Ecology, Conservation and Management of the Asian Elephant in Bannerghatta National Park, southern India

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Content

Preface

India has approximately 50% of the total population of the world's wild Asian elephants. The Nilgiri's and Eastern Ghats elephant reserve located in the confluence of Western and Eastern Ghats in South India supports the largest Asian elephant habitat and population. Parts of this reserve which fall within the territorial boundaries of the state of Karnataka are called the Mysore Elephant Reserve and include the Bannerghatta National Park (BNP).

The Bannerghatta National Park is highly irregular in shape and measures a maximum of 26 km in length from North to South and varies between 0.3 and 5 km in width from East to West. Politically the BNP is one of the smallest parks in the country. However, geographically it is a part of the largest existing habitat and one of the last remaining tropical thorn forests of the country which is considered to be one of the preferred habitats of the Asian elephant.

One of the major conservation problems of the park is the human-elephant conflict and a considerable amount of money has been paid as crop damage compensation. Given the highly irregular shape of the park, it is expected that the surrounding human habitations would experience high levels of human – elephant conflict. BNP may be acting as a day time shelter for elephants to visit villages during the night and cause damage to crops, property, kill people, and are killed by people. Given this situation, with conflict mitigation measures adopted so far being ineffective, it's argued that elephant's entry or movement into the park should be prevented by fencing the outer boundaries of the park. However, there have been no attempts to study the conflict, density, distribution, seasonal movement and demography of elephants, habitat and corridor use by them and their influence on the status of Human-elephant conflict and existing conflict mitigation measures in and around BNP.

It was during early 2002 that the idea of initiating a long term investigation of the species and its habitat in BNP was thought of. At the same time, the Indian chapter of A Rocha, an international conservation NGO was established. The unconditional and continuous support of Prof. Sukumar through the Asian Elephant Research and Conservation Centre (AERCC); a specialized division of the Asian Nature Conservation Foundation (ANCF), was one of the major reasons for initiating the long term and relatively focused study of elephants in this landscape. This support was reinforced by Mr. Thomas Mathew, Executive Director, ANCF. Support provided by A Rocha's National and International Board gave motivation to convert this short-term study into a long-term investigation.

This was truly a team effort. A Rocha India brought in the much needed qualified manpower support. Knowledge of assessing habitat and plants came from experts at CES; IISc and AERCC who involved themselves fully. AERCC took responsibility in identifying the problem, developing the concept, writing research proposals and developing datasheets for the study. AERCC conducted workshops on methodology, data collection, processing, developing GIS inputs and publication of the results. The proposals were accepted by notable funding agencies such as the Rufford Small Grants and the US Fish and Wildlife Services (USFWS).

Rapid synchronized habitat and species surveys initiated using volunteers exploring major parts of the park and villages gave some specific knowledge on habitat and corridor utilization. Crop damage compensation data extracted for 8 years from the forest department records brought out unique and systematic knowledge. Specific training sessions were conducted for the A Rocha India team by AERCC in classifying elephants in the forest. Elephants from every location of the park were identified, classified and a photographic profile was created.

The crop damage compensation record identified the villages that were most affected by the conflict. These villages were selected and were systematically monitored covering different cropping seasons and reproductive stages (vegetative, reproductive and harvest). A visit to Masaimara landscape and the A Rocha centre in Kenya, Africa was made by one of us (Surendra Varma) during the initial phase of developing elephant-proof barriers. The experience gained from the trip was the motivation for initiating a chili fence experiment in villages within and around BNP. Three research students in Wildlife and Social Sciences who wanted their research to be carried out through the project, studied the status of elephant corridor, land use around villages located close to the elephant corridor, farmers and forest staff involvement in conflict mitigation measures and villagers' perspective on HEC.

All these efforts were possible with the support received from the forest department. All the Chief Wildlife Wardens who were heading the department during the course of the project showed a focused interest in the project and listened to the presentation on the status of elephants achieved through this investigation. Chief Conservators of Forests and Conservators associated with the landscape actively participated in the workshops conducted for training both researchers and forest staff in data collection.

The active support provided by the Deputy Conservators of Forests was a major force of motivation and continuation of this investigation. Assistant Conservator of Forests, Range Forest Officers and other ground staff participated during many stages of the investigation. They drove us to the field sites, walked with us, participated in the interaction with the villagers and provided and shared food with us. The most important part of the support was the department sharing their wireless network with the researchers in identifying and monitoring elephant presence in the park.

All these efforts have gone into creating this document. The document has 15 chapters under 6 sections. Section 1 titled 'The Species' with one chapter, deals with the overall status brought under the species (Asian elephant), its distribution, conservation issues and conservation priorities. Section 2 titled as 'The Landscape' with one chapter, identifies the status of land, its contours, landscape elements, tree species diversity, distribution, richness and invasion of alien species.

Section 3 titled 'Population Density and Demography' with three chapters, estimates the elephant population numbers, provides insights into challenges in age and sex classification of Asian elephant and gives demographic details of the species in the landscape. Section 4 titled 'Habitat and Corridor' with two chapters, describes the distribution of elephants across the landscape, corridor usage and status of human-elephant conflict exclusively in the corridor region. Section 5 has been divided into 3 parts; Part 1 titled 'Human-Elephant Conflict' with two chapters, maps the status of the conflict by assessing the crop compensation records and actual ground surveys.

Part 2 titled 'Conflict Mitigation Measures' with three chapters, describes the existing conflict mitigation measures used by forest staff and farmers, in the mitigation of human-elephant conflict. Part 2 also reveals our experience of experimenting with a chilli fence barrier in preventing elephants, people's perception regarding this method and their participation in such mitigation measures. Part 3 titled 'People Perspective on Human-elephant Conflict' with one chapter reveals the minds of people on the status of Human-elephant conflict and their participation. It also identifies their strength and weaknesses in dealing with human-elephant conflict. Section 6 titled 'Capacity Building' with one chapter, testifies to the success of using manpower drawn from different walks of life in collecting and compiling data.

Except for a few chapters, for all the chapters the data sheet format used for the study is given as appendix. We hope that these data sheet formats will be useful to others to collect data on these aspects. We also assume, that if, uniform data collection formats are used (using similar data sheet) across different landscapes a comparison of patterns across the same could be made. In addition to photographs included in the document, additional figures have also been created as appendix for each chapter giving pictorial representation of data collection and other aspects associated in a given chapter.

Human-Elephant Conflict is a major conservation issue here and given the magnitude of the problem, it is essential to initiate specific mitigation measures for the issue. One of the conflict mitigation measures being practiced is the attempted chasing of elephants across the state boundary into Tamil Nadu by the elephant scaring squad. However at the border these very same elephants are not permitted to enter by the local people and concerned authorities in Tamil Nadu State. It is obvious that this movement between two habitats may affect their nutrient intake and other biological process and the amount of additional stress that the elephants experience through this process may not be measurable. The conflict, in addition to causing damage to properties, also results in elephants getting killed, an average of 2 elephants are killed and the results clearly show that the elephants killed are males.

The chasing operation reveals that about 200 (range from 80-200) elephant use the park during peak conflict season and this number may originate from some of the regions of the Elephant Reserve 7. It is important to note that currently the park has a male-female sex ratio of 1:2.7 and death of more males due to conflict related causes may affect this ratio. The observed ratio could also be an artifact of male elephants preferring this habitat as against the habitats which could be their source. Given the status of human-elephant conflict, it is possible that a proportion of elephants especially males from the Elephant Reserve 7 may get killed.

It appears that the qualitative and quantitative benefit the elephants may be getting from raiding crops is far less when compared to the animals actual foraging needs. Furthermore, it was found that the elephants consumed 5 species of crops on an average/day and an average each elephant consumed about 15 kg of crops/day. This makes us believe that human-elephant conflict will have negative impact on the elephant biology and their population. This may further confirm the negative impact of conflict on elephants and the need to mitigate the same.

The knowledge gained through this investigation now may be used as a conflict mitigation strategy by providing large habitats for elephants by consolidating lands (including private lands), establishing effective barrier mechanisms and improving farm based agricultural practices which may aid in conserving this species.

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Executive Summary

Conservation of the Asian elephant is becoming increasingly difficult due to many factors; primary among these, is the increase in human population and their activities around elephant habitats and perpetuating competition for natural resources between the two. Human influence through habitat encroachment, fragmentation and increased human activities within and around elephant habitats drives the elephants' conflict with humans.

Bannerghatta National Park (BNP) located in the Eastern Ghats, though politically measuring only about 103 km^2 in area is geographically contiguous with the last largest remaining tropical scrub and thorn forest of the country. There are around 117 human settlements located within 5 km from the Park boundary and 5 human settlements within the park. The relatively smaller size of this park which is already fragmented and degraded, coupled with a high density (during some seasons of a year) of elephant population adds to conflict with the local community.

This study carried out between the period 2004 and 2009 to gain some specific knowledge on Human-Elephant Conflict (HEC) looks at the overall ecology and conservation of Asian elephants in the park. It covers aspects such as status of landscape (contour, landscape elements, tree species and invasive species), elephant ecology (density, demography, seasonal movement, habitat usage pattern, status and usage of corridors), conservation and management (patterns of HEC: crop raiding, efficacies of elephant proof barrier mechanisms, people's perception on HEC and other related aspects).

Based on contour patterns, topography reveals that the park has relatively small hills with elevation ranging from 720 to 1025 meters. Agricultural and barren land dominates the land-use/ land-cover around the park. The vegetation of the park has high species diversity coupled with high species rarity. The canopy cover of the vegetation is in congruence with the ground cover and reveals that the vegetation is of open forest type. The invasive alien species viz. *Lantana camara* and *Chromolaena odorata* are distributed across all 3 ranges of the park.

A mean elephant density of 0.71 (95% CI - 0.51 to 0.94) animal/$km^2$was estimated during the population density assessment using the line transect indirect count method. This translates into 52 to 97 elephants for the park. The estimated elephant density for dry deciduous forest was 10 times more than the thorn forests.

This investigation also makes an attempt to develop a field key to overcome the challenges involved in the age and sex classification of wild elephants especially in forests with poor visibility and other factors. Four approaches were adapted in order to effectively age-sex classify wild elephants. Sixty possible combinations of yardsticks were arrived at by comparing the different age groups, especially to address the problem related to classifying juveniles and sub adults in elephant herds. Comparison of one individual with respect to a reference adult animal when seen from a front view, lateral view or a rear view was computed.

A total of 60 elephants were sighted and classified through direct observations. Adults constituted the major age class (55%) suggesting an adult dominated population. About 31% of the individuals sighted were males and the remaining 69% were females.

Adult females (44%) were the dominating sex class of the population followed by juvenile females (20%), adult males (16%), sub adult males (7%), juvenile males (7%) and sub adult females (6%).

Herds were sighted the most (60%) followed by solitary and all-male alliances in the park. The average size of these herds was found to be 6 elephants. The park had an adult male to female ratio of 1:2.7, which is one of the least skewed sex ratios in Asian elephant population among its range countries. The inter-calving interval of a breeding female was found to be 4.8 years per calf.

The distribution of elephants inside the national park varied temporally on a daily basis. Around 32% of elephants were found close to the villages (0-1000m) in the morning and gradually increased to 50% by afternoon. This however reduced to 18% by evening.

The corridor usage by elephants was uniform across the years too and there was no difference in the encounter rates of all the signs (fresh and old) for the same months of two different years. This similarity in the pattern of utilization of habitats and corridor across the years clearly indicates that elephants have a strong affinity to the habitat. Fresh signs during the dry seasons were absent in the microhabitats of the corridor region suggesting elephants are less frequently using the corridor habitat during the dry season. The range specific results indicate that elephants prefer Bannerghatta and Anekal ranges of the park over the Harohalli range.

The evaluation of vegetation in the northern fringe of the Karadikkal-Madeshwara corridor as part of its ecological status survey disclosed that the fringe region is an area of high plant diversity and species rarity. The land-use in the corridor area was mainly agriculture followed by natural vegetation and unusable lands. The intensity of Human–Elephant Conflict (HEC) in the corridor villages was higher than those located away from the corridor and it has been increasing steadily. Considering the narrowness of the corridor (length being 1 km and width 0.3-0.4 km) and if the corridor usage by elephants is high, human-elephant conflict in the surroundings can be expected to increase further.

Study of crop damage compensation claim and payment records collected for the period 1999-2005 showed that a total of 117 villages located around the park were affected by HEC Human-elephant conflict. An average of 595 compensation claims per year was reported from the above villages during the period 2000-2005.

The spatial analysis of compensation claims and payments revealed that elephants travelled a mean distance of 2 km (ranging from 0-20 km) from the park to visit villages. About 80% of the crop damage incidents were reported from villages that are located within 3km from the forest and the highest incidents occurring (of crop damage) in the distance range of 0.5-1 km.

Conflict zones identified using the home range estimator showed 34 villages experience intense and high conflict; villages such as Ragihalli, Mantapa, Bannerghatta, Thamanayakanahalli and Buthanahalli come under these two zones of conflict. The villages Ragihalli, Sampigehalli and Buthanahalli located in Bannerghatta range, Gottigehalli, Kaadujakkasandra, Biliganaguppe and Maralawadi located in Harohalli range and Thammanayakanahalli located in Anekal range had been affected by conflict consistently across the years.

The occurrence of conflict incidents is very obvious in the enclosures with a clear trend of increase across years and some villages even stopped cultivating due to the elephant problems. The conflict reached its peak between October and January which is also the peak cropping season in the area. A minimum of 37 different crop types grown in the region were subjected to the raids by elephants with an average of 15.5 crop types being raided per month during this period.

The crop, Ragi (*Eleusine coracana*) was the most raided followed by Banana (*Musa paradisiaca*), Paddy (*Oryza sativa*), Coconut (*Cocos nucifera*), Sorghum (*Sorghum bicolour*) and Cluster beans (*Cyamopsis tetragonoloba*). On an average only 58% of the actual value of crop loss claimed was paid as compensation to the farmers.

Monitoring villages for status of conflict showed both seasonal and annual crops were prone to raids and subsequent loss of economy. A total of 14 seasonal and seven annual crops were damaged by the elephants. Of the above crops, about 51% of the seasonal crops were in the harvest stage and 71% of the annual crops were in the reproductive stage.

Elephants were observed entering villages between 19.00 hrs and 22.00 hrs and departing before sunrise. The time between 21.00 hrs to 23.00 hrs and 24.00 to 02.00 hrs appeared to be crucial as this was the time when more incidents of elephants visiting villages were reported. Elephants of all age classes and group sizes had visited the crops. However, most belonged to the adult age class (83%) followed by sub adults, juveniles and calves.

Among the seven villages monitored; Thattiguppe, Ragihalli and Buthanahalli which cultivate crops round the year were visited by elephants almost throughout the year. The village Thattiguppe, notorious for brewing illicit liquor as well as being agriculturally progressive was the most affected.

The village Chudahalli, even though an enclosure within BNP was raided the least followed by Shivanahalli, owing to the minimal agricultural activities taking place in these villages. In Buthanahalli a high number of elephant visits were registered during the summer months which coincide with the fruiting season of mango (*Mangifera indica*) and jackfruit (*Artocarpus heterophyllus*) trees, which are extensively grown in and around this village. Maximum damage was reported during the month of December which is the harvest period in these regions.

The overall economic loss due to elephant crop damage stood at INR 48,116/- (1 USD= 48.37 INR) for the seasonal crops and INR 1, 59,483/- for the annual crops for every year. The loss was more due to trampling as compared to consumption by the elephants for both seasonal and annual crops. Another interesting point to be noted here is that the above loss resulted from elephant damaging only less than 11% of the total crop area under cultivation.

The survey on elephant proof barriers and their efficacy, covering 130 km of the total 143 km established, revealed that three types of barriers viz. Elephant Proof Trench (EPT), Rubble Wall (RW) and Electric Fence (EF) were in use in the park. About 882 breakage points attributed to 28 different causes were documented and categorized under natural causes, elephant caused, execution errors and human caused.

The damages to elephant proof barriers by elephants accounted for only about 15%, while natural causes attributed to 50% and execution errors to 23%. The encounter rate of breakages remained by and large the same between 2005 and 2008 at 6.39/ km and 6.71/km respectively.

Eight test plots of the Chilli Tobacco rope Barrier (CTB) were established across 5 villages falling under high, medium and low conflict status. This measured an average of 0.45 acres in area and was monitored for 51 days during the peak conflict season, coinciding with the peak cropping season in the park.

A minimum of 19 times and a maximum of 32 times elephants had come as close as 0-110 meters of the test plots. None of the crops in the test plots were damaged even though about 64% of the crops were in the reproductive stage (the most preferred phenological stage of the crop by elephants). However, a total of nine times the crops in the adjacent crop fields (about 73% of which were in the harvest stage) were damaged by the elephants.

The study showed the cost to be Rs. 1,280/- on an average to protect a crop of 0.5 acre area with CTB. Of this, about 95% of the cost of establishment was towards the cotton rope whilst only 5% was the cost of chilli powder, tobacco powder and used engine oil. Though the farmer does not make a substantial saving by using CTB on a crop like ragi (*Eleucine coracana*) during the first usage, subsequent usage will make a significant saving as there is no cost of establishment involved for the subsequent years.

The CTB deterrent mechanism recorded a high degree of appreciation from the villagers. Overall participation of people was rated to be very good. People were open to experimenting with the CTB suggesting they are open to try any new and innovative ideas to mitigate elephant incursions into their habitations.

The results of farmers and forest watchers efforts at preventing elephant incursions show that during Elephant Driving Observations (EDO), 100% of the times elephants were located by the forest watchers and of them about 89% of the times they were driven back.

The farmers participated on all days in the Night Watching Operations (NWO) and with all their efforts, were unable to prevent elephant visits/damages even once. Even though the effort during NWO was exhausting and de-motivating for the farmers, it was worthwhile as the crop damaged by elephants was only 5 % of the total cultivated area, if not, the extent of damage could have been more.

The local community felt that the rise in population of both elephants and humans was the primary cause for growing conflict. The others included habitat degradation, lack of food in the forest for elephants in certain seasons and increased availability of the vegetation in human habitations round the year. Given the status of Human-elephant conflict, the attitude of local people towards the elephants and their conservation was found to be discouraging. This necessitates the need for efforts to make people tolerant of elephants through various conflict mitigation measures aimed at improving the living conditions of the local community in order to conserve the species in this landscape.

In the current study, a minimum of 448 persons were trained through a series of training and capacity building programs organised at BNP. People of varied professional back ground were given opportunity to volunteer. The forest department staff gained knowledge on methods to assess and respond to management of conflict on a day to day basis.

The BNP is an important area for the conservation and management of the Asian elephant. Due to the magnitude of the human-elephant conflict in this region, specific mitigation measures need to be formulated. Certain existing mitigation measures like the unsuccessful attempted annual chasing of elephants across the state boundaries (Karnataka and Tamil Nadu) only lead to increased stress among the elephants and shifting of conflict elsewhere. This chasing operation has revealed that about 200 elephants use the Park during the peak conflict season and that this increase in elephants may be due to an influx of elephants from the other habitats adjoining the park. This conflict, apart from causing damage to property, also results in the death of an average of two elephants a year which invariably happen to be males. This can have an adverse effect on population dynamics of the animal. Under these circumstances strong conflict mitigation measures need to be followed which will help aid effective long term conservation of the species.

As discussed earlier, elephants at BNP must be studied keeping in view that these elephants belong to a larger population of elephants from Cauvery Wildlife Sanctuary (CWS) and Hosur–Dharmapuri Territorial Divisions (HDTD). Therefore, observed sex ratio and population size may be a snap shot of a larger picture. It is important to address and resolve the drivers of HEC at the level of an elephants' home range which will include a larger landscape. However, management recommendations and conflict mitigation measures may be site specific and therefore studies carried out at the scale of individual elephant would provide vital clues on their food species preference (including cultivated crops), thus helping in effective conflict mitigation.

- An in-depth study on aspects related to vegetation and invasive species in the park should be conducted and disturbance regimes be identified
- The population density and structure of elephants in this landscape should be monitored on a regular basis to understand the long term dynamics of the elephant population and to assess the impact of conflict and habitat fragmentation on the size and structure of the population.
- Consider a cut off width of 10 m for counting the dung signs while on the line transect to estimate the elephant density through indirect dung count method.
- In light of the less skewed male-female elephant sex ratio of the park, it is vital to understand the home ranges of male elephants and their contribution to the genetic viability of the population in the habitats adjoining the park.
- Population dynamics' studies on elephants should be conducted at Cauvery Wildlife Sanctuary (CWS) and Hosur–Dharmapuri Territorial Divisions (HDTD) on priority to understand the observed sex ratio at BNP and to develop appropriate management plans
- Studies on elephant habitat usage and habitat surveys to identify drivers of conflict must be carried out on priority at CWS and HDTD.
- Ascertain the variation in the sub adult elephant population through further investigations.
- As elephant movement is restricted only to Bannerghatta and Anekal Ranges it is important to take up exclusive study on habitat status in Harohalli Range, including the availability of water resources, cattle use and human related disturbances.
- Ban all human activities (for example quarrying, stone crushers, sand mining, firewood collection, lopping, Non-Timber Forest Produce (NTFP) collection and access road) including cattle grazing in the Karadikkal-Madeshwara corridor (KM) to ensure uninterrupted movement of elephants.
- Augment the width of the corridor by appending the fringe area along the northern side of KM corridor (area between Jaipuradoddi and KM corridor) with high floral species diversity and species rarity by another 150-200m.
- Considerable loss of crops (particularly Ragi) could be avoided during the harvest stages (ready to harvest/ harvested but kept in crop fields for drying/stored in the open for processing) by advancing the processing of crops (drying and separation of grain from husk) thus reducing exposure of these crops to the elephants. This can be achieved by following improved farm based practices such as better drying and storing facilities.
- Assess the elephant damages for crop compensation payment more systematically and scientifically including taking the GPS location of the damage point. Damage should be assessed based on the economic value of the product in the market at the time of damage rather than the pre fixed value of a crop for the whole year. The average of the values recorded for a particular farm produce in the Agricultural Produce Marketing Centre (APMC) across the state must be considered to arrive at the actual value of the damaged crop at that time.
- Initiate dialogues with concerned authorities to insure crops against damage by elephants.
- Speed up the process of paying compensation towards elephant damages and upgrade the existing ex-gratia payment scheme to full compensation payment scheme considering the actual damage.

- Ensure periodic maintenance of the elephant proof barriers and regularly check for breakages. Check brewing of liquor among the conflict villages by organising campaigns and awareness programs for the local communities.
- Bridge the gaps in the barrier mechanisms owing to execution errors due to reasons such as sheet rock, rocky outcrop, drain/streams cutting across, etc. especially in elephant proof trenches (EPT) on priority.
- De-silt the elephant proof trenches immediately after the monsoon and grow grass or any other suitable vegetation to minimise future erosion. Deepen the EPT along the boundary near places such as Hakkipikki colony in Bannerghatta range, Urugana doddi in Anekal range, Gullahatti Kaval and Budangaiahna doddi in Harohalli range on priority. Works of this kind can be accomplished using manpower rather than machine power making use of the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) of the Govt. Of India.
- Re-erect the rubble wall stretches of more than a decade old ensuring that the dimensions are to the current standards. This should be taken up on priority in places such as Uruganadoddi in Anekal range and Muninagara Kere in Bannerghatta range.
- A double barrier such as elephant proof trench-rubble wall, elephant proof trench-solar powered electric fence or rubble wall-solar powered electric fence can be tested as an option to preventing elephant visits to human habitations of the high conflict zone such as Buthanahalli, Ragihalli, in Bannerghatta range, Gottighalli, Kaadu Jakkasandra in Harohalli and Thammanayakahalli in Anekal .
- Design an extension program to popularise CTB and train the farming ommunity on using it scientifically for better results.
- The effect of rain on the efficacy of CTB mechanism particularly in this andscape needs to be understood.
- Community based conservation programs such as joint forest management, constitution of eco development committees, village forest committees etc can be introduced as the communities are open to new methods of mitigating the human-elephant conflict.
- An exclusive elephant scaring squad comprising both farmers and forest watchers armed sufficiently to guard the crops from elephant raids in the night should be constituted during the peak conflict season.
- A training program emphasising on the elephant driving methods, usage of crackers, usage of armouries, mode of communication, safety measures to be followed while on elephant driving operation must be organised for this squad during the beginning of the cropping season every year.
- Create a platform for regular interaction among the local community, forest department and Non Government Organisation involved, reviewing the conflict status and formulating suitable mitigation strategies.
- Extend the limits of safe zone up to 2km from the forest boundary as the forest is more linear in nature and ensure the ban of all kinds of developmental activities in this zone in spirit and action.

Section 1
The Species

Introduction

The Asian elephant is considered to be among the largest living land mammals and is presently endangered according to the IUCN red list data 2008 (IUCN, 2008). There are only around 50,000 elephants in the wild and another 16,000 in captivity, distributed across 13 Asian countries today (Sukumar 1989). India has approximately 50% of the total population of wild elephants (20,000 to 25,000) distributed across 18 states/union territories; with South India supporting around 10,000 elephants in the wild (Project Elephant 2008). The confluence of the Western and Eastern Ghats at the Nilgiris in Tamil Nadu supports the largest Asian elephant habitat in southern India. These two ranges of mountains are unique in terms of the diversity of species and habitat.

While the Western Ghats is one among the 25 biodiversity hotspots of the world, the Eastern Ghats remains the last largest remaining scrub forest for elephants within its range countries. This major habitat of southern India has been declared as the 'Nilgiris and Eastern Ghats Elephant Reserve' by Project Elephant, a conservation initiative of the Government of India (Alva 1994; AERCC 1998). This is one of the largest Elephant Reserves in India with an area of 11,000 km^2. The Karnataka part of the 'Nilgiris and Eastern Ghats Elephant Reserve' is called the 'Mysore Elephant Reserve' which includes the Bannerghatta National Park (BNP).

Profile of Bannerghatta National Park (BNP)

The BNP is one of the smallest National Parks in the country measuring about 103 km^2 (Singh 2008) in area. The park is highly irregular in shape and measures a maximum of 26 km in length from North to South and varies between 0.3 and 5 km in width from East to West. The park lies between 12^0 34' and 12^0 50' N latitudes and between 77^0 31' and 77^0 38' E longitudes (Rajeev 2002). Though politically a small National Park, geographically the park is contiguous in the south with the last largest remaining scrub forest of the country – the Hosur forest division of the Tamil Nadu state to the South-East and the Kanakapura forest division of the Karnataka state to the South-West. These two further connect to larger forest tracks of the Cauvery Wildlife Sanctuary (Figure 1) eventually joining the Nilgiri Biosphere Reserve of Western Ghats forest at Nilgiris stretching through Malaimahadeshwara hills, Biligiri Rangana Temple Sanctuary, Kollegal Forest Division and Sathyamangala Forests (Singh 2008).

The park is further divided into three forest ranges namely the Bannerghatta Range, Harohalli Range and Anekal Range for administrative purpose. The terrain of the park is highly undulating with a mean altitude of 865m and ranges between 700 and 1035m above mean sea level. The park receives an average annual rainfall of 937mm ranging between 728mm and 1352mm (Figure 2). The park experiences rainfall spread across 8 months (April-November). The maximum rainfall (50%) is received between August and October. January, February and March are the peak dry months and the rainfall ranges from 0.3 to 46mm in these months.

There are no rivers originating or flowing through the park however several self evolved streams viz. Antaragange Hole, Rayatmala Hole, Amuthi halla, Muthyala Madu halla, Shankarana halla, Bantana halla, Aane Maduvina halla, Byaladakere halla, Maavina halla are found in the park (Figure 3).

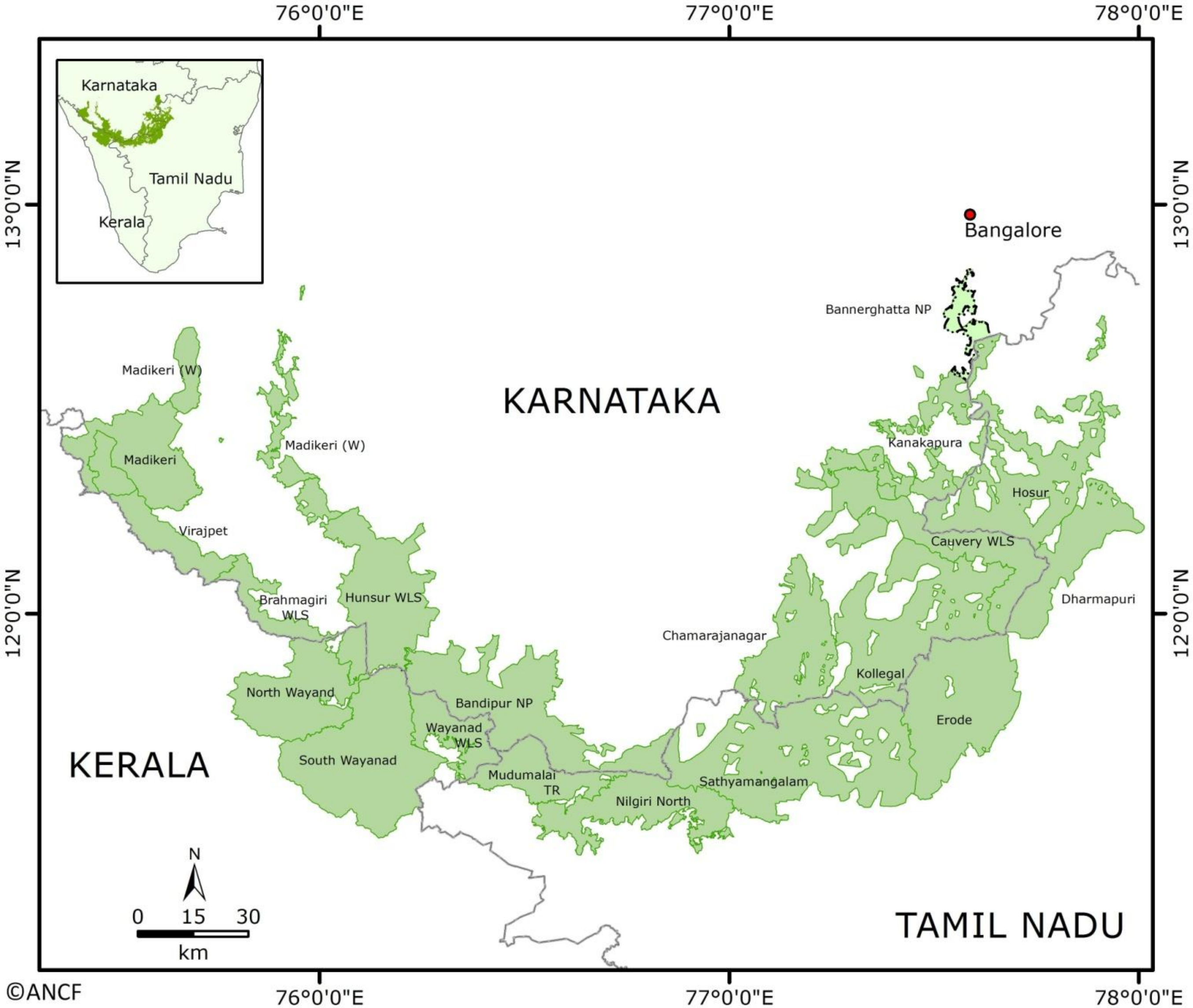

Figure 1: Map showing Bannerghatta National Park (BNP) along with other adjoining forest divisions in Elephant Reserve 7 (Source: ANCF).

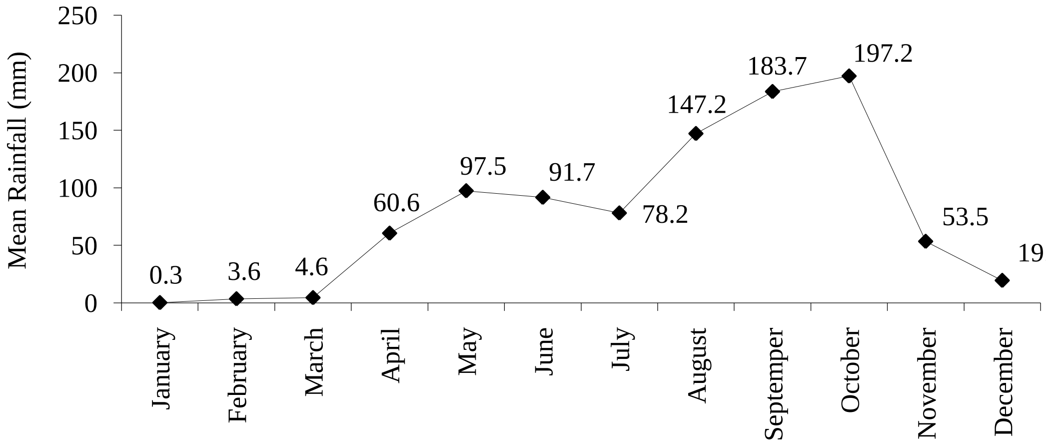

Figure 2: Mean rainfall during 1991-2001 is plotted against the months

These streams swell up to the brims during the rainy season (June – October) rendering them formidable to cross for both wild animals and human beings. These streams bordering the forest on one side and human habitations on the other side terminate in the Arkavathi rivulet of the river Cauvery after feeding several water bodies in their course. The human habitations alongside suggest the streams to be the likely attraction for human settlements in this landscape. The human interference in this landscape is prominent and has degraded the catchments areas of these streams rendering them very short lived. There are more than 50 water holes in the park, many of the water holes are natural and are constantly renovated to augment their water holding capacity along with few which are manmade (Rajeev 2002).

Figure 3: An example of a stream originating from the park (Source: Google Earth)

The geology of the park shows that the rocks are of the oldest formation revealing crypto crystalline to coarse granites and complex gneiss. The rocks are light to dark grey or whitish muscovite granite gneiss or biotite granite gneiss which varies considerably from place to place in structure, texture and appearance. According to the fineness or coarseness of the constituent grains and the relative abundance or scarcity and mode of deposition of the darker ferro minerals, their complex gneiss masses have been styled 'Peninsular Gneiss'. Granite sheet rocks characterize the higher hills and quarrying is rampant in this area. The soil on the upper regions is red and gravelly, which it is generally deep or shallow mixed with metamorphic forms of rocks on undulating grounds. The soil in the valleys is sandy loam and is formed with finer particles of the decomposed rocks washed down and deposited during rains. The soil is shallow on the hill tops and deep in the valleys and low-lying areas (Rajeev 2002; Anand *et al*. 2006; Singh 2008).

The park has two major types of vegetation viz. scrub and deciduous vegetation. The scrub vegetation is seen mostly along the fringes of the park and experiences heavy biotic pressures by the local communities for reasons such as fuel wood collection and cattle grazing. The upper regions of the park are covered by mixed deciduous vegetation type whereas the valleys, water courses and low lying areas are covered by mixed deciduous vegetation which is relatively less disturbed and degraded as it is inaccessible due to the highly undulating terrain.

The park is a home to several species of mammals, amphibians, reptiles and birds apart from the endangered Asian Elephant (*Elephas maximus*). The other prominent mammals seen in the park include Indian gaur (*Bos gaurus*), Sambar deer (*Cervus unicolor*), Spotted deer (*Axis axis*), Leopard (Panthera pardus), Wild dog (*Cuon alpines*), Wild pig (*Sus scrofa*), Sloth bear (*Melurus ursinus*), Common mongoose (*Herpestes vitticollis*), Pangolin (*Manis crassicaudata*), Slender loris (*Loris lardigradus*) and Black naped hare (*Lepus nigricollis*). The park has a notable diversity of birds with more than 222 species identified and recorded by experts (Singh 2008).

There are around 117 human settlements located within 5 km from the boundary surrounding the park and 5 human settlements within the Park. Some of these settlements seem to have formed recently suggesting encroachment of forest land. About 300 cases of encroachment have been registered as on 2008 in the forest department records (Singh 2008). Majority of the communities appear to be illeterate and from an economically lower strata. The Scheduled Tribes dominate the settlements located close to the park boundary in the South-East, and South-West including the enclosures. The local communities majorly depend on agriculture (Figure 4) and cattle keeping for their livelihood.

Figure 4: Image shows land used majorly for agriculture (Source: Google Earth)

The communities in the northern part of the park show a gradual shift from agriculture to business activities owing to the rapid urbanization in that area due to expansion of Bangalore city. Agriculture is practised throughout the year but is intensive during the rainy season (June to September) and sporadic during the rest of the year. The crops in the non-rainy seasons are cultivated using rain water stored in tanks and by the exploitation of ground water. Approximately 40% of the local community belongs to the farming communities of Gowda and Reddy and the remaining comprise of tribals with small land holdings.

These tribes such as Aadi Karnataka, Hakkipikki, Iruliga and Lambani are believed to have moved to these landscapes as agricultural laborers and were later given small pieces of land for their subsistence by the Government. These tribals also work as labourers in the lands owned by the Gowda and Reddy communities whose lands are more fertile due to the presence of rain harvesting mechanisms which the tribals themselves cannot afford. Socially, most members of the tribal community are addicted to alcohol (hooch) consumption.

The local people are also involved in illegal mining of sand deposits along watercourses inside the park as there is a high demand for it by the rapidly growing construction works in Bangalore city. Sandalwood tree poaching (Figure 5 - about 35 cases were registered as on April 2008 in the forest department offence register) largely by people from the neighboring state of Tamil Nadu and incidence of infiltration of illicit fuel wood collectors and timber smugglers are reported in the park (Singh 2008). The hacking of bamboo by the locals for basket making may also be exerting pressure on the park leading to habitat degradation. The prevailing rampant stone quarrying may also be causing disturbance to the wildlife.

