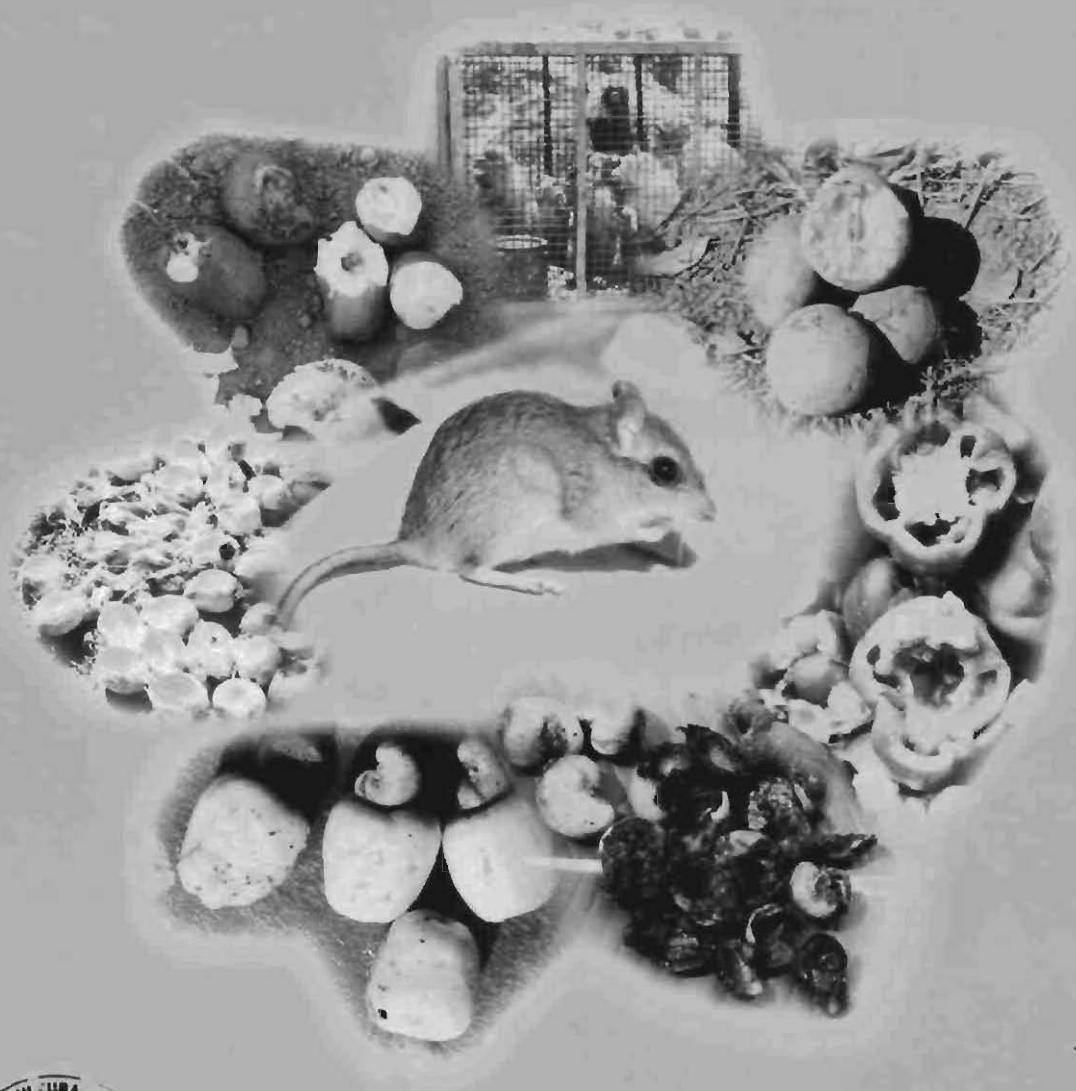


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Integrated Vertebrate Pest Management in Hilly and Coastal Zones of Karnataka

(ICAR Sponsored Ad-hoc Research Project)



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FINAL PROJECT REPORT

(01.04.1996 - 31.03.2001)



DR. K. SRIHARI,
Principal Investigator

**DEPARTMENT OF ZOOLOGY, B. S & H. COLLEGE
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK CAMPUS, BANGALORE - 560 065**

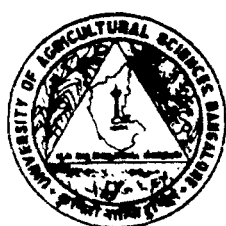
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Principal Investigator : Dr. K. SRIHARI

Co-Investigators : 1. Dr. A.K.CHAKRAVARTHY,
2. N.E. THAYAGARAJ.

DEPARTMENT OF ZOOLOGY, B.S & H. COLLEGE
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GENERAL INFORMATION

1. Project title : ICAR Ad-hoc project entitled Integrated Vertebrate Pest Management in hilly and coastal zones of Karnataka”.
2. Sanction number : ICAR-F.No.1-28 / 95 / pp dated 12-1-96
DR No / Adhoc / 121 / 96-97.
3. Report : Final Project Report
(1-4-1996 to 31-3-2001).
4. Date of Start : April, 1996.
5. Duration of the Project : Initially for three years (1996-99) (vide order ICAR-F.No.1-25 / 95 - pp dated 12 -01-1996) and extended for two years (1999-2001) (vide order No.1-28 / 95 - pp dated 23-02-1999).
6. Date of termination : 31st March 2001.
7. a) Name of the Institution / Station : University of Agricultural Sciences,
GKVK, Bangalore - 65.
b) Division / Department : Department of Zoology,
University of Agricultural Sciences,
GKVK Campus, Bangalore - 65.
c) Location of work : Hilly and Coastal Zones of Karnataka.
8. Name of the Principal Investigator : Dr. K. Srihari,
Professor and Head,
Department of Zoology,
University of Agricultural Sciences,
GKVK, Bangalore - 65.
9. Name of the Co - Investigators : 1. Dr. A.K.Chakravarthy,
Chief Scientific Officer (Entomology),
V.C Farm, RRS, Mandya - 571405,
Karnataka.
2. Mr. N.E. Thyagaraj,
Assoc. Professor,
Dept. of Entomology,
UAS, RRS,
Mudigere - 577132, Karnataka.

Approved Technical Programme (Objectives) :

1. A number of crop-protection methods will be compared. The indigenous, traditional practices will be scientifically validated in replicated plots with the help of villagers. Traps, repellents, plants and animal extracts, byproducts, mechanical, cultural and biological methods will be evaluated and their efficacy and efficiency in protecting crops from vertebrate pests will be worked out.
2. After comparison and evaluation, selected methods will be chosen for evaluation. This package of practices will be field tested in multiple locations.
3. The qualified benefits of the target vertebrate species will be identified and sustained as far as possible, while devising the management practices.
4. Effective transfer of technology that was developed by ICAR Adhoc Project and the technology developed now will be carried out through extension education unit, GKVK, concerned Horticulture, Forest Departments, Central Government Institutes and Farmers agencies, etc.
5. There is an urgent need to develop holistic approach for managing vertebrate pests on several crops such as Oil palm, Plantation crops, Rubber, Forest tree species, Sugarcane and other Fruit crops. In view of the occurrence of a vertebrate pest in several cropping situations, their role and status as a pest needs to be evaluated. The information so gathered may be useful not only for vertebrate pest management but overall management and conservation of bio-diversity in the agro-ecosystems of hilly and coastal regions.

Technical Persons employed :

Sl No.	Name with Designation	Date of joining	Date of leaving	Remarks
1	N. Prasanna (Research Associate)	25-07-1996	31-03-2001	One Field Investigator post was vacant
2	J. Brahmananda Murthy (Research Associate)	01-08-1996	31-03-2001	
3	U.R. Rudraiah (Senior Research Fellow)	25-07-1996	31-03-2001	
4	H.R. Harini (Field Investigator)	30-08-1996	01-02-1997 - left	
5	N. Mahesh Chandra (Field Investigator)	25-07-1996	14-02-1997 - left	
6	P.M. Satish (Field Investigator)	17-10-1996	28-02-1997 - left	
7	C. Sommanna (Field Investigator)	01-04-1997	28-09-1997 - left	
8	S.Pushpa (Field Investigator)	03-04-1997	31-03-2001	

- N B : 1. The sanctioned three posts of Field Investigators in the scale of Rs 1,550 (consolidated) is converted into two posts with the emoluments of Rs 2,250 (consolidated) (ICAR Letter No 1-28 / 95 pp).
2. Initially the project has been sanctioned from 1st April 1996 to 31st March 1999 with total outlay of Rs 14,18,800 lakhs (ICAR. F. No. 1-25 / 95 pp dated 12-01-96).
3. The project has been extended from 1st April 1999 to 31 st March 2001 with total out lay of Rs 14,04,040 lakhs (vide order No. 1-28 \ 95 \ pp dated 23-02-1999).

INTRODUCTION

Karnataka with a geographical area around 1.91 lakh Sq Km has a variety of topographical situations ranging from the coastal plains to gentle slopes and cultivated lands spectacular heights of the Western Ghats. Elevations in various parts do not vary greatly though the abruptness with which they change is marked in some parts, as between the narrow coastal strip, that rarely exceeds a width of 30 Km and the equally narrow Western Ghats immediately adjoining the coastal plains.

As the world population is increasing, the natural elements supporting human existence are diminishing. The social and economic pressures for development especially in the tropics are on the rise. The development schemes are often incompatible with the environmental and conservation concerns. It is in these situations that studies on ecology and management of natural resources come to play an important role. From this standpoint, management studies on vertebrates are increasingly becoming relevant. There is an urgent need to evolve research based management practices that will protect crops yet conserve the target vertebrate species and their ecological functions.

The practicable management practices compatible with environment and socio-economic conditions of people were evolved for problems posed by vertebrates in Western Ghats of Karnataka. The Western Ghats mountain range with evergreen tropical forests spread over 1,75, 000 Km² are one of the 18 biodiversity centres (hots spots) of the world, is threatened now. This region, on various accounts is rapidly undergoing extensive changes. Fragmentation of habitats and isolation of animal populations because of human activities are posing problems to Coconut, Arecanut, Cocoa, Cardamom, Coffee, fruit orchards, Rice, Vegetable and several other crops. Results of locality and species specific research applicable to Western Ghats of Karnataka are presented and discussed in the light of earlier published

works. But the results with no or some modifications could also be applicable to other tropical and subtropical parts of the world where similar such problems occur.

Vertebrate Pest Management today requires a multidisciplinary approach with as diversified fields as Biometrics, Economics, Sociology, Ethology and Environmental Engineering. Certainly the techniques / practices evolved are not wholly refined and ultimate. Attempts have been made to bring as many fields closer as possible and integrate them in as compatible manner as possible. Statistical and economic analyses, damage and yield-loss assessments and evaluation of vertebrate pests suppression methods have been made. But much more relevant and focused research is needed. This is only a beginning. Most of the studies reported here have been undertaken in Chikmagalur District in Western Ghats region of Karnataka.

Western Ghats:

Forests cover considerable area (upto 30% in some areas) in Malnad (hill region). Among the species limited to Western Ghats are Nilgiri langur, *Presbytis johni*; Liontailed macaque, *Macaca silenus*; Nilgiri brown mongoose *Herpestes vitticollis*; Malabar Giant Squirrel, *Ratufa macroura*; Civet, *Moschothera civettina*; Flying Squirrel, *Petinomys fuscocapillus*; Spiny mouse, *Mus platythrix* and The Great Indian Hornbill, *Buceros bicornis* etc., Wild animals abode forests and frequent cultivated areas in search of food and shelter. In the process, animals cause enormous losses to crops. So there is an urgent need to device protection measures that are practicable, economically feasible and ecologically and environmentally sound. The crop protection measures should also help simultaneously in conserving the beneficial activities of the concerned animals.

In hill regions of Karnataka, coffee, cardamom, tea, cocoa, arecanut, etc., need specialized agro-climatic conditions and such cultivable tracts are not extensive and met

frequently in India. So, crop protection measures should be innovative and novel. Chikmagalur phytogeographically is an inseparable part of the hill region of Karnataka and the Western Ghats. The Western Ghats range from Dangs District in Gujarat to Kanya Kumari in Tamil Nadu. In its expanse of rolling mountains and deep valleys, it supports an ever rich diversity of biotic features, whose combinations present a wide range of habitats for wildlife. It is only second to Himalayas in the biological wealth and diversity of species and communities. It contributes 12.5 % to the State Agricultural productivity (Status Report, 1989). Therefore, the productivity of the land and life of the people of Chikmagalur depend much on the way the natural resources are utilised and managed. The sustenance and perpetuation of wildlife, therefore, is of pivotal importance.

Although legislation provides for protection to wildlife, there is little protection actually provided. Several man-influenced impacts are affecting the wildlife. Of these, encroachment into the habitats of wild animals by man, conversion of forests to agricultural lands, erosion, siltation, monoculture tree plantations and pollution are some worth mentioning.

The District is located between latitudes $13^{\circ} 7' 29''$ North and longitudes $75^{\circ} 37' 35''$ East. The terrain has an elevation of 800 to 900 m in major areas. The altitudes of hill ranges vary from 667 to 2103 m.

The climate of the District is hot and humid. Rainfall varies from 15" in Kadur to 250" in Mudigere. The average annual precipitation varies from 52" to 152". South West monsoon is active during June to September. Heavy rains (70 to 75%) are received during July-August. The North-East monsoon is received in spells from October to December as a result of depression in the Bay of Bengal.

The year can be indistinctly classified into Summer (February to May), Monsoon (June to September) and Winter (October to January) seasons. Summer shower received during March-April are important for coffee for blossoming. The minimum temperature is in January (14.5 °C) and the hottest in March with mean maximum temperature of (29.9° C). At this time, a few species of trees blossom. Maximum temperature does not exceed 33° C in March. Soils in hill zone are neutral to weakly acidic. Principal soil type is red clay loam. Soil erosion in hill region (Malnad) has been mainly due to high intensity of rainfall, improper water management, overgrazing of pastures, deforestation and non-scientific methods of cultivation.

Since the Western Ghats bear Bauxite, Iron and Manganese in substantial quantities, there has been a great deal of open cast mining for these ores in the area. Each mining centre like Kudremukh is responsible for the loss of natural regeneration extending a distance of 8 to 10 km. Vegetation in mining areas is represented by broken grass and scrub patches. Such habitats hold depauperated faunas. Kemmugundi and Kudremukh are good examples for such sites. There is considerable scope for biologists to restore vegetation and animal life in these areas, so that the vertebrates are confined to area under vegetative cover.

Most rivers rise in the elevated areas of Western Ghats and flow west to east. River waters have not been appropriately tapped for sustaining clean waters for drinking and domestic purposes, irrigation, fisheries, crops and stored for times of water deficit. Krishna, Bhima, Cauvery, Hemavathi, Bhadra, Tunga, Veda and Yagachi rivers originate in and around Chikmagalur.

Coastal line:

Karnataka has a coastline running a length of about 300 Km with port facilities at Mangalore and Karwar. The broad divisions that naturally unfold themselves are the coastal region which is normally sub-divided into the Coastal plains and the Western Ghats. The

coastline has a length of about 300 km and there is gradual transition, between the Konkan coast in the North and the Kerala coast in the South. The coastal region comprises of two parts, the plains and the Western Ghats. The plain is a narrow stretch bordering the Arabian sea, rarely exceeding 30 km in width. The Western Ghats, raise in a series of terraces, but the general elevation is lower as compared to the stretch in the north or in the south. The Western Ghats run from north, north-west to south, and south-east for about 230 km.

The malnad merges into the ghats reaching a height of 1,500 to 1,800 metres. The general elevation of malnad is slightly more than that of the plateau with hills that receive larger amount of rain fall and are forested, and support one of the largest plantation economics in the country.

The coastal zone of Karnataka has a geographical area of 11.67 lakh ha, which accounts for 6.09 percent of the area of the State. The zone lies between $74^{\circ} 45''$ to $74^{\circ} 46''$ E longitude and $13^{\circ} 24' 45''$ to $13^{\circ} 25'$ N latitude. In the backyards of houses of the villages people grow, cucurbits, banana and other fruit and vegetables. So they attract rodents and small animals, which depredated on crops.

In coastal alluvium, soils are found in a narrow strip along the Western coast in the Districts of Dakshina Kannada and Uttara Kannada. The soil consists of materials washed down from the Western Ghats as well as the action of the sea and deposited in the coastal region.

The coastal zone is characterized by hot humid climate with heavy rains during kharif (June to September) and dry spell from November to May. The average annual rainfall of the zone is around 3,900 mm. The south-west monsoon normally commences from the first week of June and extends to September.

Paddy, pulses, oilseeds and vegetables are grown in these two situations, during rabi and summer seasons, taking advantage of the north-east monsoon. The temperature variations are generally narrow in the zone. The maximum temperature (32.4°) is recorded in May, while the minimum temperature (20.9°) in January.

The eastern elevated mountainous parts of the zone are cooler, than the western plain parts throughout the year. The zone is characterised by the prevalence of high humidity all round the year with maximum and minimum values of 96.5 and 84.5 and 84.5 percent, noticed during August and December, respectively. The corresponding values for open pan evaporation (5.3 mm and 1.6 mm) are observed in April and June.

The pulses and other crops normally grown after kharif paddy, include horsegram in uplands, blackgram, greengram, cowpea and sesamum in midlands and low-lands during rabi or summer after one or two crops of paddy. Vegetables are also grown after kharif paddy. In homestead gardens, they are grown throughout the year. These include coccinia, bhendi, brinjal, gourds, watermelon, chillies, cowpea, amaranthus, radish, etc. The choice of the crop depends upon water availability, duration and availability of family labour.

In coastal zone, horticultural crops have a significant role as the economy of the farmers mainly depend on these crops. This is evident from the fact that although these crops occupy only slightly more than one-third of the gross cropped area, their contribution to the economy of the region is much more than that of agricultural crops.

The plantation and fruit crops have good yielding potentialities under varied situations even under marginal and barren lands and also as rainfed crops revealing their wide adaptability among them, arecanut, coconut, cashew, cocoa, etc have received some attention in terms of research findings evolved by the central institutes / stations in the zone or the adjoining zone (Kasargod of Kerala). Jack and banana, the other common fruit crops, have

rich varietal diversity in the zone and occupy substantial area. Among the vegetables crops, sweet potato, chillies, tapioca, brinjal, bhendi, radish, etc., occupy substantial areas and are dominant here.

Vertebrate Pests:

The vegetation in Chikmagalur is diverse and its complexities vary with topography. Forests cover 350 square miles (16%). Owing to variations in rainfall, altitude and topography, mainly three types of forests are met within Chikmagalur. They are, evergreen or moist and dry deciduous forests and scrub jungle (Status Report, 1989).

Evergreen forests form a part of the Western Ghats in Mudigere (13° 17' 29" N long 75° 37' 35" E, 982 m AMSL). The canopy of the forest is formed of tall, hard and soft-wood trees. Canopy is a closed type that provides a secured niche for a variety of species of rodents (rat, squirrel, shrew), monkey and cat. Due to tree felling for plywood and timber, the canopy is now becoming open. This is imposing changes in the composition of vegetation and in turn, vertebrates. For instance, in areas of open canopy-species of *Bandicota* and *Mus* are becoming more common and abundant.

The evergreen forests envelope some of the most interesting valleys, streams and extensive rocky beds and ledges. Soil appear black due to accumulation of humus. These forests form part of the Bhadra Wildlife sanctuary and harbours bison, elephant, sambar, barking deer, porcupine, malabar squirrel and langur. Rarely panther and tiger can also be spotted for instance in Muthodi and Hebbe forests area.

Evergreen forests form good sources of matchwood and plywood in species of *Bombax*, *Evodia*, *Machilus*, *Alstonia* and *Dicopsis*. People are debarking the *Machilus* trees entirely in the area, killing all of them. This is a pernicious menace going on in the area unchecked. Much prized sandalwood trees are also present here. This is facing extinction in

the hands of the ever increasing smugglers. Evergreen forests patches consist of species of *Acrocarpus*, *Artocarpus*, *Calaophyllum*, *Dalbergia*, *Dipterocarpus*, *Diospyros*, *ipterocarpus*, *Cleodendron*, *Lophopetalum*, *Lagerstroemia*, *Mesua poecilomuron*, *Palaquium* and *Knema* are common in Gangamoola, Kudremukh, Kalasa and Agumbe but not so in Sakleshpur and adjoining areas.

One of the widely distributed tree is *Mimusops elengi* L which attracts rodents and birds by their fruits, is commonly found in Sringeri, Agumbe and Kalasa areas. *Myristica dactylodes gertu* is encountered at higher altitudes of Agumbe, Gangamoola, Kudremukh, Kalasa, Magundi and South Kodagu areas and is well known for attracting birds, bats, wildboars and rodents.

The trees in evergreen patches are traversed by woody lianas like *Bauhinia phoenicea* wt. & *arn* common in Agumbe, Gangamoola, Sakleshpur and Coorg and *Chonemorpha fragrans* Alston along the ghat roads in mid and upper ghats. Lianas, lichens and moss are a principal nesting material source for squirrels which nest in tree holes or earth cutting covered by vegetation. *Thunbergia mysorensis* (wt) Anderson a striking, showy, flowering plant and *Geetum ula* Brogn is common in semi evergreen to evergreen forests. The tree trunks are covered by *Pothas scandens* L, *Rapiclophora pertusa* (Roxb) Schoot and species of *Peperomea* and *Piper*.

The evergreen forest undergrowth in plains like Belur, Sakleshpur in Hassan mainly comprises seedlings of plants like *Alpinia melaccensis* (N.Burman), *Roscae*, *Amomum canicarpum* (Wt.) and several species of *Psychotria*. These plants do not support much arthropods as well as birds and other vertebrates. In South Coorg, *Schemannianthus virgatus* (Roxb) Rolfe forms prominent undergrowth.

Moist and Dry deciduous forests :

In these type of forests, the tree vegetation gets mixed. For instance, teak (*Tectona* sp.) forms major portions in Magundi, Koppa, Jaipura, Sangameshwarpet and Gulanpet forests area. Bamboo forms major portions in Muthodi and Hebbe forests. It is observed that in Malnad, the bamboo mixed forests hold more number of small animals than teak-mixed forests. These forests have suffered much owing to over-grazing, annual fires and over-exploitation by man. These forests cater to the needs of public for forest-based industries, timber, firewood and charcoal. *Acacias*, *Albizias* and *Cassias* are first to appear. Further improved conditions pave way for species like *Bachunania lanzan sprengal*; *Butea monosperma* (Lam) Tanb, *Cassia fistula* L; *C. siamea* Lami and *Diospyros montana* Roxb are seen. Around Arasikere, Channagiri, Kadur and Kushalnagar, *Santalum album* L is frequently seen.

Scrub jungle :

In the drier tracts of Arasikere, Belur, Kadur and Chikmagalur *Phoenix sylvestris* Roxb, forms the dominant community of scrub jungle. These forests are found in mounds, hillocks / uplands or elevated plainland where soil is poor, stony without much cover of top-soil and humus. Species of bamboo, *Albizzia*, *Acacia*, *Sapindus*, *Pongaemia*, *Odoratissima*, *Tamarindus* etc., are important.

Cultivated areas :

Coffee occupies more than 55% of the cultivated area in Chikmagalur, *Arabica* and *Robusta* are two commercially cultivated species. Agribusiness is centered round coffee in the District. *Erythrinas* occupy major portion of coffee estates as shade trees. It is attractive to birds of atleast 15 families. Coffee estates with elements of original vegetation hold atleast hare, squirrel, rat, mongoose, wildboar and monkey.

Paddy, *O. sativa* L is the most important cereal. Rainfed paddy is found in valleys and lower reaches of the slopes. Native forest and wetlands are being destroyed to accommodate expanded agricultural production. Changes in land use of the magnitude attributed to crop lands are having a serious impact on vertebrates. In plains, sorghum, pulses, oilseeds, sugarcane, *Saccharum officinarum* L and vegetables are grown.

Apart from forests and agricultural fields, the terrain throughout malnad provide a diversity of habitats for vertebrates. The higher altitude vegetation consists of particular species of plants and in many places the hill tops are devoid of tree vegetation due to heavy winds and are clothed by grasses and few herbaceous ephemerals. There is a need to manage hill tops. They should conserve water, locally recharge ground water, serve as a depot of humus and organic matter and attract higher altitude Wildlife.

The sholas near hill top mainly have species of *Elaeocarpus*, *Cinnamomum* and *Gordonia*. Often *Symplocos cochinchinensis* (Lour) Moore and *Embllica officinalis* Geartner stand as stray, stunted trees along small crevices of hill-tops. Sholas are shrinking. Because of the uniqueness, sholas are of high conservation value and hold both small animals like deer, hare etc., and large animals like elephant, tiger and bison. Shankar Shola near Kemmangundi is being threatened as large areas are being converted to coffee plantations. One of the most striking aspects of the landscape in malnad is the presence of streams. Vertebrates extensively use streams through out the year.

In the drier parts of Arasikere, Kadur and Belur there are stretches of area covered by *Phoenix sylvestris* Roxb community. The commonly encountered climbers and herbs are species of *Argyrea*, *Cadaba*, *Gymenma*, *Ionnocarpus* and *Jasminum*. After the showers, species of *Crinum* and *Scilla* appear amidst boulders and *Urginea* appear amidst grasses. In the transition areas, a richer flora is seen with representatives of *Jerminalia*, *Tectona*,

Santalum, *Pterocarpus* and *Shorea*. The roadside vegetation also supplements food and shelter requirements of vertebrates, especially goat, deer and hare. The vegetation include *Ficus bengalensis* L; *F. racemosa* L; *Mangifera indica* L; *Tamarindus indica* L; *Madhuca indica* Gmel and *Syzigium cumini* Skeels.

Role of Vertebrates :

To develop vertebrate pest management practices, it is essential that an understanding of the role of vertebrates in ecosystems is known. Understanding the relationship between vertebrates and nature conservation is the key to the ecology of Western Ghats.

The decline of a carnivore generally alters the ecological balance of its biological community. Cats are linked through predation to herbivores which are, in turn linked to each other through competition and to plant communities by their foraging pattern. Reduction in tiger population in hill region of Karnataka has led to increase in wildboar population and in turn, consumption of plant biomass. Wildboar, incurs, on an average, ten per cent yield losses in paddy, cent percent loss has been observed in paddy fields adjacent to forests without any carnivores. Forests with carnivores have generally climax vegetation type with overlapping and closed canopy trees.

Succession :

Spatial and temporal variations in the density of herbivores result from grazing / browsing in different regions. Bonnet monkey, *Macaca radiata* L feeds on new flush of leaves, buds and fruits of *Terminalia*, *Cedrela*, *Albizia*, *Ficus*, *Salmalia* and *Bombax* during post monsoon (October-February). On Oranges, *Artocarpus*, *Dipterocarpus* etc., during pre-monsoon (March-June) and on Paddy, Banana etc., during monsoon (July-September) period in coffee plantations in Chikmagalur. But animals are major regulators of their habitats in their own way. Individual vertebrate species consistently consume a characteristic proportion of

grass or browse in the diet, (b) eat only a subset of the plant species available, (c) occupy only a subset of the habitat types available at any given time and (d) partition renewable resources temporarily by using the same habitat at different times. Wildboar in Mudigere subsists on *Dioscorea alata*, *Cyperus rotundus*, paddy, potato, sweet potato, *Colocasia*, *Allocaasia* and tubers during monsoon (July-September) and post-monsoon (October-February) and on refuse heaps, ragi, rootgrubs, etc. during pre-monsoon (March-June) period. Being a highly sensitive animal, it locates food by the odorants emanating from the plants.

Seed Dispersers :

Studies in tropical forests have now shown that the highest chances of survival are possessed by seeds that have been dispersed away from the parent tree. Seedlings of cardamom, a plant of high economic value growing on tree holes, tree surfaces, amidst stones and boulders, stream edges, forest floors is a common sight in Mudigere.

This is because squirrels, rats, spurfowl a ground bird and shrew split cardamom, *Elettaria cardamomum* capsules to feed on the mucilage and defecate seeds away from the feeding site. Similarly seeds of *Ficus*, *Syzygium*, *Artocarpus*, *Michaelia* are dispersed as wildboar, monkey, large birds like hornbills feed on their fruits. In Western Ghats, large vertebrate/birds are more effective in dispersing seeds because

- (a) they tend to be more selective of large, hardwood species (=mature phase species)
- (b) they consume more fruits / feeding bout and
- (c) they tend to carry the seeds farther before regurgitating or defaecating them. More information on these aspects is available in Bawa and Hadley (1990).

Of more than 314 species (Chakravathy, 1998) of mammals and birds recorded in Muthodi, Magundi, Someshwara and Hebbe forests area, 50% are fruit and seed eaters,

exerting profound influence on vegetation. Future management plans for tropical forest should include two components:

- (a) Strategies for sustaining large vertebrate dispersers in the ecosystem and
- (b) Strategies for increasing the representation of tree species of particular economic and ecological significance. Management and conservation policies should be based on many species so that animals depending on them can survive.

These observations firmly establish the indispensable role of vertebrates in forest stands and the relationships between seed dispersal and seedling demography have profound implications for vertebrate pest management.

Energy flow and Nutrient cycling :

The high levels of herbivory in forest ecosystems have major implications for both energy and nutrient budgets. Mixed feeders (grazers, browsers, burrowing animals, etc.,) consume varying proportions of grass, green flush, seeds and fruits in different seasons. For instance, squirrels of *Funambulus* species in Mudigere feed on cardamom capsules, ants, termites, seeds of *Solanum*, ground beetles and coreid bugs during fruiting period of cardamom (August to February) and on *Salmaalina*, *Bombax*, *Carya*, *Melia*, *Syzigium*, etc., buds and flowers during non-fruiting period of cardamom in Mudigere.

Herbivore body size not only determines energy demands, it also governs the rate and the extent of energy extraction from the diet. Small herbivores (monkey, logomorphs, sheep, goat) are forced to satisfy relatively higher energetic demands by selecting high quality items such as new shoots, fresh green grass, fruits and flowers. Large herbivores (elephant, wildboar, bison) are forced to expand their diets by incorporating lower quality, more abundant and easily available plant material. So energy flow may depend on body size,

distribution within the animal community. Body size also influences the biomass consumption in agro-ecosystems.

Animals have another mechanism of plant resource partitioning. Niche differentiation allow co-occurrence of animals to reduce the impact of competition. For example, feeding at different heights from the ground contributed to resource partitioning among species as did the use of different habitats in dry and wet seasons.

Cocoa, *Theobroma cacao* S fruits in natural patches are fed upon by jackal, jungle cat, squirrel, rats and monkey. Jackals selectively harvest fruits upto 1 m height; rats and squirrels from any portion of the canopy and monkeys, from the top canopy. Of rodents, squirrels injure only fresh pods during night. Understanding niche of vertebrate pests is essential for finding the target site for placing the bait.

These observations indicate that the structure and state of natural ecosystems in Western Ghats are influenced by animal density and community species composition. Since vertebrates strongly influence species composition and structure of vegetation and also its productivity. It seems unwise to ascribe a passive role to them as recipients in a donor-controlled rainfall-determined ecosystem.

Natural ecosystems are mostly in the form of tropical forests in Western Ghats consisting of teak, *Tectona grandis*; Beete, *Dalbergia latifolia*; Mathi, *Terminalia sp.*, Nandi, *Lagerstroemia lanceolata*; Gandhagarigae, *Cadrella toona*; Bombax species, Dipterocarpus species, *Elaeocarpus*, *Evodia* species, *Machilus* species, *Santalum album*, *Sapindus*, Rosewood, etc. which are put to manifold uses. Tropical forests also have tourist, recreation and scientific value. So these forests continue to be rapidly denuded and disturbed and so are vertebrates. As a result, the productivity of the remaining forests in Western Ghats is extremely low and the quality, still lower. Therefore, an integrated approach is urgently

required for conservation of forests and vertebrates as also for their management. This will also help to reduce vertebrate depredations on crops in the region.

Under certain conditions, vertebrates can partly replace the pressure of grazing by domestic stock, of occasional selective cutting, of prescribed burning of forests and of other means often suggested now for preserving some vegetational types. The difficulty is that the precise influence of free-living vertebrates on a limited area is not predictable. The size of a conservation area for simultaneous protection of vertebrates and rare or desirable plant communities must, therefore, be rather large. The influence of vertebrates is very much variable and occasionally can even be deleterious in small protection areas. So the influence of vertebrates on vegetation can be positive, neutral or negative in terms of regeneration / succession and the possibility for occurrence of these shifts be recognized and considered by the protection specialists.

Statistics :

Use of statistical methods in vertebrate pest management studies will help researchers to make appropriate interpretations of the data. Collecting data on vertebrate pests, their numbers and damage to crops are often difficult in the forested and cultivated tracts. We need to spend more time in collecting relevant and precise data. Samples of data on vertebrate pests are often small and variable. Researchers involved on vertebrate pests need statistical techniques / methods so that data can be analysed without information on the distribution of the vertebrate population, scores which are not exact in numerical sense and computation is simple and not time-consuming. In view of these conditions, the choice of suitable statistical methods become important.

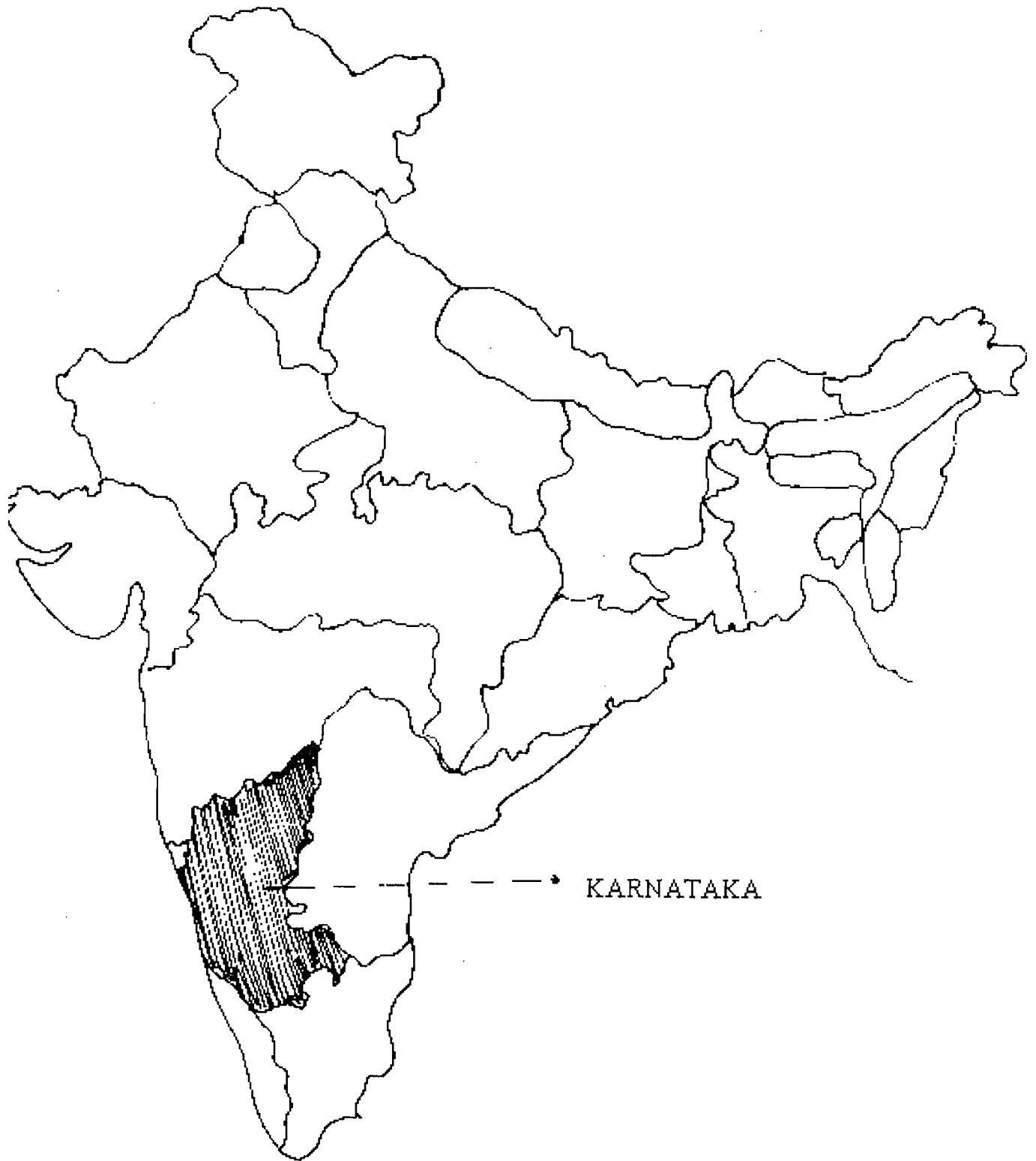
In certain situations of vertebrate pest problems, estimation of populations, crop damage and in others, tests of hypotheses become the primary concern. Both the parametric and non-parametric tests need to be deployed.

The basic conditions which must be satisfied for conducting parametric tests are that the observations must be independently drawn from normally distributed populations. In analyses concerning two groups, the populations must have the same variance and the variables are measured in atleast an interval scale. These conditions are ordinarily not tested in the course of the performance of a statistical analysis. Rather, they are presumptions which are accepted. Non-parametric tests make fewer assumptions which are suitable when samples are made up of observations from different populations and are easier to learn and apply. “Non-parametric statistics for the behavioral sciences”, (II edition) by Sidney Siegel and N.J. Castellan and “Statistical methods” by Snedecor G.W and Cochran, W.G. may be consulted for more details.

The hilly and coastal regions of Karnataka (Maps 1 to 3) thus represents specialized agro-climatic conditions where plantations, spice, fruit, vegetable and tuber crops are cultivated. In hilly region, 30% of area is covered by tropical forests which holds some of the endangered flora and fauna. This poses a great challenge to the pest manager who has to protect crops without causing harm to the endangered flora and fauna. The Indian Council of Agricultural Research (ICAR), New Delhi sanctioned a project in 1996 to generate data on “Integrated Vertebrate Pest Management in hilly and coastal regions of Karnataka”. The studies conducted from 1996-2001 have been supplemented with results obtained under the earlier ICAR Adhoc project on vertebrate pests. Therefore old data appearing in certain sections, may not be treated as outdated as most of these data are basic, important and will hold good for a number of situations. This is the final Report of the project.

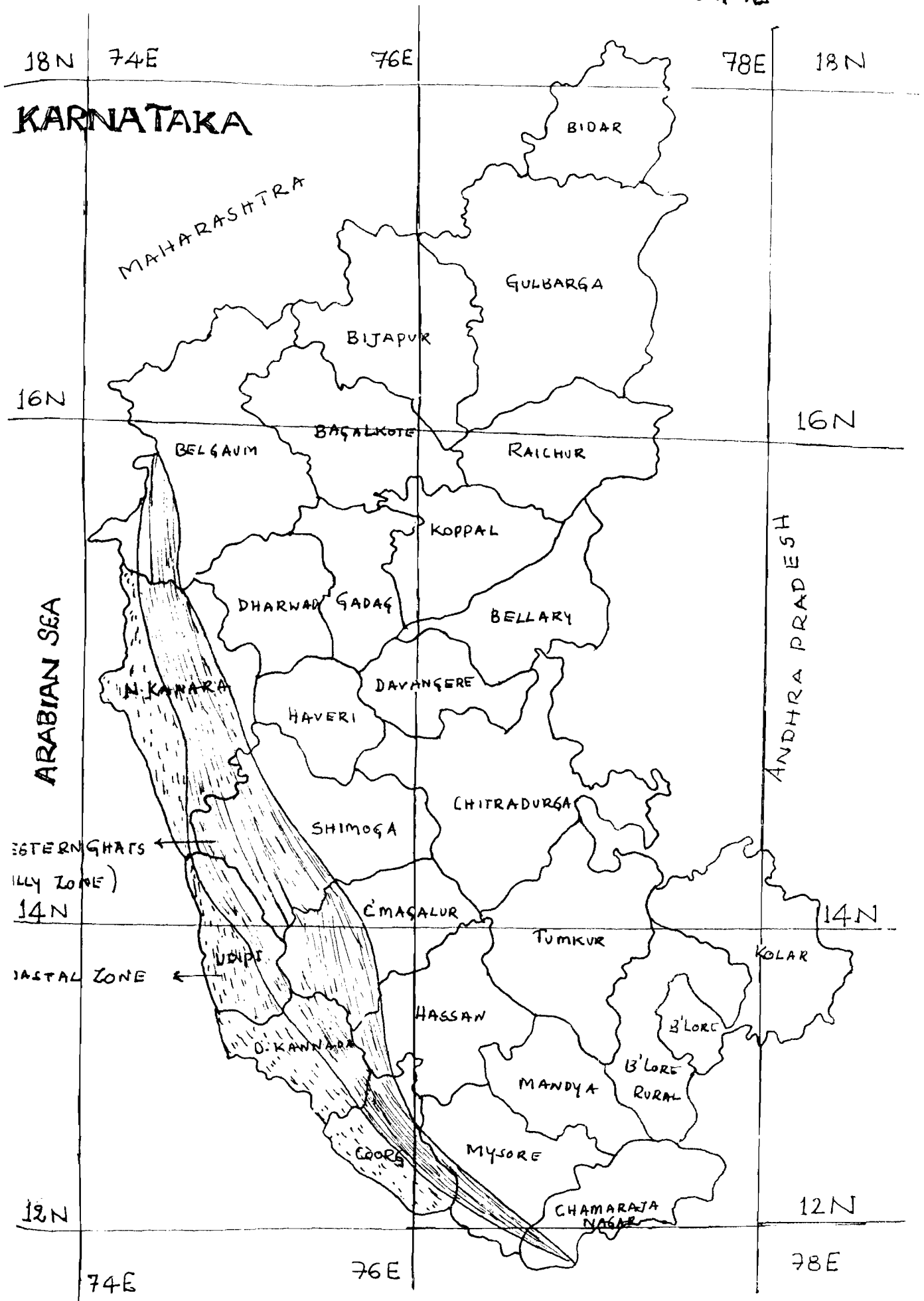
MAP : 1

INDIA

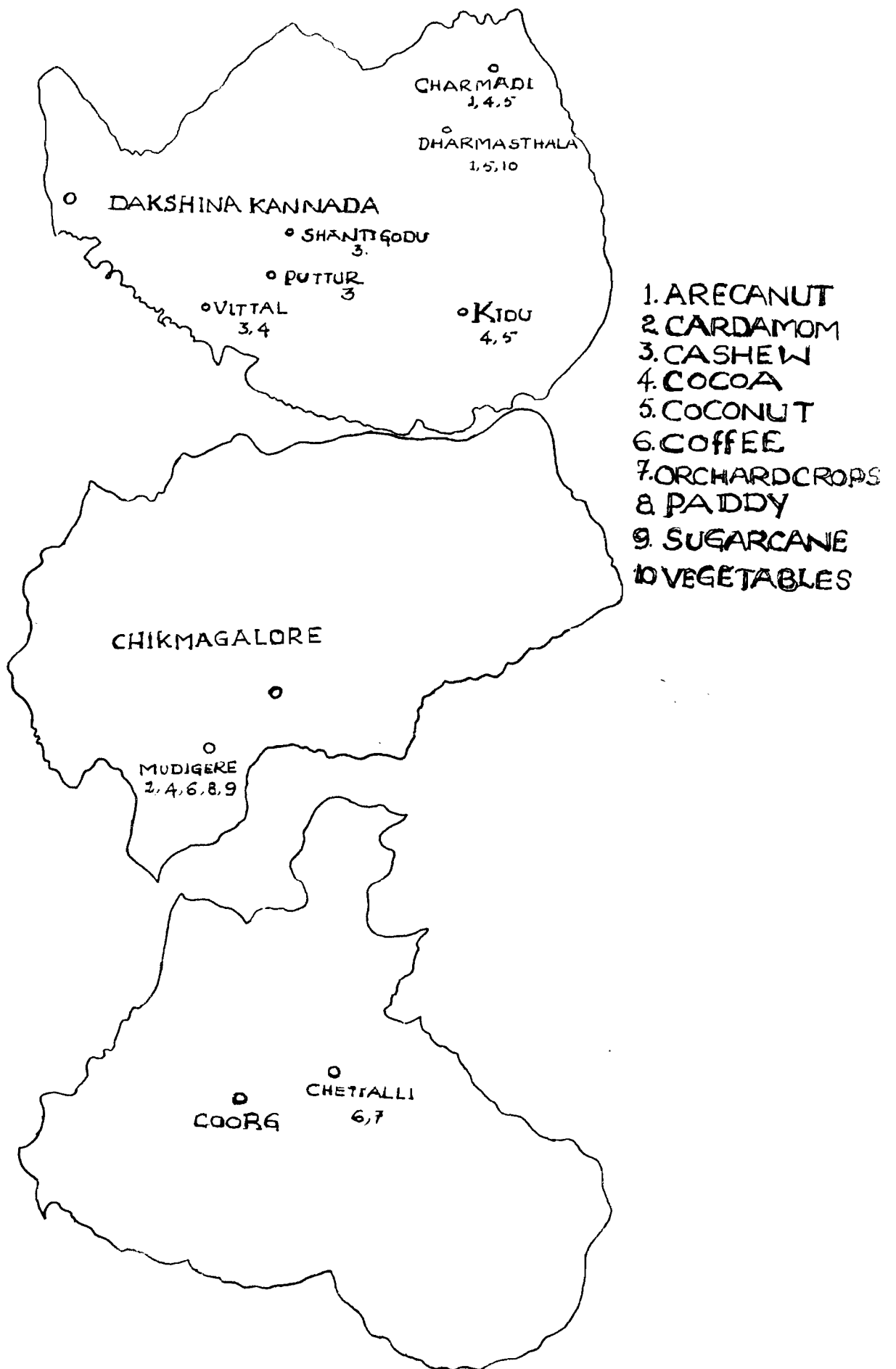


KARNATAKA

MAP:2



MAP:3



CARDAMOM

INTRODUCTION

Cardamom, *Elettaria cardamomum* Maton a principal spice crop of the hill region of Karnataka is grown in 29,000 ha with an annual production of 455 tonnes (Department of Horticulture, 1995). A number of insects and vertebrates damage the crop (Chakravathy and Khan, 1987). While crop protection methods against insect pests are available, against vertebrate pests are wanting though crop loss by vertebrates is economically important (Krishna Murthy et al., 1989).

Siddappaji and Reddy (1973) reported 10 to 12% yield loss in cardamom due to rodents. Wroughton (1915) recorded taxonomic observations on squirrels of the Western Ghats, that included species damaging cardamom. Bhat and Sujatha (1990) studied bio-ecology, damage and yield losses of the cardamom squirrel, *Funambulus tristriatus* W in coconut and cocoa ecosystems in Kerala. Rajan et al., (1987) recorded nesting of *F. palmarum* on the leaf fold of the palmyra tree. Damage by rodents and monkeys have resulted in crop failure (Chakravathy, 1993) in parts of hill region. Hence, studies on assessment of crop losses, habitat preference, species composition and response to baits by vertebrates depredating cardamom were initiated. In this report selected data of previous adhoc project on vertebrate pests from 1985 to 1992 have been included to render results comprehensive and to assist in drawing logical conclusions.

Survey :

Monthly surveys were conducted from 1991 to 1993 through out the year in four hill districts of Karnataka namely Hassan (13° N 76° E 100 m AMSL), Chikmagalur (13° 7'29" N long 75° 37'35" E 982 m AMSL), Coorg (11° 56' N 75° 22' E 3100 m AMSL) and Shimoga (13° 56' N 75° 31' E) to identify the vertebrates damaging cardamom crop.

Identification of Vertebrate Pests :

Metallic snap traps (20 x 10 cm) and locally made wooden snap traps (75 x 35 cm) were stationed @ 4 – 6 / acre through out the year. The traps were stationed at the preferred niches of rodents like along stream waters in valleys and at the base of tall trees with buttress, e.g. species of *Elaeocarpus* and *Dipterocarpus*, these spots with three dimensional niche where suitable for rodents shelter and feeding. Traps were observed at 24 hr intervals. Both diurnal and nocturnal animals were trapped. The trapped species were collected and identified in the laboratory.

Paddy grains, *Oryza sativa* L; wheat, *Triticum vulgare* L; groundnut, *Arachis hypogaea* L; corn, *Zea mays* L; flour pellets, the fish, *Gambusia* spp., jackfruit, *Artocarpus indica* L, and water extract of jackfruit, vada, a local preparations of *Cicer arietinum* L were used as baits at Regional Research Station (RRS), Mudigere.

Monkeys, *Macaca radiata* L; wildboars, *Sus scrofa* L; elephants, *Elephas maximus* L and birds were identified by visually by using a pair of 8 x 30 binoculars. The foraging activities of wildboars and elephants were identified by fresh dung pads.

