CHAPTER III
STUDY AREA

This study was conducted in the Kalakad - Mundanthurai Tiger reserve lying between 8°16' and 8°50'N lat and 77°15' and 77°30'E long in the southern end of the Western Ghats of India (Fig 1). The Western Ghats is a continuous chain of mountains lying north-south along the west coast of India. These rise sharply from the west coast and taper more gently towards the east, while in the southern end of the Ghats, the terrain becomes steeper and inaccessible from both sides. The peaks in the Southern Western Ghats range above 1600 m and the highest among them is the Agasthiar peak at 1846 m. These hills are also the source of many perennial rivers like the Tambarabarni, Manimuthar and Pachayar. The rainfall pattern in the Western Ghats changes from a two wet two dry season in the southern end to one intense wet season for over 3 months in the northern part. On an average, the annual rainfall in most places along the Ghats is over 3000 mm and occurs during the South-West monsoon between May to September. In the southern Western Ghats the period from October to December, experiences the dry north easterly winds which are often accompanied by cyclonic storms bringing very heavy rainfall to these areas. Much of the rainfall in the study area occurs during these three months (Fig 2).

The vegetation in the Western Ghats are governed by topographic relief and monsoon (Meher-Homji 1979). These range from the scrub jungle along the foothills on the eastern side to high altitude montane evergreen forest. In the southern Western
Fig. 1: Map of the study area showing the distribution of fruit plots.
Fig 2. Mean monthly rainfall of 35 years recorded near Kakachi*, Southern Western Ghats.

Rainfall (mm)

* Data from BBTC estates Nalmukku.
Ghats, evergreen forests occur above 1000m elevation on the eastern side of the ghats but from a lower altitude on the western side. Some stretches of evergreen forest also occur at a much lower elevation along streams on the eastern side. The evergreen forests between 1000m to 1450m are termed as midelevation evergreen forest and occur throughout the southern Western Ghats and are technically classified as the *Cullenia-Palaquium-Mesua* series (Pascal 1988; see Plate 1). These are the primary habitat of the endemic lion tailed Macaque (*Macaca silenus*).

Of the available forests in the Western Ghats, the forests on the higher reaches of Kalakad-Mundanthurai tiger reserve are the least exploited, although substantial areas have been converted to tea and cardamom plantations in the early thirties. Much of the midelevation evergreen forest in the southern part of the reserve has never been disturbed (Anonymous 1980). The present study was conducted in one such part of the forest at Kakachi accessible through the BBTC tea estates. The site was located on a ridge facing north east with an area of approximately 100 ha, drained by the Kakachi stream. The elevation within the site ranged between 1200m to 1550m. This site supported a troop of 17 *Macaca silenus* and seed predators like *Ratufo indica* and *Semnopithecus johnii*. The avian frugivores included the Imperial pigeon (*Ducula badia*), Wood pigeon (*Columba elphinstorii*), Small Green Barbet (*Megalaima viridis*), and Bulbuls (*Hypsipetes spp*).
METHODS

Fruit characters

Fruits were collected over 3 years from 53 species of canopy and subcanopy trees between 1991 to 1993 from different trails totaling to about 2.5 km in the forest. This constituted nearly 69% of the tree species in Kakachi and 87% of the tree species that fruited during this period. The fruits were classified into 9 categories (Appendix 1), these are size, weight, type, seed number, protection, and colour. These classification follows Gautier-Hion et al. (1985). Details are given below.

1. Fruit size (mm) length and diameter which were measured with a vernier calipers.

2. Seed size (mm) Length and diameter, measured with a vernier calipers.

3. Fruit weight Freshly collected fruits were weighed to 0.01 gm using a digital electronic balance.

4. Seed weight Fresh weight measured up to 0.01 gm accuracy using the above electronic balance.

5. The number of seeds per fruit were counted.

6. Fruit type These were classified as a Fleshy, b Dry fruit(Hard) and c Arillate.
7 Fruit protection  a Presence of a thick husky or a spiny exocarp  
Unprotected, seeds which are either exposed as in dehiscent fruits or are easily accessible to predators through a fleshy mesocarp

8 Seed protection  a Protected, seeds with a lignified seed coat which is not easy to remove  
b Unprotected seeds with a thin coat which can be easily peeled off

9 Colour  Fruits were sorted into the following colours  a violet, b blue, c brown, d green, e orange, f yellow, and g red

These categories were further divided into 29 variables and arranged in a 29x29 correlation matrix and subjected to a Principal Component Analysis following Gautier-Hion et al. (1985)

Fruits were further categorised into bird, mammal and dehiscent fruits based on the size, type of fruits and on direct preliminary observations of fruit use by vertebrates. Bird fruits were usually small (<15mm) in diameter and were fleshy (Plate 3)  
Mammal fruits were large, usually had a husk or if fleshy were eaten by bats (Plate 4)  
Dehiscent fruits were hard often protected by a tough exocarp and generally dehise their seeds (Plate 5)
Fruit Production

