, A.B. (2001). *Applied Ethnobotany: People, Wild Plant Use and Conservation*. London: Earthscan Publications.

Curtis, J.T., & McIntosh, R.P. (1950). The interrelations of certain analytic and synthetic Daniels, R.J.R. (1989). A conservation strategy for the birds of the Uttara Kannada district, PhD. thesis submitted to Indian Institute of Science, Bangalore.

Davidar, P., Puyravaud, J.P. & Leigh, E.G. (2005). Changes in rain forest tree diversity, dominance and rarity across a seasonality gradient in the Western Ghats, India. *Journal of Biogeography* 32, 493-501.

Dirzo, R., & Raven, P.H. (2003) Global state of biodiversity and loss. *Annual Review of Environmental Resources*, 28, 137–167.

Doran-Sheehy, D.M., Greer, D., Mongo, P., & Schwindt, D. (2004). Impact of ecological and social factors on ranging in western gorillas. *American Journal of Primatology*, 64, 207-222.

Downs, J.A., & Horner, M.W. (2008). Effects of point pattern shape on home-range estimates. *The Journal of Wildlife Management*, 72, 1813-1818.

Fan, P.F., & Jiang, X.L. (2008). Effects of food and topography of ranging behavior of black crested gibbon (*Nomascus concolor jingdongensis*) in Wuliang mountain, Yunnan, China. *American Journal of Primatology*, 70, 871-878.

Fangliang, H., Legendre, P. & LaFrankie, J.V. (1997). Distribution patterns of tree species in a Malaysian tropical rain forest. *Journal of Vegetation Science* 8, 105-114.

Fashing, P.J. (2001). Activity and ranging patterns of guerezas in the Kakamega Forest: intergroup variation and implications for intra group feeding competition. *International Journal of Primatology*, 22, 549-577.

Felton, A. M., Engström, L. M., Felton, A., & Knott, C. D. (2003). Orangutan population density, forest structure and fruit availability in hand-logged and unlogged peat swamp forests in West Kalimantan, Indonesia. *Biological Conservation*, 114, 91-101.

Fleury, M.C., & Gautier-Hion, A. (1999). Seminomadic ranging in a population of black colobus (*Colobus satanas*) in Gabon and its ecological correlates. *International Journal of Primatology*, 20, 491-509.

Foley, J. A., Monfreda, C., Ramankutty, N., & Zaks, D. (2007). Our share of the planetary pie. *Proceedings of the National Academy of Sciences*, 104, 12585-12586.

Fooden, J. (1982). Ecogeographic segregation of macaque species. *Primates*, 23, 574-579.

Gadgil, M. & Chandran, M.D.S. (1989). *Environmental impact of forest based industries on the evergreen forests of Uttara Kannada district: A Case Study*. Final Report submitted to Department of Ecology and Environment, Government of Karnataka.

Ganesh, T., Ganesan, R., Devy, M.S., Davidar, P. & Bawa, K.S. (1996). Assessment of plant biodiversity at a mid elevation evergreen forest of Kalakad Mundanthurai Tiger Reserve, Western ghats, India, *Current Science* 71, 379-392.

Gaonkar, D.S., Shivanagowda, S., & Harrison, M. (1998). *A Review of NTFF Management in Kanara Circle: Policy and Institutional Changes to Improve Resource Management and Rural Livelihoods*. Bangalore: Western Ghats Forestry Project, Karnataka Forest Department.

Gaulin, S.J.C., & Gaulin, C.K.(1982). Behavioral ecology of *Alouatta seniculus* in Andean cloud forest. *International Journal of Primatology* 3,1-32.

Geist, H.J., & Lambin, E.F. (2002). Proximate Causes and Underlying Driving Forces of Tropical Deforestation Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. *BioScience*, 52, 143-150.

Ghate, U., Joshi, N.V. & Gadgil, M. (1998) On the patterns of tree diversity in the Western ghats of India, *Current Science* 75, 594-603.

Gibson, L., Lee, T.M., Koh, L.P., Brook, B. W., Gardner, T. A., Barlow, J., ... & Sodhi, N.S. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, 478, 378-381.

Green, S., & Minkowski, K. (1977). *The Lion-tailed Macaque and its South Indian Rainforest Habitat.*, in Prince Rainier III and Bough, G.H (eds.), Primate Conservation, NewYork: Primate Conservation Academic Press. pp. 290-338.

Green, S., & Minkowski, K. (1977). The lion-tailed monkey and its South Indian rainforest habitat. *Primate Conservation*, 289-337.

Grueter, C.C., Li, D., Ren, B., & Wei, F. (2009). Choice of analytical method can have dramatic effects on primate home range estimates. *Primates*, 50, 81-84.

Grueter, C.C., Li, D., van Schaik, C.P., Ren, B., Long, Y., & Wei, F. (2008). Ranging of *Rhinopithecus bieti* in the Samage Forest, China. I. Characteristics of range use. *International Journal of Primatology*, 29, 1121-1145.

Gubbi, S., & MacMillan, D.C. (2008). Can non-timber forest products solve livelihood problems? A case study from Periyar Tiger Reserve, India. *Oryx*, 42, 222-228.

Gururaja, K.V., Aravind, N.A., Ali, S., Ramachandra, T.V., Velan, T.P., Krishnakumar, V. & Aggarwal, R.K. (2007). A new species from the Central Western Ghats of India and its phylogenetic position. *Zoological Science*, 24, 525-534.

Hardus, M. E., Lameira, A. R., Menken, S. B., & Wich, S. A. (2012). Effects of logging on orangutan behavior. *Biological Conservation*, 146, 177-187.

Harrison, S., & Bruna, E. (1999). Habitat fragmentation and large-scale conservation: what do we know for sure?. *Ecography*, 22, 225-232.

Harvey, P.H., & Clutton-Brock, T.H. (1981). Primate home-range size and metabolic needs. *Behavioral Ecology and Sociobiology*, 8, 151-155.

Hegde, N.R., & Vasudeva R., (2010). *Ecological cost of drying Uppage (Garcinia gummi-gutta) fruits in Western ghats* in the Proceedings of the National symposium on “Garcinia genetic resources: Linking Livelihood, Diversity and Management” in Vasudeva, R., Janagoudar, B.S., Reddy, B.M.C., Sthapit, B and Singh, H.P. (eds.), College of Forestry, Sirsi, India.

Hegde, P., Hegde, B. & Hegde, N.R. (2000). *Non-Timber Forest Products in Uttara Kannada District.*, report submitted to International Union for the Conservation of Nature and Natural Resources. Gland, Switzerland: IUCN.

Hegde, R., Suryaprakash, S., Achoth, L. & Bawa, K.S. (1996). Extraction of Non-Timber Forest Products in the Forests of Biligiri Rangan Hills, India, 1: Contribution to Rural Income. *Economic Botany*, 50, 243-51.