Figure 5: An example of Sandalwood tree poached in the park

The park has a network of about 144 km of forest roads covering most of the interior areas of it and the roads are used for regular inspection and night patrolling. Some of the roads of this network are asphalted and/ or metaled to connect bordering villages, far off towns and cities and undergo periodical maintenance resulting in habitat fragmentation and disturbance (Table 1).

Table 1: Major Roads passing through the park with right of way permitted

Sl. No.	**Name of the road**
1	Bannerghatta – Kagglipura road via Bannerghatta Reserve Forest
2	Bannerghatta – Anekal road to Ragihalli via Bannerghatta Lac & Ragihalli Reserve Forest
3	Indaluvadi – Maralawadi road via Madeshwara Reserve Forest
4	Bangalore – Bannerghatta road via Kalkere Reserve Forest
5	Thammanayakanahalli –Choodahalli road via Madeshwara Reserve Forest
6	Kanive Shivapura to Indaluvadi – Maralwadi road via Madeshwara Reserve Forest
7	Therubeedi – Maralawadi road via Bantanal Reserve Forest
8	Yelachawadi- Vasupatna Road via Bantanal Reserve Forest

In addition to these, the increasing demand for land to develop townships around the northern, north-east and north-west part of the national park is transforming the landscape into a concrete jungle. All these issues may directly and/ or indirectly have escalated the causes for conflict between humans and wildlife particularly with elephants. This gives a scope to study the status of elephants and the conflict in the national park, with the hope of finding plausible solutions to mitigate the problem for the welfare of both humans and elephants.

Figure 6: A herd of elephants seen in the park during the census program conducted in the year 2007

Status of the Asian elephant in Bannerghatta National Park

Elephants are found to be distributed in the entire park (Figure 6). There is also seasonality of elephant presence observed. This leads to fluctuations in elephant numbers in the park. Elephants are found more in Bannerghatta and Anekal ranges of the park. To move between these two ranges, they have to move through Harohalli range. The Karadikkal- Madeshwara elephant corridor located in Harohalli range is acting as a link between the two. The corridor measures about 1 km in length and 0.3-0.4 km in width connecting northern and southern portion of the park (Varma *et al.* 2005).

The elephants seem to have some preferences to locations within these ranges which are called ‘hot spots’ (Figure 7). These hot spots are defined by no or less human pressure, specific vegetation cover with adequate shade, space and proximity to water sources. The usage of these hot spots by the elephants is distinguished by the presence of signs such as dung pile, feeding and other signs. On an average 10 (ranging 5-15) dung piles are seen in these hot spots.

Figure 7: A typical elephant hotspot in the park

According to the 2002, 2005 and 2007 synchronized elephant census conducted by the government, the park had an elephant population of 71, 74 and 148 with a mean density of 0.68/ km^2, 0.71/ km^2 and 1.41/ km^2 (Table 2) respectively (AERCC 2002; AERCC 2006; Baskaran *et al.* 2007).

The mean density results suggest an increasing trend in the elephant population. While the recent census estimates a population of 148 elephants for the park, the forest staff involved in the elephant driving operations and farmers living adjacent to the park boundary suggest the number to be more than 200, with the migratory elephants moving in during the cropping season (July-November) till the end of winter season (November-February). This spurge in numbers is also believed to drive the elephants to stray into the human habitations resulting in conflict.

Table 2: Number of elephants in Bannerghatta National Park as per the Synchronized elephant census

Sl. No.	**Year**	**Mean density (per km^2)**	**Mean number of elephants estimated**	**Range of elephants number estimated 95% CI***	
				LCL	**UCL**
1	2002	0.68	71	21	121
2	2005	0.71	74	52	160
3	2007	1.41	148	105	191

CI-Confidence Interval, LCL- Lower Confident Limit, UCL-Upper confident Limit
Source: AERCC, 2002; 2006; Baskaran *et al.*, 2007,

Status of Human-Elephant Conflict (HEC) in BNP

According to the local communities, HEC did not exist until the declaration of this forest as a National Park in the year 1971. According to them elephants used to stray into the human habitations very rarely and people used to eagerly wait for their visit to catch glimpse of the magnificent animal.

But over a span of 4 decades the opinion of elephant being a gentle giant has changed to that of a destructive animal due to the severity of the conflict through increase in crop depredations and human deaths/injuries. The local community also feels that the conflict situation in the park is increasing (Gopalakrishna pers. Obs).

Crop depredations: The crop damages (Figure 8) are systematically recorded by the forest department at the Office of the Deputy Conservator of Forests and these damages are compensated to certain extent through the compensation scheme of the forest department. On an average 900 (SE = 151.93 and ranges from 470 - 1477) compensation claims are registered per year.

Figure 8: An example of a crop damaged by elephants in the park

The year 2005-2006 recorded the maximum number (1477) of crop depredations resulting in a huge economic loss of Rs. 18, 48,250 to the farmers (Table 3).

Table 3: Summary of crop damages and compensation paid by the forest department during 1997-2008

Sl. No.	Year	Number of crop damages	Compensation Amount (INR)
1	1997-1998	470	3,95,525.00
2	1998-1999	428	4,06,175.00
3	1999-2000	1085	12,56,820.00
4	2000-2001	1165	14,89,810.00
5	2001-2002	1247	11,11,565.00
6	2002-2003	-	-
7	2003-2004	-	-
8	2004-2005	-	-
9	2005-2006	1477	18,48,250.00
10	2006-2007	825	10,64,725.00
11	2007-2008	500	5,61,350.00

‘-‘Data not available; Source: BNP Management Plan (2002-2004 & 2008-09 to 2012-13)

Human death/injury: The problem of human deaths and injuries (Figure 9) due to conflict with elephants is severe in the park. On an average 2 people are killed and another 2 injured each year by the wild elephants. Most of the human deaths have occurred in the crop fields while guarding them during the night and on the roads while commuting. The table 4 below shows the number of human deaths and injuries recorded for a period of 8 years between 1997-98 and 2007-08.

Elephant death/ injury: On an average two elephants get killed in this area due to human-elephant conflict every year. The major cause was found to be electrocution (Figure 10). The electrocution of elephants is mainly caused by the illegal power lines drawn by farmers intentionally around their crop fields and elephants coming in contact with low lying high tension electricity distribution lines maintained by the state electricity department. Table 5 shows the elephant deaths in the park during the last 11 years.

Figure 9: A man injured due to elephant attack

Figure 10: Elephant death due to electrocution in retaliation to crop raids

Table 4: Summary of human death/injury reported during 1997-98 to 2007-08

Sl. No.	Year	Number of people killed	Number of people injured	Compensation paid (INR)
1	1997-1998	Nil	Nil	Nil
2	1998-1999	3	1	1,35,000.00
3	1999-2000	3	1	2,10,000.00
4	2000-2001	2	2	1,45,000.00
5	2001-2002	2	1	88,000.00
6	2002-2003	-	-	-
7	2003-2004	-	-	-
8	2004-2005	-	-	-
9	2005-2006	3	6	3,60,500.00
10	2006-2007	1	4	1,57,606.00
11	2007-2008	2	1	3,20,000.00

‘-‘Data not available; Source: BNP Management Plan (2002-2004 & 2008-09 to 2012-13)

Causes of Human-elephant Conflict in BNP

The ever increasing human activities around forest areas, shrinking habitat due to encroachments, fragmentation by roads and degradation of habitat due to biotic pressures such as fire wood collection (Figure 11), cattle grazing and poaching of trees may be some of the important causes for HEC across elephant landscapes and Bannerghatta National Park may not be an exception to this. In addition to the reasons mentioned above the following specific reasons are also believed to be influencing the conflict:

- Cultivation of crops around elephant habitat even during the dry season using stored rain water and or ground water.
- Biotic pressures on the habitat due to increasing number of human settlements close to the forest boundary.
- Change in land use around the park for the construction of townships, increasing the chances of encounters with wild elephants.
- Rampant stone quarrying and illegal sand mining around the park and occasionally inside the park.

Table 5: Summary of Elephant death/injury reported during 1997-98 to 2007-08

Sl. No.	Year	Total number of elephant deaths	Number of deaths due to poaching	Number of deaths due to electrocution	Number of elephant deaths due to other reasons
1	1997-1998	1	Nil	1	0
2	1998-1999	2	Nil	1	1 (Intoxication)
3	1999-2000	4	1	2	1(Fall from steep slope)
4	2000-2001	3	Nil	3	0
5	2001-2002	1	Nil	0	1 (Natural death)
6	2002-2003	Nil	Nil	0	0
7	2003-2004	3	Nil	2	1 (Tympony)
8	2004-2005	3	Nil	1	2 (1 Impaction + 1 Natural death)
9	2005-2006	4	Nil	1	3 (1 Natural + 1 Gunshot + 1 Accident)
10	2006-2007	1	Nil	0	1 (Premature birth)
11	2007-2008	1	Nil	0	1 (Liver failure)

Source: BNP Management Plan (2002-2004 & 2008-09 to 2012-13)

The sand mining involving high pressure washing filter mechanisms requires enormous amount of water which is met by exploiting the ground water around the national park. This may have also been depleting the surface water inside the park at a faster rate, driving elephants to human habitations in search of water and food. The well established traditional rain water storage structures in this landscape also suggest that the scarcity of water is highly prevalent in this area (Figure 12).

Figure 11: Fire wood collection by the local community in the park

Figure 12: A traditional water harvest structure in the study area

A few settlements located close to the Park are known to brew illegal country liquor which may also be an attraction for the elephants to trespass into human settlements. In north-west corner of the park, there is a distillery with 1000 acres of eucalyptus and scrub jungle along with a large water tank. Both village and industrial brewing units of alcohol with large private forest may be attracting and providing refuge to elephants during the day and thus enabling them to raid the crops at night (AERCC 1998).

Influence of Human-Elephant Conflict on elephant conservation in the park

Elephant population density and migration of elephants into the park suggests that the park is one of the high elephant density landscapes. The relatively smaller size of this park, its fragmented and degraded nature, coupled with a high density (during some seasons of a year) of elephant population is jeopardizing the life of the local community through the ever increasing human-elephant conflict.

Our personal observations indicate the presence of a high number of calves in the park coinciding with the arrival of the migratory elephants. However, except for the regular census numbers no reliable figures are available for the elephants in this landscape. The season of arrival of the migratory elephants also coincides with the peak cropping season in the landscape, thereby making the crops highly vulnerable to raids. All these factors may have been responsible and continue to result in the increasing number of encounters between the local community and wild elephants, leading to considerable economic loss and death of people and elephants.


Figure 13: A herd with the growing calves in the park

The elephant population density values further suggest that the park is one of the high priority landscapes for conserving the species. The number of calves in the migratory population suggests a possible breeding synchrony with this landscape (Figure 13; Gopalakrishna pers. obs.). No reliable information is available on the status of elephants and the quality of habitat in this landscape. The elephant movements and their demography are not understood.

The conflict issue if aspired to be resolved needs to be well understood in order to equip the local community and the park managers to avoid and mitigate the conflict. This in turn is eventually expected to increase the tolerance of locals to the elephants, thereby aiding the conservation of the species.

It is important to mention that this park though politically a small one, is geographically connected to the India’s last remaining large tropical thorn forest and is a high elephant density region. Survival of the elephant depends on the protection and preservation of this last remaining scrub forest. A detailed study on the elephant density, seasonal movement, habitat types, habitat usage pattern, status and usage of elephant corridors and status of water sources in relation to the cropping season and non-cropping season may link to conflict status, mitigation measures and the survival of Asian elephant in this landscape. Study of elephant density and habitat utilization will help in understanding conflict. While estimating the elephant density, the challenges in estimation will have to be reviewed and evaluated.

Information on the habitat types, fragmentation, degradation, biotic pressures and land use around the park would add knowledge on the quality of habitat. The attitude and perception of local communities towards elephants and the Human-elephant conflict is a neglected field. Its value in understanding and mitigating Human-elephant conflict is not explored in many of the landscapes where the conflict is severe. Information on the status and pattern of cropping, elephant crop depredation patterns, structural damages, loss of economy, human deaths/injury, elephant deaths/ injury, crop guarding mechanisms, efficacy of elephant proof barriers followed by the government agencies and local people's attitude towards the elephants will offer further insights to the understanding of the human-elephant conflict issues in the park. All this information may eventually assist in making recommendations that are practical, effective and economically feasible for the mitigation of human-elephant conflict.

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Appendix I:

Additional figures showing status of landscape, elephants and human-elephant conflict

a

b

c

d

e

f

a: Terrain and the forest cover, b: Asian elephant in the park observed during synchronized elephant census, c: Land under preparation for cultivation, d: Ragi (major crop cultivated in the landscape), e: Ragi crop damaged by elephants, f: Elephant killed by electrocution in the landscape (Source: Deccan Herald)

Section 2
The Landscape

Introduction

Bannerghatta National Park (BNP) is located in the Eastern Ghats forest ecosystem. The terrain of the park is highly undulating in nature with pronounced mountains and valleys and it is roughly linear and highly irregular in shape. BNP has predominately tropical thorn scrub vegetation followed by dry deciduous vegetation (Suresh & Bhat 2000) and patches of moist deciduous vegetation types. The park's landscape is surrounded by a high density of human settlements including five settlements and agricultural lands situated within the park (Singh 2008). Agriculture is the major activity carried out by the local community in this landscape which is changing gradually due to urbanization, especially in the northern and eastern parts of the park.

Further, many developmental projects are coming up around the park such as construction, road widening, repair and maintenance of roads passing through the park (Singh 2008). All these factors are likely to have an influence on the type and magnitude of various landscape elements in the area. The study of forest cover, type, its spread and other aspects associated within, play a critical role in long term conservation of a large mammal such as the Asian elephant. Habitat utilization also depends on the composition of food species and shade species in a forest like BNP. Thus, understanding of the species composition, diversity, richness, abundance, size distributions, canopy cover and ground cover are crucial in developing a management policy related to conservation of species like elephants.

Invasion of exotic species is among the most important global scale problems experienced by natural ecosystems and Bannerghatta National Park is not an exception to it. Today, invasion of alien species is second only to habitat loss as a cause of species endangerment and extinction (Lowe *et al*. 2000; Schei 1996). Forest and shrub lands are often invaded by the short invasive species (Wiser *et al.* 1998).

Growing human population and improved trans-continental transport have increased the degree of movement of non-indigenous organisms and the current enhanced rate of invasion constitutes one of the most important effects that humans have had on the earth (Sharma *et al.* 2005). However, in many situations, focus on understanding the status of landscape elements, vegetation and invasive species has been given no priority. Hence this study is undertaken with the following objectives.

Objectives

To study the different type of landscape elements, especially, forested and non-forested regions, their extent and spatial distribution in the landscape. This may give an opportunity to generate a classified map of landscape elements along with contours.

To establish baseline information on vegetation, more specifically, to study the tree species composition, abundance, spatial dispersion, species diversity patterns, size class distribution, species similarity and richness, and also to study the canopy and ground cover of the park.

To assess the distribution and extent of invasive weed species Lantana (*Lantana camara)* and Chromolaena (*Chromolaena odorata*) to develop a GIS map on the distribution of these two invasive species in the park.

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*With inputs from H.S.Suresh, Centre for Ecological Science, Indian Institute of Science, Bangalore

The above objectives were framed based on the following concept
Understanding the status of landscape, land use and human community's influence on both is important for the management of land and also to develop specific land use policies. The presence and distribution of different landscape elements may reflect the overall land use practices, such practices are known to influence the conservation of species like elephants. It has been known that the elephant's spatial and temporal ecological requirements are to be met from different forest and water based landscape elements, and if the presence of these elements is rare or highly fragmented, elephants may be exposed to agricultural resources, and which may lead to a conflict with the human community. Although an account of vegetation is available in the records of forest department, the scientific study of vegetation is lacking. The quality of the habitat available to the elephants mainly depend on the species composition, assemblage, abundance, diversity, spatial dispersion, size class distribution, species similarity and species richness. However, constant anthropogenic pressures have reduced this forest formation to drier formation with plants having tiny leaves and spines as an adaptation to xeric conditions resulting in thorny scrub vegetation. Many species such as Acacia, Ziziphus and Pheonix (Date palm) characterizes the landscape (Suresh & Bhat 2000).

The park, though measuring about 103 km^2 in area, some percentage of the area is unavailable to elephants due to factors discussed elsewhere (Venkatraman *et al.* 2002). Under this situation the invasion of alien species would further shrink the effective area available for the elephants. In addition, the invasive species such as *Lanatana camara* and *Chromolaena odorata* are known to contribute to the modification of the ecosystem by adversely affecting the hydrological patterns, nutrient cycles and energy budgets which eventually affects the abundance and survival of native species (Mack *et al.* 2000). Reduction in the abundance of native species is expected to create a shortage of food, water and shade in the habitat and there by drives the elephants to stray into the adjoining human habitations leading to conflict. With this back ground, a more pragmatic conflict mitigation and management plan should include an element of status of invasive species (in terms of distribution, extent and their implications on the ecosystem) in the park. In the present study an attempt was made to understand the status of two of 100 of the world'worst invasive species in the park, viz., Lantana and Chromolaena (IUCN, 2000).

Methodology & Data processing

Landscape elements: their extent and spatial distribution

Project coverage area map

The project coverage area map was created for the Bannerghatta National Park using Survey of India (SoI) topographic map No. 57 H/9 and No. 57 H/10 (Scale - 1: 50,000) sourced from the forest department.

Ground truth

The study on the landscape elements of the Bannerghatta National Park was carried out over four years from Jun 2004 to Mar 2008 during the project period. The ground truth work was done using two units of the Global Position System of the model Garmin e-trex 12 channel GPS. The geo-coordinates of the ground truth points were recorded for the vegetation type, terrain, altitude, water bodies and hills whenever the opportunity arose while in the field. Field activities such as trail surveys for elephant habitat usage assessment, line transect walk for elephant dung density estimation as well as vegetation enumeration through quadrant method at every 500 m point on the line transect were effectively made use of to achieve this objective. For vegetation alone, a total of 60 quadrants were established on 12 transect lines representing the entire vegetation of the park. For analysis IRS-P6 LISS-3 image acquired on 19-FEB-04 (path and row: 100-064) was used and False Colour Composite (FCC) was created (Figure 1). For better classification and for understanding the surroundings of the Bannerghatta National park, 7.5km buffer was created along the park boundary. The satellite image was cropped for park along with the buffer area. (The area with extent of study area (Upper Left center X: 77.440120, Upper Left center Y: 12.930000, Lower Right center X: 77.720000, Lower Right center Y: 12.529624)).

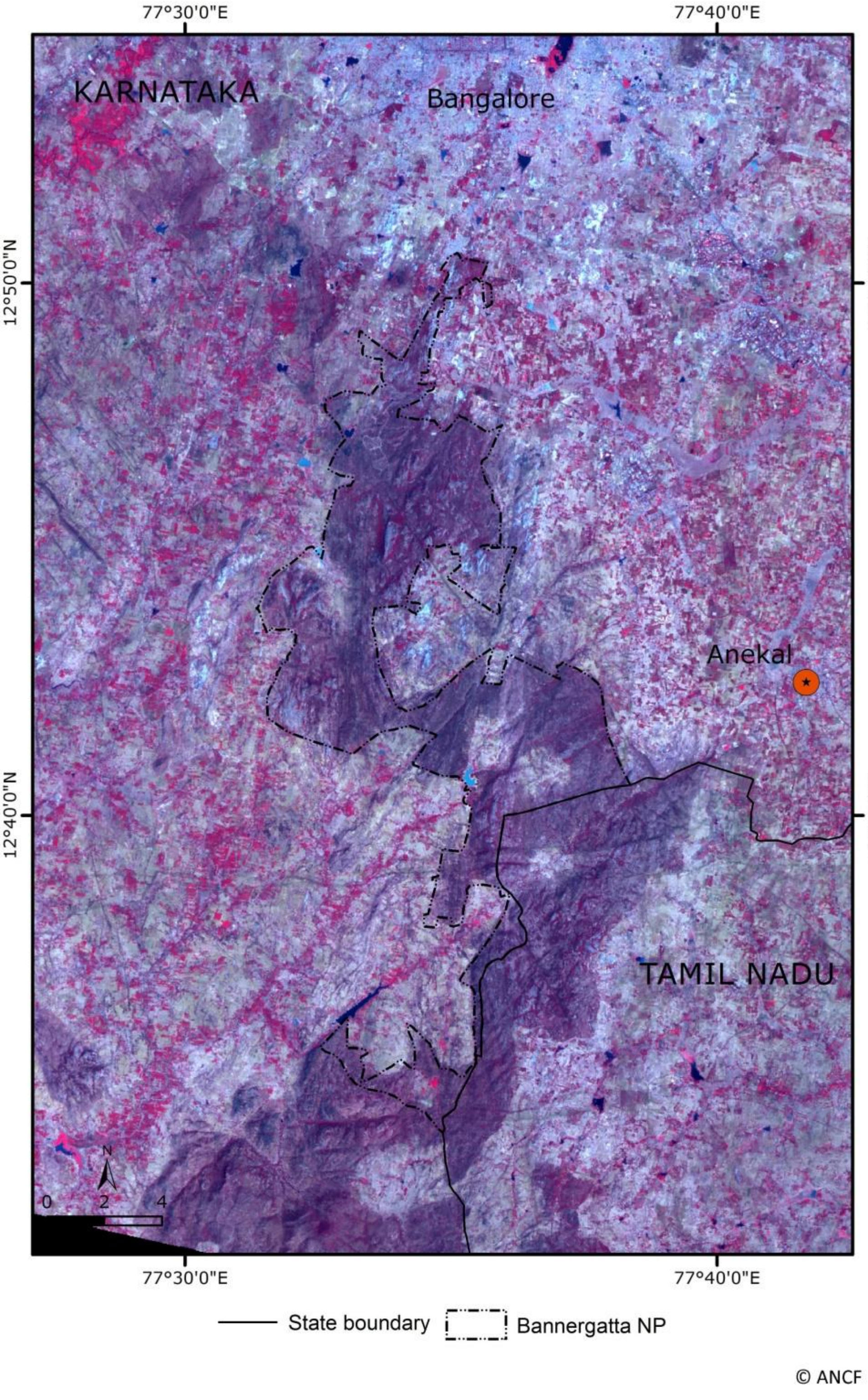

Figure 1: False Color Composite (FCC) of Bannerghatta National Park (Source: ANCF).

Contours
Contours for the landscape were extracted from Shuttle Radar Topography Mission (SRTM) data taken in 2000 from the GLCF website. 3arcsecond, filled finished-A type data of degree tile SRTM-ff03-n012e077 was used.

Accuracy assessment
The classified image was subjected for accuracy assessment. Accuracy assessment is important as it helps in determining the percentage accuracy associated with classified image. This was done using the ground truth points. Theses points are called referencing points that have a corresponding class as observed on the ground. This known reference information is then compared against the corresponding class derived from remotely sensed data.

Referenced data set of 47 points were used as user defined points to access the classification accuracy of landscape elements in Bannerghatta national park and buffer region. When the accuracy assessment function was run in the image processing software, the results obtained were reported in the form of error matrix. Accuracy here is represented in three forms: user's accuracy, producer's accuracy and overall classification accuracy. See Lillesand & Kiefer 2002 and Varma et al. 2008 for definition of three forms.

Landscape classification
Using the ground truth points collected in and around the park, signatures for seven land-use/land-covers (Water bodies, Barren land/ Rocky Outcrop, Built-up, Horticulture, Agriculture, deciduous forest and dry thorn/scrub forest) were developed. Based on the signatures, classification was done using maximum likelihood algorithm using *ERDAS Imagine 8.4.*

Baseline information on tree vegetation
The study was carried out following the line transect method. A total of 12 transects (Figure 2) each one measuring 2 km in length were established, distributed evenly across the park (Figure 3; see Appendix I for additional figures showing status of vegetation, land use elements and invasive species and appendix II & III for the data sheet used for sampling the status of vegetation and weed invasion respectively).

Figure – 2: A line transect established in the study area

At every 500m interval of each transect a quadrant of dimension 10 m x 10 m was laid accounting to a total of 60 quadrants. The data such as geo-coordinates of the quadrant, local name of the individual tree, girth at breast height (GBH), percentage canopy cover and percentage ground cover were collected using a data sheet (see Appendix-II).

The data thus collected on vegetation status was analyzed using computer programs such as Estimate S, Past, Biodiversity pro and Curve expert. Species density, abundance, basal area, similarity, spatial dispersion, species rarity were estimated.

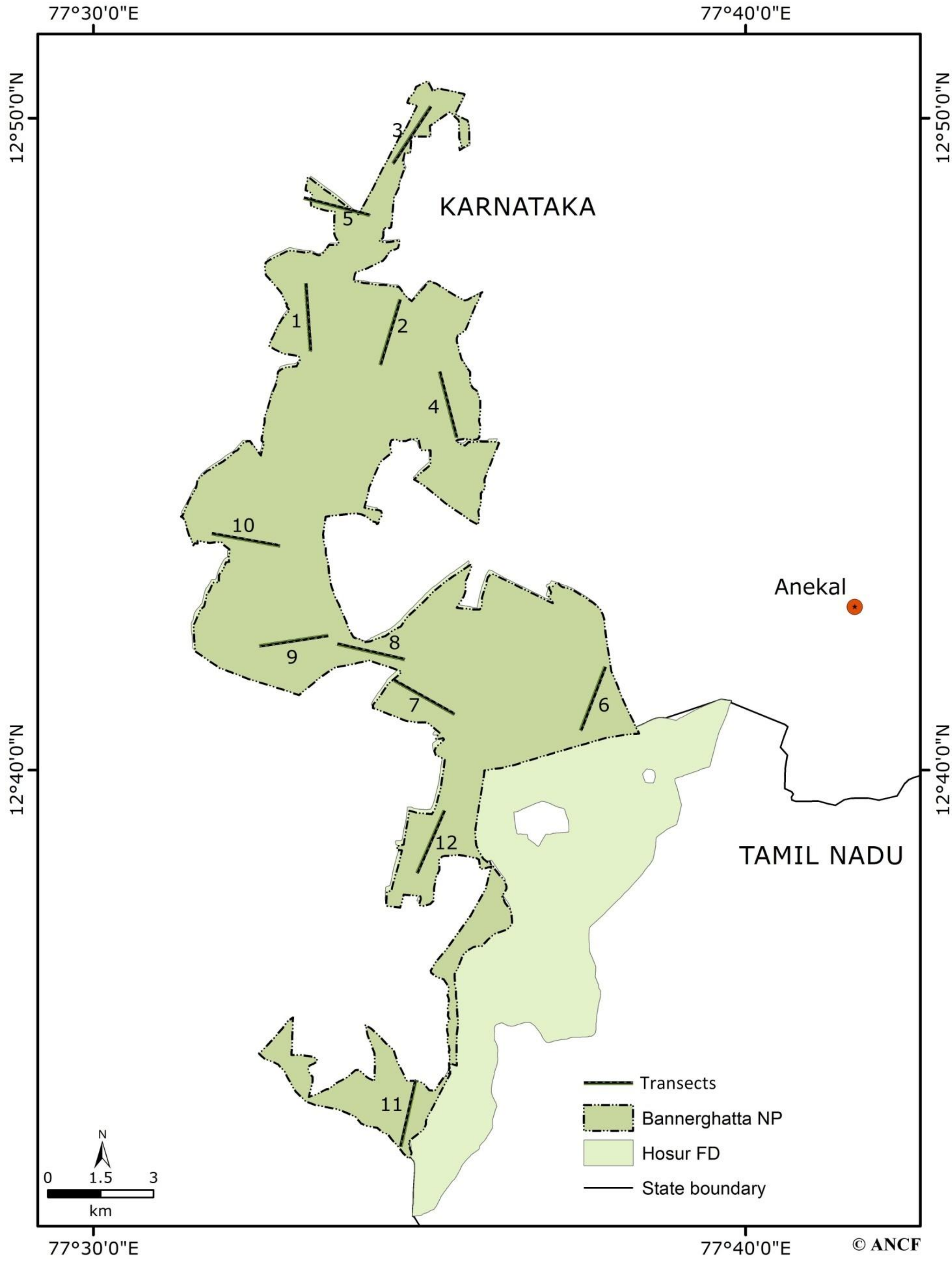

Figure 3: Transect lines used for assessing the baseline information on tree vegetation (Source: ANCF)

The distribution and extent of invasive weed species Lantana (*Lantana camara)* and Chromolaena (*Chromolaena odorata*)

A trail survey sampling method was followed to assess the infestation of invasive species in the park. A total of 20 trails were identified (Figure 4) and each trail was walked by a trained volunteer with the assistance of a tracker. As and when a patch of invasive species was encountered on the trail, the approximate length and breadth of the patch were noted down. The geo coordinates of each patch of the invasive species was also noted down in order to understand the spatial spread of these weeds. A specially designed data collection form was used for the survey (see Appendix-III).

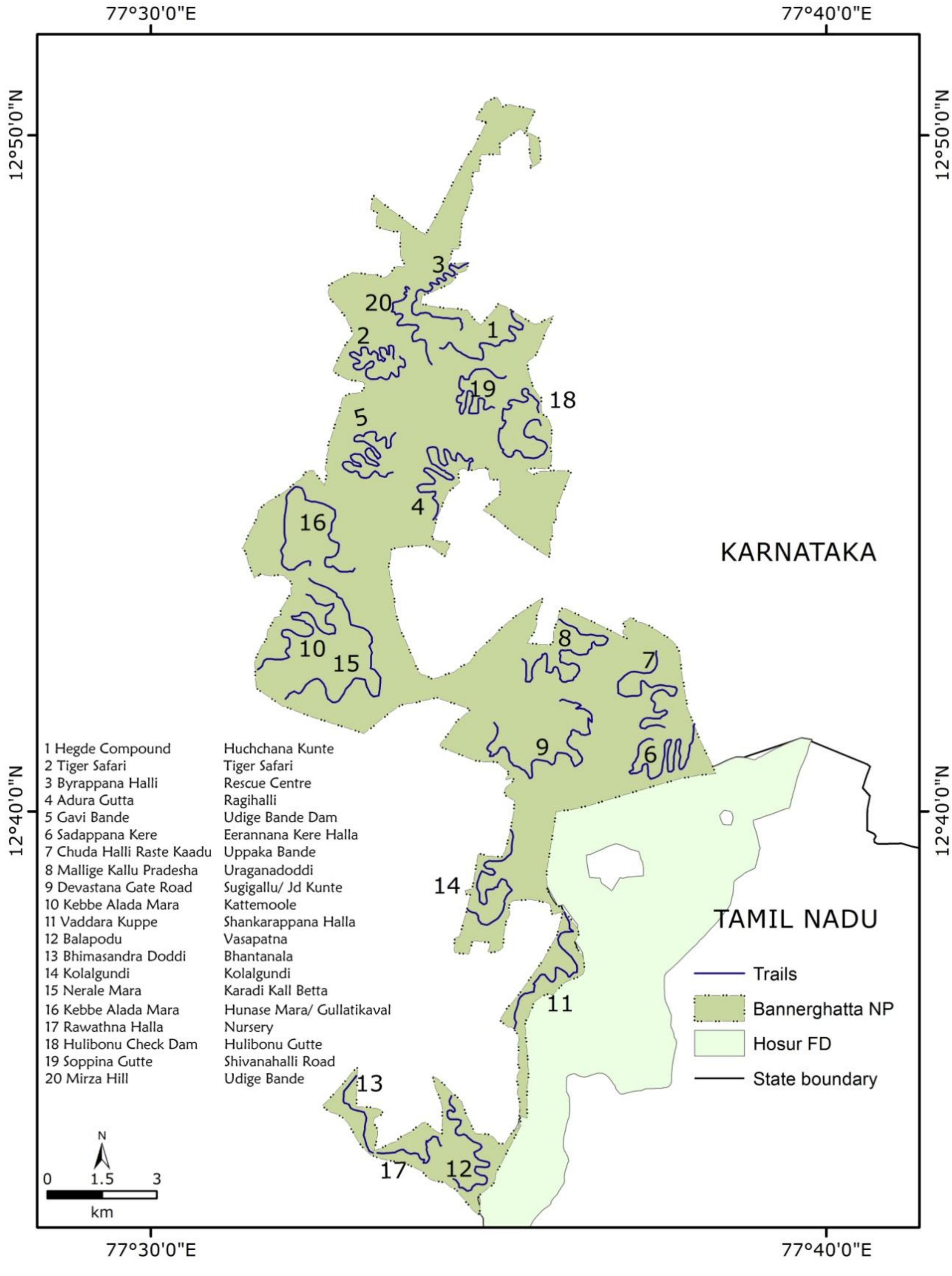

Figure 4: Forest trails used for assessing the status of invasive species in the park (Source: ANCF)

The spatial distribution of the weed species was mapped using the geo-coordinates of 450 points of weed patches encountered during the survey. The range wise total area of the park was collected from the park management plan (Singh 2008). The total area sampled was arrived by multiplying the total length of the trail with the average distance of the weed patches perpendicular to the line of walk. The total area under weed infestation of the sampled area was estimated by multiplying the average length and width of the weed patches surveyed.

These values were further divided by the total area sampled to arrive at the percentage of weed infestation. The values thus obtained were extrapolated to the range wise total area of the park to arrive at the total area of the park under infestation of invasive weed species. Further, the weed patches were categorised into exclusive Lantana patches, exclusive Chromolaena patches and Lantana-Chromolaena mosaic patches and their proportional infestation was arrived at by extrapolating the values of total infestation of the sampled area to total area of the park. ArcGIS.10 was used to creating distribution of different invasive species in the park.

Results and Discussion

Contours

Contour of the landscape range from 720 to 1025 meters and with reference to the occurrence, the contour range of 835 m dominated, followed by 930 m. the least occurring contour range of the landscape were 720m, 930m and the ranges of 1000 to 1015m. The average contour length of the landscape was 28.3 (SE=2.5, N=63), range from 0.12 to 56 km. With reference to the total length of contour, 925 m dominated measuring 55.6 km, followed by 845m (55.3 km). The least were 720 and 1025m (the contributed only 0.12 km). The distribution of both the frequency of occurrence of different contours and their total length is given in the figure 5 and the spatial distribution of the same is given in figure 6.

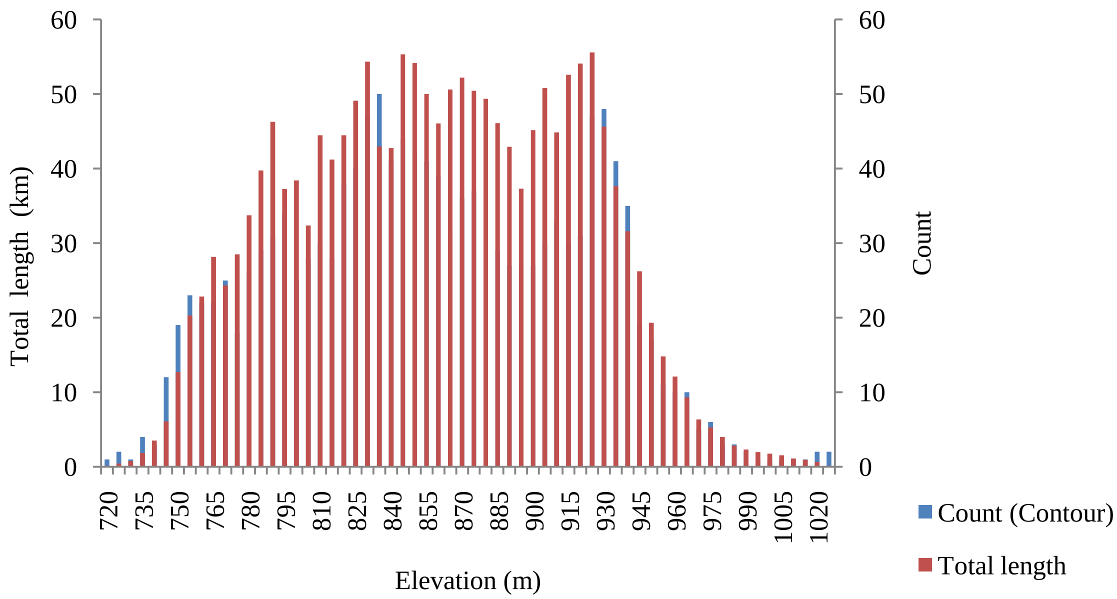

Figure 5: Distribution of both the frequency of occurrence of different contours and their total length

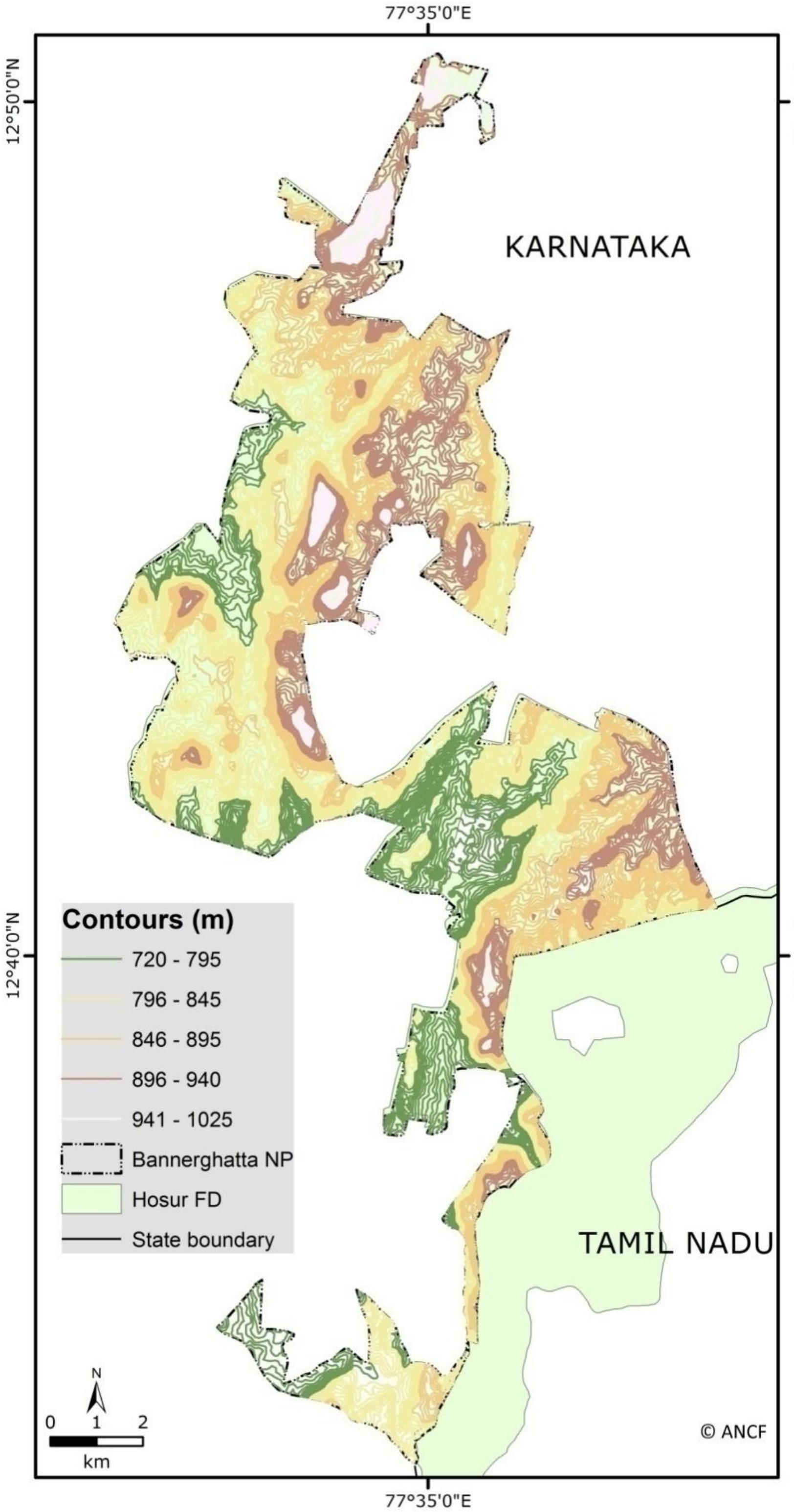

Figure 6: Spatial distribution of different contour range for the Bannerghatta National Park (Source: ANCF)

Accuracy Assessment

The overall accuracy for the classification of the study area has been found to be 72.3% (overall kappa statistics =0.67). The results of the accuracy assessment are presented in table 1.