Birds were identified from a hide of green foliage and thatch, about fifteen meters from birds' foraging sites. The birds' morphological features, plumage colours, feeding behaviour and calls, if any, were recorded for identification, following Salim Ali and Ripley (1980). Presence of faeces, plumule feathers and marks of legs provided additional clues for identification.

The identity of animals sighted and those trapped under field conditions is given in Table 1. Of the 12 vertebrate species, *B. bengalensis*, *F. palmarum*, and *M. radiata* caused economic losses and these animals are widely distributed and well adapted to feeding on the cardamom crop. The species composition of vertebrate pests did not vary considerably

from one location to another but their relative abundance did. Several other rodent species were recorded in cardamom plantations but were not found feeding on cardamom capsules. In the field, damage of capsules by rats was observed and identified by irregular holes on pericarp and lumps of seeds littered at base of the clump. This field observation was confirmed under laboratory conditions (photo 1).

Observations with 8 x 30 binoculars revealed, squirrels plucking the matured capsules by teeth, holding them with fore-limbs, shelling the capsules with their teeth by perching on the ground or on the trees and devouring the seeds with the mucilage (photo 2). This observation was confirmed under laboratory conditions. Gut content analysis revealed that a large number of cardamom seeds with chewed mucilaginous bits were found in the stomach of squirrels and the crushed bits of black seeds and mucilage were found in rats. The detailed data is available in Krishnamurthy et al., (1989).

The monkey held the base of the pseudostems with one hand and with teeth peeled out the outer sheaths, cut open the yellow- white pith and fed on it. The animals usually fed on 10% of the shoot biomass they destroyed (photo 3). Wildboars foraged gregariously during late evening after 8 p.m. to early in the morning upto 6 a.m. Any patch of green cover in damp soil was found to be damaged. Cardamom shoots are trampled upon by wildboars. Elephants incidentally trampled up on cardamom clumps while foraging. However, no feeding activity was observed. The trampled clump, depending upon the damage, either rejuvenate or the entire clump may be lost. The shrew damaged capsules almost resembled the damage caused by rats. The holes bit on the pericarp were smaller and more irregular.

Birds viz., red spurfowl, *Galloperdix spadicea* G; red jungle fowl, *Gallus spp.* and grey junglefowl, *Gallus sonneratii* T were observed feeding on cardamom capsules. The

birds with the help of beaks squeezed out the internal contents and siphoned in the mucilaginous matter leaving the lump of seeds on the ground.

Nature of damage :

Animals depredating cardamom were observed using a pair of binoculars from 8 to 10 m of foraging site. Malabar type cardamom grown in valley under the multi layered canopies of forest trees at Mudigere was used to record observations on the feeding activities of the animals between 17.00 to 18.30 hr, during 1994-95. Observations were recorded from an elevated spot. The damage symptoms were recorded from sites, where fresh attack occurred. The rodent damage symptoms were confirmed under laboratory conditions using *B. bengalensis* and *F. palmarum* in metallic cages (1.5 x 1.2 x 1.3 m lbh). There were 4 replications for each species. During 1994-95, wild *B.bengalensis* and squirrels were caught and dissected in the laboratory to find the composition of food.

Feeding behaviour :

Rodents :

Field activities of the squirrel were recorded in 20 acres on Malabar type cardamom plantation at Mudigere and adjacent 30 acres coffee, *Coffea arabica* L. Visual observations and observations through binoculars on nesting, wild foods, and habitat preferences throughout the day under natural conditions were recorded. To determine capsule age most vulnerable for rodent damage and for timing the protection measures., ten clumps / site were randomly selected. Each flower bud was labelled and capsules were categorised into three groups based on the colour development, as follows.

a. Green (70 days old) **b.** Greenish yellow (90 days old) and **c.** Yellow (110days old).

Date records were maintained (on labelled flower buds) with respect to the colour development and the damage by squirrels and rats. The proportion of capsules damaged under

each category was found on percentage basis and the data were subjected to ANOVA after angular transformation.

Field Behaviour :

Results of field studies conducted on selected vertebrate species damaging cardamom clumps are presented below. Rodents, both rat and squirrel preferred valley than slope and plain habitats as reflected by the capsule damage (Table 2). Because of the dense vegetation, less human disturbance and various combinations of niches for hiding, feeding, nesting, drinking water and breeding, the rodents preferred the valley region.

Rodents preferred 110 days old capsules compared to 70 and 90 days old (Table 3) and (fig 1). Statistical analysis showed significant differences in the preference for matured capsules. However, rodents damaged to an extent of 20% greenish yellow capsules (90 days old). The damage is economically important, so this is the stage at which protection measures are needed. Both squirrel and rat responded to the paddy grains, banana and vada when offered as bait in the wooden snap traps.

Data presented in Table 4 indicated that Malabar cardamom is preferred by rodents for feeding. This preference for feeding may be related to several factors. But in the study area, Malabar cardamom covered 99% of the area. The panicles laden with capsules run on ground in Malabar type. In Vazhukka and Mysore types, the panicles are erect and semi-erect, respectively. These differences might have influenced the rodents to prefer Malabar type cardamom.

The number of rodents with different baits in wooden and metallic traps is shown in Table 5. Paddy grains and banana, *Musa spp.* fruits attracted rodents maximally. *Mus booduga* L (photo 7) accounted 60% of the total trapped animals in cardamom plantation.

The vertebrates trapped in wooden snap traps between March -May 1990 at weekly intervals is given in Table 6.

Frequency of different activities of squirrels in cardamom plantations has been recorded (Chakravarthy, 1996). Squirrels actively searched for suitable plant surfaces to perform their activities. During January-February, the animals depended much on sprouts / flowering buds. The squirrels also actively foraged on ground especially for termites and ants as also evidenced from the gut content analyses. Squirrels restricted all activities including nesting within cardamom plantation. The field activities excepting foraging of squirrels did not differ significantly from one habitat to another. As the different habitats differed in their relative amount of food sources, the length of foraging bout also differed significantly. The squirrels spent maximum time (> 50%) for foraging. These animals with small home ranges may have to depend on few key food sources. A detailed study on activities of squirrel is warranted for exploitation of the same in the rodent pest management.

Monkey and Wildboar :

A population count on monkey was made at Mudigere during July and August, 1991. The counts were made in three habitats, viz., Valley, Plain and Slope.

Field activities of monkey troupes and wildboars were observed using binoculars and observations on troupe size, movements throughout the day each month in cardamom and coffee plantations at Mudigere and adjacent plantations from 1991 to 1994. The response of squirrel, rat, monkey, and wildboar, to natural and artificial baits were also recorded from 1993 to 1995 in field trials with 12 treatments and 10 replications following RCBD. In case of rodents, each trap and in case of monkey and wildboar each bait -station formed a replicate. The branches of shade trees in 0.5 acre cardamom plantation at Mudigere were pruned to about 20% to test if shade regulation deterred monkeys.



The bonnet monkey is distributed through out the Malnad and pose pestilence problem in cardamom plantations. Distributions of monkey locally, was influenced by the presence of trees. Monkey was so destructive at some places that cardamom cultivation is abandoned in parts of Sringeri, Agumbe, Thirthahalli, Koppa and NR Pura taluks in hill region of Karnataka .

Monkeys had no natural enemies at the study site except man. Birds-of-prey and snakes predated on rodents and tigers predated on wildboars besides man. It was also observed that a troupe or part of the troupe foraged outside the accustomed range to fetch food. During November-December, 2 or 3 troupes were found sharing a common feeding ground. Most of the mating and infant rearing were carried out in the foraging zone of the troupe. Mating and breeding activities were observed throughout the year, but peak was observed during March-April. These preliminary observations showed that the number of monkeys in a troupe fluctuated widely as also the size of their foraging and feeding zones. When food became scarce, monkeys descend down to feed on food available on ground.

The count on monkeys revealed that on an average, 27 - 40 animals in 105 acres were present. All the animals were found in one troupe. It was observed that when the food is abundant at RRS, another troupe of 25 to 30 monkeys foraged. Therefore, the population splits or coalesce depended on the availability of food. In hill region of Karnataka breeding in monkeys occurred throughout the year. However, peak occurred during April -May.

Observations throughout the year revealed that numbers increased during April-May and December- January. Monkeys could be conveniently trapped during summer (March-May) when the variety of food resources shrink or it gets limited to few patches only.

Monkey damage to cardamom in different habitats and at different age groups :

Monkey damage did not differ significantly from one habitat to another based on per cent cardamom shoots damaged, year wise. Field observations revealed that monkey preferred to feed on tender pseudostems of cardamom in the absence of wild fruits like guava, *Psidium guajava* L; jackfruit, *Artocarpus heterophyllus* L; chakota, *Citrus grandis* O; oranges, *Citrus aurantium* L; banana, *Musa pasadisiaca* L; and paddy, *Oryza sativa* L. At times of no or negligible human activity, monkeys were found entering the cropped area one by one. Monkey was the only pest feeding on cardamom shoot.

There were non-significant differences in the percent clumps loss in three habitats, viz, plains, slopes and valleys. When the loss in clumps was compared during 1990 and 1991, the loss was higher in 1990. The possible reasons are : (a) During 1991, area under cardamom increased by 6 ha (b) there was reduction in monkey population due to trapping and watch and ward was intensified and was even extended from 6.00 a.m. to 6.30 p.m. In 1992, the damage by monkeys again increased at Mudigere. Observations on monkeys damage to cardamom clumps at two different age-groups viz., below and above 3 years revealed significant differences. 'T' test showed significant differences in the per cent clumps damaged. Clumps of less than three years were preferred over those over 3 years old. Concurrent results to this effect were obtained even during 1990. Of clumps less than 3 years old, one year old clumps were the most preferred with 53.38 % damage. Less than one year old clumps are tender and so are more palatable. This experiment showed that young plantations are prone to heavy monkey depredations and need protection.

To study the seasonal movements of monkeys in cardamom plantations at Mudigere, in pre-monsoon (January to April), monsoon (May-August) and post-monsoon (September-

December) periods. During pre-monsoon period, monkeys fed on cardamom, sapota, *Achras zapota* L; guava, orange and paddy. For feeding, the troupe had to cover considerable distance in different habitats. During monsoon, the animals fed on cardamom, jackfruit, ficus, *Ficus bengalensis* L; Jambolona, *Syzigium cumini* L and lantana, *Lantana camera* L, all found in and around the same habitat. So, foraging and time distance would be less. During post-monsoon also the monkeys were found mostly in and around the cardamom plantations. The normal movements of the troupe was altered by the watch and ward, the availability of foods and social rivalry. The troupe size reduced due to emigration. The animals had to expend considerable time and energy for movements from one habitat to another, in search of food due to intra and inter troupe aggression, screams were heard frequently during this period. The average per cent loss of cardamom clumps in 9 blocks from 1989 to 1992 was 31.81 per cent. This level of loss is economically important.

Monkey damage to cardamom clumps of two distinct age groups is given in Table 7. The Binomial 'Z' test revealed significant differences between the two age groups.

Shade regulation by about 20% deterred monkeys. Monkey damage in shade regulated and unregulated sites was recorded (Table 8). The shade regulated site recorded significantly less damage than the normal site. In shade regulated plots the branches were cut and the habitat becomes open, making movement and feeding difficult. This information on the animal behaviour would be useful in the management of monkey menace in cardamom plantations.

Observations on wildboars and birds damage to cardamom are meagre. Damage to cardamom by trampling or pith feeding was observed maximally during pre-monsoon period (Jan-April) specially, in nurserie. Observations showed that wildboars subsisted on wild tubers e.g., species of *Alocasia*, *Colacasia*, *Dioscorea*, soil arthropods like rootgrubs, termites,

during lean periods (February to April) of food availability. The animal preferred wetlands with good vegetation cover to meet daily requirements of food, shelter and to avoid predators.

Birds caused negligible (< 1%) loss to cardamom capsules. In the absence of rodent damage to capsules the birds extensively fed on ripened capsules and ground foraging birds supplemented their food with cardamom capsules \ seeds. Succession in the feeding community occurred.

Yield loss assessment :

Capsule feeders :

Capsules damaged by squirrels, rats and birds were identified and separated based on damage symptoms. Damage was based on the number of split / bored capsule coat at the base of cardamom clumps. Two and half acres of cardamom crop was divided into three replicates and the damage was assessed at weekly intervals at Mudigere from 1993 to 1996, from July to January. The damaged capsule coats or pericarps were removed after each observation. The damage assessment was made on the clumps of Malabar cardamom (5 yrs old) at different localities in different habitats i.e., plain, slopes and valleys. Crop loss caused by individual vertebrate species was expressed on a cardamom clump basis, by counting proportion of damaged capsules to total capsules/ clump.

Shoot feeders :

The damage of suckers by monkeys, wildboars and elephants was assessed by the proportion of affected suckers to the total number of suckers/clump and expressing it in percentage. To express the crop loss in terms of capsules (gm) when suckers are affected the average number of suckers per clump, the average capsule (in grams) yield per sucker was worked out for 100 clumps. It was calculated (n=100 clumps) that a sucker lost was equivalent to the capsule yield loss of 27 g (dry weight).

Yield loss :

The crop loss varied from 4.3% in 1996 to 12.60% in 1997 (Table 9). In 1996, the crop yield was very low due to natural adverse factors such as long dry spells. So the loss due to rodents feeding was also less. In general, the loss caused by rodents was found to be economically important at Mudigere, Squirrel was the dominant rodent species incurring losses. But in different parts of hill region either squirrel or rat dominated in incurring crop losses.

Of the twelve vertebrates feeding on different parts of the cardamom plant, squirrel, monkey and rat caused economic losses (> 50%) (Tables 7 & 9). Siddappaji and Reddy (1973) reported ten per cent losses in capsule yields. Chakravarthy and Khan (1987), Chakravarthy (1993), Krishna Murthy et al., (1993) and Srihari and Chakravarthy (1992) also inferred that squirrel, rat and monkey damage resulted in economic losses in cardamom yield. Rodents were attracted to feed on cardamom capsules by the odour, 1, 8-Cineole, (20-60%) and Alphaterpine acetate together with smaller amounts of other oxygenated Monoterpenes, Hydrocarbons and Sesquiterpenes, Purseglove et al., (1988) emanating from matured capsules (Chakravarthy 1996). Rodents were considered as the most widespread and important vertebrate pests of cardamom (Chakravarthy, 1993). One hundred and ten days old cardamom capsules were the most preferred for feeding by the rodents (Table 3 & fig 1), Chakravarthy (1993) also inferred from studies that when capsules are 90 to 100 days old, it is the stage when crop protection measures are desired. It was observed that whenever squirrels were not dominant in causing capsule damage, rats occupied the pest status of squirrels.

Monkey, *M. radiata* caused heavy damage (20 to 30 %) to cardamom suckers (Tables 7 & 8). Cardamom clumps less than three years were preferred for damage. Evidence to this

effect is also provided by Chandrappa et. al., (1993). Young cardamom plantations are proven to heavy monkey depredations.

VERTEBRATE PEST MANAGEMENT

(a) Rodents and Birds : Three cultural practices, viz., dispersion of panicles in an overlapped fashion (photo 4), clean cultivation (without weeds) and timely harvests were evaluated at Mudigere in eight acres plantation. Soon after picking capsules panicles were placed one above the other. Timely harvest included harvesting capsules at definite intervals, as soon as capsules matured, i.e., before turning yellow. Clean cultivation included removal of weeds and unwanted materials. A parallel control plot was run, at least 0.5 km from the treated plot for three treatments. These cultural practices were evaluated during 1991-92 and 1992-93 in three replications with 50 clumps / treatment / replicate. The same experiment was repeated during 1996 to 1998 in different plots at Mudigere.

(b) Mulching : In another experiment, 0.5 ha cardamom plantation, panicles of a hundred clumps were covered by leaf mulch so that capsules were invisible to rats, squirrels and birds. Panicles of cardamom at neighbouring plot (0.5ha) were left uncovered to serve as control. Weekly observations were recorded and average per cent capsule loss was recorded. Mulching operation was evaluated as above in 1 ha cardamom plantation during 1997-98 at Mudigere with a parallel control of 1ha.

(c) Trapping : Efforts were made to trap rodents. Before setting out traps, a number of natural and prepared baits were evaluated in replicated trials (Table 15). Locally prepared wooden snap traps were used to determine trapping capability and its impact on rodent pest populations. In wooden snap traps, only paddy grains served as 'bait'. Vada (local preparation of gram, *Cicer arietinum* L) and paddy grains, *Oryza sativa* L, were used as bait in metallic and wooden snap traps, respectively to attract rodents. Two hundred metallic traps

were stationed during June-July and September-October, 1986-87 and 1987-88 and 96-97 in eight acres, at Mudigere.

Ten wooden snap traps were placed during March to December 1985 to 1987. The snap traps were stationed at a place for one month and subsequently shifted to another place. Trap design, grid and effectiveness for different lengths of time were evaluated. Observations were recorded daily and the trapped animals were dissected. During 1988 to 1990, capsule damage was compared in sites where traps were placed to sites where no traps were stationed. This was to know the extent to which traps could offer protection to the crop from rodents.

Bingo, a non-poisonous sticky substance manufactured by Rambo Chemical Industries Pvt. Ltd., Bombay was applied on to a cardboard (12" x 12"). The Bingo paste was smeared all over the board, leaving 3" space at centre to place the baiting materials (paddy grains) at the centre. The Bingo pasted cardboards were placed at 10 m distance @ 10 traps / acre. The number of rodents trapped were recorded daily and capsule loss was recorded from ten, randomly selected cardamom clumps.

(d) Fish oil and Neem oil : One to four per cent water solutions of Fish and Neem oils were prepared and sprayed on cardamom capsules on rainless days. Each concentration of each oil was replicated thrice with ten clumps/treatment. A parallel 'control' was run for each oil, since oil and water are immiscible, 4.5 ml of Vettoplant (@ 1ml / litre) was mixed with the solution. The impact of four cultural practices, viz., clean cultivation, timely harvesting, mulching and dispersion of panicles in an overlapped fashion on squirrel, rat, and the bird, damage to cardamom capsules is given in tables 10 to 13. It was found that by weeding i.e., clean cultivation 3.57 % and 2.56 % capsule loss could be avoided during 1991-92 and 1992-93, respectively. By overlapping panicles, nearly 4% and 1.2% capsule loss could be

avoided during 1991-92 and 1992-93, respectively. By timely harvesting capsules, 6.63% and 5.54% capsule damage could be saved during 1991-92 and 1992-93, respectively. By mulching 42% capsules could be saved compared to control during 1991-92.

In terms of numbers of capsules, 580 capsules per ten cardamom clumps could be saved by mulching. Statistical analyses of data revealed significant differences in damage to cardamom capsules by squirrels, rats and birds following adoption of the cultural practices. By adopting all the four cultural practices, on an average, 27% capsules could be saved. The percentage capsules being saved varied from 37.11 to 87.23. These practices proved practicable, cheap and caused no adverse effects (Table 13).

(a) Rodents : Trapping was one of the methods evaluated for reducing the rodent population and this may result in reducing the capsule damage. In ten months, 40 rodents were trapped in ten wooden snap traps (Table 14). Of these, 13 were squirrels, one shrew and the rest were rats. Of the rats, *Mus booduga* S was the most abundant accounting for 60% of the total trapped animals. A number of baits for trapping were evaluated in wooden snap traps and 'vada' a local preparation of *C. arietinum*, in metallic traps (Table 15). Germinating paddy grains in wooden and 'vada' in metallic traps proved attractive to rodents. After a series of field trials, it was found that 5 to 7 traps / acre, 10 to 15 m away from each other could be stationed continuously for a month at a spot with germinating paddy grains replenished once a week. Wooden traps could be placed preferably in valley near streams at the base of indigenous trees having buttress such as species of *Elaeocarpus*, *Dipterocarpus*, etc. Metallic traps were not popular with growers and growers preferred wooden traps.

From 1988 to 1989 capsule damage was compared in sites where traps were placed to sites where no traps were placed. The trap-operated plot recorded 8.17 % clump damage compared to 4.97 % clump damage in non-trap operated area and there were no significant

differences between the two sites (Table 16). The experiment was repeated during 1996-97. This revealed that in trap operated area immigration of rodents occurred. This was found particularly in cardamom plantations adjoining vacant sites, scrub or woodland. Further, if rodent damage was lessened, the ground birds population or feeding on cardamom capsules almost proportionately increased.

Following problems were encountered in the trapping operation :

1. Due to rains, the soil spills and settles below the trap, thereby reducing the gap meant for the entry of the animals.
2. Jute threads absorb water and cuts easily with a little weight.
3. In wooden snap traps, the wood easily gets damaged by termites and in metallic traps, the metal gets easily rusted.
4. The trapping operation is interfered by different animals. Observations revealed that while the rodent fed on the paddy grains in Bingo pasty cards, the sticky traps were unable to hold the animals and thus were ineffective.

The response of rodents in terms of capsule damage to fish and neem oils is given in Table 17. Neem and fish oils significantly reduced number of capsule damage by rodents. Yet the above two oils cannot be used for affording reasonable protection to the crop from rodents. Further odour laden fruits may even interfere with the normal flavour of capsules. It is for the flavour that cardamom capsules are valued. So use of such oils for crop protection against vertebrate pests damage cannot be suggested. Seven per cent of cardamom capsules were saved due to the combined effect of the crop protection practices against rodents and birds.

(b) Monkey : Observations on monkeys damage to Malabar cardamom clumps at four different age groups (1, 1-2, 2-3 and 3-5 years) were recorded in five acres at Mudigere.

Damage assessment was conducted in three habitats, viz., plains, slopes and valleys. Total number of suckers damaged was recorded at 15 days intervals. The damage was quantified on per cent basis. Six observations were recorded during 1986. The population of monkeys in 200 acres of the plantation was estimated.

Selective de-branching of shade trees in 2 ha Malabar cardamom plantation was affected to compare monkeys damage to clumps in shade regulated and unregulated plantation. Shade was regulated in 1986 and 1987 and observations till June 1990 on cardamom suckers damage by monkeys was recorded. During 1986 shade regulation was done so that plant growth is not affected. At the same time, interconnections among trees in the air - space was disconnected. Monkeys were thus forced to land on ground to move from one portion of plantation to another. During 1987, 'topping and lopping' was done for few trees only. Monkeys, preferred less than three years old cardamom suckers for feeding. Among the less than three years old, the animals preferred less than one and one year old with 53.58% damage, one to two years old with 48.42% suckers damage and two to three years old with 48.50% suckers damage. The least damage was recorded in suckers between three to five years old (2.90%). Thus one to three years old cardamom suckers were preferred for feeding. Surveys in different parts of Chikmagalur during 1990-92 indicated that young cardamom plantations (less than two years old) were heavily depredated by monkeys.

Shade regulated cardamom plantations in Mudigere recorded 28% and 37% lesser capsule damage on sucker basis compared to plots of same age where shade was not regulated in the cardamom plantation. The troupes of monkeys could also be repelled away by trained dogs. Thus shade regulation and scaring by trained dogs reduced monkey menace.

(C) Wildboar : During summer (February to April), extensive damage to cardamom nursery (1 to 2 years old) by wildboar, was noticed in different parts of Chikmagalur district.

Behaviour of the foraging herd in cardamom nurseries was studied and crop protection measures were evaluated in field trials during 1986 to 1988. The impact of the promising practices i.e., establishing drainage system and repelling away the animal by Thimet 10G was evaluated during 1989 and 1990 at four nurseries in Mudigere. Data were subjected to statistical analyses after appropriate transformations.

Observations during 1988 and 1989 indicated that in Mudigere, wildboars foraging in search of root grubs or subterranean tubers, incidentally caused seedling loss in cardamom nursery. The damage (up to 50%) peaked in summer. The animals are attracted to the nursery particularly when beds are irrigated. Irrigation of nursery beds facilitated probing into soil for arthropods and tubers. Field trials with several practices failed to reduce wildboar damage. It was inferred from observations that ill drained nurseries in low-lying areas were preferred and were severely damaged. Therefore, sound drainage system and fencing aided protection to seedlings.

Integrated Vertebrate Pest Management :

A plot of 400 clumps of five years old Malabar cardamom, was selected for recording impact of practices, viz., timely harvest of capsules, leaf mulching, overlapping of panicles and clean cultivation during 1997 at Mudigere. This study site was the favourite spot for the squirrel and the rat. About 0.5 k. m. away from this plot, another 'control' plot was selected. The crop protection practices were evaluated against principally the squirrel, *F. palmarum* L, rat, *B. bengalensis* B and the bird, Red spurfowl, *G. sonneratii* T. Observations were recorded during 1997 and 1998.

Parallely, to confirm crop protection practices against monkeys and wildboars damage to nursery, field trials were run at Mudigere during 1997 and 1998. Details of these trials are tabulated. Foregoing data suggests that clean cultivation, timely harvests, overlapping panicles

and mulching afforded protection to cardamom capsules from rats, squirrels and birds. Consistent results to this effect has also been documented by Chakravarthy (1993), Chakravarthy et al., (1992), Thyagaraj et al., (1993) and Srihari and Chakravarthy (1992). These practices are cheap, practicable, eco-friendly and compatible with invertebrate and vertebrate pest management practices (Krishna Murthy et al., 1989; Srihari and Chakravarthy, 1992).

Regulating shade in cardamom plantations with scaring of monkeys and establishing good drainage and fencing for cardamom nursery against wildboar damage facilitated crop protection. Cardamom is grown in evergreen tropical forest tracts, chemical methods are not desirable and have proven often ineffective (Srihari and Chakravarthy, 1992 and Chakravarthy, 1993). So cultural, mechanical and biological means of crop protection, though moderately effective are easily adoptable.

Five rodenticides were evaluated in field trials during 1986-87 and 1993-94 at Mudigere. The five rodenticides were Zinc phosphide (2.5%), Rodacake (0.005%), Bromodiolone (0.005%), 'Quintox' (0.075% Cholecalciferol) and 'Storm' (0.005% Flocoumafen). Quintox was evaluated in pellet and cake formulations. 10gm of Zinc phosphide was mixed 10gm of edible groundnut oil and then mixed with 400 gm wheat flour. 10gm of poisoned bait was placed at each baiting station. The bait was presented to the animal in small balls / pellet from laced outside with groundnut oil, after pre-baiting. Each test plot was 200 m² consisting of ten rows of 20 cardamom clumps each. The test plots were at least 0.25 km apart with three replications. The cake pieces (3 cm²) of the four rodenticides were hung from 0.3 m height over the panicles at 3 randomly selected clumps / 10 rows / plot. The plots were designated as A, B & C for each rodenticide. A plot with no rodenticide constituted the control for each rodenticide. The efficacy of rodenticide was tested by the per-

cent damage to cardamom capsules compared to the clumps in the control plot and also to the damage incurred by capsules before placing the rodenticides. The differences in the mean capsule damage was statistically tested by χ^2 .

Zinc phosphide :

Fifty Zinc phosphide pellets / 200 m² were distributed in the test plot randomly. Hoarding occurred and rats were observed hoarding the pellets in burrows. So, only 10 pellets were placed at base of clump @ 1 / clump / 200 m². Within 24 hrs. no pellet was found in the test plot and capsule damage continued. Zinc phosphide proved ineffective in checking rodent damage.

Rodacake :

This rodenticide was tested for two years, 1986-87 and 1987-1988. When compared to the control, the treated clumps recorded less than 50% capsule damage. The χ^2 test revealed significant differences between the treated clumps from rodents. Even after treatment the damage to capsules continued. Results of 1987-88 trial also showed similar trend. Hence, rodacake offered only a partial protection temporarily (Table 18).

Bromodiolone :

Bromodiolone was tested during 1988-99 and 1989-90. The rodent damage on capsules was not consistent in response to the placement of the Bromodiolone baits (Table 19). During 1989-90, rodents bit the bait pieces only at two spots and rodents responded poorly to the Bromodiolone. The capsules damage was consistently and continuously observed even after the placement. The same trend continued during 1996-97 observations.

Quintox and Storm :

Quintox pellets treated plots recorded about 25% capsule damage and Quintox cakes treated plots recorded almost 10% capsule damage compared to control. Cake proved more

promising than pellets, possibly due to the easier detection by rodents. There were significant differences among dates and the three formulations of rodenticides (Table 20). During 1993-94 the Storm and Quintox were retested. There was no response from rodents to the Storm and Quintox were retested. There was no response from rodents to the Storm and Quintox pellets and cakes. The capsule damage continued despite the placement of the rodenticides. The rodents seemed to have developed aversion to the pellets and cakes.

Testing of rodenticides in cardamom plantations against rodents damage did not yield consistent results, In most of the testing situations, the observed data was not related to the use of rodenticides. Despite these drawbacks the rodenticides excepting Zinc phosphide particularly on the first year of testing did reduce capsule damage. It is necessary to further test the rodenticides in multilocal trials.

Zinc phosphide being a stomach poison, may be the least effective in forest ecosystems, an observation which needs more field testing and confirmation, since Zinc phosphide has proved to be the best known rodenticide throughout the world, despite its limitations such as poison shyness and toxicity to non-target species. However the nerve poisons hold some promise in containing rodent damage and can supplement cultural practices in protecting capsules from rodents. Studies of Chakravarthy et. al., (1991) and Srihari and Chakravarthy (1992) over a period of three years clearly revealed that cultural practices viz., timely harvests, clean cultivation and by disposing panicles in an overlapped fashion, 2 %, 0.55 % and 4.5 % capsules could be saved respectively. Hence, an effective rodent pest management in cardamom plantations is possible.

Table 1 Species composition of vertebrates in cardamom plantation in hill region of Karnataka

Common Name	Species	Plant part infested	Districts			
			Shimoga	C'magalur	Hassan	Coorg
Rat	<i>Mus booduga</i> G	Cf	+	+	+	+
	<i>Bandicota bengalensis</i> B	Cf	+	+	+	+
	<i>Bandicota indica</i> B	Cf	+	+	+	+
	<i>Rattus rattus</i> L	Cf	+	+	+	+
Squirrel	<i>Funambulus palmarum</i> L	Cf	+	+	+	+
Jungle shrew	<i>Suncus merione</i> L	Cf	-	+	-	-
Elephant	<i>Elephas maximus</i> L	Ec	-	+	-	+
Wildboar	<i>Sus scrofa</i> W	Sf	+	+	-	-
Monkey	<i>Macaca radiata</i> L.	Sf	+	+	+	+
Spurfowl	<i>Galloperdix spadicea</i> G	Cf	+	+	+	+
Jungle fowl	<i>Gallus sonneratii</i> T	Cf	-	+	+	+
Ground Thrush	<i>Zoothera citrina</i> L	Cf	+	+	+	+

+ = Economically important
- = Not economically important

Sf = Sucker feeder
Cf= Capsule feeder
Ec= Entire clump feeder

Table 2 Rodents (rat + squirrel) damage to cardamom capsules in three different habitats at Mudigere, Karnataka

Date	Capsules (%) damage		
	Plain	Slope	Valley
23.09.89	0.16	0.25	0.44
06.10.89	0.66	0.11	1.27
14.10.89	1.16	1.38	3.65
26.10.89	3.26	1.07	3.25
08.11.89	2.49	0.88	2.48
17.11.89	12.47	0.24	7.26
27.11.89	5.61	0.56	8.21
04.12.89	8.54	0.00	7.25
08.11.96	1.30	0.40	2.40
20.10.97	3.50	1.12	12.2
Mean	3.49	0.61	4.84

CD P = 0.05 Plains v/ s Slope = 2.11; Plains v/s Valley = 2.16;
Slope v/s Valley = 2.08.

Table 3 Rodent damage in relation to the age (days) of capsules

Date	Capsules (%) damaged (days)		
	Green (70)	Greenish yellow(90)	Yellow (100)
05.10.89	3.23	16.13	80.64
06.10.89	0.00	12.50	87.50
16.10.89	0.00	30.36	69.64
19.10.89	2.09	13.99	83.92
23.10.89	4.65	81.40	13.95
24.10.89	6.56	25.00	68.44
25.10.89	2.44	12.93	84.63
31.10.89	1.02	17.41	94.55
03.11.89	3.79	09.24	86.57
06.11.89	0.00	00.00	100.00
07.11.89	3.55	19.80	76.55
10.11.89	5.66	12.93	85.41
10.11.97	4.65	3.89	77.50
Mean	2.74	20.94	77.65

Table 4 Rodent damage to cardamom capsules in relation to the plant types

Month - 1990-97	Cardamom types	Capsules (% damage)
July	Malabar	22
	Vazhukka	0
	Mysore	0
August	Malabar	94
	Vazhukka	11
	Mysore	0
September	Malabar	145
	Vazhukka	26
	Mysore	0

Table 5 Response of rodents to baits in wooden snap traps at RRS, Mudigere, Karnataka

Baits	No. of rodents (rat + squirrel) trapped /10 days in 20 traps
Paddy grains	5
Jackfruit	0
Jack fruit jelly (300 Jack fruit + 3 lit water)	0
Dehydrated Jackfruit	0
Wheat flour pellets	0
Cotton wad laced with jaggery solution	0
Wild jack fruit	0
Dry fish	0
Spagnum Moss solution (Mass 15 g + water 250 ml + Sandovit 5 ml)	0
Algal solutions (Algae 250 ml +Sandovit 10 ml + Water 100 ml)	0
Banana fruits	7
Vada (in Metallic snap traps)	24
Mean	3
CD @ 5%	NS

Table 6 Vertebrate Pests (VPS) trapped in wooden snap traps between March - May 1990 at Mudigere, Karnataka

Species	Number of rodents and vertebrates trapped									
	(w e e k s)									
	1	2	3	4	5	6	7	8	9	10
<i>Bandicota bengalensis</i>	1	-	-	4	-	-	-	-	-	-
<i>Mus booduga</i>	-	2	5	5	4	5	2	2	-	-
<i>Funambulus palmarum</i>	-	-	3	-	-	3	2	2	-	1
<i>Rattus meltada</i>	-	-	-	-	-	-	-	-	-	1
Shrew	-	-	-	1	-	-	-	-	-	-
Monkey	-	-	-	-	-	1	-	-	-	-
Red spurfowl	-	-	-	-	-	1	-	-	-	-
White breasted Ground thrush	1	-	-	-	-	-	-	-	-	-

Table 7 Monkey damage to cardamom clumps of different age groups

Clumps damaged (%)				
< 3 years age		>3 years age		
1990-91	1991-92	1990-91	1991-92	1996-97
41.57	32.37	0.00	0.00	0.00
62.57	35.70	3.20	0.24	0.49
70.04	43.23	6.10	0.59	0.35
75.41	58.83	7.30	3.93	4.72
79.98	63.73	7.80	6.05	7.50
88.70	66.70	9.06	6.93	8.45
Mean 69.71	50.00	5.58	2.96	3.54

Binomial expansion 'Z' 1.70 0.554
Age (1990 - 91) = 7.28 Age (1991-92) = 6.31

Table 8 Monkey damage to cardamom in shade unregulated and regulated plantations

Clump Damage (%)		
Plot Nos	Shade unregulated	Shade regulated
1	42.02	10.00
2	34.29	1.61
3	27.92	6.60
4	33.33	8.75
Mean	34.39	6.74

Binomial expansion 'Z' test at 1% 4.15

Table 9 Rodent damage and crop loss in cardamom at RRS, Mudigere, Karnataka

Year	Crop loss (% capsules split) *
1984	8.70 ($\bar{X}$ =7 harvests)
1985	9.91 ($\bar{X}$ =5 harvests)
1986	11.45 ($\bar{X}$ =6 harvests)
1987	12.60 ($\bar{X}$ =4 harvests)
1988	10.00 ($\bar{X}$ =7 harvests)
1989	9.50 ($\bar{X}$ = 6 harvests)
1990	10.80 (upto october only)
1996	4.30 ($\bar{X}$ =4 harvests)
1997	5.10 ($\bar{X}$ =4 harvests)

* n= 55 clumps / year randomly selected in valley region, mean of harvests.

Table 10 Effect of cultural practices on rodent damage to cardamom capsules, 1991-92

% Capsule damage in plots with					
Clump No	Clump		Clump No	Clump with panicles	
	With weeds	Without weeds		Dispersed	Overlapped
1	5.66	2.62	1	4.55	2.75
2	7.39	0.00	2	6.98	0.00
3	5.55	1.68	3	2.77	4.00
4	7.41	0.00	4	4.08	1.69
5	1.64	1.87	5	3.59	4.55
6	1.96	2.83	6	5.02	3.76
7	8.73	2.34	7	11.29	2.42
8	7.89	0.00	8	7.87	2.45
9	2.40	4.29	9	3.48	3.81
10	2.70	0.00	10	8.26	1.44
Average (%)	5.13	1.56		5.46	2.64

Binomial expansion 2.84 3.96
'Z' value

Table 11 Effect of cultural practices on rodent damage to cardamom capsules, 1992-93

Cultural practices						
Clump	Overlapped panicles	Without weeds	Timely harvest	Natural dispersion of panicles	With weeds	Delayed harvest
1	2.75	9.12	2.20	1.61	0.81	3.10
2	4.00	8.08	1.53	0.00	3.51	5.47
3	1.55	5.21	1.89	3.66	2.71	12.29
4	1.69	11.57	3.83	0.53	1.61	6.31
5	4.55	2.97	3.57	0.95	0.48	8.85
6	3.76	0.32	4.48	4.64	2.42	6.59
7	2.42	6.95	2.43	0.50	1.02	2.04
8	2.45	6.95	2.84	0.43	1.16	2.04
9	3.81	3.69	5.69	1.02	1.92	0.81
10	1.94	10.58	4.82	1.06	1.76	2.03
11	3.51	11.10	3.51	4.98	4.73	4.50
12	2.71	4.95	1.61	2.52	2.48	1.99
13	1.61	10.48	2.69	5.34	4.09	2.28
14	3.42	22.39	3.57	7.25	6.47	8.40
15	3.26	11.42	1.89	1.69	3.26	7.38
Total	43.43	36.18	39.43	46.55	74.60	122.56
Mean	2.89	2.41	2.63	3.10	4.97	8.17

Binomial expansion NS 1.103
'Z' value 0.6343

Table 12 Effect of cultural practices on rodent damage to cardamom capsules, 1991-92 and 1992-93

1991-92			1992-93			
Capsules damaged / clump						
Days after treatments	% Mulched	% Unmulched	Nos Mulched	Nos Unmulched	Overlapped panicles	Dispersed panicles
0	0.96	29.40	119.6	741.3	313.3	528.6
4	1.69	73.80	155.6	817.6	259.3	662.6
6	1.68	47.16	166.0	876.3	247.6	586.6
9	2.24	49.00	129.3	553.0	134.3	551.6
18	6.52	41.00	165.6	651.0	180.6	496.6
27	1.43	60.00	195.3	679.0	197.6	413.6
29	1.85	11.70	111.23	820.0	200.0	537.3
40	3.84	32.25	151.0	843.0	186.6	684.0
45	1.42	57.00	120.3	539.6	142.6	595.3
Mean	2.40	44.59	145.9	724.5	206.8	569.5
% Capsules saved		94.61	79.86		63.68	
Binomial expansion (Z)		6.01	19.91		12.98	

Table 13 Effect of cultural practices on squirrel damage

Year	Capsules (%) saved compared to control			
	Mulched	Weeds removed	Overlapped	Timely harvest
1989-90	-	69.53	53.55	-
1990-91	-	62.83	16.60	37.11
1991-92	94.61	-	-	-
1992-93	79.86	-	63.68	-
Mean	87.23	66.18	44.61	37.11

(-) = not tested n = 250 clumps / year

Table14 Number and species of rodents trapped in wooden snap traps between March-May 1990 in Mudigere

Week	Bb	Mb	Fp	Rm	Shrew	Total
1st Week	1	-	-	-	-	1
2nd Week	-	-	1	-	-	1
3rd Week	-	5	3	-	-	8
4th Week	1	5	-	1	-	7
5th Week	-	4	1	-	-	5
6th Week	-	5	3	-	-	8
7th Week	-	2	2	-	-	4
8th Week	-	2	2	-	-	4
9th Week	-	-	-	-	-	0
10th Week	-	-	1	1	-	2
Grand total						40

Bb= *Bandicota bengalensis*, Mb = *Mus booduga*, Fp = *Funambulus palmarum*,
Rm= *Rattus melstada*.

Table 15 Response of rodents to baits in wooden snap traps at Mudigere

Bait	Number of rodent (rat + Squirrel) trapped / 10 days in 20 traps
Paddy grains (germinating)	11
Jackfruit (<i>Artocarpus indica</i>) wet and dry or jackfruit pulp	0
Wheat flour pellets	0
Cotton wad laced with jaggary	0
Algal solution (Algae =250 ml; Sandovit =10 ml; water =700 ml)	0
Vada (in metallic traps)	30

Table 16 Comparison of rodent damage in trap operated and no-trap operated areas in cardamom plantation

Clump	% rodent damage in	
	Trap operated area	Non-trap operated area
1	3.10	9.12
2	5.47	8.08
3	12.29	5.21
4	6.31	11.57
5	8.85	2.97
6	6.59	0.32
7	2.04	6.95
8	2.56	3.73
9	0.81	3.69
10	2.03	10.58
11	4.50	11.10
12	1.99	4.95
13	2.28	10.48
14	8.40	22.39
15	7.38	11.42
Mean	8.17	4.97

Table 't' at 1% 2.76 ; 5% = 2.04 ; Calculated 't' = 1.99.

Table 17 Rodent damage on capsules treated with Neem oil and Fish oil

Concentration (%)	Capsule (Nos) damaged	
	Neem Oil	Fish Oil
0	170.33	155.67
1	137.00	102.00
2	128.00	102.67
3	59.33	82.00
4	65.00	56.00
Mean	111.99	99.67

CD @ 5% Oils = 53.7 ; Concentrations = 24.8 A x C = 17.2

Table 18 Effect of Rodacake baits on per cent capsule damage

Site	Area (m ²)	Capsules (%) damage in valley	χ^2 Test
A	200	21.0	(P>0.05)
B	300	17.0	
C	200	14.0	(P<0.005)
Control	200	46.0	

Table 19 Effect of Bromadiolone baits on rodent damage in cardamom

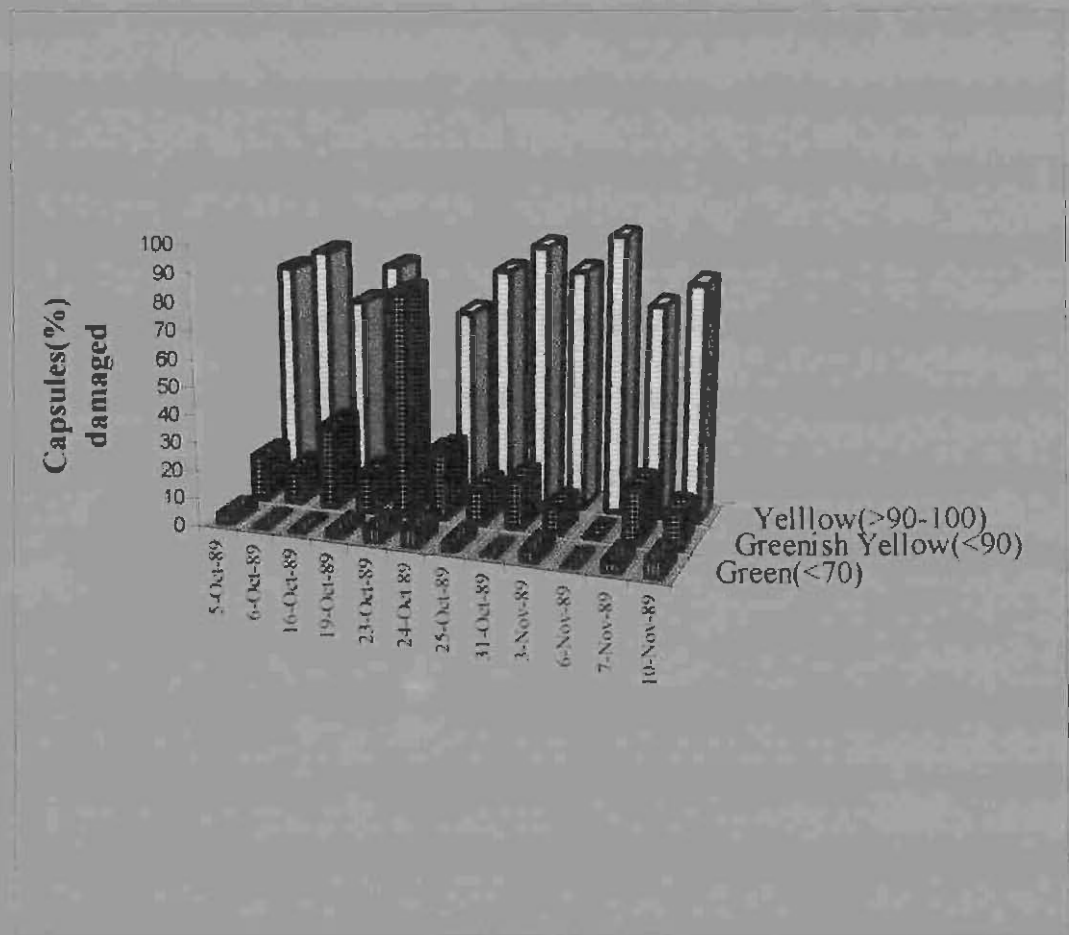
% Capsule damage *			
Date	Treated	Control	χ^2 Test
03.10.88	1.7	12.4	(P>0.05)
14.11.88	10.7	6.7	
15.12.88	5.5	7.7	(P<0.05)
05.10.89	4.6	1.2	
03.11.97	9.8	7.9	

*Mean of 20 clumps; 3 cm² bromadiolone pieces were hung from 0.3 m height over the panicles.

Table 20 Effect of 'Storm' and 'Quintox' on rodent damage in Cardamom

Dates	Capsules (Nos) damaged / clump			
	Control	Strom (Flocoumafen)	Cakes Pellets	Quintox (Cholecalciferol)
05.11.92	1768.0	126.0	139.0	153.0
10.11.92	1768.0	148.6	92.3	75.0
15.11.92	1085.0	123.0	184.7	106.7
20.11.92	1078.6	132.3	288.0	105.3
25.11.02	610.3	120.3	255.4	103.3
30.11.92	567.7	123.3	289.7	97.3
01.12.92	774.3	150.3	344.7	103.0
10.12.92	697.0	141.0	341.7	110.7
10.12.92	708.0	135.6	267.6	136.7
Mean	1006.3	133.4	255.9	110.1
CD @ 1% Chemicals = 908.22 dates = 39.85				
Chemicals x dates = 14.30				
During 1993-94 rodents did not elicit any response to the above rodenticides.				

Fig 1 Preference of rodents for Cardamom capsules of different maturity



PLANTATION CROPS

COFFEE (*Coffea arabica* L, *Coffea robusta* L)

The most unique and characteristic feature of hill region is the Coffee estates. More than 33% of the cultivated area in the region is covered by coffee estates. Vertebrates interact actively with the coffee plantations. Perhaps, this is one of the crops housing maximum number of vertebrates in the hill region. Species richness wise coffee ranks first of all crops in the region. The main reason is that it is this plantation crop that imitates closely to the natural forests and contain elements of the forest. The area under coffee is considerable and it's cultivation is increasing in traditional cultivated areas in South India. Both *C.arabica* (photo 5) and *C.robusta* are cultivated with 3.716 million bags : 1.720 million bags Arabica and 1.996 million bags of Robusta.

The planters maintain coffee plantations with fertile forest soils, leaf litter, lush ground cover, tall, multi layered and structured and indigenous trees, orchids, moss, ferns, lichens, parasitic plants and creepers. The planters do not sufficiently alter the physical variability so as to make the coffee plantations and supporting ecotones hostile for the co-existence of diverse biological communities. Coffee plantations represent the minimal modifiers of habitats for birds in the hill regions. With this background studies on the role of vertebrates in coffee plantations were initiated.

Vertebrates normally do not cause alarming losses to coffee berries. However a number of birds, squirrels and rats may feed on berries. But this shouldn't be in fact considered as loss because birds have invaluable role of play in coffee ecosystems via insect predation, deposition of organic matter and in transfer of nutrient and energy matter.

Coffee ecosystem hold a rich bio-diversity. Birds are the major species composition in the ecosystem, playing a vital role as predators, pollinators and seed dispersing agents.

Occasionally birds may become pests locally. Among other vertebrate species recorded in the coffee ecosystem, the Bonnet monkey, *Macaca radiata* L causes damage to the crop under the forced situations like scarce of food sources.

At Mudigere, during 1996-97, four coffee estates were frequented at 15 days intervals and 48 species of birds, four species of rodents, one species of Shrew and two species of quadrupeds have been identified. Further studies are in progress. Studies are also in progress in Kodagu district. Comparison of vertebrate species, composition and their functional roles will help in deducting the overall role of vertebrates in coffee estates of hill region.

Six coffee estates in and around Mudigere were frequented at 15 days intervals from June 1997 April 1998 to record activities of the vertebrates species in coffee ecosystems.