Hiremath, A.J. (2004). The ecological consequences of managing forests for non-timber products. *Conservation and Society*, 2, 211–216.

Hoffman, T.S., & O’Riain, M.J. (2011). The spatial ecology of chacma baboons (*Papio ursinus*) in a human-modified environment. *International Journal of Primatology*, 32, 308-328.

Hurlbert, S. H. (1978). The measurement of niche overlap and some relatives. *Ecology*, 59, 67-77.

International Tropical Timber Organization. (2002). *ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forests* (No. 13). International Tropical Timber Organization.

Irwin, M.T. (2007). Diademed sifaca (*Propithecus diadema*) ranging and habitat use in continuous and fragmented forest: higher density but lower viability in fragments. *Biotropica*, 40, 231-240.

Isaac, G. (1971). The diet of early man: aspects of archaeological evidence from Lower and Middle Pleistocene sites in Africa. *World Archaeology*, 2, 278-299.

- Isbell, L.A. (1991). Contest and scramble competition: patterns of female aggression and ranging behavior among primates. *Behavioural Ecology*, 2, 143–155.
- Ivlev V.S. (1961). *Experimental ecology of feeding of fishes*. Yale university press. New Haven, Connecticut USA
- Jha, C. S., Dutt, C. B. S., & Bawa, K. S. (2000). Deforestation and land use changes in Western Ghats, India. *Current Science*, 79, 231-237.
- Johns, A. D. (1988). Effects of "selective" timber extraction on rain forest structure and composition and some consequences for frugivores and folivores. *Biotropica*, 20, 31-37.
- Johns, A. D. (1992). Vertebrate responses to selective logging: implications for the design of logging systems. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 335, 437-442.
- Johns, A.D. (1985). Selective logging and wildlife conservation in tropical rain-forest: problems and recommendations. *Biological Conservation*, 31, 355-375.
- Johns, A.D. (1986). Effects of selective logging on behavioral ecology of west Malayan primates. *Ecology* 67, 684-694.
- Johns, A.D., & Skorupa, J.P. (1987). *Response of rain-forest primates to habitat disturbance: a review*. *International Journal of Primatology*, 8, 157–191.
- Johnston, M. & Gillman, M. (1995). Tree population studies in low-diversity forests, Guyana. Floristic composition and stand structure. *Biodiversity and Conservation* 4, 339-362.
- Joseph, G. (1998). *Recent Population Trends and management of lion-tailed macaque (Macaca silenus) in Silent Valley National Park, Kerala, India*.
- Joseph, G.K., & Ramachandran, K.K. (2001). Silent Valley National Park – An undisturbed abode for endangered lion-tailed macaque (*Macaca silenus*). *Tigerpaper*, 28, 25-30.
- Karanth, K.P. (2003). Evolution of disjunct distributions among Wet-zone species of the Indian subcontinent: Testing various hypotheses using. *Current Science*, 85, 1276-1283.
- Karanth, K.U. (1985). Ecological status of the lion-tailed macaque and its rainforest habitats in Karnataka, India. *Primate Conservation*, 6, 73-84.
- Kaushal, K.K., & Melkani, V.K. (2005). India: Achieving the millennium development goals through non-timber forest products, *International Forestry Review* 7, 128-134.
- Kinnaird, M.F. (1990). *Behavioral and demographic responses to habitat change by the Tana River Crested Mangabey (Cercocebus galeritus galeritus)*, Ph.D. Thesis. Florida,

- Kinnaird, M.F., Sanderson, E.W., O'Brien, T.G., Wibisono, H.T., & Woolmer, G. (2003). Deforestation trends in a tropical landscape and implications for endangered large mammals. *Conservation Biology*, 17, 245-257.
- Kirkpatrick, C.R., Long, Y.C., Zhong, T., & Xiao, L. (1998). Social organization and range use in the Yunnan snub-nosed monkey (*Rhinopithecus bieti*). *International Journal of Primatology*, 19, 13-51.
- Koenig, A. (2002). Competition for resources and its behavioral consequences among female primates. *International Journal of Primatology*, 23, 759-783.
- Krebs, J. R. (1973). Social learning and the significance of mixed-species flocks of chickadees (*Parus* spp.). *Canadian Journal of Zoology*, 51, 1275-1288.
- Krishnadas, M., Chandrasekhara, K., & Kumar, A. (2011). The response of the frugivorous lion-tailed macaque (*Macaca silenus*) to a period of fruit scarcity. *American Journal of Primatology*, 73, 1250-1260.
- Krishnamani, R. and Kumar, A. (2000). Phyto-ecology of the lion-tailed macaque (*Macaca silenus*) habitats in Karnataka, India: Floristic structure and diversity of food trees. *Primate Report*, 58, 27-66.
- Kuipers, S.E. (1997). *Trade in medicinal plants. Medicinal plants for forest conservation and health care*. In Bodekar, G., Bhat, K.K.S., Burley, J. and Vantomme, P. (eds.), Food and Agriculture Organization, Rome, Italy, pp. 45-59.
- Kumar, A. (1985). *Patterns of Extinction in India, Sri Lanka and Elsewhere in South East Asia: Implications for Lion-tailed Macaque Wildlife Management and the Indian Conservation System*. In P.G. Heltne (ed.), *Lion-tailed Macaque: Status and Conservation*, New York: R. Liss, pp. 65-90.
- Kumar, A. (1987). *The ecology and population dynamics of the lion-tailed macaque (Macaca silenus) in South India*. Ph.D. Thesis. Cambridge, University of Cambridge.
- Kumar, A. (1995). Birth rate and survival in relation to group size in the lion-tailed macaque, *Macaca silenus*. *Primates*, 36, 1-9.
- Kumar, A. (2013). Lion-Tailed Macaque: In *Mammals of South Asia*, Volume 1: Eds Johnsingh A.J.T & Manjrekar, N, (pp 117-133), Universities Press, India.
- Kumara, H.N., & Singh, M. (2004 a). Distribution and abundance of primates in rain forests of the Western Ghats, Karnataka, India and the conservation of *Macaca silenus*. *International Journal of Primatology*, 25, 1001-1018.

Kumara, H.N., & Singh, M. (2004 b). The influence of differing hunting practices on the relative abundance of mammals in two rainforest areas of the Western Ghats, India. *Oryx*, *38*, 321-327.

Kumara, H.N., & Sinha, A. (2009). Decline of the endangered lion-tailed macaque *Macaca silenus* in the Western Ghats, India. *Oryx*, *43*, 292-298.

Kumara, H.N., Pritham, N.S., Santhosh, K., Vijay Mohan Raj, V., & Sinha, A. (2011). Decline of suitable habitats and conservation of the endangered lion-tailed macaque: land cover change at proposed protected area in Sirsi-Honnava, Western Ghats, India. *Current Science*. *101*, 434-439.