Table -1: The results of the accuracy assessment

Classified Data	1	2	3	4	5	6	7	Number of points	Users Accuracy
1	4	1	0	0	0	0	0	5	80
2	0	2	0	0	6	0	0	8	25
3	0	0	3	0	0	0	0	3	100
4	0	0	0	3	0	0	0	3	100
5	0	0	0	1	10	0	0	11	90.9
6	0	0	0	5	0	7	0	12	58.3
7	0	0	0	0	0	0	5	5	100
8	4	3	3	9	16	7	5	47	
9	100	66.7	100	33.3	62.5	100	100		

1: Water bodies; 2: Barren land/ Rocky Outcrop; 3: Built-up; 4: Horticulture; 5: Agriculture; 6: Deciduous forest; 7: Scrub forest; 8: Column Total; 9: Producers Accuracy

Landscape

Supervised classification of the subset image shows that study area and its buffer landscape has a mixture of 6 different elements (Table 2 and Figure 7). The landscape within the park, dominated by Scrub/thorn forest (54%-see appendix-I for status of forest in different season) followed by barren land/rocky outcrop (25%) dry deciduous forest (16%).

Agriculture land contributes 5% of the park. If both the park and buffer created around the park is considered, agricultural lands dominated (38%), followed by barren land/rocky outcrop (20%) and horticulture (19%) and the same pattern (domination of agricultural, horticulture and barren land) could be observed if only buffer area around the park (Table 2) is taken into consideration.The results for park along with the buffer or buffer alone dominating agriculture land may have some influence on the status of human elephant conflict here. It is interesting to note that, about 25% of the area of the park (26km^2) is under unsuitable element of barren land/ rocky outcrops. In addition to this total area, the patterns of distribution of different type of landscape elements may influence the actual area available to elephants.

Table 2 Landscape elements and their extent (%) for the study region

Sl. No.	Landscape elements	BNP	Buffer	BNP & Buffer
1	Forest (Scrub/ Thorn forest/	54.0	11.8	17.1
	Dry deciduous forest)	15.5	2.1	3.7
2	Water	0.2	0.2	0.2
3	Agriculture land	4.9	42.5	37.8
4	Horticulture	0.1	21.3	18.7
5	Barren land/ Rocky outcrop	25.0	19.5	20.2
6	Built-up	0.2	2.6	2.3

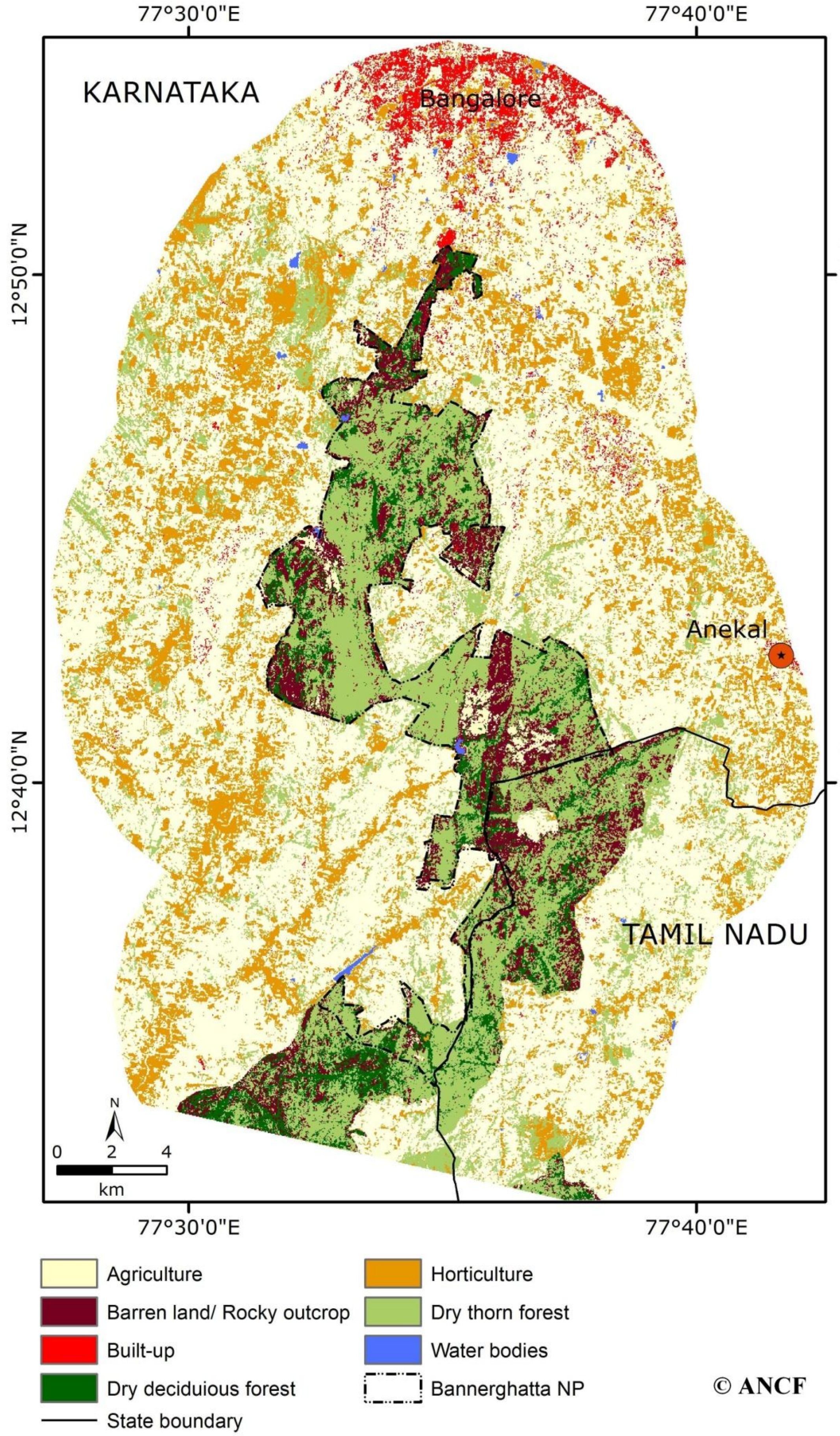

Figure 7: Landscape matrix of Bannerghatta National Park and 7.5 km buffer created around the park (Source: ANCF)

Baseline information on tree vegetation

Although the study on plants (trees) covers only about 0.006% of the total park area, it contains 309 individuals belonging to 37 species.

Species number, abundance and spatial dispersion

The species *Anageissus latifolia* (Dindiga mara-figure 8a) is found to be dominant with 99 individuals followed by *Shorea robusta* (Jalari mara-figure 8b) with 36 individuals and *Acaccia chundra* (Kaggali mara-figure 8c) with 34 individuals of the total floristic assemblage. These three species accounts for 55% of the abundance in the park.

Further, 5 species had more than 10 individuals, 3 species had more than 5 individuals and the rest of the species showed an abundance varying between 1 and 4 individuals in the park (Table 3). Of the total number of 37 species identified 18 species are represented by less than 2 individuals. This suggests that the park could be a region of high species rarity.

Figure 8a: *Anageissus latifolia*

Figure 8b: *Shorea robusta*

Figure 8c: *Acacia chundra*

Among the 37 species, 35% had significant ($p<0.05$) aggregated spatial distribution while, the rest 65% of the species showed random distribution, however the pattern was not statistically significant ($P>0.05$).

Species diversity

The species composition among the 12 different sites studied (Table 4) varied between 4 and 13 species with the mean of 8± 2.91 species per site. The number of individuals ranged from 9 to 65 with the mean value of 26± 16.68 individuals per site of area 500 m^2. The mean value of the species diversity (Shannon-Wiener's index) for the study area was found to be 1.57± 0.52 (range between 0.61 and 2.29, N = 12).

The diversity appears to be same as that of vegetation in Kalrayan Hills of Eastern Ghats (Anand 2005) which ranges between 0.74 and 2.36 (N=30). The tree species identified for the study area were more evenly distributed with a mean evenness value of 0.67 per site and ranged from 0.23 to 0.89 (N=12).

The sampling sites studied showed a high species richness for the park with a mean Fisher's alpha index value of 5.67 and ranges between 1.51 and 14.49 (N=12). Table 4 shows the patterns of tree species diversity for the study area.

Table 3: Summary of the floristic composition

Sl. No.	Scientific Name	Abundance (No. of individuals)	Relative abundance	Cumulative abundance
1	*Anogesus latifolia*	99	32.04	32.04
2	*Shorea roxburghii*	36	11.65	43.69
3	*Acacia chundra*	34	11.00	54.69
4	*Diospyros melanoxylon*	18	5.83	60.52
5	*Vajramusti mara*	16	5.18	65.70
6	*Zyzypus xylopyrus*	14	4.53	70.23
7	*Cassia fistula*	11	3.56	73.79
8	*Santalum album*	10	3.24	77.02
9	*Polyalthia cerasoides*	7	2.27	79.29
10	*Pterocarpus marsupium*	7	2.27	81.55
11	*Diosporase montana*	5	1.62	83.17
12	*Ficus benghalensis*	4	1.29	84.47
13	*Lagerstroemia parviflora*	4	1.29	85.76
14	*Limonia acidicimma*	4	1.29	87.06
15	*Boswellia serrata*	3	0.97	88.03
16	*Chloroxylon swietenia*	3	0.97	89.00
17	*Dalbergia paniculata*	3	0.97	89.97
18	*Holarrhena antidysenterica*	3	0.97	90.94
19	*Terminalia crenulata*	3	0.97	91.91
20	*Albizia amara*	2	0.65	92.56
21	*Wrightia tinctoria*	2	0.65	93.21
22	*Cassine glauca*	2	0.65	93.85
23	*Eucalyptus globulus*	2	0.65	94.50
24	*Grewia orbiculata*	2	0.65	95.15
25	*Mangifera indica*	2	0.65	95.79
26	*Pongemia pinnata*	2	0.65	96.44
27	*Butea monosperma*	1	0.32	96.76
28	*Gilke Mara**	1	0.32	97.09
29	*Goddu alipe mara**	1	0.32	97.41
30	*Kaadu Arali mara**	1	0.32	97.74
31	*Kallu goni mara**	1	0.32	98.06
32	*Kiru uluve mara**	1	0.32	98.38
33	*Melia dubia*	1	0.32	98.71
34	*Premna tomentosa*	1	0.32	99.03
35	*Syzygium cumini*	1	0.32	99.35
36	*Terminalia bellerica*	1	0.32	99.68
37	*Terminalia chebula*	1	0.32	100.00
	Grand Total	**309**	**100.00**	

*vernacular names

Table 4: Diversity patterns observed for sampled area of the park

Site No.	Taxa	Individuals	Dominance	Shannon	Simpson	Evenness	Equitability
1	8	19	0.16	1.93	0.84	0.86	0.93
2	8	40	0.40	1.34	0.60	0.48	0.64
3	5	40	0.73	0.61	0.27	0.37	0.38
4	13	36	0.21	2.01	0.79	0.57	0.78
5	7	9	0.19	1.83	0.81	0.89	0.94
6	6	14	0.32	1.43	0.68	0.70	0.80
7	4	8	0.34	1.21	0.66	0.84	0.88
8	12	26	0.12	2.29	0.88	0.82	0.92
9	11	65	0.65	0.93	0.35	0.23	0.39
10	10	18	0.14	2.14	0.86	0.85	0.93
11	8	20	0.20	1.82	0.81	0.77	0.88
12	5	14	0.38	1.25	0.62	0.70	0.78

Species Accumulation

The predicted species area curve obtained shows a steady increase in species accumulation with every 500 m^2 of area surveyed. The study shows no uniform pattern of accumulation. The species area curve (Figure 9) suggests that there is scope for more sampling as the species curve has not reached asymptote.

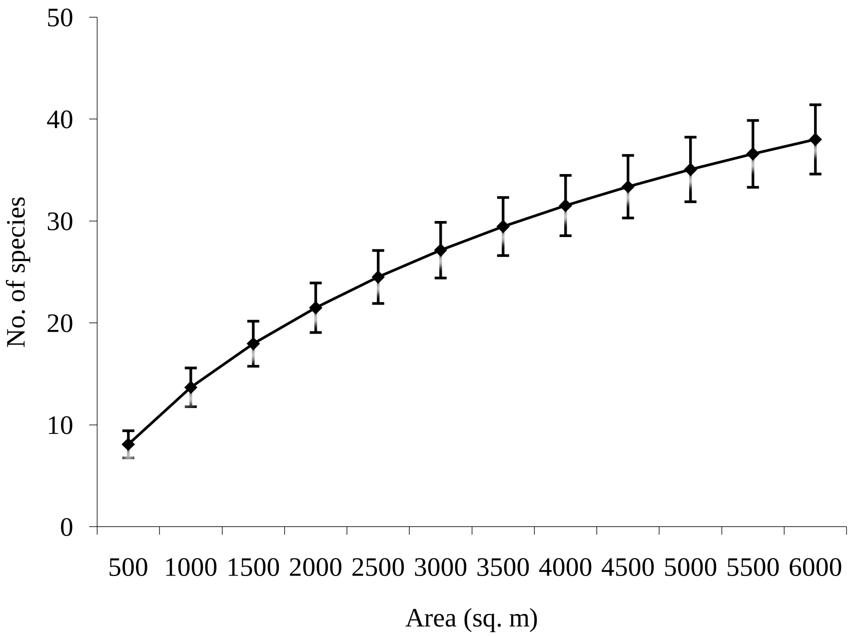

Figure 9: Species area curve: the number of species occurred were plotted against the area covered

Species similarity

The results of the species similarity suggests that the sites 9 and 2 share maximum number (53%) of species (*Acacia chundra, Albizia amara, Anogesus latifolia, Wrightia tinctoria, Boswellia serrata, Butea monosperma, Diospyros melanoxylon, Pterocarpus marsupium*) between them and are very similar (Table 5, the results of sites 2 and 9 are highlighted). The sites 4 & 7, 5 & 7 and 3 & 11 are very dissimilar (0%) with no species found to be shared between them (Table 5).

Table 5: Shows the percentage similarity of species between the sites

	1*	2	3	4	5	6	7	8	9	10	11	12
1*	*	27.1	10.2	21.8	35.7	6.1	22.2	40.0	16.7	37.8	30.8	24.2
2	*	*	7.5	34.2	12.2	195	12.5	30.3	**53.3**°	24.1	26.7	11.1
3	*	*	*	7.9	20.4	7.4	4.2	12.1	3.9	3.5	**0.0**	3.7
4	*	*	*	*	17.8	16..0	**0.0**	29.0	19.8	29.6	21.4	4.0
5	*	*	*	*	*	8.7	**0.0**	28.6	5.4	14.8	6.9	17.4
6	*	*	*	*	*	*	18.2	10.0	2.5	18.8	11.8	7.1
7	*	*	*	*	*	*	*	35.4	11.0	23.1	28.6	36.4
8	*	*	*	*	*	*	*	*	24.2	40.9	43.5	40.0
9	*	*	*	*	*	*	*	*	*	19.3	30.6	15.2
10	*	*	*	*	*	*	*	*	*	*	42.1	31.3
11	*	*	*	*	*	*	*	*	*	*	*	35.3
12	*	*	*	*	*	*	*	*	*	*	*	*

1 to 12* Sites

Size class distribution

Majority (50%) of the individuals of the tree species enumerated in an area of 0.6 ha were in the size class ranging from 5-10 cm in diameter at breast height (DBH) followed by 1-5 cm (26%) and 10-15 cm (16%). Only 5% of the total individuals of the species were in the size class of 15-20cm DBH (Figure 10). The juvenile tree species (0-10 cm DBH) constitutes about 76% of the total tree species enumerated. This suggests that the tree population is stable and the forest is growing. The mean basal area was found to be $1.98m^2$ and on extrapolation to a hectare scale basal area was found to be $3.28\ m^2$. This pattern may suggest that the park is sparsely vegetated with the tree species.

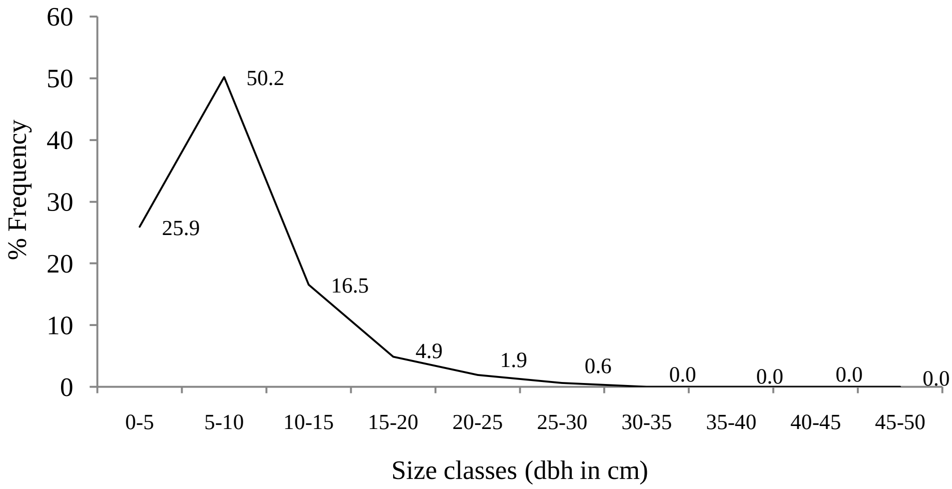

Figure 10: The size class distribution of the tree species is plotted against their frequency of occurrence in percentage

Canopy cover and Ground cover

The forest vegetation has a poor over-story with an average canopy cover of 25.7% (SE=3.50, n=60) and ranges from fully opened canopy to a closed canopy in some quadrants. The results of the under-story suggests that the forest has a good ground cover with a mean value of 62% (SE=4.0, n=60) and varies from no ground cover to a full ground cover in some quadrants.

The distribution and extent of invasive weed species Lantana (*Lantana camara)* and Chromolaena (*Chromolaena odorata*)

Species Profile
Lantana (*Lantana camara* –Figure 11a**)**

Kingdom	: Plantae
Subkingdom	: Tracheobionta
Division	: Magnoliophyta
Class	: Magnoliopsida
Subclass	: Asteridae
Order	: Lamiales
Family	: Verbenaceae
Genus	: Lantana L
Species	: Lantana camara L

Figure 11a: Lantana camara

Lantana camara complex is a native of tropical America and generally occurs in small clumps ≤1 m in diameter (Palmer & Pullen 1995). In its naturalized range, it often forms dense monospecific thickets, 1-4 m high and ≈1-4 m in diameter (Swarbrick *et al.* 1998). It is one of the 100 of the world's worst invasive species (Lowe *et al.* 2000). It is a low erect or subscandent, vigorous shrub with stout re-curved prickles and a strong odour; its root system is very strong and it gives out a new flush of shoots even after repeated cuttings.

Leaf ovate or ovate-oblong, acute or subacute, crenate-serrate, rugose above, scabrid on both sides; Flower is small, usually orange, sometimes varying from white to red in various shades and having a yellow throat, in axillary heads, almost throughout the year; fruit is small, greenish-blue black, blackish, drupaceous, shining, with two nutlets, almost throughout the year, dispersed by birds and other mechanisms. Seeds germinate very easily (Sastri & Kavathekar 1990).

Lantana is presently distributed in more than 60 countries or islands around the world (Parsons & Cuthbertson 2001). It occurs in diverse habitats and on a variety of soil types. The plant generally grows best in open un-shaded situations such as wastelands, forest edges, and forests recovering from fire or logging. Disturbed areas such as beside roads, railway tracks and canals are also favorable for the species (Thaman 1974; Thakur *et al.* 1992; Munir 1996; Day *et al.* 2003). It can grow at altitudes from sea level to 2000m (Matthew 1970 in Day *et al.* 2003).

In India, Lantana was first introduced in the early nineteenth century as an ornamental plant but now it is growing densely throughout (Thakur *et al.* 1992), occurring from the north near Jammu to the south near Trichur, on the west coast near Bangalore and in the central region near Jabalpur (Thakur *et al.* 1992; Day *et al.* 2003).

In disturbed native forests, Lantana can become the dominant under-storey species, disrupting succession and decreasing biodiversity. It is also noted that as the density of Lantana in forest increases, the species richness decreases (Fensham *et al.* 1994; Day *et al.* 2003). It has also been reported that its allelopathic qualities can reduce vigor of native plant species. Intact forests inhibit the growth and spread of Lantana (Day *et al.*

2003). In regions where there are still large areas of native forests, Lantana is currently restricted to small, isolated infestations in abandoned settlement sites (Day *et al*. 2003).

Chromolaena (*Chromolaena odarata*-Figure 11b***)***

Kingdom	: Plantae
Subkingdom	: Tracheobionta
Division	: Magnoliophyta
Class	: Magnoliopsida
Subclass	: Asteridae
Order	: Asterales
Family	: Asteraceae
Genus	: Chromolaena DC
Species	: Chromolaena odorata L


Figure 11b: Chromolaena Odorata

Chromolaena is also one among 100 of the world's worst invasive species (Lowe *et al.* 2000). *Chromolaena odorata* is a fast-growing perennial shrub, native to South America and Central America. It is also known as Siam weed. This forms dense stands and prevents the establishment of other plant species.

It grows to a height of 3 m. In areas near the equator, it grows up to an elevation of 1000 m and thrives well where the average rain fall is about 2000 mm (Muniyappan *et. al.* 2005). It is an aggressive competitor and may have allelopathic effects (Ambika & Jayachandra 1980). In heavy shade, Siam weed will not seed. It has a negative relationship with tree canopy cover and appears to be most abundant on the edge of forested areas (Feleke 2003; Luwum 2002 in Vanderwoude *et al*. 2005).

The earliest introduction of Chromolaena into India seems to have been in the mid nineteenth century and it has since spread to much of its suitable habitat in Asia. It was reported that in north-eastern India, Siam weed is regarded as a nutrient-demanding early successional species (Ramakrishnan 1992 in Vanderwoude *et al*. 2005). It takes advantage of the flush of soil that becomes available after a disturbance, such as fire or land clearing for agriculture, and exhibits relatively high foliar N, P and K contents (Saxena & Ramakrishnan 1983 in Vanderwoude *et al*. 2005).

Distribution of Lantana and Chromolaena in BNP

The result shows that the Lantana and Chromolaena are distributed in the entire park as both individual patches as well as mosaic patches. Presence of these species has been noticed both in fringe as well as interior area of the habitat. Lantana dominates over Chromolaena in terms of area occupied. Chromolaena was found to be colonizing more on the alluvial soils along the patrolling roads, water courses and also around the rock formations.

Extent of Lantana and Chromolaena

The results reveal that about 30% (31.44 sq km) of the total area (104.24 sq. km) of the park is infested by these two (Lantana and Chromolaena) invasive alien species.

Species wise infestation

The analysis of the data according to the species showed that the Lantana - Chromolaena mosaic is occupying about 16% (16.25 km^2) of the total area of the park. About 10% (10.12 km^2) of the total area of the park has been occupied by just Lantana and about 5% (5.03 km^2) of the total area was infested with only Chromolaena (Figure 12).

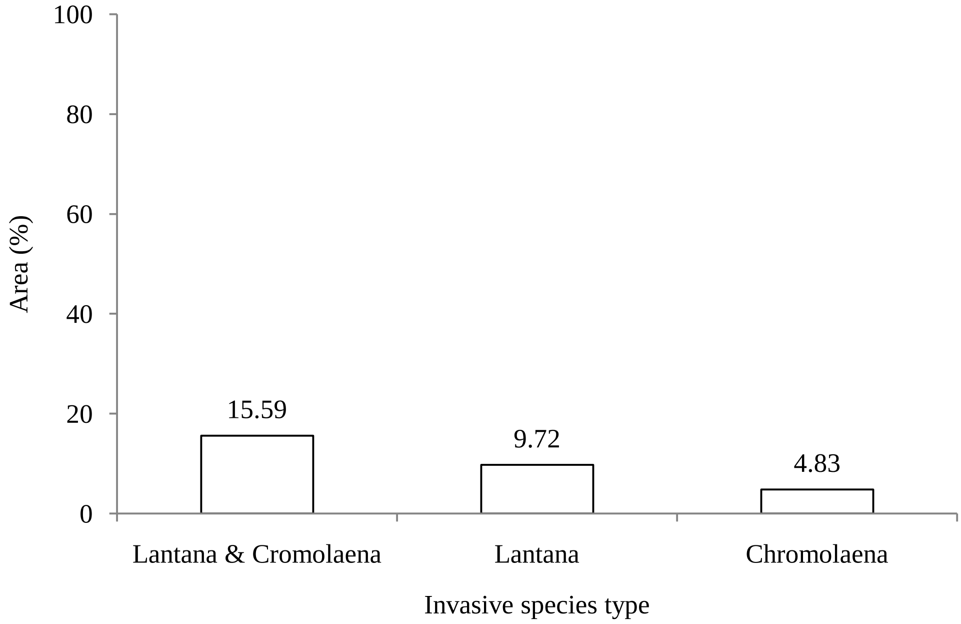

Figure 12: Proportion of types of Lantana and Chromolaena infestation

All the three administrative ranges of the park have shown a substantial amount of invasive species infestation. Anekal range has least (15% of the total area) infestation and Bannerghatta has the maximum (46% of the total area) infestation. In Harohalli, about 22% of the total area has been infested by the invasive species (Table 6, Figures 13 and 14).

Table 6: Shows the range wise extent of invasive weed infestation

Sl. No.	Range	Total Area (km^2)	Total area sampled (km^2)	Total area under invasive species (km^2)	Percentage area under invasive weed species (%)	Total area under invasive weed species (km^2)
1	Anekal	26.6	0.21	0.03	15.2	4.07
2	Bannerghatta	43.6	1.93	0.86	44.2	19.24
3	Harohalli	33.9	0.56	0.12	21.8	7.41
	Total	**104.2**	**2.70**	**1.01**		**30.72**

Bannerghatta range was dominated by the Lantana-Chromolaena mosaic (24%) infestation followed by only Lantana (17%). In Harohalli, the infestation of Lantana-Chromolaena mosaic and just Chromolaena dominated (about 11% and 7%). In Anekal, the Lantana-Chromolaena (8%) was dominating followed by only Lantana (5%) during the study period (Figure 14).

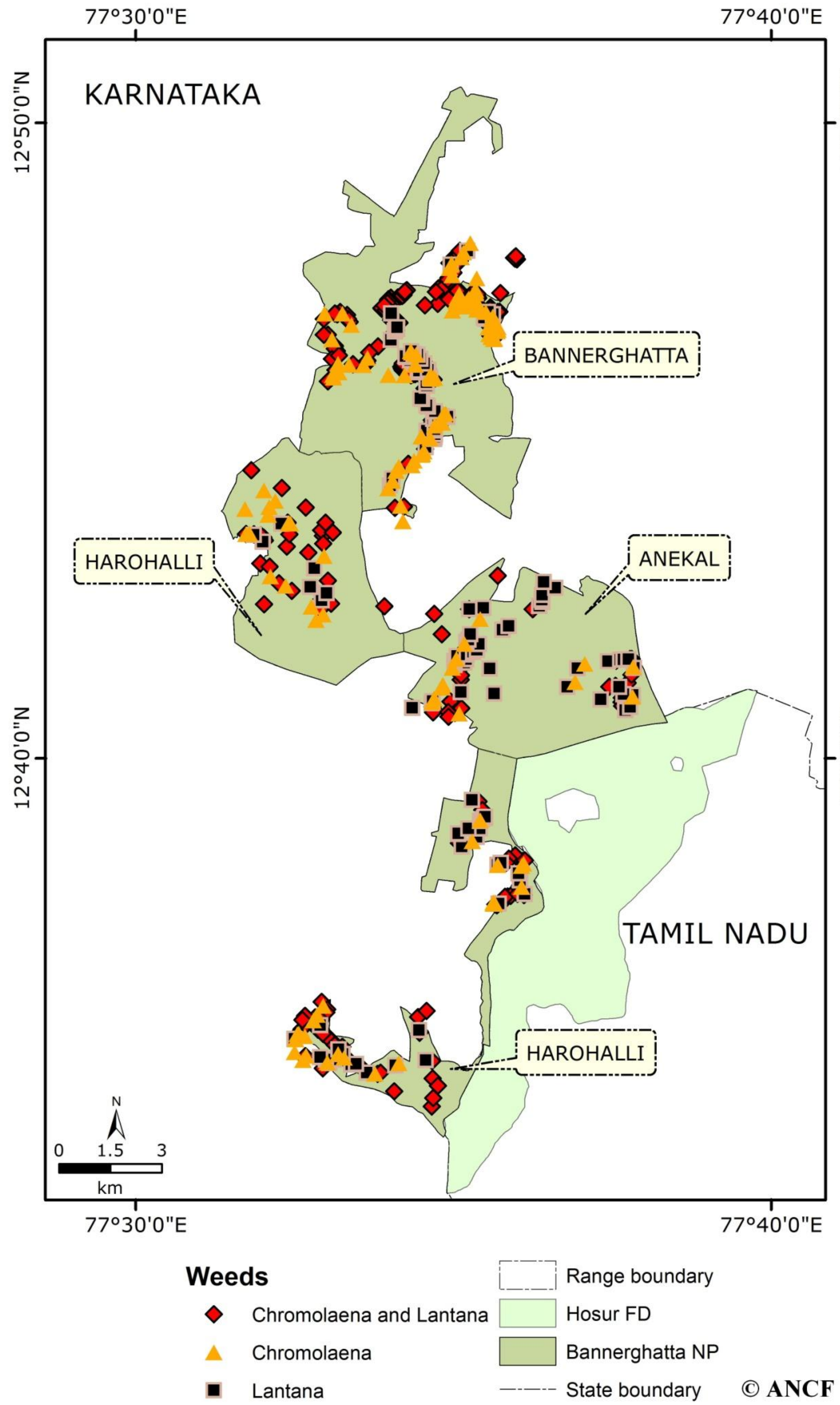

Figure 13: Distribution of invasive species along the survey routes in the Bannerghatta National Park

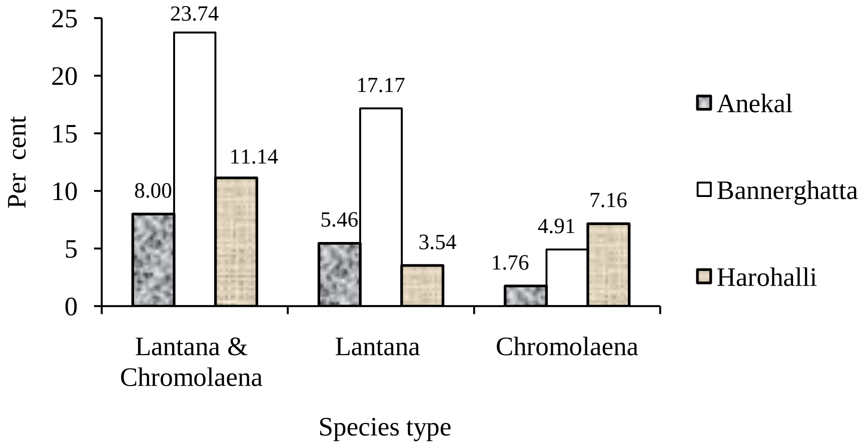

Figure 14: Invasive species wise infestation across the ranges

Conclusion

The results of the pattern of contour shows that the park has relatively small hills and their elevation ranges from 720 to 1025 meters, but their occurrence (with reference to their total length and frequency) is low, and the 835 and 930 m ranges dominated. The investigation of landscape elements for the park and the buffer created around it shows result of forests dominating in the park, but if both the park and buffer are considered together, agricultural and barren lands dominate. The study on the vegetation of the park revealed a considerable variation in the species diversity across the sites. Overall the park has a greater diversity of species. The park also appears to be an area of high species rarity. The species abundance and similarity results reveal that the vegetation in the park is heterogeneous. The species accumulation curve suggests scope for more sampling to get more reliable results. The size class distribution of the vegetation indicates that the park is more stable and growing forest type with more number of juveniles present in it. The canopy cover of the vegetation appears to be in congruence with the ground cover and reveal that the vegetation is of open forest type.

The invasive alien species viz. *Lantana camara* and *Chromolaena odorata* are distributed all across the park. The invasion of these two alien species also indicates the disturbance within the habitat. This may further bring down the quality of the habitat available for the Asian elephants within the park which may also drive them to stray into human habitations in order to meet their basic requirements resulting in the conflict. Human pressures such as cattle grazing, fire wood collection, lopping etc., could be seen as causes of disturbance in the park which is paving way for the invasion of alien species. This specific investigation also gives scope for an in-depth study on various aspects of landscape, vegetation and invasive species in order to better understand the vegetation composition and diversity as well as the degree of disturbance within the habitat which would facilitate the identification of disturbance regimes within the park.

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Appendix-I

Additional figures showing the landscape elements and their status

a

b

c

d

e

f

a: Status of vegetation during the dry season, b: Wet season vegetation, c: Second wet season vegetation, d: Water hole inside the park, e: Assessing the status of invasive species, f: crop land with ragi, one of the major crops cultivated in the landscape

Appendix-II

Assessment of vegetation type and vegetation cover

(Line transect method)

Observer: Date:

P A Name: Bannerghatta National Park
Range name:
Beat name:
Tracker name:
Transect no.:
GPS Reading:
Starting point:
Closing point:
Total length of transect line (km):
No. of quadrat:
Total area of the quadrat (sq. m):

QUADRAT VEGETATION DETAILS:

Quadrat No.	GPS Reading	Sl No	Name of the tree species Local	Scientific	GBH (cm)	Canopy cover (%) closed	Ground cover (%) closed	Remarks
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						

Appendix-III

Assessment of extent of weed infestation and Elephant habitat usage through trail survey in Bannerghatta National Park, Southern India

Observer: Data form Date:

Range:
Beat:
Name of Starting point:
Closing point:
GPS Readings
Starting point:
Closing point:
Time
Starting: Closing:
Distance covered (km):
Details of weed infestation

Weed (Lantana/Eupatorium)signs

Sl. No.	Time interval (15 minutes)	Time (In between the time interval)	GPS Readings	Weed type (Lantana/ Eupatorium)	Length of weed patch (m)	Width of weed patch (m)	Distance of weed patch from the line of walk[1] (m)	Remarks
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

1: Assess the approximate distance to the weed patch from the point of GPS readings taken on the line of walk, in case the weed patch is away from the line of walk.

Section 3
Population Density and Demography

Introduction

A reliable estimate of population status is important for meaningful species and habitat based conservation and management approaches, especially in a protected area that is under intensive management (Sukumar 2003; Arivazhagan 2005; Varma *et al.* 2008). A dearth in systematic approach for scientific, area specific enumeration of elephants may be evident from methods and results presented for the species in many of its habitats. Since 2002 Project Elephant (Govt. of India) has initiated an exclusive South India synchronized elephant census (AERCC 2002; AERCC 2006; Baskaran *et al.* 2007) and although such data provides insights on the number of elephants, its overall quality particularly the data on population density of the species is not validated. The data is collected by volunteers (Baskaran *et al.* 2007) who may not be well trained and may have less experience in this investigation.

