

**FRUIT REMOVAL, SEED DISPERSAL AND
DEMOGRAPHY OF *Emblica officinalis* AT
RAJAJI NATIONAL PARK,
UTTARANCHAL**

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By
Soumya Prasad

Under the Supervision of
Dr. Ravi Chellam
&
Dr. Jagdish Krishnaswamy

WII L&DC
Acc. no. : WF5948
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भारतीय वन्यजीव संस्थान
Wildlife Institute of India



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Wildlife Institute of India

CERTIFICATE

This is to certify that Soumya Prasad of the Wildlife Institute of India has carried out an original piece of work titled '**Fruit removal, seed dispersal and demography of *Emblica officinalis* at Rajaji National Park, Uttaranchal**' in partial fulfillment of the M.Sc (Wildlife Science) degree from the Saurashtra University, Rajkot, India. These investigations were carried out under our supervision at the Wildlife Institute of India from November 2000 to June 2001. We also certify that this work has not been submitted for any other degree of any university.

Principal Supervisor:
Dr. Ravi Chellam
Dept. of Endangered Species Management,
Wildlife Institute of India.

Co-supervisor:
Dr. Jagdish Krishnaswamy
Dept. of Habitat Ecology.,
Wildlife Institute of India.

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Place: Dehradun

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SUMMARY

Plant-frugivore interactions determine the structure and composition of plant and frugivore communities and consequently the understanding of these interactions may help in defining the management protocol for the conservation of these systems (Howe 1993). *E.officinalis* fruit are an important non-timber forest produce from Indian deciduous forests. In this study I have looked at fruit removal and seed dispersal patterns of *E. officinalis* in the context of its use by humans.

Fruit removal patterns were followed for 19 *E. officinalis* trees with a range of fruit crops (from $73 \pm 59 \times 10^3$ fruit to less than 100 fruit) at Dhaulkand, Rajaji NP. 11 of these trees were monitored to ensure that there was no human removal of the fruit. For each tree, all fruit on the ground in the fruit fall area and all fruit on 5 –7 marked branches were counted thrice every ten days in 12-hour intervals, till less than 5% of the initial number of fruits remained on the marked branches, to arrive at nocturnal and diurnal removal patterns for fruit. Factors affecting fruit persistence (number of days fruit persisted, on the marked branches) were extraction of fruit by people and fruit crop size. In the fruit-fall area, factors affecting nocturnal and diurnal fruit removal rates were clustering of fruiting trees and human induced factors.

A range of direct and indirect methods – tree watches, track plots and camera trapping were used to determine the identity of the fruit removers and to observe the mode of fruit handling by these removers. Langur (*Semnopithecus entellus*), ungulates such as chital (*Axis axis*) and barking deer (*Muntiacus muntjac*) were observed feeding on *E. officinalis* fruit. There was also evidence that the gerbil, *Tatera indica*, scatter

hoards the fruit. Retention in ungulate rumens reduced germination success of *E. officinalis* seeds.

Demography of *E. officinalis* and regeneration status of woody plant species at Rajaji was assessed along 6 one km transects across a gradient of human use intensity, 3 each in hill and plain mixed forests. The *E. officinalis* population at Rajaji was found to have very few trees below 30 cm GBH. *E. officinalis* seedlings were found only in areas almost completely free from human use. Regeneration for tree species at Rajaji was dominated by species that are not lopped for fodder.

Chapter 1. General Introduction and Literature Review

(a) *Frugivory and Seed Dispersal: terms and concepts.*

Dispersal is the movement of offspring away from the natal area. Plants, to overcome their lack of locomotive abilities, depend upon vectors such as wind, rain, insects, reptiles, birds and mammals to transport seeds away from parents. Fruits and seeds of plants are variously adapted to their modes of dispersal (Howe and Westley 1988)

In the case of animal dispersed fruits, fruit removal refers to the quantity of fruit taken by frugivores (Jordano 1995a). Patterns of fruit removal have both ecological as well as evolutionary implications. The ecological effects of fruit removal can be defined in terms of the quantity of fruits or seeds removed from a parent tree, the phenological stage at which these food items are selected, methods of seed handling, and the manner in which a given species deposits seeds within its geographic range (Schupp 1993). The evolutionary effects are seen in the way these interactions shape the fruiting season, fruit crop size, fruit size, nutritive value of fruit or seed and other strategies adopted by the plant to ensure effective dispersal and the possible coevolutionary interactions between fruiting trees and their animal dispersers. Such plant-frugivore interactions determine the structure and composition of plant and frugivore communities and consequently the understanding of these interactions may help in defining the management protocol for the conservation of these systems (Howe 1993).

Fruit removal by birds, arboreal mammals and bats is largely from fruit borne on the tree itself (Howe 1977, Jordano 1995a, Dew & Wright 1998, Korine *et al.* 2000). Terrestrial

mammals such as ungulates and rodents remove fruit from forest-floor and to a lesser extent fruits of subcanopy plants (Bodmer 1991, Forget 1990).

A fraction of the total fruit removed goes into seed dispersal (Jordano 1995a). Many hypothesis have been proposed to explain the advantages of seed dispersal for the plant:

- Janzen (1970) and Connell (1971) proposed that seed dispersal ensures escape from high seed or seedling mortality incurred under parent plants due to seed predators and herbivores. There has been evidence both in support (Janzen *et al* 1976, Howe and Primack 1975, Clark and Clark 1984) and against the escape hypothesis (Silander 1978).
- Another advantage could be colonization of rare, unpredictable or ephemeral sites (Brokaw 1985, Howe and Smallwood 1982). Widespread dispersal of seeds in the area around the parent plants will maximise the number of different sites occupied and increase the chance that some sites will become suitable in future.
- The seed shadows generated by certain dispersers might be such that they are depositing seeds in particular sites with a relatively high probability of survival. There is increasing evidence that directed dispersal occurs in many situations in which a plant has multiple dispersal agents (Howe and Smallwood 1982, Wenny and Levey 1998, Wenny 2001).

All dispersers need not be uniform in the amount of fruit they remove, fruit handling techniques or the sites at which they deposit the seeds. Some fruit consumers might leave the seed undamaged and remove it from the vicinity of the parent tree and thus effectively disperse the seeds. A fruit consumer might drop all the seeds in the vicinity of the parent tree itself where none of the above-mentioned advantages of seed dispersal operate. A fruit consumer might ultimately act as a seed predator and thus not contribute towards dispersal of the seeds. Dispersers might also alter the germination rates of seeds after gut/ rumen passage.

Disperser effectiveness is a key concept in studies dealing with plant-frugivore interactions (Howe and Smallwood 1982, Schupp 1993, Fleming and Sosa 1994).

Disperser effectiveness is defined as the contribution a disperser makes to the future reproduction of a plant. Effectiveness has both quantitative and qualitative components. The quantity of seed dispersal depends on: (a) the number of visits made to the plant by a disperser, and, (b) the number of seeds removed per visit. The quality of seed dispersal depends on: (a) the quality of treatment given in the mouth and in the gut, and, (c) the quality of seed deposition as determined by the probability that a deposited seed will survive and become an adult (Schupp 1993).

Most of the theory in frugivory and seed dispersal ecology has been centred around bird mediated seed dispersal (Howe 1977, Herrera 1982, Howe and Smallwood 1982, Jordano 1995b, Wenny and Levey 1998). Seed dispersal by primates (Estrada and Coates-Estrada 1986, Dew and Wright 1998), bats (Korine *et al.* 2000) and rodents (Forget 1990 & 1996m Diaz *et al.* 1999) have also been extensively studied. In comparison, studies that have looked at seed dispersal by ungulates and other herbivores are very few (Bodmer 1991 and Dinerstein & Wemmer 1998) and theory & methodology to study frugivory and seed dispersal by ungulates and other large herbivores is poorly developed.

(b) Sustainable use concepts and fruits as Non-Timber forest produce:

The idea that sustainable extraction of non-timber forest products (NTFPs) may provide an alternative to deforestation and ensure conservation of biological diversity in tropical forests is becoming popular (Panayotou and Ashton 1992). The underlying rationale is that NTFPs can be extracted in a sustainable manner, and that the sale of NTFPs can generate, at the

same time, enough income for the forest dwellers (Uma Shankar *et al.* 1998). We first need to set criteria for what we deem as 'sustainable' or 'unsustainable' resource use. Many authors have tried to define sustainable use and these definitions fall into three broad classes with respect to the resource users: (a) considering a single resource user, (b) considering a few resource users and (c) considering all resource users. I present below an example for each of these classes of definitions:

According to Lelé (1994), sustainable resource use is the *maintenance* of an *undiminished flow of benefits* from the *resource* to its *users over time*. Forests provide different benefits to different users and these benefits are generally *not simultaneously maximised*. Further Lelé (1994), defines 'unsustainable use' as use that results in declines in a particular benefit over time, which *ceteris paribus* would be seen as undesirable by all users.

Hall and Bawa (1993) differentiate between Economic and Ecological sustainability. According to them, extraction of NTFP may be *economically sustainable* if the value, adjusted for inflation, increases or remains constant. And in *ecological terms*, extraction is considered sustainable if the harvest has no long-term deleterious effect on the reproduction and regeneration of populations being harvested in comparison to equivalent non-harvested natural populations. Furthermore, sustainable harvest should have no discernable adverse effect on other species in the community, or on ecosystem structure and function.

If sustainability is to be achieved from the point of view of *all* the resource users: social, economic and political set-ups at local, regional and national levels need to be managed in such way that the activity (i.e. NTFP extraction) is lucrative over time, yielding

social improvement for its participants, as well as the capacity for maintaining ecological and agronomic equilibrium (Homma 1992).

There has been increasing concern globally about the impacts of NTFP extraction on the resource population subject to extraction, resource users other than humans (i.e, wildlife) and ecosystem functioning. A number of studies on population demography of resource species have reported insufficient regeneration due to NTFP extraction (Vasques and Gentry 1989, Pinedo-Vasquez et al. 1990, Olmsted and Alvarez-Buylla 1995, Umashankar et al. 1998). Many non-timber forest products contain substantial concentrations of limiting nutrients, and over the long term it is possible that the export of these nutrients from these forests may be unsustainable (Salafsky et al. 1993). With ever-increasing habitat loss and fragmentation, these resources could be of key importance to the survival of several threatened populations. The removal of a given product from a forest may upset delicate natural balances, which could then reverberate throughout the ecosystem (Terborgh 1988).

Many tropical fruit resources are important non-timber forest produce (Homma 1992, Umashankar *et al.* 1998, Chapman and Onderdonk 1998). There are a number of tropical birds and mammals that are largely frugivorous and dependent on these fruit resources (Snow 1981, Fleming and Sosa 1994, Corlett 1998). Added to this, fruit resources are seasonal and patchy both spatially and temporally in availability (Herrera 1982, van Schaik et al. 1993). Could fruit extraction by humans limit the population sizes and distributions of these frugivores? And hence, could our extractive activities become unsustainable to these other resource users?

Very few studies have looked at implications of NTFP extraction on resource users other than humans (Bakuneeta et al. 1995, Chapman and Onderdonk 1998, Lambert 1998).

Even if the resource population and wildlife resource users are far from being threatened with extinction, these plant-animal or animal-animal interactions are highly threatened.

Fruits of *Emblica officinalis* are an important non-timber forest produce in many Indian deciduous forests (Uma Shankar *et al.*, 1998, Koliyal 1997, Musavi 1999). Studies on *E. officinalis* so far have focussed on socio-economic aspects of extraction of its fruit by humans and on aspects of demography of *Emblica* populations (Uma Shankar *et al.* 1996, Uma Shankar *et al.* 1998, Koliyal 1997, Musavi 1999). The use of *E. officinalis* as a resource by non-human vertebrates and the implications these could have for sustainable use of *E. officinalis* has been largely ignored. There are no comprehensive records of its fruit removers and very little is known about the fate of these fruit in the absence of extraction by humans. To understand the impact of fruit extraction by humans on *E. officinalis* populations, we need to look at natural patterns of fruit removal, follow fate of fruits/ seeds dispersed and seedling/ saplings and then consider this in the context of use by humans.

(c) *The study species* - *Emblica officinalis*:

Emblica officinalis (Gaertner) is a member of the family Euphorbiaceae (synonym: *Phyllanthus emblica* (Linn); vernacular names: *Amla*, *Aonla*, *Amlika* Hindi; *Avala* Marati; *Nelli* Tamil, Kannada, Telugu, Malayalam; *Zibyu*, Myanmar). It is common in the tropical dry deciduous forests of India, Myanmar, Sri Lanka, Nepal and China. In India, this species is found frequently in deciduous and scrub forests, rarely in evergreen forests and is also widely planted.

Emblica officinalis is a small or medium sized deciduous tree about 10 -15 m in height, with greenish-grey bark, foliage is feathery and light green in colour. Leaves have the

appearance of a pinnate leaf, but are simple and oblong. Flowers are borne at the peak of the dry season (March to April). The flowers are small, creamish in colour and unisexual. Male flowers are numerous compared to female flowers. It is mostly wind pollinated. Fruiting peaks from November to January. Fruits are drupes and are fleshy, globose, yellow, with 6 longitudinal faint lines; about 2 cm in diameter. The endocarp is stony and generally encloses six seeds (Prasad, S., this study). The fruits have a high Vitamin C content. (Brandis 1906, Bajpai and Shukla 1985). *Emblica officinalis* has a long history of use by humans. The fruits are edible and used in pickles, hair oil and ayurvedic medicines (Wood 1992).

There has been widespread recognition of certain fruit traits being associated with certain disperser guilds (reptiles, birds, mammals). Mammal dispersed fruits tend to be dull in colour (brown, yellow or green) in comparison to bird dispersed fruits which are generally red or black in colour when ripe (Snow 1971, Howe 1986 and Corlett 1998). Also, mammal dispersed fruits (29.28 ± 22.75 mm *) are on an average, larger than bird dispersed (11.88 ± 7.22) fruits (Jordano 1995b). The colour (green) and size (ranging from 15 to 33 mm in diameter) of *Emblica officinalis* fruit are traits often associated with mammal-dispersed fruits.

Troup (1921) notes that fruits of *E. officinalis* are eaten by deer and seeds are disgorged during rumination, after which the cocci dehisces. Johnsingh (1981) found that 13 – 70% of the rumen content of chital (*Axis axis*) during the peak dry season (March) at Bandipur National Park was composed of fruit, mostly *E. officinalis* and *Randia dumetorium*. *E. officinalis* fruit formed a part of the winter diet of chital and sambar (*Cervus unicolor*) at Gir forest (Khan 1994). Schaller (1967) in one of the three sambar kills he examined during late winter at Kanha National Park, found 25% of the rumen content composed of *E. officinalis*

fruit. Kar Gupta (1991) lists *E. officinalis* fruit as a part of the winter diet of langurs (*Semnopithecus entellus*) at Rajaji NP.

(d) Previous ecological studies at Rajaji National Park:

There have been numerous ecological studies conducted at Rajaji NP previously. Of relevance to this study are those that have looked at vegetation, human use and estimated densities and food choices of ungulates and primates. Rodgers *et al.* (1990) and Rawat and Bhainsora (1999) have described the vegetation communities of this area. Bhatnagar (1991), Bhat (1993), Singh (2001) have estimated ungulate densities for Dhaultkand and adjoining areas. Kar Gupta (1991) and Tiwari (1991) found that *E. officinalis* fruits and mature leaves formed a part of the winter diet, and young leaves formed a part of the summer diet of langurs at Rajaji NP. Bhat (1993) lists *E. officinalis* as a probable food item for ungulates at Rajaji NP. Edgoankar (1995) lists *E. officinalis* as a species lopped by *Gujjars* at Dhaultkand.

(e) Objectives:

The three principal questions that I have explored in my study are:

- What are the patterns of fruit removal of *Emblica officinalis*? What are the factors influencing these patterns?
- Who are the vertebrate consumers of *E. officinalis* fruit? Are they effective dispersers of *E. officinalis*?
- What is the impact of extractive uses on the demography of *E. officinalis* at Rajaji NP?

To answer the first question fruit removal patterns were followed (both for fruits borne on the tree and in the fruit-fall) for nineteen *E. officinalis* trees from November 2000 to March

*Unless otherwise stated all results in this chapter and the chapters to come are presented at means $\pm$ standard deviations.

2001. And to address the second question, I determined the identity of the fruit removers and made observations on fruit handling using methods such as tree watches, camera trapping and track plots. Further, germination experiments were carried out to investigate the impact of passage through ungulate rumens on germination success of *E. officinalis* seeds. Demography of *E. officinalis* and regeneration status of the woody plant community was assessed in hill and plain mixed forests along a human use gradient to assess the impact of extractive uses on *E. officinalis* at Rajaji NP.

I shall first give a description of the study area (Chapter 2), outline the methods employed both field and analytical (Chapter 3), followed by results (Chapter 4) and a discussion (Chapter 5) to address each of these three major questions.