Birds :

Among 91 species recorded during the season in the coffee habitat, only two species viz., Small Green Barbet, *Magalaima viridis* and Red Whiskered Bulbul *Pycnonotus jocosus* L attained pest status as they damaged ripened coffee berries only (Table 1). They punctured the pericarp and siphoned in the sweet contents and dropped the husk and seeds on the ground (photo 6). When large scale assessment was made, the damage was found non-significant ($P>0.01$). Eighty nine other bird species were found feeding on a variety of insects and arthropods and other wild fruits, buds and flowers. Hence birds are potential predators and polynators than depredators. Thus, birds play vital role in maintaining eco-balance in the coffee habitats of Western Ghats.

Monkey :

Bonnet monkey, *M.radiata* a dominant species, which is a serious pest on cardamom occasionally damaged coffee also. *Coffea arabica* berries ripening usually starts from November-December and *Coffea robusta* during February-March in Mudigere. Due scarce of

food sources during this period monkeys were forced to feed on coffee berries. Monkeys were absorbed de-branching coffee bushes that contained flower buds, the crop of next year and carry them to tree tops to feed on the sweet mucilage of the fruits and throw the husk and the seeds. The loss caused by monkeys here is more economical as the animals damage indirectly the next year crop also.

At times (only under forced conditions), monkeys feed on the young coffee plants (*Robusta* only) as the plants possess succulent, sweet and palatable stem tissue. Timely scaring will effectively prevent the damage or loss.

A troupe of 20 monkeys caused about 10% loss in berry yields at mudigere during January 1998. This estimation is based on the number of coffee bushes damaged by monkeys to the total number of bushes present. However, based on the number of berries damaged, the troupe caused only 0.03% loss in berries. The loss caused at the study site may not be economical. Ripened berries were preferred for damage. Coffee bushes at edges were severely damaged. Both Arabica and Robusta varieties of coffee are vulnerable for monkey damage.

For effective management of monkey damage, the relationship or interaction of monkeys with the crop and habitat / food sources availability need to be studied in detail. Trapping and shifting of trapped monkeys into the forest or uncultivated area may prove effective as re-infestation of monkey damage to the estates was noticed after a considerable period (1 to 2 years). Further, studies in this regard are to be made.

Squirrel, wildboar, rats, mongoose, monitor lizard, stag and jackal were absorbed in the coffee plantations. But their activities were confined to searching for wild foods but not the coffee crop. Hence, these animals have an ecological role.

Seed dispersal :

Seeds are not dispersed to the longer distances, has the biras feed on the sweet mucilage present in the berries and drop the seeds near the base of the coffee bushes. Such fallen seeds are collected by the planters. Quality of these seeds may get reduced. Monkeys were found feeding on the coffee berries when alternate food sources get limited. As the cropping season coincides with the winter season, monkeys depend on food sources like *Ficus* spp., *Artocarpus* spp. and other wild fruits. Monkeys store the coffee berries in the pouch, run up to the tree-top and feed on the sweet mucilage, throwing the husk and the seeds below. The berry loss caused by monkeys may not be economical (<0.03%).

Table 1 Damage to Coffee (plants + berries) by different vertebrate species in coffee ecosystem, Mudigere, kharif, 1998.

Vertebrate Species	Damage **	
	Plant Parts	Berry
Birds	-	+
Monkey (<i>Macaca radiata</i>)	++	++
Wildboar (<i>Sus scrofa</i>)	--	-
Squirrel (<i>Funambulus palmarum</i>)	-	-
Rat (<i>Bandicota bengalensis</i>)	-	-
Mongoose (<i>Herpestes edwardsii</i>)	-	-
Monitor lizard (<i>Varanus Sp.</i>)	-	-
Shrew (<i>Suncus Sp.</i>)	-	-
Jackal (<i>Canis aureus</i>)	-	-

** = Observations recorded through out the year

+ = Only fruit feeder

++ = Fruit & Plant part(s) feeder

COCONUT

INTRODUCTION

Coconut, *Cocos nucifera* L. is one of the most important oil and leading plantation cash crops of the coastal region of Karnataka. India now stands first in the production and productivity of coconut, producing 13231 million nuts per annum. It is grown in 1083000 ha sharing 17 % production of the world. Karnataka occupies third position after Kerala and Tamilnadu with 4,07,024 ha and a mean production of 272.70 crores of nuts in 1994 (Department of Horticulture, 1995). Dakshina kannada district in coastal region of Karnataka stands first in area with 29601 ha (Department of Horticulture, 1995). Coconut plays an important role in the religious and traditional customs / values of Indian life and cultural heritage. Tender coconuts carry medicinal value and taken as natural drink. The coconut oil is extracted from the dried copra and the copra is used in the food preparations / confectionaries and in the bakery industries. This way every part of the plant is in great demand and is put to use. The fibrous exo carp is used in fibre industry to prepare ropes and twines.

Survey :

A survey was carried out from 1994–98 at five places of coastal region, viz., Dharmasthala (12° 59' N 75° 17' E 183 m AMSL), Charmadi (75° 6' N 13° 2' E), Kidu (12° 27' N lat, 74° 35' long), Vittal (12° 27' N lat, 74° 35' long) and Puttur (13° 27' N, 79° 33' E 149 m AMSL) to find species composition and relative abundance at different climatic conditions and habitats. Observations on vertebrates infesting coconut and their seasonal occurrence, nature of damage and symptoms (as the damage to crops found throughout the year) were studied. Monthly surveys were conducted on four wheelers to record the presence / absence and the extent of damage.

Identification of rodents was done by placing metallic snap traps (20 x 10 cm) and locally made wooden snap traps (100 x 30 cm) @ 4-6 traps / acre at niches, burrows for instance in deep valleys, along bunds, base of tall indigenous trees and the branches of trees with overlapping layers of canopy / vegetation. Four traps were inspected after every 18, 24 and 66 hr of planting. Traps were placed in the evenings, so that both nocturnal and diurnal animals could be trapped and identified.

Monkeys, wildboars, porcupines and bison were identified by visual observations and by a pair of 8 X 30 binoculars. The movement and foraging activities of wildboars, porcupines and bison herds were identified by the presence of fresh dung pads and marking / hooves / pugmarks and track measurements. The identification was also confirmed by the reports of night patrolling party. Broken coconut shells with peeled fibrous portions of coconut in the garden are also a pointer to wildboar and porcupine's damage. Bison and porcupines damage vegetative portions i.e., fronds and stems, respectively whereas, squirrel, rat, monkey, porcupine and wildboars damage reproductive parts i.e., nuts.

Nature of damage :

The animals were also observed by binoculars from 8-10 m sitting under a hut / green foliage and thatch. The activity of all these animals and their size, body colour, structure of tail, feeding behaviour and vocalizations if any were recorded. The animals were identified following, Ishwarprakash and Prater (1968).

Feeding Behaviour and Ecology :

Rodents :

Field activities of rat, *Rattus rattus* L; squirrel, *Funambulus palmarum*; wildboar, *Sus scrofa* L; porcupine, *Hystrix indica* K; bison, *Bibos gaurus* H; monkey, *Macaca radiata* L were studied in a coconut garden at Charmadi, in a plot of nine acres coconut garden in

Boliyor, four acres in Madheri, six acres in Eramadaka and eight acres in Ennakala at Dharmasthala and seven acres in coconut plantation at Kidu farm of Central Plantation Crops Research Institute (CPCRI). Visual observations and observations through binoculars on nesting activities, number of wild foods fed by the animals, foraging strategies, the frequency of activities over time throughout the day were recorded. The number of animals foraging per unit area was also recorded.

Monkey :

Field activities of monkey troupes were observed through 8 x 30 binoculars and observations on wild foods, troupe size, movements of the troupe were observed throughout the year in coconut plantations in Dharmasthala from 1996 to 1998.

Wildboar and Porcupines :

The number of animals in a herd by track measurement, the wild foods and the times at which foraging occurred, sizes of the pug marks, symptoms of damage, movements and whose population sizes were recorded. Response to natural and artificial baits was also recorded from 1994 to 1997.

Identification and damage Symptoms :

Rats :

The animals trapped were identified as *R.rattus* (photo 8) and *Bandicota bengalensis* B (photo 9). In the field damage to nuts by rats identified by the presence of a hole at perianth region / proximal end of the nut with irregular scratches around (photo 13). Nuts ranging from 1 to 8 months old were damaged, the 5 months old ones being the most attacked. Rats preferred border palms. Such damaged nuts dehisce from the palm in 4 to 8 days (Smith and Romney, 1963). Rats also leave tooth marks ingrained on the exocarp.

Squirrel invariably makes holes not near perianth / proximal end, in the middle region of tender coconut and after scraping a portion of the fibrous mesocarp (=husk) of the tender coconut to varied shape the squirrel makes a circular hole in the scrapped area on the tender coconut.

Rodents are responsible for the heavy nut shedding due to their attack in different proportions, they show distinct preference for certain palms resulting 100% shedding due to their attack. The coconut palm crown provides space for nesting with coconut husk, fibers entangled with the spathe. It is observed that rats damaged coconuts severely during rainy season i.e., from August to November. As the ground in the orchards gets drenched with rain water and finds muddy, they don't prefer to live in burrows. In turn, make / construct nests in the crown region of coconut palms. Rodents hardly visit the ground in search of food, until the favourable conditions i.e., rains cease. They feed gregariously by moving tree to tree in the garden on nuts, breed on crowns itself and cause severe damage.

Non-availability of wild foods i.e., tapioca, *Manihot esculenta* C; sweet potato, *Ipomoea batatas* Lamk; pineapple, *Ananas comosus* L; cucumbers, *Cucumis sativus* L; banana, *Musa paradisiaca* L etc., during rainy season in the wild is another reason for rats to cause serious damage to coconuts. As the nuts during rainy season will be healthy, might also be a reason for rats preference for coconut.

During summer, as the coconut yields are lesser and the nuts will be smaller and tender and most of the trees will be flowering as the rats get wild food chiefly available in the forests they preferred to be in ground and caused lesser damage to coconuts. The palms up to moderate height (5 to 8m) was preferred for damage by rat.

Monkeys :

Observations on coconut damage by monkeys in Dharmasthala revealed that monkeys caused damage to coconut at all stages. Nuts of fist size to matured size were damaged for water and creamy copra. Monkey damaged nuts were identified by a hole made on the center of the nut and the outer fibrous skin / exocarp peeled -off (photo 15).

The number of monkeys fluctuated widely in a troupe, as also their size for foraging and feeding. At times of no or negligible human activity, monkeys were found entering the cropped area one by one. The animals held the nut with their fore limbs and hind limbs, and with teeth peeled the sheath i.e., exocarp and make the hole, drink water and eat the tender endoderm i.e., copra and just drop the damaged / eaten nuts down the palm. Observations revealed that tender nuts with copra are most preferred and the trees prone to severe damage by monkeys.

The damage pattern of monkeys differed from season to season and was influenced by intercrop or companion crop i.e., arecanut, *Areca catechu* L and the wild alternative foods availability. Damage to coconut decreased as arecanuts become available to the animals. As the summer approaches the damage by monkeys declined as they get their food from the forest. Mango, *Mangifera indica* L; Jack fruit, *Artocarpus indica* L; chakotha , *Citrus grandis* Osb, paddy ,*Oryza sativa* L, etc.

Wildboar and porcupine :

Wildboar, *S.scrofa* (photo 14), Porcupine, *H.indica* damaged the matured, dried coconuts fallen under the palms in the garden. As the wildboar and porcupine are nocturnal animals, the fresh damage is seen in the early hours of the day. Wildboars and porcupines, clearly peeled off the fibrous portion of the mesocarp (photo 16) in such a way that, as if it's

man's work and take out the exocarp, opened with their strong snouts by hitting the nut to the hard surface or to the stem and devoured the copra.

The left over shell particles and fibrous portions in the garden, showed symptoms of monkey damage. Wildboars were found trampling and up- rooting 1-2 yr old and younger coconut seedlings in the nurseries to feed on pith and tender roots. Porcupines chip-out bark above the ground and cut them into pieces (photo 17) and then burrow into the stem, rendering it hollow (photo 18). Observations on wildboar and porcupines were recorded and the extent of damage was calculated at CPCRI, seed farm , Kidu.

Yield loss assessment :

The nuts damaged by vertebrate pests were identified and separated based on their damage symptoms in the garden. The nuts lost / damaged were counted at weekly / monthly intervals in a given area over a period of time. The loss in terms of rupees may be calculated against the price of a single nut.

Total nuts damage X cost.

Bison :

The herd movement, time of foraging, nature of damage, herd size, the frequency of activities over time through out foraging time were recorded. Physical and chemical methods to control their entry into the orchards were tried. Bison feeds on coconut fronds of 2-3 yrs old. The damage to the palm obviously reduced the height of the palm, reduction being proportional to the extent of damage and number of normally grown fronds.

Porcupine and wildboar :

The dried nuts devoured by porcupines and wildboars are directly proportional to the complete loss in terms of rupees calculated against the existing nut rate.

Ennakala, 12 years, Eramadaka 15 years old plantation of intercropped coconut garden, Harpadi intercropped coconut garden, Boliyor an exclusive coconut garden of with 500 coconut trees alone and Charmadi with 250 palms intercropped area at Dharmasthala coastal region was chosen to study damage by vertebrate pests. Monkey, bat and wildboar were implicated in nut losses. Observations recorded at 15 days intervals from September 1996 to April 1997 and the total damage were calculated from every plot.

When data was subjected to ANOVA, the mean % damage to coconut was on' par with each other (Table 1). But monkey damage is a critical factor as cumulative damage pattern was analogous to monkey damage.

The damage caused by the major vertebrate species was observed from May'97 to March 1998. The damage was assessed in an ha consisting of 188 palms at 30 days intervals in all the five plantations viz., Ennakala, Eramadaka, Harpadi, Boliyor and Charmadi at Dharmasthala. (Tables 2 and 3).

In 1997-98, observations showed that monkeys caused 83 % damage followed by wildboars 12% and the rats 5%. The analysis revealed that there exist differences in nut damage among different months. However, there is a need to subject the data to a more appropriate statistical test to find out if the nut damage at different intervals is statistically significant.

1. The lesser damage recorded from May to September may be due to heavy rains (100 inches) that prolonged till September. The average nut loss per month for 1996-97 was 126. The average nut loss per month for 1997-98 was 87. The loss saved per month in 1998-98 was 39 nuts costing Rs 195 @ Rs 5 / nut was just due to prolonged rains, intense patrolling.

- There were two monkey troupes in 10 ac. Each troupe consisted of 28 animals. Despite intense patrolling, the animals incurred economic losses in nut yields. Inter-cropped plantations suffered less damage than monocrop coconut plantations.

The pooled data was subjected to ANOVA. There were significant differences in vertebrates damage to coconut during the 11 months period. The damage during May-July was statistically non-significant when compared in other months. The maximum was recorded in August with an average of 366 nuts / ha (n =188 palms) (@ 75 palms / ac). The pooled data was also subjected to ANOVA with months as replicates to find out differences in nut damage among the five plantations of Dharmasthala. The coconut damage at Harpadi was significantly higher at 5% level of significance when compared to the damage at Ennakala, Eramadaka, Boliyor and Charmadi. The damage at these five sites was highly variable and the variability may be attributed to a plethora of factors, which are not easily discernable. Figure 1 shows the month-wise distribution of vertebrate pests damage to coconut in coastal Karnataka.

Location	X nuts damaged
Ennakala	32.00
Eramadaka	162.45
Boliyor	79.27
Harpadi	371.71
Charmadi	87.27

CD at 5% = 202.7274 SEM = 73.14

n = 188 palms / hectare

As a result, monkey damage to nuts decreased. Effective scaring, timely harvests and trapping may help further. Night patrolling is routinely executed in this plantation. These current damage patterns in different plots of Dharmasthala, revealed that coconut plantations

need protection from vertebrates principally from September to November and monkey was found to be the major depredating species. During the other seasons, animals spaced out in search of alternate foods viz., paddy, jackfruit, mango and arecanut. As growers attach sentiments to monkeys, they do not kill monkeys. A rigorous and continuous guarding the plantation is costly and impracticable. IBex fencing (photo 19) solar fences, timely harvests, selective de-branching of shade trees providing wild foods may help reduce the damage to some extent.

Bison :

Bisons, *B.gaurus* feed on coconut fronds. The bison damage to the palm obviously reduces the height of the palm, reduction being proportional to the extent of damage and number of normally grown fronds (photo 20).

An experiment designed following RBD with three replications was chosen at CPCRI, Kidu, in West Coast Tall coconut garden to record observations on bison damage to coconut palms. The experimental field served as a cafeteria for the herd of eight bisons. The field was regularly foraged and the animals seem to be primarily attracted by the grass. While feeding, on grass, the animals browsed on fronds of coconut

The bison damage to palms was evident by the reduction in the height of the palm, reduction being proportional to the extent of damage and number of normally grown fronds. So depending on the height, the extent of damage of palm was categorized into 4 groups.

Palm height (m)	Score weightage
4	0
3	1
2	2
1	3
<1	4

palms receiving '0' and 1 scores are only expected to give yields but may be after 2 to 3 years compared to undamaged palms. Maximum palms were most severely damaged, as 160 out of 211 had height less than a meter.

The bison damage in the field commenced from July. It was severe from August to November and started decreasing from December '96 to April '97 (Table 4). The damage was related to biomass of the grasses. Probably the presence of grasses stimulated the animals to damage the crop. A survey of the habitats adjacent to the field revealed that the area did not support the animals. The adjacent areas provided shelter to the animals. The number of animals increased at the rate of one bison per 18 months.

Census of Bison :

Census of bison was based on track counts with individual identification. This method can be followed during routine patrols, whenever the distribution of animals was concentrated in certain areas. Whenever tracks were found, the type of habitat was recorded along with vegetation type, topographical feature dung pads, browsed plants, etc.

Bison track movement :

Each track measured by taking the average of the width of the fore and hind limbs (in cm). The direction of the track was also recorded. Its age on the ground was assessed to determine whether it was a positive track (less than, a day old) or an alternative track (2-3 years old). Both types were included in the count and tracks more than three days old were excluded. The same was used to count bisons in coastal Karnataka. The population size was estimated by

$$N_e / \text{Min, Max} = \text{estimated minimum or maximum population}$$

$$N / \text{min, max} = \text{No. of positive tracks}$$

$$CF = \text{corrected factor} = \frac{\text{Utilized habitat in farm X \% effective area}}{\text{Total no of observations}}$$

$$\% \text{ effective area} = \frac{\text{Total transects where tracks were found}}{\text{Total observation transects}}$$

This method is being followed to census bison population in the study area at Kidu.

Bison caused damage to coconut by feeding on the newly emerging fronds and thus severely impairing the palm growth. During 1996-97, out of 211 palms, a mean of 112 were under one meter height, which normally ought to have been four meters and 40 palms attained four meters height (fig 2). During 1997-98, maximum number of damaged palms attained a height of 3m as a mean of 84 palms were statistically significant (Table 5) from the palms affected to varying extent. Severely damaged palms were minimum (a mean of 20 palms) and perhaps, these were the palms repeatedly foraged by the bison herd. The mean number of palms under category 1 was statistically different compared to category 3 following ANOVA.

Regular patrolling in the plantation (2 persons visiting the plot throughout the night and producing sounds with metallic sheet and rod) reduced the bison damage to coconut palms to negligible amount as 4.73 % palms were damaged during 1997-98 as against 53 % during 1996-97.

The damage was related to biomass of the grasses. Probably the presence of grasses in coconut gardens stimulated the animals to damage the crop. A survey revealed that the adjacent areas of the garden didn't support the animals. The damage done by bison in coconut orchard at CPCRI - seed farm Kidu in 1997-98 is given in Table 5. Figure 3 shows different degrees of damage to coconut by bison at Kidu.

The bison damage to coconut could not be prevented by Ibex fencing and by fencing with wires and stone pillars. Watching throughout the day by patrolling proved effective but

partly. Severely damaged palms showed recovery, but to an extent, that may not result in economic yields.

Ficus glomerata Roxb (Atti fruits), *Strychnous nuxvomica* L (kayarada fruits); Bamboo tender shoots, *Tectona grandis* L; Betta shoots are the wild foods available to the key vertebrate species viz., monkey, wildboar, porcupine and rat in coastal region during the peak fruiting season of coconut and arecanut i.e., September-November. The presence of these wild foods in a plantation may help to reduce the damage to this crop. Further the availability of wild fruits such as *Embllica concinna* G; kesubulbs, *Sapindus mukorassi* G (Antwala kai), Nare creepers are the wild foods available to animals during off-season. These foods help the animals sustain in habitats and are of survival value. Certain fruits of minor importance like *Embllica officinalis* G; Gooseberry and *Syzigium cumini* L / *jambolanum* Alst (Jambu nerele) are the wild foods available to the animals throughout the year. Usually these foods are not principally consumed by the vertebrate species, but they supplement the natural foods of the animals. All the above three kinds of wild foods influenced the crop damage and the vertebrate pest population in the study area. Further systematic observations are required to document the extent of influence, alternate foods exercised over vertebrate pest community as a whole.

Porcupine damage :

Porcupine, *H. indica* is nocturnal animal. Observations cannot be recorded during night. So the nature of damage and its implications on the palms vis-à-vis, were recorded during early hours of the day. Field observation on porcupine's damage to coconut was observed throughout the year at kidu seed farm. In addition, observations on extent of damage were also recorded.

CPCRI - seed farm - Kidu is situated 90 Km south east of Mangalore, on Mangalore-Subramanya road. CPCRI comprises of 120 ha with laterite soil.

The details of four experimental plots were as follows :

- 1) Andaman Ordinary :** This plot was 1.6 ha with 319 palms planted on July 1991.
- 2) Benalium :** This experimental plot consisted of 0.8 ha with 113 palms planted on July 1991.
- 3) Malayan Dwarf Yellow :** This plot was 1 ha with 185 palms planted on July 1987.
- 4) East Coast Tall :** This study site encompassed 1 ha with 250 palms planted on December 1988.

The above four experimental plots were selected for assessing the porcupine damage to coconut. Porcupine damage starts from the base of the palm. The findings revealed that the porcupines chip out the bark into pieces and burrow into the pith region and then feed on the fleshy portion, rendering the stem hollow (photo 18). Such damaged palms are exposed for injury to the insect pests and pathogens. In severe cases such palms succumb by wilting. An adult porcupine was observed causing mortality of seven years old palm in one night.

Depending on the severity of attack, the damage was quantified as follows :

Palms in which porcupines would forage will be assigned a bark damage score as a percentage of the total bark. Total bark would be a function of the maximum height above ground level to which the porcupines can debark (= 0.6 m) x average diameter (n=3) of the trunk. These scores will then be used to score new and old bark damage according to following classes :

Percentage bark damage	Score
0%	1
>0-5%	2
>5-10%	3
>10-25%	4
>25-50%	5
>50%	6

relationships, spatial and temporal distribution of damage, cumulative damage and other properties of crop damage by the animals could not be ascertained.

It's important to assess porcupine population size. Population can be estimated by counting number of burrows x average number of animals / burrow. Depending on the size of the burrow, the number of animals can be estimated. Burrows can be located by fecal pellets and food / food plants partially eaten by the animal. It is necessary to become conversant with the food eaten by the animal locally in the study area.

From May'97 to April'98, 20% palms were debarked (Table 8). It is clear that June onwards, the peak damage occurred (5%) and the least damage (0.8%) was during summer. This may be due to monsoon that, the study area contained lush ground vegetation. The ground vegetation renders the habitat favorable to forage and feed the animals. The cultivated palm pith portion may provide a substitute in the diet of the animal to nutritional requirements.

The damage pattern of porcupine to coconut (Benalium, East Coast Tall, and Malayan Dwarf Yellow) (Tables 9, 10 & 11) followed the same trend as Andaman Ordinary. Maximum damage occurred during July to December '97 (15%, 12% and 14%, respectively). From May'97 to April '98 (3%, 5% and 6%, respectively) From May'97 to April'98 about 75%, 50%, and 69%, respectively, palms were debarked. There were significant differences in palms damage by porcupines from one month to another. Porcupine damage (%) to Coconut at Coastal Karnataka is depicted in figure 5.

A thatch of spiny bamboo sticks grounded at the base of seedlings provided protection to palms for two years. Bordeaux + Nuvacron 36 E. C. paste, waste oil paste, coal tar paste, suspension of Thimet 10G in perforated polybags and other methods can be tried for protecting the palms from porcupine's damage.

Palms in which porcupines foraged, assigned a bark damage score as a percentage of the total bark. Total bark would be a function of the maximum height above ground level to which the porcupines can debark = ($= 0.6 \text{ m}$) $\times$ average diameter ($n=3$) of the trunk. These scores were used to score new and old bark damage according to the above classes.

The experimental plots were located in a valley region with the ground covered with lush growth of grasses and weeds (Table 6). This kind of habitat provided congenial niche for the porcupines to feed on the palms. The survey revealed that there were two types of porcupine burrows, viz., large burrows usually holding 8-10 animals and small burrows usually holding 2-3 animals, were located @ 1 burrow / Km. The alternate hosts of this animal in the study area included sweet potato, *Dioscorea esculenta* Burm; *Dioscorea* spp; tubers, *Alocasia* sps. Tender pith of the Bambusa varietites, tapioca, *M. esculenta*; *Amorphophallus bulbifer* Roxb and *A. comosus*.

Porcupine damage to Andaman ordinary coconut was assessed at Kidu from September '96 to April '97 (Table 7). However, in this plot the number of palms receiving VI category of damage was meager. With time, this number is expected to increase. ANOVA revealed significant differences in the degree of damage to palms in the experimental plot. The percent loss of palms followed a similar pattern to that of damaged palms (fig 4).

During March-April and up to July no damage was observed and during this period grasses were cut and basins of palms remained open. This might have deterred rodents from damage. This supposition gains support from the fact that during this same period palms in the forest tract were damaged and basins of these palms were thickly covered with grasses, these may favour porcupine damage to palms. The average percent palms damage for a 6-month period was 15% as 64% palms were attacked by the rodents, the density-area

Management practices :

Sets of 25 palms with uniform growth were selected to study the impact of following crop protection practices:

- (a) Coal tar :** A liquid formulation having Insecticidal / Rodenticidal properties. The coal tar was laced around the trunk of the palm up to a meter height from the ground. About one ltr liquid is required to cover the base of one palm (photo 21).
- (b) Japan black :** A strong black liquid formulation having Insecticidal / Rodenticidal properties. The Japan black was laced around the trunk of the palm up to a meter height from the ground. About one liter liquid is required to cover the base of one palm.
- (c) Bamboo thatch :** A thorny festoon of bamboo sticks was tied firmly with binding wire around the trunk of the palm from the base up to the height of 0.7 m which served as mechanical barrier to porcupines (photo 22).
- (d) Metallic mesh :** A metallic mesh (1.5" x 1.5 ") was tied firmly with the binding wire around the trunk of the palm from the base upto about 0.7m height, which served as mechanical barrier to porcupines (photo 23).
- (e) Thimet 10 G :** 10G Thimet with sand (3 : 5 gm) in sealed perforated poly bags (20 x 10 cm) was kept half buried in the soil at the base of the palm, the odor emanating from thimet granules served as chemical repellent for the porcupines.
- (f) Waste lubricant oil :** Waste lubricant oil having repellent property was laced around the trunk of the palm up to a meter height from the ground. About 1 Kg of the waste lubricant oil is required per palm (photo 24).
- (g) Weeding :** At the base of the palms all the grass and weeds were removed and the basin was maintained clean throughout the year. Palms with basins covered with lush growth of vegetation served as control.

(h) Racumin : (Coumatetralyl 0.75% w/w) **Tracking powder :** About 250 mg was sprayed around the burrow of the porcupine. It was observed that the porcupines were not using these burrows. Hence, Racumin served as chemical repellent (photo 25).

(i) Watch and ward : Two persons with torch, visiting the plot during the night, at one visit for two hours by making auditory sounds. This served as an auditory repellent to the porcupines.

All the mentioned treatments proved effective against porcupine damage. But the degree and the period to which the treatments afforded protection to palms varied as shown in Table 12.

Management practices for vertebrate pests other than porcupine on coconut :

The nature and seasonality of damage caused by vertebrate pests viz., monkey, wildboar, and rat, and damage estimation and alternate foods of vertebrate pests depredating coconut were recorded through out the year.

Perumudel :

Perumudel, 25-30 years old coconut plantation interplanted with arecanut was observed for damage by monkeys, rats and wildboar. Certain management practices were evaluated in this plot with 200 coconut palms inter planted with 3000 areca palms, in ten acres.

It's calculated that about 33% of nuts produced are lost every year due to damage by rats, wildboars and monkeys in this plantation. Data was recorded at 15 days intervals. The damage was concentrated towards scrub jungle. In March 1998, monkeys accounted for cent-percent losses in yields. All the 116 damaged nuts were due to monkeys only.

A metallic monkey trap (2.5m x 1.5 m x 1m) (photo 26) was installed under the canopy of Ficus sp. tree. The animals were fed with locally available wild fruits of banana,

jack and orange. Six animals were trapped in 2.5 months. Water was provided in an earthen vessel. The nut loss prior to the cage set-up was 116 nuts / 65 palms. After installing the trap, the nut loss dwindled to 22 nuts / 65 palms in 45 days. Afterwards, gun patrolling was replaced by trapping. After 25 days of gun patrolling, the nut fall further reduced to 15 nuts / 65 palms.

In an isolated plot of ½ acre, where the wildboar damage was severe, suspending Thimet (10 grams mixed with 50 grams of fine sand) granules to repel the wildboars was tried. Data was recorded at 15 days intervals. Prior to the treatment, 68 nuts / 40 palms were found on ground, subsequent to 45 days after treatment, no nuts were found damaged and 105 nuts were harvested @ two / day. No nut damage was found even two months after the suspension of Thimet 10 G granules. This suggests that the Thimet 10 G granules repelled away wildboars from feeding on fallen coconuts in the study site during April-May.

Madheri :

Twelve acres plot with 600 coconut palms inter planted with areca trees and seedlings received the major threat from rodents. The plot was selected to implement management practices / control measures against rodents. After 45 days of treatment, the nut loss in the entire study area was five, and after another 15 days, the nut loss was three. In all, in 60 days six rats were found killed during April-May. A block of one acre containing 50 coconut palms and 100 areca seedlings of one year old, where the rat problem was severe was selected to implement management practices to control rats. The rat species was identified as *R. rattus*.

The following methods were evaluated against rat suppression.

1. The crowns of coconut palms were cleaned off, dried plant parts, nests of rodents and birds, and the over lapping fronds of palms were pruned.

2. Metallic bands (Iron or Zinc sheets of 1 / 2 m long was rolled and fixed around the stem, at of 3 - 4 m from the ground level, (photos 27 & 28).
3. Spiny, sticky thatch of Bamboo was fixed around the shoot / stem at 3 - 4 m height from ground level.
4. "Zinc phosphide" a poison bait treatment given in the plot (Zinc phosphide placed in the center of a bread piece / in a maide ball and placed near the rat holes).
5. Bromodiolone (Roban cake) of 0.005% RB placed or tied around the coconut shoot near the crown region.

The above treatments were evaluated at weekly intervals.

Boliyor :

In this experimental plot the rat damage to coconuts was observed in patches. In the 25 acres complete coconut garden, one such patch containing 55 palms was selected to evaluate the efficacy of the following treatments. In $\frac{3}{4}$ acre, about 41 nuts were damaged by rats. The methods evaluated were :

- (a) Roban cake (Bromodiolone) treatment
- (b) Zinc phosphide bait and
- (c) A festoon of thorny bamboo sticks

The above treatments were applied as mentioned earlier. The treatments were evaluated at weekly intervals. After 50 days of treatment, on an average, 17 nuts were damaged / 55 palms. After another 25 days, no nut loss due to rodent damage was recorded. Mortality of seven rats in the study area was observed. By this method 120 nuts were saved in 60 days.

A 32 years old coconut garden was chosen for studying the impact of selected management practices against vertebrate pests. The study site was located at Charmadi, a

transitional zone between hilly and coastal Karnataka. The experimental site was within 1 sq kilometer area. The study site was located in the evergreen tropical forest.

The annual rainfall recorded in this area is over 100 inches. The monsoon season begins from June and lasts up to October. The year is divided in this region as pre-monsoon (April-May), monsoon (June-October) and post monsoon (December-March). The principal vertebrate species depredating the crops were monkey, rat and wildboar.

The management practices chosen for the study against rodents were as follows.

1. **Racumin** : Racumin, a tracking powder technically named Coumatetralyly (0.75% w/w) a Rodenticide used to control rats and mice, includes (Heilogen blue 0.30% w/w, Benzerein blue 0.016% w/w, Mg Stearate 0.50% w/w Talum 8.434% w/w, Talcum Bassermann type 100% w/w) as components.

Racumin dust was applied along runways and path trails used by rats. Dusted about 10 m long of the track paths of rat burrows. Eight such paths were treated with Racumin. In addition, the base of the 100 coconut palms were randomly dusted with Racumin, and also administrated in the form of rounded balls of 2 cm radius of wheat flour, *Triticum aestivum* L with groundnut oil, *Arachis hypogaea* L and the bait pellets were placed at the entrances of burrows in the field at the rate of one per burrow. The proportion used was 1:5 grams of the Racumin to wheat flour, respectively.

Racumin applied to 50 coconut palms chosen randomly in all the 11 acres. Rats damaged nuts on crown and ground were counted before the treatment and the pre baiting was done for three days. Treated palms were cleared off the damaged nuts so that the fresh damage could be monitored subsequent to which the baiting operation commenced at 15 days intervals twice. Control was run to compare the differences in nut damage and efficiencies.

2. Ratol : Ready to use Ratol paste having phosphorus as main chemical compound was laced between two bread slices (photo 29) (5-6 g) and rolled in a piece of filter or butter paper of 6 x 2 cm and tied in the crowns of palms. The baits were tied, so that crows and other animals do not carry away the material. The operation was carried out in a hectare of areca garden inter-cropped with coconut.

The bait preparations were placed at the crown regions of palms @ 2 pieces per palm at randomly selected 50 coconut palms. The efficacy of Ratol was determined as given above.

3. Zinc phosphide : Zinc phosphide is an amorphous rodenticide with Zinc phosphide as an active ingredient 80% w/w (min) and the inert ingredient 20% w/w (max) used against rodents. 1 g of formulated Zinc phosphide product was mixed with 5 g of wheat flour in the form of balls called 'maida balls' of 2cm radius with 6-7 g mixed and laced with groundnut oil, were used for the purpose.

The bait pellets were randomly placed in the crown regions as well as at the entrances of rat burrows (photo 30). The study site consisted of 50 coconut palms. Basic operations like bund trimming, crown cleaning, cutting the overlapping tree branches or fronds, cleaning the bases of the trees and pre-baiting etc., were attended before baiting. Number of nuts damaged before and after baiting was counted at 15 days intervals, twice in a hectare and comparisons were made for the bait efficacies with a parallelly maintained control plot.

4. Bromodiolone bait : Ready to use Bromodiolone bait (Bromodiolone 0.005% w/w and other ingredients like broken cereals, jaggery and paraffin wax. 99.995% w/w) were placed in the crown region of the coconut palms @ 2 cakes per palm. Cakes were tied in order to prevent its loss by other animals. The baits were randomly placed in 50 palms in two ha. The efficacy of Roban cake was determined as given above. The nuts damaged by rats before and

after the baiting / treatment was counted at 15 days intervals twice was counted and was compared with the control plot for its efficacy.

5. Bamboo thatch : Easily available bamboo sticks were used for the purpose. A festoon / mat of thorny bamboo sticks of $\frac{1}{2}$ to 1 m long were collected and were banded all round the coconut stem with a rope tied at 2-3 m height from the ground (photo 31). Same parameters as used before were used to evaluate the efficacy of this control method, in a given two ha plantation.

6. Thimet treatment : 10G Thimet was used against wildboars. Three grams of Thimet mixed with five grams of dry sand and used by using sealed perforated poly bags (20x10 cm) and were suspended along the barbed wire at 5 m distance each and at 1 m above the ground level (photo 32). The odor emanating from Thimet served as chemical barrier to wildboars.

Sixty such poly bags carrying the repellent were placed in a garden of five and half acres. The rest five and half acre area with arecanut as major crop was maintained as control. Efficacy of the treatment was evaluated by following basic preparations, before and after the treatment as above. The impact of treatments to rats damage on coconut at Charmadi is given in Tables 13 & 14.

The effect of five protection methods to coconut against rat damage showed that bamboo thatch afforded cent-per-cent protection, compared to over 90% by Roban cake and Ratol. There were statistically significant differences among the treatments and when compared to control. Racumin proved ineffective. Data on the comparison of damage prior to and after treatment is shown in Table 13 and that on the comparison of different treatments in Table 14. Bamboo thatch on both the basis proved the most effective. However, this study

needs to be extended in a large area to obtain consistent and reliable results. Bamboo thatch is eco-friendly and cost-effective material.

Table 1 The scenario of nut damage in coastal Karnataka 1996 - 97.

No. of Nuts Damaged during										
Plot	VPS	Sept ' 96	Oct	Nov	Dec	Jan '97	Feb	Mar	Apr	Total
Ennakala	M+R+WB	185	187	51	67	101	86	136	67	880
Boliyor	"	0	0	189	110	124	136	160	0	719
Harpadi	"	0	0	470	230	231	228	440	0	1599
Eramadaka	"	0	263	38	23	17	14	8	0	363
Charmadi	"	173	226	103	37	31	26	5	15	616
Total		358	676	851	467	504	490	749	82	4177

M = Monkey, R = Rat, WB = Wildboar, t = 15 days

Table 2 The scenario of nut damage in coastal Karnataka 1997 - 98.

No. of nuts damaged by Monkey , Rat & Wildboar												
Plot	May '97	June	July	Aug	Sept	Oct	Nov	Dec	Jan '98	Feb	Mar	Total
Ennakala	13	13	14	22	45	28	33	43	45	48	48	352
Eramadaka	24	16	17	0	25	38	46	878	456	38	249	1787
Harpadi	149	149	149	1592	796	399	0	137	205	273	240	4089
Boliyor	51	51	51	151	128	110	95	70	61	48	56	872
Charmadi	16	18	18	67	113	137	158	130	121	107	53	938
Total	253	247	249	1832	1107	712	332	1258	888	514	646	8038

n = 188 palms / ha

Table 3 Vertebrates damage to coconut 1997-1998 in the given plots of Dharmasthala.

Year & Period	Vertebrate pest	Ennakala	Eramadaka	Harpadi	Boliyor	Charmadi	Total
May '97 to Mar '98	Monkey	323	1680	3977	468	803	7201
	Rat	23	77	103	376	49	628
	Wildboar	6	30	9	28	108	181
	Total	352	1787	4089	872	960	8090

n = 188 palms / ha

t = 30 days

Table 4 Bison damage to coconut palms at Kidu, Subramanya – 1996 - 97.

Month	Height (M) of the palms			
	1	2	3	4
September' 96	161	44	6	0
October	159	46	6	0
November	161	43	7	0
December	64	109	32	6
January'97	64	109	32	6
February	64	109	32	6
March	64	107	34	6
April	64	107	34	6
	112.26	76	19.8	3

Mean = n = 211 palms

Table 5 Palms damaged by bison at Kidu, CPCRI – seed farm 1997 – 98.

Palms height (m)	Mean no.of palms damaged
Category	Bison (n = 211)
1	20.45
2	58.54
3	83.63
4	40.15

CV = 54.77, SEM = + 8.37, CD at 5% = 23.21

Table 6 Ground vegetation in Coconut plantation, Kidu, Coastal Karnataka.

Scientific Name	Vernacular Name
Boerhaavia verticellata Poir	Madanika
Leulama levlocephala	Denvit
Sida sps.	Bhemana kaddi
Cynodon barberi Ralg & Tad	Hasagarike
Lpomola sps.	Chandrakanti
Plaseola sps.	Siripotla
Brachiaria sps.	Krishna chora
Sida rhombifolia Linn	Atibala
Leucaena leucocephala Lamk	Vilayati bali
Nephrolepis sps.	Jari bali

Table 7 Porcupine damage to Andaman ordinary coconut at Kidu, coastal Karnataka 1996-97.

Month	Mean damage to paims
Sept '96	9.20
Oct	9.60
Nov	12.20
Dec	1.60
Jan '97	1.00
Feb	1.00
Mar	1.00
Apr	1.00

The percent loss of coconut palms due to porcupine activity varied from 25 on October and November to 18.9 in September.

Table 8 Porcupine damage to Andaman ordinary, at CPCRI, Kidu, Coastal Karnataka.

Month	Trees damaged (total)	Damage(%)
May ' 97	5	1.56
Jun	10	3.13
Jul	7	2.19
Aug	13	4.07
Sept	9	2.82
Oct	4	1.25
Nov	3	0.94
Dec	2	0.62
Jan ' 98	8	2.50
Feb	2	0.62
Mar	1	0.31
Apr	1	0.31
Total number of Trees per plot		319
Total number of Trees damaged per plot		65
Mean	5.41	1.69
Std.deviation	3.94	1.23

Table 9 Porcupine damage to Benalium, CPCRI, Kidu, Coastal Karnataka.

Month	Total No. of Trees damaged	Damage(%)
May-97	12	8.00
Jun	15	10.00
Jul	10	6.60
Aug	08	5.33
Sept	14	9.33
Oct	05	3.30
Nov	11	7.33
Dec	16	10.66
Jan-98	09	6.00
Feb	04	2.66
Mar	06	4.00
Apr	03	2.00
Total number of Trees per plot		150
Total number of Trees damaged per plot		113
Mean	9.41	2.38
Std.deviation	4.35	2.90

Table 10 Porcupine damage to East Coast Tall CPCRI, KIDU, Coastal Karnataka.

Month	Total No. of Trees damaged	Damage (%)
May-97	18	7.20
Jun	12	4.80
Jul	22	8.80
Aug	08	3.20
Sept	10	4.00
Oct	14	5.60
Nov	06	2.40
Dec	16	6.40
Jan-98	04	1.60
Feb	09	3.60
Mar	05	2.00
Apr	02	0.80
Total number of Trees per plot		250
Total number of Trees damaged per plot		126
Mean		4.20
Std. deviation	6.08	2.43

Table 11 Porcupine damage to Malayan Dwarf Yellow, CPCRI, Kidu,

Coastal Karnataka.

Month	Total No. of Trees damaged	Damage (%)
May '97	20	10.81
Jun	12	6.48
Jul	09	4.86
Aug	14	7.56
Sept	07	3.78
Oct	15	8.10
Nov	06	3.24
Dec	13	7.02
Jan '98	12	6.48
Feb	10	5.40
Mar	04	2.16
Apr	05	2.70
Total number of Trees per plot		185
Total number of Trees damaged per plot		127
Mean	10.58	5.71
Std.deviation	4.67	2.52

Table 12 Efficacy of different protection methods / for protecting coconut palms against Porcupine damage, at CPCRI, Kidu, Coastal Karnataka.

Sl No	Treatment	No of days for which the palm remained protected
1	Lacing coal tar	60
2	Lacing Japan black	95
3	Lacing waste lubricant oil	45
4	Covering base with bamboo thatch	210
5	Covering base with Metallic mesh	250
6	Application of 10 G Thimet	30
7	Application of Racumin (0.75%)	40

Table 13 Effectiveness of chemicals and bamboo thatch against rats damage on Coconut at Charmadi, Dakshina Kannada.

Sl No	Treatment given	Damage prior to Treatment (30 days old)	Damage after Treatment (30 days old)	Effectiveness (%)
1	Roban cake (0.005%)	562	20	96.5
2	Racumin (0.75%)	36	12	33.3
3	Zinc phosphide (80%)	33	3	90.9
4	Ratol	220	30	86.5
5	Bamboo thatch	250	0	100.0
6	Control	24	18	75.0

Calculated 'F' at 5%
N = 50 Trees

Table 14 Effectiveness of chemicals and bamboo thatch against rodents damaging coconut.

Sl No	Treatment	Effectiveness / Tree
1	Roban cake	0.40
2	Racumin	0.24
3	Zinc phosphide	0.06
4	Ratol	0.60
5	Bamboo thatch	0.00
6	Thimet	0.06
7	Control	0.36

n = 50 palms / treatment

Fig 1 The monthwise distribution of vertebrate pests damage to coconut in

Coastal Karnataka

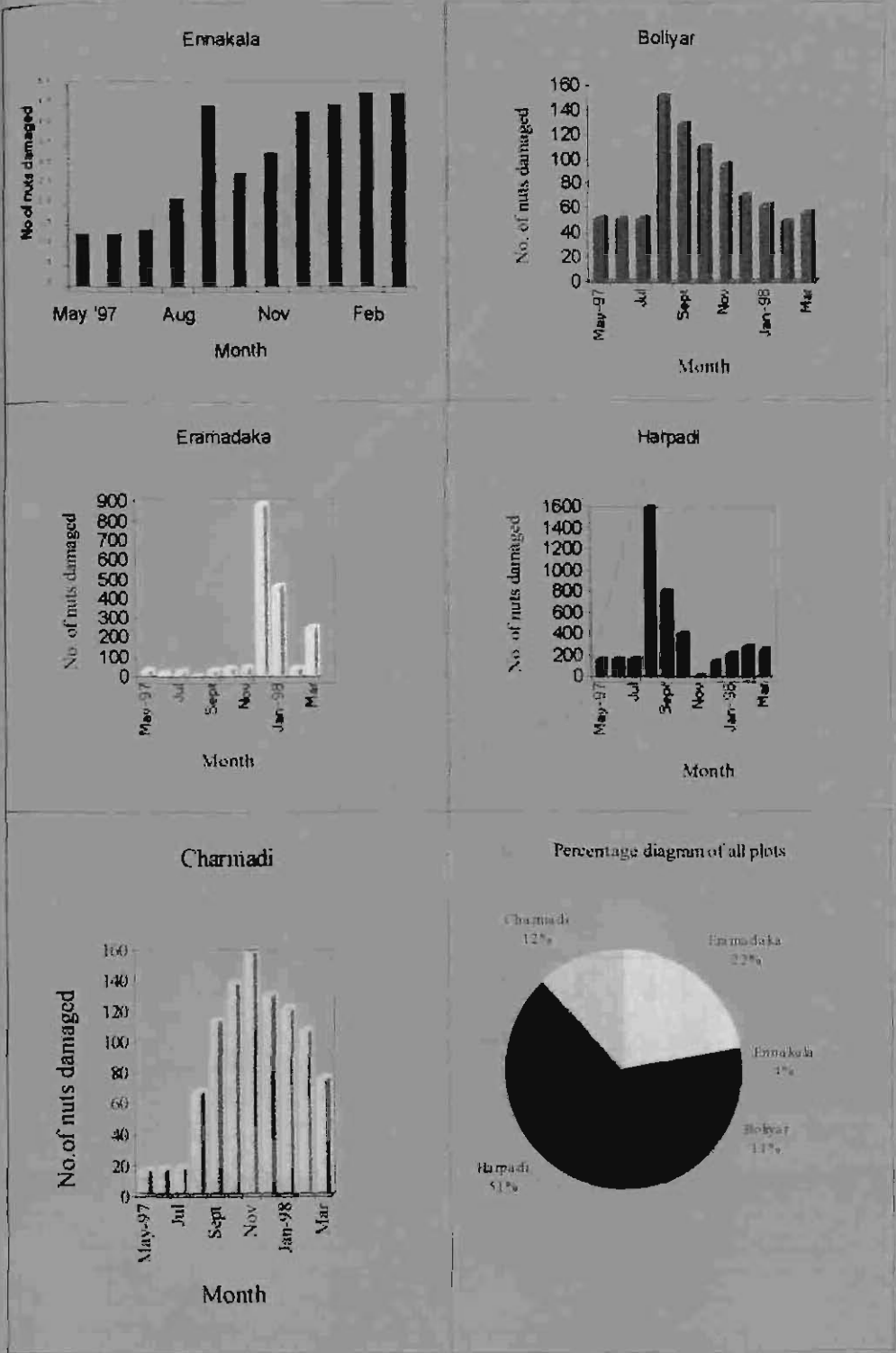
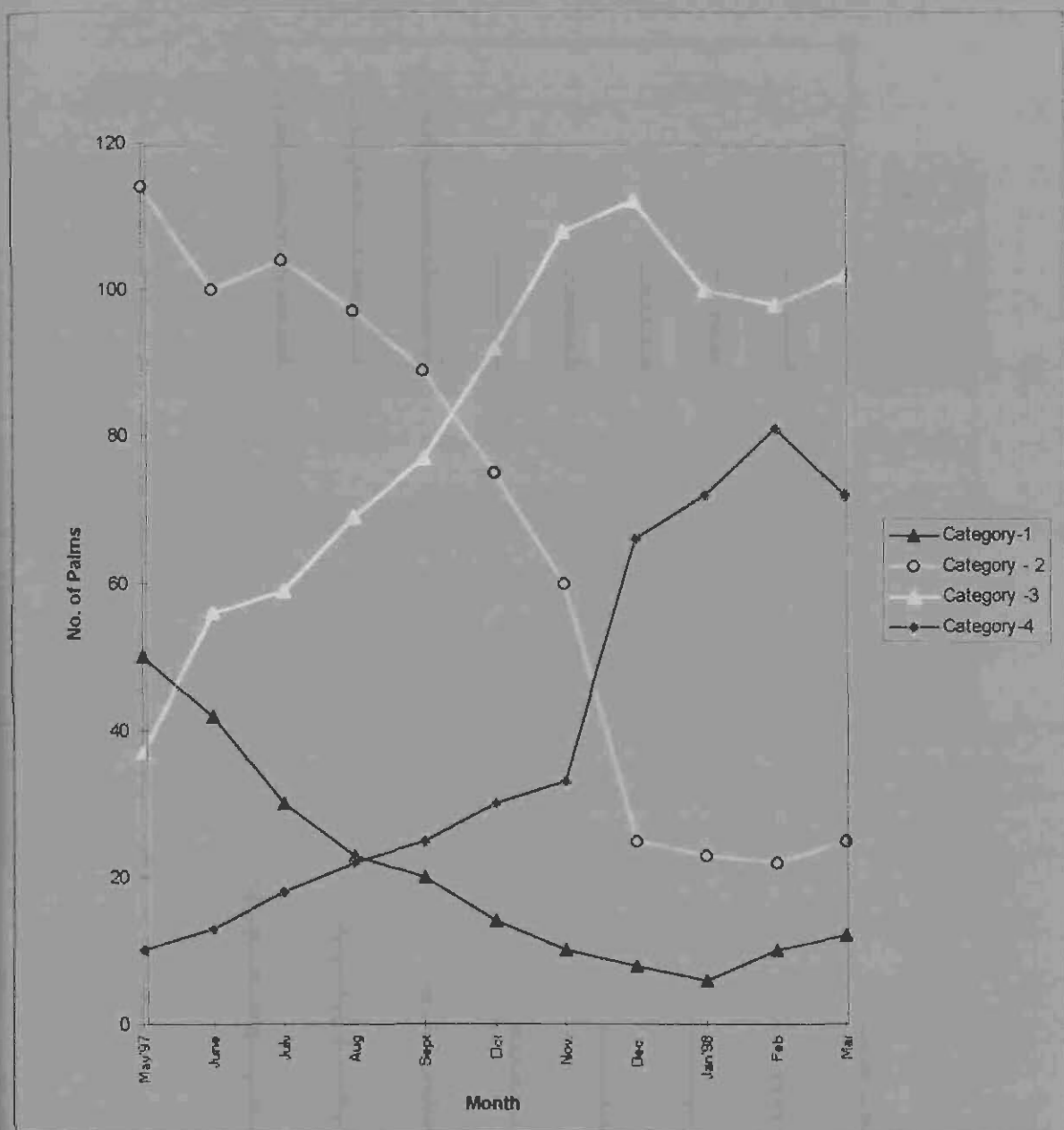


Fig 2 Bison damage to Coconut palms at CPCRI-Kidu, Dakshina Kannada



Category 1 = 1 Meter height, Category 2 = 2 Meter height, Category 3 = 3 Meter height,
Category 4 = 4 Meter height.