The BNP is surrounded by fertile, well irrigated croplands which may become one of the attractions for elephants during the crops' reproductive, harvesting and processing period. There have been records of elephants being killed by electrocution and by other means. Hence, an understanding of the population size is vital in order to mitigate conflict related elephant deaths. However, many factors create challenges, making population density investigation difficult. Line transect (Burnham *et al.* 1980) based indirect count using dung counts is the most commonly used technique for estimating elephant numbers in these forests (Barnes & Jensen 1987; Dawson 1990; Sukumar *et al*. 1991; Varman *et al.* 1995; Varma *et al.* 2008; Varma 2008).

According to Barnes (2001), dung counts for elephants give estimates that are as precise as and some times more precise than, those from aerial surveys of elephants. However, a critical review of viability of methods and data processing protocols are available only for certain methods and elephant habitats (Varman *et al.*1995). The study on ecology and conservation of Asian elephant in mixed deciduous forests of Bannerghatta National Park (Anand & Varma 2006) provide an opportunity to estimate elephant density and also to review the appropriate sampling protocols.

Objectives

To study the methods for estimating elephant densities through line transect indirect count and to identify an appropriate sampling protocol (cut off width) for the region.

To investigate the pattern of elephant dung decay rate, and review the results of sample size used to obtain daily decay rate.

Based on the sampling protocols (of cut off width and sample size of decay rate experiment), determine the population size of elephants in this region.

The objectives evolved through the following concepts

Density estimates based on dung counts usually requires three variables namely dung density, defecation rate and dung decay rate. These are later combined to give the final estimate of elephant numbers. The data on dung density is obtainable by line transect indirect count method, but data on daily dung decay rate and defecation rates are difficult to obtain (Varman *et al*. 1995; Baskaran *et al*. 2007; Varma *et al*. 2008), the result provided on these aspects are based on earlier studies which were carried out in different forest types and many years ago (Varman *et al*. 1995).

Dung decay rates are reported to vary seasonally in forests (White 1995; Barnes *et al*. 1997). However, there is no evidence so far available for seasonal variation in elephant defecation rates in forests (Tchamba 1992). Through the long term study on elephant ecology and conservation in Bannerghatta National Park, an exclusive decay rate study was initiated. This exercise was carried out with unexpected constraints, and resulted in the monitoring of only a restricted number and areas of the park for elephant dung piles. Population estimate available for the park originates from two volunteer based synchronized elephant census program, and no scientific and systematic data on the population is available for the park.

The numbers estimated through the synchronised census operations were also not validated. The current study provides opportunities to process the line transect data using different cut off widths to identify the optimal cut off width for estimating population density and also to validate the mean elephant density results by comparison of the density or population number results obtained earlier. Identifying optimal cut off width has been recommended for estimating large mammal population densities (Varman & Sukumar 1995), as the outliers within small sample sizes are known to create noise in the overall density estimates.

Methodology

The daily dung decay and defecation rates

Man power for this exercise was sourced from the forest department. A team of 24 members (Range Forest Officer, Forester, Forest Guard and Forest Watcher) representing all the 3 administrative ranges was formed. A training program for the team was organized at the Office of the Deputy Conservator of Forest, BNP. The team was trained for dung decay assessment. After the training, the personnel were asked to mark 35 fresh dung piles per range and monitor them till they disappear.

The monitoring cycle was fixed as once in 7 days. A total of 39 dung piles were considered for the study. The status of the dung pile under monitoring was being recorded periodically on a note book. The monitoring of dung piles was being supervised by a researcher who visited each dung pile once in two weeks. The location of dung pile was marked using a GPS.

Line transect indirect count for density estimation

A total of 12 transects were identified using Survey of India topographic sheet (numbers 57H/9 and 57H/10). These transects were evenly distributed representing the entire Park (Figure 1). Transect lines (Barnes & Jensen 1987) were established using a compass and Global Positioning System (GPS) instrument. The compass was used to maintain a straight line. A nylon rope was drawn all along the length of transect line as a reference line while walking.

The field researcher looked for the dung piles by walking along these transect lines. Every time a dung pile was encountered, the perpendicular distance of the dung pile to the rope was measured and documented along with the status of the dung pile (Very Fresh = previous night, Fresh = 1-3 days, Old = 4-7 days and Very old = more than 7 days). The geo-coordinates for each dung pile encountered were also recorded (Figure 2) using a data collection form (see Appendix-I for figures related to the investigation and appendix II for data sheet used to estimate the elephant dung density).

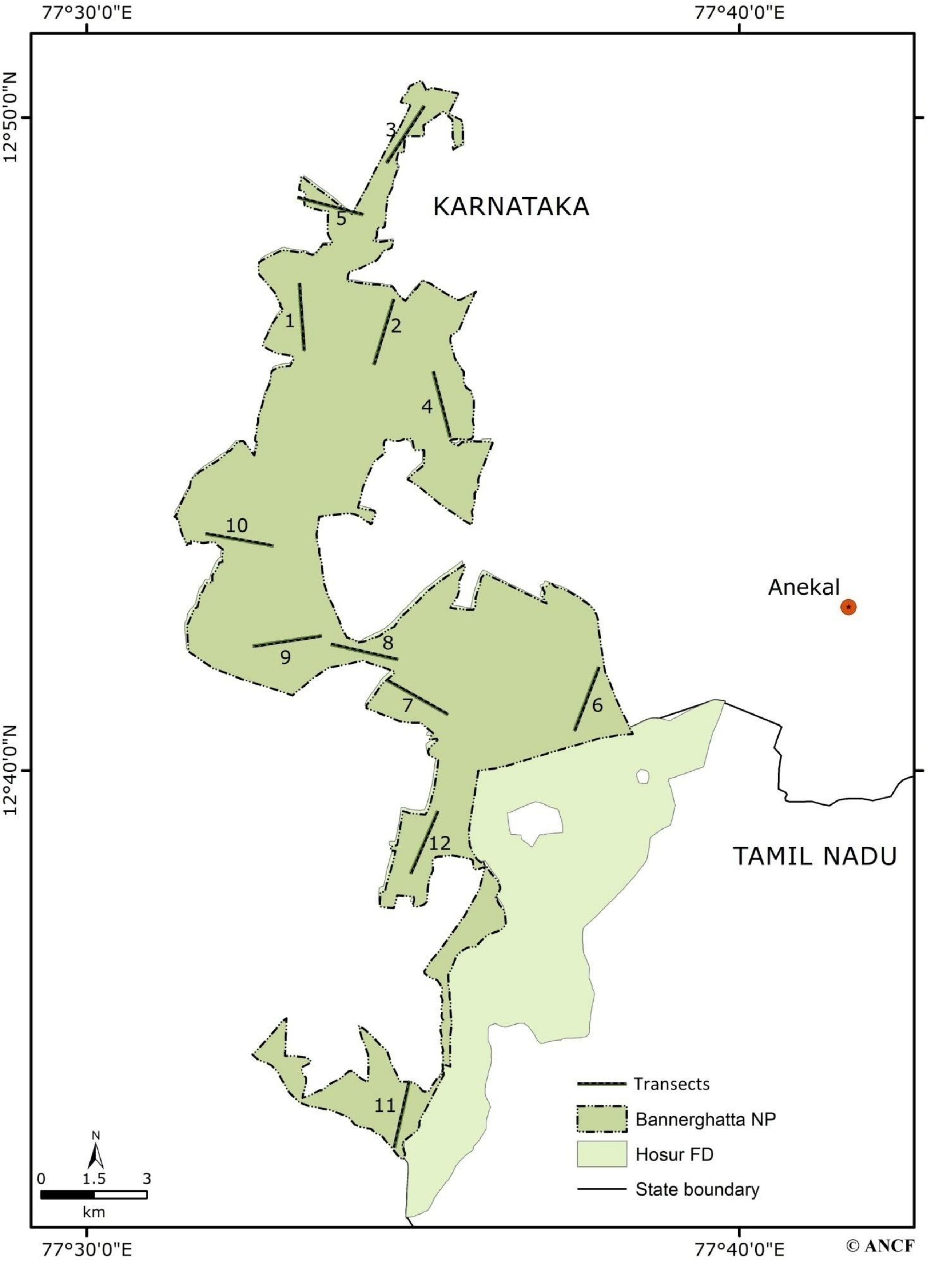

Figure 1: Distribution of transect lines used for estimating elephant dung density
(Source: ANCF)

Data Processing

In the line transect indirect count method, the elephant dung density, dung decay and defecation rates are used to estimate elephant density. The following formula is used to compute elephant density

E= (Y x R)/ D

Where,
E = Elephant density
Y = Density of dung
R = Daily rate of decomposition
D = Number of times an individual defecates per day.

Figure 2: Measuring the perpendicular distance of dung to the line of walk on line transect

Elephant dung density was estimated using the computer programme ***Distance Version 6.0 (***Thomas et al., 2009). The mean dung density, mean daily dung decay rate, mean daily defecation rate and their standard errors (SE) were converted into elephant density through ***Monte Carlo simulations*** using the programme ***GAJAHA Ver. 2.0*** (Santosh & Sukumar, 1995; Archana & Sukumar 2006). The data for daily defecation rate was arrived from Watve (1992) who estimated a mean defecation rate of 16.33 (SE = 0.8) dung piles/day.

Results and Discussion

Pattern of dung decay

A total of 39 dung plies were monitored for two different forest types. The mean dung decay rate/day estimated for the park was 0.0103 (SE 0.001). On an average the dung piles sampled stayed intact for 104 days (SE 3.66). Only 18 % of the dung piles remained for 105 days. Only 3 % of dung piles remained for lower (34 days) and higher (141 days) periods of time. The percentage of dung disappearance for the study period is presented in Figure 3.

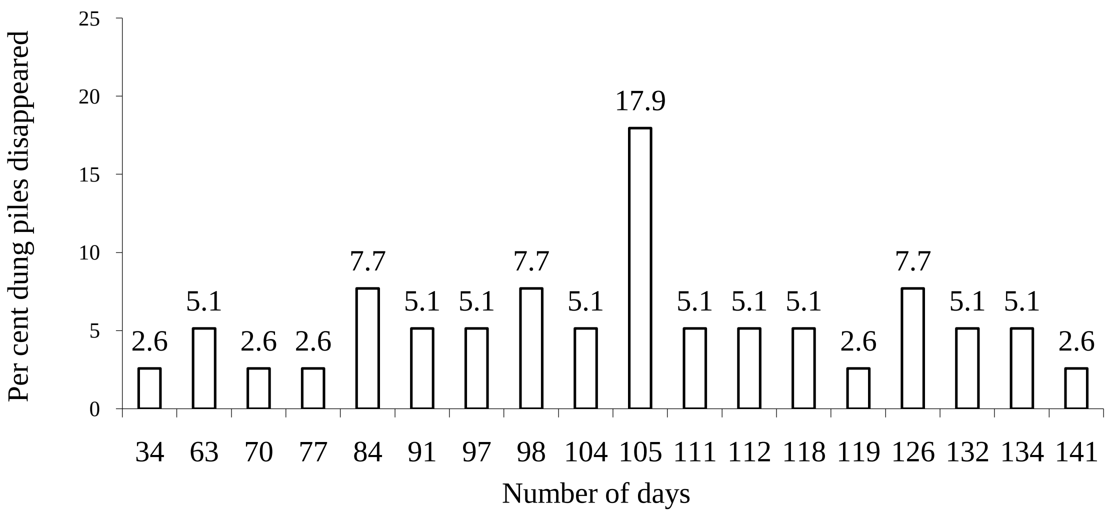

Figure 3: The percentage of dung disappearance for the study period

The patterns of decay rate with the different sample size is presented below. Even with a sample size of 39 dung plies the estimated precision appeared to be high (CV 5%, which droppped from 34%), and this precision level (say less then 10 % of CV) was achieved within a sample size of 20 dung piles (Figure 4).

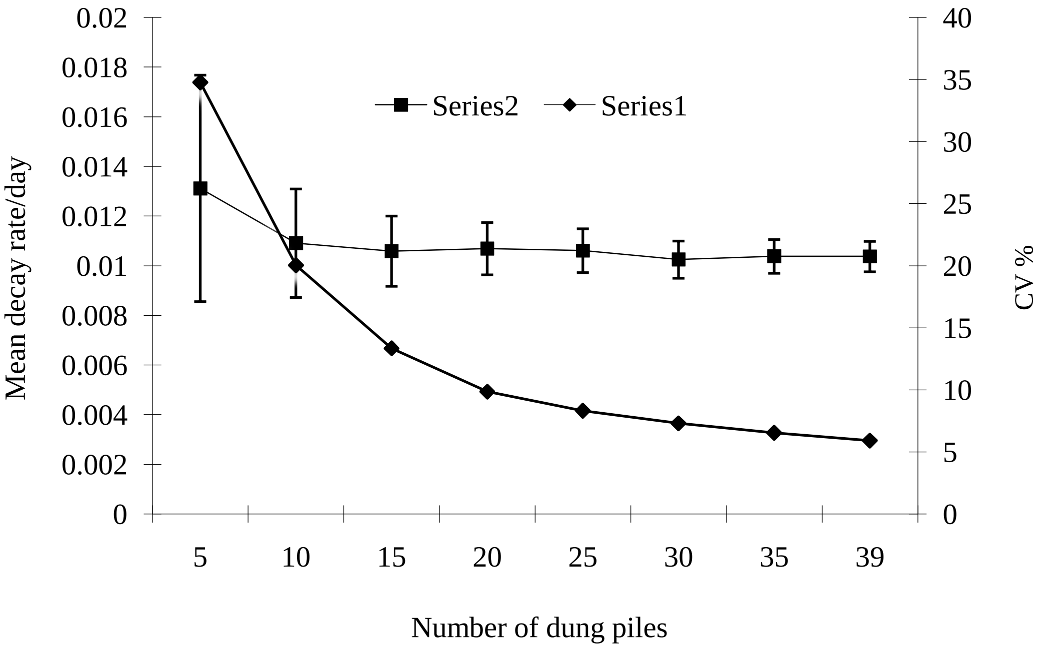

Figure 4: Pattern of decay rate for the dung piles sampled in the study region. Mean decay rate/day and % CV are plotted against number of dung piles sampled

The pattern of daily decay may also be related to many other factors such as seasonality, rainfall, temperature, forest cover or openness and micro habitat types. The presence and absence of decomposers may also play a critical role in this aspect. With large sample sizes, covering the experiments in different seasons may provide more insights on the pattern of daily decay rate of elephant dung piles. However, if the result obtained by sampling 39 dung piles for decay rate experiment in Bannerghata National Park is compared with other decay rate result obtained from mixed deciduous forest region by sampling 100 dung piles (Varman *et al*., 1995), the results are not statisitcally significant ($z = 0.27$, $p> 0.05$).

Elephant density for BNP

While sampling, elephant dung piles (see appendix I for status of dung piles encountered during the investigation) were found from 0 to 13 meters. Elephant density was calculated using different cut off widths (say 4m, 6m, 8m, 10m and > 10) to arrive at an optimal cut off width for estimating elephant density for the park. The results of dung densities for 4m and 6m cut off widths were not different, but the results of dung densities across 4m to 12m cut off and 6m to 12m cut off widths were significantly different (in all cases $p< 0.01$). But mean elephant dung densities for 8m to 12m cut off (i.e 8m & 10m , 8m & >10m and 10m & >10m) widths were not different ($p> 0.05$).

This may suggest that 8 to 12m cut off widths may be ideal for estimating elephant densities. However precision estimated around the mean dung densities and elephant densities for 10m cut off width was high (%CV of this class for dung density was only 10 and the upper and lower elephant density values were lower for 10m cut of width (see table 1; result based on 10m cut off width is highlighted). Going by the precision and the narrow conflidence limits, 10m cut off width may be an appropoiate cut off for estimating elephant density for Bannerghatta National Park.

Table 1: Elephant density estimated through different cut off widths

Sl. No	Cut off (m)	Mean elephant dung density/km^2	SE	% CV	Mean elephant density/km^2	95% CI	
						Lower limit	Upper limit
1	4	2433.4	349.4	14.4	1.5	1.01	2.15
2	6	1978.4	262.4	13.3	1.3	0.86	1.73
3	8	1230	132.2	10.7	0.8	0.55	1.05
4	**10**	**1110**	**113.9**	**10.3**	**0.7**	**0.51**	**0.94**
5	>10	1249	139.7	11.2	0.8	0.55	1.06

With 10m cut off widths, the mean elephant density estimated for the park is 0.713 (95% CI: 0.51 to 0.94) animal/km^2 and the histogram of detection probability (for 10m cut off width) is presented below in Figure 5.

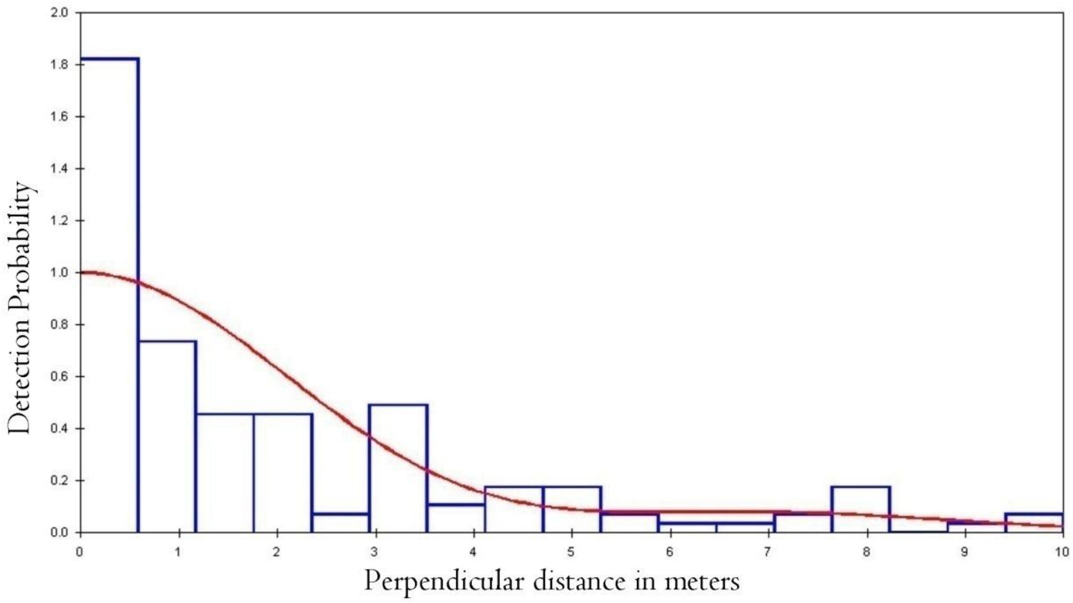

Figure 5: Probability of detecting dung piles across different distance classes. Detection probability of different distance classes were plotted against the perpendicular distance of the dung piles sighted

Table 2: Details of decay, defecation rates, dung density and overall elephant density for Bannerghatta National Park.

Parameter	Mean	Standard Error
Dung density (km^2)	1110.2	113.87
Decay rate	0.0104	0.001
Defecation rate	16.33	0.8
Elephant density (km^2)	**0.701**	**Confident Interval 0.506 to 0.941**

Comparison of elephant density

The results from the three synchornised census data for the park provide very interesting insights; the results arrived for the year 2002 and 2005 match with the present study, as the density estimated for the park in 2002 was 0.68 (SE = 0.48), for 2005 it was 0.71 (SE = 0.21).The present study estimates a density of 0.70 (SE = 0.11) elephants/km^2 and the results were not statistically significant ($p > 0.05$ for 2002 and 2005). The synchornised census carried out in 2007 estimated a density of 1.42 (SE = 0.21) and the density estimated for 2007 (Baskaran *et al*. 2007) was very high (double that of current study).The results are significantly different ($z = 3.04$, $p < 0.01$). Monitoring elephants for population structure and dynamics offered a possibility of estimating a crude density for the park, which was at 1 elephant/km^2 (but this study was limited to only two of the three administrative ranges of the park).

Two parameters determine the reliability of a survey (Norton-Griffiths 1978). The first is accuracy, which describes the closeness of the estimate to the true number of animals. The second is the precision of the estimate, which is a measure of the repeatability of the survey, articulated as the standard error or the 95% confidence limits. It would be always difficult to know the accuracy of the estimate as there are no other references available, but going by the precision of the estimate (using 95 % confidence limits) the current study has narrow confidence limits (mean 0.70, 95 % CI = 0.51 to 0.94) and the 2007 census has wide confidence limits (mean 1.42, 95 % CI = 1.01 to 1.83).

Elephant density for different habitats

There was scope for determing elephant densities across habitats and habitats such as thorn forest and dry deciduous forests were identified. The results suggests that, elephants appeared to be utilizing dry decidous forest more (Table 3).

Table 3: Elephant density estimates for different forest types in Bannerghata National Park

Sl. No	Forest types	Mean elephant dung density/km^2	SE	% CV	Mean elephant density/km^2	95% CI	
						Lower limit	Upper limit
1	Thorn	1000.8	317.7	31.7	0.6	0.21	1.08
2	Dry Deciduous	10576.0	2492.0	23.6	6.7	3.41	10.34

High density in dry deciduous forest could be related to many factors and may primaily be due to the fact that food, water and shade needs may adequately be fullfilled by dry deciduous forests patches of the park. The deciduous forest terrain also appears to be unsuitable for people and cattle, as the number of people and cattle encountered was relatively less in these patches. The dry deciduous patches within the park have undulating terrian, difficult for cattle and people to exploit. The results of the elephant sightings for the population structure monitoring investigation also suggest that 44 % times elephants were sighted in valleys and 33 % times near waterholes and these two features are relatively more in dry deciduous forest.

Conclusion

The investigation of population estimation for the park is the first of its kind, and it has followed a systematic sampling protocol, in relation to the synchornised census operation that may use untrained man power. The current study recommends the use of 10 meter cut off width for estimating elephant density. The decay rate experiment results are also unique to the study area, dominated by mixed deciduous forests. With the sample size of 39 dung piles, the estimated precision was high, however, the pattern of daily decay may also be related to many other factors. A large sample size and the experiment undertaken in different seasons may help provide more insights on the pattern of daily decay rate of elephant dung piles. Except for the year 2007 synchronised census, the elephant densities estimated by the synchornised census operations matched with the curent density estimate. The estimated elephant density for dry deciduous forest is 10 times more than the thorn forests. This may be related to the prevelance of more shade, water and valleys (offer good feeding ground) in the dry deciduous forest patches.

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Appendix I

Additional figures showing events related to the assessment of the population status of Asian elephants in the park

a

b

c

d

e

f

a and b: Briefing volunteers on estimating population count in the park, c: Watchers on dung decay rate monitoring exercise, d and e: Different stages of dung piles encountered during the line transect survey, f: A tusker sighted in the park

Appendix-II

Line transect dung count data sheet for elephant population estimation

Observer: Date

Vegetation type

Forest Division | Transect length (km)

Forest Range | Starting Time

Location (Beat) | Ending Time

S. Point GPS reading | E. Point GPS reading

Sl. No.	Perpendicular distance of dung pile from transect (in m up to 1 decimal)	Remarks
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		

Tally Mark at every 100 m of rope lengths

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	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

Introduction

Assessment of the population structure of Asian elephant forms an integral part of demography studies. Investigations on the demographic parameters such as age structure, sex ratio, fertility and mortality provide insights on the size and viability of a population (Sukumar 1989). Long term studies on the demography of elephants have been carried out at Nagarahole National Park, Mudumalai Wildlife Sanctuary, Periyar Tiger Reserve, Biligiri Ranga Hills Wildlife Sanctuary, Corbett National Park and other elephant habitats in India by personnel trained in this subject (Williams 2001). These studies give scope for population growth modelling and viability analysis which may eventually help in policy making. Project Elephant (Govt. of India), has initiated an exclusive south India synchronized elephant census incorporating population demography details since 2002, keeping in view the importance of collecting this data which may have immense management implications. Data on this aspect is also being collected at the Bannerghatta National Park (BNP) which forms part of Elephant Reserve No. 7 (AERCC 1998) by volunteers who are not well trained in the classification of elephants and therefore this data cannot be validated. Hence there is a need for a systematic, scientific and area specific enumeration (of age-sex classification) of elephants by trained personnel. An investigation of population demography and other related aspects in BNP therefore becomes imperative for scientific enumeration of the elephants. This may aid in planning for the site specific conservation of the species.

Objectives

This study has been conducted for the following objectives:
Determining the population size and structure by direct observation and age-sex based Classification
Individual recognition
Monitoring elephant movement patterns within the National Park

The above objectives were framed within the following concept
Age and sex based classification helps in calculating the various age-sex ratios which aid in determining the structure of the population and when carried out on a long term will help arrive at the viable population for the park. Individual recognition helps in avoiding recounts, to develop a database on the elephants of the park as the resident and migratory populations are unknown. The population size of elephants in a national park during a particular season has a direct impact on human-elephant conflict and also on the vegetation within the National Park. An estimate of the actual population size by direct and indirect count methods will help determine the density of the population. Monitoring the elephant movement pattern may help in understanding the preferred time of elephants' visit to water holes, feeding areas, resting places and movement across open areas. This would provide vital information in classification as the researcher can anticipate the elephant's movement and hence be positioned at these places for efficient classification and photography. Photographs would aid in individual recognition (Arivazhagan 2005).

Methodology

The study was conducted in the Bannerghatta and Harohalli (excluding Bantanala extension) Ranges of BNP covering an area of nearly 60 km^2, with nearly 41% of the population being sampled. The study was conducted between the months of January and April 2008, falling under two seasons namely the winter season (December 2007 to

February 2008) and the summer season (March to May 2008) with a few sporadic showers in late March.

Approach 1: Age and sex based classification of the elephants
On sighting the elephants, their number, age, sex, time of spotting, location, geo-coordinates of the location and duration of monitoring were recorded in a data sheet. Details on elephant hot spots (if any), activities of elephants and other general information were also documented. Photographs were taken to aid individual recognition. The photographs were then digitized and analyzed for classification of elephants into the age classes of calves, juveniles, sub adults and adults. This classification was based on the yardstick used in age based classification followed in other studies (Williams 2001; Arivazhagan 2005). The data was collected using a data sheet (see Appendix-II) with minimal disturbance to the elephants whereby each member of the herd came into view and was classified.

Approach 2: Recognition of individuals
Specific morphological features such as characteristics of tusk, ear, forehead, buccal cavity, peak, tail and other unique markings along with the extent of each feature was used for identifying individual elephants from the photographs. The following characteristics for each of the above features were considered for the study: Tusk (convergent, divergent, parallel, equal, unequal, re-curved, straight and broken), Ear (full, torn, folded, de-pigmented and shape), Forehead and buccal cavity (depression or bulge and any other unique features), Peak (low/medium/high, broken/unbroken and straight/uneven), Tail (ankle, knee or toe length) and other unique features such as lumps and puncture marks. A photographic file with sighting number, place and approximate age was created for each individual.

Approach 3: Determination of the distribution, population size and monitoring of elephants by direct observation
Using wireless radios the research team established a communication network with the BNP staff to obtain first hand information on the movement of elephants inside the national park either on the given day or on the previous day. Information regarding crop raids and audible sounds made by elephants during the previous night were gathered from the farmers residing in the villages. Based on all the above information the range and beat for the days field work was decided. Firstly, the elephant herds were followed until all the members of the herd were classified and a majority of them photographed. But this did not yield the desired results as the dense scrub jungle, undulating terrain and vegetation made clear sighting very difficult. Hence an approach based on the knowledge of elephant movement was used.

In this approach, the researcher positioned himself on a watch tower, tree or other elevated regions overlooking open areas, feeding areas, water bodies and resting zones at specific times in anticipation of the elephants, based on a prior knowledge of the presence or absence of elephants in the locality. Upon discussing with the forest watchers and by field observations of elephants, the elephant movement pattern began to emerge within a week of the commencement of field work.

The elephants preferred timing of visit to water holes, their movement from the feeding area or water hole to the resting places across open areas and the time spent in the resting places were noted. Once elephants were sighted, the location, their number and geo-coordinate of the location were documented. Elephants were also sighted rarely at other places, which are considered as chance events. Field work was carried out on foot or by vehicle from 0600 to 1800 hours. This approach was successful and improved the number of elephant sightings (see appendix I for figures related to different age and sex class of elephants and appendix II for data sheet used).

Materials used

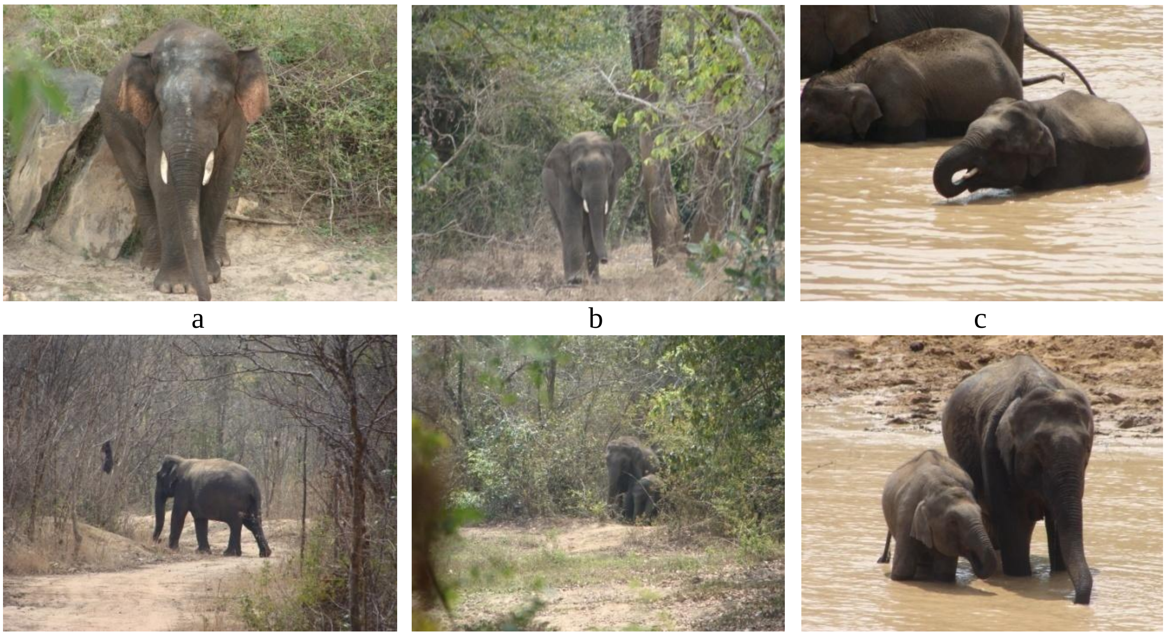
Motorola wireless communication sets were used for gathering information from the forest department on elephant sightings and movements. E-trex Global Positioning Systems were used for recording the geo co-ordinates of the elephant sighting location. A Sony Cyber shot digital still camera (DSC-H3) with 10x optical zoom and 8.1 mega pixels and a Canon S3 *IS* with 12x optical zoom and 6.0 mega pixels were used by two observers independently for photographing the elephants and finally a data sheet (See Appendix II) for documenting the data collected were all an integral part of field kit.

Results and Discussion

Approach 1: Age and sex based classification of elephants

a) Age based classification of the individuals sighted

All the individuals sighted were classified into the 4 age classes namely calf, juvenile, sub adult and adult (Figures 1a, b, c, d, e, f for examples of age and sex classes).



a b c d e f

Figure 1: a: Adult male elephant (Note the de-pigmentation and folding of the ear, thickness of the tusks and the swelling of the temporal gland as the elephant is in 'musth'. All of which may be characteristics of an adult male elephant). b: Sub adult male elephant (Note the slight folds and the de-pigmentation of the ears and size of the tusks). c: Juvenile male elephant (Note the back folding of ear, complete absence of de-pigmentation of the ear, size of the tusk and the forehead of the animal in question being in line with the middle of the adult's belly). d: Adult female elephant (Note the folding of the ear, depression of the temporal region and the buccal cavity). e: Sub adult female elephant with a calf (Note the slight folds and de-pigmentation of the ear and the peak of the calf being just above the belly of the sub adult. The peak of a calf would be under the belly for an adult elephant). f: Juvenile female elephant (Note the back fold and absence of de-pigmentation of the ear. Also the peak of the animal in question is in line with the middle of the adult female's belly)

The results (Figure 2) reveal that adults constitute the major age class (55%) followed by juveniles, sub adults and the least being the calves. Hence the current population may be considered to be an adult dominated one.

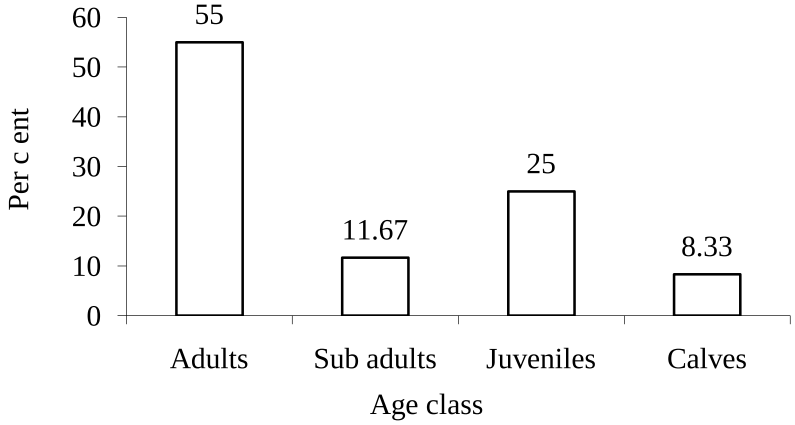


Figure 2: The percentage occurrence of different age class of Asian elephants in BNP. The percentage occurrence of elephants is plotted against the different age classes such as calves, juveniles, sub adults and adults

Adult dominated age structures as observed in the current study (see appendix I for figures related to elephant groups with more adult animals) are reported to be characteristic of several other elephant populations (Arivazhagan 2005): Nagarahole National Park (43.5%) and Mudumalai Wildlife Sanctuary (43.7%). According to Katugaha *et al.* (1999) the adult dominated age structure is not unusual in elephants whose life span, gestation period and calving intervals are all extended. The variation in the sub adult population could be due to the reproductive pattern of the species but further study on this aspect is essential. The proportion of juveniles in the population depends on the inter-calving interval of the species and the number of calves born in a given year (Arivazhagan 2005).

b) Sex based classification of all individuals sighted excluding the calves

Out of the 60 individuals classified, 5 were calves which are unclassifiable under sex classes; hence the sex based classification was limited to the remaining 55 individuals. The results (Figure 3) are expressed as percentage of males and females of each class in the given population.

Figure 3: The percentage occurrence of different sex classes of Asian elephant in BNP.

The results show that adult females constitute 43.6% and are the dominating sex class of the population followed by juvenile females and sub adult females. Sub adult and juvenile males each constitute 7.3% of the population.

Adult males constitute 16.4% of the population. The number of adult males in a population depends on the breeding system of the population i.e. it is less important when a single male mates with many females, and more important when one male mates with one female (Cotgreave & Forseth 2002). Hence this age–sex class forms a vital part of the demography of a population.

c) Age-sex ratios of the four age and two sex classes

The age-sex ratio calculation reveals vital data such as sex ratio of males to females; of adult to sub adult and juvenile to sub adult age classes, inter calving interval and birth rate, all of which are important indicators of stability and growth of a population. Table 1 indicates the adult male to female ratio to be 1:2.7.

Sub adult male to female ratio to be 1:0.8 and juvenile male to female ratio to be 1:2.8; inter calving interval is 4.8 years per calf and the reciprocal of which gives the birth rate and is 0.21 calf/year.

Table1: The various age sex ratios of the individual elephants classified during the study period.

	Adult female	**Sub adult female**	**Juvenile female**	**Adult male**	**Sub adult male**	**Juvenile male**
Sub adult female	3					
Juvenile female	2.18	0.27				
Adult male	2.67	0.33	1.22			
Sub adult male	6	0.75	2.75	2.25		
Juvenile male	6	0.75	2.75	0.81	1	
Calf	4.8	0.6	2.2	1.8	0.8	0.8

The extent of skewness in the sex ratio may be due to sex specific differences in the survival rate of elephants in the higher age classes (Jackmann 1980). In Srilanka where most of the male elephants are makhnas (tuskless bulls) the ratio of adult male to female elephants has been reported to be about 1:3 (Mckay 1973; Kurt 1974), which may therefore be considered as the ‘natural’ sex ratio in the Asian elephants (Arivazhagan 2005).

The adult male to female ratio obtained from this study is less skewed than the Srilankan elephant population. This is also true when compared with the sex ratios of other studies conducted at Nagarahole National Park (1: 5.8) and Mudumalai Wildlife Sanctuary (1: 27.7) by Arivazhagan (2005). The reason for this may be the complete absence of poaching and hence selective elimination of adult male elephants is nonexistent.

Also the fact that the study was conducted after the annual elephant driving operation (November and December) where in herds of elephants are driven out of BNP to adjoining protected areas to reduce conflict. It is also expected that the demography of the elephant population changes seasonally as herds migrate into and out of BNP. Adult bulls are not normally driven as they are too dangerous to approach and are known to escape the driving party.

Sex ratio of adults cannot be viewed in isolation and it is important that the sex ratios for different age classes are also taken into account (Baskaran & Desai, 2000). The average fecundity rate in Nagarahole National Park, Mudumalai Wildlife Sanctuary and Periyar Tiger Reserve are 0.20, 0.19 and 0.15 respectively (Arivazhagan 2005) and in the Eastern Ghats population during the early 1980s it was 0.22 (Sukumar 1989), which closely matches with the value obtained for this study.

d) Group structure (herds, bachelor alliance and solitary) of elephants observed during the study period

Most of the elephants were found in herds during the study period although an all male alliance with three male elephants comprising of two adult and one sub adult male was documented and the results are shown in Figure 4. Of the total number of elephants classified, herds dominated (60%) followed by solitary and all-male alliance.