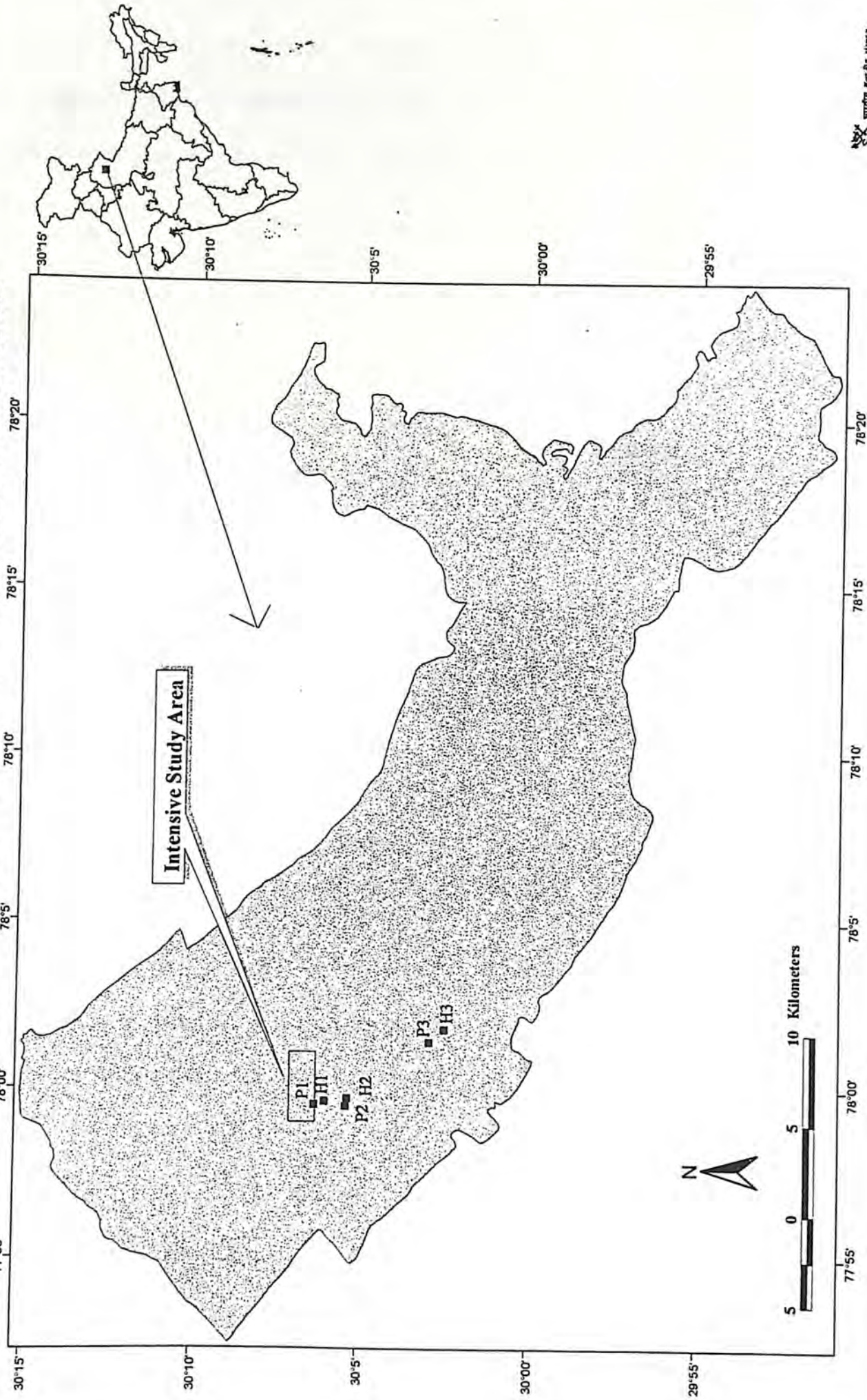
Chapter 2. Study Area

(a) General and Physical:

The study was conducted at Dhaulchand and adjacent areas of the proposed Rajaji National Park. The intensive study area (roughly about 2 sq. km.) is situated at Dhaulchand (77.60° E and 30.06°N). Besides Dhaulchand, sampling for demography of *E. officinalis* population was done at Malawala (77.59° E and 30.05°N) and Beribada (78.01° E and 30.02°N). Rajaji NP covers an area of 824 sq.km in Dehradun, Haridwar and Pauri districts of Uttaranchal. In 1983, the Government declared its intention to create this park by merging Chilla WLS (wildlife sanctuary), Motichur WLS and Rajaji WLS. However the final notification is yet to come. Rajaji, besides containing a large area of the fragile Shivalik system, is also the home of the north-western most population of the Asiatic elephant, *Elephas maximus* (Rodgers *et al.* 1990). The Shivalik ecosystems are of considerable interest owing to the interspersed floral and faunal components of two biogeographic regions, viz., the Himalayan and the upper Gangetic plain.

Rajaji is bisected by the Shivalik Ridge into its Northern and Southern halves. The Shivaliks are a recently uplifted ridge system, 2 to 10 million years old. They are composed of material eroded from the Himalayas and deposited in the alluvial pans and basins at the foot of the mountains. These have now been uplifted to form unconsolidated boulder deposits of sandstone and conglomerate (Rodgers *et al.* 1990). The upper Shivaliks are made up of conglomerates with alternate layers of sandstone and grits. The middle Shivaliks are largely composed of sandstones, alternating with gravels and clay. South of the Shivaliks, lies the 'Bhabar' tract. Bhabar landscape is a series of pans

Fig 1 MAP OF RAJAJI N.P. WITH INTENSIVE STUDY AREA AND TRANSECT LOCATIONS



consisting of boulders, gravels and sand deposits from the streams of the Shivaliks. Porosity is high leading to limited surface water. Soils are poorly developed due to the young landscape and extreme erosion. Generally soils are acidic with pH 5.2 to 6.5 (Rodgers *et al.* 1990).

(b) Climate:

There are three distinct seasons at Rajaji NP (months in brackets are transitional): Winter: November to February, (March), Summer: April to June, and Monsoon: July to September (October). The average annual rainfall is 1531 mm (Rodgers *et al.* 1990). Rainfall is experienced both in winter and monsoon. However, winter rains which are characteristic of this region was absent this year.

(c) Vegetation

According to Champion and Seth's classification, the vegetation in the intensive study area at Dhaukand falls under categories: **Tropical Moist Deciduous Forest (Type 3C/C2a, 3C/C2bi), Tropical Dry Deciduous Forests (5B/ C1a, 5B/ C2 and 5B/1s2), forest type and Subtropical Shivalik Chir Pine Forest (9/ C1a)** (Champion and Seth 1968).

The vegetation in the Shivaliks is distinct from the Bhabhar track. Within the Shivaliks, the hills and the plain areas have mixed forests and forests dominated by Sal (*Shorea robusta*). The mixed forests in the plains are characterised by *Bridelia retusa*, *Caseara tomentosa*, *Terminalia bellirica*, *Adina cordifolia* and *Mitragyna parviflora*. Along the raus (riverbeds), the mixed dry deciduous forests have *Acacia catechu*,

Dalbergia sisso, *Zizyphus mauritiana* and *Cordia obliqua*. In the hill mixed forests, gentler slopes have *Emblica officinalis*, *Anogeissus latifolia* and *Kydia calycina*. The steeper slopes have *Anogeissus latifolia*, *Buchnanian lanzan* and *Semecarpus anacardium*. The ridge vegetation is composed of *Pinus roxburghii* and its associates (refer Rawat and Bhainsora, (1999), for a more detailed description). In the Sal forests, the main associates of sal are *Mallotus philippinensis* and *Terminalia tomentosa*. Some areas have been planted with *Tectona grandis* and *Ailanthus excelsa*. Of interest to this study are the two vegetation types containing *Emblica officinalis* at Rajaji NP: plain mixed forests and the hill mixed forests along gentler slopes.

(d) *Fauna:*

Mammals include tiger (*Panthera tigris*), leopard (*Panthera pardus*), jackal (*Canis aureus*), elephant, sambar, chital, barking deer (*Muntiacus muntjac*), goral (*Nemorhaedus goral*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), porcupine (*Hystrix indica*), Himalayan yellow throated marten (*Martes flavigula*), rhesus macaque (*Macaca mulatta*) and langur. 312 species of birds have been reported from Rajaji NP (Pandey et al. 1994).

(e) *Human Use:*

Extensive cultivation, industrial developments, livestock grazing, large scale fuel wood and non-timber forest produce extraction, lopping of trees for fodder by the resident as well as migratory pastoral communities and poaching of large mammals have led to the degradation of forests of Rajaji National Park. Though parts of Dhaukand block are

closed for grazing and lopping, they are still grazed and lopped illegally. There are both resident and migratory Gujjar households at Dhaulkand. Bhabar grass (*Eulaliopsis binata*) is a major source of income for the villages adjoining Rajaji NP. At Dhaulkand, I noted bhabar grass cutting from November 2000 till March 2001. The movement of bhabar grass cutters at Dhaulkand peaked in November and December and declined after the first week of January. The bhabar cutters came in from different routes and it was difficult to estimate their exact numbers. During the peak bhabar-cutting season, on each day, a few hundred villagers entered the adjoining hills through the intensive study area.

In winter the main extractive uses observed at Dhaulkand were lopping of trees for fodder and collection of grass (both for fodder and tatch making) by the *Gujjars*, extraction of Bhabar and other non-timber forest produce (mainly *E. officinalis* fruit, *Zizyphus mauritiana* fruit, flower buds of *Bombax ceiba*). In summer, there was very little lopping for fodder by the *Gujjars* (since most fodder trees had shed leaves by then). Bark of *Litsea chinensis* was removed both in summer and winter.

People extracted *E. officinalis* in three ways: (a) complete fruit crop extraction (by shaking fruit off the branches), by those who had come in specifically to extract *E. officinalis*, (b) partial fruit extraction where only a part of the fruit crop was taken out (c) pelting stones and picking up a handful of fruit.

(f) *Study period:*

The study was conducted from November 2000 to April 2001. *E. officinalis* fruiting peaks from October – December at Rajaji NP and fruits persist till end of March. The first part of November was spent in surveying the area and tagging branches on study

trees. Data collection began in the late November and thus this study captures the peak and waning of *E. officinalis* fruiting at Rajaji NP. From November 2000 to March 2001, I collected data on fruit removal and seed dispersal of *E. officinalis*. April 2001 was spent in collecting data on *E. officinalis* demography at Rajaji NP. .

Chapter 3. Methods and Analysis

All data analysis was conducted using S-Plus 2000 statistical package (release version 1999 – 2000).

3.1 Study trees

Methods:

(a) *Initial survey and selection of study trees*: The study area was surveyed in mid November 2000 and fruiting *E. officinalis* were located and mapped. For each of these, fruit crop size was noted along a nominal scale as high (above 5000 fruits), medium (5000 – 1000 fruits) or low (below 1000 fruits). 44 trees (11 high, 15 medium and 18 low fruit crop bearing trees) were located during the initial survey.

Of these, 19 individual *E. officinalis* fruiting trees (8 high, 5 medium and 6 low fruit crop bearing trees) were observed for fruit production and fruit removal from November 2000 to March 2001. This period represents the peak followed by waning period of fruiting for *E. officinalis* at Rajaji NP. These trees were selected such that both travel time from the base camp and degree of human activity close to the tree were minimised. Each study tree was assigned a number and tagged.

Outside of the study trees, 20 other fruiting *E. officinalis* trees which had been located during the mid-November 2000 survey, were relocated in the last week of December during a resurvey of fruiting trees in the intensive study area. Most of them bore signs of fruit extraction by humans. Of these 20 trees, which during the initial survey had 3 high, 9 medium and 8 low fruit crop bearing trees, only 6 trees still bore fruits (all with low fruit crop size) during the resurvey.

(b) *GBH and canopy radius measurement.* GBH was noted at 1.34m above ground level.

In the case of multiple stems, the multiple stems were measured individually and GBH was noted as a sum of these. Along four mutually perpendicular axes (0° , 90° , 180° and 270°), the canopy radius was measured by stretching a measuring tape from the tree trunk to the edge of the canopy. The mean radius was then used to calculate a circular projected area.

(c) *Clustering of Study Trees.* To arrive at clustering of the study trees, inter-tree distance was measured using a compass and a measuring tape (for distances $<100\text{m}$) or by pacing (for distances $>100\text{m}$).

(d) *Fruit size and fruit mass:* To arrive at a relationship between fruit size and mass, 128 fruits were collected from 17 different trees in the intensive study area. Fruit size was calculated as the product of diameters of a fruit along three mutually perpendicular axes and fruit mass was obtained using a weighing balance. For 20 randomly chosen fruits from the fruit fall area (all fruits present were considered if there were less than 20 fruits in the fruit-fall area) of each tree, diameters were measured along 3 mutually perpendicular axes.

(e) *Total fruit crop estimate:* Mature fruits of *Emblica officinalis* range from 1.5 to 3.3 cm in diameter and the trees average around 10 – 15m in height. The fruit are large, and the trees of moderate height, and thus one can obtain fairly accurate visual counts (Chapman *et al.* 1992). Initially, I tried out three methods to estimate total fruit crop size. I counted

all fruits on a tree and then counted fruits on 10% of the fruiting branches. Both these methods were found to be time consuming and were abandoned in the favour of the third method described below.

For each tree, branches were divided into two categories: main branches, and secondary branches (only branches bearing fruits were considered in each category). The total number of main branches was counted. The number of secondary branches was noted on eight randomly chosen main branches. The number of fruits per secondary branch was assessed by counting them on twenty secondary branches chosen at random. Total fruit crop size of each tree was estimated as a product of its total number of main branches, average number of secondary branches per main branch and the average number of fruits per secondary branch. For trees bearing less than 500 fruits, I counted all the fruit on the tree. It took two – five hours to estimate fruit crop by this method. Only one observer conducted all the total fruit crop estimates. Total fruit crop estimates for all the study trees were obtained within the first four weeks of the study period. Since the total fruit crop estimates have wide standard deviations it is better to consider them as indicative of a range rather than a point estimate. Hence the 19 trees were divided into 10 fruit crop size classes and ranked in an ascending order of fruit crop size. These ranks for the fruit crop size classes will be referred to as 'fruit crop size ranks' in the remaining text.



Fig. 2 *Emblica officinalis* tree with
'Low' fruit crop (Jan. 2001)

Fig. 3 *Emblica officinalis* tree with
'High' fruit crop (Jan. 2001)



Analysis:

(a) A cluster analysis was performed for the inter-tree distances between study trees using divisive hierarchical method with euclidean dissimilarity measure and average linkage type.

(b) Variances and standard deviations for total fruit crop estimates, canopy radius and canopy area were calculated using Goodman's exact variance of products formula (Goodman 1960) as:

$$\text{variance}(a.x.y) = a^2.[\text{mean}(x))^2.\text{mean}(y) + (\text{mean}(y))^2.\text{mean}(x) - \text{variance}(x).\text{variance}(y)]$$

(c) Fruit mass and fruit size relationship: The relationship between fruit mass to fruit size was worked out using a linear regression. Using this regression equation, for each study tree average mass of a fruit was calculated.

(d) Relationships between fruit crop size, fruit mass and GBH: Correlations were done between GBH, fruit mass and fruit crop size estimate (both mean and rank) to examine relationships between them.

3.2 Fruit Removal Patterns of *E. officinalis*

Methods:

During the initial days of the study period, for each study tree, 5 – 7 accessible branches with at least 10 and not more than 60 fruits were marked with paint and tagged with aluminum tags. These branches were generally the lowermost fruiting branches on a tree. The ease with which fruit could be counted was also taken into account and branches with fruits in clumps or branches having dense foliage were not considered.

Fruits fell largely in the under-canopy area (98.37% of 239 fruit) or just outside it. The fruits being 2 – 3cm in diameter were fairly easy to spot. Under all study trees an intensive search was done for fruits both under the canopy and just outside it, except under one study tree, where a fraction (74%) of the fruit-fall area was searched due to the presence of dense clumps of *Vetiveria zizanioides* that made search efficiency very low. Each fruit was picked up individually, marked with small numbers using a ballpoint pen (taking care not to damage the fruit coat) and put back in its original position after marking it.

For each tree, all fruit on 5 –7 marked branches and all fruit on the ground in the fruit-fall area were counted thrice every ten days in 12-hour intervals to arrive at nocturnal and diurnal removal rates of fruits. The fruit were counted on the tree and in the fruit-fall area till less than 5% of the initial number of fruit remained on the marked branches. Morning counts were conducted between 700 hrs - 900 hrs and evening counts between 1430 – 1630 hrs.

To check whether the fruit removers exhibited any avoidance for the fruit marked in the fashion described above, on three occasions, I set up equal numbers of marked and



Fig. 4 Marked branch on *E. officinalis* study tree



Fig. 5 Marked fruit in fruit-fall area

unmarked fruit in a systematic fashion under fruiting trees and monitored these once every 12 hours.

To arrive at deposition rates of fruit into the fruit fall area, during December 2000, observers were made to sit under trees and ensure that there was no fruit removal. Duration of the monitoring session, initial and final number of fruits present was noted. The number of fruits encountered in the fruit-fall area, when none of the fruits from the previous count were removed, was also considered as number of fruits deposited for that tree (for December 2000 alone).

I kept a note of all human activities in the intensive study area during the fruiting period. The range and intensity of human activities (check dam construction, movement through the area, fruit extraction, poaching) varied both in space and in time. 11 of the study trees (5 with high, 3 with medium and 3 with low fruit crop size) were monitored to ensure that there was no human removal of the fruit. During the fruiting period, observers monitored these 11 trees from dawn to dusk. 8 study trees (3 with high 2 with medium, 3 with low fruit crop size) were left unmonitored.

Analysis:

- (a) *Deposition Rates*: Number of fruit deposited in the fruit fall area (in 10 hours) was correlated with fruit crop size estimate (mean and rank) to arrive at the relationship between deposition rates and fruit crop size.