Fig 3 Different degrees of damage to Coconut by Bison at Kidu, Subramanya

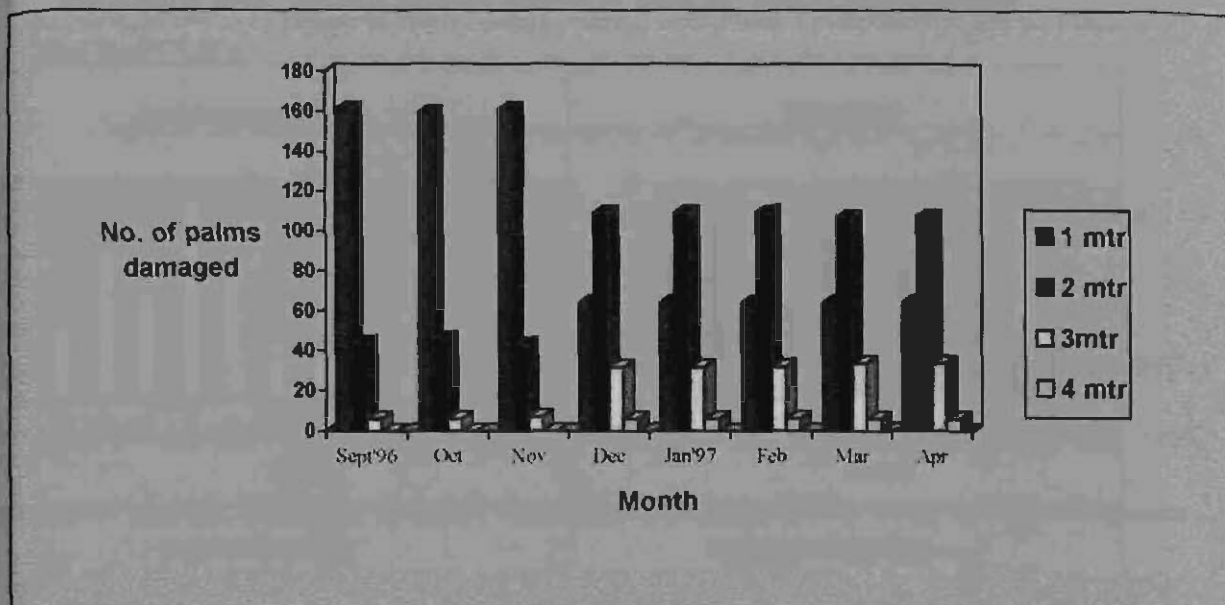


Fig 4 Porcupine damage to ECT Coconut palms at Kidu, Subramanya

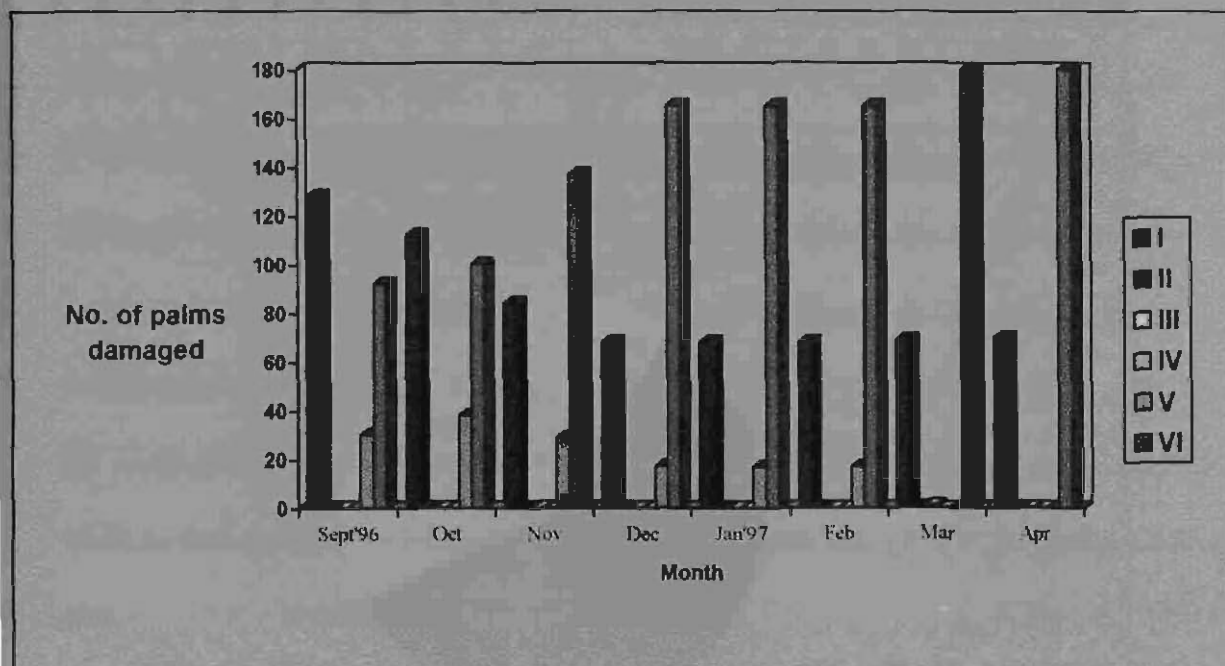
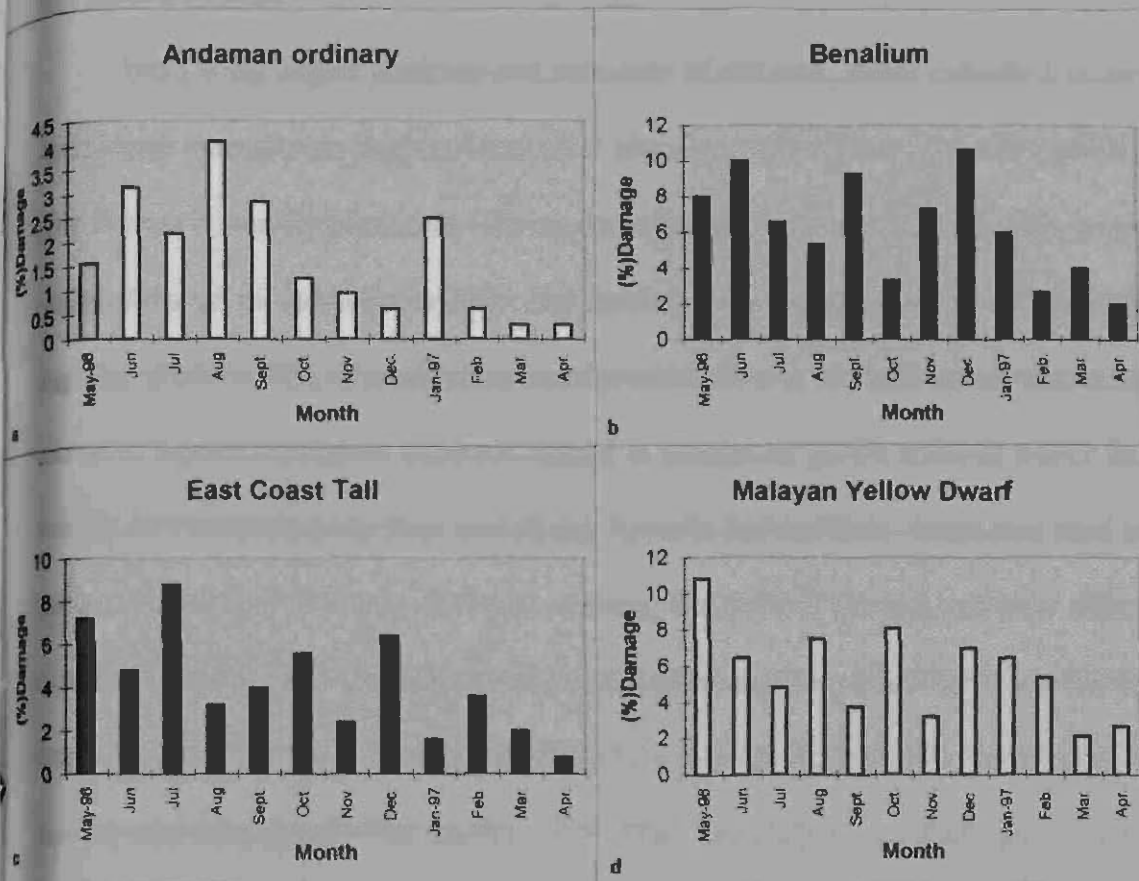
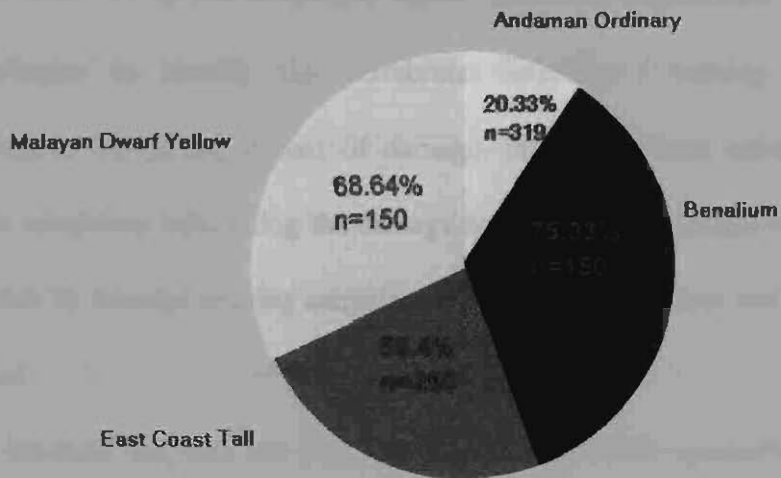


Fig 5

Porcupine damage to Coconut Palms at CPCRI, Kidu-Coastal zone



Pie-diagram of Porcupine damage (a-d) to coconut at Kidu, Coastal Karnataka - 1997 - 98



ARECANUT

INTRODUCTION

India is the largest producer and consumer of arecanut, *Areca catechu* L in the world. Areca crop contributes roughly about 250 crores rupees to the National Income and its contribution is steadily increasing. Karnataka is the major areca producing state, contributing nearly 44% of the total production and stands second in production after Kerala which together produce 76% of total Indian areca production of 1.65 lakh tonnes amounting to 90 crores of rupees. Dakshina Kannada district in Karnataka grows areca in 24891 ha. where studies on Vertebrate pests were carried out. Areca in Indian-Hindu- customs is used as one of the main ingredient in rituals. Chewing of areca, is a habit of the rich and poor alike. Being closely interlinked with the religious and social customs of our country, its use has spreaded fast.

Survey and Damage :

Monthly surveys were conducted from 1996 to 1997 in four plots of Dharmasthala (12° 59'N 75° 17' E 183 m AMSL) region, Ennakala, Eramadaka, Harpadi and Charmadi on four wheeler to identify the vertebrates infesting / causing damage to areca crop. Observations on nature, extent of damage, crop loss were estimated and the symptoms, climatic conditions influencing the damage and behavioural studies of vertebrate pests, time of infestation by damage causing animals, their habitat preferences and species composition were recorded.

Rodents viz., rats and porcupines were trapped for species identification by deploying, wooden snap traps (75 x 35cm) and metallic traps (20 x 10cms) and the rectangular traps (6.5' x 2.5' x 2.5'). The traps were stationed @ 4 – 6 / acre at niches preferred by rats, i.e., along the bunds, along stream waters between the bushes and at the base of tall indigenous trees

with overlapping layers of canopy / vegetation. Traps were inspected after every 18, 42 and 66 hr of planting the traps.

Traps were placed in the evening so that both nocturnal and diurnal animals could be trapped. Paddy grains, fruits, flour pellets, dry fish, Jack fruit peel and water extracts of ripened jackfruits and natural baits / bait preparations were used as baiting material. A number of artificial and natural baits or bait preparations were tried to render traps more effective. Local preparations of Bengal gram flour called 'Vada' was used to attract the rats found more effective bait in trapping the rats. Monkey, bat and wildboar were identified using a pair of 8 x 30 binoculars from 8-10 m and by fresh fecal pellets and hoof markings, and by visual observations.

Wildboar, porcupine and stag damage nursery plants and their herds were identified by presence of fresh dung pads and hoof markings / pug marks (photo 33). The identity was also confirmed by night patrolling parties. The stags trampling areca seedlings / grazing areca seedlings could be clearly seen during late evenings and wee hours of the day.

Areca grown in valleys, plains under the multi layered canopies of forest trees was selected for this purpose. Sitting over a bund or an elevated area, the feeding activities of monkeys and rodents were observed. The damage symptoms were recorded whenever fresh damage / attack occurred in the sites. Mosquitoes, leeches, ticks, mites and horse flies were repelled by applying ointment during the time of taking observations in areca gardens.

The species composition of vertebrate pests didn't vary considerably from one locality to another, as also the rodent species complex, but relative abundance of species varied from one habitat to another (Table 1). Monkey, *M.radiata* L; rat, *R.rattus* L; bat, *Pteropus giganteus* Brun as major vertebrate pests and wildboar, *S. scrofa* L; porcupine, *H. indica* K as lesser important animals depredating arecanut.

Among vertebrate pests, monkey is considered as the major species followed by bat, rat and wildboar. Monkeys were so destructive that crop in many areas of Dharmasthala received a serious threat. Two to three troupes consisting 25-30 monkeys surround the crop from various directions and feed on areca fruits. The un-ripened fruits were plucked-off and dropped down the trees. Such nuts carried stalks and tooth marks. Monkey's damage on nuts identified by the irregular peelings on epicarp or exocarp of the fruits. Almost all the sizes or the stages of fruits in the garden are prone to monkey menace (photo 34).

Monkeys just tend to depend on the juices of pulp mesocarp and exocarp. The dropped nuts under the trees are collected by the farmers and marketed at lower cost. Such nuts are sold under second quality at reduced prices than the actual price per ton. Bat, *P. giganteus* damage was restricted to ripen or over-ripened fruits alone. Fruits were irregularly punctured by beaks and left the fruit surface damaged. The punctured fruits may be dropped down the trees or will be taken to the roosting sites. Bats were observed carrying the fruits with their beaks to the roosting sites. Bats tend to depend on over- ripened fruits for their juicy secretions or sweet pulp.

The foraging of bats to areca gardens was observed during late evenings. A troupe consists of 25 to 30 bats at a stretch visit the garden and pick up the areca fruits. Damage to areca starts from November-December and the damage is considered as complete loss (nuts are taken of to far off places) and economically important.

Wildboar was considered minor pest on arecanut. It feeds only on the fallen ripened or dried nuts. Wildboars chew the fallen nuts or fruits and drink the juices of fruits leaving the chewed nuts nut pellets or cake on the ground. As the wildboars eat arecanut as an alternate food, their loss is considered negligible. It was found that wildboars damage to arecanut seen

in some places only where tuber crops, sugar cane, paddy, banana are not grown and the loss caused by wildboars is a complete loss.

R.rattus and *B.bengalensis* are dominant species found damaging areca. The rats in the areca gardens hoard ripened or dried arecanuts or fruits in their burrows. They store the fruits or nuts in the hollows of trees, logs, dead wood, etc. It was found that there were about 4 to 5 fruits or nuts found in a rat burrow. Growers considered rat is a serious pest under stored conditions. (photo 35). In absence of coconut rats preferred areca fruits especially.

Damage by vertebrates will be lesser in December as harvesting of all important crops come to an end. Higher monkey damage occurred from August to November, bat damage from November to December and November to December for wildboars and rat damage from December to January. The damage was intense in November, as trees have full of ripened bunches of fruits and will be prone to all kinds of damages by animals. Stag, *Cervus canis* K locally called 'Kaduve' was observed destroying the a month's old nursery plants. The animals uproot the saplings and eat upon them, causing retardation.

Yield loss :

Flowering in areca palm starts from March to April attain button size by June and the maximum by August. Ripening of areca fruits start from September and the first harvest takes place in October / November. The total harvest / complete harvest may be done by three to four installs and the crop comes to an end by February / March. The vertebrate pests start damaging the crop after ripening of fruits i.e., from October. Intense damage is recorded during November-December. As the crop reaches to an end the animals especially rats and monkeys tend to depend on summer wild fruits and coconut. Observations during November '96 to January '97 at Harpadi, revealed the entire damage caused to areca was just by monkeys. Sampling of nuts adequately covered all portions of the experimental site

This estate had coconut as an intercrop. There were non-significant differences in vertebrates damage to nuts in all the three months.

<u>Month</u>	<u>Damage to arecanuts</u>
November '96	1346.67
December	343.00
January '97	05.50
C.D at 5%	NS

Mean of 200 palms / month.

The damage was more in November as palms had ripened fruit bunches. The damage was less in December. In 1997 the damage by vertebrates was very less (4%) On an average (n=6), 4 fruits were found in rat burrows. Growers considered rat as a serious pest under stored conditions.

At Eramadaka, the mean number ($\bar{x}$ of 300 palms) of nuts damaged by monkeys during November and December 1996 were significant statistically. The mean number of nuts damaged was 1120 and 1170 during November and December '96, respectively. In November 1997, the damage was negligible or the loss was not economical. Just 350 fruits weighing 5 kg of dried nuts would be sold under second quality. Such damaged nuts will be sold lesser than the first quality nuts. The less damage may be due to the following reasons :

- Prolonged rains (50" to 70" for 30 days continuously) might have deterred the vertebrate pests.
- Coconut being an intercrop might have influenced the damage as it was preferred than arecanut, i.e., intercrop influence.
- Intense watch-n-ward.

Nuts damaged by monkeys were collected by farmers and were marketed. Such nuts are sold under second quality at reduced prices. That is to say the grower incurs a loss about 1/3 rd per ton due to monkeys.

Damage severity increased from August to November and decreased from December to February and no damage occurred as the crop matured. This way, the monkey damage differed in its extent of damage from one type of environment (crop condition) to an other. The natural disturbances like urbanization too had an influence over vertebrate pests in causing damage. At Charmadi, 70 acres areca garden was monitored for vertebrate pests damage. Nut fall due to monkeys, bats and wind as a natural factor was assessed during September and November 1996 and November in 1997, shows the damage 78.8% and 21.2% by monkeys and bats, respectively in 1996. The mean number of nuts damaged during September and November was 1003 and 257, respectively. Their being non-significant differences statistically. The data was analyzed following ANOVA, CRD.

In Charmadi, where coconut is an intercrop with a major crop of arecanut grown in 15 acres. Here the vertebrate pests damage is expected to be severe because of evergreen tropical forests surrounding the areca plantation and the place located adjacent to the foot hills of Western Ghats. The richness of vertebrate species is high here. The mean number of nuts damaged per 500 palms during September-November was 369, 46,159 and 41, respectively there being non-significant differences statistically (ANOVA, CRD at 5%).

In 1997 the damage intensity was high in November. It was calculated that there was about 450 to 500 Kg of fresh fruits damaged by vertebrates, collected for two and half days of time costing Rs 12,000 (200 Kg x 60 = 12,000, 200 Kg = dried nut weight) after drying the nut, the loss incurred was Rs 2000. Such nuts are sold under second quality Rs 10 / kg lesser than the first quality sold at Rs 70 per kg.

At Ennakala the vertebrate pests damage was less as the plot was in an urban locale. The plot was divided into three patches viz., along the forest (patch 1) along the roadside (patch 2) and center of the garden (patch 3). The data was collected for December and comparison made among the patches for the extent of damage (Table 2). There were non-significant differences in damage to nuts among the three different patches in the garden.

During December 1996, 25% damage was accounted by monkeys at patch 1, 5.8% at patch 2 and 69.2% at patch 3.

Comparative damage pattern to Arecanut by Vertebrates in coastal region is given in Table 3.

CROP PROTECTION :

The following practices were found currently being practiced by the farmers.

1. Protection of crop by Gun patrolling.
2. Making auditory sounds like drum beating, cracker bursting etc., to scare away the monkeys.
3. Spraying of repellents like Wild-Thulasi (Ocimum) extracts and wildboar extretory extract at the places, where the wildboars make an entry in the garden. The odour repels the wildboars.
4. Sound produced by Gun-shot and drum sounds, cracker bursting will scare away the bats.
5. The odour of bursting tyre repels the bats.
6. A slit made at the tip of bamboo pole installed in the garden, sounds high on pulling and releasing one half of the slit, scares away the wildboars.

Table 1 Species composition of vertebrate pests and their status as pest on Arecanut.

Vertebrate species	Plant part affected
Monkey (<i>Macaca radiata</i> L)	Fruit
Bat (<i>Pteropus giganteus</i> B)	Fruit
Rats (<i>Rattus rattus</i> L) (<i>Bandicota bengalensis</i> B)	Fruit
Wildboar (<i>Sus scrofa</i> L)	Fruit, Nut, Nursery
Stag (<i>Cervus canis</i>)	Nursery plants
Porcupine (<i>Hystrix indica</i> K)	Fallen nuts,Fruits, Nursery plants

Table 2 Scenario of damage to Arecanut at Ennakala 1996.

Sl No	Patch	Nut damage
1	Along the forest	40.33
2	Along the road	09.33
3	Center of the garden	111.67

C.D at 5% NS

n = 300 palms / month

Table 3 Comparative pattern of damage to areca by vertebrates in Coastal region.

Plot	Month	% damage by		
		Monkey	Bat	Wildboar
Ennakala	Dec'96	100	00	00
Harpadi	Nov	100	00	00
Eramadaka	Nov'96	100	00	00
	Dec	100	00	00
Charmadi	Sept'96	78.8	21.2	00
Plot 1	Nov	61.5	24.8	00
Plot 2	Sept'96	61.8	38.2	00
	Oct	58.9	41.1	00
	Nov	84.0	16.0	00
	Dec	73.8	26.0	00
Avg dam (%)		83.52	15.23	1.25

COCOA

INTRODUCTION

In south India, cocoa, *Theobroma cacao* S is a popular crop cultivated with areca, *Areca catechu* L; coconut, *Cocos nucifera* L; coffee, *Coffea arabica* L and cardamom, *Elettaria cardamomum* M or as a pure crop. Areca also forms a component crop of natural forest-like habitat in hill region of Karnataka. Because cocoa is being increasingly used in confectionary and beverages in India. It is an important crop. In addition to insect pests, vertebrates cause damage. The depredations due to rodents is reported by Abraham and Padmanabhan (1967) and Bhat et al., (1981). The species involved for most of the damages is the Wroughtons rat, *Rattus rattus* L and the Western Ghat squirrel, *Funambulus palmarum* L. Bhat (1978) recorded up to 51.3% damage to the crop in Kerala. Abraham and Remamony (1979) reported up to 60% crop loss in Kerala due to rodents. In Dakshina kannada district of coastal Karnataka and Kanyakumari district of Tamilnadu, the rodent damage reached upto 47.6% and 50% respectively (Bhat et al., 1981). Pod loses varied from place to place. In the Pacific Islands loss of 400 kg dry pod per ha was recorded (Morgan, 1973).

In Sierra Leone, monkey damage increased due to increase in their population due to hunting of leopards and ban was introduced not to eat monkeys. As a result, losses of 20 to 50 % have been attributed to monkey and squirrel attack.

A four-wheelers survey indicated that the Jungle cat, *Felis chaus*; squirrel, *F.palmarum* and rat, *R.rattus* are the important species. It's difficult to distinguish the damage by different animals under field conditions.

Species composition and seasonality :

In hill region generally, fruit setting in cocoa starts from May to July / August. Pods continue growing till the end of March. The annual pod production showed two peaks, one

occurred during July-August and the other minor during November-December. Squirrel damage commenced at the beginning of the fruiting season (July / August). The Jungle cat damage is more during pod ripening stage (October-November) and the rat damage persists throughout the season (July-December). Monkey, *M.radiata*, jackal, *C.aureus* and birds were found damaging pods during ripening stage. Stag, *Cervus canis*, bison, *Bibos gaurus* H, elephant, *Elephas maximus* L, wildboar, *Sus scrofa* L, porcupine, *Hystrix indica* K, damaged non-reproductive plant parts.

In Dakshina Kannada (12° 27' and 13° 58' N lat and 74° 35' and 75° 4' E longitude), cocoa forms an important raw material for many industries. In many situations the crop is abandoned due to vertebrate depredations. In addition to the vertebrate species mentioned above the bandicoot, *Bandicota bengalensis* L was implicated in damage. The spatial and temporal differences in feeding among different animal species helped to identify the typical damage symptoms. A definite pattern was associated with each animal species. Squirrel damaged pods during the day by making irregular, small hole at the pod terminal region (photo 36) to feed on the internal contents. The jungle cat made circular hole at middle portion of the pod, sufficiently big enough to insert head inside and feed on the contents (photo 37). Squirrel fed on unripened or ripening pods while jungle cat attended ripened pods. Monkeys fed on cocoa pods from tender to ripening stages. But their damage was restricted to certain portions of the canopy. In most cases of their feeding, the pods hang by their stalks with a portion of eaten pod. The chewed-up portions of pods are strewn at base. Monkey carried the plucked pods in jaws to various corners of the orchard and then consumed the pods (photo 38). Rats damage was mostly confined to the proximal end by gnawing rind and making a small hole. Rats preferred to damage already damaged pods, leaving a circular hole at the site of damage. Rats and bandicoots also burrow at base.

Jackals fed on pods born at the lower canopy only. Jackals held the fruits with forelegs and fed on pods as much as possible. Half-fed pods hanging at lower plant canopy is a sign of feeding by jackals. Monkey and birds followed no definite pattern of feeding. Similarly stag, *C. canis* feeds on pods (photo 39) of all stages of a tree to the extent it can rise its head by standing on hind-limbs, stretching its fore-limbs on the stem of the tree or in the air. Jackal and the stag may eat the whole pod, leaving fruit stalk to the stem or a portion of pod.

Stag, elephant, bison and wildboar debranch (photo 40) or break branches partly or peel off the bark while rubbing body or horns against the trunk. Animals while foraging may bend, trample, de top or uproot the young cocoa plants. The peeled-off branches are prone to termites or bark borers attack subsequently. The stag eats tender shoot tips, leaves and growing tips up to 2m. The stag and bison damaged seedlings and the affected seedlings failed to attain normal height and accumulate biomass.

Yield loss :

Jungle cat caused 20% and rats and squirrels 10% loss in pod yields in hill region of Karnataka (n=250 trees). Monkey, birds and jackal caused 5% loss in pod yields. On the whole 35% yield losses in cocoa was attributed to vertebrates damage in hill region of Karnataka.

At Charmadi, out of 5000 cocoa pod yielding trees 40 trees were randomly marked and pods damaged were monitored. Pods damaged by different animals were identified. The number of vulnerable pods | tree to the number of damaged pods was counted at fortnightly intervals in March and April 1997. The proportion of vulnerable pods to vertebrates feeding was at peak in March. Jungle cat and rodents damaged 81.34% and 31.13% pods, respectively. This was economically important.

At CPCRI-Kidu farm in Dakshina kannada district, bison and stag damaged non-reproductive parts of the plant. Bison fed on tender shoots causing significant reduction in plant height (Table 2). At CPCRI-Vittal farm, out of 276 cocoa seedlings, bison and stag debarked 2% and stunted 25-35% seedlings from September 1996 to April 1997. Field observations revealed that 13 to 15 bisons foraged in the experimental plot.

The damage pattern to cocoa pods by vertebrates at 30 days intervals from podding to ripened pods stage showed that the damage recorded in 1997-98 was less than that in 1996-97. The difference in pod damage was attributed to continuous heavy rains from May to September 1997 compared to that in 1996. Observations recorded showed that stag caused, on an average (n=100 trees) 243 pods / month (=100%) during March and April 1997. But in 1998, stag damaged, on an average 56 pods / month (24%), followed by Jungle cat (54%), rat (4%) and monkey (15%) (Table 2). Jungle cat caused statistically significant pod damage (Table 3). The annual pattern of cocoa pod production showed two peaks. The major peak was observed during May-August 1997 as 8000 to 9000 pods / 25 trees were recorded. The minor peak occurred during November 1997 to March 1998, where 1000 to 2000 pods were recorded at the study site.

The proportion of total pods, vulnerable pods, pods damaged by rodents for the nine months period at (CPCRI) Vittal (12° 27' N Lat and 74° 35' Long) is given in Figure 1. The ANOVA revealed significant differences in rodents damage. The pod damage during May and June was significant compared to other months (figure 2). The difference in pod damage may be attributed to the availability of a large number of vulnerable pods to which rodents are attracted.

An extensive survey of hill region covering Shimoga, Chickmagalur and Coorg was conducted in our earlier works. At Thirthahalli, in two acres cocoa plantation jungle cat and

rodents together caused 30.6% pod loss. At Nemmar (Sringeri), Chikmagalur the pod loss due to monkey, squirrels and rats amounted to 60%. At Thangalesara (2 acres) and Hugluvalli (1.5 acres), Thirthahalli, there was a cent percent loss and the farmer abandoned cocoa cultivation. At Kuruvalli, Thirthahalli, Jungle cat damage began 100 days after flowering and it was 21% and due to rodents pod damage was 7.06%. At Niranki (Mudigere) pod damage due to Jungle cat was 15.20 percent, squirrel (10.15%) and birds was 2.5% (Table 4).

Observation on feeding potential of Jungle cat and rodents was recorded at Hugluvalli, Thirthahalli earlier. The farmer cultivated 220 cocoa plants. Fruits were harvested during April-May and October-November. Each squirrel and rat was observed feeding on 4.4 and 6.7 pods, on an average (n=30 days) per day. Jungle cat damaged 5.6 pods (n=30 days) per day. Rats and squirrels could be easily trapped in wooden snap traps baited with paddy grains. The cocoa pods damaged at Hugluvalli by four vertebrates is given in Table 5.

Crop protection :

Poison baiting trial with Carbofuran 3%G and Warfarin was undertaken at three localities. Fruits of banana variety 'puttabale', a local cultivar were incised and 2 to 4 g of above two poisons were placed in split portions of banana. Three such banana fruits were hung at 1.0 to 1.5 m height on the tree branches. Twelve such baits were placed per acre. Observations were recorded 24 hours after baiting. Locally made wooden snap traps were also placed with banana serving as bait.

Baiting operation against jungle cat need to be taken when first few pods turn yellow (Table 6). Baiting and trapping proved effective and eco-friendly. The number of healthy pods / plant significantly increased in the treated plots compared to untreated plots. At Kuruvalli (Thirthahalli), Carbofuran baited banana claimed mortality of 9 jungle cats in 3 months. Before crop protection measures, the farmer realized Rs 900 and after measures were

executed the farmer realized Rs 2,200 per year. In Sirsi, Uttara Kannada district, wet jaggary served as bait carrier. Cocoa adjacent to forest suffered the heaviest damage largely because of its seasonal cropping pattern, as cocoa formed a part of the diet of the mammalian species. Everard (1964) stated indiscriminate use of poisonous chemicals on cocoa pods to be avoided as much as possible. However, spraying the pods with poisons should be rejected as poisons are hazardous to environment and after ineffective and uneconomical. In open field conditions, repellents have proved ineffective. Under laboratory conditions, anti-coagulant treated baits have proved effective (Mathur and Ishwar Prakash, 1980) against small mammals.

In coastal region, *Ficus glomerata*, *Artocarpus hirsuta*, *Terminalia bellarica*, *Emphilica officinalis* G etc., are the wild foods available to the key vertebrate species feeding on cocoa during April-June i.e., podding stage of crop. Species of *Phoenix*, *Strychnous*, *Amorphophallus* etc., are available to animals through out the year. The above wild foods influenced crop damage and population of wild animals depredating cocoa in the study area. The presence of wild foods helped in reducing crop damage. So habitat management, timely harvests, snap trapping and baiting can form essential components of Vertebrate Pest Management in Cocoa.

Table 1 Stag and bison damage to Cocoa seedlings as indicated by height.

Month	Height (m) of the seedlings						
	0.25	0.50	0.75	1.00	1.25	1.50	1.75
No of seedlings							
September '1996	33	146	0	97	0	0	0
October	58	146	0	72	0	0	0
November	43	50	119	12	52	0	0
December	12	53	53	108	7	43	0
January '1997	12	53	53	108	7	43	0
February	10	55	50	201	7	43	0
March	9	24	72	59	83	4	25
April	0	3	19	84	41	93	6

Expected height of seedlings = 2m

Table 2 Monthly damage pattern to cocoa by Vertebrates at Charmadi, Dakshina Kannada.

Month	Monkey	Stag	Damage caused by			Pods damage by all vertebrates (%)
			Squirrel	Rat	Jungle Cat	
May '1997	19	26	13	9	64	13.67
June	18	27	12	10	63	13.41
July	19	26	13	9	66	13.90
August	87	144	0	10	324	59.60

Stag = 24%; Rat = 4%, Squirrel = 4%, Monkey = 15%, Jungle Cat = 54%

Table 3 Mean number of pods damaged by Vertebrates at Charmadi, Dakshina Kannada.

Vertebrate species	Mean no. of pods damaged in 4 months
Monkey	35,750
Stag	55,750
Squirrel	9,500
Rat	9,500
Jungle Cat	129,250

CD at 5% = 99.33; SEM + 46.39; CV = 136.84; n = 100 tree

Table 4 Damage by Vertebrate pests to cocoa pods in hill region of Karnataka.

Location	Vertebrate Pest					
Taluk / District	JC	M	S	R	J	B
Sringeri	29	1	1	1	0	1
Koppa	24	0	2	1	0	0
Kalasa	7	1	13	7	1	1
Thirthahalli	9	0	19	13	1	1
Sagar	18	0	15	4	1	5
Soraba	14	1	11	17	12	2
Sirsi	43	2	27	19	19	1
Total	144	5	88	62	34	11
Mean	20.5	0.71	12.57	10.28	4.85	1.57

* = Actual pods damaged. Mean of two seasons data.

JC = Jungle cat; M = Monkey, S = Squirrel, R = Rat, J = Jackal, B = Birds.

Table 5 Vertebrates damage to pods at Huguluvalli.

Plot Nos.	Jungle cat	Monkey	Jackal	Squirrel	Rat
1	29	1	0	0	0
2	24	0	0	0	0
3	7	0	0	13	7
4	7	0	0	12	11
5	18	0	0	12	0
6	12	0	32	3	17
7	42	0	0	27	30

Mean CD at 5% 19.85 0.14 4.57 9.57 9.28

Table 6 Effect of poison baiting * on vertebrates feeding on pods ** in hill region of karnataka

Location	Treated plots		Control plots Healthy pods /plant at begin ing of season	Healthy pods/ plant at end of season
	Healthy pods/plant Before treatment	Healthy pods/plant after treatment		
Nemmar	06	40	11	5
Hugluvalli	09	28	13	3
Kalpatharu	11	33	14	2
Total	26	101	38	10
Mean	8.68	33.66	12.66	3.33

0.05% Carbofuran 3%G, 0.05% Warfarin, ** = 200 plants/location, mean of 2 seasons

Fig 1 Vertebrate Pests (Rodents and Jungle Cat) damage to Cocoa pods at CPCRI-Vittal, Dakshina Kannada, Coastal Karnataka

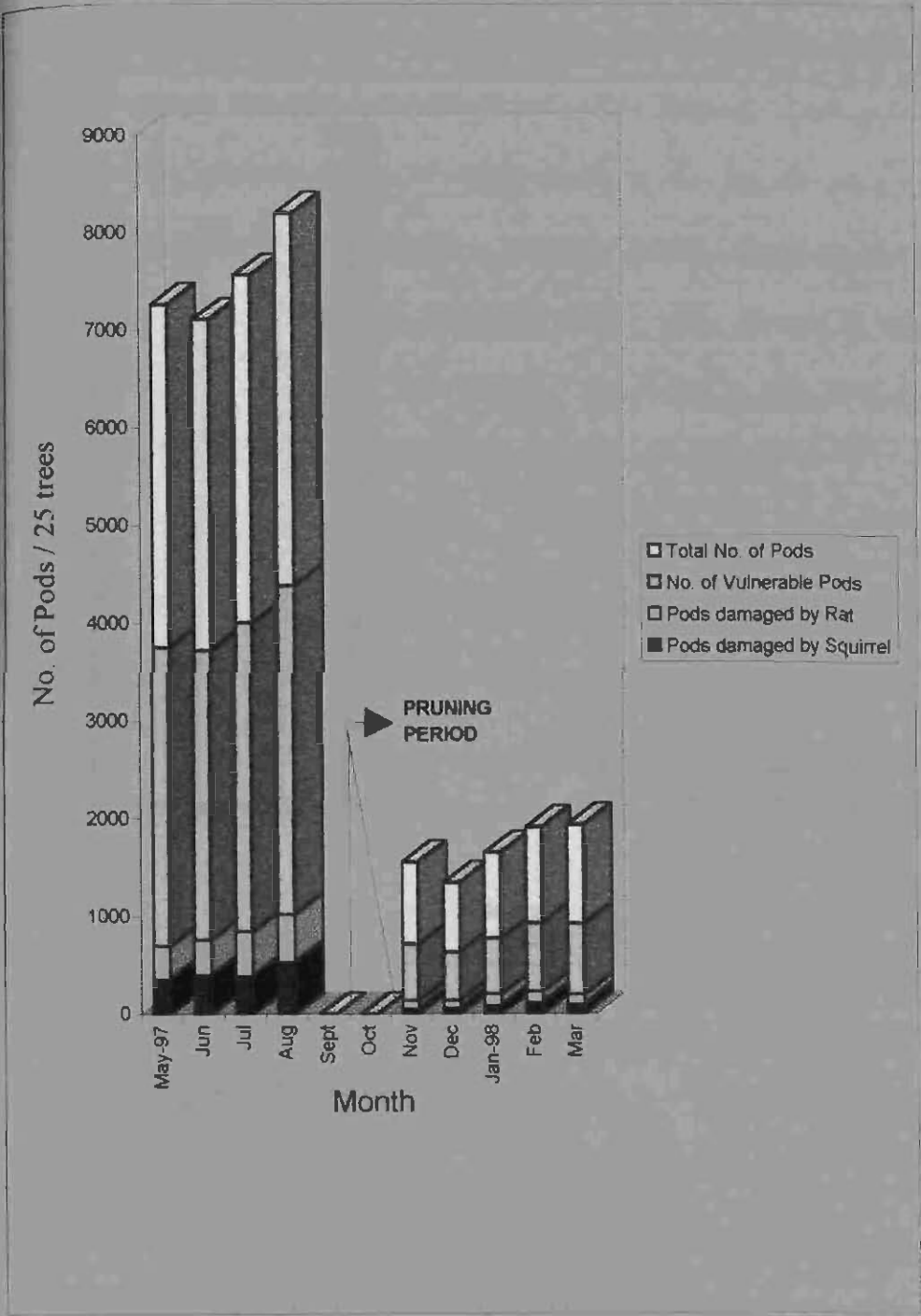
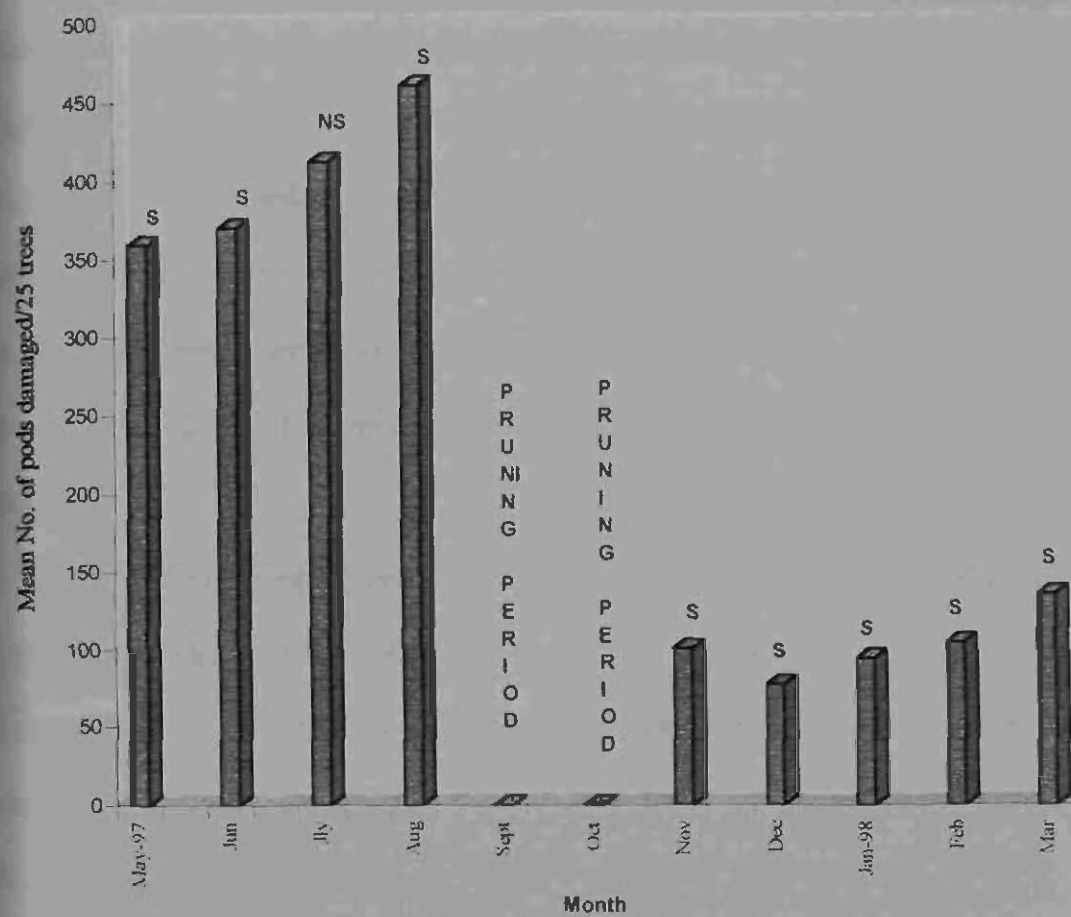


Fig 2 Vertebrate pests damage to Cocoa pods at CPCRI - Vittal , Dakshina
Kannada. Coastal Karnataka



Bandicota bengalensis

OIL PALM

INTRODUCTION

India will have to import more than one million tonnes of edible oils to bridge the gap between demand and domestic availability (Sood, 1996). Oilpalm, *Elaeis guianensis* Jacq, the highest oil yielding crop per unit area has bright prospects to bridge this gap, which is annually incurring millions of dollars for the country. In Karnataka, the crop was introduced in 1989 and is now grown in over 2800 ha (KCOGF, 1996). The growers in Shimoga district, experienced severe damage to oil palm fruits by vertebrates particularly birds. So studies were initiated to protect oil palm fruits from bird damage in Shimoga.

Survey :

Birds frequenting oil palm plantations in Shimoga, Bhadravathi, Lakkavalli, Tarikere and Channagiri taluks in Bhadra command area were identified with a pair of 8 x 30 binoculars from 10 to 20 m. Observations on flock size, frequency of visits, feeding rate, time of feeding and age of palm were recorded.

Porcupine (*Hystrix indica* K) :

Oil palm, is also increasingly being damaged by the Indian Crested Porcupine, *H. indica* in Hosanagara, Honnalli, Sagar and NR. Pura, taluks of Shimoga and Chikmagalur districts, respectively. As man is encroaching upon animal's habitat, its pestilent activity is increasing.

The porcupine was observed injuring the oil palm during night either by burrowing at the base and feeding on the basal portion of the stem and feeding on roots or by gnawing at the tissues of the stem. As the palm grows, the animal peels off the bark with its sharpened incisors. After gaining access to the seedling (1 or 2 years old) or young plants (usually of 3 to 4 years age), the 'heart' or 'core area' of seedling is eaten off. The young palm succumbs, despite the fronds remaining green for a long time.

Observations with torchlight and date records revealed that a porcupine damaged on an average, four seedlings (n=25) \ day. Compared to coconut and arecanut, oil palms are covered with scaly, spiny fissures, the damage inflicted is comparatively less. Yet in palm seedlings. (1 or 2 years old) the damage can be severe and may warrant crop protection measures. In coconut and areca, observations have shown that after injuring the bark and basal portion, the animal gains access to the bole region, the pith and as a result, the entire palm is killed. Rats were also observed causing damage to the bole region by burrowing (photo 41).

NATURE OF DAMAGE :

Roseringed parakeet, *Psittacula krameri* K; Indian myna, *Acridotheres fuscus*; house sparrow, *Passer domesticus*; jungle crow, *C. macrorhynchos* and house crow, *C. splendens* were identified as important pests (Table 1). In addition, wildboar, country hen, *Gallus indica* and jackal, *Canis aureus* feed on fruits. Of all, it is the bird pests that are important economically (Table 2).

In different parts of Shimoga, oil palm seedlings, fruit bunches and palms were observed to be damaged by rats. At Mudigere, among 35, Two-years old seedlings, four were completely destroyed by *Bandicota bengalensis* B. Cleaning the palm basins, removal of weeds, closing burrows and incorporation of 10 G Thimet into active burrows alleviated the problem.

Crows are the most potential pests of oil palm in Karnataka. When alternative foods are not available, birds caused considerable losses to oil palm. Mechanical protection to bunch from bird feeding can be accomplished by covering the bunch completely and firmly by bags or thatch. But, as bunches will be borne at heights, covering the bunches will be difficult.

Vertebrate depredations are a major constraint to increasing oil palm productions in Karnataka. It is a new crop, grown in small areas and it bears energy-rich fruits to which the

animals are attracted. In fact, understanding animal-oil palm interaction is so important that for successful cultivation in river-canal tracts, a separate and detailed study is urgently required.

The damage symptoms on fruits of different cultivars were recorded. Damage to fruit bunches was quantified and fruit-losses were assessed in terms of number of fruits lost due to bird feeding. In affected plantations, protection methods involving dried plant-parts, poly bags and gunny bags were tried with ten palms / treatment x 3 replicates. A parallel control was run at least 20 m away from the treated spots. The protection afforded to the palms in terms of number of fruits saved was quantified and practical feasibility of protection methods was evaluated.