Kumara, H.N., Singh, M., Sharma, A.K., Santhosh, K., & Pal, A. (2014). Impact of forest fragment size on between-group encounters in lion-tailed macaques. *Primates*, *55*, 543-548.

Kurup, G.U., & Kumar, A. (1993). Time budget and activity patterns of lion-tailed macaques (*Macaca silenus*), *International Journal of Primatology*, *14*, 27-39.

Lambert, D. (1998). Primate Frugivory in Kibale National Park, Uganda, and its Implications for Human Use of Forest Resources. *African Journal of Ecology*, *36*, 234-40.

Lange, D. (1998). *Europe's Medicinal and Aromatic plants. Their Use, Trade and Conservation*, TRAFFIC International, Cambridge, U.K.

Laurance, W.F. (1999). Reflections on the tropical deforestation crisis. *Biological Conservation*, *91*, 109-117.

Leimgruber, P., Gagnon, J.B., Wemmer, C., Kelly, D.S., Songer, M.A., & Selig, E.R. (2003). Fragmentation of Asia's remaining wildlands: implications for Asian elephant conservation. *Animal Conservation*, *6*, 347-359.

Leimgruber, P., Kelly, D. S., Steininger, M. K., Brunner, J., Müller, T., & Songer, M. (2005). Forest cover change patterns in Myanmar (Burma) 1990-2000. *Environmental Conservation*, *32*, 356-364.

Li, B.G., & Zhao, D.P. (2005). Female multiple copulations among wild Sichuan snub-nosed monkeys (*Rhinopithecus roxellana*) in the Qinling Mountains, China. *Chinese Science Bulletin*, *50*, 942-944.

Li, Y.M. (2001). The diet of the Sichuan snub-nosed monkey (*Pygatrix roxellana*) in Shennongjia Nature Reserve, China. *Folia Primatologica*, *72*, 40-43.

Li, Z., & Rogers, E. (2004). Habitat quality and activity budgets of white-headed langurs in Fusui, China. *International Journal of Primatology*, *25*, 41-54.

- Lindburg, D.G. (2001). A Century of Involvement with Lion-tailed Macaques in North Amerika. *Primate Report*, 51-64.
- Luo, Z.X., Crompton, A.W., & Sun, A.L. (2001). A new mammalian form from the early Jurassic and evolution of mammalian characteristics. *Science*, 292, 1535-1540.
- MacArthur, R. H., & Pianka, E. R. (1966). On optimal use of a patchy environment. *American Naturalist*, 100, 603-609.
- Magurran, A. E. (2004). Measuring biological diversity. *African Journal of Aquatic Science*, 29, 285-286.
- Mahapatra, A. & Mitchell, C.P. (1997). Sustainable development of non-timber forest products: implication for forest management in India. *Forest Ecology and Management*, 94, 15-29.
- Mahapatra, A.K., Albers, H.J, & Robinson, E.J.Z. (2005). The impact of NTFP sales on rural households' cash income in India's dry deciduous forest. *Environmental Management*, 35, 258-265
- Maithani, G.P. (1994). Management perspectives of minor forest produce. *MFP News* 2.
- Majeed, M., Rosen, R., McCarty, M., Conte, A., Patil, D. & Butrym, E. (1994). *Citrin: A Revolutionary Herbal Approach to Weight Management*. Burlingame, CA: New Editions Publishing.
- Malcolm, J.R., & Ray, J.C. (2000). Influence of Timber Extraction Routes on Central African Small-Mammal Communities, Forest Structure, and Tree Diversity. *Conservation Biology*, 14, 1623-1638.
- Maruhashi, T., Saito, C., & Agetsuma, N. (1998). Home range structure and inter-group competition for land of Japanese macaques in evergreen and deciduous forests. *Primates*, 39, 291-301.
- Matsuda, I., Tuuga, A., & Higashi, S. (2009). Ranging behavior of proboscis monkeys in a riverine forest with special reference to ranging in inland forest. *International Journal of Primatology*, 30, 313-325.
- Mehlman, P.T. (1989). Comparative density, demography, and ranging behavior of Barbary macaques (*Macaca sylvanus*) in marginal and prime conifer habitats. *International Journal of Primatology*, 10, 269-292.
- Mendiratta, U., Kumar, A., Mishra, C., & Sinha, A. (2009). Winter ecology of the Arunachal macaque *Macaca munzala* in Pangchen valley, western Arunachal Pradesh, northeastern India. *American Journal of Primatology*, 71, 939-947.

Menon, S., & Bawa, K. S. (1997). Applications of geographic information systems, remote-sensing, and a landscape ecology approach to biodiversity conservation in the Western Ghats. *Current Science*, 73, 134-145.

Menon, S., & Poirier, F.E. (1996). Lion-tailed macaques (*Macaca silenus*) in a disturbed forest fragment: activity patterns and time budget. *International Journal of Primatology*, 17, 969-985.

Menon, S.A. (1993). *Ecology and conservation of the endangered lion-tailed macaque (Macaca silenus) in the landscape mosaic of the Western Ghats*.

Mesta, D.K., Ramachandra, T.V., Chandran, S., Rao, G.R., Ali, S., & Gururaja, K.V. (2008). Discovery of two critically endangered tree species and issues related to relic forests of the Western Ghats. *The Open Conservation Biology Journal*, 2, 1-8.

Mills, L. S., Soulé, M. E., & Doak, D. F. (1993). The keystone-species concept in ecology and conservation. *BioScience*, 43, 219-224.

Moegenburg, S.M. (2002). *Harvest and Management of Forest Fruits by Humans: Implications for Fruit-Frugivore Interactions*. In Levey, D.J., Silva, W.R. and Galetti, M. (eds.), *Seed Dispersal and Frugivory: Ecology, Evolution and Conservation*, Wallingford, UK: CAB International, pp. 479-494.

Molur, S., Brandon-Jones, D., Dittus, W., Eudey, A.A., Kumar, A., Singh, M., Feeroz, M.M., Chalise, M., Priya P., & Walker, S. (2003). *Status of South Asian Primates: Conservation Assessment and Management Plan (C.A.M.P.) Workshop Report*. Zoo Outreach Organization / CBSG South Asia, Coimbatore, India

Morgan, D., & Sanz, C. (2007). *Best practice guidelines for reducing the impact of commercial logging on great apes in Western Equatorial Africa*. IUCN.

Mori, S.A. & Boom, B.M. (1983). Southern Bahian Moist Forests, *The Botanical Review* 49, 155-232

Murali, K.S., Shaankar, R.U., Shankar, U. Ganeshiah K.N. & Bawa, K.S. (1996). Extraction of Non-Timber Forest Produce in the Forests of Biligiri Rangan Hills, India, 2: Impact of NTFP Extraction on Regeneration, Population Structure and Species Composition. *Economic Botany*, 50, 252-69.