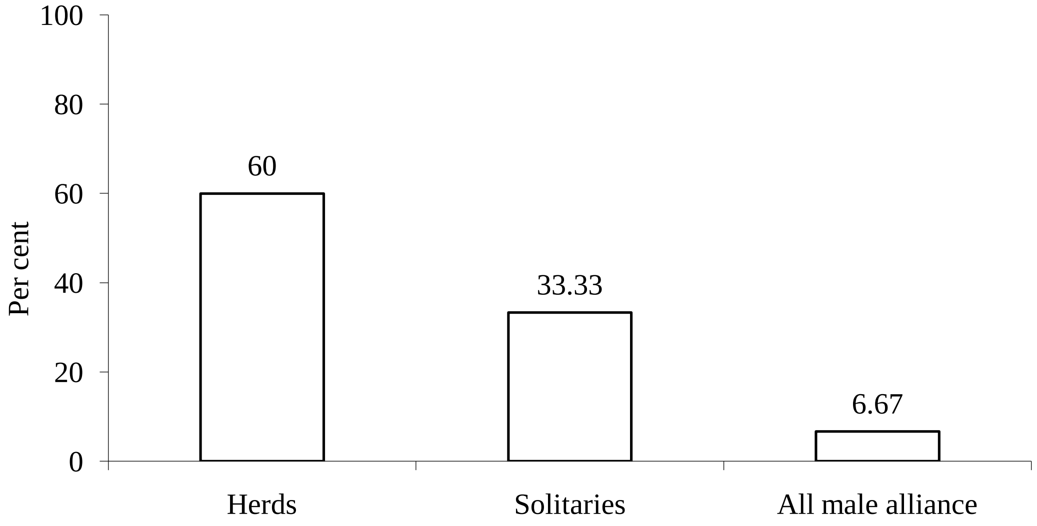


Figure 4: Percentage occurrence of different elephant alliances at BNP. The percentage occurrence of alliances of elephants is plotted against different alliance types

A higher proportion of elephants can be expected to be seen as herds as they are social animals, having strong bonds and it is also observed to be a natural phenomenon. Male elephants leave the herds when they are at the threshold of sexual maturity, usually between the age of 10 and 15 years. Young maturing bulls spend more time away from their herd, either alone or in the company of other young bulls. Adult bulls spend 20 to 25 percent of their time on an average with family groups (Sukumar 1996). The occurrence of all male alliances is very rare. According to Sukumar (1996) this kind of association between bulls for crop raiding is common. A solitary existence is the norm otherwise.

Approach 2: Recognition of individuals

The protocol followed for individual recognition is as follows: It can be safely assumed that, an animal sighted at a given occasion if belongs to the same sex, same age category (Adult/sub adult/juvenile or calf) and has similar identification marks as the animal sighted at a different occasion to be the same individual elephant.

If at least one of the above characteristics is not similar then the elephants are non-identical and thus are different individuals and therefore can be differentiated from one another. As seen from results and figures (for example figure 5), all the elephants classified are not of the same sex (there are males and females in a population) and belong to either one of the two sexes and thus we have two different sets of individuals.

Also not all the elephants belonged to the same age class and hence we have at least 8 different individuals belonging to two sex and four age classes. Members of this population were found to belong to all the 7 age–sex classes (as calves cannot be sexed).

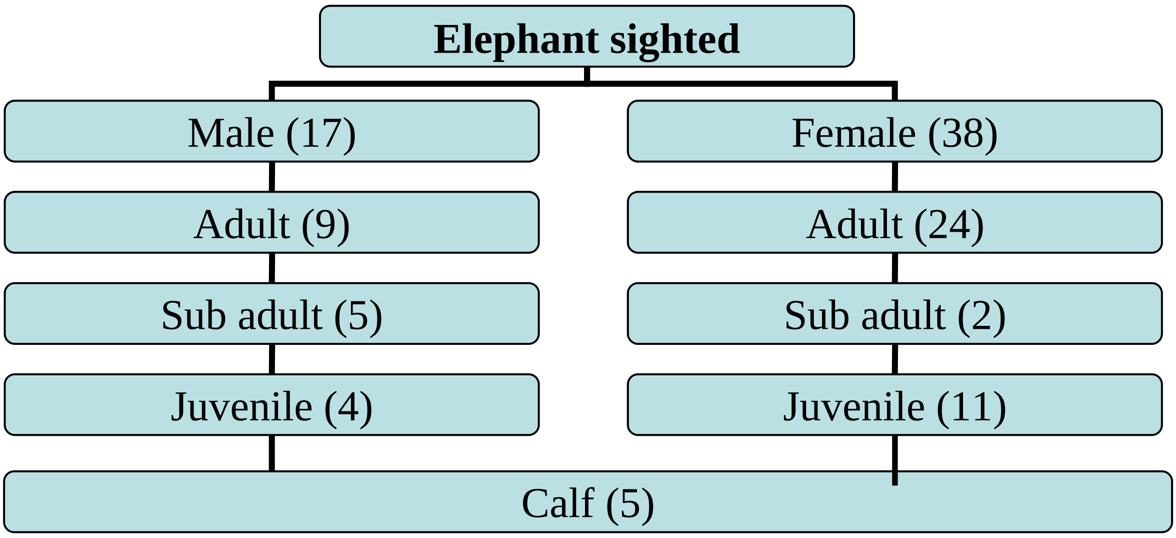


Figure 5: Profile of elephant sighted and their age and sex classes in Bannerghatta National Park

The remaining elephants (52 individuals) must also belong to one of the age-sex class. When more than one elephant is found to belong to the same age and sex class they can be differentiated from one another using the unique identification marks on their body. The results suggest that out of the total number of elephants sighted, 31% were males and 69% were females.

Among the age–sex classes, individuals with distinct identification marks were clearly identified. The challenge arose when two or more individuals of the same age and sex classes with few unique identification marks were to be identified. This was especially true with adult female elephants.

Out of the total number of individuals sighted and classified, 65% (n=39) were photo classified and the remaining 35% (n=21) were not. This was either due to non availability of photographs or poor quality of photographs for classification. For such individuals their characteristic features were noted down.

A comparative differentiation of individuals who were classified under the same age and sex class (Figures 6a, b, 7a and b) using the photographs is shown below. The two adult male elephants out of the 9 adult males classified were differentiated from one another based on identification marks (6a and b). A similar protocol was followed for other elephants of the same/different age classes too.

Figure 6a: An adult male elephant recognized as Venkataiahana Kunte bull (above) by its characteristic identification marks as shown in figure below

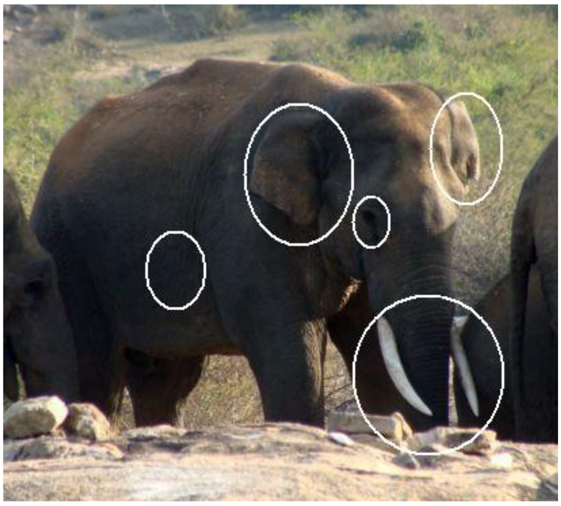


Figure 6b: An adult male elephant recognized as Suvarnamukhi bull (above) by its characteristic identification marks as shown in figure below

a b c

f e d

a b c

Identification marks (clock wise)	Identification marks (clock wise)
a. *Ear*: Forward folded, full, half de-pigmented, extensive folding of the ear on top and on sides b. *Unique marks*: Poke mark behind right fore leg c. *Eye*: Shrunken. d. *Tail*: No brush and of knee length. e. *Tusk*: Convergent, thick, balanced, flattened on the sides, blunt with slight re-curve	a. *Ear*: No folds, right ear full, 1/4th de-pigmented. Left ear has a V notch b. *Tusk*: Convergent, thin, long, balanced, downward pointing with a slight re-curve c. *Eye*: Clear and open d. *Tail*: No brush and of ankle length. f. *Unique marks*: V notch on the ear and the absence of poke mark behind left fore leg

The two adult female elephants out of the 24 adult females classified were differentiated from one another based on identification marks as shown in figures 7a and 7b. However out of the 24 adult female elephants, 22 could be easily differentiated from one another as each elephant had certain unique features such as the tear in the ear, absence of brush in the tail, length of the tail, broken peak and lumps on the body.

Figure 7a: An adult female elephant recognized as BVH 1 by its characteristic identification marks as shown in figure

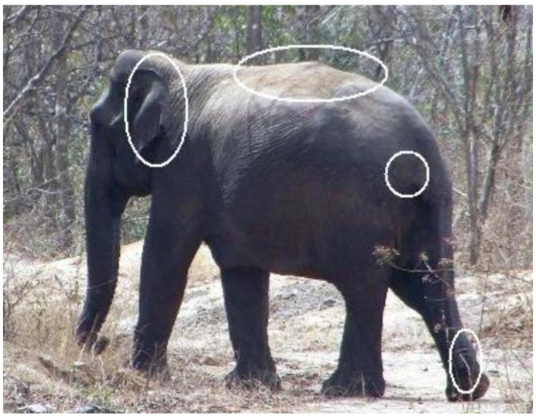


Figure 7b: An adult female elephant recognized as BCH 1 by its characteristic identification marks as shown in figure

a

c b

a

d c b

Adult females were one of the most difficult age classes to differentiate as most females belonging to the same age class were identical with subtle differences in their ears, tail, peak and other unique body markings, if any

Identification marks (clock wise)	**Identification marks (clock wise)**
a. *Peak:* Straight or a flat peak	a. *Peak:* Medium peaked and unbroken.
b. *Tail:* Complete absence of brush and presence of lump on the left flank	b. No unique marks or lump on the left flank of the elephant
c. *Ear:* Almost completely de-pigmented and left ear folded forward on the top and side, no tears and a full ear	c. *Ear:* Only 1/4th of the ear de-pigmented, no forward folding but does have the top and side folds
	d. *Tail:* Ankle length and has brush

Sub adult females, sub adult males, juvenile females and juvenile males were differentiated using the above said identification marks. All the individuals within their age class had differences in these characteristics and therefore could be identified easily. However, if clear photographs of calves were not available the adult females and the other members of the herd were scrutinized. Thus if the members of the groups were different then the calf also had to be a new individual.

Approach 3: Determination of the distribution, population size and monitoring of elephants by direct observation

a) Estimating the distribution of elephants using elephant sighting locations

The individual recognition exercise suggests that out of the total number of elephants sighted, 13 elephants have been re-sighted. Two adult males (hence forth known as AM 1 and AM 2), one sub adult male (solitary) hence forth known as SA and two herds (hence forth known as H 1 and H 2) constitute the 13 individuals. GPS readings of each of the re-sighting locations were taken to know the distance between any two sightings of the same individual (Table 2).

Table 2: Distribution of re-sighted individuals

Type of solitary/ alliance re-sighted	Number of individuals	Number of days of interval between the 1st sighting and the re-sightings		Re-sighting distance from the 1st sighting location (m)		Distance of the nearest village from the sighting and re-sighting locations (m)		
				Re-sighting number		Sighting and re-sighting number		
		2nd	3rd	2nd	3rd	1st	2nd	3rd
AM 1	1	1	2	500	700	700	1200	1000
AM 2	1	13	-	1000	-	2000	2000	-
SA	1	15	-	1000	-	2000	2000	-
H 1	3	1	-	500	-	800	300	-
H 2	7	1	-	0	-	2000	2000	-

AM 1 may have remained in the same location (forest beat) for three days. The reason for the animal to be found at a distance of 700m from the 1st sighting location even after 3 days, could be due to the presence of a female captive elephant in oestrous (based on keeper information and the attempts by AM 1 to mount on the animal) belonging to the Bannerghatta Biological Park (BBP) and also the presence of plantations in the vicinity of this beat.

Based on the information provided by the watchers, AM 2 was involved in crop raiding in a village at a distance of 1000m from its 2nd sighting location. This could probably be the reason for the elephant to have remained in the same beat for a long period of 13 days. SA was found along with AM 2 during the 2nd sighting after a period of 15 days. It is known from the watchers that SA was also involved in crop raiding in the same village as AM 2. It was sighted at a distance of 1000m from its 1st sighting location. H1 was sighted only 200m from the forest boundary and 700m from its 1st sighting when re-sighted after a day.

H 2 was sighted at the same water hole during successive days. The presence of water could be the main attraction. Presence of females in oestrous, water, shade and food within the park; plantations, cultivated crop fields and liquor in the surrounding villages seem to be attractants for elephants. Hence these individuals were not travelling long distances over a period of time.

b) Distance of the nearest village from the elephant sighting location

All the elephants sighted during the investigation were found to be distributed at an average radius of 4586m from the maximum elephant sighting location, represented as the centre point or point zero in Figure 8.

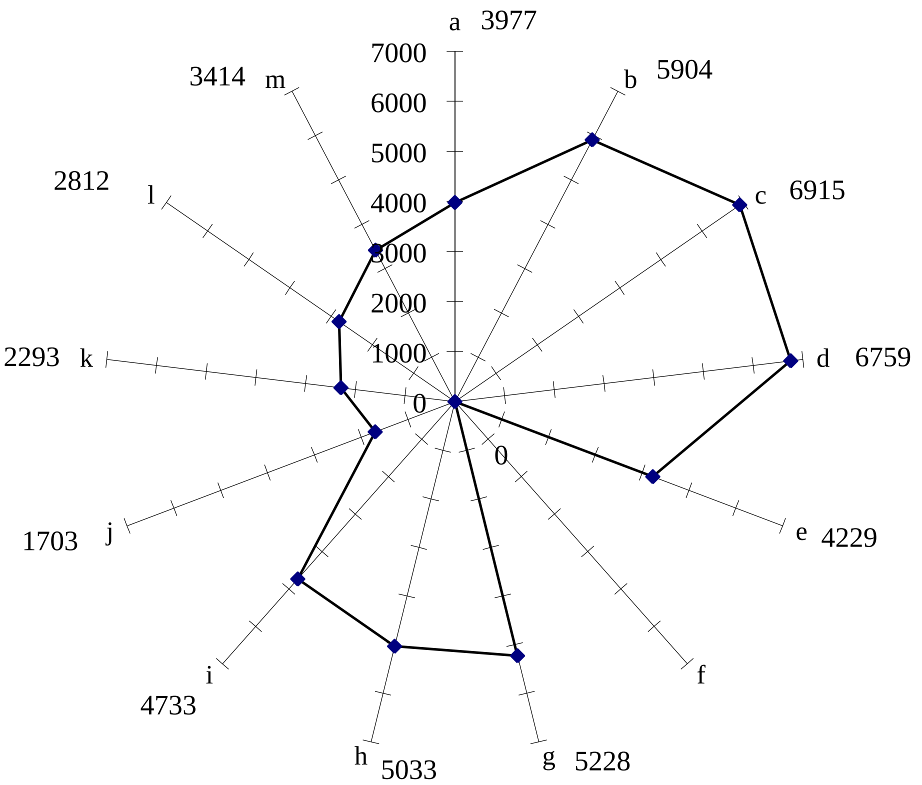


Figure 8: Represents the distribution of elephants from the location of maximum elephant sighting (considered as point '0')

About 68.3% of the individual elephants classified were sighted within an average radius of 4586m from point zero. Nearly 50% of the elephants observed were sighted at point zero in 22.2% of sightings. The rest were sighted at a minimum and maximum distance of 1703m and 6915m respectively from point zero during 77.8% of the sightings.

This demonstrates the utility of identifying locations that are preferred and most used by elephants; proving to be rewarding in elephant classification. The results show (Table 3) that, out of the total number of elephants sighted, 61.6% were found at an average distance of 2033m (SE = 140.31) from the nearest cultivated crop field.

Also the average size of these groups was found to be 6 elephants. However, the remaining 38.4% of the elephants were found at an average distance of 722m (SE = 46.02) from the nearest cultivable crop field. The average group size of these elephants was found to be 3.

Table 3: Distance of sighting of the elephants from the nearest village and the number of elephants sighted

Parameters	Number of elephants sighted from 0 to 1000m from the cultivable crop land	Number of elephants sighted from 1000m to > 2000m from the nearest village	Distance of 1000 to >2000m of the cultivable crop land from the elephant sighting location	Distance of 0 to 1000m of the cultivable crop land from the elephant sighting location
	5	1	2200	800
	3	3	2300	800
	3	1	2300	500
	1	1	1500	800
	1	3	1200	500
	1	12	2200	700
	3	16	2200	800
	4	1	2200	800
	7	7	2200	800
Total	**28**	**45**	**18300**	**6500**
Mean	**3.11**	**5.00**	**2033.33**	**722.22**
SE	**0.72**	**1.96**	**140.31**	**46.02**

It is interesting to note that the distribution of elephants inside the national park varied temporally on a daily basis (Figure 9). The results show that out of the total number of elephants sighted, 62.2% were at an average distance of 2033m (SE = 140.3) from the nearest cultivable crop field in the morning (06.30 to 11.30 hrs). However by evening (16.30 to 18.30 hrs) only 2.2% of the elephants were found at this distance from the crop fields.

Furthermore, 50% of the elephants were sighted at an average distance of 722m (SE = 46.0) from the nearest crop field by afternoon (11.30 to 16.30 hrs) and 17.9% of the elephants were sighted at this average distance from the nearest crop field in the evening (16.30 to 18.30 hrs).

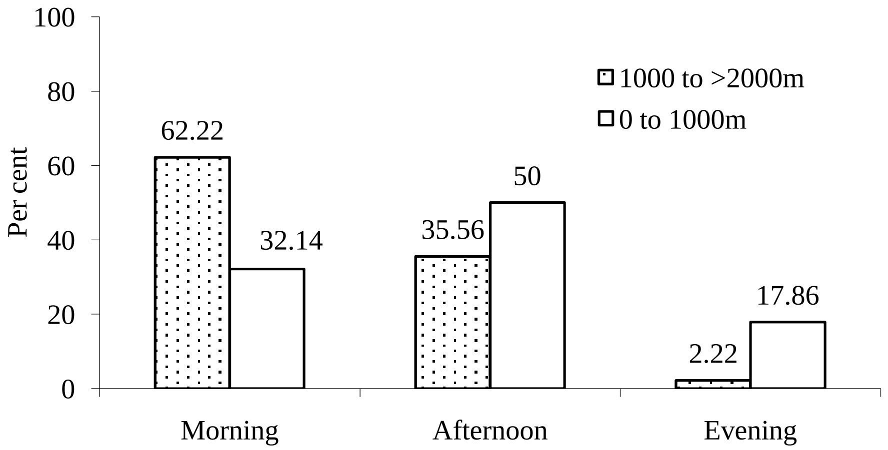


Figure 9: Percentage of elephants found at varying distances from the nearest cultivable crop field at different time intervals in a day. Percentage of elephants sighted at 0 to 1000m and 1000 to >2000m from the nearest cultivable crop field is plotted against the time zones in a day

c) Time of sighting of elephants

Percentage of time intervals during which the elephants were sighted indicates that majority of the sightings were between the time interval of 06.30 and 10.30 hrs in the morning constituting 44.4% (SE=0.56) of the total number of elephant sightings (Figure 10). They were sighted between 10.30 and 12.30, 12.30 and 14.30 and 14.30 and 16.30 hrs for 16.7% and from 16.30 to 18.30 hrs for 5.6% of the number of times of sighting elephants. The maximum percentage (44.4 %) may be due to the fact that elephants were returning from the crop fields to the national park at this hour and could be involved in activities such as moving to the resting places, bathing/drinking or even at times feeding in case of an unsuccessful raid.

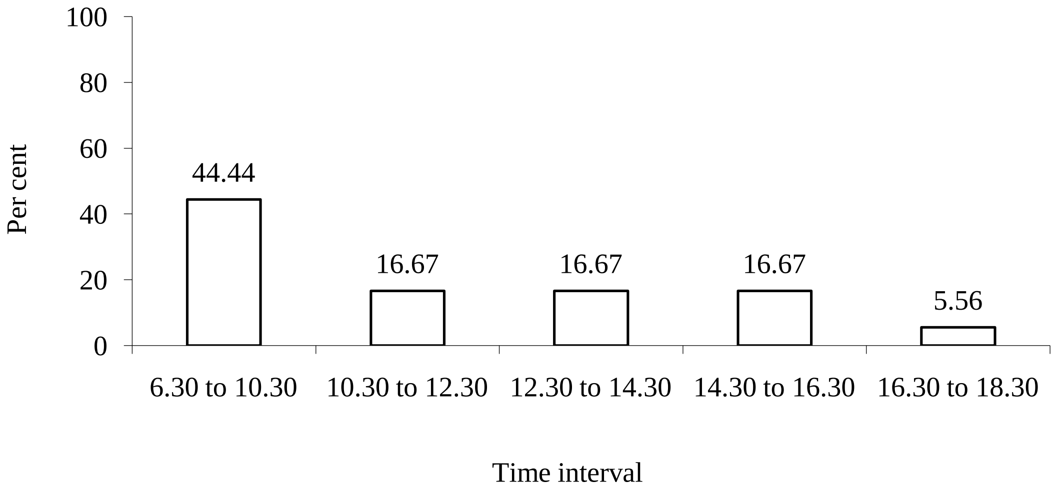


Figure 10: Percentage of elephant sighted across different time intervals

d) Elephant sighting locations

A large number of elephant sightings were in the valley or at water holes, which may be due to the fact that all most all their daily requirements such as shade, water and food are prevalent in these areas (44.4% of the times sighted in valley, 33.3% near water holes and 5.6% of the time each near river, in open area, on hills and others as seen in Figure 11).

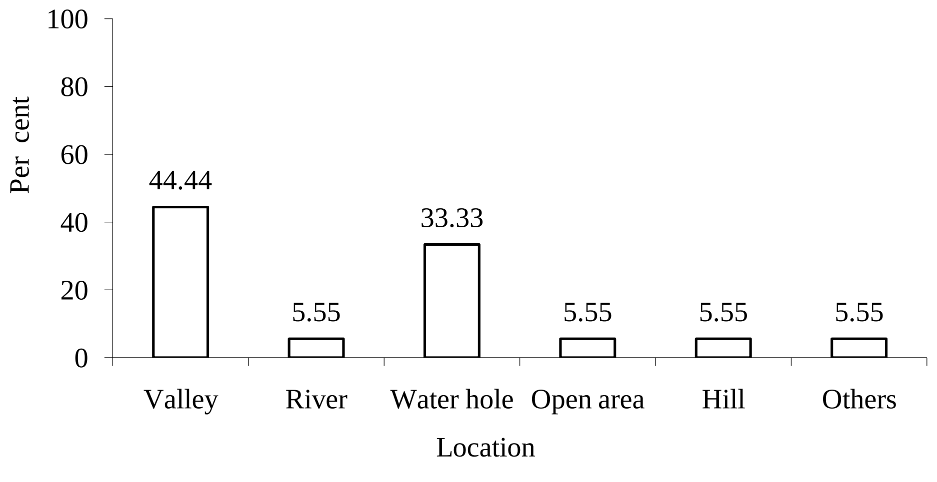


Figure 11: Percentage of times elephants sighted in different areas

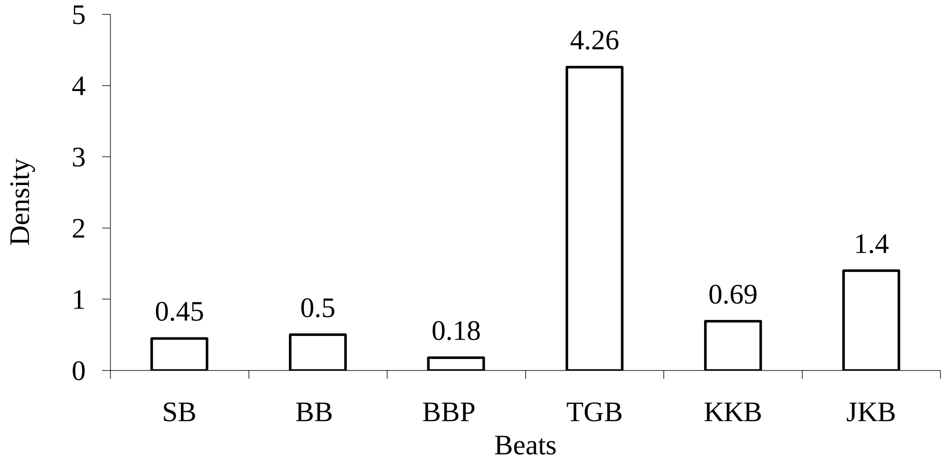
e) Density of elephants in the study area by population demography investigation

This investigation gave scope for estimating a crude density for the park, which was 1 elephant/km^2. The density of elephants as per elephant census 2007 was 1.4 elephant/km^2 (Baskaran *et al*. 2007)**.** It was also found that the Bannerghatta Range of BNP has a higher density of elephants when compared to the Harohalli Range (excluding Bantanala extension), which could be due to the proximity of the former range to cultivation lands and also due to the presence of many perennial water holes. Bannerghatta Range had a density of 1.15 elephants/km^2 and Harohalli Range (excluding Bantanala extension) an elephant density of 0.5 elephants/km^2.

f) Micro habitat wise density of elephants in Bannerghatta and Harohalli

The administrative beats were considered as micro habitats and the density of elephants was arrived at by taking the ratio of number of individuals recognized as elephants sighted in that beat by the total area of the beat. The elephant density (elephant/km^2) was found to be the highest in Thattiguppe Beat followed by other beats. Figure 12 shows a reduction in density when moved away from Thattiguppe Beat of Bannerghatta Range.

Thattiguppe beat of Bannerghatta Range had the highest density with 4.3 elephants/km^2 and BBP Beat of the same range had the lowest density of 0.18 elephant/km^2. The later beat's high density may be due to the presence of crop lands which dominated villages in the vicinity. Also, the beat itself had good water source and resting places which were also feeding grounds for the elephants. All these elephants were sighted within 800m to 2000m of this (Thattiguppe) village. The low density in BBP Beat of the same range may be due to high fragmentation because of the presence of the Bear, Lion and Tiger safari of the Bannerghatta Biological Park which brings along with it vehicular and people movement. A combination of these factors may have resulted in the low density of elephants in this beat.



SB: Suvarnamukhi Beat; BB: Begahalli Beat, BBP: Bannerghatta Biological Park; THB: Thattiguppe Beat; KKB: Karadikall Beat and JKB: Jenukall Beat

Figure 12: Density of elephants estimated for different administrative beat of the park

g) Encounter rate of elephants during the study period

The encounter rates of elephants is calculated for all-male alliance, herds and solitaries by taking the ratio of the number of different associations of elephants were sighted to the number of days of field work. The overall encounter rate per day (Number of elephants/Number of days of field work) of elephants is 2.25 (n=73), and for groups it is 0.031, herds it is 0.28 and for solitary animals it is 0.16 (Figure 13).

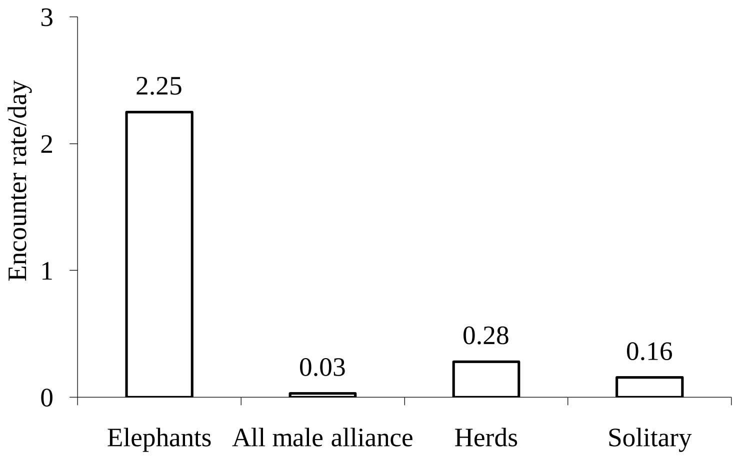


Figure 13: The encounter rates of the Asian elephant and its various alliances in BNP. The elephant encounter rate/km of the elephants and its alliance is plotted against different types of alliance and elephants in general

Since 60% of the total elephant alliances enumerated were herds, their encounter rate was also the highest. Solitaries were seen more often than all-male alliances (as adult males are mostly solitary animals) and the proportion of solitaries enumerated is also higher compared to all-male alliances. All male alliances are very rarely seen and have been documented by experts in other study areas. These alliances formed a minuscule proportion of the elephants enumerated and hence their encounter rate is also the lowest. In all, the chances of encountering herds were the highest in this park followed by solitary animals and all-male alliances. However one can expect to see 2.25 elephants/day.

Conclusion

The present study reveals that the adult sex ratio (male to female) in BNP (1:2.7) is one of the least skewed when compared to Nagarahole National Park (1:5.8), Mudumalai Wildlife Sanctuary (1:27.7), Periyar Tiger Reserve (1:79.6) (Arivazhagan 2005.) and Eastern ghats (1:5) (Sukumar 1996), indicating the absence of selective elimination of adult males which is otherwise a common cause for highly skewed sex ratios in other areas of elephant occurrence. The results also show how significant this population of elephants is, in contributing to the genetic viability of the population of Elephant Reserve No. 7, which is the single largest population of elephants in southern India (AERCC 1998). The population structure in this study area should be monitored on a regular basis to understand the long term dynamics of the population and to assess the impact of conflict and habitat fragmentation on the size and structure of the population.

Although an adult male to female sex ratio of 1:2.7 at BNP is less skewed when compared to other protected areas and elephant populations across India, BNP cannot be viewed at in isolation. The current sex ratio observed at BNP could be due to factors such as high level of protection and resulting reduction in poaching. Since elephants are large ranging animals with home ranges of 14 – 10,000 km^2 (See Sukumar 2003 for review), sex ratio of elephants in BNP will have to be looked at in a larger context. BNP is contiguous with large forest patches to its south, namely, Cauvery Wildlife Sanctuary (CWS) and Hosur – Dharmapuri Territorial Divisions (HDTD). Studies from these areas suggest a high level of human induced disturbance including conflict related deaths of elephants.

Hence it is strongly believed that elephants, especially the adult males prefer BNP as a refuge. Thus, the sex ratio seen at BNP may be an artifact of the above described process and hence it would be important to conduct detailed study of elephant population and demography at CWS and HDRF on priority to understand the population dynamics. Moreover, male elephant mortality at BNP is high due to human – elephant conflict which may result in selective cropping/elimination of these male elephants from a larger population of elephants resulting in further skewed sex ratios. Reduced number of breeding-males at CWS or HDTD may result in a few males contributing to most of the reproduction which would result in lowered genetic diversity.

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Appendix-I

Additional figures showing different age and sex classes of Asian elephant encountered during the population demography study in the park

a

b

c

d

e

f

a and b: Elephant herds, c and d: Solitary bulls, e: Adult male in a herd, f : Male-male alliance sighted in the park

Appendix-II

Assessment of Elephant Population Structure in Bannerghatta National Park

Date:
Observer Name:
Range name
Beat name
Starting time
Closing time
Weather condition : Sunny/ Cloudy/ Rainy
Geo-coordinates (GPS)

Sighting location
General vegetation type

Sl. No.	Sighting time	Number of individuals	Herd structure								Remarks
			AF	**SAF**	**JF**	**AM**	**SAM**	**JM**	**Calf**	**UI**	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

CLASSIFICATION DETAILS
AF: Adult Female >7 ft, SAF: Sub Adult Female> 5-7 ft, JF: Juvenile Female >4-5 ft, AM: Adult Male >8 ft, SAM: Sub Adult Male >5-8 ft, JM: Juvenile Male >4-5ft, Calf = up to 4 ft.

Introduction

A study on the population size and structure of the Asian elephant involves a study of the demography parameters such as age structure and sex ratio (Sukumar 1989). Knowledge of age structure of an elephant population is essential for investigating trends in recruitment, mortality, reproductive status of the population and the possible influence of direct exploitation by humans. Age structure information also provides data needed for population viability analysis and subsequent management implications (Sukumar 1996). While classifying elephants in the wild one can expect to have a sighting of the elephant in open forests or at water holes, open areas and grass lands in closed forests with trees and thick bushes. Under such circumstances, identification of individuals on the basis of age and sex becomes challenging due to behavioural factors and local environmental settings.

Environmental setting can be referred to as those natural elements or objects which form an integral part of the environment in question. Behavioural factors may be referred to as the activities of the animal in question. Both the above factors are time and space based and influence classification process. The classification of individuals in the forest becomes relatively more difficult as certain factors such as the visibility of the animal reduces due to tree and vegetation cover, coupled with the factor of distance and angle of view, terrain and light conditions.

Terrain (specifically 'slope') adds to the existing factors of visibility, range, light conditions and makes age based classification more challenging. Slopes are known to negate the difference in heights between the individuals belonging to different age classes. The identification of an individual is a challenge as the individuals are involved in various behavioural activities such as bunching, lying-down, feeding, rubbing and play fighting, etc., which will hinder the classification process by way of adults blocking the other individuals thus reducing their visibility (at times the calf may totally be blocked by adults).The Juveniles and sub adults, especially, must be first classified as they are relatively invisible in a group or more active than the other layers (calves and adults which are relatively easy to classify) making them the most difficult individuals to classify.

A field guide developed on the above lines will assist in the classification and identification of wild Asian elephants, with specific emphasis on the Juveniles and Sub adults as they are the most active age groups. The use of new yardsticks in combination with the traditional classification methods (Sukumar 1986; Arivazhagan 2005; Varma *et al*. 2006) using the shoulder heights at different ages from known ages of captive elephants would aid in classification when confronted by the factors such as visibility, terrain and activity. The applicability of these yardsticks in the wild Asian elephant classification may help ease the classification process.

Objectives

The major objectives of the study were the following:

Classifying captive Asian elephants when in open or closed forest in spite of environmental and behavioural challenges

To prepare a field key on Asian elephant classification; thereby enable the classification of the wild Asian elephants when in open or closed forest using yardsticks as applied to the captive Asian elephant classification

The objectives may have the following insights
This is the first time that a comprehensive and detailed study of the population size and structure of the Asian elephants as related to demography has been taken up at Bannerghatta National Park (BNP). As mentioned earlier, elephant's behavioural pattern and the environmental settings in which it is observed in the given time and space pose many challenges, making age and sex based classification difficult. This is predominant in landscapes dominated by scrub and dry deciduous forest vegetation and numerous valleys like that of BNP.

The study in BNP or elsewhere requires constant effort in observing elephants in the wild and also a proper, user friendly methodology and training in the classification of the elephants into different age and sex classes. A field guide developed based on observing captive elephants in different environmental and behavioural settings will assist in the classification and identification of Asian elephants in the wild with specific emphasis on the more active age groups.

Methodology
Five distinct approaches were followed in order to classify Asian elephants when in open or closed forest.

Approach 1: Classification of captive Asian elephants when in open forest
The research team observed captive elephants at Bannerghatta Biological Park (BBP) and classified them using the yard sticks developed for this purpose (see approach 4). The elephants were housed in an open enclosure which did not restrain them in going about their natural activities (see Appendix I) and care was taken to ensure that the animals were not influenced by any other external factors.

The visibility was good as it was an open enclosure and the animals were at a close range (10 to 40 ft). This approach was adopted to understand and anticipate the complexities/challenges one would encounter in the wild. Observations were made and possible combinations on the basis of orientation and view of one individual in relation to the other were observed and arrived at (writing down combinations whenever the animals presented the opportunity). A photographic documentation matching the above combinations (see Appendix I) was also undertaken.

Approach 2: Classification of captive elephants when in closed forest
The captive elephants were observed when they were free ranging in the natural landscapes of Bannerghatta National Park. A wild bull elephant had also joined the herd of 5 captive elephants as one of the females was in oestrous. These factors created conditions which mimicked a wild elephant herd. The herd was observed for a period of 8 hrs spread over two days. All possible combinations on the basis of orientation and view of one individual vis-à-vis another were written down and photographic documentation (see Appendix I) was done as and when the opportunity arose.

Approach 3: Classification of captive elephants when on a slope
The captive elephants were observed for a period of 2 hrs. They were photographed and an attempt was made to classify the captive elephants of Bannerghatta Biological Park when they would be descending or ascending the slopes while free ranging in the National Park area.

For the above purpose the slope was defined as a positive or negative inclination of the surface of the ground/ landscape in relation to the horizontal surface/terrain and 'the slope effect' refers to the effect slope/gradient has in altering the physical characters (such as height) of one elephant in relation to another when viewed by a 3rd person.

Approach 4: Preparation of field key on Asian elephant classification
Many possible combinations (see appendix-II) were arrived at by comparing the different age groups, especially to address the two layers (juveniles and sub adults) which are relatively difficult to classify by computing the combinations namely Calf to juvenile/sub- adult/ adult, Juvenile to sub-adult/ adult, Sub-adult to adult. Comparison of one individual with respect to an adult elephant used as the reference animal when seen from a front view, lateral view or a rear view was computed.

Approach 5: Classification of wild Asian elephants when in open and closed forest
The direct observation method of classification was then tested in the classification of wild elephants. The strategy adopted initially was to track the elephants with the help of the watchers and photograph them.