Ten bird species were recorded feeding on palm fruits (Table 1), of which the parakeets, the crows and the common myna were considered as major pests based on feeding rate and abundance. Of the two species of crows, jungle crow was economically important because of its higher feeding rate, larger size and population. In Shimoga, this species is more abundant and large flocks (> 50 birds / flock) are frequently sighted on oil palm. Jungle crow is dominant over house crow. Crows begin feeding on palm fruits right from the first year of bearing. Jacob and Mathew (1995) recorded mynas, crows and babblers on oil palm in Kerala.

The rose ringed parakeet caused severe damage to oil palm when fruit bunches are borne above 3m. At greater heights, parakeets were observed landing on palms in flocks of 15 ± 4.5 birds (n=50) and on an average 27 ± 5.5 birds / acre (n= 50) were observed in plantation at Tarikere during 1995-96. Parakeets and crows followed a clump distribution pattern while foraging on in small (even in an acre) and isolated patches compared to large (over 1000 acres) plantations in traditional oil palm (for example in Kerala) growing areas and palm is a new food for birds. This allowed the birds to congregate and cause fruit-losses.

Behavior, Damage and Loss :

Crows possess a very expressive and eloquent vocabulary for announcement of food finding. As one individual alights on a ripening oil palm bunch, the bird emits a series of croaks and soon crows gather in the plantation and begin feeding. With their heavy, slightly incurved bill, the whole fruit is wrenched off the bunch. The fruit pulp is gulped bit by bit. Crows caused considerable extra depredative losses (wastage) than actually what they consumed.

The orientation of bunch on palm did not allow crows to damage all fruits in a bunch. Crows damaged only easily accessible fruits and moved on to another bunch for feeding. However, parakeets preferentially fed on basal portion of fruits as the pericarp here matured early and birds were sighted even 'upside-down' feeding on fruits. The crows and parakeets frequented oil palm plantations specifically to feed on fruits and damaged only healthy, fresh fruits. Crows and parakeets are dominant species and in oil palm are **primary feeders**.

Mynas preferred to feed on fruits damaged by crows and the parakeets. So mynas are **secondary feeders**. The fruit damage by birds was related to the fruit production and bird population. Based on the number and extent of fruits damaged, crows and the parakeet caused significantly more fruit-yield losses (Table 2). During November 1994 and May 1995, the palms did not attain height and so parakeets did not damage the fruits. Of 50 bunches, crows and parakeets together caused damage to 44 bunches. However, the methods, loss and analysis used to quantify damage in oil palm from birds or other animals need to be compared and standardized (Wood and Lian, 1984).

Protection methods :

Birds :

All observations were recorded from 1990 to 1996 in aforementioned taluks of Shimoga. During December 1993 to February 1994 and 1996-98 at Santekadur village, in a two acres, four years old oil palm plantation, three protection methods were evaluated following Complete Randomized Design (CRD). Ten palms were selected for each method with three replicates per treatment.

Method I : Ripening, un attacked fruit bunches were covered with a thin, wire mesh (0.8 x 0.3 m width) sheet.

Method II : Waste polybags (0.5 x 0.3 m) were used to cover the bunches as thoroughly as possible.

Method III : Six to eight, dried (waste) bunches were tied along a metallic wire and the entire 'garland of bunches' was placed on the bunch. This is popularly called as **K.K. bunch** method in Shimoga.

The above three methods were evaluated with a control. Fifteen days after treatment, average number of fruits damaged / bunch by birds was recorded. During April-May 1995 and 1996-98 in a 5 acres, four years old plantation, another set of three control methods were tried. Ten palms were chosen for each method. Each treatment was repeated twice with a control plot. Paddy straw thatch, palm-leaf thatch and 'K.K. Bunch' were evaluated.

Wire mesh covered bunches recorded 10.9 per cent damage, plastic bag covered bunches, 9.2 per cent while the 'K.K. bunch' recorded the least fruit damage of 1.6 per cent. The mean fruit damage in wire mesh and plastic bag covered bunches was statistically on par with one another. The control bunches recorded a mean of 48.95 per cent damage. ANOVA revealed significant differences among the methods (Table 3). The results were consistent in

all the three sets of experiments. In addition, K.K. bunch cover method was tried at Tswarachikenahalli and Virapura villages in Bhadravathi in June 1996. The method protected the bunches from bird damage (Chakravarthy, 1997). Similarly, paddy straw and thatch prepared from discarded oil palm parts ensured protection to bunches from birds damage in replicated trials (10 palm / treatment x 3 replicates) at Barandur village, Bhadravathi during June, 1995. However, growers heavily pruned leaves of palms and this practice may be counter productive (Chakravarthy, 1996). The above protection methods are practicable only when fruit bunches are below 3 m. Jacob and Mathew (1995) also evaluated wire net, reed basket, plaited coconut leaves and oil palm leaves and found them useful in protecting bunches from bird damage.

Protection methods using repellent tapes or reflective ribbons, light reflectors, distress calls, ultra sound scaring, other auditory and visual scarers (hanging dead crows, drum beatings) in Kerala (Jacob and Mathew, 1995) and 'K.K. bunch' in Karnataka (Chakravarthy and Abraham, 1995) have been tried, but with little success. There is a need to develop and integrate, eco-friendly approach which would sustain oil palm without killing birds. Timely harvests, scaring away birds during peak feeding periods, provision of alternative foods for birds in and around plantations, covering fruit bunches and intercropping are component tools worthy of investigation.

Porcupine :

The basic consideration is that the base of palms (be it coconut, areca or oil palm) should be firmly covered with or wrapped up with thorny bamboo sticks or dry sticks, compactly and tightly or a wire guard netting is fixed around the basal region to protect the seedlings. However, when the wire guards are fixed, it must be loosened now and then, so as not to restrict the basal growth of seedlings. The Stockade trap, is an approved method of

trapping porcupines, a paste of cement or Bordeaux mixture or waste lubricant oil or coal tar can be laced to about half a meter from base. Weeds or bushy growth from basins can be removed and base of the palm should be exposed. Nurseries containing seedlings of different age can be effectively protected by electric fencing. The animal dwells in tree hollows, burrows and such hollows / burrows can be destroyed. Damage to oil palm in Shimoga is severe during summer (February to April-May). The grower needs to be more vigilant during this period. Porcupine proof fences, fall traps, 10% G Thimet, Zinc phosphide baits with palm oil in cassava roots, etc., can also be used to protect palms from porcupine damage. These methods are being currently evaluated in replicated plots in different parts of Shimoga.

Table 1 Bird pests of Oil palm in Karnataka.

	Status	Economic Status	Abundance
<i>Psittacula krameri</i> (Roseringed Parakeet)	R	M	A
<i>Corvus macrorhynchos</i> (Jungle Crow)	R	M	A
<i>Acridotheres tristis</i> (Indian Myna)	R	M	A
<i>Corvus splendens</i> (House Crow)	R	M	A
<i>Centropus sinensis</i> (Crow Pheasant)	R	M	A
<i>Pycnonotus cafer</i> (Redvented Bulbul)	R	m	LA
<i>Passer domesticus</i> (House Sparrow)	R	m	LA
<i>Acridotheres fuscus</i> (Jungle Myna)	R	m	LA
<i>Sturnus pagodarum</i> (Brahminy Myna)	R	m	LA
<i>Gallus indica</i> (Country Hen)	R	m	LA

R	=	Resident
M	=	Major pest (> 0% fruit yield loss)
m	=	Minor pest (< 10% fruit yield loss)
A	=	Abundant (> 100 / km ²)
LA	=	Less Abundant (< 100 / km ²)

Table 2 Details of bird damage to Oilpalmⁿ, 1994 to 1998.

November 1994	Crows	Parakeets	Mynas	Country hens	Other birds	Other animals
Fruit-bunches damaged no.	11	Nil	6	6	5	7
Extent of damage (%) (n=35), CD P = 0.05	1-75 NS	Nil	1-15	1-15	1-10	-
Extent of damage (%) (n=55), CD = 0.05	2-80 8.78	Nil	1-25	1-10	1-10	-
May' 1996, 97 & 98 (avg) Fruit-bunches damaged no.	24	20	14	Nil	3	5
Extent of damage (%) (n=50), CD P = 0.05	1-90 11.24	1-90	1-10	Nil	1-10	-

ANOVA conducted for only number of fruit-bunches damaged.
NS-Non Significant

Table 3 Methods tested for protecting Oilpalm from bird damage.

Method	Fruitdamage (%) / bunch	Cost (in Rs / bunch)
Wiremesh cover	10.9	3.00
Plastic cover	9.2	1.00
K.K. bunch cover	1.6	1.00
Control (no protection)	48.95	0.15
CDP = 0.05	7.55	0.15

Mean of 3 sets of data : each set = mean of 10 palms. Data subjected to ANOVA

ORCHARD CROPS

INTRODUCTION

Vertebrates may use orchards for food, shelter, nesting and roosting, cause often either temporary or permanent damage. The fruit-loss due to vertebrate pests is of great magnitude and little attention is paid to their management. This is because cultivation of edible fruits has come to fore in India only in the twentieth century. Also crop losses due to vertebrates are often accepted as part of the normal run of events or the crop itself is avoided.

Orchards in India represent usually a small, mixed crop, biologically diverse ecosystems in tropical and subtropical parts where, cultivation is not along modern lines. This implies that methods of pest management like chemical applications are not desirable. Much of the damage to orchards is as a result of conversion of or encroachment into, the natural habitats of wild animals. Field observations on vertebrates inflicting injuries to fruit crops were initiated at the Central Horticultural Experimental Station (CHES), Chettalli (11° 56' N and 75° 22' E 3,100 m AMSL), Kodagu, and at Mudigere (75° 37' 35" E, 13° 7' 29" N long 982 m AMSL), Chikmagalur, Karnataka. The total area under cultivation of fruits in Karnataka is 1,02,540 ha and an average production of 9,24,642 tonnes (Mango, Banana, Guava, Sapota, Lemon) (Report-1999, Directorate of Economics and Statistics, Bangalore).

Observations on vertebrate pests depredations on orchard crops was recorded at Central Horticultural Experimental Station (CHES), Chettalli which lies on the summits and the eastern and western slopes of the Western Ghats. Western Ghats are situated on the south-west part of Karnataka. CHES is surrounded by thick teak forests on the east and south which forms natural habitat for elephant, *Elephas maximus* L; bison, *Bibos gaurus* L; bats, *Pteropus giganteus* B; *Cynopterus sphinx* V; wildboar, *Sus scrofa* L; porcupine, *Hystrix indica* K; birds, roseringed parakeet, *Psittacula krameri* K; jungle crow, *Corvus*

macrorhynchos W; house crow, *Corvus splendens* V; redvented bulbul, *Pycnonotus cafer* L; red whiskered bulbul, *Pycnonotus jocosus* L; chloropsis *Chloropsis aurifrons* T; lorikeets, *Lorichulus sp* .The list of vertebrates depredating on Guava and their pest status is given in Table 1.

Lack of grass in the forest is forcing vertebrates to take to fruit crops in the station. Elephants destroyed fence, walls and bison jumped over fence of about 3m. Night patrolling, cracker and dynamite bursting, construction of elephant proof trenches, fires and use of high intensity lights during nights are being vigorously executed in the station. It is under this background that observations on vertebrate pests were recorded. Observations were also recorded at Gonikoppal, Kutta and Ponnampet. in Kodagu district. Results of experiments on fruit crops is reported below.

Guava (*Psidium guajava* Linn) :

Observations on vertebrate pests of guava, *Psidium guajava* L and sapota, *Achras zapota* L fruit crops were recorded at the CHES, Chettalli. Area of guava and sapota plots were 1.5 ac and 2.5 ac, respectively. ‘Allahabad Safeda’ and ‘Cricket Ball’, cultivars were planted during 1989 and 1990. The guava plot was surrounded by papaya (Coorg Honey Dew) and banana (Cavandish) on the South and Citrus plots on the East. An uncultivated patch was found on the West and by buildings on the North. The area experiences 70-80” rainfall annually.

The Roseringed parakeet, *Psittacula krameri* K and two species of bats viz., Indian flying fox, *Pteropus giganteus* B and Short nosed Indian fruit bat, *Cynopterus sphinx* V above were the principal depredators on guava fruits, causing losses over 90%. Amongst different species of birds, the parakeets, lorikeets and crows were the primary feeders

(photo 42), bulbul and chloropsis, the secondary feeders, and others like munias, *Lonchura spp.* were the tertiary feeders as these birds fed on already damaged fruits only (photo 43).

The seasonal pattern of vertebrates damage to guava fruits at CHES (Table 2) showed that peak damage (28.12%) (nearly 3,000 fruits / 25 trees) occurred during August and minimal during February (3.49 %) (363 fruits / 25 trees) and March (7.1 %) (738 fruits / 25 trees). From April to June, guava fruits were not available to the animals. Much of the damage (%) occurred between August to December when protection to fruits is desired. The crop protection measures need to be initiated by July.

The number of fruits damaged among four weeks was statistically significant but within a week, the damage was non-significant. Interestingly the fruit damage was statistically significant amongst different weeks. This indicates that the harvest of ripened fruits can be delayed within a week but not beyond a week. If the harvest of fruits is delayed beyond a week, significant number of fruits get damaged or lost.

The number of guava fruits damaged varied significantly from one month to another (Table 2, fig 1). When the fruits began ripening, the damage was lesser and as the number of fruits increased, the damage also increased. From August to December, the percentage damage of fruits remained almost constant.

The number of birds and bats visiting the guava plot during morning (6.30 to 9.40 a.m.), noon (12.00 to 3.15 p.m.) and evening (4.00 to 7.15 p.m.) was monitored using a pair of 8 x 30 binoculars from 4 to 5m. Irrespective of the months, maximum number (965) of birds and bats visited the plot during evening, followed by morning (862) and then noon (91) (Table 3). There were significant differences in the number of birds and bats visiting the field. These differences may be attributed to the proportion of parakeets to bats, availability of alternate food sources and the environmental factors. More number of birds and bats foraged

in the guava plot during August to January coinciding with the period of maximum fruit damage (Tables 2 & 4). Thus confirming that fruit loss in the plot was mainly due to feeding of birds and bats .

The number of pecks (feeding rate) per ten minutes during morning (6.30 to 10 a.m.), noon (12 to 3.15 p.m.) and evening (4.00 to 7.15 p.m.) in different months by an individual parakeet is given in Table 4. Statistically significant number of pecks were made during evening (1153), compared to morning (785) and noon (346). This trend coincided with the trend in the number of individuals of parakeets. The number of pecks by a parakeet during different times of a day and during different months varied. The trend in the density of birds and bats at different times in a day and the variations in their feeding rates are also depicted in Figures 2 & 3 .

The number of vertebrates (mainly parakeets) foraging for feeding remained more or less the same varying from 197 to 230 from August to March in the guava plot. The fruit feeders reached carrying capacity in March. Several individual feeding bouts got terminated within 10 minutes due to various reasons under the field conditions . On the West the Station is surrounded by wetlands which formed part of the natural habitat of the wild animals. On the north the Station is surrounded by coffee, *Coffea arabica* L & *Coffea robusta* L which imitate the natural habitat of wild animals.

Roseringed parakeets fed on seeds, berries, fruit and nectar and severely damaged guava fruits. Small green barbet and jungle crow, *Corvus macrorhynchos* damaged guava fruits in hill region of Karnataka, where birds on an average, incurred 14% unripe, 24% partially ripe and 33% ripened fruit loss. Birds gnaw even unripe fruits, wasting far more than they actually eat. The loss caused by birds to fruits was positively correlated with age. Redvented bulbul and redwhiskered bulbul are minor pests. Indian flying fox, Indian short

Short-nosed fruit bat (photo 44) and parakeet are major pests on guava in hill region of Karnataka. In guava orchards, birds particularly parakeets caused so much loss that protection is warranted. Bisons, elephants, cattle debranch and trample (photos 45 & 46) the guava trees while they pass through the orchard. Bisons graze on guava fruits gregariously and cause economic losses. The guava seeds in the bison dung pad (photo 47) show the severity of damage caused by them. Watch-n-ward, night patrolling, cracker bursting, drum beating, auditory sounds can alone drive the animals to some extent.

SAPOTA (*Achras zapota* L) :

Observations on vertebrate pests depredating sapota, *Achras zapota* L were recorded at CHES. Thirty years old Cricket ball sapota in two and half acres was selected for recording observations on vertebrate pests. The sapota trees had good canopy cover and growth up to 4 m. The bare ground was littered with leaf mulch. The red sandy loam soils were rich in organic matter and the trees were spaced at 3 x 3 m. Fruiting in trees began in June with a peak during February.

A survey was conducted during 1999-2000 in and around CHES to determine the species composition of vertebrates depredating sapota. Sixteen vertebrate species were found depredating sapota. Of this, roseringed parakeet and the bats, *C. sphinx* (Shortnosed fruit bat), *P. giganteus* (Giant flying fox or Large flying fox) were the main depredators causing economic losses. All the vertebrates were divided into fruit feeders and shoot feeders (Table 1).

Symptoms and Nature of Damage :

Birds :

Birds were found damaging ripening fruits. Birds punctured the fruits by sharpened beaks and feed on the internal sweet pulp or content. Birds peck the fruit leaving the markings

of their beaks on the fruit. Whereas the crows, lorikeets, redvented bulbul, redwhiskered bulbul and chloropsis showed very sharp and acute markings made deeper into the fruits as their beaks are sharp and long.

Bats :

The distribution of bats and their foraging patterns were largely influenced by the seasonal flowering and fruiting. Smaller fruit bats were observed hovering and picking fruits on the wing. Bats feed usually at resting position hanging head downwards. All the bats are voracious feeders. A small fruit bat may eat more than its own weight of fruit at a single meal. The pulp of the fruit is chewed, only the juice is sucked and the substance rejected as they live upon liquid, not upon solid food. Fruits damaged by bats can be distinguished by their teeth (incisors) markings seen as narrow canals or grooves on the fruit, covering more fruit surface superficially (photo 48).

Bison, cattle, elephant and wildboar destroyed the branches while they forage through the orchard and the cattle fed vigorously on the ripened fallen fruits. Wildboars uprooted the orchard or nursery plants. These animals caused either debarking (photo 49) or debranching (photo 50). Similar damage is inflicted to citrus (photos 51 & 52) debranching and debarking, respectively).

Jungle cat, *Felis chaus* G fed on ripened fruits. Porcupines, *H. indica* were found feeding on the fallen ripened or ripening fruits. The chewed up portions of fruits fallen in the orchard showed porcupine's entry into orchard. The jungle cat and the porcupine depredated on sapota, when preferred foods like root vegetables, bulbs, etc., were not available to the animals. These two animals were of less economic importance. Monkeys, *Macaca radiata* L fed on ripening and ripened fruits in troops consisting 20 to 25 animals. The monkeys didn't feed on the un ripened fruits. The half eaten fruits were found strewn all over the orchard.

Parakeets and bats were observed partially feeding on each fruit before switching on to fresh fruit. Nevertheless, even partially fed fruit is considered as complete fruit loss because such partially fed fruits lose market value.

Bats damaged the fruits partially and left them hanging on the tree itself. While carrying the fruits in flight bats were observed dropping few fruits. Whereas birds were not observed carrying the fruits and leaving the partially damaged fruits on the tree.

The number of sapota fruits damaged by birds (Predominantly, *P. krameri*) and bats (predominantly, *C.sphinx* and *P. giganteus*) is given in Table 5 and the same data is depicted in Figure 4. The trend in the pattern of sapota fruits damage by birds and bats was similar i.e., peak damage occurred during January and declined March onwards. The bat damage occurred throughout the fruiting period i.e., from September to March. While the bird damage occurred from November to March. This suggests that bats are incurring losses by damaging even un sized and un ripened fruits. The two types of animals are mutually exploiting the resources by feeding at different times of the day i.e., bats during night (nocturnal) and the birds during day (diurnal). The sapota fruits damaged by birds and bats during different months was found statistically significant, CD being 19.59 for 7 months data (Table 5). The fruit damage was statistically more during January and February and it was significantly less during December and March. The mean fruit damage attributed to bats through 7 months period was 279 fruits and that due to birds was 247. The factorial ANOVA yielded significant differences between the two (CD at 5% = 19.59).

The fruit damage depended primarily upon the number of fruits per tree or plot. The fruit damage was more as the number of fruits increased. The number of fruits per tree and the damage were positively and significantly correlated. The correlation and regression analyses revealed damage due to birds was positively and significantly correlated with the

number of fruits per tree ($r = + 0.8598$). The bat damage was also positively and significantly correlated with the number of fruits per tree ($r = + 0.9497$) (Table 6). The fruit damage was influenced precisely by the number of vulnerable fruits available i.e., to say, the availability of ripened fruits for feeding.

Data on fruit damage among 25 sapota trees is given in Table 7. The same data is depicted in Figure 5. ANOVA analysis revealed non-significant differences in fruit damage among 25 trees. This indicates that as the sapota trees were similar in age, size, growth canopy structure and shared the same environmental conditions, the tree and the fruit parameters didn't influence the fruit damage among 25 trees.

To confirm field observations, data on girth at breadth height (GBH) was subjected to correlation and regression analysis. It revealed that both GBH and canopy size was not correlated with number of fruits (Table 8) per tree, indicating that, GBH and canopy size will also not be correlated with fruit damage. Indeed when the data ($n = 25$ trees) on GBH and canopy size was subjected to analysis, no relationship was obtained (Table 9). The same data is depicted in Figure 6.

Three visits were made everyday for counting the parakeet population in the orchard. However, the birds were seldom sighted feeding on the fruits during noon and less population or frequency observed during evenings. On an average, 46 parakeets per day were found visiting the orchard (Table 10). On an average, seven bats were observed per day in the experimental plot and 23 at the roosting site (Table 11). In general, it was found that about 700-800 bats foraged in the area per day and the observational plot was situated within the feeding and foraging zones of the bats. This data is preliminary and further observations are required throughout the year.

Feeding rates of Roseringed parakeet and Jungle crow :

To determine the economic importance of fruit feeders, observations on feeding of roseringed parakeets and jungle crows on sapota fruits were recorded. The parakeets alight in the orchard as flocks consisting six to eight birds during active morning hours. Birds perched on single tree in which they found more fruits vulnerable or exposed at periphery of the canopy. Birds don't get into the canopy and feed. Birds hardly spent 15-20 min for feeding on each tree. Feeding. The parakeets were not found feeding individually but in flocks. Jungle crows fed independently. Roosting sites of parakeets were generally found in surrounding borders / areas, and so birds used orchards for feeding only. The damage to sapota by parakeets is considered comparatively less as the guava, crop stands as an alternate and active feeding zone / crop in CHES.

The feeding rates of parakeets calibrated as number of pecks per minute varied from 12-18 pecks per minute. (n = 11, observations spread over nine days), obviously the rates were maximum during early hours i.e., between 6 to 9 a.m., and there was a decline in feeding rates between 12 to 2 p.m. However, the birds were seldom sighted feeding on the fruits during noon. The feeding rates during evening hours i.e., between 4 to 6 p.m. ranged between 9 to 10 pecks per minute. The feeding rates of jungle crow was calibrated as 19 pecks per minute (n = 5, observations spread over 5 days). So parakeets and Jungle crows have equal potential to cause sapota fruit losses. However, since the number of parakeets far exceeded the number of crows in the observational cropped area, the parakeets were found economically more important than jungle crows.

Observations on sapota fruit damage were recorded for 90 days spread over seven months i.e., from September 1999 to March 2000 for 25 trees at CHES. Data records established that a total of 1542 fruits were damaged of which 928 fruits (60.18 %) attributed

to birds (mainly parakeets) and 614 fruits (39.8 %) to bats. More details are furnished in Table 12.

The fruit damage in relation to the phenology of sapota crop is given in Table 13. During February there was maximum damage as the number of preferred fruits available for feeding were more. During December the fruit damage was less, as the number of fruits of preferred stage (vulnerable) was less, though the fruits attained maximum size. The minimum fruit damage was recorded during March as the total number of fruits and number of preferred fruits reduced, as the season to an ended. This indicated that stage of fruit influenced fruit damage and in turn, the fruit loss.

Crop protection in Orchards :

Birds represent a dominant group depredating fruit crops. Effects of shooting, trapping and scaring were evaluated as tools for crop protection. None of the above three methods protected orchards from birds damage. Destruction of bird roosts and nests and covering vulnerable portions of canopy with thatch during fruiting period saved 20 % of guava fruits in Mudigere, Chikmagalur. Bird scaring with traditional methods, erecting nylon neting around bower and covering the canopy with brier and twigs gave almost complete control of bat damage in grapes vineyards in Bangalore.

A combination of scaring birds by lighting, watch-n-ward, covering vulnerable portions of canopy with dry thatch, timely harvests and destruction of nearby birds nests and nests, saved on an average 38 % (n = 2 yrs, 50 trees) guava and 27 % sapota fruits during fruiting season of 1999 and 2000 at chettalli, Kodagu mainly from three species of birds viz., roseringed parakeet, *P.krameri*, Small green barbeet, *M. viridis* and jungle crow, *C. macrorhynchos*.

ORANGE (*Citrus aurantium* L.)

Citrus sp. is grown in 50948 ha with an annual production of 1681284 tonnes in Karnataka. In Kodagu district *Citrus sp.* is grown in 16189 ha and stands first in its production in Karnataka (Annual report 1994-95, Department of Horticulture, Government of Karnataka).

Quite a good number of citrus fruits are present in the orchard like Mandarin group, orange group. Pammelt-Grape fruit, Grape and Acid Grape, etc. In hill region, orange, is grown in coffee estates. Shade trees planted or naturally present in estates, serve as nesting and roosting sites for a number of birds. During the fruiting period (December to February) birds feed on fruits. Jungle crow was the dominant species feeding on oranges. An individual crow gives out calls and other crows gather and seven to eight crows per tree were found feeding on fruits. The crow extracted pulp, gulped it down and moved to a fresh fruit to insert beak and feed on pulp. On an average, a crow per day destroyed eight fruits in the estate.

In hill region of Karnataka, Oranges are grown in coffee estates. Shade trees planted or naturally present in estates, served as nesting and roosting sites for more than 90 bird species. Fruit losses due to various species of vertebrates in Karnataka on oranges is given in Figure 7. Jungle crow was the dominant species. An individual required 12 ± 1.4 min (n=18) to empty the contents of a fruit. On an average, a crow destroyed 8 fruits / day and in 15 days in the estate, crows destroyed over 2000 fruits. Goldenfronted chloropsis, *Chloropsis cochinensis* siphoned out juice from the fruit by inserting beak. While the fruit remained intact on the tree, but starts rotting subsequently.

Bison, elephant and wildboar also caused damage to citrus orchard by breaking branches, peeling off the bark, de top the tree or dislodge the young plants. An estimation revealed that by proper watch and effective scaring, about 50% fruit-loss could be saved.

Monkeys, *Macaca radiata* L; bison, *Bibos gaurus* H; elephants, *Elephas maximus* L and wildboar, *Sus scrofa* L caused damage to guava orchards. While monkeys feed on fruits, others dislodge / detop / trample seedlings, break branches / twigs or peel off the bark while rubbing horns or body against the tree trunk. Porcupines, burrow at base and may dislodge young trees in severe cases of attack. The peeled off branches are prone to termites or bark borers attack.

Subsequently, Orange fruit depredation by vertebrates was compared in watch-n-ward orchard with no watch-n-ward orchard from January to March 1997 at Mudigere, Chikmagalur. By watching 42% fruit losses could be prevented (Table 14) and there is further scope for saving fruits by effectively watching orchards and scaring away birds. In selected situations, shooting, trapping, scaring, destruction of bird roosts and nests and encouragement of natural enemies like owls help. Covering vulnerable portions of canopy during fruit-bearing period with thatch (locally available materials) saved 20% fruits in Mudigere. The scenario of damage at Mudigere is depicted in Figure 7.

POMEGRANATE (*Punica granatum* L)

Squirrels and species of *Funambulus* are the principal pests feeding on Pomegranate fruits through out India. The damage starts when the fruits are ripe (Patel, 1993). The partially damaged fruits are left behind and the animals search fresh fruits for feeding. The fruit loss is cent per cent during Summer (February to May) when alternate food sources are scarce. Species of *Bandicota* (photo 11) and *Rattus* work on such damaged fruits during night and empty the contents. Seeds are extracted from damaged fruits by birds like redvented bulbul (CAZRI, 1988-89, Chakravarthy, Pers. observation, 1993).

Snap trapping, sticky bands, covering fruits with poly bags and cloth-bags laced with waste oils were the methods adopted in a replicated (n=6) trial to protect the fruits under

Bangalore conditions in small orchards (1 ha) and backyards of houses. Ripening fruits of pomegranate and custard apple laced with oils of neem, *Azadirachta indica* and castor protected the fruits, *Ricinus communis* from vertebrate depredation for a longer period (Chakravarthy, 1996). Small green barbet; coppersmith, *Megalaima haemacephala* and mynas of *Acridotheres spp.* were observed feeding on fruits (Chakravarthy, 1993, IVPMP Project Annual Report, 1998, IVPMP Project Annual Report, 1997).

PAPAYA (*Carica papaya* L)

Papaya is grown in 4988 ha with an annual production of 433956 tonnes in Karnataka. Papaya is grown in 33 ha in Kodagu district. Mysore stands first in its production with 641 ha (Annual report, 94-95, Department of Horticulture, Government of Karnataka).

Ripen fruits of papaya were damaged by birds, squirrels, rats, monkeys and elephants. Usually development of yellow colour marks the beginning of damage to fruits by birds. Two Green barbets, *M. viridis* consumed on an average, pulp of a medium sized papaya in 12 min (n = 8) in Belthangady, Dakshina Kannada.

In Chettalli, Kodagu, an acre of 'honey dew', papaya crop was raided by elephants. Thirty plants, out of 600 (6%) were damaged by a troupe of five elephants, when the plants were five months old. The plants were uprooted. Wildboar generally squeezes the stem tissues and de tops the plant. At times in chettalli, wildboar was found browsing on young papaya plants. In half acre papaya plot, 50 plants were browsed by a herd of three wildboars.

In Gonikoppal, Kodagu, Jungle myna, *Acridotheres fuscus* and Brahminy myna, *Sturnus pagodarum* secondarily fed on papaya fruits, i.e., they fed on fruits damaged by jungle crows (photo 53). Covering fruits with thatch, gunny bag or a festoon of thorny sticks, nylon nets and scaring facilitated management of vertebrate pests at Mudigere.

BANANA (*Musa paradisiaca* L)

Banana is grown in 50948 ha with an annual production of 1681284 tonnes in Karnataka. It is grown in 4875 ha with 656-4219 ha, Cavandish and other varieties, respectively in Dakshina Kannada. (Annual report, 1994-95, Department of Horticulture, Government of Karnataka). Banana grown in 1296 ha with 1996-1997 ha of Cavandish and other varieties respectively, in Kodagu district.

Banana was found preferentially damaged by all larger animals like elephants, bisons and wildboars. Elephants split the pseudostem into two vertically, to feed on pith (photo 54). In one ha of Neypoovan banana planted during July 1995 in Chettalli, six plants were damaged by elephants, despite the plot being lighted by bulbs, bonfire and patrolled by men daily during nights.

At Ujire, Belthangady taluk, Dakshina Kannada, three varieties namely Mysore bale, 'Nanjungud' and 'Nendran' were planted. The banana fruits were depredated by monkey, *M. radiata*; small green barbet, *M. viridis* (photo 55) and bat, *P. edwardsii*. The barbet damaged ripening fruits. The bird worked on the bunch to get lumps of pulp in its beak. A bird partially damaged 1-2 fruits per bunch and continued to forage in search of next ripening bunch. A count of damaged fruits from bunches revealed that birds damaged 12 out of 67 bunches and out of 3220 fruits, birds damaged 40. Interestingly, it was found that by retaining damaged fruits on the plant, bird damage to banana was lessened. This was because birds revisited the damaged fruits to feed on the sweetened fruit portions. It is possible that by injuring the fruits, ripening is hastened. While the birds attended on Nendran variety when the fruits were still green, damage on fruits of other varieties began when the fruits turned yellow. The preference by birds was in the following order. Nendran > Nanjungud > Mysore.

The 'Mysore' variety fruits were the least preferred because it secreted a mucilaginous ooze which probably rendered the fruit distasteful.

The number of fruits/bunch in the plot varied from 240 to 490. Damage was more related to the age of the fruit than number of fruits/bunch. Observations recorded from September '96 to January '97 showed that damage by birds to banana occurred only during September and from October, birds concentrated feeding on cucumbers, papayas, etc. Of 3220 fruits, only 125 were fed upon by birds. Thus, availability of alternate foods in the garden affected damage to banana fruits by birds.

At CHES, Kodagu, germplasm maintenance of banana had to be abandoned due to raids by bison and elephants.

MANGO (*Mangifera indica* L)

Roseringed parakeets feed both on immature and mature mango, *M. indica* fruits in Punjab (Toor, 1982). In Chettalli, Coorg, mango is damaged by wildboars (photo 56) bison and elephants, breaking branches, splitting the bark or uprooting young (< 5 years old) trees were common.

PINEAPPLE (*Ananas comosus* L)

On an average, pineapple, *A. comosus* fruit-losses due to vertebrate pests (Jungle crow, Squirrel and Rat) amounted to 22% and 12.5%, respectively in coastal and hill regions of Karnataka. In a field trial, 70% of fruits uncovered were destroyed by vertebrate pests compared to no damage on fruits covered with either leaf or dry thatch (Chakravarthy, 1996). Fruit-losses due to vertebrate pests were reduced by effective watch, timely harvests, covering fruits with thatch and by driving away the animals (Nagarajan, 1994). Mongoose, *Herpestes edwardsii* L posed the major threat in some areas.

Table 1 List of Vertebrates depredating Guava and Sapota.

Vertebrate	Plant part damaged	Economic status
Birds :		
Roseringed Parakeet (<i>Psittacula krameri</i> K)	FF	M
Jungle Crow (<i>Corvus macrorhynchos</i> W)	FF	M
House Crow (<i>Corvus splendens</i> V)	FF	M
Redwhiskered Bulbul (<i>Pycnonotus jocosus</i> L)	FF	M
Redvented Bulbul (<i>Pycnonotus cafer</i> L)	FF	M
Chloropsis (<i>Chloropsis aurifrons</i> T)	FF	m
Lorikeets (<i>Lorichulus spp.</i>)	FF	m
Bats :		
Flying Fox (<i>Pteropus giganteus</i> B)	FF	M
Small Fruit Bat (<i>Cynopterus sphinx</i> Vahl)	FF	M
Other vertebrate pests :		
Monkey (<i>Macaca radiata</i> L)	FF	m
Bison (<i>Bibos gaurus</i> H)	SF	m
Elephant (<i>Elephas maximus</i> L)	SF	m
Jungle cat (<i>Felis chaus</i> G)	FF	m
Porcupine (<i>Hystrix indica</i> K)	FF	m
Wildboar (<i>Sus scrofa</i> L)	SF	m
Cattle (<i>Bibos domesticus</i> L)	FF	m

FF = Fruit Feeder

SF = Shoot / bark feeder

M = Major (economically important)

m = minor (economically not important but may become so in some situations.

Table 2 Parakeet damage to Guava fruits at CHES.

GBH (cms)	No. of fruits damaged / 25 trees									Total & (%)
	Jul' 99	Aug	Sept	Oct	Nov	Dec	Jan'00	Feb	Mar	
19	32	93	27	36	48	55	26	12	18	347(3.33)
20	48	102	25	43	53	56	34	14	52	427(4.10)
38	26	122	38	49	29	53	39	8	34	398(3.82)
16	42	98	49	48	42	52	23	16	33	403(3.87)
48	28	103	44	39	36	50	46	5	23	374(3.59)
45	23	120	38	46	34	48	20	20	27	376(3.61)
51	44	128	36	32	33	43	47	22	14	399(3.83)
46	25	104	49	29	49	38	26	15	29	364(3.50)
16	32	128	43	24	57	57	39	18	31	429(4.12)
14	38	122	53	28	29	43	42	16	42	413(3.97)
50	32	150	58	42	28	36	26	13	28	413(3.97)
53	24	128	56	39	49	53	33	19	39	440(4.23)
49	43	123	49	44	42	68	49	17	41	476(4.57)
51	25	124	37	52	36	54	27	13	28	396(3.80)
39	29	125	39	63	39	62	23	17	35	432(4.15)
36	29	126	18	47	46	54	26	9	27	382(3.67)
32	44	106	45	44	49	56	34	6	24	408(3.92)
44	27	128	59	49	46	62	32	23	33	459(4.41)
45	22	109	68	55	32	61	18	19	30	414(3.98)
48	48	124	64	56	4	51	43	21	25	436(4.19)
43	53	131	73	46	49	62	49	18	24	505(4.85)
40	58	98	56	43	37	32	22	13	29	388(3.73)
52	46	108	54	59	61	48	32	12	33	453(4.35)
47	59	115	52	65	49	33	45	7	22	447(4.30)
35	46	108	46	46	46	54	42	10	17	415(3.99)
Total	923	2923	1176	1124	1023	1281	843	363	738	
%	8.88	28.12	11.31	10.81	9.84	12.32	8.11	3.49	7.1	
Mean	36.92	116.92	47.16	44.96	40.92	51.24	33.72	14.52	29.52	
SD	11.42	13.46	13.16	10.34	11.79	9.39	9.77	5.06	8.41	

Table 3 Number of Parakeets in 1.5 acre Guava plot at CHES*.

Time	No. of Vertebrate Pests visiting the plot									Total
	Jul' 99	Aug	Sep	Oct	Nov	Dec	Jan'00	Feb	Mar	
Morning	86	98	104	98	102	88	99	87	100	862 (44.94)
Afternoon	8	11	10	6	8	7	12	13	16	91(4.74)
Evening	91	103	111	126	115	102	114	102	101	965(50.31)
Total	185	212	225	230	225	197	225	202	217	
%	9.64	11.05	11.73	12.00	11.73	10.27	11.73	10.53	11.31	
Mean	61.67	70.66	75	76.66	75	65.67	75	67.3	72.3	639
SD	46.54	51.73	56.40	62.78	58.38	51.29	55.1	47.6	48.8	

*Bats not included in this estimation

Table 4 Feeding rates of Parakeet on Guava fruits at CHES.

Time	No. of pecks / ten minutes of one Parakeet									Total (%)
	Jul'99	Aug	Sept	Oct	Nov	Dec	Jan'00	Feb	Mar	
Morning	101	105	105	68	124	127	33	114	8	785 (34.37)
Afternoon	14	12	16	23	36	45	158	30	12	346 (15.15)
Evening	126	116	138	145	180	168	154	14	112	1153 (50.48)
Total	241	233	259	236	340	340	345	158	132	
%	10.55	10.20	11.34	10.33	14.88	14.88	15.10	6.91	5.78	
Mean	80.33	77.66	86.33	78.66	113.33	113.3	115	52.7	44	761
SD	58.79	57.13	63.10	61.69	72.59	62.63	71	53.7	58.9	

Table 5 Sapota fruit damage by birds and bats during different months at CHES.

Months	Mean (n = 25 trees) Fruit damage		Mean fruit damage by (%)	
	Birds	Bats	Birds	Bats
Sept'99	0.70	1.92	17.67	48.11
Oct	0.70	1.70	17.67	42.50
Nov	1.62	1.89	40.58	47.33
Dec	1.43	1.20	35.89	30.16
Jan'00	2.50	2.10	64.89	52.51
Feb	1.98	1.56	46.63	39.19
Mar	0.84	0.79	21.14	19.74
	X =1.40	X =1.59		

SD at 5% = 41.74 19.59 C.V = 36.11

Table 6 Vertebrate pests damage to sapota in relation to fruit production.

No. of Trees	Total production of fruits	Fruit damaged by		Avg % Loss
		Birds	Bats	
25	4816	252	146	
Mean	192.64	10.08	5.84	13.02

$r = \text{Birds} = +0.8598$

$n = 25 \text{ trees}$

$r = \text{Bats} = +0.9497$

$t = 31 \text{ days (December)}$

Table 7 Vertebrate pests (birds and bats) damage to Sapota crop at CHES

Tree Number	Treatment mean *
1	2,7692
2	3,0000
3	1,8462
4	3,0769
5	2,6154
6	2,7692
7	2,9231
8	1,6923
9	2,3846
10	3,0769
11	3,9231
12	3,0000
13	3,9231
14	1,3846
15	1,8462
16	3,2308
17	2,0769
18	2,0000
19	2,3846
20	3,3846
21	3,4615
22	3,2308
23	1,9231
24	1,8462
25	2,3846

$CD \text{ at } 5\% = 2.037 \text{ (NS)} \quad SEM + = 0.7337$

* From 25 observations

Table 8 GBH of 25 Sapota trees in relation to fruit production.

No. of trees	GBH (cms)	Production of fruits
25	2,100.75	4,816
Mean	84,036	192.64

$r = + 0.0190$ $n = 25$ Trees $t = 31$ days (December)

Table 9 GBH of 25 Sapota trees in relation to birds and bats damage to fruits.

No. of Trees	GBH (cms)	Mean fruits damaged by	
		Birds	Bats
25	2,100.75	252	146
Mean	84.036	10.08	5.84

$r = \text{Birds \& Bats} = +1.2361$ $t = 31$ days (December)

**Table 10 Population of Roseringned parakeet in the experimental sapota orchard
at CHES.**

Dates	Morning (6 to 9.30 Am)	Noon (12 to 3 Pm)	Evening (3 to 6.30 Pm)	Total
28.01.2000	25	6	5	36
29.01.2000	19	19	23	61
30.01.2000	25	10	13	48
21.02.2000	19	4	10	33
22.02.2000	24	8	18	50
Average	22.4	9.4	13.8	45.6

Table 11 Popualtion of bats recorded in the experimental plot at CHES.

Date	Frequency of bats at	
	Orchard	Roosting site
27.01.00	4	24
28.01.00	15	26
29.01.00	18	26
30.01.00	0	26
16.01.00	4	13
21.02.00	0	12
22-23.00	5	45
7 Dates	Avg = 6.6	Avg = 23

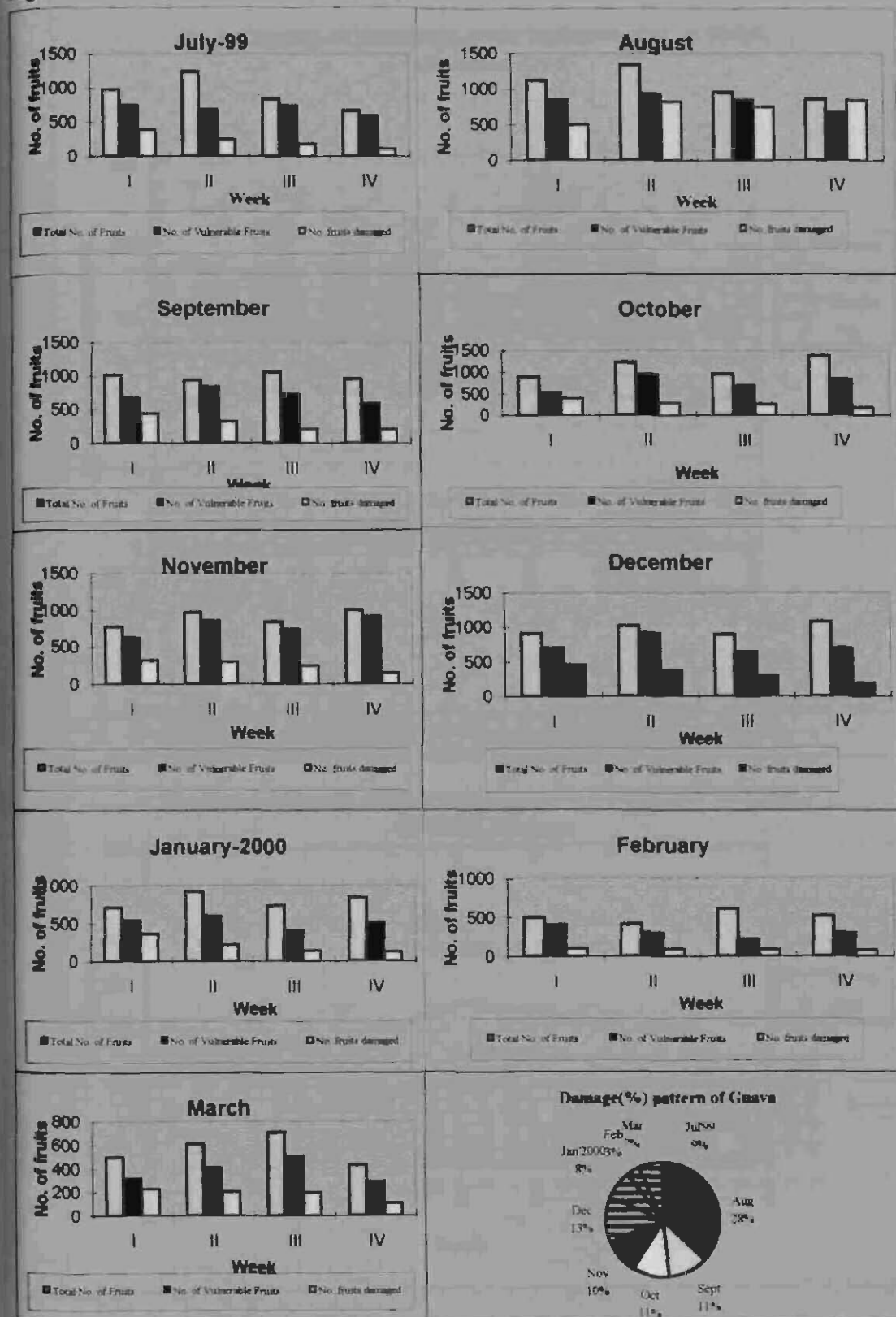
Table 12 Pattern of Sapota damage by Vertebrate pests at different months
at CHES.