- (b) *Fruit Persistence Patterns on the tree:* Fruit persistence (number of days till less than 5% of initial number of fruits counted remained on the branches) was compared between monitored and unmonitored trees using Mann Whitney test.
- (c) *Fruit removal from the fruit-fall area:* For each study tree, proportion of fruits removed from the fruit-fall area in each 12 hour interval for every 10 day cycle was calculated to arrive at nocturnal and diurnal removal rates. For trees whose counting cycles were conducted on the same day, removal rates (pooling both nocturnal and diurnal rates) were compared between trees which were < 50m apart from each other (level 1 clustering), trees which were > 50m but < 100m apart from each other (level 2 clustering), and trees which were > 100m apart from each other using a Wilcoxon match paired sign test. Each 24-hour counting cycle was taken as a replicate for this purpose. Removal rates were compared between day and night hours (using Wilcoxon match paired sign test).

3.3 Fruit removers and seed dispersal of *Emblica officinalis*

A range of direct and indirect methods were employed to address the above questions including tree watches, track plots, camera trapping and germination experiments. Each will be addressed as a separate section with a description of the methods employed and data analysis.

(a) *Tree Watches:*

Using a 7 X 35 binocular fruiting *E. officinalis* trees were watched at different periods of the day and night to determine the identity and visitation patterns of its fruit removers. Since animal movement, especially that of ungulates, was observed to be mostly during the late evening hours, sampling hours were scheduled between 1400 and 1800 hrs. All behaviours observed while animals foraged for fruit and all opportunistic sightings I had of animals feeding on *E. officinalis* fruit were noted. A total of 35.5 hours were sampled during scheduled tree watches starting from early December 2000 to the first week of March 2001)

Animals are very wary of human presence at Rajaji and to obtain sightings of animals feeding on fruit, observation points had to be at least 200m away from the fruiting tree. Further, care had to be taken to ensure that these observation points did not come in the approach routes of animals to the tree.

Langur troops were observed to spend long hours at fruiting trees. When langurs were on them, chital and barking deer foraged for lengthy periods under fruiting trees. During the fruiting period, I followed langur movements and noted their roosting sites in the study area and was able to attend two such 'langur parties'. During these extended

feeding bouts, all behaviours displayed by langurs and chital while at the fruiting tree were noted, and scans were conducted once every 10 – 15 minutes to arrive at the number of langurs, chital and barking deer at the tree. A total of eight focal animal samples lasting 5 minutes each were taken of clearly visible langurs which were feeding on fruit to note foraging behaviours.

(b) *Track Plots:*

I kept a note of all mammal tracks under and close to fruiting *E. officinalis* trees. Further, under four fruiting trees with medium to high fruit crop (group A) and under four trees without fruit or with very low fruit crop (group B), I set up 3 - 8 1m X 1m square track plots covering 10% of the under canopy area of the trees. The track plots were cleared of litter and undergrowth and the soil was levelled. The plots were reset (i.e., cleared of all old tracks) and monitored after 24 hours. To count the number of tracks in a track plot, a 1m X 1m point intercept grid having 89 intercepts set at every 10 cm from each other was used. The grid was overlaid on a track plot and the tracks encountered under each intercept were noted. Mann Whitney test was performed to examine differences in the number of tracks encountered between group A and group B trees.

(c) *Methods used to determine fruit handling by langurs:*

An attempt was made to quantify the number of fruits in the fruit-fall area immediately after langurs had left the tree to note the proportion of fruits which had signs of langur handling. Fruits handled by langurs were classified into two classes: those which had less than 50% of the pulp remaining and those which had more than 50% of

the pulp remaining. Even langur-handled fruit were removed by other frugivores. It was possible to mark only those fruit which had more than 50% of the pulp remaining and these were monitored after 12/ 24 hours. Removal rates were compared between langur-handled fruits with more than 50% of the pulp remaining and fruit without signs of langur handling using Wilcoxon signed rank test.

Whenever there were signs of recent langur activity at *E. officinalis* fruiting trees, an intensive search was conducted to find any signs of seed damage among langur-handled fruits in the fruit – fall area.

(d) *Methods used to detect fruit removal and fruit handling by rodents:*

Under two fruiting trees, rodent tracks were seen frequently. Under both these trees, the rodent tracks were similar in size and shape.

- i. Fruit tied with varying lengths (1 to 5 m) of string (twine, cotton thread, dental floss) were left under these trees within their fruit fall areas. These fruit were placed in sites from where it would be difficult for ungulates to remove them (in a small gap under a log).
- ii. Under both these trees I set up Sherman traps baited with *E. officinalis* fruit only.
- iii. In mid – January 2001, I dug out a rodent burrow near these trees.
- iv. A *Tatera indica* was trapped and kept in captivity for three days and three nights in late March 2001. It was offered *E. officinalis* fruit, groundnuts and some leafy vegetables as food.

(e) *Monitoring kills and scats for presence of E. officinalis fruit:*

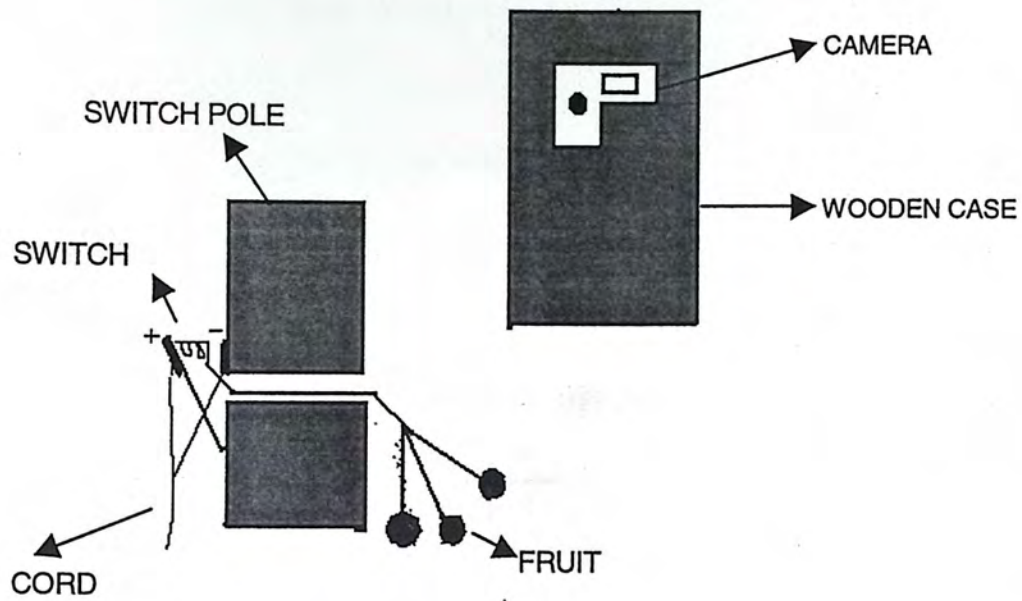
An effort was made to locate fresh kills of ungulates such as sambar, nilgai, chital and barking deer during the fruiting period. Two sambar kills (both less than 24 hours old) were located (on 5th Dec 2000 and 5th Jan 2001) and their rumen contents were searched.

During the fruiting season droppings of jackal, wild pig and porcupine (>15 scats of each species) encountered were examined for the presence of *E. officinalis* fruit.

(f) *Camera trapping:*

Camera traps have been used for a wide range of purposes – to estimate mammal densities (Karanth and Nichols 1998), to arrive at distribution of mammals (Mudappa 1998). I used camera traps to determine the identity of animals that remove *E. officinalis* fruit. Pressure pads (Mudappa 1998) and infrared beams (Karanth and Nichols 1998) have been used extensively as tools for camera trapping. With either of these approaches, the camera can be triggered even by animals that are passing through the set up, and not necessarily removing fruit. Described below is the design for a camera trap that is triggered by animals trying to remove fruit.

The set up consisted of an Olympus -AF30: 35mm autofocus camera with an in-built flash and autorewind. The camera was modified such that an external switch triggered its shutter release. Four to five *E.officinalis* fruit tied with a short length (15 – 20 cm) of translucent plastic fishing line were attached to the switch with the aid of a light metallic spring in such a way that the switch contact was made only when the fruit was moved. The switch was mounted on to a wooden pole and the external cord was buried under litter and soil. The camera trap was set under fruiting trees and the fruit



SCHEMATIC DIAGRAM OF CAMERA TRAP

Figure 6 Schematic Diagram of camera trap set up used to get photographs of animals removing *E. officinalis* fruit.

baited at trap set within the tree's fruit-fall area. The camera was kept functional through night and day. The set up was checked each morning and evening for frame number, tracks and remaining fruit at the camera trap or any other signs of animals having removed fruit (refer Figure 3.3.1).

(g) *Monitoring ungulate boluses with E. officinalis cocci.*

At Rajaji NP, ruminant regurgitated boluses containing cocci (endocarp with seeds) of four fleshy fruited species, viz., *E. officinalis*, *Terminalia belerica*, *Zizyphus mauritiana*, and *Zizyphus xylopyra* were recovered from the forest-floor in the intensive study area during the study period. Each regurgitated bolus contained one or more of the above mentioned species in varying proportions. The five wild ruminants at Rajaji NP are chital, barking deer, goral, sambar and nilgai.

E. officinalis endocarps (with seeds) were observed in ruminant regurgitated boluses from November 2000 to February 2001. These endocarps dehisce to release seeds on to the forest-floor. *E. officinalis* endocarps from ungulate boluses (with seeds) were monitored on two 100m transects each with ten 1m X 1m plots set at 10m intervals to follow post dispersal patterns of persistence of seeds on the forest – floor.

(h) *Germination experiments.*

Seeds of *E. officinalis* for the germination trials were collected from ruminant regurgitated cocci (treatment seeds) and cocci for which pulp was removed manually (control A). Alongside, I also monitored 100 *E. officinalis* fruits set in the plastic trays and left exposed to natural site conditions. The fruits shrivelled up and the cocci dehisced

to release seeds. These seeds were also used for germination trails (control B). Control A was used to examine the effect of rumen passage on germination rates. Control B was used to examine the effect of pulp removal and rumen retention by ungulates on germination rates.

All seeds for the germination trails were obtained from the intensive study area itself. All cocci were placed in the open and allowed to dehisce naturally. Germination tests were performed under site conditions in plastic trays with sockets for individual seeds. The sockets were lined with tissue paper and each was filled with the same volume of sand and all seeds were placed in the same position and buried under the same depth of sand. The seeds were watered once in one or two days such that they remained moist throughout the day and night. Each seed received the same volume of water. Measurements were taken once in three days and the number of germinated seeds was recorded and the trays were monitored till the end of April 2001. The criterion for germination was visible radicle protrusion.

Germination trials were conducted with 190 *E. officinalis* seeds each for treatment, control A and control B. Within the treatment, control A and control B seeds, 95 were watered and 95 were not watered but left exposed natural moisture conditions at the site. Germination trails for seeds from langur handled fruits had to be abandoned due to fungal infections of the seeds.

For comparison, germination trails were also done in a similar fashion with *Zizyphus mauritiana* (Rhamnaceae) another fruit whose cocci were frequently encountered in ruminant regurgitated boluses along with *E. officinalis*. Unlike *E. officinalis*, *Z. mauritiana* cocci are indehiscent and contain 1 – 2 seeds. For *Z.*

mauritiana, 49 cocci from ruminant regurgitated boluses (treatment) and 49 fruits with pulp (comparable to control B of the *E. officinalis* experiment) were set up in the same fashion as *E. officinalis*. All *Z. mauritiana* cocci were watered.

For *E. officinalis*, treatment seeds (watered), control A seeds (watered), and fruits (from which control B seeds were obtained later on) were set up in mid December 2000 within a day or two of each other. Treatment and control A seeds which were not watered were set up in early January 2001. Control B seeds which were not watered were set up in late March 2001 and Control B seeds which were watered were set up in early April 2001. *Z. mauritiana* cocci were set up in mid March 2001. *E. officinalis* shows hypogeal germination while *Z. mauritiana* shows epigeal germination.

Differences between control and treatment for both the species was examined using a g test.

3.4 Demography of *Emblica officinalis* and regeneration of associated woody plant species at Rajaji National Park

Emblica officinalis, though not a commonly encountered species in Rajaji NP, occurs in both hill and plain mixed forests. In the hill mixed forests it occurs mostly along gentler slopes and in the plains along valleys flanking the raus (Prasad pers. observation). Extractive uses of *E. officinalis* observed at Rajaji are fruit extraction and lopping of leaves & branches for fodder. Further, factors like intensive grazing, heavy fuel wood collection and widespread human use (NTFP collection – bhabar and other grasses, various fruits, flowers and bark, honey; poaching) of the area might affect the population structure of *E. officinalis*.

The question that is being addressed in this section is: what is the impact of extractive uses by humans on the population structure of *E. officinalis*? Ideally to understand impact of fruit extraction on such an *E. officinalis* population, we should look at natural patterns of fruit removal, follow fate of fruit/ seed dispersed and seedling/ saplings and then consider this in the context of use by humans. Such information can be collected only by long term studies. Hall and Bawa (1993) recommend comparative sampling of populations, encompassing both the range of habitats and the varying intensities of human use, to determine the status of populations that are being harvested.

The above question is addressed by taking a comparative approach:

1. Comparing *E. officinalis* population structure and regeneration across a human use gradient.
2. Looking at *E. officinalis* regeneration in the context of woody plant community regeneration at Rajaji, NP. across a human use gradient.

Design:

In both hill and plain mixed forest habitats, I considered three blocks with differing intensities of human use (low, intermediate and high) and in each of these a transect of 1 km was laid. Replication was not possible due the fact that I could locate only one low human impacted site in the two habitat types (hill and plain mixed forest) and psuedo-replication was also ruled out since both these areas are very narrow and cover less than 3 sq.km each. Thus it is a 2 X 3 design.

The first, Dhaulkand block, is closed for grazing and lopping. This area has the Dhaulkand range quarters, a rest house and a watch tower which are frequented by officials and visitors and hence is subject to very low levels of use by both the gujjars and villagers. The second block, Malawala, though closed for grazing and lopping, is grazed and lopped illegally to a larger extent than Dhaulkand. The third block, Beribada, is open for grazing and lopping. Further, Dhaulkand and Malawala are atleast 8 km away from the nearest village, while Beribada is just 3 km away from the nearest village. The number of gujjars dependent on these areas increases from Dhaulkand to Malawala to Beribada. These blocks were chosen based on conversations with gujjars, forest department staff, villagers and few other people familiar with these areas. Initial surveys were conducted in these blocks and few other areas during which I did a visual estimation of the extent of lopping and searched for *E.officinalis* trees.

E. officinalis fruit extractors in Rajaji have good knowledge of the location of most, if not all, *E.officinalis* trees and come back to these each year. And hence, in each of these blocks I expect *E. officinalis* to be subject to extraction each year when in fruit with the

exception of the hill area of Dhaulkand block (where trees with even high fruit crop were not extracted during 2000 – 01).

The Dhaulkand (low human use intensity) block hill and plain transects will be referred to as H1 and P1 respectively. Similarly, Malawala (intermediate human use intensity) and Beribada (high human use intensity) will be referred to as H2 & P2 and H3 & P3 respectively. Dhaulkand and Malawala are separated by a ridge and are less than 2 km apart. Beribada is less than 7 and 8 km from Malawala and Dhaulkand respectively. Start points of H1 and P1 are less than 500m apart and the two run perpendicular to each other. H2 and P2 are less than 500m apart and run almost parallel. H3 and P3 are less than a kilometre apart and run perpendicular to each other.

Since *E. officinalis* trees occur at very low densities at Rajaji NP, using conventional sampling techniques such as plots and belt transects, would have yielded very small sample sizes. Hence the line-transect approach (Buckland *et al.* 1993) was chosen to estimate densities of *E. officinalis* trees at Rajaji NP.

Method:

In each of these blocks, a transect of 1 km was laid along a bearing or a path keeping the start point random. Along each transect, aided by two other observers and a 7 X 35 binoculars, I searched for *E. officinalis* trees. These transects were conducted in the end of March and April 2001. The mixed forests are fairly open and during this period *E. officinalis* trees bear leaf flush of a distinctive green colour that can be picked out easily in the backdrop of a largely brown deciduous forest in its dry season attire. For each located tree, I measured distance (using a measuring tape) and bearing from the line,

height, GBH and looked for evidence of lopping. Underneath each located *E. officinalis* tree, a search for *E. officinalis* seedlings (less than 10 cm GBH or 1.3 m in height) in 1m X 5m plots along four mutually perpendicular radii was conducted. For each located seedling, height of the seedling and distance from adult was noted.

Every 100m, on offsets of 25m on alternating sides of the transect, a 20 X 20m plot was laid to arrive at woody plant community structure and disturbance indices. Within these plots, total number of cut and broken stems and dung of domestic animals (buffalo, cattle, horse) were noted. GBH and lopping intensity of all woody plants above 1.3m in height and 10cm in GBH, occurring within this plot were measured. Lopping intensity was quantified along an ordinal scale as,

0 = no signs of lopping

1 = very low, generally evidences of lopping in the past

2 = moderately lopped, with a number of lateral branches still left on the tree

3 = heavy lopping, with a few lateral branches still left on the tree

4 = very heavy lopping, with no lateral branches left on the tree.