Fruit fall was measured by laying 100m x 0.7m plots on the forest floor. Sixteen such plots with a total area of 1120 m² were laid over an area of 100 ha. This 100 ha forest comprised nearly 90% of tall evergreen forest with few Ochlandra facies. The plots were laid in proportion to the habitat available and 11 plots were laid in the tall evergreen forest. To check for fruits being removed from the ground by vertebrates, control plots were baited with known amount of fruits and censused periodically. Results of these indicated some fruit removal of larger species especially Myristica dactyloides however there were always husks, eaten seeds and other evidence left behind which helped to quantify removal. To arrive at a more species specific fruit removal estimate, few ground predators like Rattus sp were captured and fed with the fruits available at that time to see their fruit processing behaviour and identify dental marks left on fruit parts.

Sampling was done from March 1991 to March 1994. Number of plots initially were 11 which were subsequently increased to 16 in September 1992 as new areas were added along the ridge between 1250m to 1450m in elevation. Plots were marked permanently and sampled at 15 day intervals for the entire period of 3 years. Between November 1992 and December 1992 these could not be sampled since the area was made inaccessible due to a cyclonic storm. During each sampling period all fruits fallen within the plots were collected and later sorted to species and number per species. Fruits were later put back into the forest away from
the plots. Unidentified fruits were collected and preserved in 70% alcohol for later identification. Eaten fruits were also collected and wherever possible added to the fall data. Scats of civets were also collected from the fruit plots at the same time and the fruit species was identified and the number of seeds recorded.

Ripe fruits on trees or freshly fallen fruits, were collected and weighed to 0.01 gm. These were later multiplied by the total fruits for each species to arrive at the biomass (wet weight). Biomass was calculated separately for each plot and later the cumulative total was obtained. It was represented as kg/ha.

Plant species were identified based on flower/fruit characters using Gamble (1928) and were later referred with herbarium specimens at Botanical Survey of India, Coimbatore for confirmation.

Community level estimates of fruit biomass in tropical forests has been done by sampling fallen fruits at periodic intervals over a specific area (Smythe 1970, Foster 1982, Terborgh 1983, Schaik and Terborgh 1987, White 1994). This method gives an underestimate of fruit production as only the residual fruit fall is accounted for and not those fruits removed from the trees by frugivores (Terborgh 1983). An improvement on this estimate would be to measure the amount of fruits removed by the frugivores and add it to the fruit fall.

Fruit production in Kakachi incorporates this in two ways. Generally large number of (39 sp) fruits have many inedible parts which are left behind by the
frugivores below the tree. From this an estimate of number of fruits eaten and discarded can be obtained or by the direct observation of fruit removal by birds, bats and civets.

Species which suffered predation were either dispersed by birds or bats or these fruit were dehiscent. For bird dispersed species an approximate amount of fruit removed by birds was arrived at based on direct observations of fruits eaten by birds during the peak fruiting period similar to that described by Chapman et al (1992). Trees were observed between 7.00 to 14.00 hrs during which the tree was scanned at every 10 minute intervals for one minute and the number of birds at the tree, the species, and number of birds feeding on fruits was noted. Individual birds were followed for a maximum of 5 minutes to note number of fruits consumed and dropped during that period. Fruits eaten per minute was calculated and multiplied with number of birds on the tree at that time. This gives a rough estimate of number of fruits eaten from the tree per minute. This was extrapolated to an hour and then to 8 hr which is the approximate diurnal foraging period of these birds (personal observation). Crop size of the sampled trees was estimated by counting fruits on small branch and extrapolating to other branches. Three trees each of Elaeocarpus munronii and Tricalysia apiocarpa were observed. Visitation was done on species only during peak ripe fruit availability and proportion of crop removed based on rate of fruit removal was calculated. For some species very few fruits ripen at any time most of which are removed by birds (Personal observation). The number of ripe fruits was then used as an estimate of fruits removed by dispersers for that species as negligible amount of ripe fruit fall to the ground. Other methods to account for dispersed fruits were not
very reliable like fruit crop censuses, at periodic intervals. Due to foliage, height and poor light condition during a large part of the season, accurate census of even a small branch could not be done regularly for most species except for species with large and conspicuous fruits.

No direct estimate of fruit removal by bats or civets could be done but an index for seed dispersal based on seeds in civet scats in the fruit plots was arrived at.

# of scats X seeds per scat was calculated for each species and converted to density per m². This was done in all plots over the regular schedule of fruit sampling and was considered as an estimate of seeds that have been dispersed (Appendix 2). The proportion of seeds dispersed was calculated by dividing this by the total seed density (including dispersed and undispersed seeds) in the plots for a particular species at that time. For bat dispersed species collection of 'bat hoarded' seeds were counted when encountered along fruit plots which were then considered dispersed similar to civet dispersed species.