Murthy, I.K., Bhat, P.R., Ravindranath, N.H., & Sukumar, R. (2005). Financial valuation of non-timber forest product flows in Uttara Kannada district, Western Ghats, Karnataka. *Current Science*, 88, 1573-1579.

Murthy, I.K., Bhat, S., Sathyanarayan, V., Patgar, S..... & Saxena, R. (2016). Vegetation structure and composition of tropical evergreen and deciduous forests in Uttara Kannada district, Western Ghats under different disturbance regimes. *Tropical Ecology*, 57, 77-88.

Myers, N. (1988). Tropical forests: much more than stocks of wood. *Journal of Tropical Ecology*, 4, 209-221.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403, 853-858.

Nameer, P.O. (2000). Checklist of Indian mammals. *Thiruvananthapuram, India: Kerala Forest Department*.

Negi, C.S. (2003). 'Yar Tsa Gumba'. *Down to Earth*, pp. 49-51.

Nelder, J.A., & Wedderburn, R.W.M. (1972). Generalized Linear Models, *Journal of Royal Statistical Society* 135, 370.

Oates, J. F. (1996). *African primates. Status survey and conservation action plan* (No. 333.959 A258 1996). IUCN, Gland (Suiza).

Oates, J.F. (1986). Action plan for African primate conservation. *World Wildlife Fund, Stony*.

O'Brien, T.G., & Kinnaird, M.F. (1997). Behavior, diet, and movements of the Sulawesi crested black macaque (*Macaca nigra*). *International Journal of Primatology*, 18, 321-351.

Pandey, P.K. (2006). Regeneration behaviour of important tree species in relation to disturbance in joint forest management adopted village forests in Satpura plateau, Madhya Pradesh, India. *Indian Forester* 132, 91-104.

Parthasarathy, N. (1999). Tree diversity and distribution in undisturbed and human-impacted sites of tropical wet evergreen forest in southern Western Ghats, India. *Biodiversity & Conservation*, 8, 1365-1381.

Parthasarathy, N. (2001). Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. *Current Science* 80, 389-393.

Parthasarathy, N., & Karthiketan, R. (1997) Biodiversity and population density of woody species in a tropical evergreen forest in Courtallam reserve forest, Western Ghats, India. *Tropical Ecology* 38, 297-306.

Pascal, J.P., & Peilssier, R. (1996). Structure and floristic composition of a tropical evergreen forest in Southern India. *Journal of Tropical Ecology* 12, 191-214.

Pascal, J.P., & Ramesh, B.R. (1987). *A field key to the trees and lianas of the evergreen forests of the Western Ghats (India)*. Institut Francais de Pondichery. Pondicherry, India. pp 236.

Pascal, J.P. (1988) *The Wet evergreen forests of the Western Ghats of India*. Pondicherry: French Institute, India.

Peres, C. A. (1994). Primate responses to phenological changes in an Amazonian terra firme forest. *Biotropica*, 26, 98-112.

Peters, C.M. (1994). *Sustainable Harvest of Non-Timber Plant Resources in Tropical Moist Forest: An Ecological Primer*. Washington, DC: World Wildlife Fund.

Peters, C.M., Gentry, A.H. & Mendelsohn, R.O. (1989). Valuation of an Amazonian Rainforest. *Nature* 339, 655-56.

Philips, E.A. (1959). *Methods of vegetation study*. Henry Holt company, New York, 107p.

Phillips, O.L., Vargas, P.N., Lorenzo, A., Monteagudo, A.L., Cruz, A.P., Zans, M.E.C., Sanchez W.G., Halla M.Y., & Rose, S. (2003). Habitat association among Amazonian tree species: a landscape-scale approach. *Ecology* 91, 757-775.
phytosociological characters. *Ecology* 31, 434-455.

Pinto, A. C., Ramos, C. A., & de Carvalho, O. (2003). Activity patterns and diet of the howler monkey *Alouatta belzebul* in areas of logged and unlogged forest in Eastern Amazonia. *Animal biodiversity and conservation*, 26, 39-49.

Porter, L. M., Sterr, S. M., & Garber, P. A. (2007). Habitat use and ranging behavior of *Callimico goeldii*. *International Journal of Primatology* 28, 1035-1058.

Posey, D. (1982). Keepers of the Forest. *Garden* 6, 18-24.

Prasad, S.N., Vijayan, L., Balachandran, S., Ramachandran, V.S., & Verghese, C.P.A. (1998). Conservation planning for the Western Ghats of Kerala: I. A GIS approach for location of biodiversity hot spots. *Current Science* 75, 211-219.

Putz, F. E., Zuidema, P. A., Synnott, T., Peña-Claros, M., Pinard, M. A., Sheil, D., ... & Zagt, R. (2012). Sustaining conservation values in selectively logged tropical forests: the attained and the attainable. *Conservation Letters*, 5, 296-303.

Pyke, G.H. (1984). Optimal foraging theory: A critical review. *Annual Review of Ecology and Systematics* 15, 523-575.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

R Development Core Team (2011) *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/> Accessed 17 November 2014

Raffaelli, D. (2004). How extinction patterns affect ecosystems. *Science*, 306, 1141-1142.

Rai, N.D. (2003). *Human Use, Reproductive Ecology, and Life History of Garcinia gummi-gutta, a Non-Timber Forest Product, in the Western Ghats, India*. Ph.D. thesis. University Park: Pennsylvania State University.

Rai, N.D., & Uhl, C.F. (2004). Forest product use, conservation and livelihoods: the case of Uppage fruit harvest in the Western Ghats, India. *Conservation and Society* 2, 289-313.

Ramachandran, K.K., & Joseph, G.K. (2000). Habitat utilization of Lion tailed macaque (*Macaca silenus*) in Silent valley National park, Kerala, India. *Primate Report*, 58, 17-26

Ramachandran, K.K., & Joseph, G.K. (2001). Distribution and demography of diurnal primates in Silent Valley National Park and adjacent areas, Kerala, India. *Journal of Bombay Natural History Society* 98, 191-196.

Ramesh, B.R., Menon, S., & Bawa, K.S. (1997). A vegetation based approach to biodiversity gap analysis in the Agastyamalai region, Western Ghats, India. *Ambio* 529-536.

Remis, M. J., & Jostrobinson, C. A. (2012). Reductions in primate abundance and diversity in a multiuse protected area: Synergistic impacts of hunting and logging in a Congo Basin forest. *American journal of primatology*, 74, 602-612.

Richard, A. (1977). The feeding behaviour of *Propithecus verreauxi*. *Primate Ecology: Studies of Feeding Behavior in Lemurs, Monkeys and Apes*, Academic Press, London, 71-96.

Richard, A.F., Goldstein, S.J., & Dewar, R.E. (1989). Weed macaques: the evolutionary implications of macaque feeding ecology. *International Journal of Primatology* 10, 569-594.