Within this 20 X 20m plot, two 2m X 2m plots were laid randomly. All woody plant regeneration (less than 10cm GBH or 1.3 m in height) was recorded. Among the woody plant community at Rajaji, stress tolerant and non-palatable woody weed species like *Lantana camera* and natives like *Adathoda vasica* and *Vitex negundo* dominate in areas subject to large-scale grazing. For community level analysis of regeneration, it might be more suitable to examine this guild separately. These species were considered as 'Regeneration 2' and the rest of the woody plant community as 'Regeneration 1'. Woody

plant regeneration was classified as from seed origin or as resprout (from root or stem stock) and identified to the species level (Kanjilal 1928).

Data Analysis:

(a) Human Use Indices and woody plant community regeneration across treatments.

The following were computed for each plot:

- a. **C**, Cut Stem Index: total number of stems with signs of cutting found in the 20 X 20 m plot.
- b. **D**, Dung Density Index: total number of domestic dung piles (buffalo, cattle, horse) found in the 20m X 20m plot.
- c. **L**, Lopping Index: product of the total number of trees with signs of lopping with the sum of lopping intensity scores of all trees with signs of lopping found within the 20m X 20m plot.

Further, combinations of Cut Stem Index, Dung Density Index and Lopping Index were worked out as:

- i. **A₁**, Additive Human Use Index (1):

$$\text{Cut Stem Index} + \text{Dung Density Index} + \text{Lopping Index}$$

- ii. **M₁**, Multiplicative Human Use Index (1):

$$\text{Cut Stem Index} \times \text{Dung Density Index} \times \text{Lopping Index}$$

It was observed that species preferred for lopping occur in higher densities in the hill mixed forest habitat. Since this might bias results when comparing between hill and plain mixed forest habitats, a second set of combination indices were computed as,

- iii. **A₂**, Additive Human Use Index (2):

Cut Stem Index + Dung Density Index

iv. M_2 , Multiplicative Human Use Index (2):

Cut Stem Index X Dung Density Index

For each plot, the sum of the seedlings and resprouts from the two sub plots (2 X2 m) was considered and classified as regeneration 2 for *L. camera*, *A. vasica* and *V. negundo* and regeneration 1 for all other woody plant species.

The scores for each human use index and regeneration were standardised such that all the values lay between 0 to 100. Further, they were arcsine transformed as $p' = \arcsin\sqrt{p}$ (Zar 1974). These transformed scores were examined for normality using a quantile – quantile normal plot and the variances were examined graphically using box plots. The arcsine transformed distributions were found to be approaching normal distributions in the mid range values, while at the extreme ends of the range (0 and 100) the fit was not good, except for regeneration (refer Figure 3.1a, b, c, d, e and f). However, the variances of the scores among transects for each index and regeneration were very heterogeneous (refer Figure 3.2 a, b, c, d, e and f).

A Kruskal Wallis test was performed to examine for differences between the hill and plain transects of the three treatments for the human use indices and regeneration. The differences between these treatments were examined by comparing their means & medians (refer Table 3.1) and by graphical exploratory data analysis tools (refer Figure 3.2 a, b, c, d, e and f). Regeneration (1 & 2) were regressed with the human use indices (C, D, L and A_2).

Shrubby species like *Mallotus philippinensis*, *Helicteres isora* and *Colobrookia oppositifolia* are characterized by multiple stems arising from common rootstocks. While

examining for trends in seedling to resprout ratios they mask the difference between treatments. Hence these trends were examined for tree species (all woody plant species excluding *Mallotus philippinensis*, *Helicteres isora* and *Colobrookia oppositifolia*) alone. For each transect trees species regeneration was pooled across plots. The proportions of seedling to resprout densities were compared between transects using chi square test. The tree species were ranked in a descending order of abundance for each transect. Species composition was compared between transects using top ranking species for each transect which cumulatively contributed to 50% of the regeneration.

(B). Emblica officinalis densities and regeneration across treatments.

The program DISTANCE 3.5 (Buckland *et al.* 1993) was used to calculate densities of *E. officinalis* trees for hill and plain mixed forests. GBH size class structure was examined graphically for *E. officinalis* trees sighted within 10m & between 10 and 20 m and in hill & plain forests. The presence of very few seedlings (just 2 from 6 transects) made comparisons between treatments for regeneration of *E. officinalis* meaningless.

Chapter 4. Results

4.1 Characteristics of Study Trees

(a) The cluster diagram of study trees separated by inter-tree distances was not sensitive to method (divisive or agglomerative) or linkage type (average or wards) used. The study trees fall into four primary clusters which are at least 350m apart from each other (refer Fig.7 and Fig.8). These primary clusters will be referred to as the IA, IIA, IIIA and VA patches in the chapters to come. The study trees were clustered at two levels (refer Fig.7 and Fig.8):

- Level 1(within 50m): 9 of the 19 study trees had one conspecific fruiting neighbour within 50m. They fall into 5 pairs: IA7 ~ IA8, IIA1 ~ IIA2, IIA2 ~ IIA3, IIIA2 ~ IIIA3 and VA1 ~ VA2.
- Level 2 (within 100m): 15 of the 19 study trees had at least one conspecific fruiting neighbour within 100m. These 15 trees form five clusters:
 - ✧ IA8 ~ IA7 ~ IA6 ~ IA5 ~IA3
 - ✧ IIA1 ~ IIIA2 ~ IIA3
 - ✧ IIIA1 ~ IIIA2 ~ IIIA5
 - ✧ IIIA6 ~ IIIA7
 - ✧ VA1 ~ VA2

All other fruiting trees in the intensive study area, other than the study trees themselves, were more than 100m away from any of the study trees.

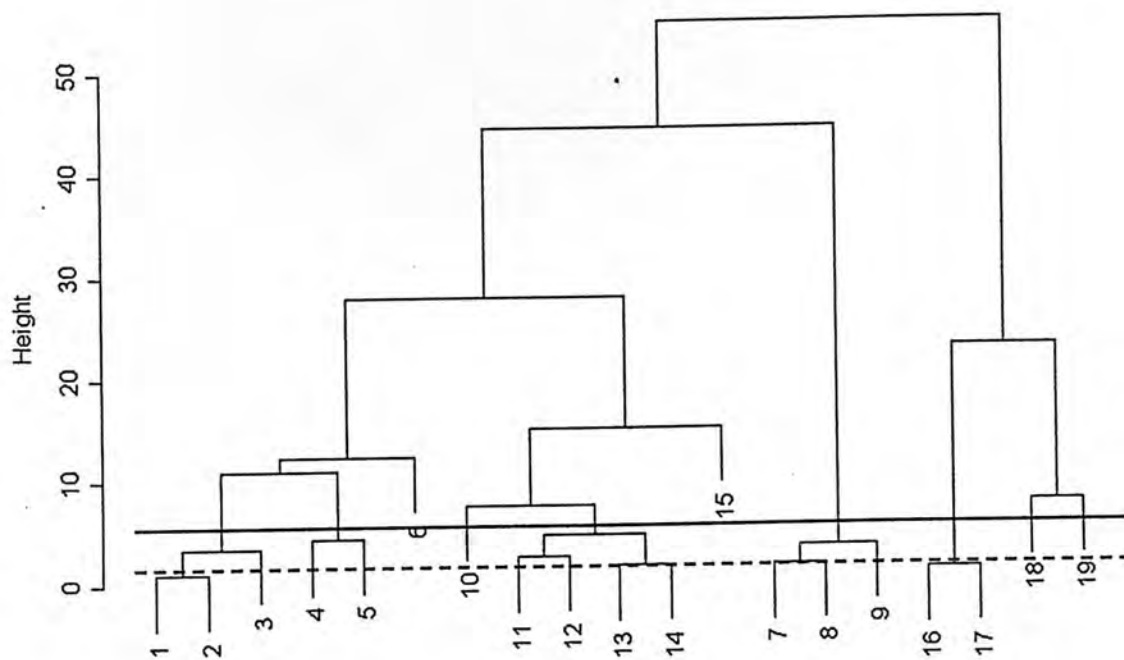
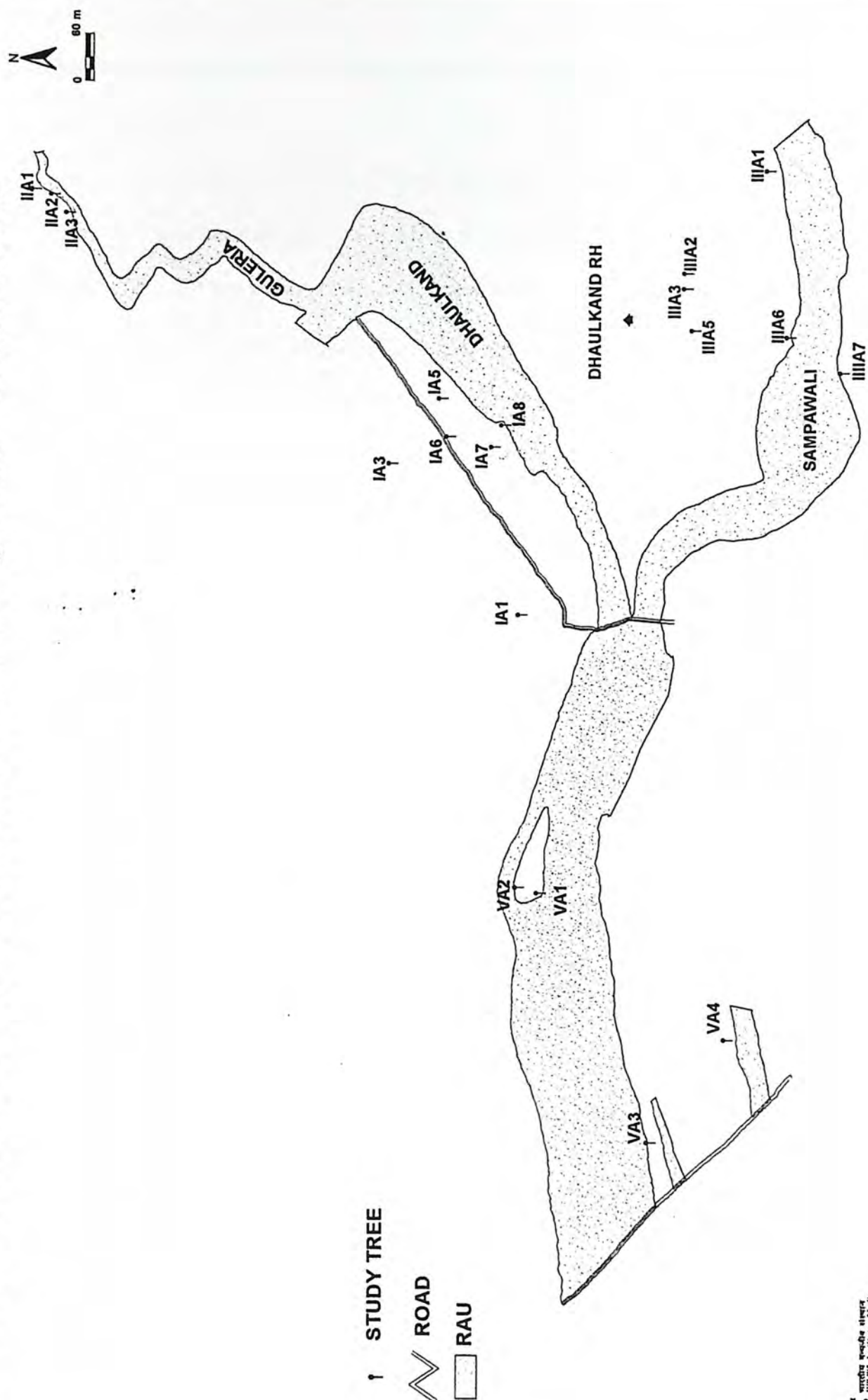


Figure 7 Cluster Plot of Study Trees separated by inter-tree distances. Clusters below the dashed line are of trees that are less than 50 m apart from each other (level 1). Clusters below the solid line are of trees which are within 100 m of each other (level 2). The individual tree identities are 1 = IIIA2, 2 = IIIA3, 3 = IIIA5, 4 = IIIA6, 5 = IIIA7, 6 = IIIA1, 7 = IIA1, 8 = IIA2, 9 = IIA3, 10 = IA3, 11 = IA5, 12 = IA6, 13 = IA7, 14 = 1A8, 15 = IA1, 16 = VA2, 17 = VA1, 18 = VA3, 19 = VA4.

Fig. 1. MAP OF INTENSIVE STUDY AREA WITH *Emblica officinalis* STUDY TREES



(b) Fruit mass was related to fruit size by the linear regression ($r^2 = 0.96$, $p = 0.00$, $n = 128$) equation:

$$\text{fruit mass} = 0.5993 + 0.0006 (\text{fruit size}) \quad \text{.....equation 1.}$$

Using this equation average mass of a fruit was computed for each tree (refer Table1). For the *E. officinalis* population of the intensive study area, fruit diameter was an average 23 ± 2.5 mm ($n = 128$) and ranged from 16.7 to 33.8 mm. Average fruit mass was 7.2 ± 2.21 g. Average seed mass was 0.017 ± 0.0071 g ($n = 46$). Average cocci mass was 0.46 ± 0.122 g ($n = 26$). The cocci were 10 to 11 mm in diameter. The seeds were deep brown to black in colour, reniform and 4 – 5 mm long along their longest axis.

(c) For the study trees, GBH was not significantly correlated to either rank ($p = 0.43$, $n = 19$) or mean values ($p = 0.33$, $n = 19$) of the fruit crop size estimate or to fruit mass ($p = -0.31$, $n = 19$). Average mass of a fruit was not significantly correlated with rank ($p = 0.16$, $n = 19$) and mean values ($p = 0.02$, $n = 19$) of fruit crop size estimate. The sample sizes however are too low to arrive at any conclusion about the presence or absence of any relationships between these parameters.

Table 1 Characteristics of *Embica officinalis* study trees at Rajaji NP. Results are presented as means $\pm$ SD. Values in *parentheses* present sample size. GBH is the girth of the stem at breast height. Trees tagged with '*' were monitored to ensure that there was no fruit removal by humans. Fruits from trees tagged with 'v' were extracted by people. FCS is fruit crop size. FCS categories: H = high (>5,000 fruits), M = medium (1000 to 5000 fruits) and L = low (<1000 fruits).

Tree #	GBH (cm)	Canopy Radius (m)	Canopy Area (sq.m)	Fruit Mass (g)	FCS	FCS Category	FCS Rank	Persistence (days)
IA6*	147	3.2 $\pm$ 0.2	32 $\pm$ 6	8 $\pm$ 1.3(2)	63	L	1	49
IIIA2*	104	3.3 $\pm$ 0.4	33 $\pm$ 9	8 $\pm$ 1.6(3)	240	L	2	43
IIA3	84	3.4 $\pm$ 0.2	36 $\pm$ 6	8 $\pm$ 1.8(20)	343	L	2	39
IIA1	62	2.8 $\pm$ 0.2	25 $\pm$ 6	5 $\pm$ 0.7(20)	372	L	2	39
VA1	88	3.1 $\pm$ 0.3	31 $\pm$ 8	6 $\pm$ 0.6(3)	443 $\pm$ 442	L	3	38
IIIA5*	240	4.0 $\pm$ 2.3	50 $\pm$ 26	2 $\pm$ 0.7(9)	565 $\pm$ 575	L	3	51
VA2	89	2.7 $\pm$ 0.4	24 $\pm$ 8	7 $\pm$ 1.0(16)	1107 $\pm$ 878	M	4	70
IA7*	93	2.9 $\pm$ 1.4	27 $\pm$ 18	6 $\pm$ 0.8(14)	1228 $\pm$ 1025	M	4	57
IA5*	152	4.3 $\pm$ 1.3	58 $\pm$ 21	4 $\pm$ 1.0(7)	2131 $\pm$ 1978	M	4	49
IIIA6*	111	3.6 $\pm$ 3.9	41 $\pm$ 29	8 $\pm$ 1.0(13)	3627 $\pm$ 3373	M	5	51
IIA2	96	4.2 $\pm$ 5.2	54 $\pm$ 39	11 $\pm$ 1.5(20)	4885 $\pm$ 3565	M	5	85
VA4 v	152	4.1 $\pm$ 0.3	54 $\pm$ 10	6 $\pm$ 0.1(6)	9432 $\pm$ 7155	H	6	23
IA3*	170	4.6 $\pm$ 0.1	66 $\pm$ 6	9 $\pm$ 1.3(11)	9881 $\pm$ 10487	H	6	49
IIIA1*	181	4.6 $\pm$ 0.1	66 $\pm$ 7	5 $\pm$ 1.1(20)	12307 $\pm$ 10291	H	7	72
IIIA3*	147	5.6 $\pm$ 0.5	98 $\pm$ 17	7 $\pm$ 1.5(17)	14746 $\pm$ 10077	H	7	72
IA1 v	152	6.8 $\pm$ 0.8	146 $\pm$ 27	10 $\pm$ 1.7(20)	16427 $\pm$ 7172	H	8	47
VA3 v	208	5.0 $\pm$ 1.0	80 $\pm$ 22	8 $\pm$ 0.6(20)	17082 $\pm$ 14927	H	8	38
IA8*	97	3.8 $\pm$ 0.4	44 $\pm$ 11	7 $\pm$ 1.0(18)	37613 $\pm$ 36302	H	9	94
IIIA7*	192	5.2 $\pm$ 0.4	86 $\pm$ 14	6 $\pm$ 0.7(20)	72515 $\pm$ 59127	H	10	114

4.2 Fruit removal patterns of *E. officinalis*

I shall first give an overview of human activities in the intensive study area and then examine deposition rates, factors influencing fruit persistence and fruit removal from the fruit-fall area:

(a) *Overview of human activities in the intensive study area:*

Human movement was more or less similar in all the four patches of study trees since there are a number of paths which people used other than the roads and the raus. Two of the IIA trees had signs of animals being poached under them. People extracted fruits from three of the unmonitored trees (IAI, VA3 and VA4, refer Table 1). For the other unmonitored trees, though there was no signs of fruit extraction (complete or partial), I had no way of knowing whether removal was by wildlife alone.