This however had to be changed as photographing the animal when in thick bush was difficult and only the rear of the animal was seen most often. The second strategy adopted was to understand the movement patterns of the elephants from the watchers and narrow down on the most probable open area or water body they might visit.

It must however be pointed out that the strategies used are time and place specific and is based on the intelligence and knowledge of the watcher, forest officials and the researcher about the elephants and the terrain. On sighting the elephants they were classified using the yardsticks developed exclusively for this purpose.

The photographs from all the 4 approaches were then digitized and analyzed to determine the correctness of the individual classification. All these exercises were carried out at the Bannerghatta Biological Park (BBP) and Bannerghatta National Park (BNP), using the camp Asian elephants as the reference animals and were then tested on the wild elephants.

The Asian elephant was classified into 4 classes on the basis of age group namely calf (0-2), juvenile (2-5), sub adult (5-15) and adult (>15) years based on the relative difference in the morphological features between the age groups.

They can be further classified as males and females on the basis of sex. Considering both the classifications a total of 8 classes (4 classes each of male and female) could be arrived at. However, technically there may be only 7 classes (which can be determined in the wild) as the calf cannot be sexed.

Results and Discussion
Approach 1: Classification of captive Asian elephants when in open forest
Basic profile of the elephants observed: The Park has 8 individual elephants reflecting a social group. The proportion of animals based on age group is as follows: 62.5% adults, 12.5% sub adults, 12.5% juveniles and 12.5% calves (Figure 1).

The proportion of animals based on sex is as follows: 25% males, 62.5% females and the remaining 12.5% unclassified (calf).

Figure 1: Proportion of various age class of captive elephant herd

Field keys applicable under these conditions: The field keys that could be used for classification of elephants when in open forest are given in appendix III. The layering of the animal (sub adult or juvenile or calf) in question with respect to the reference animal (adults) was carried out and recorded with photographic documentation as and when the opportunity arose. Figure 2 is an example of one of the ideal conditions for classifying elephants. Individuals of all age classes are seen in this picture. An example of field key used in the age based classification of the two most difficult classes to classify namely the sub adult and the juvenile is given below.

a. Juvenile: Forehead of the animal in question in line with middle of the sub adult's ear/in line with sub adult's eye
b. Activity: Standing

Figure 2: From left to right: calf, sub adult, adult male, adult female and juvenile. Age and sex based classification can be done effectively from this photograph as the elephants are seen from front, visibility is clear and at a short distance and they are involved in standing activity

Challenges encountered during the classification process: Distance/range of the elephants was close (10 to 40 ft), visibility was clear as the observations were made from 09.30 hrs to 13.30 hrs on a clear sunny day and vegetation cover was almost nil. The elephants stayed in the open enclosure for the entire period of observation. The terrain was flat and the animals could be viewed from various angles. The layering (age class) and identification of an individual is a challenge as the individuals are involved in various behavioural activities such as bunching, lying, feeding, rubbing and play fighting, etc. (see appendix III).

These were hindering the classification process by way of adults blocking the other individuals and at times the calf was totally blocked. The juveniles and sub adults were the most active age classes but could be classified easily as they would normally be close to the adults in the group. It was observed that bunching was the most important challenge when the animals were in open. Accuracy level of classification when faced with challenges: An accuracy level of 100% could be achieved in spite of the challenges faced in the given time and space. Most of the above mentioned challenges except for bunching did not have a negative effect on the classification process.

The challenge of bunching could however be addressed by investing more time in observing the individuals and classifying them as and when the opportunity arose. The above conditions may be considered to be near ideal when classifying elephants.

Approach 2: Classification of captive elephants when in closed forest
Basic profile of the elephants observed: Six individuals were observed for a period of 4 hrs, they reflected a social group. The proportion of animals based on age groups are as follows: 50% adults, 33.3% sub adults and 16.7% calves. The proportion of animals based on sex (Figure 3) is as follows: 16.7% males, 66.7% females and 16.7% unclassified (calf).

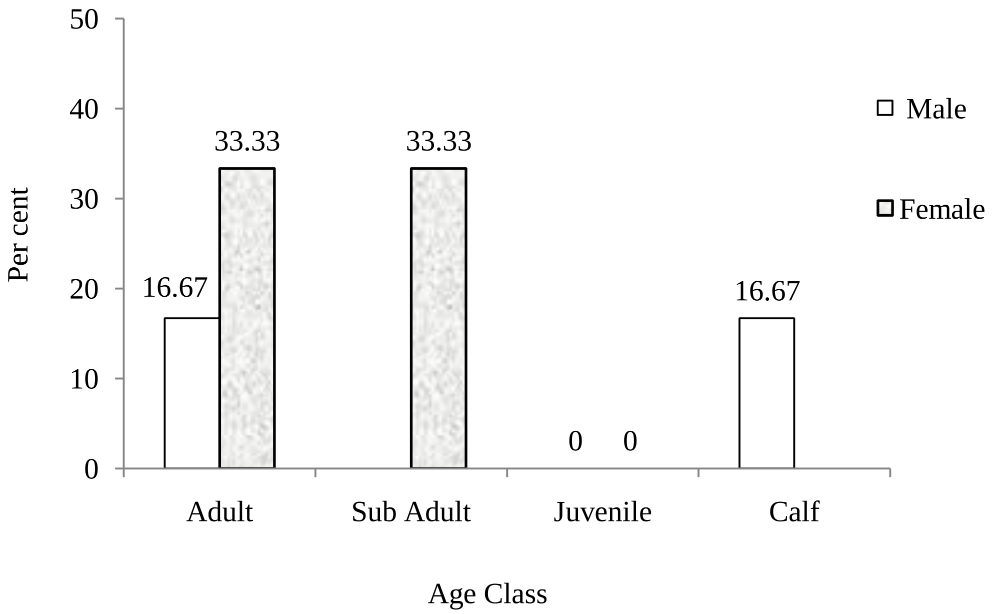

Figure 3: Proportion of age class of captive elephants classified when in closed forest

Field keys applicable under these conditions: The field keys that could be used for classification of elephants when in closed forest are given in appendix I. The layering of the animal in question with respect to the reference animal (adults) was carried out and recorded with photographic documentation as and when the opportunity arose (Figure 4).

The challenges can however be addressed over time and space and at small intervals of time when the elephants are less active.

a. Sub adult: Peak of the animal in question is in line with the middle of the adult male elephant's ear
b. Activity: Bunching

Figure 4: Captive elephants in bunching activity in a closed forest

Challenges encountered during the classification process: The elephants when observed in closed forest moved from one environmental setting to another during the period of observation. The settings varied from dense bamboo cover to open jungle and the terrain from flat to slope. Classification was carried out from 08.30 hrs to 10.30 hrs in the morning and 14.30 hrs to 16.30 hrs in the evening.

As it was in summer, the sky was clear with bright sunlight. Elephants were observed from a distance of 50ft to 300ft. However, this did not affect the classification process when individuals were clearly visible. When elephants were in thick bush (bamboo), the number of elephants, age and sex classes of all the elephants could not be determined. The vegetation cover was 70% during most of the time.

Occasionally elephants did break cover to make way for other members of the group and exposed one self. This opportunity was cashed in to classify the individuals. Elephants however did move across open jungle during the observation period which helped to document their number, age and sex classes.

Furthermore, they were involved in activities such as dust bathing and bunching which blocked the view of the calf very often and hence classification proved to be challenging even when in open jungle.

Accuracy level of classification when faced with challenges
When in thick bush: As the elephants were in thick bamboo cover (Figure 5) (90% cover), initially only 50% of the individuals could be located, however their classification was not possible.

Figure 5: Elephants in thick bamboo vegetation making classification and determination of their number very difficult

Over a period of time, elephants did move out of cover (40% cover) exposing some of the individuals making it possible to know their number and age classes. Even then age and sex based classification of 50% of the individuals (Figure 6) was only possible.

Figure 6: Captive elephants free ranging in BNP. Also seen is the typical elephant habitat dominated by bamboo (*Dendrocalamus strictus*)

The elephants are not clearly seen because of the thick bamboo cover thus, affecting the visibility and effective classification of the elephants depicts that, of the total number of adults, sub adults and calves in the observed social group, 20% of the adults, 100% of the sub adults and 0% of the calves could be classified.

When dust bathing and bunching: When the individuals of the group were bunched the calf was completely hidden from view and the activity of dust bathing (Figure 7) reduced the visibility of other members of the group considerably (by 50%). These factors certainly reduced the efficiency of classification, thus, making it more challenging. These factors can however be negated over time and space.

When animals are bunched, of the total number of adults, sub adults and calves in the observed social group, 50% adults, 100% sub adults and 0% of the calves could be classified based on age classes. When the group is dust bathing, of the total number of adult females, sub adult females and adult males in the observed social group, 20% adult females, 100% sub adult females and 0% adult males could be classified.

Figure 7: Behavioural activity of dust bathing and bunching by the elephants. It can also be seen that the calf is completely hidden and individuals to the left of the dust bathing adult female are not visible for effective age and sex classification

Approach 3: Classification of captive elephants when on a slope
A total of 3 hrs was spent in observing ‘the slope effect’ on the physical characters of the elephants and all the individuals were successfully classified.

Basic profile of the elephants observed: Five elephants representing a social group were photographed. The proportion of animals based on age groups is 60% adults, 20% sub adults and 20% calves. The proportion of animals based on sex is 80% females and the remaining 20% unclassified (calf).

Field keys applicable under such conditions: The field keys that could be used for classification of elephants when on slopes are given in appendix I. The layering of the animal in question with respect to the reference animal (adults) was carried out and recorded with photographic documentation. The challenges (angle of view) can however be addressed over time and space. Although ear and shoulder of the elephants are visible (Figure 8), traditional method of classification becomes difficult as the elephants are following one another and are not next to one another.

Using the new yardstick, classification can however be carried out when the animal in question and the reference animal are moving along the same or uniform gradient as follows: upper tip of the forehead of the animal in question in line with the upper tip of the tail of the adult ─ considered as sub adult. In case the sub adult is replaced with a juvenile, it could be classified as: upper tip of the forehead of the animal in question in line with the middle of the adult tail ─ considered as juvenile.

When not along a uniform gradient, relative size of the two animals can be taken into consideration for classification. The figure below is an example of classification (field) key for a sub adult elephant when on a slope.

a. Negative slope
b. Sub adult: The upper tip of the ear of the animal in question is in line with the eye of the adult and the mouth of the animal in question is in line with the peak of the calf

Figure 8: A calf, sub adult and adult captive elephant walking up the slope

Challenges encountered during the classification process: The elephants were observed from a distance of 500ft to 250ft on a clear sunny day from 08.30 to 11.30 hrs and hence the factors of range, visibility and light conditions did not adversely affect the classification process. The factor of terrain (specifically 'slope') however, made the classification more challenging.

Slopes negate the difference in the heights between the individuals belonging to different age classes (Figure 9). Furthermore, the calf was not visible when the elephants were observed from a lateral view. While descending or ascending slopes elephants seem to follow one another thus blocking the view of the individuals behind an adult elephant (Figure 9) making sex and age based classification difficult.

Figure 9: Photograph showing the captive elephants free ranging and descending a slope one behind the other. Also seen is the thorny scrub jungle of BNP

Accuracy level of classification when faced with challenges

When the elephants were observed from a lateral view: The calf was completely hidden (Figure 10). The other four individuals were visible partially due to the vegetation cover (40% cover) and hence sex based classification was not possible. But age based classification could be done by comparing relative heights of the individuals seen.

Figure 10: Effect of slope and vegetative cover in age sex classification

From the figure it can be seen that the individual at the end of the line is a sub adult as the forehead of the individual in question is in line with the upper tip of the adult's tail (see appendix I, for field keys).

The calf is also not seen and sex based classification is difficult. Of the total number of adults, sub adults and calves in the social group observed, 100% classification of adults and sub adults and 0% classification of calves was possible.

When the elephants were observed from front view: In this case the calf, leading female and the last female were visible. The other members following the leading individual were partly visible (only the peak and forehead). Although age based classification could be done by comparing the relative body size of the individuals, sex based classification of the partly visible individuals was not possible.

Of the total number of adults, sub adults and calves in the group, 67% adults, all three calves and sub adults were classifiable. Sex based classification of the group when seen from front suggests that of the total number of adult females and sub adult females in the group, 66.67% of adult females and 0% sub adult females were classified. Calf is not included as it is unclassifiable.

Approach 4: Preparation of field key on Asian elephant classification

A photographic key (see appendix I) was prepared from all the 4 approaches which will aid the process of classification of Asian elephants, in general, and specifically at Bannerghatta. An example of one such key is given below (Figure 11).

Sub adult: The rear of the animal in question is in line with the upper tip of adult's tail
Activity: Bunching and dusting
Visibility: Close range but individuals not clearly visible due to the activities
Terrain: Evenly sloped
Challenge: The calf is completely hidden and sex classification not possible because of rear view

Figure 11: An example of the field key developed for classification of elephants. The activities, sloping terrain and rear view of the animal makes sex based classification challenging as seen in the picture

Approach 5: Classification of wild Asian elephants when in open and closed forest
Basic profile of the elephants observed: Three herds and five bulls adding up to a total of 23 individuals were classified for this approach. The proportion of individuals on the basis of age and sex classes are 22% adult male elephants, 35% adult females, 22% juveniles (4.3% juvenile males and 17.7% juvenile females) and 21% calves (unclassified). A total of nearly 8 hrs was spent in observing the animals in the Bannerghatta Range of the National park.

Field key applicable under such conditions: The field keys that could be used for classification of elephants when in closed forest are given in appendix I. The layering of the animal in question with respect to the reference animal (adults) was carried out and recorded with photographic documentation as and when the opportunity arose. The challenges can however be addressed over time and space and at small intervals of time when the elephants are less active.

The figure below is an example of one of the classification keys that can be used in the age based classification of the two most difficult age classes to classify, namely, the juvenile and the sub adult when in open forest (Figure 12).

a. Juvenile: Upper tip of the tail of the animal in question is in line with the eye of the sub adult
b. Activity: Bunching

Figure 12: An example of the field key developed for classification of elephants especially the juvenile and sub adult age classes of the herd when in open forest

Challenges faced while observing elephants in the wild

When observed in closed forest: Of the 23 individual elephants classified, 26% were observed in closed forest. They were observable for a duration of 2 hrs under bright and sunny conditions. The visibility was poor due to thick bamboo cover (70% cover) most of the time and only their peaks were visible. The number of individuals visible was recorded but the presence of a calf could not be ascertained.

There were instances wherein elephants did move from one cover to another across relatively open forest (40% cover). These occasions were capitalized to check for the presence of calf, number, age and sex of the individuals. The elephants were spread across the 'space' and at times were bunched. Another important challenge was the wind direction and sounds made while tracking.

When observed in open forest: The remaining 74% of the individual elephants (n=23) were observed in open forest (at water holes and in open jungle). The visibility was good as the forest cover was almost zero when at the water hole and the cover was only 30% when in open jungle. The range of observation was 150ft to 75ft. The observations were made from 12.30 hrs to 15.30 hrs on a bright and sunny day.

Hence these factors were similar to classification of captive elephants in open forest. However, when the elephants were submerged in water the classification of many of the individuals especially sub adults, juvenile, calves and some of the adults was challenging.

Level of classification when faced with challenges: In both the cases 100% classification of the individuals was possible given the time and space, and the different environment settings in which the elephants were observed. But when each setting is seen independently the following results emerge.

When in closed forest (70% cover): Age and sex classification of 6 individuals (26% of the total elephants classified in the wild) was not possible when in 70% forest cover. However, when in 40% cover, classification of all the individuals was possible.

When in open forest: Age and sex based classification of all the individuals sighted was possible under these conditions. However, when the elephants were inside the water the level of classification reduced. When compared with the basic profile (Figure 13) of these elephants; of the total number of calves, juveniles, sub adults and adults classified; 0% calves, 100% juveniles, 50% of the sub adults and 83.33% of the adults were classifiable as the elephants were in the water during specific time and space (Figure 14)

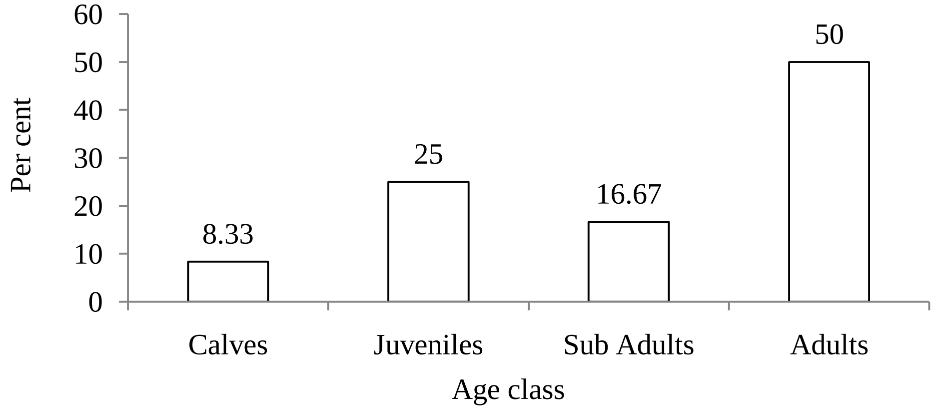

Figure 13: Shows the basic profile of the wild elephants classified in open forest

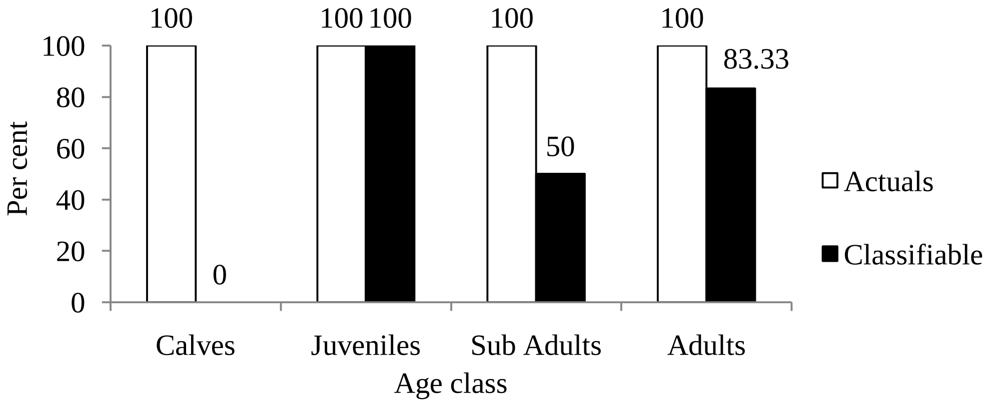

Figure 14: Classifiable elephants as they were in the water during specific time and space

In case of sex based classification, of the total number of juvenile males and females, sub adult males and females and adult males and females; 100% juvenile males and females, 100% sub adult females, 0% sub adult males, 60% adult females and 0% adult males were classifiable in specific time and space when submerged in water.

Conclusion

The results of the exercise have clearly indicated that environmental and behavioural factors (some of them have been listed in appendix III) play a crucial role in deciding the accuracy and efficiency of classification of the Asian elephants. These factors may cause a reduction of 50% on an average in the classification efficiency. However they can also be satisfactorily addressed given time and space, by the use of a combination of yard sticks as mentioned in this exercise. This exercise has aided in understanding and developing method of classification of Asian elephants and in highlighting the challenges and difficulties involved in it. It also seeks to find practical solutions to most of these challenges. Furthermore, it has been observed that the yardstick used here have proved to be useful in the classification of the elephants in the wild during the demographic studies at Bannerghatta National Park. It has been a knowledge building activity giving the research team a practical exposure at the ground level in the various precautions and necessary measures that one has to adhere to when accomplishing the task, ways in which the herd has to be approached to enable efficient classification and to take photographs of the individuals which can later be used in their identification. Furthermore, it has also been helpful in preparing a field guide for classifying elephants with specific importance to the two layers namely Juveniles and Sub-adults which are the most difficult to classify among the 4 classes. We hope that the inclusion of more measures in addition to the traditional ones would ease the process of classification and help in satisfactorily addressing the difficulties/challenges discussed above.

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Appendix –I

Photographic field keys for the classification of Asian elephants

Photographic key 1 for captive elephants in open enclosure

Note:

a. The following classification uses adult as the reference animal to which the remaining layers are compared to.
b. Specific importance is given to the classification of juveniles and sub adults.

a. Juvenile: Peak of the animal in question in line with middle of the adult's belly
b. Sub adult: Forehead of the animal in question in line with middle of adult's forehead
c. Activity: Standing

a. Juvenile: Peak of the animal in question in line with the Adult tail upper tip
b. Play fighting and standing respectively

a. Calf: Animal under belly of Adult
b. Activity: Standing

a. Juvenile: Peak of the animal in question in line with the adult's eye
b. Activity: Standing

a. Sub adult: Rear of the animal in question in line with adult's eye
b. Activity: Bunching

a. Juvenile: Forehead of the animal in question in line with lower tip of the adult's ear
b. Activity: Bunching

a. Juvenile: Forehead of the animal in question in line with middle of adult's belly
b. Activity: Bunching

a. Juvenile: Forehead of the animal in question in line with adult's eye
b. Juvenile: Peak of the animal in question in line with middle of adult's belly
c. Activity: Standing

a. Sub adult: Peak of the animal in question in line with upper tip of adult's belly
b. Sub adult: Peak of the animal in question in line with middle of the adult's forehead
c. Activity: Standing

a. Sub adult: Forehead of the animal in question in line with middle of adult's forehead
b. Sub adult: Peak of the animal in question in line with upper tip of adult's ear
c. Activity: Standing

a. Juvenile: Rear of the animal in question in line with middle of the adult's tail
b. Sub adult: Rear of the animal in question in line with upper tip of the adult's tail
c. Activity: Standing

a. Juvenile: Rear of the animal in question in line with adult's ear lower tip/adult's eye
b. Juvenile: Peak of the animal in question in line with the upper tip of sub adult's ear
c. Activity: Standing

a. Juvenile: Forehead of the animal in question in line with sub adult's eye
b. Juvenile: Peak of the animal in question in line with adult's eye
c. Sub adult: Forehead of the animal in question in line with middle of the adult's belly
d. Sub adult: Peak of the animal in question in line with middle of the adult's forehead
e. Activity: Bunching

Photographic Key 2 for captive elephants in closed forest

Note:

a. The following classification uses adult as the reference animal to which the remaining layers are compared to.
b. Specific importance is given to the classification of juveniles and sub adults.

Individuals of a herd (adult females)
Activity: Feeding
Visibility: Close range but in the bush.
Terrain: Uneven
Challenge: Only the peak of the individuals are seen

An adult female
Activity: Feeding
Visibility: Close range and major part of the animal is visible (Ideal situation)

Herd behind a bamboo bush
Activity: Feeding
Visibility: Close range but in the bush.
Terrain: Even
Challenge: The number, age and sex of the individuals cannot be determined

An adult female
Activity: Feeding
Visibility: Close range in the forest
Terrain: Even
Challenge: Due to forest cover the sex of the individual cannot be determined

Sub adult: The rear of the animal in question is in line with the upper tip of adult's tail
Activity: Bunching and dusting
Visibility: Close range but individuals not clearly visible due to the activities
Terrain: Even
Challenge: The calf is completely hidden and mostly rear of the individuals is seen

Sub adult (on the right): The rear of the animal in question is in line with the rear of the adult animal
Activity: Feeding
Visibility: Close range but major part of the body is hidden in the bush
Terrain: Downward sloping
Challenge: Classification based on the differences in height becomes difficult in undulating terrain

Photographic key 3 (as viewed by the reader) for captive elephants descending a slope

Note:

a. The following classification uses adult as the reference animal to which the remaining layers are compared to.
b. Specific importance is given to the classification of juveniles and sub adults.

a . Negative slope
b. Sub adult is at a lesser angle of gradient than the adult and hence can be easily classified

a. Lateral view
b. Negative slope for the elephants
c. Elephants moving in a line
d. The relative size of the sub adult is less than the adults

a. Negative slope
b. Although a negative slope for the reader, the sub adult on the right is at a higher gradient than the adult female on the left and hence their heights match (due to uneven slope)

a. Positive slope
b. Front view
c. The sub adult is the 3rd animal from front.
d. The heights of the 2 two adults and the sub adult matches because of ‘the slope effect’

a. Positive slope
b. Front view
c. The sub adult is the 3rd animal from front
d. The heights of the 2 two adults and the sub adult matches because of ‘the slope effect’
e. Relative size of the sub adult is lesser than the adults

Photographic Key 4 for wild elephants in open and closed forest

a. ***For elephants in open forest:***

Adult male
Activity: Feeding
Visibility: Close range and in the open
Terrain: Even
Ideal situation

Activity: Bathing
Visibility: Close range and only part of the animal
Challenge: Both age and sex based classification is difficult

Herd with animals of different age groups and sex
Activity: Bunching
Visibility: Close range, but smaller members of the herd are hidden by larger ones
Challenge: Classification of the hidden members

Adult male
Activity: Running
Visibility: Close range and in the open
Terrain: Even
Challenge: Bringing the camera into focus at the same time anticipating the animal's movements

Juvenile: The upper tip of the forehead of the animal in question is in line with mouth of the adult
Activity: Bathing
Visibility: Close range and in open
Challenge: Major part of the animal is seen and hence can be classified

Calf: Under the belly of the adult.
Activity: Standing
Visibility: Close range and in open
Challenge: The adult and the calf are used as reference animals to which the other age classes are compared

Herd with animals of different age groups and sex
Activity: Bathing
Visibility: Close range and in the open
Terrain: Even.
Challenges:
a. Some of the herd members in this case the calf is not visible and juveniles, sub adults cannot be classified when in the water
b. Cannot be sure if male or female

Herd with animals of different age groups and sex
Activity: Bathing
Visibility: Close range and in the open
Terrain: Even
Challenge: Some of the herd members in this case the calf is not visible and juveniles, sub adults cannot be classified when in the water

b: For elephants in closed forest or bush:

Adult male
Activity: Feeding
Visibility: Close range and a major portion of the animal is seen and hence classification is possible and is an ideal situation
Terrain: Undulating

Adult female
Activity: Feeding
Visibility: Poor at close range but in forest cover
Challenge: Age and sex classification is difficult from the picture because of the above two factors

Adult male
Activity: Feeding
Terrain: Undulating
Visibility: Close range but in thick bush
Challenge: Although close range only a black background of the animal is visible

Adult female
Activity: Feeding
Terrain: Even
Visibility: Close range but forest cover.
Challenge: Only the rare of the animal is seen and hence age and sex classification is difficult

Appendix –II

The combinations on the basis of age group and the relative position of any 2 individuals (belonging to different age groups)

Age group of animal Individual in question	Compared to	Position
a. Calf	Adult/Sub adult/Juvenile	Head to head
		Rear to rear
		Rear to head (leading)
		Head to rear (following)
		Head parallel
		Rear parallel
		Peak parallel
		Head-rear parallel (anti-parallel)
		Head to belly
		Rear to belly
b. Juvenile	Sub adult/ Adult	Head to head
		Rear to rear
		Rear to head (leading)
		Head to rear (following)
		Head parallel
		Rear parallel
		Peak parallel
		Head-rear parallel
		Head to belly
		Rear to belly
c. Sub adult	Adult	Head to head
		Rear to rear
		Rear to head (leading)
		Head to rear (following)
		Head parallel
		Rear parallel
		Peak parallel
		Head-tail parallel (anti-parallel)
		Head to belly
		Rear to belly

Appendix–III

Activities of individuals/herd (as observed at BBP*)*

a. Dusting
b. Rubbing body against one another
c. Playing/ play fight
d. Laying
e. Feeding (from mother, fodder)
f. Bunching (standing together, leads to blocking of other individuals)
g. Standing (standing separately, the body of an individual available for observation is more)
h. Biting ear of another animal
i. Sniffing the air and trumpeting when alarmed
j. Moving together (2 or more individuals)
k. Moving individually
l. Standing orderly (in a line)

Section 4
Habitat and Corridor

Introduction

Understanding habitat usage by elephants particularly in narrow strips of forest dotted with human settlements is challenging and crucial in determining the status of human-elephant interaction (Anand & Varma 2006) especially when the contiguity of many of these habitats (sub-regions) and the population is maintained by narrow corridors (Varma 2008). The pattern of habitat use is species-specific, which depends on a number of factors like forest status and type, the distribution of food-plant species, the location of human settlement, and cultivated lands over a period of time and space, (Balasubramanian *et al.* 1995; Animon & Cheeran 1997; Sivaganesan & Johnsingh, 1993; Sukumar,1990). Among all these factors, the distribution pattern of food plants (both wild and cultivated) within or surrounded by a given habitat determines the spatial distribution of a given species (Animon & Cheeran 1997; Sukumar 1990). Habitat loss is the single greatest threat to the survival of substantial numbers of wild Asian elephants (AERCC 1998; Varma 2008). When the elephant gets isolated into small pockets of forests without adequate food and water, it raids the neighbouring cultivation, ripe for harvest (AERCC 1998) and may become habituated to crop raiding.

The seasonal and annual requirement of space and vegetation type by elephants is an important consideration in minimizing human-elephant conflict (AERCC 1998). The study area Bannerghatta National Park (BNP) is one such narrow strip of forest dominated by dry thorn scrub forest and dry deciduous forest types in flat lands with moist deciduous forests and bamboo (*Bambusa arundunaceae*) in the valleys. The park is surrounded by fertile, well irrigated croplands where paddy (*Oryza sativa*), ragi (*Elusine coracana*), castor (*Ricinus communis*), maize (*Zea mays*), banana (*Musa paradisiaca*), sugarcane (*Saccharum officinarum*) etc., are grown, which are considered as alternate food source for elephants during the growing and harvesting months of the crops. The current investigation on understanding elephant habitat, corridor usage and elephant distribution is significant, as no systematic surveys or studies on elephants and their status have been conducted in this region. The other purpose of the investigation was to demonstrate the value of short term, but quick synchronized surveys (spread across different years and months) in understanding the spatial pattern of distribution, and habitat usage of the Asian elephant in this high human-elephant conflict region of southern India.

Objectives

This study aims to understand the habitat usage and distribution pattern of elephants in the national park. The following are the objectives of the study:
To study the overall habitat usage pattern of elephants throughout the landscape and to know the trend in habitat utilization over the years.
To study the habitat usage and distribution of elephants at various elevations in relation to the overall altitudinal range and villages that report human-elephant conflict.
To study the usage of Karadikall-Madeshwara corridor region by the elephant.
To study the habitat usage and distribution of elephants in various administrative divisions (ranges) of the park based on habitat utilization pattern. Comparing the pattern with that of density estimates obtained from direct sightings (during the dry season).

The perception behind arriving at the above objectives is as follows:
A study of the overall habitat usage pattern by elephants gives an indication of the extent to which the elephants are dependent on the forest habitat and the surrounding crop fields

for their daily requirements of food, water and shade. An understanding of the dependency and usage of habitat by elephants in different seasons is crucial in mitigating human-elephant conflict. Knowledge on distribution of elephants in the habitat area would help to know whether the distribution is clumped or uniform. Furthermore, possible reasons for the distribution type observed could be arrived at by looking at the pattern.

Since corridors play an important role in conservation of the species it is important to know the extent to which the present corridor is being used by the elephants and also the conflict levels especially in the corridor villages. Increasing conflict in the recent past has resulted in the development of a negative attitude towards the elephants. Focusing Human-elephant conflict issue as a central issue of the park, the habitat usage and distribution of elephants have to be investigated; this includes the investigation of seasonal, altitudinal and administrative range-wise usage.

Except for a study by Varma (2008), no details of the patterns of occurrence of different signs (both fresh and old) for given elephant habitat is available. Old signs may reflect no or earlier presence of elephants and fresh signs are living evidences of elephant presence and utilization of the habitat. Investigation of specific signs (dung or track or feeding or other or a combination of all signs) in a given habitat has several advantages, for example, dung piles are very prominent and easy to locate in the field. Elephants are reported to defecate 16.33 times/day (Watve 1992) and the chances of missing dung signs in the field are less compared to missing out the other signs (Varma 2008).

Investigation of habitat usage across years is important to understand the spatio-temporal variations. Elevation wise details may be related to the presence or absence of specific food or other resources in a given altitude. The elevation wise data also may provide insights of locations of villages that may have crop and other attractants for elephants.

As one of the conflict mitigation measures, the elephant driving or scaring squads chase elephants out of the villages and elephant’s presence and absence (old or new signs) through studies on habitat usage in a given range or village, provides scope for planning driving operations. This approach has several advantages, providing instant results for specific reactions. It provides scope for training a large set of man power resources, including forest department staff, or as good capacity building exercise, it has high repeatability, and the reliability of such data could be tested by the ongoing long term studies.

Methodology

Habitat utilization pattern

To understand the overall habitat usage pattern of elephants, 20 trails were surveyed (Figure 1) during four surveys covering different seasons. These trails covered all forest types, different microhabitats, and administrative zones within the 103 km^2 habitat of BNP. One observer and field tracker(s) walked along these routes.

Data relating to elephant signs (tracks, dung, feeding and other signs), time of sighting, location name and GPS reading whenever possible, number and status of the sign (fresh or old) were documented using a specially designed data sheet (see Appendix-I for figures related to survey and appendix II for data sheet used). A uniform pace was maintained during walking so as to calculate the sighting intervals (in minutes) of each sign.

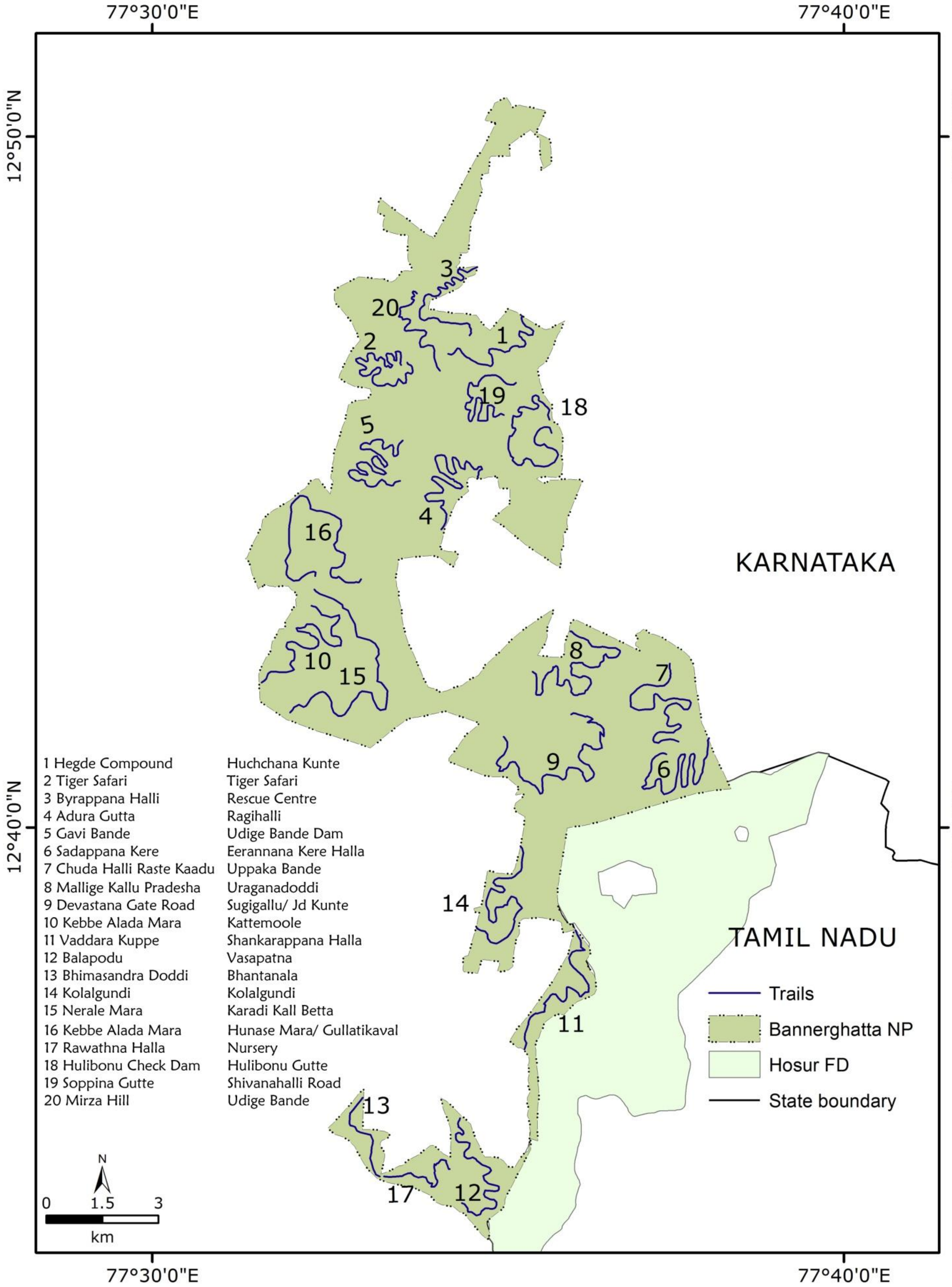

Figure 1: Forest trails used for assessing the status of elephant signs and distribution in the park (Source: ANCF)

The encounter rate/km of elephant signs (inclusive of fresh and old) was calculated by dividing the number of signs sighted in each trail by the distance covered in that trail. The survey also gave a scope for providing the details of the patterns of different signs of elephant (see appendix I for examples of different elephant signs) for the park. Comparison across all the signs was also made to know the trend in habitat utilization. Fresh signs were considered as the true indicators and measure of recent habitat utilization by the elephants as the old signs accumulate over time due to differences in decay rates. Hence fresh signs were chosen to study the habitat utilization and distribution of elephants in the current investigation. The encounter rate/km of all the fresh signs during the same season of two different years were processed and compared to know the trend in habitat utilization.