Richter, C., Taufiq, A., Hodges, K., Ostner, J., & Schülke, O. (2013). Ecology of an endemic primate species (*Macaca siberu*) on Siberut Island, Indonesia. *SpringerPlus*, 2, 1-26.

Riley, E.P. (2008). Ranging patterns and habitat use of Sulawesi tonkean macaques (*Macaca tonkeana*) in a human modified habitat. *American Journal of Primatology* 70, 670-679.

Riley, E.P. (2008). Ranging patterns and habitat use of Sulawesi tonkean macaques (*Macaca tonkeana*) in a human modified habitat. *American Journal of Primatology*, 70, 670-679.

Rode, K.D., Chapman, C.A., Mcdowell, L.R., & Stickler, C. (2006). Nutritional correlates of population density across habitats and logging intensities in red tail monkeys (*Cercopithecus ascanius*). *Biotropica* 38, 625-634.

Roy, K. (2011). Resource partitioning in three sympatric primates in the rainforests of the northern Western Ghats. Ph.D. Thesis. Mysore: University of Mysore.

Roy, K., Singh, M., & Singh, M. (2011). Diet and Dietary-Niche Breadth of Diurnal Rain Forest Primates in the Central Western Ghats, India. *Folia Primatologica* 82, 283-298.

Roy, K., Singh, M., Sushma, H.S., & Singh, M. (2010). Stand structure of a primate rich rainforest region in the central Western Ghats of southern India. *Journal of Threatened Taxa* 2, 930-939.

Russon, A. E., van Schaik, C. P., Kuncoro, P., Ferisa, A., Handayani, D. P., & Van Noordwijk, M. A. (2009). Innovation and intelligence in orangutans. *Orangutans: geographic variation in behavioral ecology and conservation*. Oxford University Press, New York, pp. 279-298.

Saibaba, K.S. (2002). Working Plan for the Forests of Sirsi Division. Working Plan Wing, Karnataka Forest Department, Dharwad.

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., ... & Wall, D.H. (2000). Global biodiversity scenarios for the year 2100. *Science* 287, 1770-1774.

Samarajeewa, U., & Shanmugapirabu, N. (1983). *A Cheap Method for Preservation of Fish*. In Proceedings of the 6th International Congress of Food Science and Technology, 1, 80-81.

Santhosh, K., Kumara, H. N., Velankar, A. D., & Sinha, A. (2015). Ranging Behavior and Resource Use by Lion-Tailed Macaques (*Macaca silenus*) in Selectively Logged Forests. *International Journal of Primatology*, 36, 288-310.

Santhosh, K., Raj, V.M., & Kumara, H.N. (2013). Conservation prospects for the lion-tailed macaque (*Macaca silenus*) in the forests of Sirsi-Honnava, Western Ghats, India. *Primate Conservation* 27, 125-131.

Schoener, T. W. (1971). Theory of feeding strategies. *Annual review of ecology and systematics*, 2, 369-404.

Schoener, T. W. (1974). Resource partitioning in ecological communities. *Science*, 185, 27-39.

Sergio, W. (1988). A natural food, the Malabar tamarind, may be effective in the treatment of obesity. *Medical Hypotheses* 27, 39-40.

Shaanker, R.U., Ganeshaiyah, K.N., Krishnan, S., Ramya, R., Meera, C., & Aravind, N.A. (2004a). Livelihood gains and ecological costs of non-timber forest product dependence: assessing the roles of dependence, ecological knowledge and market structure in three contrasting human and ecological settings in south India. *Environmental Conservation* 31, 242–253.

Shaanker, R.U., Ganeshaiyah, K.N., Krishnan, S., Ramya, R., Meera, C., & Aravind, N.A. (2004b) Ecological consequences of forest use: from genes to ecosystem - a case study in the Biligiri Rangaswamy Temple Wildlife Sanctuary, South India. *Conservation and Society* 2, 347–363.

Shahabuddin, G. & Prasad, S. (2004). Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. *Conservation and Society* 2, 235–250.

Shankar, U., Murali, K.S., Shaanker, R.U., Ganeshaiyah K.N., & Bawa, K.S. (1996). Extraction of NTFP in the Forests of Biligiri Rangan Hills, India, 3: Productivity, Extraction and Prospects of Sustainable Harvest of Amla *Phyllanthus emblica* (Euphorbiaceae). *Economic Botany* 50, 270-79.

Shankar, U., Murali, K.S., Shaanker, R.U., Ganeshaiyah K.N., & Bawa, K.S. (1998). Extraction of Non-Timber Forest Products in the Forests of Biligiri Rangan Hills, India, 4: Impact on Floristic Diversity and Population Structure in a Thorn Scrub Forest. *Economic Botany* 52, 302-15.

Shanker, K., Hiremath, A. & Bawa, K. (2005). Linking biodiversity conservation and livelihoods in India. *PLoS Biology* 3, 394.

Sharma, A.K., Singh, M., Kaumanns, W., Krebs, E., Singh, M., Kumar, M.A., & Kumara, H.N. (2006). Birth patterns in wild and captive lion-tailed macaques (*Macaca silenus*). *International Journal of Primatology* 27, 1429-1439.

Sharma, N.P. (1992). *Managing the World Forest: Looking for Balance between Conservation and Development*, Kendall Hunt Publishing Company, Iowa, pp. 605.

Singh, M., Kumar, M.A., Kumara, H.N., Sharma, A.K., & Kaumanns, W. (2002). Distribution, population structure, and conservation of lion-tailed macaques (*Macaca silenus*) in the Anaimalai Hills, Western Ghats, India. *American Journal of Primatology* 57, 91-102.

Singh, M., Kumara, H.N., Ananda Kumar, M., & Sharma, A.K. (2001). Behavioral responses of lion-tailed macaque to a changing habitat in a tropical rainforest fragment in Western Ghats, India. *Folia Primatologica* 72, 278-291.

Singh, M., Roy, K., & Singh, M. (2010). Resource partitioning in sympatric langurs and macaques in tropical rainforests of central Western ghats, south India. *American Journal of Primatology* 71, 1-12.

Singh, M.R., Singh, M.E., Kumar, M.A., Kumar, H.N., Sharma, A.K., & Sushma, H.S. (2000). Niche separation in sympatric lion-tailed macaque (*Macaca silenus*) and Nilgiri Langur (*Presbytis johnii*) in an Indian rain forest. *Primate report* 58, 83-95.

Sinha, A. (2005). Not in their genes: Phenotypic flexibility, behavioural traits, and cultural evolution. *Journal of Biosciences* 30, 51-64.

Sinha, A., & Mukhopadhyay, K. (2013). *The monkey in the town's commons, revisited: An anthropogenic history of the Indian bonnet macaque*. In Radhakrishna S., Huffman M.A., The Macaque Connection pp. 187-208, Springer, New York.