(b) *Deposition Rates:*

Number of fruits deposited in the fruit fall area (in 10 hours, during December 2000) was not significantly correlated with either mean ($p = 0.67$, $n = 48$) or rank ($p = 0.67$, $n = 48$) of the fruit crop size estimate, but there is a weak positive trend (i.e., increase in number deposited with increase in fruit crop size) observed. In a 24 – hour period, for any medium or high fruit crop size tree, less than 1% of the total fruit crop size was deposited naturally (refer Fig. 9 and 10).

(c) *Fruit Persistence Patterns:*

1. Fruit persistence (number of days till less than 5% of initial number of fruits counted remained on the branches) on monitored trees (64 ± 22 days) was significantly greater

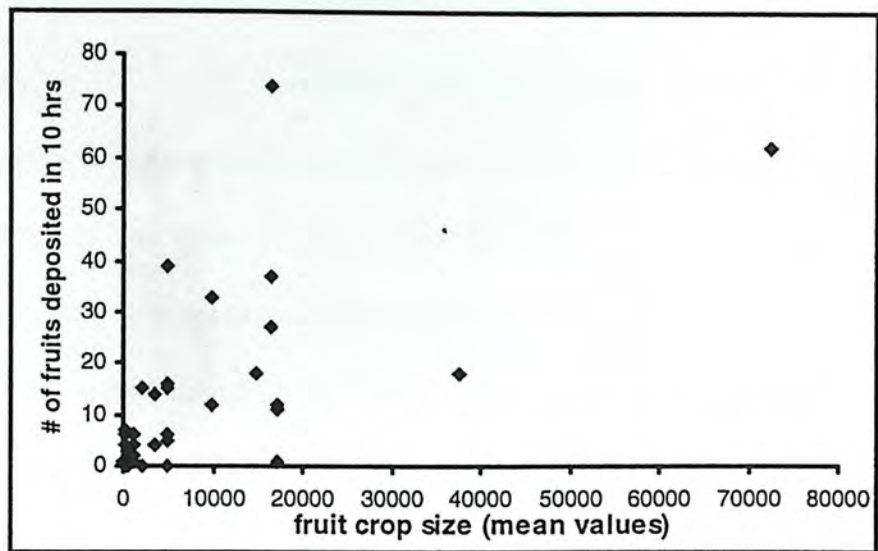


Figure 9. Number of fruit deposited in 10 hours during Dec 2000 vs. mean values of fruit crop size estimate

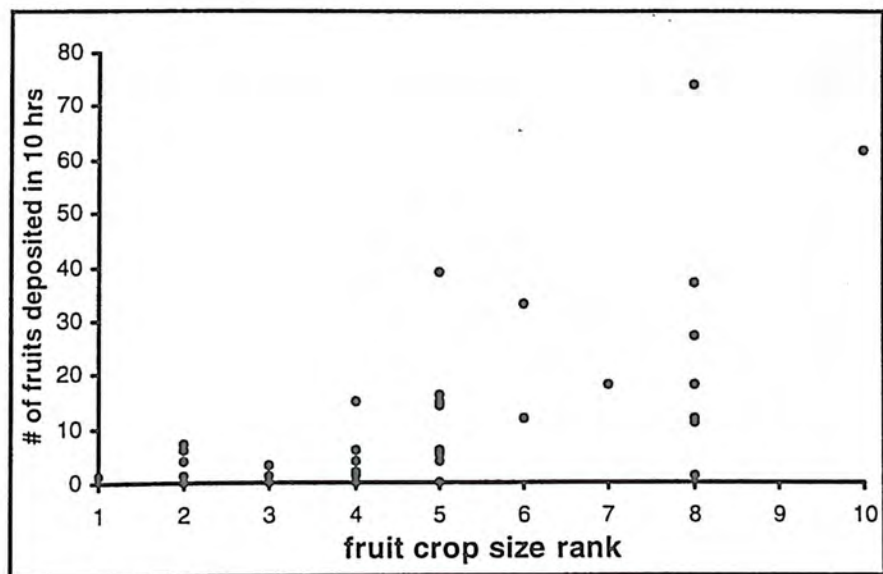


Figure 10 Number of fruit deposited in 10 hours during Dec 2000 vs. rank of fruit crop size estimate

than unmonitored (47 ± 20 days) trees (one tailed Mann Whitney test statistic, $U = 71$, $n_1 = 11$, $n_2 = 8$, $0.05 < p < 0.025$). All the 3 (of the 8 unmonitored trees) which bore evidence of fruit extraction by humans, had fruit crop size $>$ than 5,000 fruits (high fruit crop size trees). Among the high fruit crop trees, fruit persistence was significantly different between the monitored (80 ± 25 days) and the unmonitored (36 ± 12 days) trees (one tailed Mann Whitney test statistic, $U = 15$, $n_1 = 5$, $n_2 = 3$, $0.05 < p < 0.025$). Among the low and medium fruit crop trees, fruit persistence was not significantly different on monitored (50 ± 12 days) vs. unmonitored (54 ± 12 days) trees (one tailed Mann Whitney test statistic, $U = 18$, $n_1 = 6$, $n_2 = 5$, $p > 0.01$). (refer Table 1 and Fig. 11)

2. In the monitored trees, although there a clear linear trend detected graphically between fruit persistence and mean or rank of fruit crop size estimate, the correlation coefficients are not significant (due to low sample sizes) for either mean ($p = 0.72$, $n = 8$) or rank ($p = 0.56$, $n = 8$) of fruit crop size estimate (refer Fig. 12 and 13).
3. Within a tree, changes in proportion of fruit crop remaining were minimal within a 24-hour cycle. On rare occasions, when substantial changes in proportion of fruit crop remaining was noted within a 24 hour cycle they were associated with langur foraging activity at the tree (refer Fig. 14).

(d) *Fruit removal from the fruit-fall area:*

1. There was no difference between removal rates of the control fruit ($n = 44$) and marked fruit ($n = 44$). All fruit (both control and marked) were removed by animals within 12 hours of being marked on each of the three occasions.

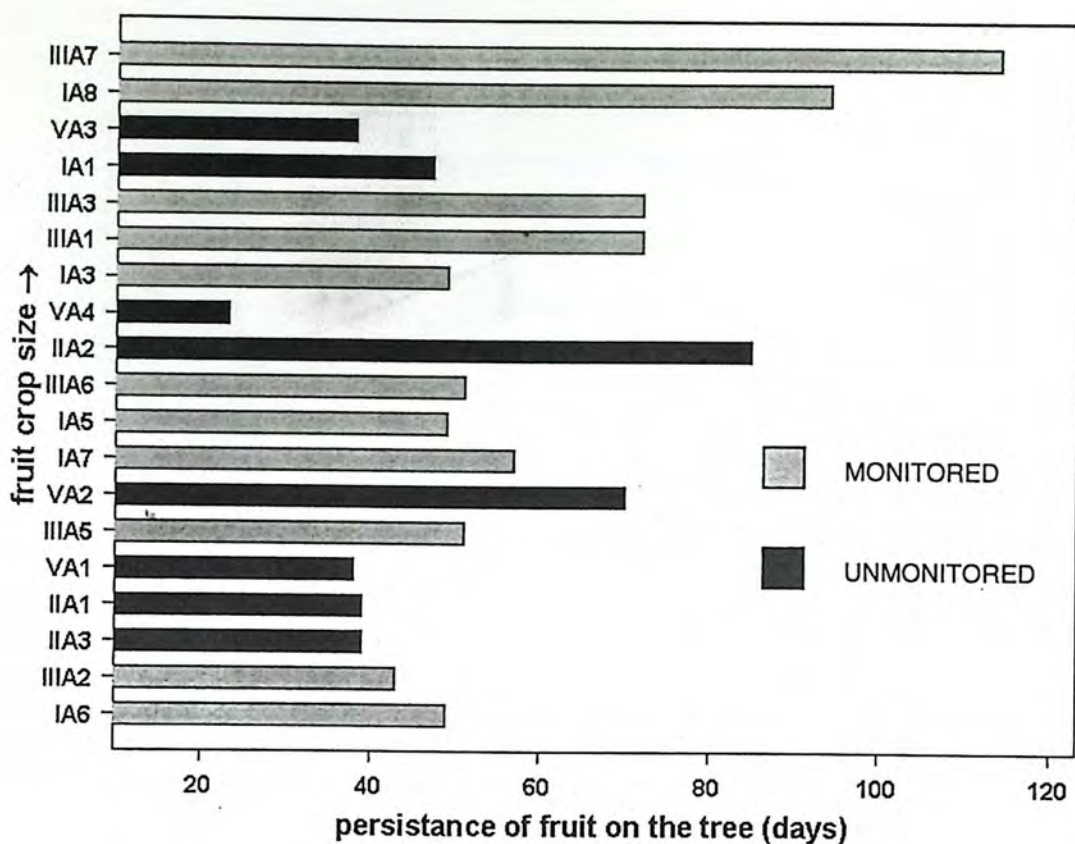


Figure 11 Comparison of fruit persistence (number of days till less than 5 % of the initial number of fruits remained on the marked branches) between monitored and unmonitored trees.

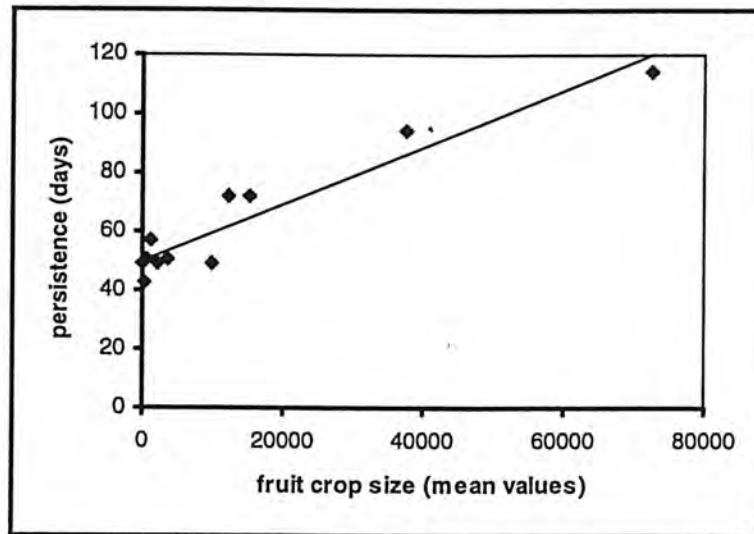


Figure 12 Relationship between fruit persistence (number of days till less than 5 % of the fruit remained on the marked branches) and fruit crop size (mean values of fruit crop size estimante) for the monitored trees (n = 11).

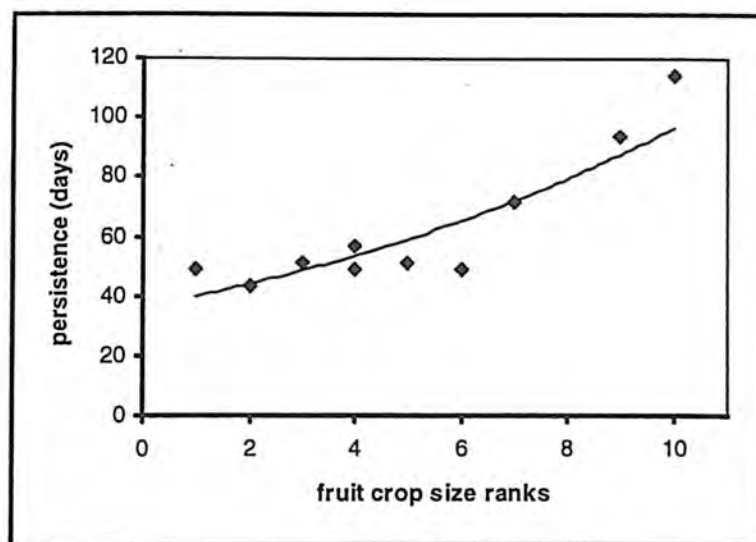


Figure 13 Relationship between fruit persistence (number of days till less than 5 % of the fruit remained on the marked branches) and fruit crop rank for the monitored trees (n = 11).

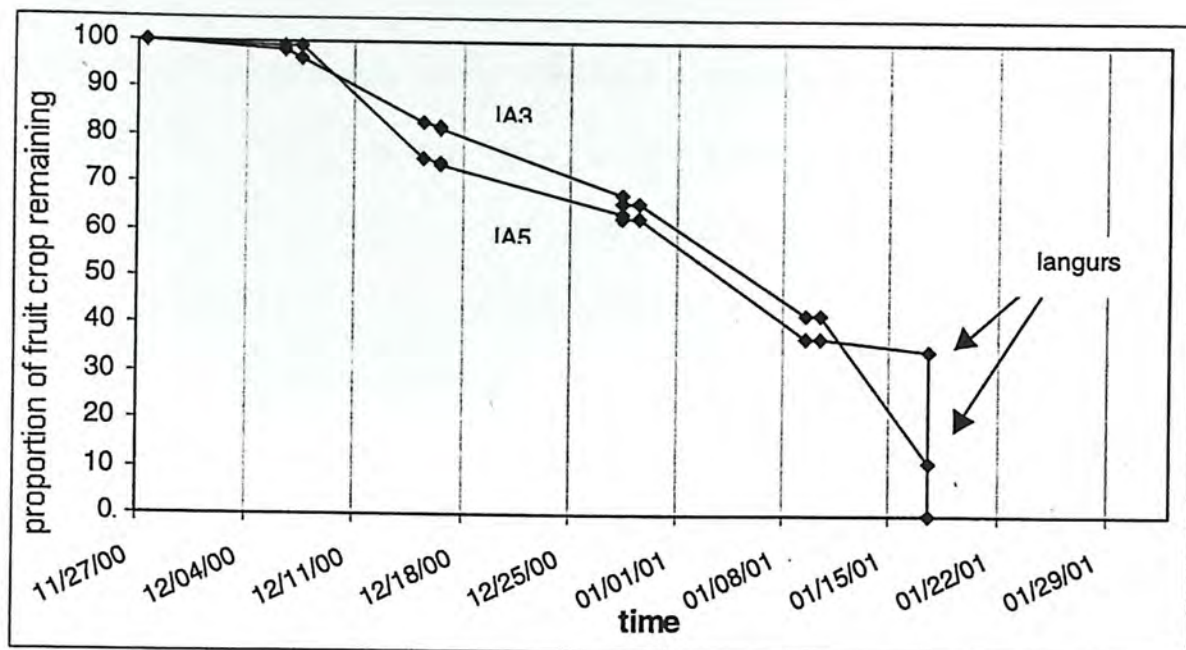


Figure 14 Fruit persistence patterns for two study trees. The sharp change proportion of fruit crop persisting within a single day (22nd Jan 2001) was brought about by langur troops feeding on the trees.

2. Removal rates (pooled nocturnal and diurnal rates) did not differ significantly between trees which were within 50m (level 1 clustering) from each other (Wilcoxon statistic $Z = 0.48$, $p\text{-value} = 0.63$, $n = 34$). Removal rates differed significantly between trees that were >50 but <100 m (level 2 clustering) from each other (Wilcoxon statistic $Z = 2.11$, $p\text{-value} = 0.04$, $n = 6$) and between trees which were >100 m apart (Wilcoxon statistic $Z = -1.96$, $p\text{-value} = 0.05$, $n = 34$).
3. Median values of nocturnal and diurnal removal rates show distinct patterns (refer Table 3). All trees which had both nocturnal and diurnal removal rates > 0.5 were trees with high (> 5000 fruits) fruit crop size. Trees which had both nocturnal and diurnal removal rates below 0.5 are largely low fruit crop bearing trees (57% of 7 trees). Two of the trees (IIA1 and IIA3) which had both nocturnal and diurnal removal rates below 0.5 had signs of animals having been poached under them. A third tree (IIA2), with medium fruit crop, which was within 50 m from both IIA1 and IIA2 also had low nocturnal and diurnal removal rates. Six trees experienced diurnal removal < 0.5 and nocturnal removal > 0.5 .
4. When all the trees are considered, median values of diurnal removal rates are significantly (Wilcoxon statistic $Z = -2.78$, $p = 0.00$ and $n = 19$) lower than nocturnal removal rates.

Table 2: Median values of nocturnal and diurnal rates for the study trees. Trees tagged with a * had signs of animals having been poached under them.