Month	Days observed	Fruits damaged by		Total fruits damaged
		Birds	Bats	
Sept'99	1	11	11	22
Oct	1	7	13	20
Nov	6	75	95	170
Dec	31	241	146	387
Jan'00	5	165	110	275
Feb	28	401	223	624
Mar	18	28	16	44

7 Months 90 Days 60.18% 39.80% 1542

n = 25 trees t = 90 days

Fig 1 Monthwise pattern of Parakeet damage on Guava at CHES-Chettalli



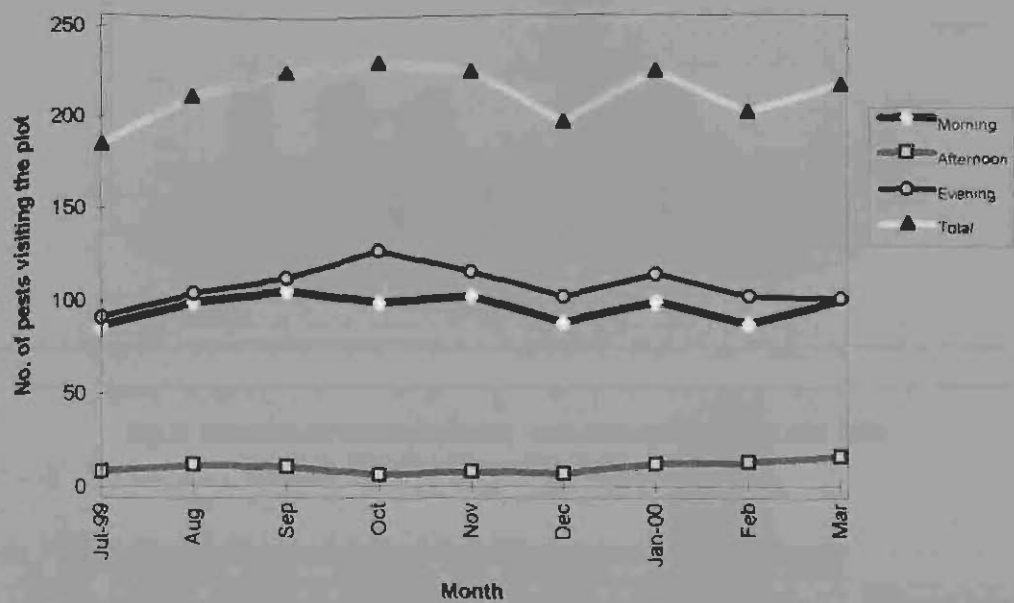


Fig 3 Feeding rate of Vertebrate pests in Guava plot at CHES, Chettalli, Kodagu

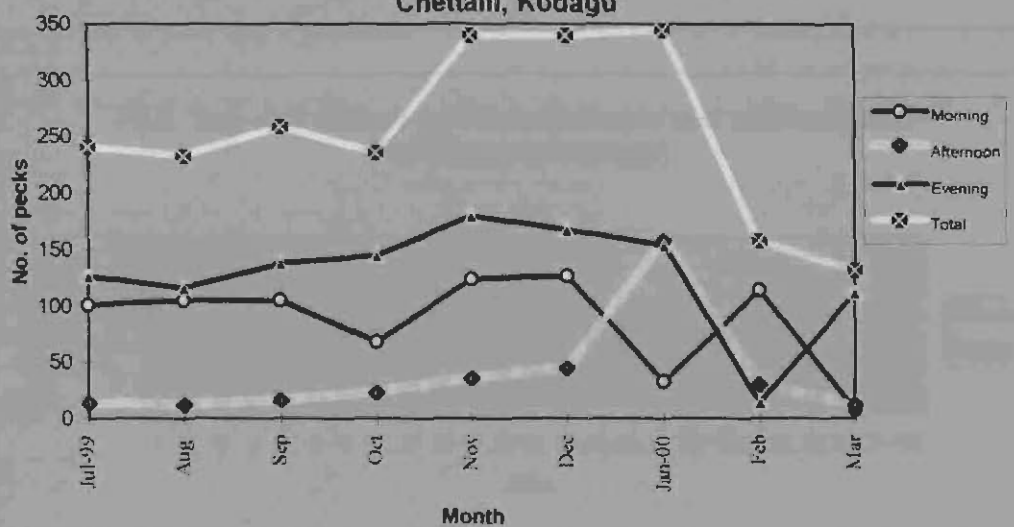


Fig 4 Sapota fruits damaged by birds and bats during different months at CHES

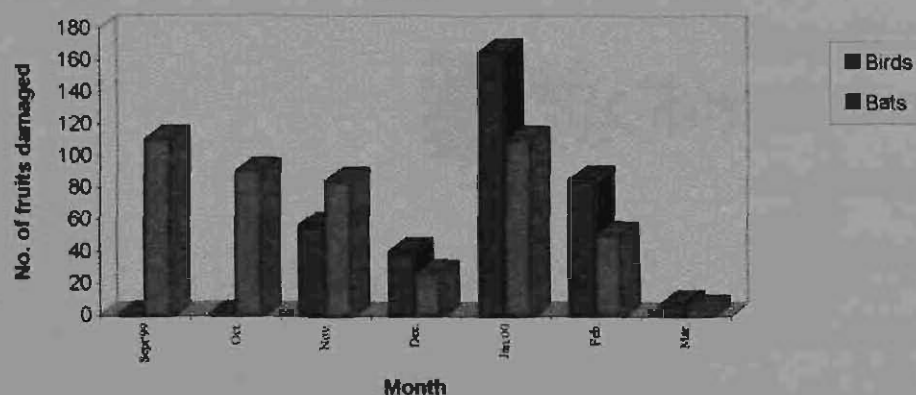


Fig 5 Number of fruits produced and damage by birds and bats against individual tree (December- 31 days)

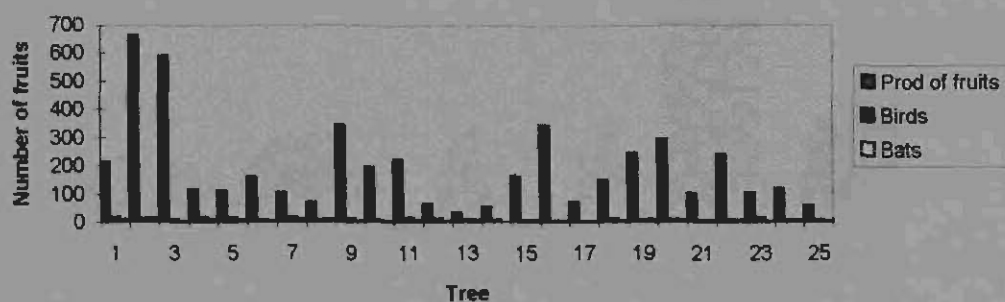
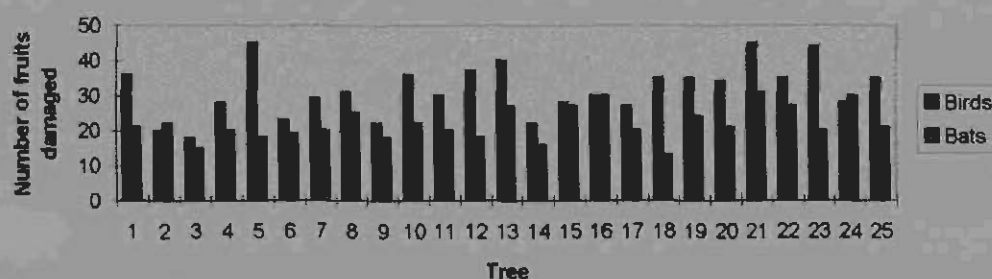
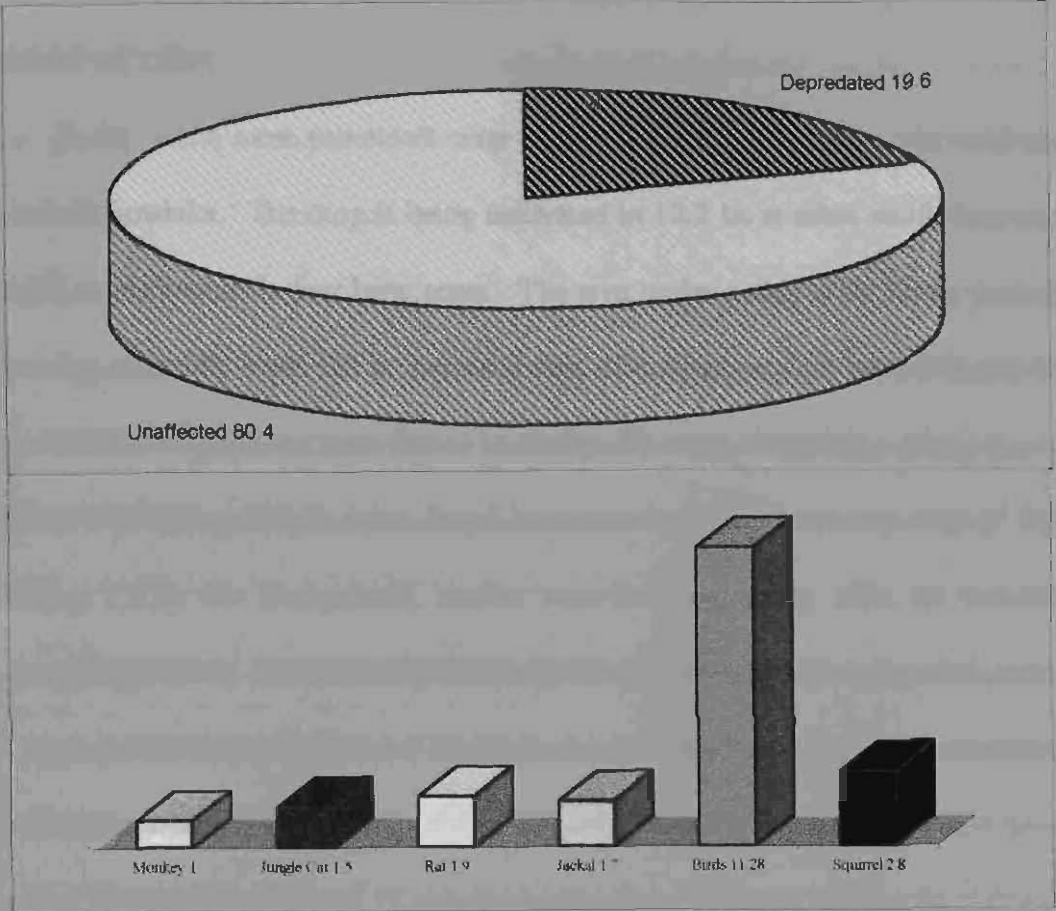


Fig 6 Tree wise damage pattern by vertebrate pest species against GBH (90 days of damage)



Tree No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
GBH	50	110	89	89	97	97	120	120	75	70	91	79	86	79	77	79	56	82	81	85	80	102	63	77	73

Fig 7 Feeding losses in Oranges by birds in Mudigere



FIELD CROPS

Paddy (*Oryza sativa* Linn)

INTRODUCTION

Paddy is the most prominent crop grown in over 45% of the cultivated area in hill region of Karnataka. The crop is being cultivated in 12.2 ha in often small, fragmented plots adjacent to plantations in low lying areas. The area under paddy is shrinking gradually in the region due to mainly steep fall in increased cost of cultivation, loss caused by the insect and pests and others. Growers were forced to change the crop. Vertebrate pests viz., wildboars, rodents, elephants and birds were found to cause enormous losses by way of feeding and trampling. With this background, studies were initiated during 1996 on vertebrate Pests adopting indigenous, locally available management practices. More attention was given to vertebrate pests other than rodents, since lot of work on rodent pests on rice was carried out by other scientists.

Species Composition :

Field identification of vertebrate species, species composition, nature of damage and damage symptoms were recorded at selected places in and around Mudigere (13° 7' 29" N and 75° 37' 35" E 982 m AMSL) which represent the hill region of Karnataka. Impact of management practices were evaluated in different locations against important vertebrate species causing damage to the paddy crop at different stages. Effect of integrated pest management tools were systematically evaluated in RCBD (Randomized Complete Block Design) with three replications at the different locations. The data was statistically analysed and the results are furnished below.

Survey :

Survey revealed that there were following important vertebrate pests viz., rat, *Bandicota bengalensis* L; Birds, Black headed munia, *Lonchura malacca*; Baya weavers *Ploceus* spp., Roseringed parakeet, *Psittacula krameri* K; Bluerock pigeon, *Columba livia*; wildboar, *Sus scrofa* L and Indian hare, *Lepus nigricollis* were found to cause damage to paddy crop at five different pheno-phases (Table 1).

In paddy nursery, blue rock pigeon and roseringed parakeet were the two major species found damaging seeds. Results showed that there was significant reduction in birds damage after adopting indigenous management practices. The loss reduced from 16.9 % to 3.6% (Table 2).

B. bengalensis is another important rodent species found damaging paddy seeds after sowing in the nursery beds (photo 57). Rats scooped out the soil to feed on germinating paddy seeds and caused damage of the seedlings. Rat damage from about 4.58 to 6.54 m² reduced to 1.20 to 1.05 m² / bed by adopting indigenous protection practices (Table 3). The impact of management practices in affording protection to paddy seedlings was significant and proved effective, economical and practicable.

Main fields :

Indigenous management practices were evaluated in four locations for the management of rats in the main rice fields revealed that there was significant reduction in damage from 10.11 to 2.39 %. Generally rat damage starts 2 to 3 weeks after planting in the main fields. Damage pattern studies revealed that no damage was recorded during maturity stage. Number of live burrows were more during milky to maturity stages than when seedlings were in transplantation stage (Table 4). Rat damage to paddy is shown in Photo 58.

In the main fields, during milky and maturity periods, finch birds, viz., black headed munia, red munia, *Estrilda amandava*; sparrow, *Passer domesticus* and roseringed parakeet, are the aggressive feeders attacking the crop in flocks of 30 to 50 numbers . Finch birds preferred maturity stages of the crop than milky stages (photo 59). The birds perched on the rice plants and fed on the grains.

The parakeets cut the panicles and carried to the perching trees. Observations also revealed that almost all the tall and late maturing rice cultivars received less damage than dwarf and early cultivars as birds were unable to perch on tall rice varieties, these varieties bent downwards. Indigenous management practices proved effective and economical. The damage to grain reduced from 22.00 % to 3.80 % (Table 5).

Wildboar is a common and widely distributed quadruped in hill region of Karnataka. A series of observations made over four years revealed that the extent of damage to rice crop varied from one plot to another depending on factors such as natural habitat (adjacent to rice fields), uncultivated forest areas, scrub jungle, natural predation and illegal hunting, which facilitates the wildboar for resting and breeding activities during the day. Wildboar damaged the crop in three ways i.e., browsing / feeding, trampling and lodging (photo 60). Observation revealed that the fields in valley and adjacent to forest areas were damaged more severely than those in plain midlands and uplands. Indigenous management practices / IPM practices were very effective against wildboar damage as the damage was reduced from 61.74 % to 18.17 % (Table 6). From the study it is also revealed that depletion of food sources in the forest have forced the wildboars to attack paddy crop. Observations revealed that wildboars have no definite pattern of feeding and they are very sensitive in nature.

As a playful behaviour and with a purpose for searching small worms (larvae) which were present in the root moss of the seedlings, crows, *Corvus* spp. uprooted the planted

seedlings immediately after planting. This causes for the growers to replant the seedlings again. Crows start feeding during evening hours. The crows uprooting seedlings reduced from 18.25 ± 2.30 to 14.35 ± 2.01 after adopting indigenous management practices (Table 7). When water level in the paddy fields was maintained at about 75 cm level, birds were unable to alight and settle on the sheet of water. So there by uprooting ceased.

Table 1 Vertebrates damage at various phenophares to the rice plant.

Vertebrate	Nursery stage	Tillering stage	Flowering stage	Milky stage	Maturity stage
Bandicoot rat (<i>Bandicota bengalensis</i>)	+	+	+	+	+
Indian rabbit (<i>Lepus nigicolis</i>)	+	+	+	+	+
Wildboar (<i>Sus scrofa</i>)	-	-	+	+	+
Birds*	+	-	-	+	+

*Black headed Munia, Lorikeets, Rosringed parakeet, Blue rock pегion and jungle crow.

+ = Feeding

- = Not feeding.

Table 2 Effect of IPM practices in paddy nursery damage due to birds

(Mean of 4 years data).

Plot No.	Seed loss (% area) *	
	Adapting IPM practices**	
	IPM Non-adopted	IPM adopted
1	15	3
2	30	5
3	15	5
4	20	3
5	20	5
6	15	1
7	10	5
8	19	3
9	15	5
10	10	1
Total	169.00	36.0
Mean	16.90	3.60

Binomial Expansion

Z' value 2.689

* = 1 m² Quadrates / replicate x 3 replications.

** = 1. Timely scaring the birds for 20-25 days (Germination).

2. Debranching the trees in the surrounding areas wherever possible.

3. Tying the waste cassette tape all-round the nursery beds for a stretch of about 20- 25 days.

Table 3 Effect of IPM* practices on Paddy seedlings damage due to rodents in nursery
(Mean 0+ 4 years data).

Seedlings loss (m ² / bed)							
IPM non-adopted plots				IPM adopted plots			
L I	LII	LIII	L IV	Li	Lii	Liii	Liv
8.0	7.0	9.0	3.3	0.0	0.0	2.5	1.0
6.0	9.0	7.0	4.2	1.0	0.0	1.5	0.0
7.0	9.0	2.5	4.3	1.5	1.5	1.0	0.0
8.0	4.0	6.0	3.5	2.0	2.6	3.0	6.0
10.0	3.0	3.5	10.0	1.0	1.0	1.0	1.0
3.7	1.5	5.0	6.5	1.0	0.0	0.0	0.0
4.0	8.0	9.0	2.0	0.0	3.5	0.0	1.0
2.5	6.5	11.0	6.5	0.0	1.5	0.0	0.5
3.5	3.9	6.5	3.5	3.5	0.0	0.0	1.0
54.20	59.30	65.40	45.80	12.50	11.10	10.50	10.50
Mean 5.42	5.93	6.54	4.58	1.20	1.11	1.05	1.05

'F' for seedling loss before and after treatment 2.13 (NS)
 'F'' for seedling loss among locations before treatment : After treatment

$$L_1 = 34.62$$

$$L_2 = 34.39$$

$$L_3 = 17.94$$

$$L_4 = 1.00$$

- *1. Bund cleaning, trimming and weeding
 2. Mechanical collection of rats
 3. Baiting with Bromadiolone 0.005% roaban cake @ 8 / acre
 4. Setting of wooden snap traps for killing

Table 4 Effect of indigenous management practices * on rat damage on rice at its different growth stages.

Month	Stage of crop	Percent tiller damage (10 x10 m ²)			
		IPM non-dopted plots	Number of burrows	IPM-adopted plots	Number of Live burrows
July	Transplantation	0.0	2	0.0	0
August	Tillering	0.088 ± 0.19	2	0.0	0
September	Tillering	3.33 ± 0.35	5	0.81 ± 0.18	0
October	Flowering	5.95 ± 0.45	7	1.11 ± 0.19	1
November	Milky	7.19 ± 0.95	7	2.10 ± 0.23	2
December	Maturity	10.11 ± 1.35	9	2.39 ± 0.24	2

- *= 1. Bund cleaning, weeding & trimming.
2. Mechanical collection of rats at 15-20 days intervals.
3. Baiting with Bromodiolone 0.005% cake @ 10 /ac.
4. Setting of wooden snap traps @ 4-5 / ac.
** = Mean of 3 locators / years.

Table 5 Effect of Indigenous management practices* on bird damage to paddy during milky and maturity stages (Mean of 4 years data).

Plot No.	Paddy grains loss (%) (10 x 10 m ²)	
	IPM non-adopted plots	IPM adopted plots
1	30.00	1.00
2	30.00	3.00
3	15.00	9.00
4	25.00	6.00
5	20.00	4.00
6	20.00	3.00
7	10.00	2.00
8	30.00	1.00
9	15.00	7.00
10	25.00	2.00
Total	220.00	38.00
Mean	22.00	3.80

Binomial Expansion
Z value

2.769

- *1. Timely scaring the birds for 20-25 days (at milky or maturity).
2. Debranching the trees in the surrounding areas wherever possible.
3. Growing taller (> meter) and late maturity (> 5 months) cultivars.

Table 6 Effect of Indigenous management Practices on wildpig damage to paddy crop (Mean of 4 years data).

Location	Yield loss (Tillers damage / m ²)					
	IPM non-adopted plots			IPM adopted plots		
	Browsing / feeding	Trampling	Lodging	Browsing / feeding	Trampling	Lodging
1	15.11	5.95	7.25	3.30	1.00	1.00
2	15.10	10.00	11.99	2.10	1.05	5.00
3	24.75	8.09	9.09	5.59	3.30	1.09
4	22.08	20.06	19.75	13.06	3.33	5.39
5	25.05	24.10	29.45	7.75	6.66	9.69
6	19.80	26.00	26.55	4.09	7.79	11.00
7	30-21	45.00	10.88	15.10	11.09	1.10
8	25.73	22.15	21.09	5.55	5.49	6.60
9	24.10	20.19	35.09	6.08	6.63	8.88
10	25.03	11.35	26.11	9.09	1.50	7.09
Total	226.96	192.89	197.75	71.71	47.84	56.84
Mean	22.69	19.28	19.77	7.17	4.78	5.68
CD @ 5%	4.990	3.690	3.990	1.990	1.956	1.970

- * 1. Suspending 3 to 5g thimet 10G + 5g dry sand in a perforated plots bags in the entry area of the paddy fields all along the fence.
2. Scaring the animals during nights for 30-40 days.
3. Selective killing by shooting mainly.
4. Erecting electric fencing wherever possible along the borders of the entry paths.

Table 7 Effect of indigenous management practices* on paddy seedling loss due to jungle crow in the main field (Mean of 4 years data).

Plot No.	Paddy seedlings pulled out (%)	
	Without IPM	With IPM
1	19.00 ± 1.09	5.00 ± 0.25
2	35.00 ± 2.35	9.00 ± 0.45
3	19.00 ± 1.09	1.50 ± 0.19
4	16.00 ± 1.00	2.50 ± 0.25
5	25.00 ± 1.39	9.00 ± 0.45
6	09.00 ± 0.45	3.50 ± 0.40
7	11.00 ± 0.55	1.50 ± 0.19
8	05.00 ± 1.36	1.00 ± 0.10
9	29.00 ± 1.36	3.50 ± 0.40
10	14.50 ± 0.99	1.50 ± 0.19

- * 1. Scaring the birds for 2-3 days (Preferably morning * evening hours).
2. Maintaining water level at 73 cm in the main field for atleast three to four weeks.

VEGETABLE CROPS

INTRODUCTION

Vegetables are rich sources of vitamins, minerals, proteins and carbohydrates. As such vegetables play an important role in the balanced diet of humans. But the intake of fruits and vegetables is very low in India. It's partly due to inadequate production of these crops and partly due to ignorance in the public about the advantages of intake of vegetables and also lack of affordability for balanced diet. Remedies available for disease causing insect pests can be controlled at any stage of the attack. The damage / infestation by vertebrate pests is so high and it's management involves high risks, that the vegetable cropping system is abandoned in many parts of hilly and coastal regions of Karnataka.

COWPEA :

Cowpea, *Vigna unguiculata* L form staple vegetable of the local people. Popularly called as 'Alasande' is grown in 1.37 lakhs ha in Karnataka, with an annual production of 0.54 lakhs tonnes (Directorate of Economics and Statistics, 1995). It was sown in 1.5 ha at Rathnamanasa farm at Belthangady, where the observations were recorded for the identification of vertebrates damaging cowpea, their nature of damage, damage symptoms, extent of damage and the evaluation of possible control measures. Cowpeas are trailed on wooden frame of local wood and coconut fibres called 'pendal'. It is used both as green vegetable or as seed and cultivated as a sole crop or intermixed with maize, *Zea mays* L, ridgegourd, *Luffa acutangula* L; cucumber, *cucumis sativus* L; or bottlegourd, *Lagenaria longissima* L.

Vertebrate depredators :

Among birds Small Green Barbet, *Megalaima viridis*; Red Vented Bulbul, *Pycnonotus cafer* and Rose Ringed Parakeet, *Psittacula krameri* K, frequented the plot to feed on

flower, birds and pods and found economically important pests infesting cowpea. Rats, *Rattus rattus* L and *Bandicota bengalensis* L, squirrel, *Funambulus palmarum* L were also found significant vertebrates infesting cowpea.

Nature of damage and damage symptoms :

Rats eat the matured or ripened pods irregularly and make the pod fragmented. The pod is eaten irregularly leaving few seed inside the pod. Rats chew the pod roughly and leave on the ground. Chewed bits of pods were found in the rat burrows and in the field. Squirrel do damage both unripened and ripened pods. Squirrels damaged the pods without cutting into bits, but the seeds were devoured. Markings with irregular scratches were seen on pod rind. Birds damage the beans which are ripened / matured. Birds made holes on pods and plucked the seeds. Sometimes, the edges of the whole pod got opened by birds and all the seeds were exposed.

Birds caused severe damage to pods compared to rats. Red Vented Bulbul restricted it's feeding on flower buds and extracted seeds from already damaged pods. Small Green Barbet and Rose Ringed Parakeet together caused severe pod losses. The birds increased pod losses much more than what they fed. Rose Ringed Parakeet extracted seeds from ripened pods by puncturing or peeling-off the skin. Sometimes the pods were also chipped-off or cut.

Yield loss :

Twenty rows of cowpea bushes were selected to find the intensity of vertebrates damage at Rathnamanasa farm. Observations were recorded during September and October 1996. Three other plots intercropped tapioca, *Manihot esculenta* C intercropped ridgegourd *Lacutangula*, and other with maize, *Zea mays* L were also selected for the study. Birds caused severe damage to pods compared to rats and squirrels and found there exists statistically significant differences in their damage to beans (Table 1). Rat damage was

confined to pods near the ground. Rats also restricted to hoarding of pods. Much of the feeding by birds occurred during morning and evening hours.

1. Tapioca x cowpea :

The damage caused by all the vertebrates found non- significant differences in pod damage (Table 2).

2. Ridgegourd x cowpea :

Ridgegourd grows very rapidly and forms a bush with a thick canopy. Ridgegourd is not preferred by birds or squirrels or rats. Pods of cowpea are hidden by foliage to some extent. Birds cannot locate very easily the pods of cowpea when they perch on ridgegourd. Rats and squirrels don't prefer to enter into the bush and damage the pods (Table 3). The flowers of ridgegourd may be repellent to birds. So the vertebrates did not prefer the ridgegourds for feeding.

3. Maize x cowpea :

At Rathnamanasa farm, maize is grown as an intercrop with cowpea to give support for the creepers of cowpea as stakes. Birds start eating the maize seeds and may avoid eating cowpea pods as lesser pod damage was recorded on cowpea. The average number of sprouts / seedlings per row was 35 (n=50 rows) and in each row the number of seedlings lost varied from 11 to 28 i.e., from 31.3% to 80%. The damage was concentrated more at the edges.

To find if the position of the seed in the plot influenced the damage by vertebrates, the distance of each row from fence was recorded and percentage seeds lost was recorded. Correlation and regression analysis revealed that the damage decreased as the distance of the row from the fence increased ($r = 0.8939$), there being significant (at 5%) and positive correlation between the two parameters. Putting up a barrier against scooping out of the soil by locally available materials may reduce loss of seeds / seedlings.

Indigenous methods of Crop Protection :

Some of the indigenous methods are being practiced to minimize the depredators damage to cowpea.

1. Much of the feeding by birds occurred during morning and evening when it's essential to scare away the birds.
2. Cowpea cultivation may be avoided from sites where birds have access for perching, feeding, nesting and roosting. However, the barbet, bulbul and the parakeet cannot be branded as pests in Belthangady taluk as their feeding is highly localized. Presence of natural foods like *Ficus sp.* and *Prima indica* berries may restrict bird feeding on cowpeas.
3. Intercropping.
4. Cowpea can be grown at the center of the garden / plot away from trenches or paths in order to reduce the damage by rats, squirrels or to prevent their entry.

CUCUMBER

Cucurbitaceous vegetables are grown in 11578 ha with an annual production of 236232 tonnes in Dakshina Kannada (D.K.) district (Department of Horticulture, 1995). Cucumber, *C. sativus* L is a local delicacy in D.K district grown in small scale, organic farming systems to meet local market needs. The vegetables are cultivated with family labour at backyards, paddy fallows or as a border crop. In some parts of the district, it was observed that birds damaged the fruits and the loss caused may be economically important apart from rabbit and squirrel damage.

Birds damage to cucumbers was noticed at sowing and fruiting. At sowing stage Blue Rock Pigeon, *Columba livia*, found damaging / scooping out the seedlings or germinating seeds. The birds may associate color and structure of flower to the taste and nutrient content of flowers. Birds peck at the colourful petals and the gynoecium of flowers get detached

from petals and androecium also gets damaged. Flowers of other cucurbitaceous plants may also contain repellent or distasteful compounds in their flowers. Although flowers of *Snakegourd*, *Trichosanthes anguina* L; Ridgegourd, *L.acutangula* and Bittergourd, *Melugo charantia* were found abundantly, the birds preferred cucumber flowers only. During October 1996, 19.7 % Cucumber flowers were damaged by Red vented Bulbul, *P. cafer*.

Rabbit, *O.cuniculus* damaged cucumber crop from seedlings to the fruiting stage. The shoot tips / growth tips of seedlings were cut randomly leading to the retardation of creepers growth or the complete loss of seedlings. An estimation during March revealed that, on an average, rabbit caused a loss of 30.5% and 17.2% seedlings. Interestingly as most of the vegetables in the farm were harvested, alternate foods for the animals were not available. Visual estimates showed, that on an average six rabbits were inhabiting in 20 acres. An estimation revealed that, rabbits caused a loss of 30% in one plot and 20% in another plot of cucumber during March (n = 40). 'T' test for paired means revealed significant differences between the two means. Five days old seedlings were preferred for damage by rabbits. Such seedlings were about 0.3m above ground. Rabbits caused damage to 70% seedlings at the edges.

Rabbit damage was found less under the following conditions in a plot :

- a. Where the place was bushy.
- b. Where the creepers were above 0.5 m..
- c. The creepers were in the middle or center of the plot.

Following conditions in the plot facilitated damage by rabbits :

- a. The damage was more at the edges of the rows.
- b. Where the creepers were independent.
- c. The creepers were below 0.5 m height.

- d. The creepers situated near trenches or path / road.
- e. The tender seedlings / creepers were preferred .
- f. As the dwarf seedlings and it's shoot tips were easily accessible to rabbits, the creepers below 0.5 m which were tender and tasty for the animals.

MAIZE :

Maize, *Zea mays* L is not a very popular crop of coastal zone. But at Rathnamanasa farm, Belthangady (12° 59' N 75° 17' E 183m AMSL). Maize is grown in 221716 hectares in Karnataka (Department of Economics and Statistics, Govt of Karnataka, 1995).

Maize was grown as an intercrop in a ridgegourd, *Luffa acutangula* field in 0.25 ac. Cob damage by vertebrates was studied on first and fifth December 1996. A hundred plants were sampled. Cobs were categorized into two groups based on the extent of grains removed per cob : (1) More than 50% and (2) Less than 50% grains removed. Thus, 2 cobs with less than 50% damage (i.e., about 50% grains removed along the length and rim of the cob) made up for the loss of a cob. On this basis, 112.67 cobs were lost (60.71%) and the loss is economically important.

The most dreaded pest was the Roseeringed parakeet, *Psitacula karmeri* followed by jungle crow, *Corvus macrorhynchos* and Mynas of *Acridotheres spp.* The relative numbers of birds preferentially picked-up grains from the milky to maturing grain stage from cobs compared to young or developing grain stage-cobs. Thus, damage appeared to be dependent on age of the cob. Squirrel as minor pest depredating maize crops occasionally (photo 61) cause lesser damage and consider economically non-significant. Further observations are in progress.

Deccan maize seeds were sown on 15-12-1996 at Rathnamanasa, Belthangady. The average number of seeds / row was 32 (n=50) and 32 rows were observed for seed / seedlings

missing. Observations were recorded on 27-12-1996 and 29-12-1996. The number of seeds / seedlings lost / row varied from 12 to 28. Seventy two percent seeds / seedlings were lost due to feeding by rats and parakeets, resulting in the abandonment of the field itself and seeds of other crops were sown instead.

Table 1 Pod yield losses due to bird and rat at Rathnamanasa farm.

Month	Mean % pod damage by			Remarks
	Bird	Rat	Squirrel	
Sept '96	61.2	38.8	0.0	Cowpea X Tapioca
Oct	71.2	26.3	0.0	Cowpea X Ridgegourd
Nov	75.0	25.0	0.0	Cowpea X Ridgegourd
Sept '96	81.4	18.6	0.0	pure cowpea
Oct	70.5	21.6	0.0	Cowpea X Redgram
Mar '97	9.60	72.0	17.6	Cowpea X Redgram

n = 40 creepers

Table 2 Cowpea damage by vertebrates at Rathnamanasa

Intercropped with Tapioca.

Month	Cowpea pod damage (Mean)
Sept '96	44.0
Oct	85.5
CD at 5 %	NS

* Mean of 15 rows, @ 13 plants / row.

Table 3 Vertebrate damage to Cowpea pods when intercropped

with Ridgegourd.

Month	Pod damage (Mean)
Sept '96	85.5
Oct	90.0
Sept '97	81.2
Oct	89.5
CD at 5 %	NS

* Mean of 25 rows, @ 16 plants / row

CASHEW

INTRODUCTION

In Karnataka Cashew, *Anacardium occidentale* L is grown in 87,000 ha with an annual production of 35,000 MT having 460 kg / ha productivity. The raw nut price during 1996-97 was Rs 1,300-2,000 / quintal (The cashew vol XII No. 3,181-182). During 1998-99 observations on vertebrate pests damage in cashew planted area at Kidu were recorded. An estimate of damage was recorded by collecting the number of chewed apples of cashew found at the base of 25 trees selected randomly.

Cashew is highly depredated by vertebrate pests like birds, bats and rodents. Among rodents, porcupine, *Hystrix indica* Kerr caused damage to cashew nuts. While the bat caused damage to the cashew apple (photo 62). In view of the severity of damage and economical loss caused by porcupines to the cashew nuts, observations were recorded at CPCRI - seed farm Kidu, Dakshina Kannada.

Nature of damage :

Porcupines with their sharp incisors made irregular splittings of the cashew nut shell (photo 63) and gained an access to feed on the nutritious cotyledons of the nuts. Scattered nut shells under the trees and the foot prints clearly indicated the movement of porcupines and their number.

In cashew orchard, on an average there were 20 apples / tree during May 1998. At the base of the tree there were five fallen apples and 15 nut shells were littered. The close examination revealed that one porcupine ate about 15 nuts / night. Because the run trials and the fresh foot prints clearly indicated that there were three animals in the plot and under these trees, the observations indicated that each animal damaged 15-20 nuts / night. Interestingly whether the fruit is ripened or raw, the porcupines damage the fallen cashewnuts. Because of the wind and other factors the ripened and unripened apples with nuts will fall on the ground under the canopy of the cashew trees. These nuts were damaged by porcupines.

Management Practices :

The management of porcupines and their methods were discussed earlier in coconut chapter (Pages 69-70). The bat management in orchard crops is discussed in the chapter on bats.

Elephant Raids on Cultivated Crops

A series of reports on elephant raids appeared during 1998 in local newspapers in Coorg, Chikmagalur, Hassan and Shimoga districts. Based on the reports, the affected areas were surveyed and facts and features of the cultivated areas were collected. As per the interviews made with local farmers of the respective areas, it was clear that the elephant raids are increasing year-after-year. In some parts of the affected areas farmers believed that elephants are a major threat to crops. Nevertheless no rigorous action is being implemented to mitigate the problem. Areas of elephant raids during 1998 are given in Table 1.

Reasons for Elephant raids :

A survey revealed that the natural habitat of the animals is shrinking year-after-year due to the human encroachment for cultivation of forest lands. Major forest areas are being deforested for many reasons. On the other side, due to the strict enforcement of Wild life Protection Act, the population of animals has increased remarkably in some pockets. The food searching activities and foraging are affected by restricting the home range of the animals. Un-natural conditions created by human beings have pushed the animals to invade the cultivated tracts.

Seasonality :

Observations revealed that the increasing elephant raids are reported during dry periods (January-May). Villages adjacent to forests (Reserve forests) received heavy damage and the crops cultivated (Coconut, Banana) under irrigated conditions were the most affected. Fruit crops grown in and around Chettalli in Coorg received heavy losses throughout the year. October, November and January to April are the months during which more raids occurred.

Crop Losses :

It is very difficult to quantify the crop losses. Crop loss occurred due to feeding and trampling or breaking the productive parts of the plants. In coconut and banana, loss is very serious as elephants destroyed the whole plants. The losses can be considered as economical and the management practices to be adopted are as follows.

Management Practices :

- 1) The public should be aware of the elephant raids.
- 2) The deep trenches or elephant proof trenches are to be opened wherever possible.
- 3) Electric fencing can be established at some places.

- 4) Sulphur tears can be used to repel the elephants during their raids, though it is practically difficult.
- 5) Regular night patrolling using flood lights, strobe lights will check elephants raids.
- 6) Bon fires, burning of old tyres etc., can also help.

Government responsibilities :

Karnataka state government has implemented certain programs for controlling elephant raids through the forest department. Regular training programs and camps are conducted for the local people to educate about the elephant raids by the help of resource persons. A team of experts is constituted to assess the actual crop losses caused by elephants. Compensations for crop losses have been raised from Rs 2000 to Rs 5000. Compensations for human deaths have been raised from Rs 25,000 to Rs 1,00,000. State government is making serious efforts to get central assistance in order to speed up the programs.

Table 1 Areas where elephant raids were recorded during 1998.

District	Taluks	Villages	Crops (Main)
Coorg	Somwarpet	Kodlipet, Shanivara Santhi, Somwarpet, Jamboor, Kumboor, Igoor.	Coffee, Banana, Paddy, Cardamom.
	Madikeri	Moornadu, Madikeri, Madapura, Thitimathi, Hebbale	Coffee, Cardamom Paddy,.
	Virajpet	Polybetta, Virajpet, Bagamandala, Chattahalli, Gonikoppa, Ponnampet	Fruit crops, Paddy, Coffee.
Chikmagalur	Mudigere	Byrapura, Kundur, Saragodu, Guthihalli, Gubgol, Koove, Kalasa, Kumbardi, Gonibeedu.	Coffee, Cardamom, Paddy, Banana.
	Chikmagalur	Muthodi and surrounding, Balehonnur	Coffee, Areca, forest, nursery, Bamboo.
	Koppa	Koppa and surrounding	Areca, Banana, Coffee.
	N.R. Pura	N.R. Pura and surrounding.	Areca, Rubber, Paddy, Banana, Vegetables.
Hassan	Belur	Gandehalli, Tohalu, Cheekarahalli, Arehalli, Bikkodu.	Paddy, Coffee, Sorghum, Ragi, etc.,
	Sakleshpura	Hethur, Hadlahalli, Vanagoor, Goddu.	Cardamom, Banana
Dakshina Kannada	Belthangadi	Ujire, Charmadi, Kakkinge, Mundage, Pernal, Thotathadi.	Areca, Coconut, Rubber, Banana, Vegetable crops.

PEACOCK (*Pavo cristatus*)

From October 1998 to February 1999, three surveys were conducted in Koyoor (Belthangady Taluk), Durga, Kervase, Tellar, Siralal and Mala villages (Karkala taluk) to record rice crop damage by peacocks. The observations recorded through a pair of 8 x 30 binoculars and crop damage assessment made are briefly described below.

Paddy was the dominant crop damaged by peacocks. Damage by birds was caused by trampling, lodging the tillers and by picking grains and cutting the entire panicles. In Koyoor village 'Jyothi' cultivar of paddy was damaged at the edges along the bunds. Birds were observed roosting on trees in the up-lands adjacent to paddy fields. The birds caused damage throughout the year. However, peacock damage occurred during August and September. Besides paddy, birds damaged cucurbit vegetables, brinjal, cowpea, ladiesfinger (okra) and pulses. The details of crop damage village wise is furnished in Table 1.

The population of birds in the fields varied from 2-3 in about 5-10 acres of crops. The farmers reported that breeding in these birds occurred during October-November. The clutch size in the bird varied from 2-3 eggs. As evidenced from interviews conducted with growers, the crops damaged by these birds is increasing year after year probably due to increase in the local bird populations.

The public due to religious sentiments (Lord Kumaraswamy / Subramanya) the birds are worshipped as vahana of 'Lord Kumara Swamy'. The birds are not being killed and instead they are worshipped. Secondly, the peacocks are predators on snakes and leeches. So with the presence of birds, the snakes are checked. Thirdly, these birds are beautiful and people do not wish to kill these birds.

The birds in the Kudremukh wild life sanctuary and other forest areas are freely breeding as they have no predators such as Tigers and Leopards. These factors are

responsible for local population build up. Albeit, few individuals are being killed by the hill tribes for extracting oil which is of medicinal value.

In none of the villages surveyed, farmers are keen to take-up any crop protection measures. The crop fields surrounding the Northern side of Kudremukh National park and other forest areas are being severely (50%) damaged. In these crop fields crop protection measures are desired. During the peak feeding period, the birds may be chased away. One farmer in Durga village (Mundi Jarkala) used trained dogs to indicate the entry of the birds to the paddy fields. Then the farmer would come and chase away the birds and this method saved much of his crop. The bird landing and the movements in the field could be obstructed by sprigs of thorny bushes at strategic points. This is only an interim report, a detailed study is in progress.

Table 14 Peacock damage to paddy in Dakshina Kannada.

Village	Plot area (acres)	% damage	Yield loss (kg)	Remarks
Koyoor	06	08	80	Damage occurred along the periphery only grain feeding No. of birds ranged 2 to 20.
Umedabaile	04	10	60	Damage only at the borders, grain picking, number of birds = 2 to 3.
Kaliyady	10	05	80	Damage only at the borders, grain picking, number of birds = 2 to 3.
Sirlal	02	18	40	Damage in patches, panicle swallowing, number of birds = 2 to 3.
Durga	02	15	40	Damage in patches at all places, panicle swallowing, number of birds = 4 to 5.
Mundli jarkala	01	20	120	Damage in patches, group feeding, trampling, lodging and panicle cutting : number of birds = 2 to 3.
Hankibetta	0.5	6 to 8	40	Damage in patches, group feeding, trampling, lodging and panicle cutting : number of birds = 4 to 6.
Kervase	02	12	100	Damage in patches, group feeding, trampling, lodging and panicle cutting: number of birds = 5 to 6.

Bison Raids on Plantation crops

India is the third largest country producing coconut, *Cocos nucifera* L in 1083,000 ha with a production of 5,734 million nuts per year, sharing 17.5% production in the world. Karnataka with 4,07,024 ha and a mean production of 272.70 crores of nuts in 1994, shared 14.2% of the country's production and occupied third position (Annual Report, Department of Horticulture, 1994). Coconut is cultivated in coastal and plains of Karnataka and is depredated by vertebrate pests. Bison, while feeding on grass and other wild vegetation browse on the newly emerging fronds of the coconut palms. So, coconut plantations at the vicinity of forest or wild tracts are highly vulnerable to the bison damage. Bison feeding behavior (Prater, 1971) and bison damage to palms (Fitzwater and Ishwar Prakash, 1989) has been reported. Ajit et. al., (1997), Williams (1968), Davidar (1969) and Ullas Karanth (1984) have published observations on various aspects of bison behaviour under field conditions.

Bison, *Bibos gaurus* H, like, elephant, *Elephas maximus* L is increasingly causing crop depredations in hill region. In Chikmagalur and Kodagu districts, banana plantations are mainly affected. In coastal Karnataka, the animal damaged areca, *Areca catechu* L, sugarcane, *Saccharum officinarum* L; coffee, *Coffea arabica*. L & *Coffea robusta* L. and coconut plantations mainly. These animals also grazed on vegetables like radish, *Raphanus sativus* L; chilli, *Capsicum annum* L; brinjal, *Solanum melongena* L etc., Hence, studies on assessment of crop losses and habitat preference were initiated.

Survey :

Monthly surveys were conducted from 1996 to 1999 through out the year at Central Plantations Crops Research Institute's seed farm at Kidu. Observations were recorded from September 1996 to April 1997, from May 1997 to March 1998 and from May 1998 to March 1999 to find the seasonality of damage. Regular patrolling (two persons visiting the plot from

late evening to early morning) in and around the experimental plot was undertaken to estimate the bison population. Pug marks of the animals were also matched for estimation of the bison population in entire area of the farm i.e., 300 acres. Data was subjected to statistical analyses.

Nature of damage :

Studies conducted during 1996 revealed that bisons, during night also depredated crops in groups. Both the young and adult entered the fields together. Plenty of grasses and tender foliage on medium and small trees/bushes attracted the animals to the cropped area for grazing.

Bisons by rubbing body against branches / trunk caused losses in yields in cocoa, *Theobroma cacao* L (photo 40), sapota, *Achras zapota* L (photos 49 & 50), citrus, *Citrus sinensis* B (photos 51 & 52) and guava, *Psidium guajava* L (photo 45) The animals also caused losses due to trampling to crops at seedling stage while foraging. Bisons foraged repeatedly in the same fields.

Loss assessment :

Observations were recorded on bison damage to coconut seedlings from 1996 to 1999. Since bison feeding caused reduction in height of seedlings and decrease in the number of healthy fronds, the extent of damage on seedlings was categorized into the following four groups.

Plant height (m) and mean number of healthy fronds / seedling	Score weightage
4 (10)	1
3 (6)	2
2 (4)	3
0 to 1 (2)	4

*Figures in brackets are mean (n=25) number of normally grown fronds / seedling.

The experimental coconut field served as a 'Cafeteria' for the bison herd. The experimental plot was regularly foraged and the animals were primarily attracted by the grasses and the ground vegetation. The bison damage commenced in the plot from July, after monsoon rains, when ground vegetation was dense. The bison feeding reached peak from August to November and started decreasing from December to April. The damage to coconut seedlings was related to the ground biomass production, the animals while feeding on ground vegetation (Table 1) incidentally also fed on young coconut fronds.

Regular surveys of the areas (extending to about 20 acres) surrounding the plot revealed that the area only provided shelter but no food to the foraging animals. This situation attracted the animals to aggregate and forage in the experimental plot. Observations of three years revealed that the number of bison in the 300 acre farm increased at the rate of one bison per 18 months. On an average, there were an estimated eleven animals in the farm ($n=18$).

The seasonal occurrence of damage to coconut fronds by bison is shown in figures 1 to 3. Peak damage occurred during October to December with peak production of ground biomass. Of 211 seedlings, 20 in 1996-97 attained 4m height i.e., these seedlings were free from damage. From 20, their numbers increased to 112 in 1998-99. As the age of seedlings increased, the feeding pressure of bison decreased. As a result, the number of severely damaged seedlings (bison damage category 4) decreased from 49 in 1990 to 3.0 in 1999. This may be due to regular patrolling by night staff in the experimental plot and with increase in age, the leaves developed toughness and lignin, rendering leaves distasteful to animals. There were statistical significant differences in the number of seedlings in different damage categories (Table 2). On an average, 53% palm seedlings showed damage during 1996 and about 5% during 1998. On an average, the number of normally grown leaves in severely damaged seedlings were only two and this drastically impaired growth of seedlings and in some cases

the seedlings perished. Such seedlings showed no recovery and fresh fronds did not emerge. The trend in the proportion of healthy to damage fronds / seedling (Table 3) was similar to the seasonal damage pattern. During 1996-97 the proportion of healthy to damage fronds was in 1 : 2 ratio. During 1997-98, this ratio reduced but during 1998-99, number of healthy fronds prepondered over damage fronds (Table 3) i.e., with increasing age of coconut seedlings, the bison feeding damage decreased.

Management practices :

Management practices include Ibex fencing, trenches, use of strobe lights and bonfires, timely harvests and clean cultivation help in reducing bison damage to crops in hill region of Karnataka. The bison feeding on young (2 to 3 years old) coconut palms could not be prevented by IBEX fencing and by fencing with wires and stone pillars (photo 19). Watching and scaring the animals during night afforded some protection. There is a need to find protection methods against bison feeding on coconut seedlings in coastal and hilly regions of Karnataka. Proper regulation of ground vegetation in the young plantations may render the area less attractive to the animals and lessen the damage.

**Table 1 Ground vegetation in coconut plantation at CPCRI-Kidu,
Coastal Karnataka.**

Sl No.	Scientific Name	Vernacular Name
1	<i>Boerhaavia verticellata</i>	Madanika
2	<i>Leulama levlocephala</i>	Denvit
3	<i>Sida</i> spp.	Bhemana kuddi
4	<i>Cynodon arcuatus</i>	Hasagarike
5	<i>Ipomola</i> spp.	Chandrakanti
6	<i>Plaseola</i> spp.	Siripotla
7	<i>Brachiaria</i> spp.	Krishna chora
8	<i>Sida rhobifolia</i>	Atibala
9	<i>Leucaena leucocephala</i>	Vilayati bali
10	<i>Nephrolepis</i> Spp.	Jari bali

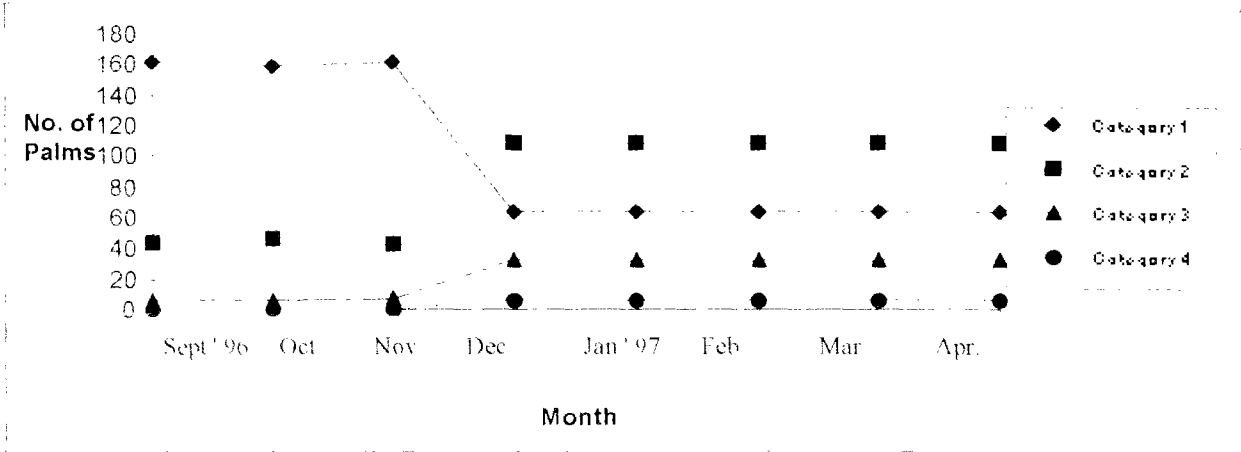
**Table 2 Mean number of coconut palms in four different bison damage categories,
1996 to 1999.**

Plant height (m)	Bison damage Categories	Mean number of palms damaged (n=211)		
		1996-97	1997-98	1998-99
4	1	20.45	18.00	112.26
3	2	58.54	62.27	76.00
2	3	83.63	85.36	19.83
1	4	48.50	45.37	3.00
	C.D at 5%	21.78	23.21	27.35

Table 3 Proportion of healthy and damaged fronds in Coconut palms, raided by bisons at CPCRI-Kidu.