Skorupa, J. P. (1986). Responses of rainforest primates to selective logging in Kibale Forest, Uganda: a summary report. In *Primates* (pp. 57-70). Springer New York.

Skorupa, J. P. (1988). *The effects of selective timber harvesting on rain-forest primates in Kibale Forest, Uganda* (Doctoral dissertation, Ph. D dissertation, University of California, Davis, 1985. Snowdon, CT).

Sorensen, T. C., & Fedigan, L. M. (2000). Distribution of three monkey species along a gradient of regenerating tropical dry forest. *Biological Conservation*, 92, 227-240.

SPSS Inc. (2007). SPSS for Windows, Rel.16.0.0. Chicago (USA): SPSS Inc.

Srinivas, V. (1997). *Tree Community structure, floristics and changes with altitude in the tropical lowland evergreen forests of Agumbe, Central Western ghats, India*; M.S. Thesis, Pondicherry University, Pondicherry.

Sterck, E.H.M., Watts, D.P., & van Schaik, C.P. (1997). The evolution of female social relationships in non human primates. *Behavioural Ecology and Sociobiology* 41, 291-309.

Stevenson, P.R. (2006). Activity and ranging patterns of Colombian woolly macaques in north-western Amazonia. *Primates* 47, 239-247.

Stickler, C. M. (2004). *The effects of logging on primate-habitat interactions: a case study of redbtail monkeys (*Cercopithecus ascanius*) in Kibale National Park, Uganda* (Doctoral dissertation, University of Florida).

Strier, K.B. (2008). Seeing the forest through the seeds: Mechanisms of primate behavioral diversity from individuals to populations and beyond. *Current Anthropology* 50, 213-228.

Struhsaker, T.T. (1997). Ecology of an African rainforest: logging in Kibale and the conflict between conservation and exploitation. Gainesville: University presses of Florida.

Suarez, S.A. (2006). Diet and travel costs for spider monkeys in a non seasonal, hyper diverse environment. *International Journal of Primatology* 27, 411-436.

Survey of India, Karnataka, 1 : 50,000 toposheet (1979). Uttara Kannada and Shimoga districts, Government of India, 1st edition.

Sushma, H.S. (2004). *Resource utilization and niche separation in sympatric rainforest arboreal mammals*. Ph.D. Thesis. Mysore: University of Mysore.

Sushma, H.S., & Singh, M. (2006). Resource partitioning and interspecific interactions among sympatric rain forest arboreal mammals of the Western Ghats, India. *Behavioral Ecology* 17, 479-490.

Symington, M. M. (1988). Environmental determinants of population densities in Ateles. *Primate Conservation*, 9, 74-79.

The IUCN Red List of Threatened Species. Version 2015-3. www.iucnredlist.org>.Downloaded on 31 October 2015.

Thierry, B., Singh, M., & Kaumanns, W. (2004). *Macaque Societies: A Model for the Study of Social Organization* (pp 3-10) Cambridge: Cambridge University Press

Ticktin, T. (2004). The Ecological Implications of Harvesting Non-Timber Forest Products., *Journal of Applied Ecology* 41, 11-21.

Tosi, A.J., Morales, J.C., & Melnick, D.J. (2003). Paternal, maternal, and biparental molecular markers provide unique windows onto the evolutionary history of macaque monkeys. *Evolution* 57, 1419-1435.

Townsend C.R., Begon, M., & Harper, J. (2008). *Essentials of Ecology*- 3rd edition. Blackwell Publishing, USA. p.96

Tsuji, Y., & Takatsuki, S. (2009). Effects of yearly change in nut fruiting on autumn home-range use by *Macaca fuscata* on Kinkazan Island, northern Japan. *International Journal of Primatology* 30, 169-181.

Tucker, C.J., & Maxwell, E.L. (1976). Sensor design for monitoring vegetation canopies. *Photogrammetric Engineering and Remote Sensing* 42, 1399-1410.

Twinomugisha, D., & Chapman, C.A. (2007). Golden monkey populations decline despite improved protection in Mgahinga Gorilla National Park, Uganda. *African Journal of Ecology* 46, 220-224.

Umapathy, G. (1998). *Impacts of habitat fragmentation on the arboreal mammals in the wet evergreen forests of the Western Ghats, south India*. Phd thesis, Bharathiar University, Coimbatore, India

Umapathy, G., & Kumar, A (2000). Impacts of habitat fragmentation on time budget and feeding ecology of Lion-tailed macaque (*Macaca silenus*) in rain forest fragments of Anamalai hills, South India, *Primate report* 58, 67-82.

Vaisquez, R., & Gentry, A.H. (1989). Use and misuse of forest-harvested fruits in the Iquitos area. *Conservation Biology* 3, 350-361.

van Schaik, C.P. (1989). *The ecology of social relationships amongst female primates*. In: Boinski S, Garber PA, (Ed.), *On the move* (pp 351-374). Chicago: University of Chicago Press.

van Schaik, C.P., Van Noordwijk, M.A., Warsono, B., & Sutriyono, E. (1983). Party size and early detection of predators in Sumatran forest primates. *Primates* 24, 211-221.

Vavrek, Matthew J. 2011. fossil: palaeoecological and palaeogeographical analysis tools. *Palaeontologia Electronica*, 14:1T.
http://palaeo-electronica.org/2011_1/238/index.html

Velho, N., & Krishnadas, M. (2011). Post-logging recovery of animal-dispersed trees in a tropical forest site in north-east India. *Tropical Conservation Science*, 4, 405-419.

Volampeno, M.S.N., Masters, J.C., & Downs, C.T. (2011). Home range size in the blue-eyed black lemur (*Eulemur flavifrons*): A comparison between dry and wet seasons. *Mammalian Biology-Zeitschrift für Säugetierkunde* 76, 157-164.

Wada, K., & Ichiki, Y. (1980). Seasonal home range use by Japanese monkeys in the snowy Shiga Heights. *Primates* 21, 468-483.

Wada, K., & Tokida, E. (1981). Habitat utilization by wintering Japanese monkeys (*Macaca fuscata fuscata*) in the Shiga Heights. *Primates* 22, 330-348.

Watts, D.P. (2000). Mountain gorilla habitat use strategies and group movement. In: Standen V, Foley RA (Ed.), *Comparative socioecology: The behavioral ecology of humans and other mammals* (pp 195-218) Oxford: Blackwell.

Whitmore, T.C. (1998). *Potential impact of climatic change on tropical rain forest seedlings and forest regeneration*. In *Potential Impacts of Climate Change on Tropical Forest Ecosystems* (pp. 289-298). Springer Netherlands.