	Tree #	Fruit Crop Category	Median Diurnal Removal Rates	Median Nocturnal Removal Rates
1	IA6	L	0.00	0.00
2	IIA3*	L	0.00	0.09
3	IA7	M	0.00	0.33
4	IIA1*	L	0.03	0.28
5	VA3	H	0.13	0.06
6	IIA2	M	0.22	0.09
7	VA1	L	0.00	0.33
8	IIIA2	L	0.00	0.50
9	VA2	M	0.00	1.00
10	IA8	H	0.06	0.81
11	IIIA5	L	0.06	0.79
12	IA3	H	0.18	1.00
13	IA5	M	0.33	0.91
14	IIIA1	H	0.58	0.94
15	IIIA3	H	0.65	1.00
16	IIIA7	H	0.75	0.86
17	VA4	H	0.84	0.90
18	IA1	H	0.93	1.00
19	IIIA6	H	0.95	0.40

4.3. Fruit Removers and Seed Dispersal of *Emblica officinalis*

(a) *Track Plots*: A range of mammal tracks were noted in the vicinity of fruiting trees including those of rodents, jackal, porcupine, yellow throated marten (?), wild pig, sambar, chital, barking deer, langur, elephant, tiger, and domestic buffalo. Tracks of chital and barking deer were the most commonly encountered under fruiting trees. On one occasion, wild pig tracks were seen under three adjoining fruiting trees (whose under canopy area had been cleared of old tracks the previous evening), and none of the fruit marked the previous evening had been removed. Track plots do not yield any conclusive results about the identity of the fruit removers since animals could just pass under fruiting trees and not remove any fruit.

Tracks of chital, jackal, porcupine and langur were encountered in the track plots. The number of chital tracks encountered in group A trees was significantly greater than for group B trees (one tailed Mann Whitney statistic $Z = 1.6054$, $n_1 = 4$, $n_2 = 3$, $p = 0.0542$). For other species, i.e., langur, jackal and porcupine there was no significant difference between group A and group B trees (one tailed Mann Whitney statistic $Z = -1$, $n_1 = 3$, $n_2 = 1$, $p \text{ value} = 0.8413$).

(b) *Fruit Handling by Chital and Barking Deer*: Chital was the most frequently observed fruit remover (67% of 18 sightings), followed by barking deer (22% of 18 sightings). The behaviours noted while chital and barking deer foraged for fruit under fruiting trees were: searching and feeding on fruit. Chital and barking deer search intensively for fruit on the ground under *E. officinalis* trees with heads bent and noses on the ground, pick up one to few fruit and chew once or twice before swallowing the fruit. On one occasion, I was able

to count fruit in the fruit fall area of a tree just before and immediately after a chital doe fed on fruit under the tree. In 13 minutes the chital doe had consumed 30 of the 33 fruit under the tree.

The two extended feeding bouts at *E. officinalis* fruiting trees by langur troops gave me an opportunity to observe chital foraging for fruit for six hours. Barking deer were seen at only one of these feeding bouts and for a very short time (<10 min) (refer Table 3).

During these occasions, other than foraging for fruit under the tree, chital were seen moving, showing aggression (pushing other chital out of the fruit fall area) and standing alert (standing in a spot with head and body held stiff and ears cocked up). Foraging behaviours included searching and feeding on fruit. They also looked up once in a while to locate langurs feeding on the tree and went and stood directly below them. Any fruits that fell were fed upon instantaneously by chital.

(c) *Fruit Handling by Langur*: During both the extended feeding bouts that I got to observe, I arrived at the tree after langur troops had started feeding on them and hence can only state that langurs along with chital and barking deer spend more than 5 hours at a stretch at fruiting trees.

While at fruiting trees, besides feeding on fruits, Langurs were observed to sleep, sit without feeding on fruit, groom each other, and move from branch to branch. Foraging behaviours included reaching out and picking fruit from branches, taking a few bites of the fruit, and dropping the remaining fruit. As they move on the tree, leaping from branch to branch they bring a number of fruits down. Even while foraging, they drop a number

Table 3 Details of langur, chital and barking deer foraging under *E. officinalis* fruiting trees during extended feeding bouts by langur troops. Results are presented as means $\pm$ SD. Numbers in *parenthesis* give sample sizes (number of scan samples).

date	tree#	duration	maximum # of animals observed	average # of animals observed
29/12/00	IIIA 1	4.5 hours	14 chital, 5 langurs.	7.4 $\pm$ 3.2 chital (23) 2.4 $\pm$ 1.6 langurs (23)
03/01/00	IIIA 3	1.5 hours	18 chital, 2 barking deer, 10 langurs.	10.7 $\pm$ 5.7 chital (8) 0.3 $\pm$ 0.8 barking deer (8) 6.6 $\pm$ 3.2 langurs (8)

of fruits. Though not quantified rigorously, the number of fruits dropped due to langur activities were far more than those they fed upon. The fruits dropped by langur fell under the parent tree itself. Fruit fed upon by langur had characteristic bite marks and occurred with a range of pulp content: from almost the entire pulp intact to less than 5 % remaining around the cocci.

On most occasions, by counting fruit in the fruit fall area, it was not possible to arrive at the number of fruits dropped by langurs vs. the number of fruit fed by them since fruit dropped by them are fed upon almost instantaneously by chital and barking deer standing below the tree.

In the fruit-fall area of fruiting trees, removal rates did not differ significantly between langur-handled fruits with more than 50% of the pulp remaining and fruit without signs of langur handling (one tailed Wilcoxon statistic, $Z = 1.4142$, $n_1 = n_2 = 4$, p value = 0.0786). It was observed that langur handled fruit with very little pulp around the cocci were not removed unlike other langur handled fruit. These generally dehisced to release seeds enclosed within them under the parent tree itself.

On five out of seven occasions when I looked among langur-handled fruit (with 60, 10, 17, 10 & 40 langur-handled fruits) in the fruit-fall area of study trees after recent langur activity, there were signs of seed damage by langurs (one broken endocarp fragment or damaged seed on each occasion).

(d) *Fruit handling by rodents:* All the fruit set in the manner described in section 3.3(d) under fruiting trees were found dragged into rodent burrows close to the trees. Out of ten trapping nights, one rodent was trapped (14th Jan 2001) in a Sherman trap baited with *E.*

officinalis fruit. The rodent was identified as the Indian Gerbil, *Tatera indica* (head: body: tail = 4: 13: 20 cm). In mid January 2001, from this burrow, (length of the burrow = 2.97m, maximum depth = 36 cm below soil surface), a rodent cache of 12 *Emblica officinalis* fruit and 175 *Zizyphus mauritiana* cocci were recovered. 4 of the 12 *E. officinalis* fruits had rodent feeding signs (with characteristic rodent incisor marks). The *E. officinalis* cocci and seeds were intact and showed no signs of damage. On the other hand, most of the *Zizyphus mauritiana* cocci were damaged and the seeds had been fed upon. The *T. indica* maintained in captivity fed upon the pulp of *E. officinalis* fruit but did not attempt to break open the cocci or feed upon the seeds.

(e) *Other species*: Elephants were seen under fruiting trees twice. On both the occasions, they made no attempt to reach for the fruits on the tree. It was not possible to see whether they fed on fruit that was on the ground under the trees. Jackal (once), wild pig (twice), nilgai (twice) and sambar (six times) were also seen under / passing close to fruiting trees. I did not note any of them foraging under fruiting trees except for sambar, which was seen feeding on other browse. None of these animals attempted to 'search' for fruits under the tree as chital and barking deer did when under fruiting trees. Rhesus macaques were seen foraging under fruiting trees on three occasions. On two of these occasions, though they were seen picking up things from the ground and feeding on them, I could confirm whether they were actually feeding on the fruit. On one of these occasions when I was close enough to make confirmed feeding observations, the macaques did not feed on any fruit.

There were no *E. officinalis* fruit, cocci or seeds in the rumen contents of either of the sambar kills examined. None of the droppings examined of jackal, porcupine or wild pig contained *E. officinalis* fruit, cocci or seeds; while cocci of *Zizyphus mauritiana* and *Cassia fistula* seeds were often encountered in the droppings of all the three species.

(f) *Camera trapping*. The camera trap was set for 15 days (143.5 daylight hours) and 21 nights (288 night hours). On 7 (47%) days and 6 (29%) nights fruits were not removed from the vicinity of the trap. Using this set up, on three occasions pictures were obtained of animals (twice chital and once a rodent) which had tried to feed on the fruit tied at the camera trap. On other occasions, though animals had fed upon the fruit tied at the trap or close to it, photographs were not obtained due to inappropriate settings.

By the time this set up gave its first results (after a months effort) the only camera I had started malfunctioning and the fruits were also running low. The first and last pictures that I obtained with the camera trap were of Chital (*Axis axis*) (see Figure 15) and a rodent (most probably *Tatera indica*). In both the cases, the animals after triggering the camera by pulling at the fruit had moved back when the auto-focus got activated.

At Rajaji NP, ungulates and primates were very wary of human presence which necessitated that observation points be at least 200m from fruit trees. Further, fruit removal was largely during late evening and night hours. Night observations were hampered by fog and presence of elephants. And in my case, lack of a good spotting scope and night vision equipment made obtaining confirmed feeding observations of even relatively large animals like ungulates, difficult. To arrive at confirmed feeding records of small animals (like rodents) I had to rely completely upon indirect methods



Fig. 15 Camera Trap Picture of Chital

and camera traps. With some amount of planning and sufficient number of cameras set along lines that I have described above one should be able to obtain not just reliable results, but also the complete range of species that remove the fruit of interest.

(g) *Monitoring Ungulate Boluses.*

Though I have not quantified composition or densities of ungulate boluses, I am reporting some 'natural history' observations here that are important to obtain a better picture of *E. officinalis* seed dispersal at Rajaji NP. In October 2000 (during an earlier visit to the field site), ungulate regurgitated boluses were commonly encountered along the raus (river beds) in the intensive study area and were mostly composed of *E. officinalis* and *Terminalia belerica* endocarps. In November, I failed to locate any fresh ungulate boluses along the raus after an intensive search. However during November, boluses were frequently seen in flat open areas with few trees and were composed of *E. officinalis*, *Zizyphus mauritiana* and *Terminalia belerica* endocarps. In December, boluses were mostly found in area with good tree cover and were rarely encountered along the raus or in open areas. During December, they were largely composed of *Zizyphus mauritiana* and *E. officinalis*. *Z. xylopyra* endocarps started appearing in ungulate boluses from January onwards. None of the cocci that were found in ruminant regurgitated boluses had signs of external damage.

An average of 6 ± 3 *E. officinalis*, 22 ± 12 *Z. mauritiana* and 1 ± 2 *Z. xylopyra* endocarps were set in each plot. *E. officinalis* endocarps dehisced within 2-3 days and released 5 to 6 seeds each. The seeds spread out within a radius of 1-2m from the cocci after dehiscence (Prasad, pers. observation). Median number of days upto which *E.*

officinalis seeds persisted in these plots was 33 days. Post-dispersal, *E. officinalis* seeds were subjected to further movement due to trampling by animals and wind. *E. officinalis* seeds were also predated by insects and rodents. Seed predation of *E. officinalis* and *Z. xylopyra* was far lower than that observed for *Z. mauritiana*.

(h) *Germination experiments.*

None of the *E. officinalis* seeds (treatment, control A or control B) which were not watered had germinated by the end of April 2001. Among the watered *E. officinalis* seeds, germination rates of control A seeds (54% of 95) was significantly different ($g = 53.59$, $p = 0.00$, $df = 1$) from germination rates of treatment seeds. The average time taken to germinate was very similar for control A (97 ± 19) and treatment *E. officinalis* seeds (105 ± 19).

All the *E. officinalis* fruits left exposed to site conditions had dried by late December 2000 and all the cocci dehiscid by mid March 2001. 71 % of the watered *E. officinalis* control B seeds had germinated by the end of April 2001. These germinated within an average of 11 ± 4 of days after being set up. Control B has far higher germination rates than treatment seeds ($g = 95.10$, $p = 0.00$, $df = 1$), but control A and control B are very similar and differences between them are not significant ($g = 5.75$, $p = 0.05$, $df = 1$). Thus germination of *E. officinalis* seeds is influenced by passage through ungulate rumens, and not merely removal of pulp from the cocci surface by ungulates during feeding.

In the case of *Z. mauritiana*, control seeds (4 % of 49) had lower germination rates ($\chi^2 = 32$, $p = 0.00$, $df = 1$). than treatment cocci (51 % of 49) The average time

taken to germinate was very similar for control (38 ± 6 , $n = 2$) and treatment *Z. mauritiana* seeds (33 ± 7 , $n = 25$).

Moisture certainly had a role to play in *E. officinalis* germination rates since only the watered treatments germinated. Watered *E. officinalis* seeds set up in winter, i.e., early December 2000 (treatment and control A) started germinating only towards the end of February 2001, while seeds set up in summer, i.e., early April (control B) started germinating in mid April 2001. Sinha (2000) notes that there was no seed dormancy involved in germination of *E. officinalis* seeds at BRT sanctuary, south India. Thus day length or temperature or both which differ sharply between winter (average winter day length was 10 hrs, temperatures ranged from 4°C to 20°C in shade) and summer (average day length was 14 hrs, temperatures ranged from 27°C to 39°C in shade) at Rajaji NP might have a role to play in *E. officinalis* germination.

4.4 Demography of *Emblica officinalis* and regeneration of associated woody plant species at Rajaji National Park

(A) Human Use Indices and woody plant community regeneration across transects.

The individual arcsine transformed indices were weakly correlated with each other (refer Table 5). Due to the presence of too many zeros it was difficult to explore differences between and within hill and plain mixed forest habitats using the multiplicative indices. The Kruskal Wallis test was significant for all indices (indices C, D, L and A₂) and for regeneration (1 & 2) densities (refer Table 6). It was observed that preferred species for lopping occurred in higher densities in the hill mixed forests. Hence lopping index (L) was not used for comparisons between hill and mixed forests.

(a) Human Use Indices across treatments:

Within Hill and Plain Forests for C, D, L and A₂, (refer Table 4 and Figure 15 a,b,c,d), H1 < H2 < H3 along all human use indices, while no such clear trends emerge for plain transects. Between Hill and Plain Mixed Forest for C, D, and A₂ (refer Table 4 and Figure 15 a, b and d), H1 had the lowest mean and median values for all human use indices. H1 < P1 along all human use indices. It is not possible to distinguish between H2 and P2 along any of the indices. P3 < H3 along C and A₂ and differences are not apparent along D.

Table 4: Mean, Variance and Median Values for arc sine transformed values of Human Use Indices and Regeneration scores of all transects (n = 10 for each index per transect).

Cut Stem Index

	H1	H2	H3	P1	P2	P3
Mean	0	3.65	33.21	4.14	3.11	16.41
Var	0	14.76	557.42	34.85	31.30	310.57
Median	0	3.65	29.45	0	0	10.34

Dung Density Index

	H1	H2	H3	P1	P2	P3
Mean	0	6.0	14.04	12.66	9.97	27.49
Var	0	175.83	109.46	288.10	79.55	575.56
Median	0	0	16.74	10.74	8.87	20.18

Lopping Index

	H1	H2	H3	P1	P2	P3
Mean	0.11	9.86	32.83	0.4	0.58	8.65
Var	0.11	29.71	797.77	0.71	1.64	25.29
Median	0	10.47	24.03	0	0	8.11

Additive Index 2

	H1	H2	H3	P1	P2	P3
Mean	0	8.12	35.72	13.47	11.90	35.18
Var	0	149.32	448.94	260.46	54.05	717.78
Median	0	6.96	34.98	12.89	8.47	22.72

Regeneration 1

	H1	H2	H3	P1	P2	P3
Mean	34.29	31.97	27.25	23.90	34.67	15.98
Var	168.80	556.21	135.93	289.02	439.73	47.12
Median	32.49	24.69	26.83	18.29	37.21	17.59

Regeneration 2

	H1	H2	H3	P1	P2	P3
Mean	1.52	0	20.21	49.35	12.07	45.09
Var	6.21	0	166.17	479.59	172.25	79.71
Median	0	0	18.57	50.16	9.3	43.44

Table 5: Matrix of correlation coefficients for arcsine transformed Human Use Indices. C = cut stem index, D = dung density index and L = lopping index.

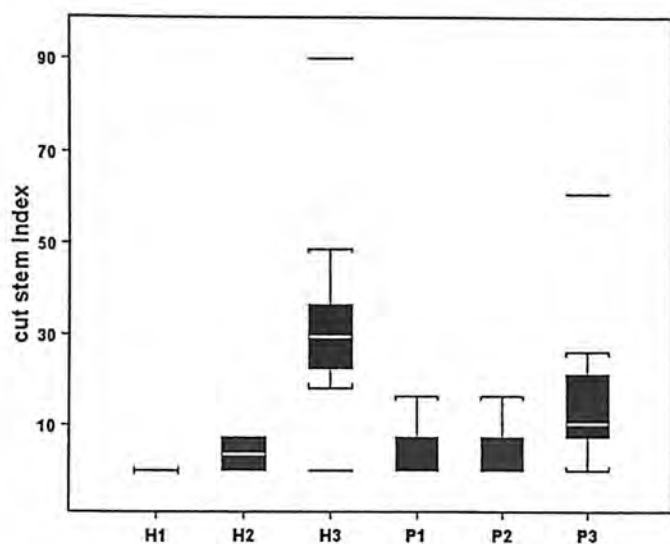
	C	D	L
C	1.00	0.28	0.51
D	0.28	1.00	0.21
L	0.51	0.21	1.00

Table 6: Kruskal Wallis test results for arcsine transformed Human Use Indices, Regeneration-1 and Regeneration-2 (n = 6 treatments for each).