Karadikall-Madeshwara Corridor usage by elephants

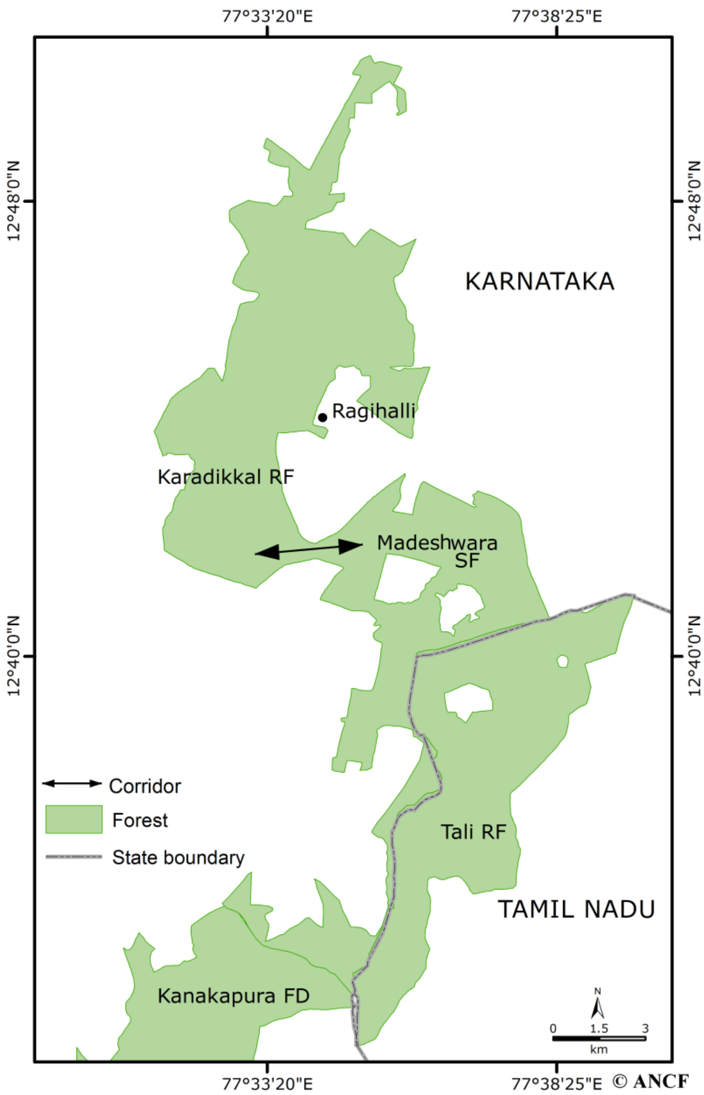

Figure 2: Map showing the location of Karadikal-Madeshwara corridor in BNP (Source: ANCF)

The trails surveyed (3) around the Karadikall-Madeshwara corridor (Figure 2-Varma *et al.* 2006) were grouped under corridor trails, to understand the specific pattern of usage within the corridors, the trails were brought under three micro habitats. The data collected for habitat utilization pattern from the corridor region (3 microhabitats) was processed and the results compared with the corridor utilization pattern across surveys to know the trend within corridor region usage pattern.

Elephant distribution and habitat usage in different elevation and administrative divisions of the national park

The data collected on habitat utilization pattern was used to understand the distribution and density of elephants in the administrative divisions (ranges) of the national park. In each range the encounter rate was calculated by dividing the number of dung piles sighted in the trail surveys at given range by the total number of trail surveys conducted in that range.

This was compared with the density estimates made through direct sightings during the dry season. An attempt was made to determine the distribution of elephants in relation to the altitude of the study area using the GPS readings obtained from the direct sighting of elephants.

Results and Discussion

Pattern of encounter rates of different elephant signs

Elephant dung: A total of 279 dung piles were encountered (average of 14 dung piles/km/trail and a SE of 2.6/trail) during the survey. Only 50% of the trails had fresh dung piles and were sighted on an average of every 12.9 minutes (SE = 1.57/trail) in these trails. The mean encounter rate of old dung piles (week to a month old) dominated with 1.1/km/trail (SE = 0.22). Old dung piles accounted for 81.1% of the total number of dung piles encountered. The encounter rate of fresh dung piles (within a week) was 0.2/km/trail (SE = 0.08) and constituted 19.9% of the total number of dung piles encountered.

Feeding signs: A total of 60 feeding signs were encountered (average of feeding signs 3/km/trail and a SE = 0.8/trail) during the survey. Only 30% of the trails had fresh feeding signs and 25% of the feeding signs were fresh, the rest were old signs. The mean encounter rate of old feeding signs dominated with 0.2 (SE = 0.1)/km/trail. The encounter rate of fresh feeding signs was 0.1 (SE = 0.04)/km/trail. Old feeding signs accounted for 75% of the total feeding signs encountered.

Track signs: A total of 64 track signs were encountered (average of track signs 3.2/km/trail and a SE = 0.9/trail) during the survey. Only 45% of the trails had fresh track signs of which 43% of the track signs were fresh, the rest were old track signs. The mean encounter rate of old track signs dominated with 0.2/km/trail (SE = 0.1). The encounter rate of fresh track signs was 0.09/km/trail (SE of 0.03). Old track signs constituted 57% of the total track signs encountered.

Other signs: A total of 20 'other' signs were encountered (average of other signs 1.0/km/trail and a SE = 0.4/trail) during the survey. Only 25% of the trails had fresh signs of which 35% of the other signs were fresh, the rest were old signs. The mean encounter rate of old 'other' signs dominated with 0.1/km/trail (SE = 0.03). The encounter rate of fresh other signs was 0.03/km/trail (SE = 0.01). Old other signs accounted for 65% of the total other signs encountered.

All signs (combined): A total of 429 signs were encountered (average of signs 21.5/km/trail and a SE = 3.8/trail) during the survey (Figure 3a). Ninety percent of the trails had elephant signs and 61% of these trails (n=18) recorded fresh signs. The mean encounter rate of old signs dominated with 1.7/km/trail (SE = 0.36). The encounter rate of fresh signs was 0.4/km/trail (SE = 0.2). Old signs accounted for 58% of the total signs encountered (see figure 3b for the patterns of fresh and old elephant signs recorded during the surveys).

The distribution of elephant signs fresh or old suggest elephant use entire park all the years. Consistently all the years, two trails had no observations of elephant signs. The result also show only three trials (all located in Northern region of the park) encountered elephant signs all the years.

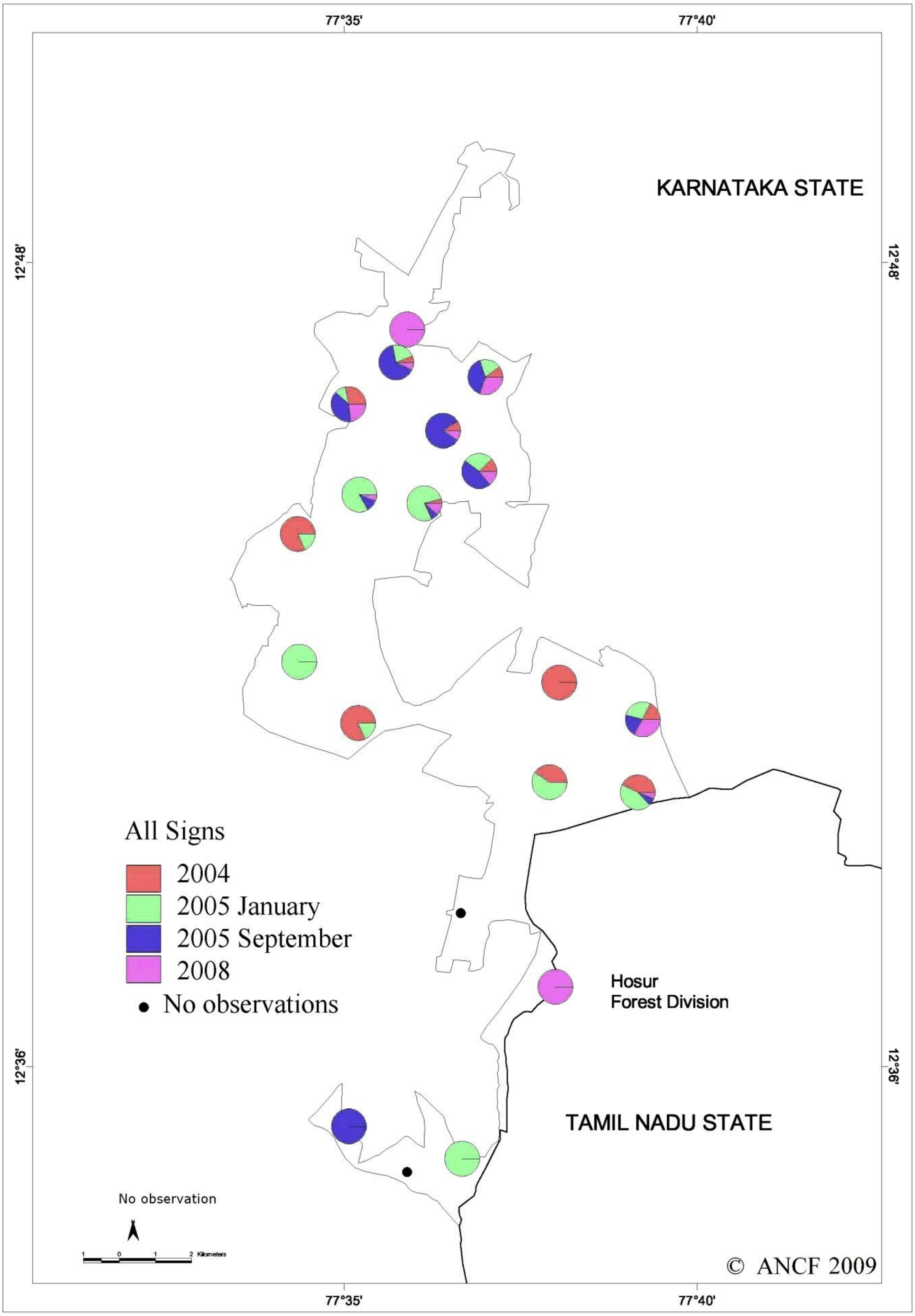

Figure 3a: Distribution of elephant signs recorded during forest trails surveys in the park (Source: ANCF)

Figure 3b: Patterns of fresh and old elephant signs recorded during forest trails surveys in the park (Source: ANCF)

A comparison of the encounter rates of signs obtained from the four surveys

Mean percentage of old signs appeared for each survey was high (Figure 4) and the percentage of occurence of old and fresh signs across the survey period may not be different.

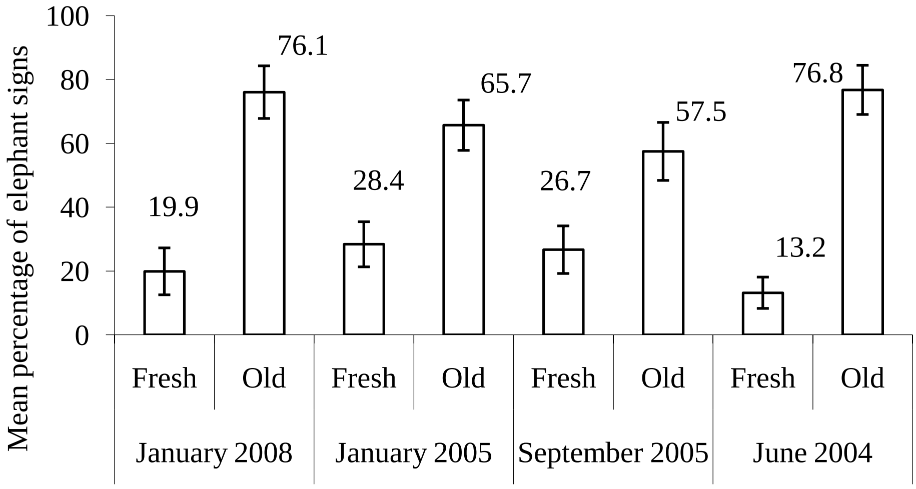

Figure 4: The mean percentage of fresh and old signs is plotted against the different survey periods

The old dung piles may stay for longer periods of time than expected in the system and if only fresh dung piles are used the results may show a difference in the pattern of results. The results from the four surveys (Table 1) for fresh signs indicate that the elephants are using this habitat uniformly all through the year; the mean encounter rates of elephant signs for all the years are not different ($p > 0.05$ for all the years). Habitat selection is determined by identifying the disproportionate use of habitats (Johnson 1980), however the results suggest that, irrespective of the years, the habitats have been uniformly used by elephants in the national park.

Table 1: Comparison of the mean encounter rate/km of all the signs from the four trail surveys

Sl. No	**Details of the sign**	**Survey 1 Mean (SE)**	**Survey 2 Mean (SE)**	**Survey 3 Mean (SE)**	**Survey 4 Mean (SE)**
1	Mean encounter rate of fresh dung piles/km/trail	0.11 (0.04)	0.30 (0.08)	0.34 (0.12)	0.22 (0.08)
2	Mean encounter rate of fresh feeding signs/km/trail	0.04 (0.03)	0.06 (0.03)	0.14 (0.06)	0.08 (0.04)
3	Mean encounter rate of fresh track signs/km/trail	0.14 (0.05)	0.21 (0.09)	0.19 (0.08)	0.09 (0.03)
4	Mean encounter rate of fresh signs/trail	0.38 (0.11)	0.74 (0.21)	0.71 (0.24)	0.43 (0.16)

But if only the fresh dung piles were considered across the years, there was a difference between the results of the 1st and 2nd surveys ($z = 2.2$, $p < 0.05$) but for other periods of surveys, number of fresh dung piles encountered/km were silimar (p>0.05 for survey 3 and 4). Large herbivore mammals have accurate spatial memory and have the ability to use spatial memory to improve foraging efficiency; primarily, the distribution pattern of large mammals appears to result from decision making process made on a variety of spatial and temporal scale. With such abilities the animals could return to nutrient rich sites more frequently than to nutrient poor sites (Bailey 1996).

A comparison of the encounter rates of signs for similar months of different years (January 2005 and January 2008)
A comparison of the two trail surveys shows that the mean encounter rates of fresh signs are not significantly different across two similar months of the two years (p>0.05), data of mean encounter rate of fresh dung piles, feeding signs, tracks and other signs are also similar (not statistically different p>0.05 in all cases) for both these years, clearly indicate a uniform usage of the habitat by the elephants in this season (Table 2). It can be assumed that, if habitat is uniform (in terms of vegetation type) and not fragmented (within the park), elephant may use the habitat uniformly. The random distribution and the relatively low abundance of food species may also result in wider movement or distribution of elephants in search of food plants (Varma 2008).

Table 2: Comparison of mean encounter rates of signs of trails surveys held during the same months of different years.

Sl. No.	Details of the sign	January 2005 Mean (SE)	January 2008 Mean (SE)
1	Mean encounter rate of fresh dung piles/km/trail	0.30 (0.08)	0.22 (0.08)
2	Mean encounter rate of fresh feeding signs/km/trail	0.06 (0.03)	0.08 (0.04)
3	Mean encounter rate of fresh track signs /km/trail	0.21 (0.09)	0.09 (0.03)
4	Mean encounter rate of fresh signs/trail	0.74 (0.21)	0.43 (0.16)

Distribution of elephants in relation to the altitude, based on direct sighting of elephants in the dry season
During the study period, elephants were found in altitudes (Figure 5) ranging from 785 to 970m above msl; with 24% of the elephants in the range of 758 to 820m, 5% of the elephants in the range of 845 to 895m and 71% of the elephants in the range of 922 to 970m above mean sea level.

The park elevation starts from 698 to 1035 m, with an average of 932m and about 65 % of the park area falls under the elevation of 800 to 1000m, and more sightings of elephants in 920 to 970 m range may be related to more area falling under this elevation range. There could be a relation between elephant sightings and the altitudinal location of villages plagued with conflict (where crops are cultivated and crop damage, human death and injury, structural damages and elephant deaths/injuries are reported).

The Mean elevation of the villages studied was 819 (SE = 8.63, N 110) and ranged from 683 to 1030m. Elevation in relation to 110 villages where conflict is reported suggests only 20% of the villages fall under 900 to 1000 m (range where more sightings of elephants were reported). Villages that have more conflict status and claimed high number of compensation from the forest department for conflict issues are located in the range of 800 to 900m. That is low lying areas around the national park.

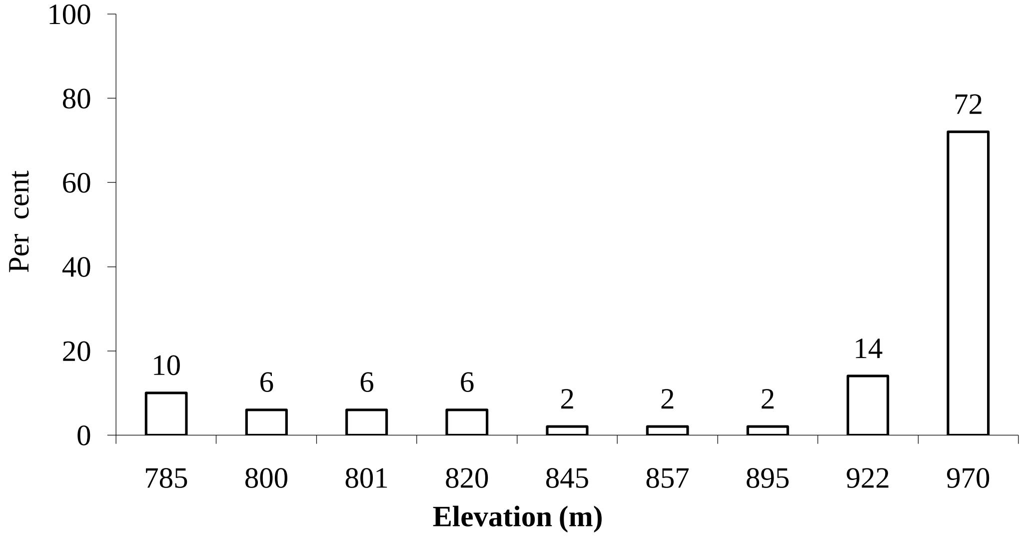

Figure 5: Variation in the distribution of elephants with altitude when the numbers of elephants were plotted against the altitudes

Karadikall–Madeshwara corridor usage pattern of elephants
Usage across different years

No fresh signs were sighted during January 2008 and September 2005 surveys, and the mean number of fresh signs (all categories) sighted for June 2004 and January 2005 were not different ($z=1.94$, $p>0.05$). If all the signs of old and fresh were combined and the differences were tested, there would not be any statistical difference in the results as the variance around each mean was very wide and it may overlap (Figure 6).

Usage pattern across similar months of different years

The results of corridor usage (using all the signs of both fresh and old) is presented in Figure 7 and there is no difference ($z=0.55$, $p>0.05$) in the encounter rates of all the sings (fresh and old) for the months of January (January 2005 and 2008), which suggests that the elephants have similar pattern of using the corridor during this month, even though they are of different years.

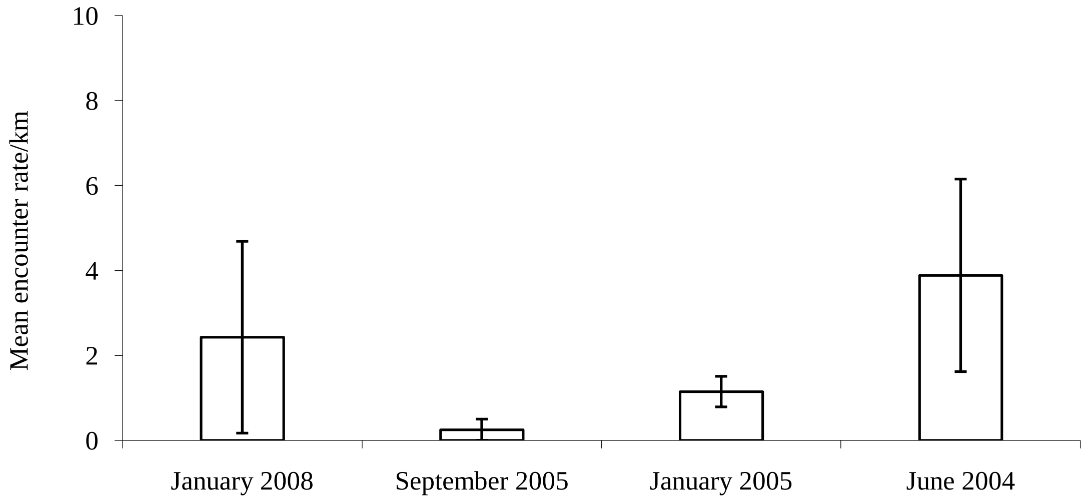

Figure 6: Mean encounter rate across the seasons

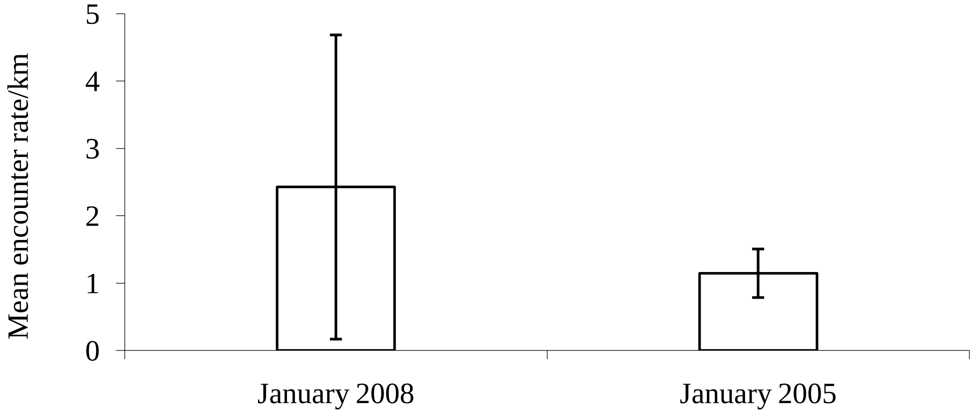

Figure 7: Mean encounter rate of all signs in January 2005 and 2008

Usage pattern during dry season

The trails falling within the corridor region were brought under three micro habitats (Figure 8). None of the microhabitats falling under the corridor region recorded fresh signs. However microhabitats 1 and 2 recorded only old signs. Microhabitat 1 recorded 70.1% and microhabitat 2 recorded 30% of the total number of signs found in the three microhabitats.

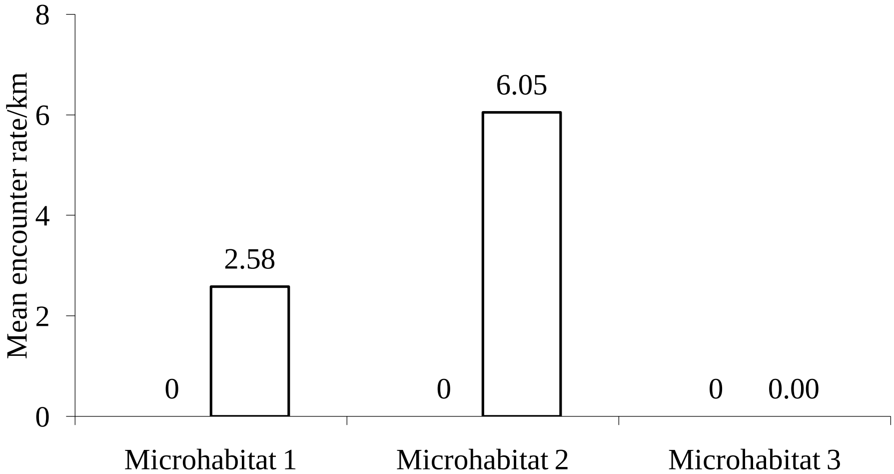

Figure 8: Mean encounter rates (/km) of old signs in different microhabitats

A comparison of the habitat usage pattern in the three microhabitats in January 2005 and January 2008 (Table 3) suggests an increase in the usage of the habitat over the years but is also indicative of the fact that the proportions of usage of the microhabitats have remained similar. Furthermore the absence of any fresh signs in the microhabitats suggests that elephants are not using this habitat extensively during the dry season.

Table 3: Comparison of habitat usage of the microhabitats in January 2005 and January 2008

Details of the dung Signs	**Microhabitat 1**		**Microhabitat 2**		**Microhabitat 3**	
	Jan 05	Jan 08	Jan 05	Jan 08	Jan 05	Jan 08
Mean encounter rate of dung piles (km/trail)	0.77	2.17	0.10	1.55	0	0

Habitat usage by elephants in the three ranges (Bannerghatta, Harohalli and Anekal) of the park

Encounter rates of signs

Elephant dung: A comparison of the three ranges with respect to the encounter rates of dung piles indicates that the Bannerghatta range recorded the highest number of dung piles (n=156) in relation to the area surveyed. Furthermore, it also recorded the highest number of trails with fresh dung piles (87.5%) and highest number of fresh dung piles (19.8%). In Anekal range about 50% of the trails recorded fresh dung piles and 12.5% of fresh dung piles of the total number of dung piles were recorded in this range.

For Bannerghatta range, the mean encounter rate of old dung piles (week to a month old) dominated with 1.6/km/trail (SE = 0.26). The mean encounter rate of fresh dung piles (within a week) was 0.4/km/trail (SE = 0.42). For Harohalli range the mean encounter rate of old dung piles dominated with 0.9/km/trail (SE = 0.3). The mean encounter rate of fresh dung piles was 0.04/km/trail (SE = 0.04). For Anekal range the mean encounter rate of old dung piles dominated with 0.7/km/trail (SE = 0.4). The mean encounter rate of fresh dung piles was 0.14/km/trail (SE of 0.12).

Feeding signs: Bannerghatta range recorded the highest number of feeding signs (n=23) in relation to the area surveyed. It also recorded the highest number of trails with fresh feeding signs (62.5%) and the highest number of fresh feeding signs (52.2%). This was followed by Anekal range with 25% of the trails recording fresh feeding signs and 15% of the fresh feeding signs of the total number of signs recorded in this range. In Bannerghatta range, the mean encounter rate of old feeding signs (week to a month old) was 0.16/km/trail (SE = 0.08). The mean encounter rate (Figure 9) of fresh feeding signs (within a week) was 0.2/km/trail (SE = 0.10) slightly higher than the old feeding signs. In Harohalli range, the mean encounter rate of old feeding signs dominated with 0.3/km/trail (SE = 0.20) and no fresh signs were recorded. In Anekal range, the mean encounter rate of old feeding signs dominated with 0.2/km/trail (SE = 0.2). The mean encounter rate of fresh feeding signs was 0.06/km/trail (SE = 0.07).

Track signs: Bannerghatta range recorded the highest number of track signs (n=30) in relation to the area surveyed and it also recorded the highest number of trails with fresh track signs (87.5%). The highest number of fresh track signs, calculated per total tracks within each range, (71.4%) was recorded in Anekal followed by Bannerghatta range with 50% of the trails recording fresh track signs (Table 4).

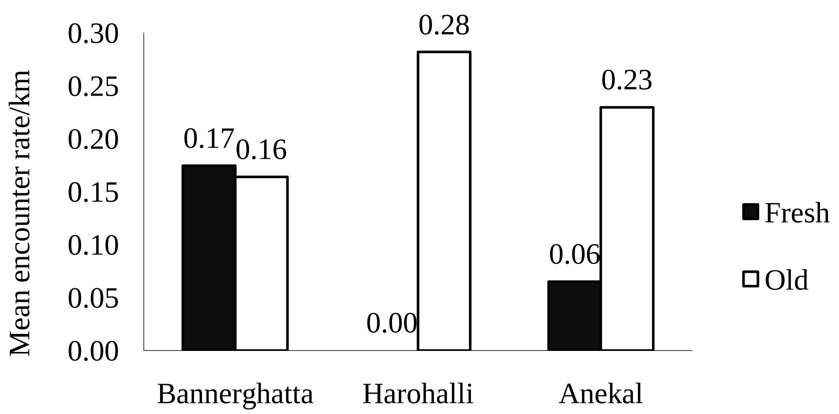

Figure 9: Shows the mean encounter rate of fresh and old feeding signs in all three ranges of the national park

Table 4: Comparison of the details of track signs between the three ranges of the national park

Sl. No.	Details of the signs	Bannerghatta	Harohalli	Anekal
1	Number of trails	8.0	8.0	4.0
2	Number of track signs	30.0	27.0	7.0
3	Average number of track signs/trail	3.8	3.4	1.8
4	Trails with track signs (%)	100.0	50.0	50.0
5	Trails with fresh track signs (%)	87.5	0.0	50.0
6	Fresh track signs (%) of the total number of track signs	50.0	0.0	71.4

In Bannerghatta range, the mean encounter rate (Figure 10) of old track signs (week to a month old) was 0.2/km/trail (SE = 0.1). The mean encounter rate of fresh track signs (within a week) was 0.2/km/trail (SE = 0.05) slightly higher than the old track signs. In Harohalli range, the mean encounter rate of old track signs dominated with 0.3/km/trail (SE = 0.20) and no fresh signs were recorded. In Anekal range, the mean encounter rate of fresh track signs dominated with 0.1/km/trail (SE = 0.03). The mean encounter rate of old track signs was 0.03/km/trail (SE = 0.06).

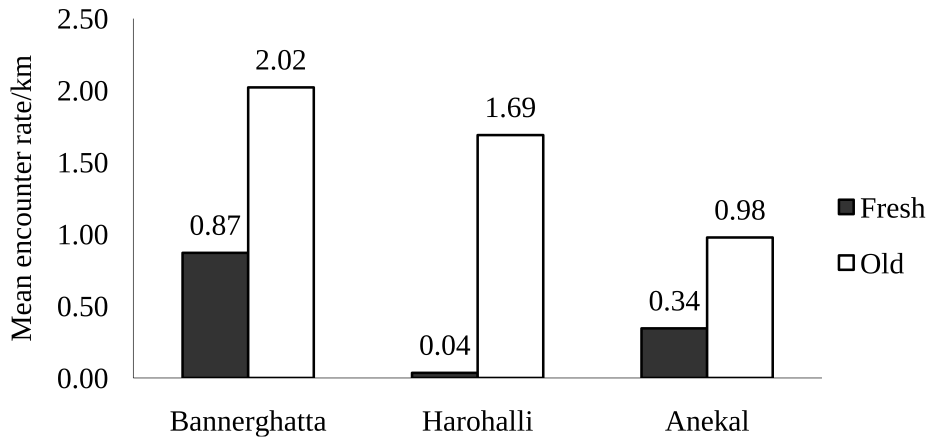

Figure 10: Mean encounter rate of fresh and old track signs in the three ranges of the national park

Fresh and old signs (combined): Bannerghatta range recorded the highest number of signs (n=222) in relation to the area surveyed and it also recorded the highest number of trails with fresh signs (100%). The highest number of fresh signs (28%) was recorded in Bannerghatta Range followed by Anekal Range with 20% fresh signs and Harohalli Range with only 0.9% of the signs being fresh.

In Bannerghatta range, the mean encounter rate (Figure 11) of old signs (week to a month old) was 2.0 /km/trail (SE = 0.50). The mean encounter rate of fresh signs (within a week) was 0.8/km/trail (SE = 0.3). In Harohalli range, the mean encounter rate of old signs dominated with 1.7/km/trail (SE = 0.7) and fresh signs with 0.04/km/trail (SE = 0.04) were recorded. In Anekal range, the mean encounter rate of old signs was 1.0/km/trail (SE = 0.28). The mean encounter rate of fresh signs was 0.3/km/trail (SE = 0.7).

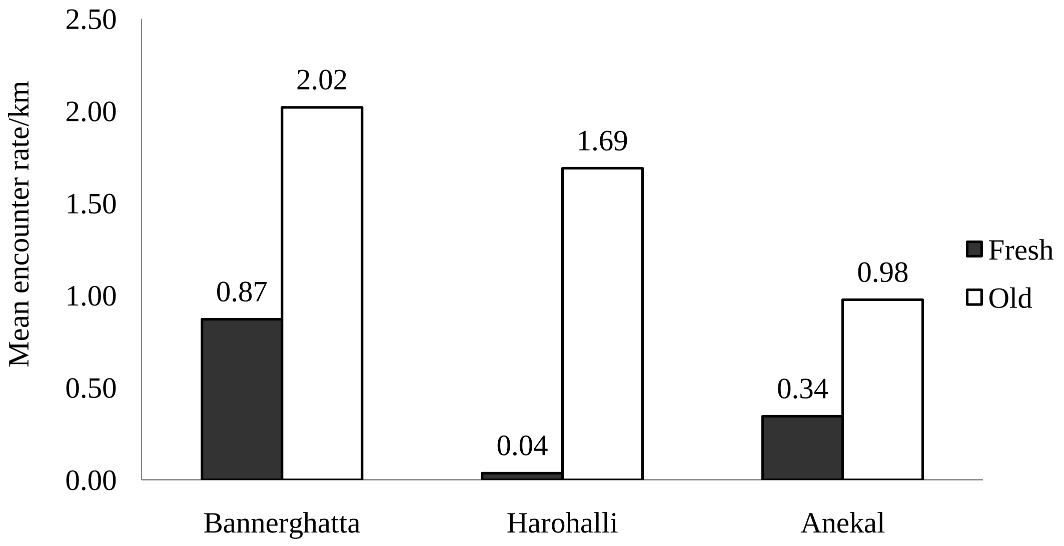

Figure 11: Mean encounter rate of fresh and old elephant signs in the three ranges of the national park

A comparatively higher percentage trails with fresh signs were observed in Bannerghatta Range followed by Anekal and Harohalli Ranges (least) are supported by the fact that 66.7% of the total number of direct sightings having been recorded in Bannerghatta Range, 33.3% of direct sightings in Anekal Range and no direct sighting of elephants in Harohalli Range during the trail surveys.

The results of the mean encounter rates of fresh signs/km (Table 5) show that there is difference between the encounter rates of fresh signs of Bannerghatta and Harohalli range ($z=2.49$, $p<0.01$) and there is no difference between the encounter rates of Bannerghatta and Anekal ($z=1.22$, $p>0.05$) and between Harohalli and Anekal ($z=1.06$, $p>0.05$).

This may suggest the pattern of habitat usage by elephants for Bannerghatta-Anekal and Harohalli- Anekal are similar. An estimate based on the population demography showed a density of 1.15 elephants/km^2 for Bannerghatta Range and 0.5 elephants/ km^2 for Harohalli Range.

Table-5: Comparison of the details of all signs between the three ranges of the national park

Sl. No.	**Details of the signs**	**Bannerghatta**	**Harohalli**	**Anekal**
1	Number of trails	8.00	8.00	4.00
2	Number of signs	222.00	117.00	90.00
3	Trails with fresh signs (%)	100.00	12.50	50.00
4	Mean encounter rate of fresh signs/km/trail (SE)	0.87 (0.33)	0.04 (0.04)	0.34 (0.28)

Distribution patterns are affected by factors such as slope, distance to water and foraging quantity & quality and disturbance levels. In general, food, water and shade are the three basic resources that can be expected to influence the movement of a large herbivore such as the elephant (Sukumar 2003).This clearly indicates that Bannerghatta and Anekal Ranges of the national park were used more extensively by the elephants than Harohalli Range during this season.

Conclusion

The results of the study reveal consistent use of habitat by elephants in the national park across the years. The usage of corridor by elephants is also uniform across the years and similar during certain months of two different years. The similarity in the patterns of utilization of habitats and corridor across the years clearly indicates that elephants have a strong affinity to habitat, which may also be linked to their learning process (of the status or availability of resources) which may help them to know more about the habitat and utilize them accordingly. Any disturbance to the habitat or elephants may have a negative effect on their long term survival.

The elephants seem to confine themselves to specific ranges of the park (Bannerghatta and Anekal ranges during the dry season) which may meet their daily needs of food, water and shade. The range specific results indicate that elephants prefer Bannerghatta and Anekal ranges of the park over the Harohalli range during this season. The possible reasons for this may be the availability of water source, feeding grounds and shade. In addition to the forest habitat, these areas are also surrounded by cultivable lands, some of which are cultivated all through the year thus forming an additional source of fodder for the elephants. The lesser extent of elephant distribution in the Harohalli range could be mainly due to the non-availability of water and high degree of human disturbance. The conservation of elephants in habitats such as BNP cannot be viewed in isolation as it forms a part of the elephant reserve number 7 (a larger elephant habitat area).

The less preferred habitat of Harohalli Range is connected with Anekal Range via the Karadikall–Madeshwara corridor and also has contiguous forests with Bannerghatta Range. Therefore the corridor plays a pivotal role in facilitating the movement of elephants within the national park and to the other elephant habitats as well. In addition, research on the seasonal movement, preferred elephant food species and crop raiding patterns within the national park area, and their surroundings settlements will provide vital insights into the habitat utilization pattern of elephants and thus help mitigate human-elephant conflict in the study area.