Length of fruiting: Data on the length of fruiting period of individual trees were obtained from marked trees followed for phenology at the same site.

Vegetation density

All trees >10 cm DBH were enumerated in a 100 x 10 m² belt along the fruit plots. There were thus 16 plots. Density of individual tree species was calculated from these 1.6 ha sample.
Seed Predation

Seed predation by vertebrates can be estimated directly and indirectly. Direct means included focal observations on vertebrates handling fruits. Indirect means include counting fallen fruits discarded by vertebrates and estimating the number of fruits handled over a specified area or over a time period. At the community level the former method is not feasible or economical, hence the latter method was adopted. Indirect methods of sampling seed predation could be done for species whose seeds are never completely eaten or the husk surrounding the seed is discarded. Indirect methods also suffer from the effect of vertebrate removal of seeds away from the tree, this is not a serious problem in Kakachi except for a few species like Artocarpus heterophyllus and less frequently Cullenia exarillata. Five trees per species were sampled and for common species upto ten trees were included.

For each individual species predation levels was estimated by laying nylon nets of 1 m² under the canopy. Roughly 10% of the canopy area for each tree was sampled by the nets (Plate 2). Number of nets ranged from 1 to 10 with a median of 3. Nets were sampled once a week or once in 2 weeks depending on the phenology of the species. Species with extended phenology were sampled once in two weeks. Fruits fallen in the nets were collected, sorted according to the damage to the seeds and animal species involved in the damage. Proportion of seeds damaged was calculated at the end of the fruiting period this was corrected for proportion of seeds dispersed as:
Proportion of seeds eaten = total number of seeds eaten / (Total number of seeds sampled - No. aborted)x(1 - proportion of seeds dispersed).

For species with large fruits (>10 cm) like *Artocarpus heterophyllus* and *Cullenia exarillata*, direct crop census once a week or once in 2 weeks were done. During each census number of whole fruits, eaten fruits and number of aborted (dried) fruits were recorded.

**Foraging behaviour of seed predators**

It was not always possible to closely observe fruit handling by the seed predators as these animals were shy, especially the Nilgiri langur (*Semnopithecus johnii*) and also difficult to see because of the dense foliage and tall canopy. Fruit handling behaviour of the seed predators was therefore observed on all possible and accidental encounters and also along the regular census routes. Fruits falling after being eaten by seed predators were immediately collected and observed for dental marks which subsequently helped in identifying the predator.

**Relative abundance of frugivores/seed predators**

A transect of 2.5 km was marked through the primary forest. These were walked at fortnightly intervals in the morning between 7.30am and 11.00am preferably under sunny weather conditions.

*Mammals*: Each transect was walked at a slow pace of 1 km per hour noting the mammals heard or seen in the vicinity of the path. On sighting animals the
perpendicular distance of the animal to the path and the citing angle between the path, observer and the animal was recorded. These were later used to calculate the species density. For monkey troops, number of troops encountered in the transect was recorded however it was not possible to estimate the exact number of animals in a troop every time.

**Birds:** For avian frugivores number of birds seen or heard during the first 1.5 km length of transect was recorded.

**Climatic variables**

Data on rainfall, maximum and minimum temperature, and the number of rainy, cloudy and sunny days were obtained from the BBTC weather station located 3 km from the study site at the same altitude on an adjacent hill. Daily readings were taken and total rainfall and mean temperatures were calculated for the 15 day sampling interval. A day was treated cloudy or sunny if 50% or more of it was as such.

**Analysis**

Comparison of fruit characters and Spatial fruit abundance were done by using the Principal Component Analysis. Fruit biomass and Fruit abundances were standardised and expressed in Kg/ha and abundance /ha respectively. The effect of increase in fruit plots from September 1992 onwards on fruiting patterns was checked by treating the 10 plots and 16 plots separately. As these were strongly correlated \( r=0.91 \ n=16 \ p<0.001 \) the plots were pooled for all analysis. Comparison of fruiting patterns between years was done by Friedman Two Way Anova corrected for tied
data sets. Between year differences in predation levels was analysed using Tukey's test for multiple comparison of proportions with necessary correction for high and low proportion values. Kruskal Wallis multiple comparison test was used to determine differences in abundance patterns between years. As parametric test was not possible due to non-normal distribution of data, Mann Whitney test was used for differences between groups. Spearman rank correlations were used unless otherwise stated. Principal Component Analysis was done using the factor module in Systat package (Wilkinson 1989). Density was calculated using Transect II program (Laake 1979). All statistics followed Zar (1984).
Plate 1. View of the wet evergreen forests of the southern Western Ghats.
Plate 2. Nylon nets (lmxim) used for sampling seed predation levels of individual trees.

Plate 3. Bird fruit - Antidesma menasu
Plate 4. Mammal fruit - Artocarpus heterophyllus

Plate 5. Dehiscent fruit - Cullenia exarillata