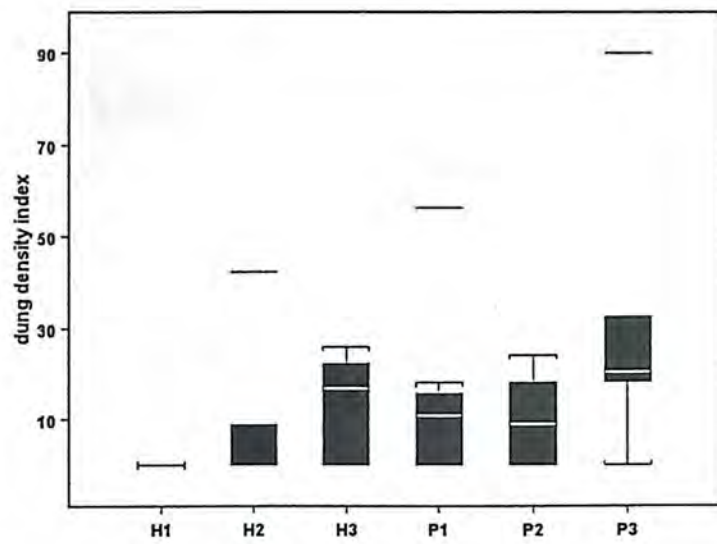
	χ^2	Asymptotic significance
Cut Stem Index	31.468	0.000
Dung Density Index	22.680	0.000
Lopping Index	49.919	0.000
Regeneration-1	11.913	0.000
Regeneration-2	45.966	0.000

Table 7 Regressions between arcsine transformed Human Use Indices and Regeneration & Weed Density (n = 60 for each).

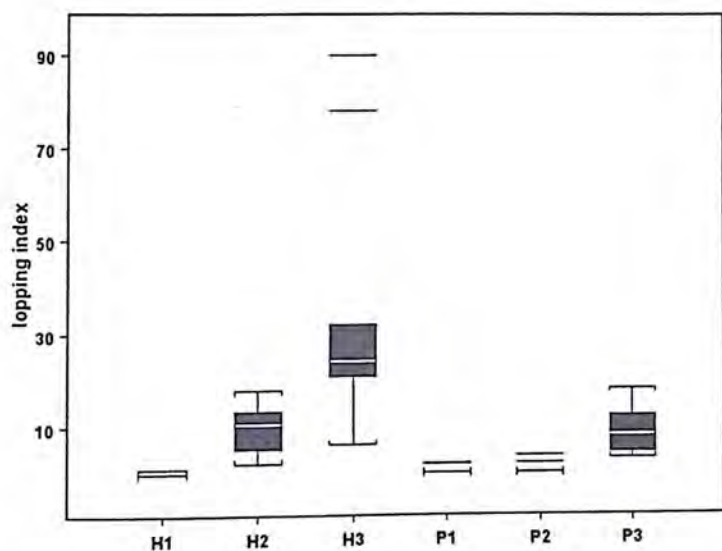
Human Use Indices	Regeneration-1			Regeneration-2		
	coefficient	P	r^2	coefficient	p	R^2
Cut Stem Index	-0.0878	0.5237	0.007047	0.2674	0.1347	0.03817
Dung Density Index	-0.2629	0.0625	0.05853	0.4847	0.0077	0.1161
Lopping Index	-0.2710	0.0523	0.06339	-0.0612	0.7419	0.001884
Additive Index 2	-0.1728	0.1157	0.04213	0.3522	0.0128	0.1021



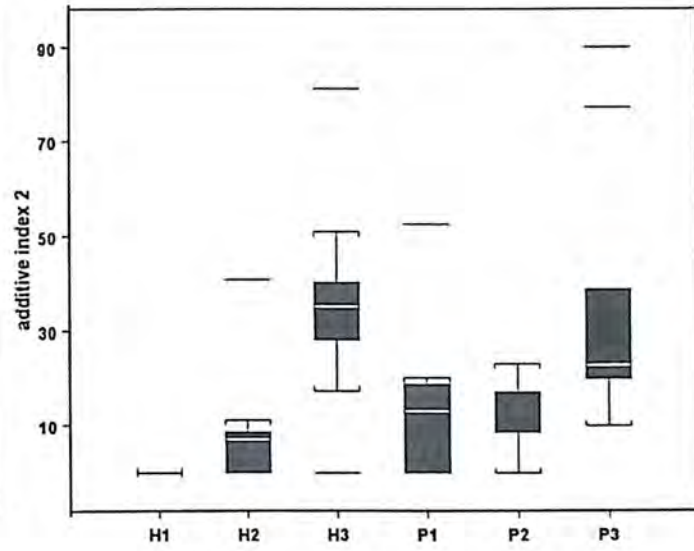
15 (a)



15 (b).



15 (c).



15 (d)

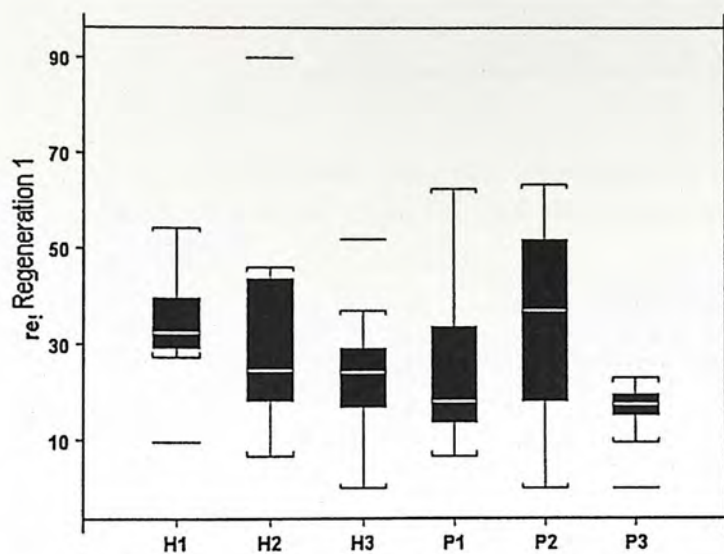
Figure 15: Box Plots from different transects for arc sine transformed Human Use Indices indicating inter quartile range (box), median (line within box), 1.5 x inter-quartile range (whiskers), extreme values (lines above and below the whiskers). 15(a) Cut Stem Index; 15(b) Dung Density Index; 15(c) Lopping Index; 15(d). Additive Index2. The transects are, H1 - Hill Low Human Use; H2 - Hill Intermediate Human Use; H3 - Hill High Human Use; P1 - Plain Low Human Use; P2 - Plain Intermediate Human Use; P3 - Plain High Human Use. n = 10 for each transect.

(b) Regeneration of woody plant species across treatments:

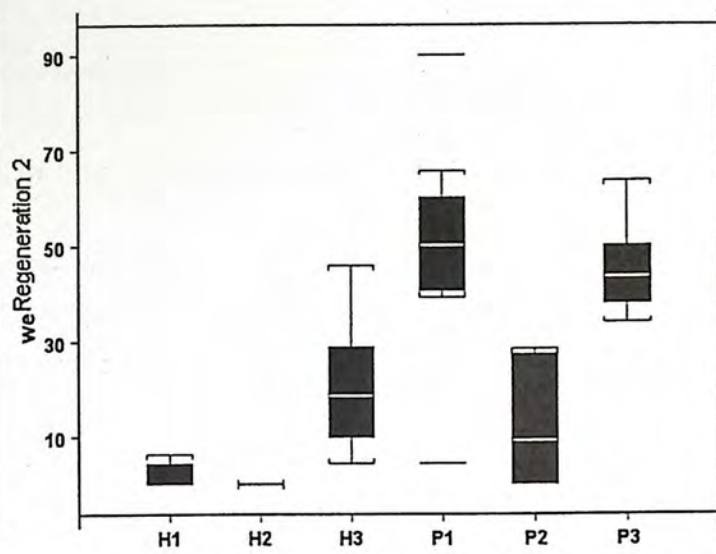
Though the regression coefficients were not significant, regeneration1 was negatively influenced by C, D, L and A₂, and regeneration2 was positively influenced by C, D and A₂ (refer Table 4). H1 > H2 > H3 (along mean) for regeneration 1 (refer Table 7 and Fig. 15.e). For regeneration 2, H3 > H2 $\cong$ H1. No such trends emerge in the plain transects.

For tree species regeneration, the proportions of seedlings and resprouts are not significantly different among the three treatments for both the hill and the plain transects (refer Table 9 for chi square test results). However, the cumulative number and proportion of seedlings decreased from H1 to H2 to H3. And the cumulative number and proportion of resprouts increased from H1, to H2 to H3 (refer Table 8). Once again, no such trends emerge along the human use gradient for the plain transects. *Holarrhena antidysenterica* and *Ehretia laevis* and dominate the regenerating tree species community (refer Table 10).

Summarising the above results, human use indices increase from low to intermediate to high for the hill transects, and correspondingly regeneration density falls from H1 to H2 to H3. In contrast, for the plain transects no such patterns emerge. The lack of trends in the plains could be because plain forests are more accessible than hill forests to people and the plain forests of the low, intermediate and high blocks could be used to the same extent. The other reason could be that my measures of human use indices are not sensitive enough to detect any existing differences in the plain mixed forests.



(e)



(f)

Figure 16. Box Plots from different transects indicating median, inter quartile range (box) 1.5 x interquartile range (whiskers), extreme values (lines above and below the whiskers) of arc sine transformed scores. 16(e). Regeneration 1 & 16(f) Regeneration 2. The transects are, H1 - Hill Low Human Use; H2 - Hill Intermediate Human Use; H3 - Hill High Human Use; P1 - Plain Low Human Use; P2 - Plain Intermediate Human Use; P3 - Plain High Human Use. n = 10 for each transect.

Table 8: Number and proportion of tree species seedlings and resprouts across transects.

transect	seedlings	resprouts	Total
H1	56 (79%)	15 (21%)	71
H2	27 (36%)	47 (64%)	74
H3	23 (34%)	44 (66%)	67
P1	59 (75%)	20 (25%)	79
P2	22 (52%)	20 (48%)	42
P3	32 (57%)	24 (43%)	56

Table 9: Chi-square test results for proportions of tree species seedlings and resprouts in the three treatments for hill and plain transects.

	seedlings			resprouts		
	χ^2	Df	p	χ^2	df	p
Hill	0.64	2	0.72	0.66	2	0.72
Plain	0.82	2	0.66	0.12	2	0.94

Table 10 Top ranking tree species (by abundance) contributing 50% cumulatively to regeneration for each transect. Terms in *parenthesis* indicate part of the plant that is extracted. H1 - Hill Low Human Use; H2 - Hill Intermediate Human Use; H3 - Hill High Human Use; P1 - Plain Low Human Use; P2 - Plain Intermediate Human Use; P3 - Plain High Human Use. n = 10 for each transect.

transect	species	lopped	other extractive uses	proportion of total regeneration
H1	<i>Holarrhena antidysenterica</i>		* (bark)	35 % of 71
	<i>Shorea robusta</i>	*		17 % of 71
H2	<i>Holarrhena antidysenterica</i>		* (bark)	19% of 86
	<i>Ehretia laevis</i>			17% of 86
	<i>Syzygium cumini</i>			16% of 86
H3	<i>Holarrhena antidysenterica</i>		* (bark)	37% of 67
	<i>Zizyphus sps</i>		* (fruit)	12 % of 67
P1	<i>Ehretia laevis</i>			34% of 47
	<i>Holarrhena antidysenterica</i>			34% of 47
P2	<i>Holarrhena antidysenterica</i>			26% of 42
	<i>Cordia obliqua</i>			21 % of 42
P3	<i>Zizyphus sps</i>		* (fruit)	61% of 56

Only one extreme of the range of intensity of human use at Rajaji N.P, i.e., the lowest has been quantified. While the hill mixed forests in low human use block are nearly free from human use, the same is not true of the plain forests. In the intermediate human use block, there were no differences detected between hill and plain mixed forests. And in the third block, the hill forests had higher human use index scores. Again this might be due the fact that my measures of human use indices might not be the best to detect differences between hill and plain mixed forests. Thus it is not possible to conclude whether plain mixed forests are more used by people than hill mixed forests from my results.

Weeds like *Adathoda vasica*, *Lantana camara*, *Vitex negundo* occur in higher densities in the plain mixed forests compared to the hill mixed forests. They occur in the hill forests under high intensity of human use and are nearly absent on the hill transects with low and intermediate intensities of human use. Overall, the hill transects show higher variances than plain transects. This could be because of topographic features in the hills that make certain areas more accessible to humans than others.

The proportion of resprouts in tree species regeneration increased from H1, to H2 to H3 along with an increase in human use intensity. Disturbances like fire, cutting and grazing tend to increase the importance of vegetative reproduction relative to sexual reproduction (Hoffman 1998). The ability to resprout is not uniform across species. Species that are able to resprout from existing root and stem stocks are likely to be at a greater advantage under frequent burning or heavy grazing.

(B). *E. officinalis* densities and regeneration across treatments.

A total of 78 *E. officinalis* trees (above 10 cm GBH and 1.3m in height), 52 in the hill and 26 in the plain mixed forests, were sighted along the line transects. The density of *E. officinalis* trees was higher in the hill mixed forests (1.99 trees per hectare, CV = 34.57%) compared to the plain mixed forests (0.86 trees per hectare, CV = 39.30%) at Rajaji NP (refer Table 11 and Figure 17). In all transects except H1, *E. officinalis* trees bore signs of have been lopped.

There is no difference in size class structure for GBH below 60cm between trees sighted within 10m and from 10 to 20m from the line (refer Figure 18) and hence I have assumed that there is equal probability of sighting all GBH classes within 20 m from the line. Though trees below 30cm GBH have not been sighted within 20m from the line, they have been sighted *beyond* 20m (refer Figure 19). And hence absence of trees below 30cm GBH within 20m from the line is not because of reduced sighting probabilities of lower girth size classes.

GBH class structure is more skewed in the plain forests than the hill forests, with trees with GBH below 60cm are being almost completely absent in the plain mixed forests (refer Figure 19). Sample sizes (per transect) are too small to compare GBH class structure between transects.

E. officinalis seedlings were found only in 2 out the 10 plots on H1. Resprouts from stem stock were found in 1 out of the 10 plots on H3. *E. officinalis* seedlings were found under 6 of the 11 (55%) of the trees located on H1. In all the other transects, no seedlings were found under any of the located *E. officinalis* trees.

Table 11 DISTANCE results for *E. officinalis* trees sighted within 50m from the line for hill and plain mixed forest transects. Effort = 3 km , # of transects = 3, CV is coefficient of variation, ESW is effective strip width.

	HILLS TRANSECTS:	PLAINS TRANSECTS
# of observations	48	22
Model	Half-normal cosine	Half-normal cosine
Encounter rate (trees/km)	16.000 (CV = 31.25%)	7.3333 (CV = 2.4037)
ESW (in m)	40.252 (CV = 14.78%)	42.634 (CV = 9.2446%)
Density (trees/ha)	1.9875 (CV = 34.57%)	0.86002 (CV = 39.30%)

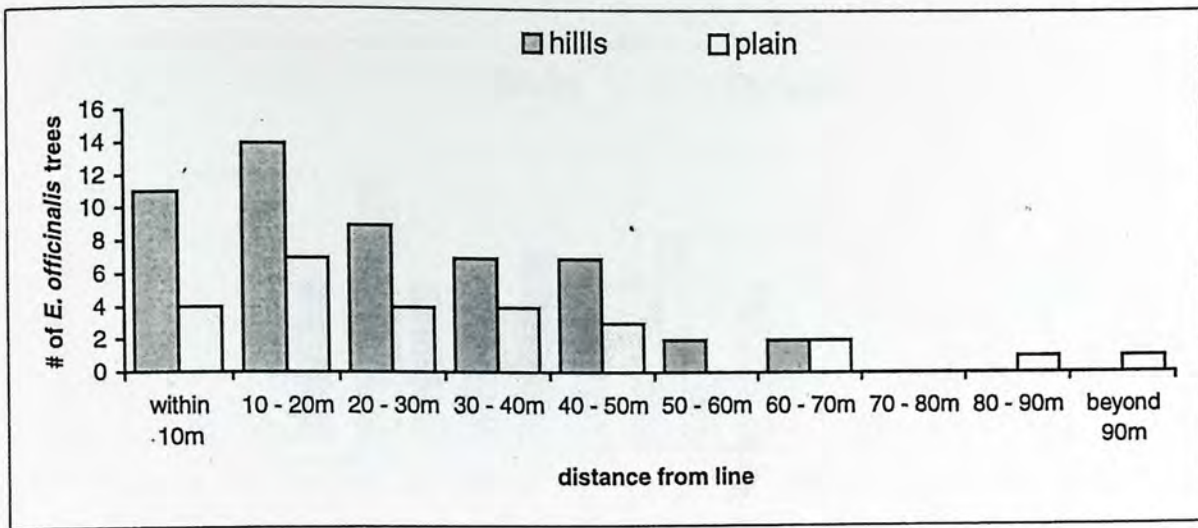


Figure 17 Number of *E. officinalis* trees (n = 78) sighted at varying distances from the line transect.