Whitmore, T.C., Burslem, D.F.R.P., Newbery, D.M., Prins, H.H.T., & Brown, N.D. (1998). Major disturbances in tropical rainforests. In *Dynamics of tropical communities: the 37th symposium of the British Ecological Society, Cambridge University, 1996*. (pp. 549-565). Blackwell Science Ltd..

Wibisono, H. T., Linkie, M., Guillera-Arroita, G., Smith, J. A., Sunarto, S., Asriadi, B. P., ... & Dinata, Y. (2011). Population status of a cryptic top predator: an island-wide assessment of tigers in Sumatran rainforests. *PLoS One*, 6, e25931.

Wibisono, H.T., Linkie, M., Guillera-Arroita, G., Smith, J.A., Sunarto, S., Asriadi, B.P., ... & Dinata, Y. (2011). Population status of a cryptic top predator: an island-wide assessment of tigers in Sumatran rainforests. *PLoS One* 6, e25931.

Wrangham, R.W. (1980). An ecological model of female-bonded primate groups. *Behaviour* 75, 262-299.

Wyss, A. (2001). Digging up fresh clues about the origin of mammals. *Science* 292, p.1496.

Xiang, Z.F. (2005). *The ecology and behavior of Black-and-White Snub-nosed Monkeys (Rhinopithecus bieti, Colobinae) at Xiaochangdu in Honglaxueshan National Nature Reserve, Tibet, China*. Ph.D. Thesis. China: Kunming Institute of Zoology.

List of publications



Ranging Behavior and Resource Use by Lion-Tailed Macaques (*Macaca silenus*) in Selectively Logged Forests

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Abstract Physical and ecological factors such as season, rainfall, food availability, number of plant species eaten, intergroup encounters, and degree of terrestriality influence the daily path length (DPL) and home range use of animals. We examined whether these factors influenced DPL and home range use in a group of endemic lion-tailed macaques (*Macaca silenus*) in the selectively logged forests of Sirsi-Honnava in the central Western Ghats Mountains of south India. We predicted that monthly rainfall, fruit tree density, number of plant species eaten, intergroup encounters, and terrestriality would correlate with DPL, and fruit tree density, overall tree density, and richness of fruiting tree species would correlate with home range use. We collected data on feeding ecology from scan sampling, and DPL and home range use by recording the geo-coordinates of the focal group with a handheld GPS during daily follows. We obtained 1230 h of observations over 24 mo between 2008 and 2011. We collected data on the density of food species and of all trees using the point-centered quarter method in 1-ha grid cells overlaid on the home range of the study group. Results showed that the mean monthly DPL correlated positively with the number of trees fruiting in a month and negatively with rainfall. Overall tree density and fruit tree density correlated positively with habitat use. These findings support the hypothesis that primary food resources are a major determinant of primate ranging patterns. Our results are also

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Conservation Prospects for the Lion-tailed Macaque (*Macaca silenus*) in the Forests of Sirsi-Honnava, Western Ghats, India

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Abstract: The lion-tailed macaque (*Macaca silenus*) is one of the most threatened of the primates of the Western Ghats. Confirmation of its large metapopulation in a relatively unprotected area (a reserve forest) of Karnataka has marked an important step for the future of this population. The number of lion-tailed macaques estimated was 638 in 31 groups with an average group size of 20.6, excluding lone males. A review of the literature confirms that this is one of the larger known populations in the wild. This reserve forest faces a number of threats because of anthropogenic activities such as habitat fragmentation, encroachment and developmental projects. In an attempt to save and restore the northernmost habitat of the lion-tailed macaque, we proposed that the forests where they live be declared a wildlife sanctuary or conservation reserve, using them as an umbrella species for conservation. In response to this, the forest department of the Government of Karnataka notified the proposed area, with only minor modifications to the boundary, as the ‘Aghanashini Lion-tailed Macaque Conservation Reserve’. We suggest some immediate management interventions to minimize further pressure on this highly threatened habitat.

Key words: Primates, protected area, umbrella species, conservation reserve, management intervention, Karnataka, lion-tailed macaque

Introduction

The hill ranges of the Western Ghats cover less than 6% of India’s landmass but harbor more than 30% of the world’s plant and vertebrate species (Das *et al.* 2006), and are thus considered a global biodiversity hotspot (Myers *et al.* 2000). About 12% of the mammal species present in the Western Ghats is endemic (Das *et al.* 2006). The IUCN Red List ranks the lion-tailed macaque (*Macaca silenus*) as Endangered (IUCN 2013); endemic to the narrow ranges of the southern and central Western Ghats. Molur *et al.* (2003) projected a total lion-tailed macaque population of about 3,500 individuals in 49 sub-populations in eight locations in the Western Ghats. They are locally threatened in most of the protected areas and reserve forests of the state of Karnataka (Kumara and Sinha 2009). Karanth (1985) reported about 3,000 individuals in 123 groups in 19 locations in Karnataka from the northernmost Kumta range to southern Brahmagiri Wildlife Sanctuary. Since then, however, there have been declines in numbers of about 69% to 90% in 14 of these forest reserves due to habitat loss and fragmentation and hunting, and hunting

has eliminated them entirely from five reserves (Kumara and Sinha 2009).

In a study based largely on secondary information, Karanth (1985) reported few lion-tailed macaque groups in the forests of Sirsi-Honnava. A short survey by Kumara and Singh (2004a), however, indicated a population of more than 250 individuals in the same forests; among the few large populations of this species in the entire Western Ghats (Kumara and Singh 2004a). The Sirsi-Honnava lion-tailed macaques are, however, facing severe threats from encroachment of the forests and valleys for agriculture, developmental activities such as construction of roads, transmission lines, dams, hydroelectric power plants, and hunting (Kumara and Singh 2004a; Kumara *et al.* 2008). The problem is that reserve forests are not part of the protected area network. The forests are contiguous, and a conservation strategy is urgently needed for the lion-tailed macaques there (Kumara *et al.* 2008; Kumara and Sinha 2009). This region also harbors many endemic and endangered species, including plants such as *Semecarpus kathalekanensis* (Anacardiaceae), *Madhuca bourdillonii* (Sapotaceae), and *Syzygium travancoricum* (Myrtaceae) (Chandran *et al.* 2008),

Impact of forest fragment size on between-group encounters in lion-tailed macaques

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Abstract Between-group encounters are an obvious outcome of intergroup competition. Between-group encounters in primates range from avoidance to fatally aggressive. The prevailing hypotheses explain such encounters as mate defense strategy by males and resource defense strategy by females. However, the rate and nature of between-group encounters may also be influenced by habitat and demographic characteristics. We studied the effect of forest fragment size on group encounters in lion-tailed macaques in the Western Ghats of southern India. The encounter rate decreased as the fragment size increased. Group density and home range overlap correlated positively with the encounter rate. The aggressive encounters were more in the relatively medium-sized fragment where the observed frequency of between-group encounters was higher than the expected frequency than in the small fragment and the large forest complex. Together, these results indicate a complex pattern of effects of fragment size on between-group encounters in primates.