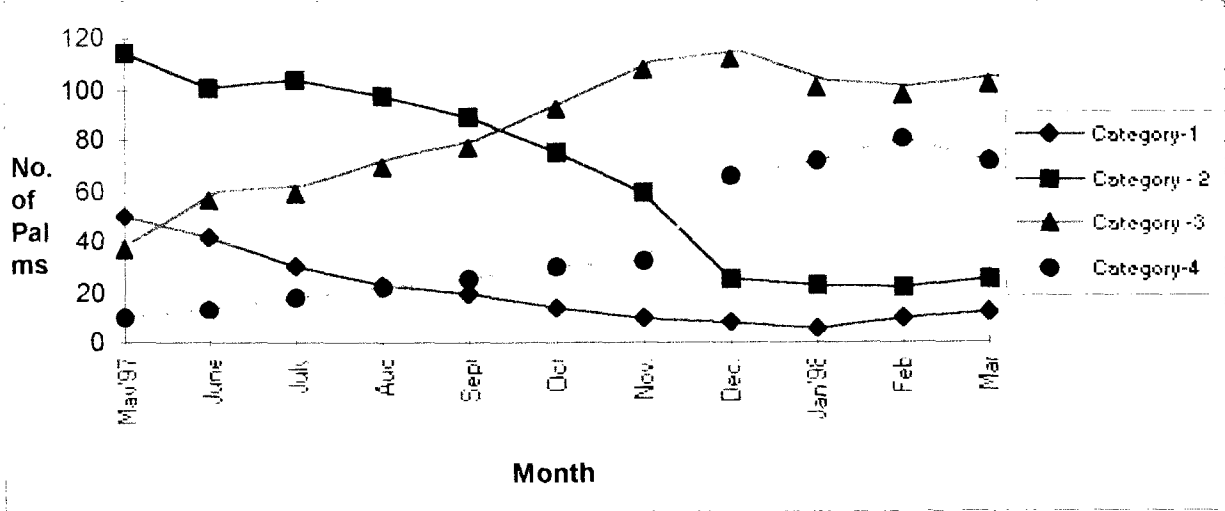
Month	No. of fronds		Month	No. of fronds		Month	No. of fronds	
	Healthy	Damaged		Healthy	Damaged		Healthy	Damaged
Sept'96	422	949	June'97	982	1062	June'98	1214	914
Oct	514	1150	Jul	1010	1090	Jul	1230	762
Nov	610	1282	Aug	1022	1110	Aug	1243	912
Dec	621	1315	Sept	1031	1122	Sept	1268	710
Jan'97	714	1462	Oct	1059	1128	Oct	1271	618
Feb	719	1480	Nov	1084	1135	Nov	1292	706
Mar	722	1494	Dec	1099	1162	Dec	1310	624
April	731	1512	Jan'98	1118	1173	Jan'99	1314	643
Mean	631.625	1330.5	Feb	1152	1188	Feb	1322	612
t Critical	1.9		Mar	1163	1194	Mean	631.625	1330.5
(One-tail)			Mean	631.625	1330.5	t Critical	1.8	
t Critical			t Critical	1.8		(One-tail)		
(two-tail)	2.36		t Critical			t Critical		
			(two-tail)	2.14		(two-tail)	2.2	

Fig 1 Bison damage to Coconut Palms (1996-97) at CPCRI, Kidu,
Dakshina Kannada (Coastal Zone)



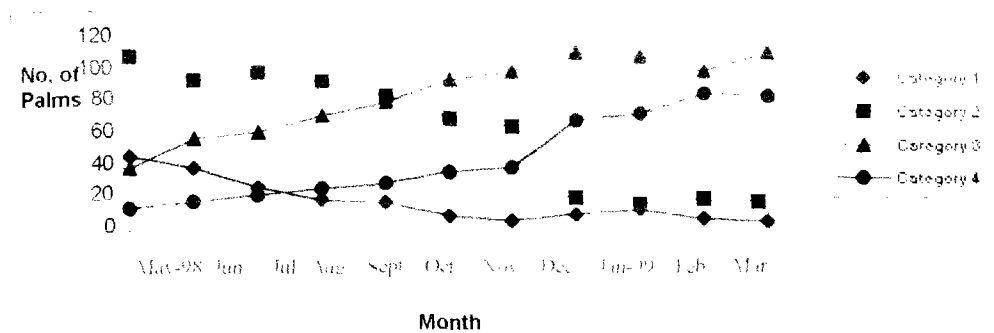
Category 1 = 1 meter height, Category 2 = 2 meter height,
Category 3 = 3 meter height. Category 4 = 4 meter height .

Fig 2 Bison damage to Coconut Palms(1997-98) at CPCRI, Kidu,
Dakshina Kannada (Coastal Zone)



Category 1 = 1 meter height, Category 2 = 2 meter height,
Category 3 = 3 meter height, Category 4 = 4 meter height

Fig 3 Bison damage to Coconut Palms (1998-99) at CPCRI, Kidu,
DakshinaKannada (Coastal Zone)



Category 1 = 1 meter height, Category 2 = 2 meter height,
Category 3 = 3 meter height, Category 4 = 4 meter height

WILDBOAR

INTRODUCTION

Wildboar, *Sus scrofa* Linn. is the most common and widely distributed quadruped, and an economically important vertebrate incurring economic losses in rice, *Oryza sativa* L; arecanut, *Areca catechu* L; rubber, *Hevea sinenses* L; berry, *Morus alba* L; sunflower, *Helianthus annuus* L; finger millet, *Eleusine coracana* L; sugarcane, *Saccharum officinarum* L; sorghum, *Sorghum vulgare* L; potato, *Solanum tuberosum* L and groundnut, *Arachis hypogaea* L. Cent-percent crop yield losses were recorded in fields adjacent to forests without any carnivores. Activities of wildboars also accrues benefits to the ecosystem. Wildboars turn sub-surface soil to surface, feed on arthropods injurious to crops and help maintain soil fertility. Prater (1971) briefly described the habits and life-cycle of wildboar in the Indian sub continent. Brooks et al., (1989) surveyed various parts of Pakistan and identified wildboar as a major vertebrate pest on several field crops and the workers also assessed yield loss. Beg and Khan (1982) studied the distribution and movement patterns of wildboar in Pakistan. Shafi and Khokar (1986) advocated protection measures to sugarcane from wildboar damage. Thomas and Naidu (1995) observed large-scale damage to rice by *S.scrofa* in areas adjacent to bamboo forests in Tindhini, Jabalpur, North India. Chakravarthy (1993) highlighted the role of wildboar in evergreen tropical forests of Western Ghats region in regulating vegetation and soil fertility. He also described the nature of damage on selected crops.

Wildboar is an even-toed ungulate belonging to order Artiodactyla and family Suidae. In hill region, wildboar was observed to breed throughout the year but principally during post-monsoon period (September to December) when more than 50% of cultivated area is under rice. Wildboars foraged gregariously either in the morning before 6.00 a.m. or late in the

evening after 7.00 p.m. Generally, on moon-lit days, the animals began foraging late. The animal is widespread with a turnover rate/year varying from 6 to 8 in hill region.

The seasonal food of wildboar in hill region included tubers of *Colacasia spp.*, *D. alata* L; sorghum, maize, *Zea mays* L; potato, sugarcane, cardamom, *Elettaria cardamomum* M tillers / rhizome, pineapple, *Ananas comosus* L, groundnut, etc. Herds were found foraging on heaps of refuse and backyards of human dwellings also. During summer (February to May) the feeding pressure on cultivated crops is high as the cultivated area in the region shrinks by about 60%. Rice is the most prominent cereal grown in over 79% of the cultivated area in hill region. The crop is cultivated in small, fragmented plots in low-lying lands, slopes and uplands.

Wildboar damage to rice often results in entire crop failures. The extent of damage to rice crop varied from one plot to another depending on factors like natural habitat (adjacent to forest) which facilitated the animals for resting, breeding activities and shelter. Hunting, lighting bonfire and watch and ward are the indigenous methods adopted by farmers to protect rice from wildboar damage. Often these methods are ineffective and risky. So, proper methods of crop protection are desired.

Survey, Damage and yield loss :

Surveys were conducted from 1989 to 2001 in Shimoga, Chikmagalur, Kodagu and Hassan districts to assess the damage and loss in rice yields caused by wildboar. The foraging routes of the animal in a field was mapped on a graph paper to determine foraging patterns. Observations from an elevated, enclosed hideout (commonly called as 'Machan') (photo 67) during night with a torch were recorded on herd size, time of foraging, nature of damage and food preferences. Binoculars (8 x 30) were used to sight the animals from the hides. Survey

was made throughout the year but concentrated during kharif (June to December), which is the main rice growing season.

During our earlier studies, damage to rice by wildboar was assessed. The damage was categorized into three types : trampling, lodging and browsing. The percent area containing lodged clumps was measured and expressed as percent of the total plot area. The average number of grains / ear head was worked out (with $n = 1000$ ear heads). Then the total loss of rice (equivalent to number of tillers lodged) in terms of kgs was worked out.

Wildboar while foraging in paddy fields trampled the plants and caused loss of ear heads. The clumps affected were expressed as number of clumps trampled / m^2 . The loss caused by wildboar by feeding on grains was expressed in terms of number of ear heads fed by wildboar. The kgs rice loss was expressed as rupees loss @ Rs 4.60 / kg.

Surveys revealed that wildboar is an economically important vertebrate pest causing economic losses in rice yields in Chikmagalur, Kodagu, Shimoga and Hassan districts of Karnataka. In Hassan and Kodagu, the animal is more extensively hunted and so the population generally remains at lower levels. During our preliminary studies the crop damage ranged from 5 to 90% in different taluks of the four districts (Table 1). On an average, wildboar incurred twelve percent yield losses in paddy ($n=20$ fields / taluk x 7 taluks x 3 years). Cent-percent losses in rice yields were recorded in fields adjacent to or in forest tract. Rapid deforestation and depletion of food in the forests have forced the wildboars to become a destructive rice pest. Fields in valleys were more severely damaged than those in midlands and uplands. Wildboar encroachment into the fields was identified by hoof-marks found on bunds. The extra-depredative (spillage on ground) losses far exceeded losses due to direct feeding. Usually, the corner and border plots received the maximum damage. The damage to rice

varied considerably from one plot to another depending on sowing date, variety, duration, plant height, scent and natural habitat adjacent to the paddy fields.

Examination of fields foraged by herd revealed that wildboar has no definite foraging pattern. Usually the animals fed rice along borders or across the field diagonally. Fields with early maturing, tall rice cultivars sustained heavier damage than late maturing, dwarf rice cultivars. Animals foraged the same patch at a gap of 2 to 3 days.

Yet another our earlier studies shows that, a rice growing tract of 27 ha in Mudigere taluk was used to estimate yield losses. Yield loss was measured at harvest by quantifying the area under rice trampled and was expressed as per cent area over the total area. The estimation revealed that the yield loss amounted to 24% i.e., 6.25 ha out of 27 ha.

At Mudigere (Chikmagalur district), damage assessment due to wildboar was carried out in 6 acres of Intan rice. The area containing lodged clumps was measured and expressed as per cent of the total area. The wildboars caused lodging in about 4465 m² area i.e., 13.5% of ear heads loss was estimated to about 10,800 ear heads. The average number of grains / ear head was 350 (n=1000 ear heads). The total loss was 330 kg and in rupees it worked out to be Rs 1518. That is a herd consisting of a female and three young ones caused a loss of Rs 1518 in 16 days from 14-12-1991 to 30-12-1991 @ Rs 4.60 / kg rice.

The wildboar damage to rice by lodging, trampling and feeding in 8 acres of Intan rice in Mudigere taluk is given in Table 2. There were non- significant differences in the three types of damage. However, among dates and types of damage a significant difference was obtained. In all, the wildboar caused a loss of about 418 kg rice. This amounts to Rs 1992 @ Rs 4.60 / kg.

A herd of four wildboars in 18 days caused a loss of 20 hills/ m² of one ha Intan paddy in Mudigere during December 1992. The total number of hills lost was 12,942,

weighing about 52 kg of rice grains. This much loss amounted to about Rs 240 @ Rs 4.60 / kg, which may not be an economical loss. The percent crop area, damaged per plot varied from 0.0% to 15%. The damage was severe during dark night compared to moonlit night (1998). Tall varieties suffered more damage compared to dwarf ones. In space, the distribution of damaged clumps was patchy (Table 3).

Wildboar caused about 59% yield losses from three types of damage in the study area. Depletion of food in the forest forced the wildboar to attack paddy crop (Table 4).

Crop Protection Measures :

Dioscorea alata L, tuber was found to be the preferred food of the animal in the wild. This creeper is widely distributed especially around paddy growing tracts. To exploit this preference, field trials were conducted. Tubers and cuttings of the creeper were placed around rice growing tracts during kharif of 1993 and 1994 at Mudigere.

The Indian wildboar has highly developed olfactory and visual senses. Trials were conducted during 1991 to 1993 in rice fields with Thimet 10 G to serve as a repellent. 5 to 10 g, 10G Thimet granules were mixed with 10gm dry sand and the mixture was held in punched poly bags. Such poly bags were hung at the boundaries of rice fields at 3m distance and at 0.6m to 1.0m. height. This trial was run in 8 rice fields for three years. The size of rice fields varied from one to three acres. The poly bags containing 10g Thimet were suspended along the boundaries from which the animal encroached the field (photo 32). These experiments were repeated during karif -1998 also, which gave similar results.

The field trial with *D. alata* did not elicit any response from the wildboar population. The trial with Thimet 10 G proved successful. The animals were repelled away from the field for 30 to 50 days. Thimet 10G could protect eight rice fields in all the three years and this method proved safe and effective. After harvest of rice, Thimet 10G granules could be used

against rats damaging rice plants. Rogor 30 EC and Malathion 50 EC proved ineffective when applied in a similar manner with dry sand. Thomas and Naidu (1995) found herds disturbing the entire rice fields by digging and trampling in Madhya Pradesh. During the ripening stage of rice, the damage was more severe particularly for local, tall rice varieties. But cultivars with long auricles on panicles were less preferred. So, farmers in Madhya Pradesh are growing dwarf rice with long auricles on panicles to lessen wildboar damage. Observations in 1999 at Mudigere revealed that the wildboar damage can be reduced by practicing Integrated Pest Management practices mentioned below from 59% to 18% (Table 4) evaluated systematically in RCBD with three replications at four locations. The data was statistically analysed.

1. Suspending 3 to 5g Thimet 10G + Dry sand (5-9 g) in perforated poly bags in the entry areas of the paddy fields.
2. Scaring the animals during nights for two months.
3. Selective killing by mainly shooting.
4. Erecting electric fencing, wherever possible along border from where the animals invaded.

The same above mentioned practices proved effective at Mudigere in 2000-2001, reduced the damage from 59.5% to 18.46% (Table 5).

**Table 1 Wildboar damage to cultivated rice in different taluks of hill region,
of Karnataka.**

Taluk	Area invaded / spoilt (m ²)	Percent of the plot spoilt
Sringeri	378	33
Koppa	243	30
Thirthahalli	462	41
Mudigere	1181	75
Chikmagalur	729	50
Ponnampet	225	10
Madikeri	420	5
Bhadravathi	2070	30
Hassan	3240	90
Belur	225	61

Table 2 Types of wildboar damage to rice in hill region.

(Earlier studies of the authors)

Dates	Tillers damaged / m ² by Wildboar		
	Lodging	Trampling	Direct feeding
14-12-94	7.25	5.95	11.11
16-12-94	13.98	8.00	12.29
17-12-94	7.31	8.15	24.70
21-12-94	28.47	26.66	23.38
23-12-94	25.55	23.00	17.80
26-12-94	10.88	40.00	29.21
28-12-94	21.08	22.00	23.73
30-12-94	33.14	21.00	24.04
Total	167.39	176.76	188.87
Mean	18.59	19.97	20.98
CD@ 1% types of damage = 8.73%; Dates = NS			
Types of damage x dates = 1.09			

Table 3 Wildboar damage to rice at Mudigere, kharif 1998.

Variety	Month	R1	R2	R3
IET 7191	November	0.0%	15%	2.5%
IET 7191	December	1%	4%	3%

Table 4 Effect of IPM practices on Wildboar damage to paddy crop - 1999.

Plot No.	Yield loss (Tillers damaged / m ²)					
	Before adopting IPM tools			After adopting IPM tools		
	Browsing / feeding	Trampling	Lodging	Browsing / feeding	Trampling	Lodging
1	11.11	5.95	7.25	1.11	1.00	2.00
2	12.27	8.00	13.98	2.20	1.05	6.00
3	24.70	8.15	7.37	6.60	3.30	1.05
4	23.38	26.16	19.73	5.50	6.63	6.75
5	22.61	24.0	28.47	12.05	10.06	11.05
6	17.80	23.00	25.55	6.75	7.75	10.11
7	29.21	40.00	10.88	3.75	13.05	3.03
8	23.73	22.15	21.08	16.04	5.50	7.05
9	24.04	21.05	33.14	4.44	6.63	9.15
10	25.03	10.16	26.09	7.05	1.50	7.31
Total	213.9	188.3	193.54	65.49	56.47	63.50
Mean	21.39	18.83	19.35	6.55	5.65	6.35
SD @ 5%	4.99	3.69	3.98	1.98	1.95	1.97

**Table 5 Effect of IPM practices on Wildboar damage to rice crop in hill region of
Karnataka -2000-2001.**

Location / Plot	Yield loss (Tillers damaged / m ²)					
	Before adopting IPM tools			After adopting IPM tools		
	Browsing / Feeding	Trampling	Lodging	Browsing / Feeding	Trampling	Lodging
	20.11	6.75	25.15	3.33	3.00	1.15
	16.00	5.16	6.95	2.16	1.00	5.05
	23.80	18.39	7.30	6.55	6.60	6.15
	19.60	15.60	30.19	10.05	12.85	10.06
	21.00	25.00	25.10	3.75	5.50	3.33
	29.75	39.65	7.25	16.00	6.61	7.05
	26.00	29.60	14.10	5.55	5.00	6.10
	21.75	19.60	24.60	7.05	1.55	7.31
	18.60	20.00	32.00	5.50	3.30	2.00
	29.00	11.11	6.66	10.06	10.00	11.06
Total	225.61	190.86	179.30	70.00	55.41	59.06
Mean	22.56	19.10	17.93	7.00	5.54	5.93
CD @ 5%	4.99	3.69	2.98	1.98	1.95	1.98

FRUIT BATS AND CROP PROTECTION

INTRODUCTION

Among living vertebrates, bats and birds are unique in their ability to fly and it is this common feature that sets them apart ecologically from other groups. Bats are in some ways the nocturnal equivalent of birds, having evolved and radiated into a diversity of forms to fill many of the same niches. Bats have successfully colonized almost every continental region on earth (except Antarctica) as well as many oceanic Islands and archipelagos. They comprise the second largest order of mammals (next to rodents) in the number of species and probably exceed all other groups in the overall abundance. Bats exhibit a dietary diversity unparalleled among other living mammals. Bats are either monogamous or polygamous.

The vast majority of what we know about the ecology of bats is derived from studies of only a few of the approximately 850 species. The tropical regions of the world support the highest diversity of bat faunas known, but unless steps are taken to decelerate current rate of loss. Since bats are distributed from tropical habitats to alternate land-use patterns, the ecological diversity of bat fauna may never be fully known.

There are about 4200 living species of mammals and almost 1000 of them belong to the order chiroptera. Only rodents, over 1700 species are more specious and most species of bats (88%) are exclusively tropical and the 12% which live in temperate regions, are members of the vesperpillionidae. Bats (order : Chiroptera) can be sub divided into two sub-orders viz., Megachiroptera and Microchiroptera

Suborder :

1. Megachiroptera :

These are the medium to large, mostly frugivorous bats of the Old World tropics referred as flying fox or simply fruit bats. All belong to the family Pteropididae. Megabats are

so different from microbats, members of the sub-order Microchiroptera, that some chiropteranalysts deny that the two suborders arose from a common ancestor. Unlike Microbats, Megabats do not use high frequency echolocation, although a couple of species use a distinctive and probably low-frequency level based on 'tongue licking'. Megabats have large eyes and well developed vision. The wings and flight anatomy are much less sophisticated than in microbats of dental and cranial anatomy suggest a remote relationship at best. Megabats feed on fruits, flowers and pollen other than biting off and swallowing mouthful of fruits, some seem to crush the fruit and swallow the juices and spit out the pulp. Several small species have elongate snouts and tongues that specialize in nectar and pollen feeding. Most megabats roost in trees, sometimes aggregating in huge flocks. The echolocating species such as (*Rousetteus*) tend to have access to subterranean caves and boulders.

Morphological aspects :

Certain aspects of morphology, especially the over all size of trophic structures have been used to make predictions about their size of items, such as fruits ingested. (Generally a positive relationship caused but it is complicated when the type of foraging and energetic come into the review of statistics). The idea that ecological divergence of close competitors in areas of sympatry leads to morphological divergence have been formalized by the term "character displacement". If morphological variability matches ecological variability and if the competition must be minimized to permit coexistence, then morphological relationships between stable communities or guilds should be predictable. In case of various fruit bats foraging on a particular site or orchard the observation was that the larger flying foxes had taken more larger fruits than the other two smaller varieties of fruit bats such as the Indian short nosed fruit bat, *Cynopterus sphinx* (photo 68) and the fulvous fruit bat, *Rousetteus leschaunaulli*.

Individual bats of the same species vary in behaviour as a result of learning, genetic disposition etc., and the like. However, some bats develop rapidly and must become independent at an early age, the role of experience and learning in structuring the behaviour is minimized and the dominance of unherited factor are likely to be measured.

Foraging strategies of plant-visiting bats :

Approximately 250 of the 850 known species of bats are particularly or wholly dependent upon plants as a source of food. These bats are involved in a mutualistic exploitation system with plants in which the bats obtain food in the form of nectar, pollen or fruit, providing mobility of pollen grains.

With few-exceptions, bat-plant interactions are restricted to tropical parts of the world. Plant-visiting bats are found in two families, the Phyllostomidae of the New World tropics and the Old World tropics. Bats of the Old World tend to pollinate a large variety of tree species and some are economically important. Plant-visiting bats have been interacting from evolutionary times with angiosperms less than 50 MY, during which they have had an appreciable influence on angiosperm diversity at the generic and species level. Increased plant diversity, inturn has undoubtedly had a diversifying effect on the Old World fruit bats.

In India, 117 species of both fruit and insect eating bats have been recorded, of which 12 Pteropids have been recorded. Only three species such as the Indian flying fox, *Pteropus giganteus* (photo 69) the fulvous fruit bat, *Rousetteus leschaunaulli* and the short nosed fruit bat, *Cynopterus sphinx* cause considerable damage in orchards and farmlands in Southern India.

The Indian flying fox, *Pteropus giganteus* live in colonies and hangs from branches such as banyan, *Ficus religiosa*; mango, *Mangifera indica* and tamarind, *Tamarindus indica*.

Compared to other bats, *Pteropus* has few predators. Humans are potential predators and may hunt them as a source of protein.

The fulvous fruit bat, *Rousettus leschaunaulli* roosts in clusters in unused buildings and temples. They weigh about 110g. The short nosed fruit bat; *Cynopterus sphinx*, prefers roosting in dried leaves of kutul and window caves. It weights about 45-50g, living in small colonies of about 10-28 individuals.

Food availability and foraging strategies :

Plant visiting bats have four major concerns regarding the nature of their food supply. The question is what kind of plant foods are available, how much is there of each, where are they located and for how long is it available ? The answers to these questions reflect in part the outcome of the co-evolution between bats and plants. On the botanical side, this co-evolution have effected the morphology of flowers and fruit maturation, the amount of pollen and nectar, the nutritional characteristics of pollen and fruits.

Regarding overall phenological patterns, Genky recognized two patterns (flowering) ranging from four flowering patterns, (i.e.) the production of a large number of flowers over a short period (big bang) to the production of a small number of flowers over an extended period (steady state). The remaining two strategies include 'cornucopia' (a rather large number of flowers over a months' time), and 'multiple bang' (several widely spaced, large flowers / crops per year). Fruit strategy analogous to each of the flowering / fruiting patterns also exist.

There are two extreme patterns, big bang (BB) and steady state (SS) represent a significantly different phenological strategies in a number of ways. BB plants usually attract a large number of opportunistic plant visitors and are probably less predictable in space and time than SS plant.

SS plants in contrast appear to maximize the quality of the services their visitors provide while sacrificing the quantity of propagules dispersed. SS plants attract a smaller number of specialized visitors, which render more reliable services. In general, the nutritional rewards provided by SS plants should be more predictable in time and space.

We might expect plants to produce fruits that lack certain dietary items, so that the animals could feed on other plants too, for a more reasonable diet. The species producing fruit at the same time of the year and utilizing the same dispersal agents should have complementary nutritional deficiencies, whereas species of fruiting at different times might converge in their nutritional awards. Plants gain a two fold advantage from this strategy. First, they gain greater mobility for their seeds and secondly they experience less interspecific competitor for seed-dispersal services.

General Foraging Strategies

Optimal diet breadth has been a central issue in many discussions of foraging behavior and deals with the question, what conditions promote the evolution of specialized rather than generalized diet? Variables that influence diet breadth are numerous and include the following: (a) the abundance, diversity, and seasonality of different kinds of prey (b) the relative costs of searching for, pursuing, handling, and assimilating different prey species (c) the nutritional characteristics of alternate prey and (d) the predation risks involved in finding and eating different prey species. Because they involve rather restricted conditions, such as constant availability, balanced nutritional composition, and high density of preferred prey, completely specialized (monospecific) diets should be uncommon among plant-visiting bats. Owing to the seasonal occurrence and diversity of sizes, shapes, biochemistry, and abundance of bat fruits and flowers, generalized (or at least polyspecific) diets should be the rule among these bats. Dietary generalization should be expected, particularly if different fruit or flower

species are nutritionally complimentary. Resource seasonality might also promote sequential specialization in which a bat species concentrates on its foraging efforts on a limited number of food species at different times of the year. This foraging strategy would offer the benefits that accrue to specialists (e.g., more efficient searching and food-handling behavior) while retaining some of the resource flexibility that characterizes generalists.

In Schoener's terminology, plant-visiting bats are pure searchers rather than 'pursuers'. Their prey items are expected to be found but often occur in patchy distributions and are ephemerals. Given these conditions, how should a bat search for food so as to maximize its net rate of energy in take? Refusing roosting strategies can potentially complicate this matter, because resource availability rates are likely to vary with distance from the central roost, especially if hundreds of conspecific bats roost together. In general, we expect resources located close to the central roost to disappear faster during the night than those located farther from the roost, because bat density should decrease with increasing distances from the roost. Thus, plant-visiting bats for a search strategy should involve (a) how far to travel from the roost before beginning to look for food (this is usually called the "commute" distance), (b) whether or not to be constantly alert for food both while commuting and during the actual search, and (c) whether or not to search along a regular path or an irregular one that include searching currently unproductive areas for upcoming blooms of flowers or fruits.

The optimal solutions to these problems involve a number of variables, including the spatiotemporal predictability of resources and the predator's risk. Regarding commute distances, refusing theory suggests that when resources are homogeneously distributed, commuting different distances from the refuge involves a trade-off between travel costs and expected resource availability. Short distances involve low travel costs but also low food density (because of high intra-roost competition), whereas longer distances involve higher

travel costs but relatively higher food density. Under these conditions we might predict that short-commuting bats should visit a greater number of (less rich) feeding areas than longer-commuting bats to fulfill their daily energy requirements. When resources are heterogeneously distributed, clear-cut predictions regarding tradeoffs between travel costs and energetic gains are difficult to make but could be modeled by computer simulation.

A second question related to searching strategies is, when should food-searching behavior take place-whenever the bat leaves its roost or only in the vicinity of known or suspected food locations? The spatiotemporal distributions of different food species will obviously influence this decision. For example, we might predict that bats should be constantly alert for food that is uniformly distributed and/or is available for long time periods, where as they should rely more on locational memory and not be constantly alert for food when it occurs in low density, ephemeral patches . The former strategy requires that commute and search behaviors occur simultaneously, where as the latter involves the separation of these two behaviors.

A final aspect of search behavior is the travel path taken between roost and different feeding areas. The two end points of what is probably a behavioral continuum are a regular path with stops at the same places each night over long time periods (trap-lining behavior) and an irregular path with frequent visits to new areas in search of upcoming food resources. Constancy of resource availability will influence this aspect of foraging behavior. Whenever food locations are highly predictable in time and space, trap-lining behavior, which minimizes commute and search distances and costs are likely to evolve. Whenever food locations are less predictable, selection should favor those foraging paths in which some time is spent looking for future food patches. Because of their greater length, irregular foraging paths will

be energetically more expensive than trap lines and, to the longer flight times increase a bat's exposure to predators, they are riskier.

Since most plant-visiting bats live gregariously in day roosts, they have a potentially wide range of group sizes in which to forage. The two basic choices, solitary versus group foraging, provide contrasting advantages and disadvantages to individuals. At first glance, solitary foraging might appear to be less advantageous because it does not provide three of the advantages often ascribed to group foraging: increased protection from predators, an increased sensory area with which to locate patchily distributed food, and increased knowledge of which food patches have already been visited by conspecifics each night. Loss of these advantages must be weighed against the advantages of potentially reduced feeding interference and/or reduced competition for food within a feeding area that accrues to solitary foragers. Resource densities and distributions will again influence this aspect of foraging behavior. Group foraging maximizes individual foraging efficiency when resources occur in rich but ephemeral, widely spaced patches. A predator – rich environment will reinforce the advantage of group foraging when resources are patchily distributed. In contrast solitary foraging should be optimal when resources are more predictable in space and time; predator free environments should also favor solitary foraging. Resource predictability might possibly influence another aspect of chiropteran sociality, namely, the strong tendency to live in gregarious rather than solitary day roosts in the present core. At the colonial roosts of a wide array of birds serve as information centers in which individuals parasitize each other's knowledge of the location of good feeding sites. Rich but ephemeral food patches might favor the evolution of group foraging. Plant-visiting bats may be gregarious for similar reasons.

Once a plant-visiting bat arrives at a feeding site, it is faced with two important behavioral decisions: whether or not to defend that site against other bats and how long to

remain at the site before moving to another food patch, back to its roosts or elsewhere. Decisions concerning site defense, which increases overall foraging costs, center around the area's economic defendability. Theoretical discussions and empirical work indicate that resource density is a key variable in determining whether or not a consumer should defend a food site. In two situations, low and high resource density, defense costs outweigh the advantages of defending a food site and consumers should tolerate the intrusions of other individuals. At intermediate resource densities, the advantages of exclusive access to known amounts of resource outweigh the costs of resource defense and territorial behaviors have to be expressed.

Allocation of time among different feeding areas has received considerable theoretical attention. Intuitively, we expect the residence time of a consumer in a feeding area to be directly proportional to the food density in that area, because searching effort should always be concentrated in those areas in which expectations of reward is the greatest. In addition to the food value of a consumer's current food patch, however, residence time is also influenced by a relative value of alternate potential food patches. Assuming that resource renewal rates are low, as it likely to be the case for fruit or flower resources each night, residence time per patch should be lower when alternate patches are food-rich than when they are food-poor. This is true because after a consumer has begun to deplete its present feeding area. It is more likely to increase its net rate of food intake by moving to a new area in a food-rich environment than in a food-poor one.

Mutualism :

Plant-visiting bats influence community diversity by contributing to the survival of plants (direct-effects), and through plants, bats indirectly influence the diversity of herbivores and their predators. The influence of bats is not always diversifying, because mutualistic

dependence on bats involves risk to the plants. A mutualist that loses its ability to persist without the interaction (an obligate mutualist) is especially vulnerable to variation in pollination or dispersal services. If a plant is specialized as well as obligate in its mutualism, it may follow its partner to extinction. Specialized and obligatory mutualistic bats would be exposed to similar risks. The flexibility of bat feeding strategies reduces the risks of mutualism to bats. Plants also show flexibility in pollination and dispersal systems; often pollination or dispersal can be accomplished by interacting with several species of bats, or with birds and non flying mammals. The relatively long generations times of trees and shrubs also buffers obligate pollination and dispersal systems against unusual population crashes by bats. An added consequence of the long generation times of plants is that pollination or dispersal failure in one year will not disrupt food supplies for bats : individual plants are likely to continue reproductive activity whether or not offspring are successful in a particular year.

A potential problem with increasing disturbance to tropical ecosystems is the progressive loss of flexibility in mutualistic systems. Destruction of natural habitats with the elimination of many roosting sites may reduce the number of species available to interact in mutualistic systems. Because flexibility is a stabilizing influence in obligate mutualism, each loss of a potential mutualist increases the chance that another species will follow.

The potential impact of population reduction or extinction, extends beyond the interacting bats and plants. Plants support assemblages of herbivores and food webs are based on these. The fates of species in different food webs are linked by the mutualistic services of pollinators and seed dispersers. Sometimes the persistence of many mutualists depend upon a 'keystone mutualist' that supports species at critical times . The bat-pollinated plant, *Ceiba acuminata* is an example of a 'keystone mutualist', because at times its flowers provide the only nectar available for many animals that are mutualists for other plant. We do not know

whether 'keystone mutualists' are found frequently, but they would make communities especially vulnerable to the disturbances of mutualistic interactions.

An important question is whether interactions between bats and plants affect the dynamics of relatively undisturbed communities. Whether this mutualism affects community stability depends on whether the interactions influence variation in reproductive rates or carrying capacities.

Mutualism, according to these models, may result in three patterns - (a) one or both mutualists will go extinct, which is most likely to happen when a mutualist is obligate. (b) both mutualists will increase in number until limits are set by some factor like predators, competitors or catastrophe, which is external to the mutualists' systems. This is the positive feedback that led to conclude that mutualism is a destabilizing force in communities. This result is called 'persistence', but this term obscures the fact that such growth tendencies may alter competitive or predator-prey balances. (c) the balance between benefits from mutualism and self-regulating factors may set stable equilibria for mutualist populations. Stable populations of mutualists are promoted by two factors. One factor is a significant effect of predators on one mutualist. Predators can increase the range of benefits that allow stable co-existence, even when predators alone are not a limiting factor. The juxtaposition of seed-predator and bat-pollinator effects in the *Bauhinia ungulata* system may promote system stability. Future studies of mutualism would benefit from tests for the effects of predators or herbivores. The second factor that promotes stable mutualism is an increase in mutualist density (density-dependent effects). This would occur in pollination and dispersal systems when the proportion of pollinated flowers or dispersed seeds fail to increase consistently with increasing numbers of mutualists.

Behavior within feeding areas :

Since plant-visiting bats often visit more than one feeding area in a night, the question arises, do changes in feeding sites represent attempts to maximize rates of food intake, to obtain a nutritionally balanced diet, to avoid competitors or predators, or to attain some combination of these goals?

BATS AS PEST ON ORCHARD CROPS

Bats are one of the most successful mammalian orders and are probably the most diverse group. The 966 species provide an unparalleled exhibition of variation on the mammalian theme and a broad lesson in biology.

IMPORTANCE OF FRUIT BATS AND THEIR SIGNIFICANCE

More than 250 bat species eat fruit, nectar and pollen. In doing so, fruit bats provide dispersal and pollination to at least 130 plant species. These interactions have profoundly influenced the evolution and the timing of flowering and nectar production that prelude pollination and dispersal. Fruit bats illustrate the potential changes produced by evolutionary responses to the interactions between bats and plants. Either group may become very specialised, but the cost of specialisation has decreased its flexibility. Given the trade off between the effects of specialisation on the efficiency and flexibility, we expect many degree of dependence between bats and plants. Broad generalisation about the economic significance is difficult to formulate because the selective pressures on them is diverse. The dependence of bats on plant for increased nutritional value, varies as most bats disperse seeds very close to the parent plant. Thus reducing the off spring growth to a greater extent.

The economic importance is directly related to the diets of these fruit bats that help in the dispersal of man-made fruits. Thus, fruit bats rarely help in the dispersion of seeds to greater distances but rather in the eradication of vital man-made fruit plants.

THE MEGA BATS :

The Old World fruit bats or Flying foxes are confined to the Old World tropics and feed exclusively on fruits, leaves and pollens. As a group, they are larger than micro bats but show considerable variation, in relation to forearm 40-220 mm. The forearm is relatively consistent with species and can be measured easily to the necessary degree of accuracy in a live bat. A general indication of the overall size, the body length of a bat is similar to its forearm length of the fruit bat. Megabats weigh from 2-1.5 kg with wingspans approaching 2m. With the exception of several species of the Genus, *Rousettus*, megabats do not echolocate. They have generally large eyes, ears simple and simple muzzle. The second and the third are largely independent of each other and the second has a claw. Tail and the tail membrane are small and non-existent.

Most megabats have rather dog face and hence the name flying fox is suggested. Skull and teeth are adapted to their particular feeding habits. Skull and teeth are typical large and strong, to deal with rough skinned fruit. The shape of the head often reflects the need for large areas for muscle attachment and large biting forces: this often means short, heavy jaws and a large brain case. Molar and premolar teeth have large and flat grinding teeth \ crushing surfaces and canines are large to grasp and penetrate tough fruits. The incisors are small. Nectar and pollen have lighter skulls. The jaws are elongated and narrow correspondingly smaller teeth. This allows them to probe deeply into flowers with their long tongues, to extract nectar. Facial structures may be determined by the factors other than their feeding behaviour. Although generally drab in colour, of shades brown or black.

Most species roost on trees in large colonies. Cave roosting bats such as *Rousetteus* can be seen in large colonies. Megabats often forage in large groups thus having located a flower or a fruiting tree. Roost sites may be 15 to 50 Km or more from a particular feeding site and the colony will take flight before dusk to travel to the particular particular fruiting tree.

THE MICROBATS :

Microbats are large and very diverse group of mammals. Forearm length ranges from 22 - 110 mm. All species have the power of echolocation and make full use of it. Eyes are small and complicated for the purpose of echolocation.

FORAGING STRATEGIES OF PLANT VISITING BATS:

FOOD AVAILABILITY:

Fruit bats have 4 major concerns regarding the nature of food supply :

What kind of foods are available, how much is there of each kind, where is it located and how long is it available. The answer to these questions reflects the part of the outcome between the relationship of fruit bearing trees and habitat fragmentation. On the other side i.e., the botanical side, the morphology of the fruit bearing trees, their numerous phenological traits, the timing of flowers and fruit production, the degree of inter specific synchrony in the floral presentation, fruit maturation, the size of the fruit or fruit crop, the amount of pollen and nectar or the ripe fruit available per plant per night. Altogether the main criterion is the nutritional factor which plays an important role for the foraging fruit bat damage in many areas in Southern India.

FOOD HABITS AND DIET:

The available information on the food habits indicate that most fruit bats are generalists and not food specialists. In this case, a case study was undertaken at three places i.e. at Uppinangadi, Kidu, Dakshina Kannada and Chettalli, Kodagu.

In the first case i.e., at Uppinangadi, fruit bats such as the flying fox forage at the Horticultural Research Station. They tend to destroy fruits such as tamarind, *Tamarindus indica* L; Mango, *Mangifera indica* L; guava, *Psidium guajava* L ; cashew, *Anacardium occidentale* L; arecanut, *Areca catechu* L and *Annona* plantations. There has been a major shift in their diet in adjacent orchards and farmlands. It was further observed that a single individual carried, on an average 9 fruits (n=55) per visit per hour, which was mostly concentrated during the early part of dusk and early morning. In the second case i.e., at Kidu a more devastating effect of damage was recorded. The usual enemies are the flying foxes which devastate cashew and guava plantations. Cashew is usually eaten during the early part of the fruiting period.

In the third case i.e., at Chettalli, guavas, mangoes, sapotas, *Achras zapota* L and bananas are regularly eaten by flying fox which used to roost 10 Km from the plantation zone. About 55-60 percent loss of plant food was incurred during each season.

ROOSTS IN AGRICULTURAL PLANTATIONS :

In three selected roosts it was none other than the flying fox and the Indian short nosed fruit bat. Here the former species live in huge colonies and were seen roosting on Jackfruit, *Artocarpus heterophyllus* L tamarind, raintree, teak, *Tectona grandis* L mango, black wood tree, *Dalbergia sissoo* and *Triewia nudiflora*. The total population at Uppinangadi was in the range of 2500-4000 individuals. Figure 1 depicts the population from 1994 to 1999. In accordance with the people residing near by the roosting sites, the breeding period of bats is

during March when 10-12 dead individuals were found on ground under roosting trees. This could be due to the young mothers were not able to deliver them in the right fashion. Every day 3-5 young individuals died during the breeding season. Each year death of 50- 70 individuals was recorded at the roosting site. Here the roosting site of the flying foxes on tree species had a peculiar smell of sweetness and the defecating of faecal matter on the trees to which they roost was destroyed due to the constant faecal droppings. This caused much damage to many of the tree species they tend to visit. This type of behaviour of defecating at the roosting site was not noticed in other two areas. This may lead to the constant harassment of people surrounding the roost and bat killing by shooting or throwing of stones by people.

The Short-nosed fruit bat, *C. sphinx* also played an important role in much of the damage at Uppinangadi. This species destroyed the young arecanut seedling during the phases of growth. These fruit bats lived in temporary colonies of 2-14 members (photo 70). We have not noticed any permanent colonies of this species in the study area.

In Kidu, smaller fruit bats caused extensive damage to mango, cashew, guava plantations. A large number of temporary colonies could be seen under banana leaves and caves. It was further noticed that a particular colony would surround a particular plant food and devastate the entire area. Much fighting could be heard during these fruit raids.

At Chettalli, a huge colony of flying foxes covering an area of 4-6 Km was sighted. This is situated in the middle of a coffee, *Coffea arabica* L plantation much away from humans and predators. On entering the area of the flying fox roosting site, we could divide the flying foxes into two zones. The outer zone consisting of young individuals and the inner zone consisting of older individuals. Constant flying of individuals was seen at regular intervals of 15- 20 minutes. No dead individuals were seen beneath the roosting site.

FORAGING BEHAVIOUR OF FRUIT BATS :

At Uppinangadi the fruit bat *P. giganteus* were seasonal in feeding in farmlands and the orchards. Much of the movement was in the north - westerly direction. The flow of individuals towards the regional station, was monitored for 9 months (fig 2) This was recorded on 12 occasions during the fruiting and non fruiting seasons. (fig 3) At Kidu much of the destruction was caused by fruit bat, *C. sphinx*. This fruit bat usually settled in temporary colonies in window caves, banana plantations, etc., etc. The number of individuals varied from 2 - 28 during the study period in a 30 acre plantation. At Chettalli, the short nosed fruit bat usually resided in temporary roosts in building and in near on by plantations of wooded tree species such as teak. This bat was the first to fly out and forage on the nearby fruiting tree species.

CROP PROTECTION MEASURES :

Damage and protection :

It is likely that plant-visiting bats are efficient foragers, particularly when the effects of resource seasonality, social status, and predator pressure are taken into consideration. Although it will always be profitable to study foraging behavior with predictions of optimal foraging behavior in mind, it should be clear that foraging behavior cannot be isolated from other aspects of animal's lives. Links between social behavior and foraging appear to be especially strong in the case of bats reviewed in this chapter, and it would be therefore seem unwise to study one of these aspects of chiropteran biology without giving considerable attention to the other.

Damage done by bats :

For bats, nutrition is an obvious benefit of mutualism with plants, but a less obvious and more variable benefit is the potential reduction of fluctuations in food supplies.

Fluctuation in food supplies has been an important selective force for bats, as seen in responses in basal metabolic rates and the timing of reproduction by bats to avoid lactation during times of food scarcity. Although no studies have demonstrated that variability in food supply affects size of bat populations, these responses show that such an effect is possible.

Bats belong to the order Chiroptera. This order can be sub-divided into two major sub-orders: Mega-bats and Micro-bats. Mega bats are confined to the Old World Tropics and are exclusively phytophagous (eat plants) whereas micro bats are more cosmopolitan and are largely insectivorous. In India among 12 species of fruit bats, three are the most commonly known: viz., the flying fox, the fulvous fruit bat and the short-nosed fruit bat. About 70–100 species of insect eating bats are found in different parts of India and are more diverse in the Eastern and Western Ghats, Himalayas, Andaman and Nicobar Islands. Approximately, 250 species of bats of the Paleo-tropical family Pteropodidae and the Neotropical family, Phyllostomidae regularly visit plants for either fleshy fruits or floral resources. The foraging activities of frugivorous bats can be simply described as follows: At dusk, fruit bats leave their roosting site and commute to a particular resource patch, which is often a fruiting tree. This bat then selects a fruit from those available and either eats it or carries down to its roosting place. During feeding it might feed on an entire fruit or sometimes a part of it leaving the remains as masticated or rejected pellets or uneaten parts, which is usually found under the tree. The bat may probably carry a gut load during its foraging activities. At dawn, bats return to their roosts and a final gut load is either eaten or regurgitated. In the eyes of a frugivorous bat, not all plant species are equally attractive. Within and between fruit trees, there is a considerable variation in ripeness, size and other physical or chemical attributes. Fruits eaten by bats are usually fleshy or have a musty odour and high sugar content. The role played by bats as seed dispersers help in promoting gene flow,

making seeds less obvious to seed predators and moving seeds to more favourable sites for colonising. The benefit the plant receives when pollinated, depends on the amount of pollen deposited. Large amount of pollen increases the proportion of ovules that could develop. The second possible benefit of depositing is, the competition among pollen grains may increase the quality of progeny in plants. Flower size, the number of flowers visited and the amount of pollen produced by the flower, influences the quality of pollen that the bat carries. Movement of pollen between individuals thus promotes plants to produce smaller amount of nectar so that the bat would visit more than one individual flower to satisfy foraging requirements. Thus in case of key stone species such as *Ficus spp.*, bats help in the propagation of seeds, promote dispersion of seeds to various patches far away from the parent plant. Thus, there exists a kind of mutual relationship between fruit bats and the plants served by them for pollination and dispersal.

Most bats are seasonal at various patches. The phenologies of fruiting correspond directly to the reproductive status of these bats. As frugivores, both Mega-bats and man have similar tastes and both share many fruits. So man, through the tending of wild fruit trees and planting enhances the chances of experiencing heavy damage to fruits in farmlands and orchards. One possible reason for the increasing menace of bats in fruit orchards is the dwindling population of wild fruit trees and a general reduction of forest cover. The rapid loss of *Ficus spp.*, trees has lead bats to forage in orchards is perhaps a strong factor. Thus certain management techniques could be looked into in managing this menace.

The techniques can be classified into two main categories :

- 1) Roost management**
- 2) Crop management**

1) Roost management :

i) Physical methods:

Making sounds at their roost site, which are present in window leaves or palmyra, trees. The making of loud sounds could keep bats away for sometime two to three weeks.

ii) Chemical repellents :

Chemicals having a bad odour could drive bats away. This should be sprayed when bats leave their roost during the late evening hours. For example, cow dung fresh mixed with water, goat dung or paint.

2) Crop management :

The success of crop protection methods depends on the availability of alternative food resources in the nearby vicinity. Roost control methods are effective only if alternative foraging habitats are available closely otherwise they would continue to forage in orchards although their roosts may be shifted.

Plantation strategies :

The following long - term strategies could be adopted :

- i) Buffering with other fruit crops :** Planting of other fruit trees with higher sugar content could alleviate the pressure.
- ii) Block plantation :** Divide the plantation into smaller compartments, which can be covered by nylon or mosquito nets.
- iii) Conservation and planting species :** such as *Ficus bengalensis* L; *F.glomerata* L; *F .religiosa* L; *F. benamina* L and *F. mysorensis* H would certainly reduce the load of bats in orchards and farmlands.

Methods suggested above are at the best speculative, since a lot has to be known about behaviour and the type of destruction caused. While farmers could experiment with these methods, research on some of the fundamental issues should be done simultaneously. Future studies should focus on bat– plant range of frugivorous bats and their exploitation in managing bat damage to commercial fruit orchards. But management must focus on regulating fruit bat population to tolerable levels rather than their elimination. This could cause cascading effects on both natural and man-made ecosystem.

In further analysing their trends in population during this study at Chettalli, Kodagu, about the damage caused by flying foxes. On noticing the different graphs available we did notice that the population fluctuated in various periods. (Table 1, July - March) In July due to the post breeding season these fruit bats tend to be lesser in degree of their previous population structure which is about 2500-3500. The selection of one part of the fruit bats roosting site was examined and the results was qualified for a period of nine months.

During July the fruit bats visited the plot area only during the early morning hours. This could be seen in the graph as the number of individuals had increased drastically. The fruit bats were seen feeding upto early morning. A lot of faecal matter was seen below the roosting site. In August slight rains did not deter them away, leaving their individuals roosting alone in the tree. There was a slight increase in the number of individuals. The increase in the number of individuals could be due to the presence of *Ficus* tree present in the surrounding areas near the regional station. In September and October there was not much of population increase as the constant rains did push them to nearer localities of roosting sites towards the Regional station. This also can be observed during November, December and January were the numbers of individuals also increased as the food availability too. During, February and March, there was a drastic increase in the number of individuals and the fruit loss was more

The average taken for the three sessions were that more often the fruit bats tend to forage in either midnight or early morning. The possibility could be that the dew present could supplement their diet during these odd hours. It could be seen that these fruit bats tend to encompass a particular area and eat the ripe fruits during the above-mentioned time. These fruit bats unlike other fruit bats do not take back the fruit parts but ingested materials are thrown away. This could neither help in the conservation nor dispersal of fruit plants as recorded by various authors. Here the type of dispersal is done very close to the parent plant itself, as a natural cycle would not allow the offspring enough sunlight.