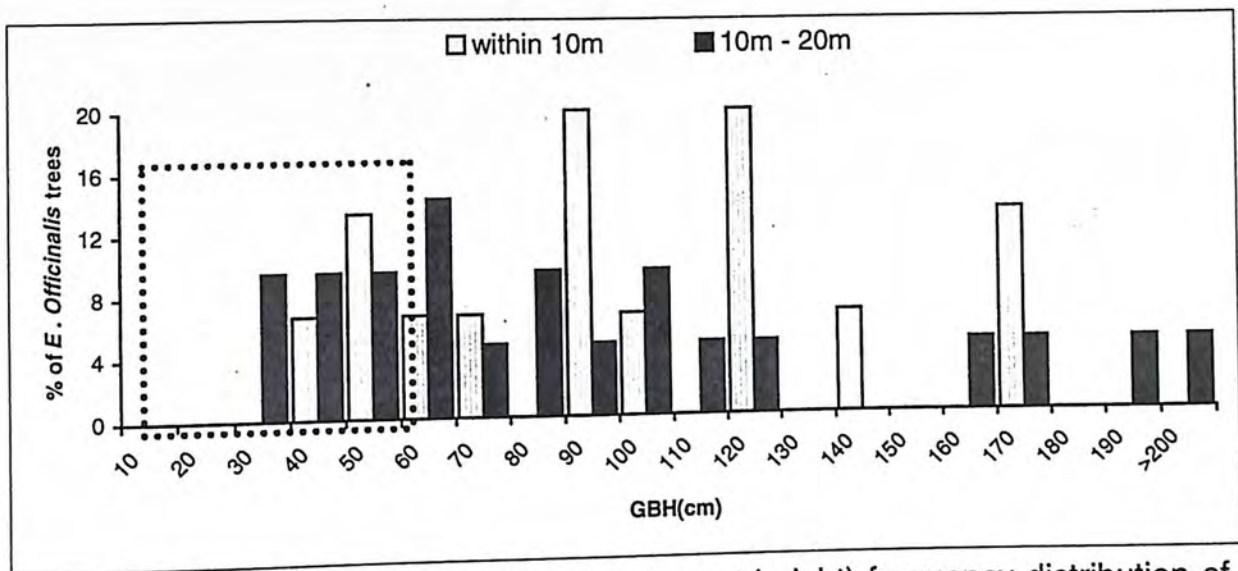


Figure 18 A comparison of GBH (girth at breast height) frequency distribution of *E. officinalis* trees sighted within 10m (n = 15) and between 10 – 20m (n = 21) from the line transect. Note the absence of trees in the 10 – 30cm girth classes. Also note the similarity of girth class structure for trees sighted within 10 and between 10 – 20m for girth class intervals below 60cm.

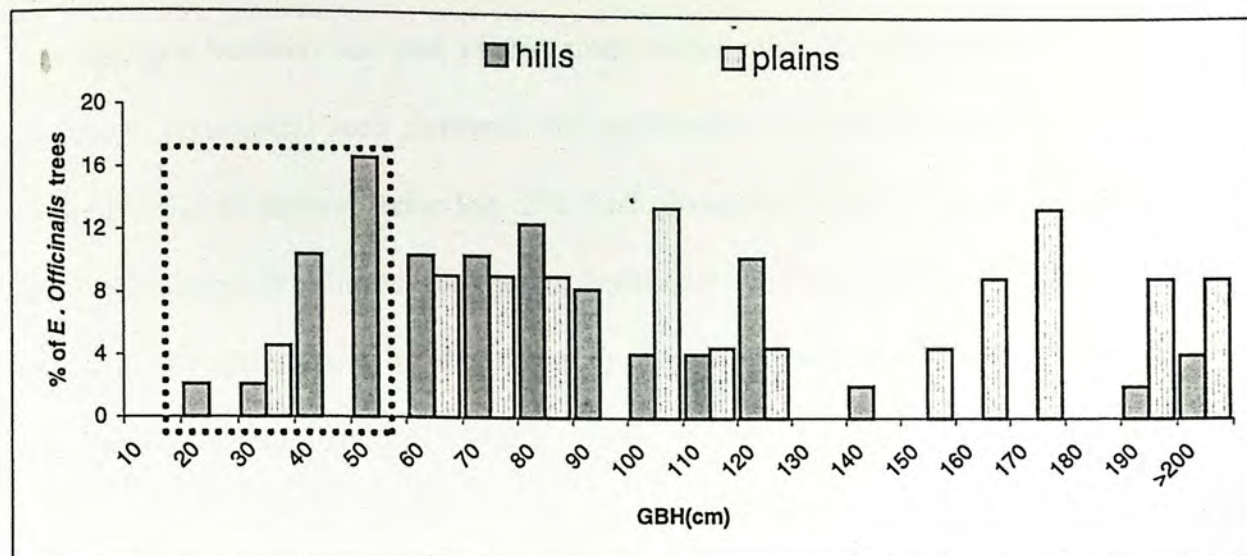


Figure 19 A comparison of GBH (Girth at Breast Height) frequency distribution of *E.officinalis* trees sighted within 50m for hill (n = 48) and plain mixed forest transects (n = 22). Note the low percentage of trees in the 10 – 30cm girth classes. Also note the difference between hill and plain mixed forests in girth class structure below 60cm GBH.

Chapter 5. Discussion

The linkages between one part of this study to the other are quite clear: fruit removal leading to consequent seed dispersal and regeneration and thus influencing demography of the species of interest (refer Fig. 20). And disruptions of any of these linkages might have cascading effects in the ecosystem. I will now attempt to answer the three questions raised in the introduction to this thesis by exploring each of these aspects of the life history of *E. officinalis*:

(a) Factors affecting fruit removal of *E. officinalis*:

Fruit persistence on *E. officinalis* trees was influenced by extraction of the fruit by people and by fruit crop size. Factors affecting removal rates of fruits from the fruit-fall area were clustering of fruiting trees and human induced factors.

Let us first examine the human induced factors. Among high fruit crop bearing trees (>5000 fruits), fruit persistence was longer on the monitored (80 ± 25 days) than unmonitored (36 ± 12 days) trees by a month and half on an average (refer Fig. 11). Fruits thus disappeared well ahead of time on the unmonitored trees with high fruit crop due to human activities.

For the study trees, diurnal removal rates were lower than nocturnal removal rates. This might be because of human movement which was observed to be largely during the day time hours which might in turn might affect ungulate movement (most frequently encountered fruit removers of *E. officinalis* at Rajaji NP – 89% of 18 sightings), which was observed to be largely during late evening and night hours in the intensive study area.

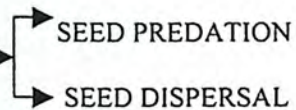
Fig-20 FRUIT REMOVAL AND MORTALITY PATTERNS
OF *Emblica officinalis*

UNHARVESTED SCENARIO



ON TREE

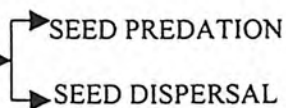
- FRUGIVORY BY VERTEBRATES
- INSECT/ PATHOGEN ATTACK
- INTRINSIC MORTALITY
- PHYSICAL (WIND, RAIN)
- NATURAL FRUITFALL



↓
REGENERATION

ON FOREST -FLOOR

- FRUGIVORY BY VERTEBRATES
- INSECT/ PATHOGEN ATTACK
- INTRINSIC MORTALITY



↓
REGENERATION

HARVESTED SCENARIO



- PEOPLE REMOVE MOST OF THE FRUITS FROM THE ECOSYSTEM PERMANENTLY.
- REMAINING FRUITS SUBJECT TO NATURAL REMONAL ~MORTALITY PATTERNS.
- FRUITS NOT AVAILABLE TO FRUGIVORES.

↓
LACK OF SEED DISPERSAL

↓
LACK OF REGENERATION

In the intensive study area, I observed that fruiting trees of *E. officinalis* and *Z. mauritiana* were often used as baits to set noose traps for ungulates (fruits of both these species are consumed by ungulates). Due to movement and presence of a large number of people in and around Dhaul Kand, it is humanly impossible to monitor any such activities. Two of the study trees (refer Table 1) had signs of animals being poached under them. These two trees and a third which was within 50m from both these trees, experienced low nocturnal and diurnal removal rates (refer Table 3).

Coming to factors other than human induced ones that influence fruit removal, fruit crop size affects fruit persistence and clustering of fruiting trees had a role to play in removal rates from the fruit-fall area. Although among the monitored trees, there was a clear linear trend detected graphically between fruit persistence and fruit crop size (refer Fig 12 & 13), fruit persistence was weakly correlated with fruit crop size which might be due to the small sample size. Within a tree, proportion of fruit crop remaining changed very little within a 24-hour cycle and, and when substantial changes did occur they were always associated with langur foraging activity at the tree (refer Fig 14).

Fruiting trees which were within 50m from each other experienced similar removal rates from the fruit-fall area on any given day or night. This did not hold true for fruiting trees which were > 50 but < 100m apart and for pairs of trees which were > 100 apart. Thus, if a tree is within 50m from another fruiting tree, there is a high probability of it having fruit removed when its neighbour has fruit removed. This similarity could be due to foraging behaviours of ungulates like chital and barking deer that remove fruit from the fruit-fall area.

Other studies have found fruit crop size (Howe and DeSteven 1979, Gryj & Dominguez 1996, Korine *et al.* 2000), phase of fruiting season (Forget 1996), moon phase in the case of fruit removal by bats (Korine *et al.* 2000) to influence patterns (proportion of fruit crop removed and removal rates) of fruit removal.

(b) Fruit Removers – are they effective dispersers of E. officinalis?

Four species were identified as confirmed fruit removers of *E. officinalis* at Rajaji NP – chital, barking deer, langur and the Indian gerbil (*T. indica*). Langur damaged seeds on some occasions and dropped more fruit from the tree than those that they actually fed upon. But in turn, they facilitated use of *E. officinalis* fruits by chital and barking deer. Ruminant regurgitated boluses recovered in the intensive study area did not contain any damaged *E. officinalis* cocci. However, retention in ungulate rumens reduced germination success of *E. officinalis* seeds. Aspects of fruit handling by *T. indica* are yet to be explored.

Primates and scatter-hoarding rodents are generally considered to be seed predators (Forget 1990, Norconk *et al.* 1998). Primates drop seeds into the fruit-fall during preparation. From the point of view of seed dispersal, there is no advantage to the plant if the seeds/ fruits remain under the parent itself. But primates may in turn facilitate secondary dispersal and make fruits available to other animals which consume fruit from the fruit-fall area (Norconk *et al.* 1998). Scatter-hoarding rodents also aid seed dispersal by post dispersal manipulation of seeds (Forget 1990 & 1996).

At Rajaji NP, I found ruminant regurgitated cocci of *E. officinalis*, *T. belerica*, *Z. mauritiana* and *Z. xylopyra* and wild pig droppings with damaged *Z. mauritiana* and

Cassia fistula seeds (I did not find any *E. officinalis* in wild pig pellets) as evidences of frugivory by ungulates. However, it was not possible to determine the identity of the ruminant for the regurgitated boluses containing *E. officinalis* cocci. For *E. officinalis*, passage through rumen reduced germination rates. In the case of *Zizyphus mauritiana*, passage through rumens enhanced germination rates. In comparison, for Amazonian ungulates, Bodmer (1991) found that seeds passed undamaged through tapir stomachs, peccaries damaged seeds during mastication and brocket deer swallowed seeds whole and damaged them during reticulo-rumen fermentation.

Plants adopt a range of defense strategies to evade seed predation: by physical characters such as hardness or spines, chemical toxins and saturation strategies (Janzen 1971, Bodmer 1991). Species whose cocci I found in ruminant boluses at Rajaji had a common defense strategy – all had seeds enclosed in hard stony endocarps. In the case of *T. belerica*, *Z. mauritiana* and *Z. xylopyrus*, the cocci are indehiscent, while in *E. officinalis* the cocci dehisce to release the seeds. For *E. officinalis*, an average cocci enclosing six seeds (0.46 ± 0.122 g) weighed nearly four times the mass (0.017 ± 0.0071 g) of 6 *E. officinalis* seeds.

What happens when no animals eat *E. officinalis* fruits? As indicated by the results of the germination study when whole fruits (set up during the peak fruiting season) were left to dehisce naturally (control B), they dehisce after a period of three months to release seeds on to the forest floor. Though germination success of these seeds is greater than ruminant regurgitated seeds, ruminant regurgitated cocci dehisce within a day or two and release the seeds onto the forest-floor well before they would arrive there if nothing ate them. Temperature, moisture and soil conditions may then act in combination on the actual germination

success of seeds from these two sources. However, when no animals remove the fruit, seeds stay under parent trees or very close to it and none of the advantages of seed dispersal operate here (refer pg 8). Pacheco and Simonetti (2000) have demonstrated that gene flow is reduced within a population of a plant deprived of its seed disperser.

Most of the fruiting period was spent collecting data on fruit persistence and removal rates and a small fraction of it was spent collecting data on fruit handling. The list of *E. officinalis* fruit removers is far from complete. It is difficult to arrive at conclusions on the effectiveness of any of these dispersers of *E. officinalis* since I have very few observations of animals feeding on *E. officinalis*. While I have attempted to answer some of the questions related to the 'quality' aspect of disperser effectiveness for *Embllica officinalis*, the 'quantity' aspect has not been addressed. Do langurs ingest fruit? What happens to fruit that rodents scatter hoard? What are the seed-shadows generated by ruminants? These and many other questions are yet to be explored.

(c) Demography of E. officinalis and associated woody plant species at Rajaji NP.

On comparing human use indices and regeneration densities across treatments, human use indices increase from low to intermediate to high for the hill transects, and correspondingly regeneration (1) density falls from H1 to H2 to H3. While for the plain transects no such patterns emerge. It is not possible to conclude whether plain mixed forests are more used by people than hill mixed forests from my results (refer Table 4 and Fig. 15).

Regeneration is a good indicator of present day extractive pressures. Regeneration of species other than the stress-tolerant species (*Lantana camera*, *Adathoda vasica*, and

Vitex negundo) shows a weak negative relationship with human use indices (refer Table 7). Tree species regeneration at Rajaji NP is dominated by species that are not lopped for fodder (refer Table 10).

E. officinalis trees occur in higher densities in hill mixed forests than plain mixed forests at Rajaji NP. Due to small sample sizes it is not possible to compare the population structure between habitats (hill and plain) or between treatments (high, low and medium intensities of human use). However certain aspects emerge - *E. officinalis* trees with GBH less than 40cm form very small proportions (6%) of the population (considering only trees encountered within 20m from the line). More importantly, *E. officinalis* seedlings were encountered *only* in areas that were almost completely free from human use (lopping, grazing or extraction). The lack of trees in lower GBH classes indicates that the factors affecting *E. officinalis* regeneration might have been in operation for years.

Looking at these results in the context of other studies that have tried to work out the impact of NTFP extraction on plant demography, Koliyal (1997) and Umashankar (1998) have been able to establish that NTFP extraction affects regeneration of *E. officinalis* and sites in central and south India respectively. It is however not meaningful to compare *E. officinalis* regeneration densities between these sites and Rajaji NP since topography, climate and vegetation communities themselves are different from site to site.

A closer look at these two studies reveals: Koliyal (1997) found in her study at two central Indian sites, that species like *Emblica officinalis*, *Madhuca indica*, *Buchanania lanzan* which are harvested for NTFPs (fruit or flowers) had poor

recruitment at the extracted site compared to species like *Tectona grandis* and *Bauhinia racemosa*, which were not subject to NTFP extraction but were harvested for timber and fuel wood at the site. When compared with the unextracted site, again the extracted site showed lower recruitment for the NTFP species.

Umashankar *et al.* (1998) from their long term study on the impacts of NTFP extraction on population structure at Biligiri Ranagana Betta Temple (BRT) Sanctuary found that there was a lack of recruitment in the 1 –2 cm and 2 – 3cm dbh class, both in the less extracted and more extracted site for NTFP species (*E. officinalis*, *Strychnos potatorum*, *Anogeissus latifolia*, *Chloroxylon swietenia*, *Acacia sundra*, *Grewia oppositifolia*). Other species, lacked regeneration only in the 1-2cm dbh class, but not to the extent of NTFP species. Further, they found that the impact of extraction on individual NTFP species varied depending on plant part extracted and intensity of extraction.

Conclusions - resource use by wildlife in the context of use by humans:

In this study, I have followed resource use patterns of a single plant species. Fruits of *E. officinalis* disappeared from the system well ahead of the time due to man-mediated activities. A large proportion of plant resources found in our protected areas are used by people along with wild animals as documented by Umashankar *et al.* (1998) who found that over 70% of woody plant species in the scrub forests of BRT, south India, were used by the local tribes in one form or the other. This has lead to severe competition between humans and wildlife both in and outside protected areas. Edgaonkar (1995) has demonstrated that there is an overlap of 39% between elephant and buffalo food plant

species at Rajaji NP. *What is left for wild animals to eat at Rajaji NP?* The ever-increasing human-wildlife conflict in many parts of our country might not just be a reflection of habitat loss and fragmentation, but also habitat degradation due to factors like NTFP extraction.

What is apparent from the results of this study is that fruits of *E. officinalis* are removed from the vicinity of the parent plant and thus dispersed by two ungulates (chital and barking deer) at Rajaji NP. However, aspects of effectiveness of these ungulates as dispersers of *E. officinalis* is not known. Species with relatively large fruits (with diameters greater than 20mm) are known to depend upon on few large mammals, which are in turn highly vulnerable to hunting, for seed dispersal (Bodmer 1991, Corlett 1988). Hunting of large mammals has cascading effects in the ecosystem (Terborgh 1988) as demonstrated by Wright *et al.* (1999) who have shown that removal of mammalian frugivores due to poaching from tropical forests affects seed dispersal, seed predation and seedling recruitment.

Thus, both the links in this ecosystem process - *E.officinalis* and its disperser community and that of the frugivores and one of their food resources, are disrupted due to man-mediated activities.

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