Keywords Lion-tailed macaques · Fragment size · Home range · Group density · Between-group encounters

Introduction

Despite the fact that associating with increasing number of individuals increases feeding competition, most primates live in groups of varying sizes. One of the hypotheses that explains group living is that it facilitates defense of food resources during intergroup competition (Wrangham 1980). An obvious consequence of intergroup competition is between-group encounters. Between-group encounters are known to be generally agonistic among gregarious species (Cheney 1987). Availability of resources might determine the competition and type of encounters between the conspecifics, among them food and mate being the major resources (Wrangham 1980; Davies 1991). The type of between-group encounters can range from avoidance to fatal aggressive (Wrangham 1980; van Schaik 1989; Isbell 1991). Several socio-ecological hypotheses have been proposed to explain the complexities of between-group encounters in primates (Wrangham 1980; van Schaik 1989; Isbell 1991; Sterck et al. 1997). The two key explanations for between-group aggression are food resource defense by adult females (Wrangham 1980) and mate resource defense by adult males (Trivers 1972), which in turn result in adopting different strategies by males and females to defend their resources. Whereas the mate defense strategy by adult males is evident among many species, resource defense by adult females is reported in some species (Fashing 2001). Defending the mate resource through defense of a food resource by adult males has been reported in a few species of primates (Rubenstein 1986; Fashing 2001; Cooper et al. 2004). Although consistent with male mate

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8. Bhattacharya, A. R. and Agarwal, K. K., Mylonites from the Kumaun Lesser Himalaya. *Neues. Jahrb. Mineral. Abh.*, 1985, **152**, 65–77.
9. Bhattacharya, A. R. and Agarwal, K. K., Strain analysis and fold shape modification in a crystalline complex of the Lesser Himalaya. *Krystallinikum*, 1989, **20**, 7–25.
10. White, S. H., Burrows, S. E., Carreras, J., Shaw, N. D. and Humphreys, F. J., On mylonites in ductile shear zones. *J. Struct. Geol.*, 1980, **2**, 175–187.
11. Passchier, C. W. and Trouw, R. A., *Microtectonics*, Springer Verlag, Germany, 1996, p. 289.
12. Spry, A., *Metamorphic Textures*, Pergamon Press, Oxford, 1969, p. 350.
13. Bali, R. and Bhattacharya, A. R., Geological and structural studies of the rocks of the Dwarahat–Chaukhutia area, Kumaun Lesser Himalaya with special reference to the North Almora Fault. *Geosci. J.*, 1988, **IX**, 215–230.
14. Bali, R. and Agarwal, K. K., Microstructures of mylonites in the Almora Crystalline Zone, Kumaun Lesser Himalaya. *Gondwana Res. Group Memoir.*, 1999, **6**, 111–116.
15. Sibson, R. H., Generation of pseudotachylite by ancient seismic faulting. *Geophys. J. R. Astron. Soc.*, 1975, **43**, 775–794.
16. Sibson, R. H., Fault rocks and fault mechanisms. *J. Geol. Soc., London*, 1975, **133**, 191–213.
17. Clarke, G. L., Pyroxene microlites and contact metamorphism in pseudotachylite veinlets from Mac Robertson Land, East Antarctica. *Aust. J. Earth Sci.*, 1990, **37**, 1–8.
18. Cosca, M. A., Cabyb, R. and Bussy, F., Geochemistry and ⁴⁰Ar/³⁹Ar geochronology of pseudotachylite associated with UHP whiteschists from the Dora Maira massif, Italy. *Tectonophysics*, 2005, **402**, 93–110.
19. Patro, R., Mohapuro, S. N., Bhattacharya, A., Pant, N. C., Nanda, J. K., Dey, A. and Tripathy, A. K., Chemical heterogeneity in an enderbite-hosted pseudotachylite, eastern India: evidence for syn-deformation multi-reaction melting in pseudotachylite. *Contrib. Mineral. Petrol.*, 2011, **161**, 547–563.
20. Philpotts, A. R., Origin of pseudotachylites. *Am. J. Sci.*, 1964, **262**, 1008–1035.
21. Grocott, J., Fracture geometry of pseudotachylite generation zone: a study of shear fractures formed during seismic events. *J. Struct. Geol.*, 1981, **3**, 169–178.
22. Maddock, R., Frictional melting in landslide-generated frictionites (hyalomylonites) and fault-generated pseudotachylites discussion. *Tectonophysics*, 1986, **128**, 151–153.
23. Maddock, R. H., Grocott, J. and van Nes, M., Vesicles, amygdaloids and similar structures in fault-generated pseudotachylites. *Tectonophysics*, 1987, **20**, 419–432.
24. Spray, J. G., Artificial generation of pseudotachylite using friction welding apparatus – simulation of melting on a fault plane. *J. Struct. Geol.*, 1987, **9**, 49–60.
25. Spray, J. G., A physical basis for the frictional melting of some rock-forming minerals. *Tectonophysics*, 1992, **204**, 205–221.
26. Lin, A., Microlite morphology and chemistry in pseudotachylite, from the Fuyun fault zone, China. *J. Geol.*, 1994, **102**, 317–329.

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Decline of suitable habitats and conservation of the endangered lion-tailed macaque: land-cover change at a proposed protected area in Sirsi–Honnavara, Western Ghats, India

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Habitat fragmentation, loss of habitat and other anthropogenic activities have caused a population decline in many species, caused restriction in their distribution or even led to their local extinction. We attempted to understand the impact of such pressures on the newly identified and possibly the largest population of the endangered lion-tailed macaque, *Macaca silenus* in the Reserve Forests of Sirsi and Honnavara, Karnataka, using a temporal series of satellite images. Classified images showed a major increase in open area with a rapid decline in vegetation cover of about 11.5% in the wet evergreen forests over the last decade, amounting to a loss at the rate of 1.9% per year. We thus consider habitat protection and restoration of evergreen forest as the top priority along with the enforcement of conservation steps, including legal action against encroachment, extraction of timber and further fragmentation, to protect this critically important habitat of the lion-tailed macaque.

Keywords: Habitat loss, fragmentation, *Macaca silenus*, satellite imagery, wet evergreen forest.

THE primary forests of Asia, particularly those of the Western Ghats in southwestern peninsular India, are disappearing at an alarming rate due to anthropogenic activities and are undergoing a change in land-use patterns, including being replaced by forests comprising inferior secondary species¹. The hill ranges of the Western Ghats are rich in biodiversity and display high endemism, and have thus been considered as one of the biodiversity hotspots of the world². The Western Ghats, however, also has a high human density³. Although these hills have been inhabited for several thousands of years⁴, the forests of the Western Ghats are declining drastically and have undergone severe fragmentation in recent years due to a

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