There was a significant increase in the number of fruit bats from (518) and August (1708). This could be due to the lactation period of fruit bats. The increase in individuals could be due to the arrival of fruit plants within the Horticultural Regional Station. This also corresponds to the increase in the number of individuals over the months from the time of observation for the entire period of study (9 months). In accordance with the variation was high within months than in between months and the corresponding P-value was not greater than 2.0. Thus indicating no further increase in the population within months. A student 'T'-test was also conducted to check the variance in-between months. The variables taken such as variance, P-correlation showed higher values indicating an increase in the number of individuals in the particular month. The effect of increased growth is due to the increased food resource at the Regional Station.

Thus this study indicated that fruit bats *P. giganteus* increased during the post-breeding season. This is due to the increase in food resource at the horticultural Station.

Table 1 Number of bats visiting the CHES Farm,Chettalli

July -1999

Week	Early Dusk	Mid Night	Early Morning	Total
I	15	10	50	75
II	17	20	23	60
III	20	39	110	169
IV	22	46	146	214
Total	74	115	329	

August

Week	Early Dusk	Mid Night	Early Morning	Total
I	100	18	140	258
II	167	341	29	537
III	155	200	45	400
IV	200	145	167	512
Total	622	704	381	

September

Week	Early Dusk	Mid Night	Early Morning	Total
I	109	314	345	768
II	56	167	200	423
III	78	398	170	646
IV	189	123	139	451
Total	432	1002	854	

October

Week	Early Dusk	Mid Night	Early Morning	Total
I	300	200	200	700
II	132	456	345	933
III	451	560	456	1467
IV	400	567	490	1457
Total	1283	1783	1491	

November

Week	Early Dusk	Mid Night	Early Morning	Total
I	400	234	600	1234
II	456	345	234	1035
III	678	456	387	1521
IV	800	543	458	1801
Total	2334	1578	1679	

December

Week	Early Dusk	Mid Night	Early Morning	Total
I	345	567	345	1257
II	321	890	467	1678
III	300	785	908	1993
IV	459	450	786	1695
Total	1425	2692	2506	

Jan-2000

Week	Early Dusk	Mid Night	Early Morning	Total
I	200	234	267	701
II	890	342	908	2140
III	567	678	786	2031
IV	478	987	563	2028
Total	2135	2241	2524	

February

Week	Early Dusk	Mid Night	Early Morning	Total
I	564	256	675	1495
II	456	786	452	1694
III	123	564	324	1011
IV	143	606	351	1100
Total	1286	2212	1802	

March

Week	Early Dusk	Mid Night	Early Morning	Total
I	345	123	200	668
II	876	453	786	2115
III	654	764	547	1965
IV	234	700	432	1366
Total	2109	2040	1965	

Fig 1 The status of fruit bat (*Pteropus giganteus*) at Uppinangadi, Dakshina Kannada - 1994 to 1999



Fig 2 Movement of *Pteropus giganteus* for a period of nine months, found at CHES, Chettalli, Kodagu

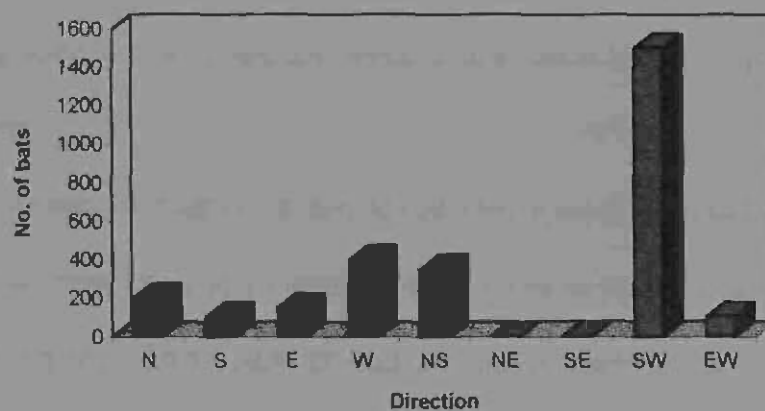
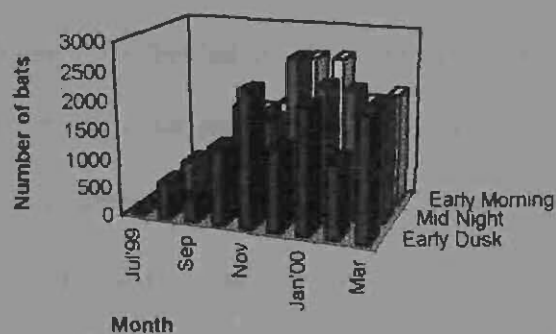


Fig 3 Population of Bats at CHES- Chettalli



Fruit Bats and their Management in Orchards

In this chapter the importance of frugivorous bats and their pest control measures, which are eco-friendly rather than the current practice of shooting them, are discussed. Approximately, 250 species of bats of the Paleo-tropical family, Pteropodidae and the Neotropical family, Phyllostomidae regularly visit plants for either fleshy fruits or floral resources. At dusk fruit bats leave their roosting site and commit a particular resource patch which is often a fruiting tree. This bat then selects a fruit from those available and either eats it or carries down to its roosting place. During feeding it might feed on an entire fruit or sometimes a part of it leaving the remains as mastigated or rejected pellets or uneaten parts, which is usually found under the roosting site. The bat may probably carry a gut load during its foraging activities. At dawn, bats return to their roosts and a final gut load is either eaten or regurgitated.

In the eyes of frugivorous bat, not all plant species are equally attractive. Within and between fruit trees, there is a considerable variation in ripeness, size and other physical or chemical attributes. Fruits eaten by bats are usually fleshy or have a musty odor and high sugar content.

The role played by bats as seed dispersers help in promoting gene flow, making seeds less obvious to seed predators and moving seeds to more favorable site for colonizing. In case of pollination, the benefit the plant receives when pollinated, depends on the amount of pollen deposited. Large amount of pollen increases the proportion of ovules that could develop. The second possible benefit of depositing is, the competition among pollen grains may increase the quality of progeny in plants. Flower size, the number of flowers visited the amount of pollen produced by the flower, influence the quality of pollen that the bat carries. Movement of pollen between individuals thus promotes plants to produce smaller amount of nectar, so that

bats would visit more than one individual flower to satisfy foraging requirements. Thus in case of key stone species such as *Ficus spp.*, bats help in the propagation of seeds, promote dispersion of seeds to various patches far away from the parent plant. Thus, there exists a kind of mutual relationship between fruit bats and the plants served by them for pollination and dispersal.

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The technique can be classified in to two main categories :

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(b) Crop management

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1. Physical methods :

Making of sounds at their roosts site which are present in window leaves of palmyra trees.

The making of loud sounds could keep bats away for some time.

2. Chemical repellents :

(a) Chemicals having a bad odour could drive them away. This should be sprayed when bats leave their roosts during the late evening hours. For example cow dung fresh mixed with water, goat dung or paint.

(b) Crop management :

The success of crop protection methods depends on the availability of alternative food resources in the nearby vicinity. Roost control methods are effective only if alternative foraging habitats are available closely otherwise they would continue forage in orchards although their roosts may be shifted.

1. Plantation strategies :

The following long-term strategies could be adopted :

- (i) Buffering with other fruit crops: Planting of other fruit trees with higher sugar content could alleviate the pressure.
- (ii) Block plantation : Divide the plantation into smaller compartments which can be covered by nylon or mosquito nets.
- (iii) Conservation and planting species such as *Ficus bengalensis*, *Ficus glomerata*, *Ficus religiosa*, *Ficus benjamina* and *Ficus mysorensis* would certainly reduce the load of bats in orchards and farmlands.

Methods suggested above are at the best speculative, since a lot has to be known about behaviour and the type of destruction caused. While farmers could experiment with these methods, research on some of the fundamental issues should be done simultaneously. Future studies should focus on bat-plant range of frugivorous bats and their exploitation in managing bat damage to commercial fruit orchards. But management must focus on regulating fruit bat population to tolerable levels rather than elimination. This could have cascading effects on both natural and man-made ecosystem.

This area which is covered by thick plantations of coffee and cardamom has been grown from early times. The other crops in this area are in the land of the Central Horticultural Station Chettalli. Here this farmland grows mango, sapota and guava. The

investigations were done to estimate the damage done to the crops in the farm and of this station. The primary loss of natural forest fruits has been the main concern. The change in landscape area has led to this eventual change of diet of fruits at this farm station.

This field trip was undertaken to know about the foraging area of the large flying fox and their related diets. These fruit bats regularly invade large areas of fruit crops accompanied by smaller fruit bats such the common fruit bat. The smaller fruit bats live in temporary roost colonies very near to the feeding area, where as the large fruit bats live in huge colonies four-five km from the farm land.

Roosts :

The huge flying fox roost site is about four-five km from the farm land. This is situated in the middle of coffee plantation zone, as this is the safe refuge from predators and man. On entering the area we could notice that the roosting colonies could be divided into two zones. The outer zone which consisted of the young individuals and the inner zone i.e., the core zone consisted of elderly individuals. Constant flying of individuals was seen due to the heavy down pour of rains in this area.

Food :

Due to the arrival of the rains and the absence of any of fruiting tree, the dispersal of fruit bats was not seen in the direction of the farm land. They tend to move north towards the forest area. Certain amount of fruits seeds such as guava, arecanut and *Ficus spp.*, were seen below the roosts.

The various landscape changes and the removal of natural fruits has led, fruit bats tend to destroy large areas of farm land in and around the vicinity of the farm land. A proper study of their movements, change of food would help us further in understanding the management of fruit bats as pest to farm land.

ECOLOGICAL APPROACHES FOR THE MANAGEMENT OF VERTEBRATE PESTS IN WESTERN GHATS REGION OF KARNATAKA

INTRODUCTION

The most imposing, but extremely threatened, topographical, floristic and faunistic feature of the Indian subcontinent, after the Himalayas, is undoubtedly the Western Ghats. Spread over 175,000 km in six Indian states, this mountain range contains the remaining tropical rain forests on its Western slopes. This threatened South Asian mountain system, is now regarded as one of the 18 biodiversity centers of the world ("hotspots") and needs immediate conservation efforts. The presence of faunal elements from Oriental, Palaearctic and Afrotropical biogeographical regions on the Western Ghats suggests a complex natural history and biogeography and makes the Western Ghats, one of the most important and interesting regions of the world (Ganokar, 1996).

The Western Ghats are now practically surrounded and criss-crossed by extensive network of railways and roads and extensive agricultural mining and plantation activities have reduced the forest cover to less than 50 percent of what it was only fifty years ago. The wilderness in the forests has reduced and wild animals are encroaching cultivated areas in search of food and shelter. In the process, wild animals are causing enormous losses to crops. For instance, elephant, *Elephas maximus* L particularly in Kodagu district and wildboar, *Sus scrofa* L in Chikmagalur district, in some patches, caused cent per cent losses in rice yields.

The use of chemicals in Eastern Ghats has the major drawback of undesirable effects on non-target animals, soil and water pollution. Therefore, eco-friendly crop-protection measures are needed. This chapter is a concise synthesis on vertebrate pest management practices that contribute to sustainability in selected agro-ecosystems in Western Ghats region.

Survey :

Studies on vertebrates damaging crops in Western Ghats and the results of studies on five selected crops, viz., rice, cardamom, cocoa, cucumbers and pineapple in four districts, viz., Chikmagalur, Hassan, Shimoga and Kodagu are presented here. The period of study, sample unit sizes, number of replicates, procedures adopted and statistical analysis of data are indicated under the respective tables. Most of the studies were conducted in Mudigere, Chikmagalur district.

Birds were observed with a pair of 8 x 30 binoculars. The surveys were carried out in concentrated areas of quadrupeds based on track counts census and pug marks. A team consisting of two forest guards, a local guide and investigator patrolled the areas surrounding experimental plots and identified tracks and marks. The maximum count recorded was considered for assessing the population. Other signs indicating the presence of quadrupeds included dung, partially eaten plants or plants affected by the animal's movements, etc. Crop-damages and yield-losses were assessed following standard procedures and effects of treatments were compared with a 'control' plot. The treated plots and 'control' plots were maintained at least 150 m apart.

Species composition, Seasonality, yield loss and efficiencies of management practices :

Crop : 1 Rice

Rice, *Oryza sativa* L is the most prominent cereal, grown in over 45 percent of the cultivated area in small fragmented fields and so individual farmer suffers heavily from wildboar damage. Rapid deforestation and depletion of food in the forest have caused wildboar to become the most destructive rice pest in this region. Wildboar caused damage to paddy by lodging, trampling and browsing (Table 1) (photo 60) incurring, on an average, ten percent losses in yields.

Replicated field trials conducted at four locations, viz., Mudigere, Banakal, Kadamadakal and Beekanahalli of hill region have shown that 5g Thimet 10 G mixed with 10g of sand when suspended along the borders of rice fields, protected the crop from wildboar damage for 30 to 50 days. The bags were suspended at 3m distance and at one meter height. Growing early maturing, dwarf rice varieties, timely harvests, scaring away wildboar during milky to grain maturation stages and synchronizing sowing and crop maturity at a patch, protected rice crop from wildboar damage in hill region. Growing rice cultivars with long auricles on panicles also generally suffered less from wildboar (Chakravarthy, 1994 a).

Crop : 2 Cucumbers

A section of farmers in Dakshina Kannada district and part of hill region, grow vegetables on small scale (0.1 to 1.0 ha) with family labour mostly to suit personal and local market needs. Small green barbet, *Megalaima viridis* damaged cucumber, *Cucumis sativus*. On an average (n = 40), 8 individual birds caused a loss of 37.7 percent fruits when grown as a sole crop on wooden pendal – a frame work of wooden straps. When cucumber is grown on raised basins (2m dia. 0.2 m high) with bottle gourd and pumpkin and vines are allowed to run on the ground, the bird damage was reduced to 8.5 percent. Statistical test revealed significant difference in the damage between the two systems (Table2). This is because in intermixed cropping system, damage was less because the bird was observed expending considerable time in searching and locating cucumber from among cucumber, bottle gourd and pumpkin fruits, partly or fully covered by foliage. Under basin system, however, Jackal, *Canis aureus*, caused considerable damage to cucumber. In situations where jackal is not a pest, basin system can be followed (Chakravarthy, 1994 b).

Crop : 3 Pineapple

Pineapple, *Ananas comosus* L Merr. is cultivated along borders of vegetable and fruit gardens in coastal and hill regions of Karnataka. Porcupine, *Hystrix indica* K, wildboar, jackal, jungle crow, *Corvus macrorhynchos*, koel; *Eudynamys scolopacea*; crow pheasant, *Centropus sinensis* and other birds cause economic losses to farmers. On an average, it was estimated from a survey conducted that, pineapple fruit yield losses ranged from 18 to 22 percent in coastal and hill regions. In order to protect the fruits from vertebrate damage, trials conducted revealed that fruits covered with rosette of spiky leaves and thatch of dry grass helped to minimize fruit damage (Chakravarthy and Balakrishna, 1993).

Crop : 4 Cardamom

Of the spice crops, cardamom is the most important and is threatened by vertebrate pests among which rodents are very prominent. Data on the impact of three cultural practices on rodent damage is given in Table 3. It was found that by weeding 3.57 percent loss can be avoided and by overlapping panicles at regular intervals 2.95 percent damage can be prevented. By timely pick, 6.63 percent damage to capsules can be avoided. Although the loss prevented is small, yet the practices are desirable as these are practicable, cheap and cause no side-effects. These practices together with natural rodent predation and habitat modification would ameliorate rodent problem. Mulching the panicles also reduced rodent damage. On an average, mulching reduced rodent damage on capsules to 2.5 per cent compared to 41.80 per cent in the control. There was statistically significant reduction in capsule damage. However, in the long run, over a large area, this method cannot be recommended as periodical removal of mulch over a large area, may accelerate soil erosion.

Local people use wooden snap traps to kill rodents. Systematic studies conducted revealed that 12-15 traps / ha of cardamom from August to October stationed at favorite sites

of the squirrel and rats in cardamom plantation especially in valley region, trapped maximum rodents. The trap at a spot should be stationed for not more than ten days. Sprouting paddy grains are the most preferred bait in snap traps (Srihari and Chakravarthy, 1992; Chakravarthy, 1994 a) interestingly use of Rodacake and Bromodiolone did not result in consistent results.

Crop : 5 Cocoa

Cocoa, *Theobroma cacao* L is depredated upon by rodents, jackal, monkey and jungle cat. Jungle cat, *Felis chaus*, is the most important pest. A systematic baiting trial was undertaken at Kuruvalli and Huguluvalli at Thirthahalli and at Addegadde, Sringeri in altogether 6 ha of cocoa plantation. Two to three fruits of banana (preferably of local variety, 'Putta bale') were incised and 2-3g of Carbofuran 3G was placed in each fruit and the fruits were placed on the plant near cocoa pods, which were liable to be attacked. This method gave complete protection to cocoa from jungle cat at all the three study sites.

Generally, production of cocoa pods peaks during August-September and December-January. Baiting with Carbofuran needs to be done just before peak production so that maximum pods are saved. In the region growers were found to use crabs, wet jaggary or rice balls in addition to banana as bait carrier.

Observations in different taluks of Chikmagalur and Dakshina Kannada districts have shown that when cocoa is grown as an intercrop in areca, coffee or cardamom plantations it suffers less from vertebrate pests than when grown as a sole crop. In addition to baiting and intercropping, timely harvests, clean cultivation and trapping rodents with local wooden snap traps at the time of peak production of pods aid in protecting cocoa from vertebrate pests (Thyagaraj et al., 1996).

The above instances of crop protection against vertebrate pests demonstrate that it is possible to protect crops in Western Ghats region by cultural and crop husbandry practices

that also help in harvesting sustainable crop yields. The practices are cheap, practicable, eco friendly and harmless to non-targeted organisms.

Table 1 Types of wildboar damage to rice in hill region.

Tillers damaged / m			
Dates	Lodging	Trampling	Feeding
14-12-96	19.25	16.95	14.61
16-12-96	13.98	8.60	14.29
17-12-96	17.31	8.15	28.70
19-12-96	19.73	26.66	26.38
21-12-96	28.47	25.00	22.61
23-12-96	25.55	23.00	17.80
26-12-96	0.88	90.00	9.21
28-12-96	21.08	22.00	23.73
30-12-96	24.00	26.00	50.00
Total	170.25	246.36	207.33
Mean	18.91	27.37	23.00
CD (p = 0.05) Types of damage = 8.83 Dates = NS			

Table 2 Small green barbet damage to cucumber in two planting systems.

Site	Mean *cucumber fruit damage (%)	
	Pendal system (Sole Crop)	Basin system (Intermixed crop)
A	40.0	10.0
B	36.0	7.0
C	38.0	8.0
D	37.0	9.0
Mean	37.5	8.5

$\bar{X}$ of 100 fruits \ site \ planting system randomly chosen at each site on four different dates.

Table 3 Effect of cultural practices on rodent damage to Cardamom capsules.

Capsules (%) damaged						
Clump No	With weeds	Without weeds	Dispersed panicles	Overlapped panicles	Delayed harvest	Timely harvest
1	0.81	9.12	1.61	2.75	3.10	2.20
2	3.51	8.08	0.00	4.00	5.47	1.53
3	2.71	5.21	3.66	1.55	12.29	1.89
4	1.61	11.57	0.53	1.69	6.31	3.83
5	0.48	2.97	0.95	4.55	8.85	3.57
6	3.42	0.32	4.64	3.76	6.59	4.48
7	1.02	6.95	0.50	2.42	2.04	2.43
8	1.16	6.95	0.43	2.45	2.04	2.84
9	1.92	3.69	1.02	3.81	0.81	5.69
10	1.76	0.58	1.06	1.94	2.03	4.82
11	4.73	1.10	4.98	3.51	4.50	3.51
12	2.48	4.95	2.52	2.71	1.99	1.61
13	4.09	10.48	5.34	1.61	2.28	2.69
14	6.47	22.39	7.25	3.42	8.40	3.57
15	3.26	11.42	1.69	3.26	7.38	1.89
Mean	2.62	7.05	2.41	2.89	4.93	3.10
% Capsules saved						
	62.83		16.60		37.11	
Binomial expansion						
'Z' value	1.103		0.634		NG	

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INTEGRATED VERTEBRATE PEST MANAGEMENT:

Three cultural practices, viz., dispersion of panicles in an overlapped fashion, clean cultivation (without weeds) and timely harvest together with snap trapping and mulching saved 14.40% cardamom capsules from rodent pests (Srihari, K and Charkravathy, A.K. 1998). Selective debranching of shade trees in cardamom plantations during May reduced clump damage due to monkeys from 49 to 3.2% in 40 ha at Mudigere. Suspending a mixture of 5g Thimet 10G granules + 5g sand in punched polybags along borders of cardamom nursery+ good drainage + watch and ward reduced damage due to wildpig from 10 to 15% to 3 to 5% seedling damage during summer (Chakravathy, A.K. 1993). The above practices were consistent and additive in their effects. At Dharmastala, Belthangady during 1996-99 and in oilpalm plantations in different parts of Shimoga district during 1993-1997.

A systematic baiting trial undertaken at Kuruvalli and Huguluvalli at Thirthahalli, Shimoga and at Addegadde, Sringeri, Chikmagalur in 6 ha of cocoa plantation from 1991 to 1993 and 1996-97 and observations in different taluks in Dakshina Kannada district from 1985 to 1993 revealed that cocoa plantations were effectively protected from jungle cat, rodents, jackal, monkey and stag damage. Carbofuran 3% G baiting in local banana fruits or wet jaggary, intercropping with areca or coffee, timely harvest, clean cultivation, snap trapping at peak pod production period (August/September and December/ January) effectively protected the crop (Thyagaraj N.E et .al., 1996).

A three years trial in arecanut and coconut gardens at Dharmasthala revealed that clean basin cultivation, crown cleaning, trunk banding, burrow baiting, I-bex fencing with atleast one metre of open space on either sides, and covering base of seedlings (upto 2 to 3 years) with tightly cover thorny bamboo sticks or porcelain pipes wherever the coconut and arecanut palms were regularly prone to rodents damage saved 46% nuts compared to 'control'

against rodents, monkeys and wildboar depredations. The practices to some extent afforded protection against raids by bison and elephant.

In oilpalm, covering ripening bunches with gunny bags or thatch of farm forests or paddy straw, timely harvests and scaring away vertebrates by odour, acoustic or watch and ward 62% fruits from birds, rodents and wildboar compared to control. These practices showed consistent results under heavy animal depredations.

The above instances of crop protection against vertebrate pests demonstrated that it is possible to protect crops by cultural and crop husbandry practices that also helped in harvesting sustainable crop yields. The practices were cheap, practicable ecofriendly and harmless to non-targeted species including humans.

CONSTRAINTS:

It is clear that barring few species that are host-specific or have restricted geographical distribution, the same vertebrate species is implicated in causing damage to more than one crop. This is because of the preference and adaptiveness of the species to forage in several cultivated ecosystems. Determination of economic status and ecological roles of vertebrates in their natural habitats and cultivated ecosystems is important. For instance, adult house sparrow feeds on fruits and nuts but feeds its young ones with insects, some of which injure crop plants. Similarly rats, squirrels and porcupines which variously damage a variety of fruit crops, are important regulators of surface and sub-surface vegetation, soil fertility and soil fauna. Perhaps with the exception of roseringed parakeets and few rodents all other animals perform diversified roles in their habitats and cultivated ecosystems. **Determination of economic status of vertebrates is therefore difficult and complicated. But studies with multidisciplinary approach by teams of workers in this direction are urgently required.**

Horticultural crops cultivated in or near forest tracts have high vertebrate pressure and face unique problems. This is because such horticultural systems are found in the natural habitat of vertebrates concerned. In such situations, part of the requirements of the vertebrates are met by cultivated crops.

The traditional approaches to crop protection from vertebrates depredations are mentioned by many workers (Fitzwater, W.D. and Prakash Ishwar 1973). There is a need to scientifically validate local methods and improve their effectiveness and flexibility to varying conditions of cropping systems, if possible. For instance, sometimes troupes of lungur, *Presbytis entellus* heavily feed on blooms of mahua, *Madhuca indica*. To keep them away, Bhils in Salumber Tehsil, Udaipur, Rajasthan tie a festoon of spiny branches of *Acacia nilotica* around the stem. Some farmers of Saurashtra catch / trap one or two rats. A little quantity of 'Sindur' (vermillion) is mixed either in water or milk. The mixture is poured on rats caught in the trap/cage. These 'coloured rats' are released in fields where rodent damage to crops is observed. When other rats see 'coloured rats', they are repelled away.

The secretive and in some species, nocturnal habits of vertebrates and their mobility make it most unlikely that they will actually be seen damaging the crop. **Identification and mobility of a vertebrate is a major operational constraint. In many places in India entomologists are looking after vertebrate pests problems in the zones. There is a lack, in general, of trained personnels in vertebrate pests. There should also be a network among vertebrate researchers in universities/institutes with ecologists and vertebrate pest managers.**

No programme of pest management in horticultural systems can be effective unless it is based on knowledge of the animal's natural history. Studies of habitat preferences should be combined with records of seasonal population changes so as to provide basic information

for pest management (Prakash et al., 1971). Telemetry is by far an accurate means of monitoring activities of vertebrate pests, two years data on population fluctuation should be gathered. Hone described and critically reviewed literature on a range of analysis used in vertebrate pest research and management. Statistical, economic and modeling analyses are described with spectrum of damage by vertebrate pests and the methods used to suppress these pests.

Estimates on crop losses are pre-requisite for implementation of management practices against vertebrate depredations. There are a volley of methods used for assessing crop losses due to vertebrate pests. Parameters used for assessing crop-losses vary from one investigator to another, thus rendering the data often uncomparable. For instance, in orchards, losses are caused by vertebrates from flowering to the ripening stage of the fruits. Usually many flowers are consumed, the unripe fruits are nibbled and dropped from the tree and then the ripe fruits are scooped from the inside and large number are broken off the branch and dropped to the ground. This type of damage is severe in some parts of the country and cultivation of the crop is abandoned altogether.

There is an urgent need to standardize the methods of assessing losses due to vertebrate pests. In rodents and birds, the AICRP on rodents and AICRP on Economic Ornithology, respectively have made remarkable progress. Similarly CAZRI, Jodhpur, Rajasthan scientists have done for desert ecosystem vertebrates (Anonymous, 1980-1986). In India, the Directorate of Plant Protection, Quarantine and Storage, Ministry of Agriculture and Integrated Pest Management Centres, Centres of ICAR, New Delhi, Universities, Institutes, NGOs are associated with applied research on vertebrates. The government should make a synthesis of pieces of information available on various aspects of vertebrates like distribution,

population fluctuation, pest management, etc in the country. **After all control measures are to be based on a proper translation of ecological factors in to management policy** (Prakash Ishwar,1964). A nodal agency can constitute a committee of experts to find gaps in research and set priorities for zone-wise research on vertebrate pests, for the 21st century.

The Vertebrate Pest Manager should not aim at eliminating a specific community of animals to realise cent per cent crop protection. For instance, in cardamom plantation when in a patch of two and half acres squirrels were removed, rats occupied the niche. When rats were exterminated from the patch, birds devoured the capsules in a major way. When specific bird species (Jungle fowl) were trapped and eliminated from that patch, ground birds like thrush and pitta occupied the niche. Thus a succession in the community of animals depredating cardamom capsules occurred. Similarly, application of chemicals against damage of vertebrates may result in biomagnification. Total protection may lead to consequences difficult to monitor in the ecosystem.

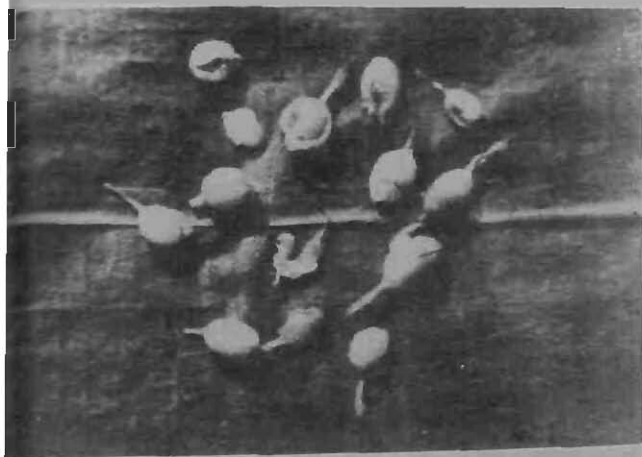
PRIORITIES :

Novel tools for vertebrate pest management in cultivated systems in India can include solar power operated fence, plant/animal products, provision of alternate or known natural foods for vertebrates in the vicinity of agroecosystems, trenches, cultural practices that do not involve much labour such as polyculture, timely harvests, lacing repellent pastes made of easily available materials and mechanical barriers made of locally available biodegradable and renewable materials.

Use of botanicals especially in the evergreen tropical forest tracts have considerable potential (Bhat S.K. et al., 1995). Infact botanicals serve as the ideal tools for Integrated

Vertebrate Pest Management (IVPM). But little is done in this regard. Neem, cluster beans, agave, tree bark decoctions and species of *Acacia* are plants worthy of investigation.

It is not always necessary to use chemicals to protect crops from vertebrates. Baiting is the most common method adopted against rodent pests. While horticultural products should find way into international markets devoid of any chemical residues, products slightly damaged by vertebrates can find a place in local markets, pickling, canning industries and in confectioneries. Public in general, in India should tolerate little damage by vertebrates in view of the ecological and environmental roles vertebrates play in different ecosystems.



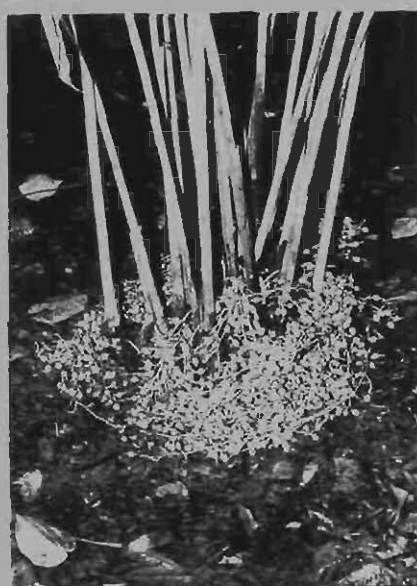
1. Cardamom capsules damaged by Rats



2 Cardamom capsules split by Squirrels



3 Cardamom clump damaged by Monkeys



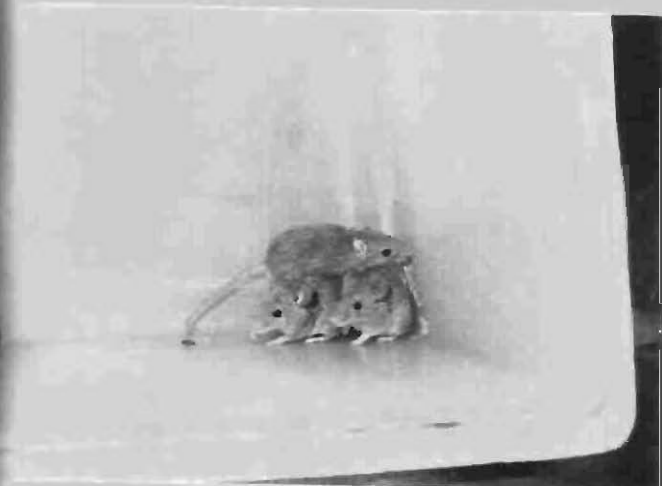
4 Panicles of Cardamom 'Overlapped'



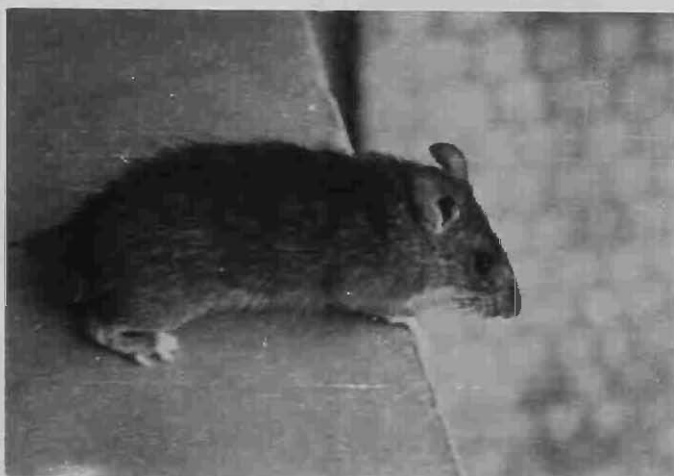
5 Coffee plant with ripened berries



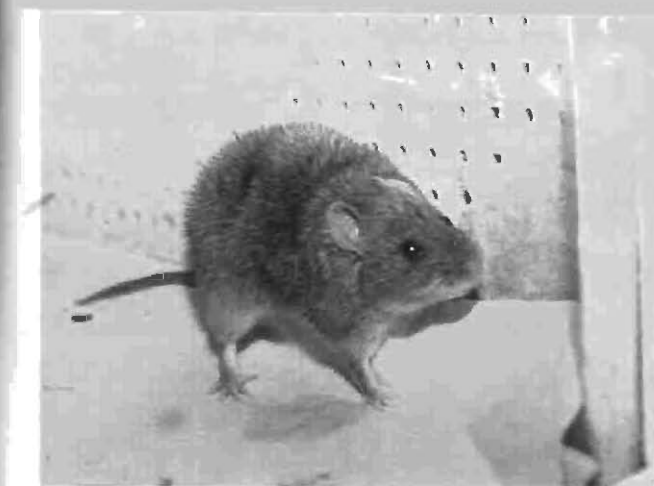
6 Bird damage to coffee



7. *Mus booduga*



8. *Rattus rattus*



9. *Bandicota bengalensis*



10. *Tatera indica*



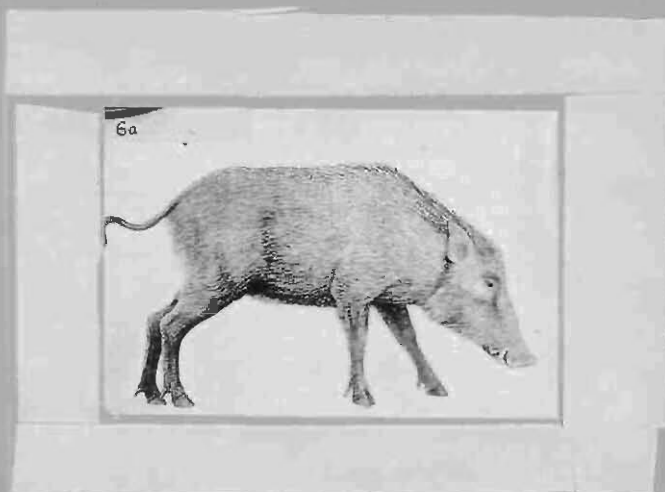
11. *Bandicota indica*



12. *Rattus meltda*



13 Rat damage to Coconut



14 Wildboar



15 Monkey damage to Coconut



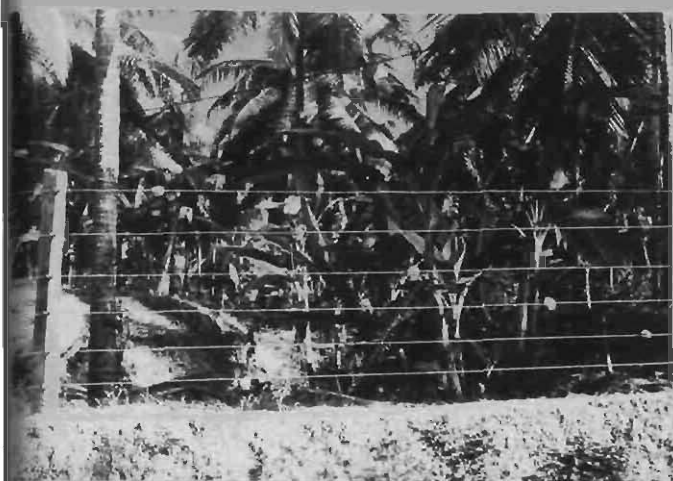
16 Wildboar damage to Coconut



17 Porcupine damage (bark chipout) to Coconut palm



18 Coconut palm succumbs by Porcupine damage



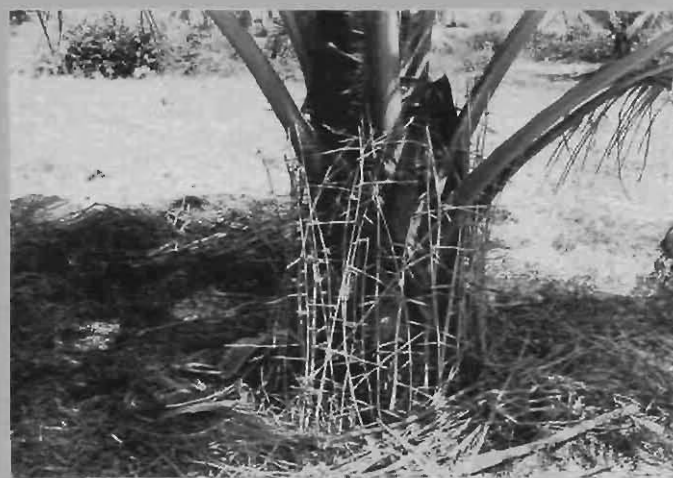
19. 1- Bex Fencing



20. Bison damage to fronds of Coconut seedling



21. Coal Tar application against Porcupine damage



22. Coconut palm trunk covered with Bamboo thatch



23. Banding Metallic mesh against Porcupines damage



24. Application of Waste Lubricant oil to Coconut palm trunk



25. Racumin dusted near Porcupine burrow



26 Trapped Macaques



27 Banding Iron sheet against Rodents damage to Coconut



28 Banding Zinc sheet against Rodents damage to Coconut



29 Method of Ratol Application (Between bread slices)



30 Zinc phosphide application in Maida balls against Rats



31 Banding Bamboo thatch against Rodents



32 Suspension of Thimet polybags against Wildboars



33 Pug marks of Wildboars



34 Monkey damage to Arecanut (Fruits)



35 Arecanuts damaged by Rats (under stored conditions)



36 Squirrel damaga to Cocoa pod



37 Jungle cat damage to Cocoa pod



38 Monkey damage to Cocoa pods



39 Stag damage to Cocoa un-ripened pod



40 Bison damage to young Cocoa plant



Palm (bole portion) damaged by Rat and baited with Bromadiolone



42 Parakeets damage to Guava fruits (Primary feeders)



43. Bird damage to Guava fruits (Secondary feeders)



44. Bat damage to Guava fruit



45. Bison damage to Guava tree



46. Elephant damage to Guava tree



47. Dung pad with Guava Seeds



48. Bats damage to Sapota fruits



49 Bison damage to Sapota tree (Debarking)



50. Bison damage to Sapota tree (Debranching)



51. Citrus tree damaged by Bison (Debranching)



52. Citrus tree damaged by Bison (Barksplitting)



53. Jungle crow damage to Papaya



54. Elephant raids on Banana orchard



55 Small Green Barbet damage to Banana fruits



56 Wildboar damage to Mango



57 Young Paddy seedlings damaged by Rats



58 Rat (*B. bengalensis*) damage to Paddy crop



59 Finch bird damage to Paddy ear heads



60 Wildboar damage in Paddy cropped area



61 Squirrel damage to Maize cob



62 Bat damage to Cashew apples



63 Porcupine damage to Cashew nuts



64 Rat damage to Groundnut



65 Rat damage to Capsicum



66 Rat damage to Tomato



67 An elevated Hideout - Machan



68. Short nosed fruit Bat, *Cynopterus sphinx*



69 Indian flying Fox, *Pteropus giganteus*



70. Temporary roost of *Cynopterus sphinx*



71 Storm Block bait application in the Bait box on the bunds



72. Bat damage to Grapes

SEMINARS / WORKSHOPS / CONFERENCES ATTENDED

ABSTRACTS PRESENTED (Connected with Vertebrate pest management.)

1. Bird Pest Management in Oil palm plantation in Karnataka (A.K.Chakravathy, K.Srihari).
2. Rodent Pest Management in Cardamom (*Elettaria cardamomum Maton*) with Cultural practices (A.K. Chakravarty and K. Srihari, N.E. Thyagaraj).

(Papers presented during First National Symposium on Pest Management in Horticultural Crops - Environmental implications and thrusts . October , 15 - 17, 1997 - Bangalore).

3. Systems of planting to protect crops from bird damage to small scale sustainable farming systems in Dakshina Kannada, Karnataka. (A. K. Chakravathy and K. Srihari).
4. Ecological approaches for the management of Vertebrate pests in Western Ghats. (K.Srihari and A.K. Chakravathy).

(Papers presented during International Conference on ecological agriculture-towards sustainable development -November 15-17, 1997, Chandigarh , India).

5. Dr. K. Srihari , Professor and Head , Principal Investigator, Department of Zoology and Dr. A.K. Chakravathy Co-Investigator participated in the work shop on conservation Assessment and Management plan (CAMP) for Indian Mammals at Center for Ecological Sciences , Indian Institute of Science , Bangalore during 25-29 August 1997.
6. Dr. K. Srihari, Professor & Head Department of Zoology and P.I attended “International Conference on Pests and Pesticide Management for Sustainable Agriculture” (ICPP MSA-1998) during 11-13 December 1998 and presented a paper entitled “Electric fencing; a

tool for wild life management and crop protection in hill region of Karnataka”. (Dr. K. Srihari and Dr. A.K. Chakravartly) at Chandrasekar Azad University of Agriculture and Technology-Kanpur-Uttar Pradesh, India.

7. Dr. K. Srihari, Professor & Head, Dept. of Zoology and P.I attended III International / 15th National Symposium on “ Recent trends in life Sciences” and presented papers entitled
 1. Bison (*Bibos gaurus* H) damage to coconut (*Cocos nucifera* L) Palms In Coastal Region Of Karnataka. (A.K. Chakravartly, K. Srihari and N. Prasanna).
 2. Wildboar (*Sus scrofa* Linn.) damage to rice (*Oryza sativa* L) in hill region of Karnataka. (A.K Chakravartly, K. Srihari and J.B Murthy) during 2000 at Bangalore.
8. Dr. K. Srihari, attended and presented a paper entitled “Arthropod parasites on wild Avifauna in the tropics; some ecological considerations” at 13th National Congress of Parasitology during 24-26 February 1999 at centre for applied Genetics Bangalore University, Bangalore.

A. RESEARCH PAPERS PUBLISHED

1. Vertebrate pests of Cocoa (*Theobroma cacao* L.) and their management practices in hill region of Karnataka. **IPM & sustain Agri-an ent. Appr.** 6: 214-218, 1996. (N.E. Thygaraja, A.K. Chakravartly and K. Srihari).
2. (Iligalu Hagu avugala Niyanthrana in Kannada)
Kissan Bharathi - proceedings - 161 - 167, 1997. Bharathiya Kissan sangha, D.K. Karnataka (K. Srihari).
3. Laboratory manual for Vertebrate Pest Management (Zool.509) and Rodent Pests of Agriculture and Management (Zool.511) (Dr. K. Srihari et al.,).

4. Rodent Pest Management in Cardamom with Cultural Practices **Proc. I, Nat. Symp. Pest Mgmnet. Hort. Crops**, Bangalore (A.K. Chakravarthy, and K. Srihari. 188- 194) 1998.
5. Management of Bird Pests in Oilpalm Plantations in Karnataka. **1, Nat. Symp. Pest Mgment. Hort. Crops**, Bangalore (A.K. Chakravarthy and K. Srihari. 183-187) 1998.
6. Ecological approach for the Management of vertebrate pests in Western Ghats region of Karnataka, South India **Ind. J. Ecol. 25 (1); 55-61**(K. Srihari and A.K. Chakravarthy) 1998
7. Efficacy of Bromodilone 0.005% RB against Rats in farm Store house **Pest Mgmnt. 36** (N.E.Thyagaraj , A.K. Chakravarthi and K. Srihari) 1998.
8. Battada Beleyalli Iligala hathoti mathu Niyantrana. Hybrid Batta Edt, by Vidya Chandra et al., UAS, RRS, V.C. farm, Mandya - 85 - 98. (Srihari. K) 1999 - 2000.
9. Laboratory and comparative field evaluation of Storm Blocks flocoumafen 0.005% against rodent pests in paddy. **_(Pest Management, Indian pest control Association-New Delhi -1997).** (K. Srihari et al) Mysore J. Agri. Sci., 32: 306-312 (1998).
10. Srihari K., Chakravarthy A.K., (2000) Vertebrate Pests of Cardamom (*Elettaria cardamomum* Maton) in Hill Region of Karnataka, South India. **Pest Management in Horticultural Ecosystems.Vol. 6 ,pp 139-148.**

B. RESEARCH PAPERS ACCEPTED FOR PUBLICATION

- 1.. Systems of planting to protect crops from bird damage in small scale sustainable farming systems in Dakshina Kannada, Karnataka. (A.K. Chakravarthy and K.Srihari).
2. Chakravarthy A.K. and K. Srihari. Vertebrate Pest Management in Horticultural Crops. Chapter in the book entitled **“IPM in Horticultural Crops.”**
3. A.K. Chakravarthy, K. Srihari and N. Prasanna. (2000) Bison (*Bibos gaurus* H) damage to coconut (*Cocos nucifera* L) Palms In Coastal Region Of Karnataka.

Proc.Fourth International/ 16th National Symp. on Recent trends in Life Sciences.

4. A.K. Chakravarthy, K. Srihari and J . B.Murthy. (2000) Wildboar (*Sus scrofa* Linn.) damage to rice (*Oryza sativa* L.) in hill region of Karnataka. **Proc. Fourth International / 16th National Symp. on Recent trends in Life Sciences.**

C. RESEARCH PAPERS SENT FOR PUBLICATION

1. “ Vertebrate Pest Management in orchards” chapter in a book entitled “Pest Management in Horticultural crops” edited by O.P Balla, Solan, H.P. (K.Srihari and A.K. Chakravarthy).
2. Social Engineering activity on rodent Control- Impact on Farming community Chapter in a book entitled “ Crop production as system approach”. Oxford and IBH publishers - New Delhi-1998. (K. Srihari et al)
3. Priorities for conservation of Kokkare Bellur Heronry in karnataka, South India. (A.K.Chakravarthy and K. Srihari). Proceedings of Salim Ali centenary seminar on conservation of Avifauna of wetlands and grasslands

D. Manuscripts under preparation

1. Vertebrate pests of cocoa in coastal regions of Karnataka

OUR VISITORS

1. Dr. T.P. Sriharan Retired ADG. ICAR visited the Department on 26.6.1997.
2. Dr. G.C. Tiwari, Sr Scientist (PP) ICAR visited the department on 21.6.1997 and discussed with staff on various research projects, including ICAR research projects.
3. Dr. O.P. Dubey, Sr. Scientist ICAR, visited the department and had discussion about the on going ICAR research projects in the department on 26.9.97.
4. Dr. A.M.K.Mohan Rao, Sr. Rodent specialist, CPPTI Hyderabad, visited the department on 8th July 1998 and had discussions on Research projects on Rodents and other vertebrae pests with Dr.K.Srihari.
5. Dr. Abdul Rehman, Vice Chancellor, Kannur University visited the department on 25th July 1998 and had discussions with the staff members about the on going Research projects.
6. Dr .B. Venkateshwarulu, former Director, CRRI, and Member of Board of management Acharya N.G.Ranga Agricultural University, Hyderabad-500020 visited the department on 10th September 1998 to discuss on vertebrate pests management with Dr.K.Srihari.
- 7 .Dr. Anil Kumar, Professor of Zoology from Kannur University, visited the department on 21.5.1999 to discussed about the research project with Dr.K. Srihari.
8. Dr.Archunan, Professor of Zoology, Bharathidasan University, Thiruchinapalli, visited the department on 4.8.99 to discuss with staff on research work on Rodents.
9. Dr. O.P Dubey, Asst. Director General, ICAR, New Delhi visited the department on 26.10.99 to discuss with Dr. K. Srihari, about conducting Summer School on Vertebrate Pest Management

10. Dr. U.V.M. Mohamed, Professor & Head, Department of Zoology, Calicut University visited the Department on 11.11.99 and has discussed the various aspects especially about the rodent control.
11. Professor K. Radhakrishnaiah, Department of Zoology, S.K. University, Anantapur, A.P. visited the department on 11.11.1999 and discussed various research and extension activities.

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- 8) Assoc.Director of Research, V.C. Farm , Regional Research Station, Mandya.
- 9) Assoc.Director of Research, Regional Research Station, Mudigere
- 10) Directors and Station Heads of
 1. Central Plantation Crops Research Institute (CPCRI), Kasargod and it's Regional Stations at Vittal and Kidu, D. K. District, Karnataka.
 2. National Research Center for Cashew (NRCC), Puttur and it's Regional Station at Shantigodu.
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K. SRIHARI,
Principal Investigator,
Professor and Head,
Department of Zoology,
UAS, GKVK, Bangalore

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