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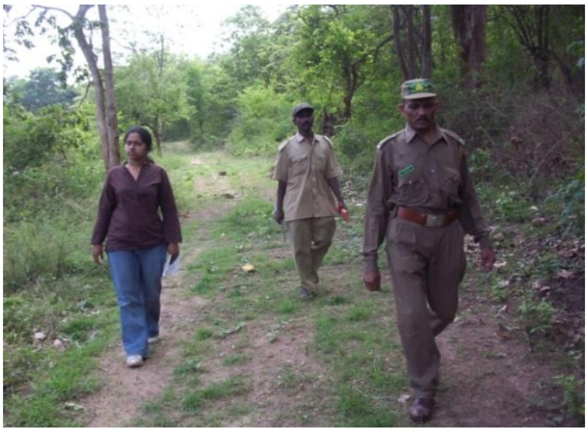
Appendix-I

Additional figures showing the habitat usage pattern survey carried out using trail surveys

a

b



c

d

e

f

a: Introduction to the trail survey, b and c: The team, including forest department staff looking for elephant signs, d: Mapping trails using a GPS instrument , e and f:Elephant signs in the form of dung and feeding signs

Appendix-II

Elephant habitat usage survey through trail survey Bannerghatta National Park, southern India

Observer: Range: Date:

Name or number of the trail:
Location/name/GPS:
Starting:
Closing:
Time Starting: Closing:
Distance covered (km):

Details of the signs encountered:

Vegetation				**Elephant signs**				
Sl. No	Time interval[1]	Name of the plant (local) [2]	Remarks	Sl. No.	Time of sighting	Type of sign[3]	State of sign[4]	Remarks
1		1						
		2						
		3						
		4						
2		1						
		2						
		3						
		4						
3		1						
		2						
		3						
		4						
4		1						
		2						
		3						
		4						
5		1						
		2						
		3						
		4						

1: Time interval: Approx 30 minutes **2: Name of the plant:** identify nearest 4 trees **3: Type of signs**: Elephant dung, track, feeding, sound (of elephant) and others 4: **State of Sign**: Very Fresh (VF one day old) Fresh (F 2 to 3 days old) Old (O above 3 days).

If the distance covered (for plant data) and number of signs encountered is more than the space available in this datasheet, please use a separate blank sheet to complete/continue the records.

Ecological Status, Land Use and Pattern of Human-Elephant Conflict in and around Elephant Corridors*

Introduction

Corridors play an important role in the conservation of Asian elephants and its management, particularly when habitats are fragmented, disturbed and are inadequate for their usage as a passage (Venkataraman *et al.* 2002; Varma *et al*. 2005; Varma 2008). Wildlife corridors that link fragmented habitats (of protected areas, territorial forest divisions, private and revenue forests and lands) provide a strategy for offering pathways for survival in landscapes heavily impacted by humans (Chapman 2006). Linking up existing better quality forest patches through strips of lands with similar habitat (corridors) offers the much needed contiguity for genetic flow and mitigates the negative biological impacts of habitat fragmentation (Soule 1986). Therefore, when the remaining available habitats are extensively fragmented, properly planned corridors would ensure a viable form of long-term management and continuity of the species, and may also reduce man animal conflict (Prabal *et al*. 2008).

Understanding corridor usage by elephants is an essential tool for elephant conservation particularly in BNP, where habitat around the periphery of the park is highly fragmented and infested with road networks, developmental and stone quarrying activities. The management of the park is challenged by its ongoing severe elephant human conflict issue (Rajeev 2002). One of the efforts required to mitigate the problem is to first understand the land use around the park, in addition to the habitat usage by elephants which includes the corridor region of the park across the seasons. Habitat or corridor usage by elephant may be influenced by the quality and extent of area available for the species. Keeping these aspects in mind, this investigation attempts to understand overall status of the corridor through the objectives presented below.

Objectives

The broader objective is to understand the overall status of the corridor region; specific objectives are as follows:
To study the floral diversity and its associated factors around the corridor region
To study the overall land use pattern more specifically the pattern of cultivations, road networks, settlements, other developmental activities around the corridor
To link the influence of land use pattern to the status of human-elephant conflict in the corridor region

The above objectives were arrived from the following concepts.
The natural vegetation adjoining the corridor may act as both shelter and as a feeding place for the elephants. However, local community’s dependency on forest resources through activities such as wood cutting, fires and over grazing by cattle makes it an unsuitable feeding ground and shelter for elephants. This pattern influences the need for critical analysis of the status of vegetation adjoining the corridor.

The findings on the extent and quality of the natural vegetation around the corridor region may also be useful in the decisions on augmenting adjoining areas to the corridor. While natural vegetation-cover around the corridor act only as shelter, the land use such as agricultural cultivation may become attractive alternative feeding sites for elephants.

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*With inputs from Nimmy Varkey, A Rocha India, # 23 Anjaneya Street, Austin Town, Bangalore and H.S.Suresh, Centre for Ecological Science, Indian Insitute of Science, Bangalore

In the process, the local communities incur losses due to crop damage-leading to severe human-elephant conflict. This necessitates the importance of knowing the major land use pattern and the status of conflict around the corridor region (Figure 1). The wise or unwise pattern of land use by the local community may also have a positive or negative impact on the quality of the habitat for elephant and other wildlife that depend on it.

Figure1: An overview of the Karadikall – Madeshwara elephant corridor

Methodology

The area selected for this study comprises of a 3 kilometre radius around the Karadikall-Madeshwara elephant corridor. There are five human settlements falling within this radius namely the Biliganakuppe, Jaipurdoddi, Vijayappandoddi, Godurudoddi and Shivanahalli which are at a distance ranging from 0.25 to 2.85 km from the corridor.

Floral diversity and sampling

Floral studies were based on the description and investigation of plant communities in the field and then the floral segments were sampled through analysis of representative sub areas or stands within the recognized segments. The first part of the vegetation study was in identifying and demarcating the microhabitat for the study, which fell under the private forest lands on one side of the corridor towards the settlement called Jaipurdoddi. Within the microhabitat, 3 sites were selected for vegetation studies (Figure 2; see Appendix I for additional figures related to sampling).

Figure 2: Study of flora by point centred quadrant method

The sampling technique adopted was the point centred quadrant (PCQ) method. A distance of 500 meters was walked in each site of the microhabitat. At every 50 meter point interval, four nearest trees were enumerated for species name, distance of the tree from the line of walk, Girth at Breast Height (GBH), canopy cover, ground cover and every form of human disturbance observed during the time of the study, was recorded. Champion and Seth's classification (1968) system was adopted for the identification of vegetation types. Names of species were confirmed using local flora and field guide (Bhat 2000; Mathew 2001) through consolidation with the herbarium at the Centre for Ecological Sciences, Indian Institute of Science, Bangalore. The data obtained was then analyzed using computer programme PAST, Biodiversity Pro (www.biodivesityprofessional) and EstimateS (www.uub.kentuky). Standard vegetation parameters associated to species diversity such as dominance, diversity indices, evenness and equitability were computed along with measures of species dispersion, similarity and diameter distribution.

Landscape Survey

Each landscape is composed of several landscape elements which appear as patches and are distinguishable in size, shape, type, heterogeneity and boundary characteristics. Each of the landscape elements has its own above mentioned characteristics and significance in ecosystems and is thus important in evaluating landscape structure (Ravan *et al*. 1995). Thus the landscape mapping of the five villages was undertaken to understand the land use pattern of the study area. The mapping of each landscape element within each village up to one kilometer radius from the center of the village was accomplished by field surveys.

Landscape Analysis

The data on land use pattern of each village collected through field surveys was grouped into human habitation, public facilities, water resources, public infrastructure, agricultural land, unusable land and natural vegetation. The aspects such as the number of houses with and without backyard, vegetable garden, houses under construction were grouped under human settlements (Figure 3 as an example of landscape survey near a settlement). These details play an important role in the understanding of the community dependency on forest.

Figure 3: Landscape Survey

The number of schools, hospital and places of worship were considered as public facilities. Water resources mainly covered the number of water towers, water tanks, bore wells and natural water bodies such as streams and ponds. The number of main roads and connecting roads, even though poorly maintained were considered as public infrastructure. Agricultural land consists of lands with plantations and the cultivated land, even though some of these were not under cultivation at the time of study. Barren land, rocky hills and mining areas were accounted as unusable land and forest was considered as natural vegetation (Figure 3). The averages under each category were computed to understand the land utilization pattern in the study area from which the dominant landscape element for each village was found out.

Crop damage assessment

In order to justify the relationship between forest cover/status and the patterns of cultivations/land use pattern on human-elephant conflict, five villages were selected and the status of conflict in these villages was investigated. These villages were located at an average distance of 1.5 km from the corridor. The compensation claims made by farmers for the crop loss due to depredation by elephants from the period 1999 to 2005 was collected from the Forest department. The records were analysed to find out the total number of compensations claimed, the peak conflict season, the crop types, the total land area cultivated and affected due to crop raids**.**

Results and Discussion

Floral diversity and its associated factors

Species Abundance

The total number of tree species identified was 41, spread over 132 individuals. The species found in abundance were *Lagerstroemia parviflora* and *Acacia chundra* with 14 individuals each and *Terminalia crenulata* with 11 individuals, accounting for 30% of the total floristic composition of the microhabitats. Out of the 41species, 18 species were represented as single individuals (Table 1).

Table 1: Relative and Cumulative Abundances of various species found in all Microhabitats

Sl. No.	Scientific Name	Abundance	Relative Abundance	Cumulative Abundance
1	*Lagerstroemia parviflora*	14	10.6	10.6
2	*Acacia chundra*	14	10.6	21.2
3	*Terminalia crenulata*	11	8.3	29.5
4	*Maytenus emarginata*	6	4.5	34.1
5	*Anogeissus latifolia*	5	3.8	37.9
6	*Diospyros montana*	5	3.8	41.7
7	*Elaeodendron glaucum*	5	3.8	45.5
8	*Buchanania lanzan*	5	3.8	49.2
9	*Diospyros melanoxylon*	5	3.8	53.0
10	*Acacia auriculiformis*	4	3.0	56.1
11	*Wrightia tinctoria*	4	3.0	59.1
12	*Cassia fistula*	4	3.0	62.1
13	*Azadirachta indica*	4	3.0	65.2
14	*Ficus religiosa*	4	3.0	68.2
15	*Ficus benghalensis*	4	3.0	71.2
16	*Shorea roxburghii*	3	2.3	73.5
17	*Dalbergia lanceolaria*	3	2.3	75.8
18	*Semecarpus anacardium*	3	2.3	78.0
19	*Terminalia chebula*	3	2.3	80.3
20	*Anacardiaceae family*	2	1.5	81.8
21	*Tectona grandis*	2	1.5	83.3
22	*Dolichandrone atrovirens*	2	1.5	84.8
23	*Ixora nigricans*	2	1.5	86.4
24	*Zizyphus mauritiana*	1	0.8	87.1
25	*Dalbergia latifolia*	1	0.8	87.9
26	*Albizzia amara*	1	0.8	88.6
27	*Premna tomentosa*	1	0.8	89.4
28	*Pongamia pinnata*	1	0.8	90.2
29	*Ficus exasperate*	1	0.8	90.9
30	*Erythrina suberosa*	1	0.8	90.7
31	*Scutia myrtina*	1	0.8	92.4
32	*Styrax benzoin*	1	0.8	93.2
33	*Grevillea robusta*	1	0.8	93.9
34	*Cordia dichotoma*	1	0.8	94.7
35	*Bridelia retusa*	1	0.8	95.5
36	*Chomelia asiatica*	1	0.8	96.2
37	*Grewia tiliifolia*	1	0.8	97.0
38	*Grewia asiatica*	1	0.8	97.7
39	*Sapindus emarginatus*	1	0.8	98.5
40	*Vitex altissima*	1	0.8	99.2
41	*Flacourtia indica*	1	0.8	99.9
	Total	**132**	**99.9**	

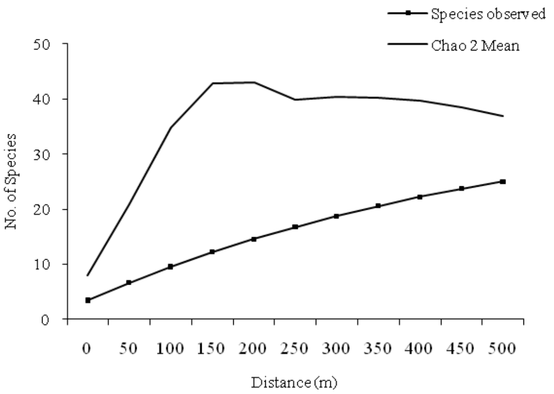
Diversity pattern

The various estimates of diversity for different sites within the microhabitat are given below (Table 2). Higher number of species was encountered from site 1; species dominance also appeared to be similar for all the sites with 11 % individuals represented by one species.

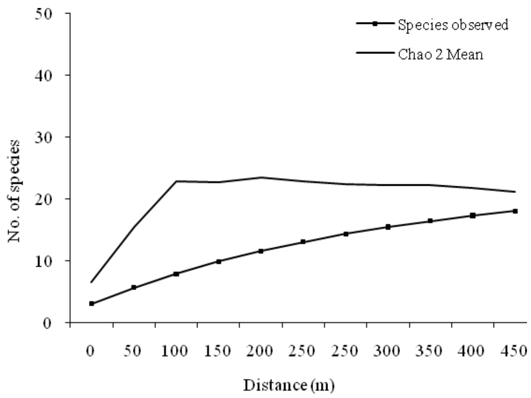
Table 2: Shows diversity pattern across the sites in the microhabitat

	Site 1	Site 2	Site 3
Taxa	25.0	19.0	18.0
Individuals	44.0	44.0	44.0
Dominance	0.1	0.1	0.1
Shannon	3.1	2.7	2.5
Equitability		0.9	0.9

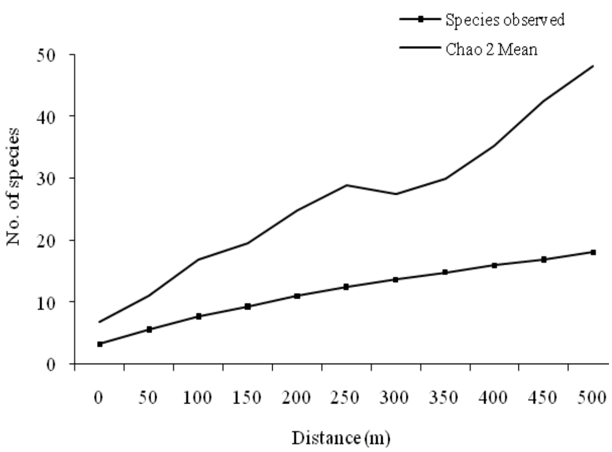
The observed number of species did not show an asymptote, indicating the potential for species accumulation with sampling effort. The predicted curve based on species estimator (Chao's estimate) also indicated the scope for intensive sampling i.e. there is more scope for species to accumulate (Figure 4a, b & c)



Site 1



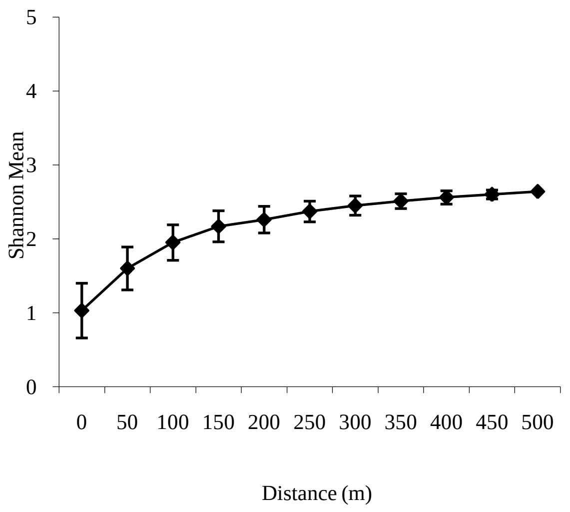
Site 2



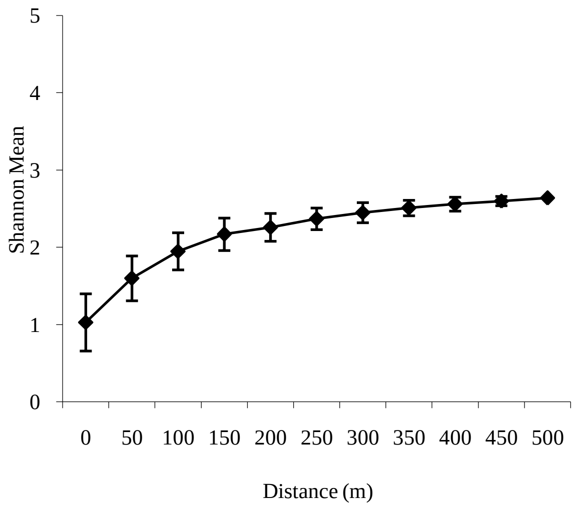
Site 3

Figure 4 a, b, & c: Species Accumulation across the three sites

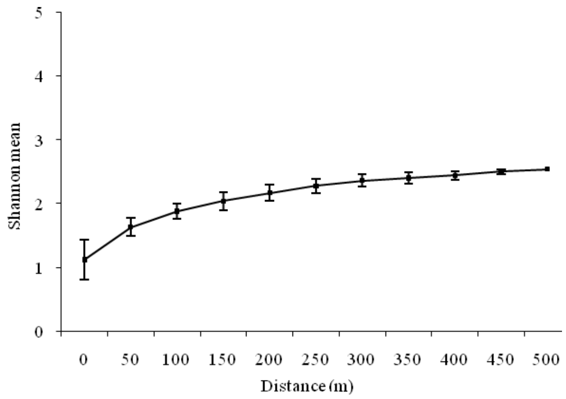
Accumulation of heterogeneity was plotted across the three sites in the microhabitat (Figure 5). It is clear from the figure that the variability in heterogeneity reduces along the microhabitat. In fact at the 400 meter length the variability starts reducing indicating that the variability would have been captured by the 400 meters.



Site 1



Site 2



Site 3

Figure5: Shannon–Wiener Index across the three sites

Measure of species similarity

Cluster Analysis was based on presence or absence of a given species in the microhabitat. The two most similar sites in this matrix are combined to form a single cluster. The cluster analysis of the microhabitats shows that there is more similarity between site 1 and 3 than site 2 and 3, and between sites 2 and 1 (Table 3).

Table 3: Measure of Similarity across the Microhabitat

Similarity Matrix	Site ***1***	Site ***2***	Site ***3***
Site 1	*	33.33	38.64
Site 2	*	*	23.81
Site 3	*	*	*

Diameter distribution among the sites sampled

The results of diameter distribution across 3 different sites are presented in the Figure 6. The difference was tested using the non parametric statistical test Kolmogorov Smirnov sample test (K-S). The test is used to check the difference in distribution of sites given variable.

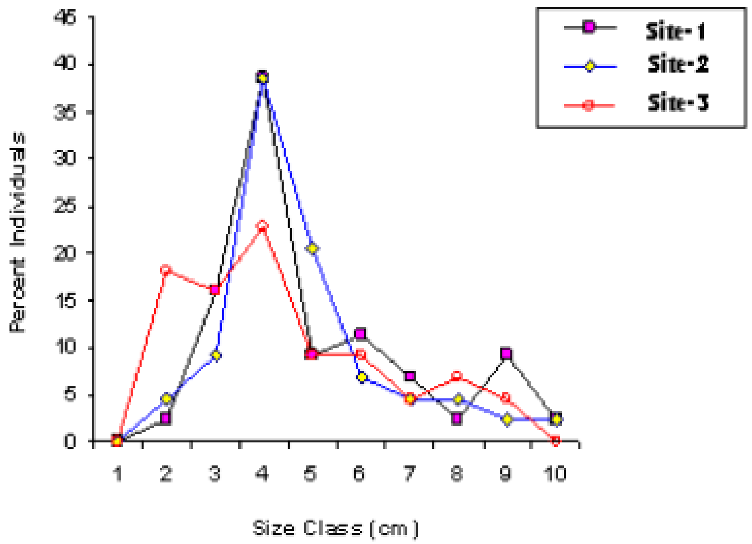


Figure 6: Diameter distribution of the three sites. The graph is prepared by plotting the diameter size class (cm) against the percentage individuals

Table 4: Diameter distribution between different sites in the microhabitat

		Site 1 and 2	Site 1 and 3	Site 2 and 3
D	Difference	0.1818	0.0909	0.0909
P	Probability	>0.10	>0.10	>0.10

Table 4 given above shows that the diameter distribution across 3 sites is not significantly different.

Basal Area

The basal area across the sites of the microhabitat was 0.18 m^2/ha for site 1, 0.64 m^2/ha for site 2 and 0.21 m^2/ha for site 3.

Species dispersion

Species dispersion was measured as mean to variance ratio. In site 1, *Lagerstroemia parviflora* showed significant aggregated dispersion (mean = 0.36, variance = 0.85, x^2 = 24, df = 10 and p=0.009) even at 500m length. *Ficus religiosa* and *Ixora nigricans* showed significant random dispersion pattern (mean = 0.18, variance = 0.36, x^2 = 20, df = 10 and p=0.029) even with very low sample size. In this site, other species showed insignificant random dispersion.

For site 2, *Lagerstroemia parviflora* showed significant random dispersion (mean = 0.73, variance = 1.41, x^2 = 19.5, df = 10 and p=0.034) and others showed insignificant random dispersion. In site 3, no species showed significant random dispersion.

Human influenced disturbances

The finding on human disturbances across the sites (Figure 7) clearly indicates the following activities as the major source of disturbances: manmade paths constituting 38% followed by firewood collection with 34% and man induced forest fires with 21%. The combination of the above mentioned disturbances together accounts for 93% of the disturbance

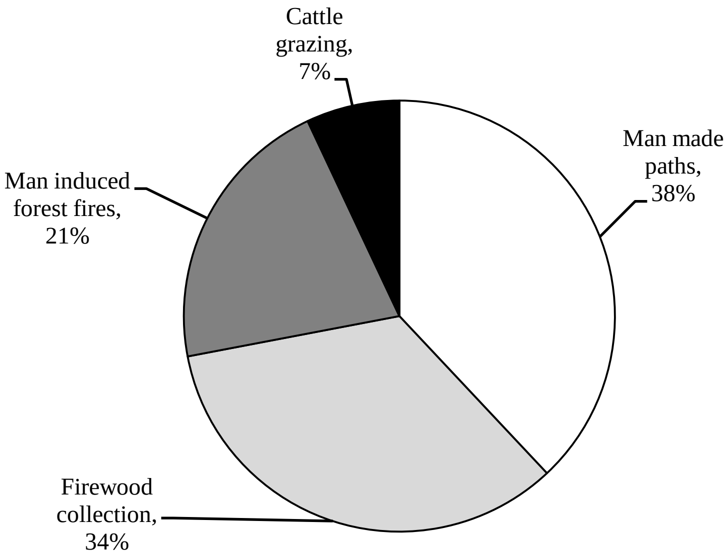


Figure 7: Human influenced disturbances: Proportion of different types of human influenced disturbances across the sites in the microhabitat

A comparison of other diversity patterns and human disturbances (Table 5) indicate that human disturbance is highest in site 3 and is the least in site 2. It further implies that human disturbances such as manmade paths, firewood collection, fodder and animal grazing may have a significant effect on diversity.

Table 5: Comparison of Diversity Pattern and Human distribution across the sites

Site	**No. of Individuals**	**No. of species**	**Shannon Weiner Index (H)**	**%Canopy Cover (Avg)**	**%Ground cover (Avg)**	**% Human disturbance**
1	44	25	3.06	25.6	36.3	61.3
2	44	19	2.69	30.7	36.3	47.7
3	44	18	2.54	21.6	39.7	68.2

Landuse pattern in villages around the corridor region

(a) Biliganakuppe: The landscape elements identified within 1 km radius of this village were human habitation, public facilities, water resources, public infrastructure, agricultural land and natural vegetation. Among the human habitation category, there were 93 houses recorded with backyards for cattle shed and firewood storage. This is clear indication of dependency of forest for cattle and fire wood. In the category of water resources, the village had a stream running adjacent to it, two manmade ponds, one water tower and one water tank.

The public facilities had two temples and a school which was located at two different locations within the village. The public infrastructure comprised of 14 connecting roads and 3 main roads. Within 1 km radius of this settlement there was no rocky hill or barren land, while most of the land was under cultivation. Major Landscape Elements of Biliganakuppe: Among the different element types, the dominant landscape was found to be agricultural lands accounting for 80% of the total land area as shown in Figure 8. Human settlements accounted for 7.9%, while public facilities was 0.3%, water resources was 0.4%, public infrastructure accounted to 1.3% and natural vegetation being the second highest, accounted for 10% of the total land area.

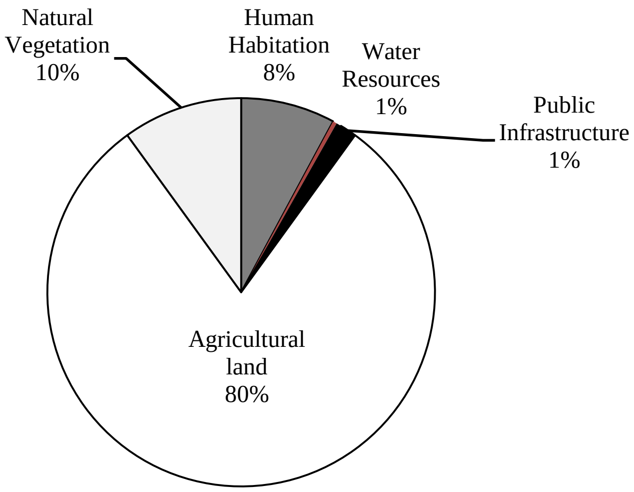


Figure 8: The proportion of major landscape elements of Biliganakuppe

(b) Jaipurdoddi: A detailed study of the land use pattern around Jaipurdoddi, the second closest corridor dependant village, showed that the major landscape element identified were human settlements, public facilities, water resources, public infrastructure, agricultural land, unusable land and natural vegetation (Figure 9).

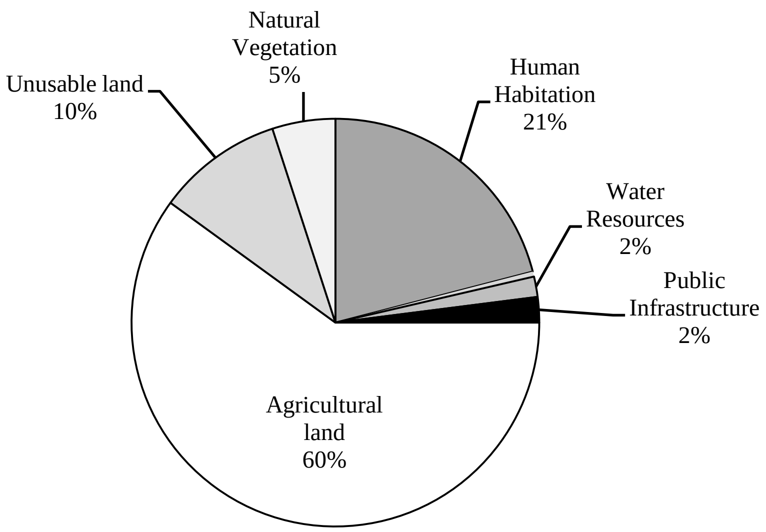


Figure 9: Proportion of major landscape elements of Jaipurdoddi

This settlement which is at a distance of 0.5 km from the elephant corridor was found to have a human habitation of 51 houses, out of which 48 houses (94 %) had backyards which were very well maintained with vegetable gardens and space for cattle and firewood. The public infrastructure was not well maintained yet the 4 connecting roads and the single main road made the village well connected. The village was also characterized by rocky hills of which, some were subject to mining activity just about 1 km from the village.

Since the village was at a distance of 1.15 km from the corridor, natural vegetation bordered one side of the village and accounted for 10% of the total land area. The dominant landscape element was agricultural lands accounting for 60% of the total land area, followed by human settlements which accounted to about 21%. Comparatively Jaipurdoddi was found to be a smaller settlement than Biliganakuppe.

(c) Vijayappanadoddi: The land use pattern of this settlement which is at a distance of 3 km from the elephant corridor included an elephant proof barrier erected at a distance of 0.25 km from the village. The different landscape elements of the village were found to be human habitation, water resources, public infrastructure, agricultural land, unusable land and natural vegetation. This village was found to have human habitation comprising of 18 houses. It had no public facilities like a temple or a school. The people got their water resources from a bore well and a single water tank right at the centre of the village. The village was very small and had only one road, which bifurcated into 2 connecting roads.

The dominant landscape elements of this settlement were natural vegetation and unusable land which together covered about 70% of the total land area followed by agricultural land accounting for 25% of the total land area (Figure 10). The natural vegetation which was otherwise known as the forest area was at a distance of 0.25 km from the village signifying the fact that the settlement had extended towards the park boundary and the kind of impact this would have on the forest area is comprehensible.

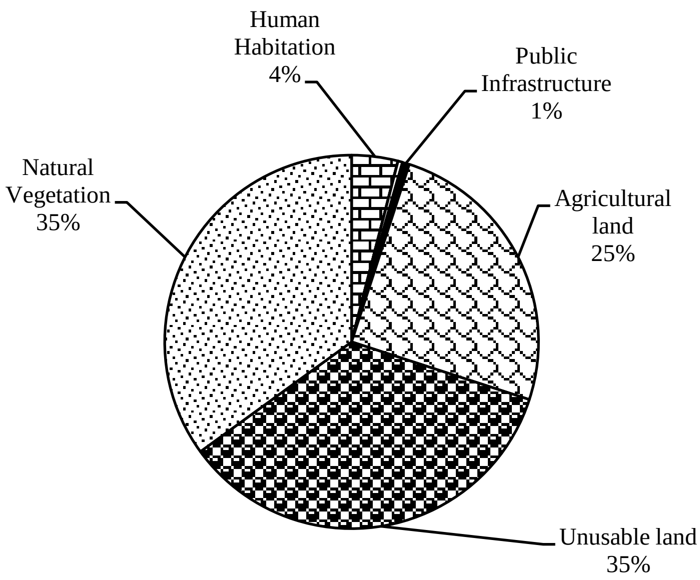


Figure 10: Proportion of major landscape elements of Vijayappanadoddi

(d) Godurudoddi: Godurudoddi was the smallest settlement among the 5 villages sampled. It was 2.3 km away from the center of the corridor and the elephant barrier erected was at a distance of 0.5 km .The land use pattern of this settlement showed that the different landscape elements of this village were human settlements, public facilities, water resources, public infrastructure, agricultural lands, unusable land and natural vegetation. The human settlements comprised of 13 houses accounting for 7.2% of the total land area. The 13 households depended on a single bore well for their water resources. Most of the households did not use land for cultivation, hence it was barren and unusable accounting for 10%. The dominant landscape element was agricultural land covering 60% of the total land area, which was constituted mainly of private estates belonging to three different landowners followed by natural vegetation accounting for 20% of the total land area (Figure 11).

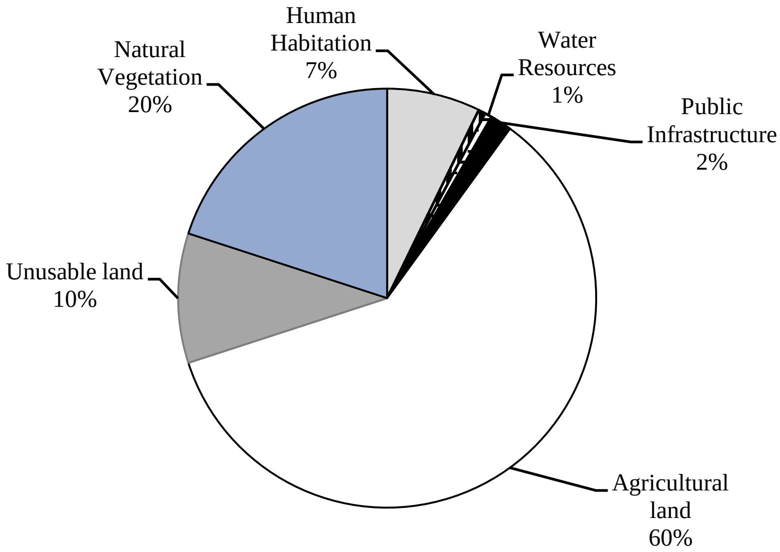


Figure 11: Proportion of major landscape elements of Godurudoddi

e) Shivanahalli: The land use pattern of Shivanahalli, which is 2.85 km from the corridor, revealed that the different landscape elements of this settlement were human habitation, public facilities, water resources, public infrastructure, agricultural lands and unusable land. This village was the biggest in comparison to the other four villages under study with human habitation (116 households) covering 12 % of the total land area. The dominant landscape element was agricultural land accounting for 50% of the total land area followed by unusable land accounting for 35% of which major portion was a rocky hill which was subjected to mining activity (Figure 12).

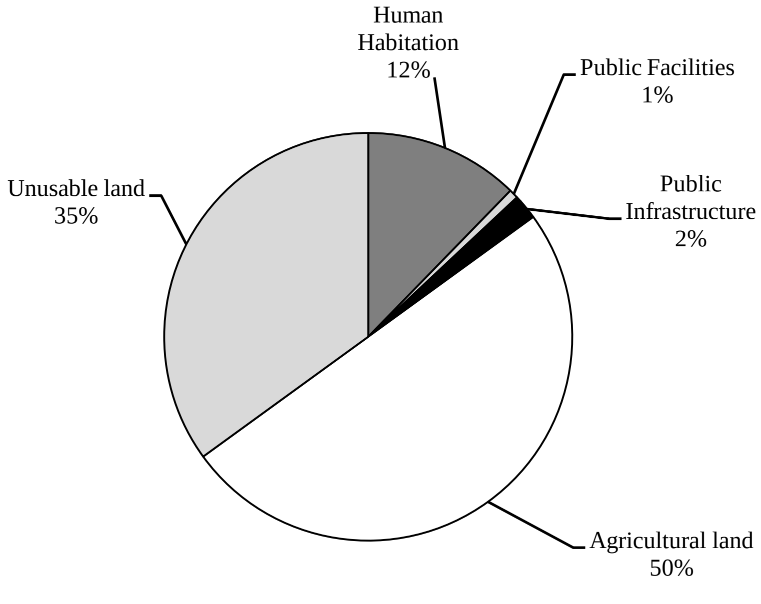


Figure 12: Proportion of major landscape elements of Shivanahallii

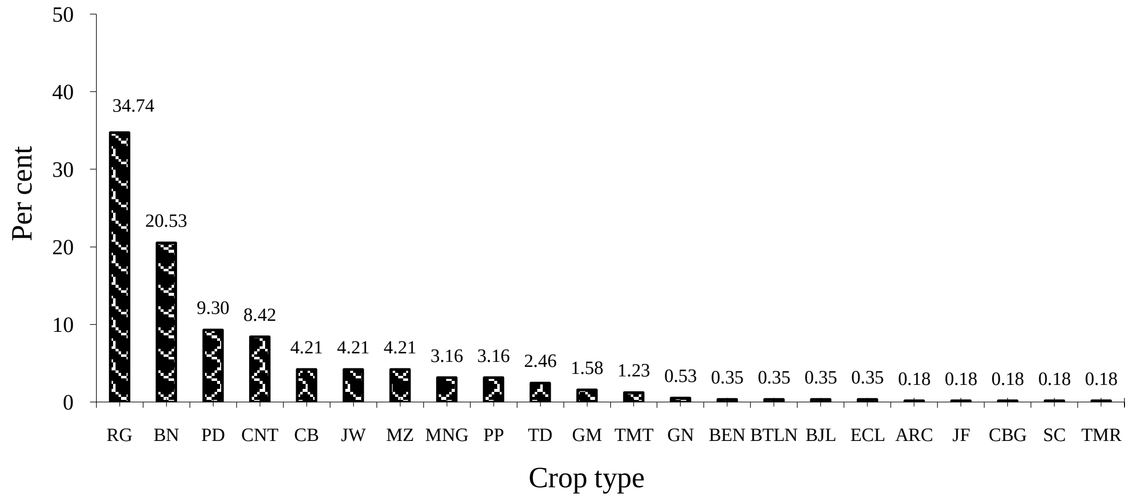
Status of human-elephant conflict around corridor region

i) Cultivation pattern

The cultivation pattern of the study area showed that different crops were grown by the farmers within the 5 study villages: Ragi (*Eleusine coracana*), Banana (*Musa paradisiaca*), Paddy (*Oryza sativa*), Coconut (*Cocos nucifera*), Cluster beans (*Cyamopsis tetragonoloba),* Jowar (*Sorghum bicolour),*Maize (*Zea mays*), Mango (*Magjifera indica*), Pigeon pea (*Cajanus cajan),* Tomato (*Lycopersicon esculentum),* Ground nut (*Arachis hypogaea*), Great millet (*Sorghum vulgare*), French beans (*Phaseolus vulgaris*), Brinjal (*Solanum melongena),* Areca (*Areca catechu),* Jack fruit (*Artocarpus heterophyllus*), Cabbage (*Brassica oleracea),* Eucalyptus (*Eucalyptus globulus*) Sugarcane (*Saccharum officinarum)* and Tamarind (*Tamarindus indica*) (Figure 13).

Within the 22 cultivated crops, Ragi accounted for 34% of the total crops grown and was also the most damaged crop during the study period. The other major crops grown were Banana (20%), Paddy (9%) and Coconut (8%). This was followed by Cluster beans, Jowar and Maize each accounting for 4% of the total crops cultivated.

Mango was 3% and the other crops such as Pigeon pea accounted for 2%, Great millet for 1.5% and Tomato was 1.2% of the crops grown. Ground Nut, French beans, Brinjal, Areca, Jack Fruit, Cabbage, Eucalyptus, etc., were found to be cultivated to a very small extent.



RG=Ragi, BN=Banana, CNT=Coconut, CB=Cluster bean, JR=Jowar, MZ=Maize, MNG=Mango, PP=Pigeon pea, TD=Tur dal, GM=Great millet, TMT=Tomato, GN=Ground nut, ECL=Eucalyptus, BEN=Beans, BTLN=Betel nut, BJL=Brinjal, ARC=Areca, JF=Jack fruit, CBG=Cabbage, SC=Sugarcane, TMR=Tamarind

Figure 13: Cultivation pattern in the study area: Percentage of crop cultivated is plotted against crop types

Patterns of crop compensation claims

An average of 66 compensations was claimed from the 5 villages under study for the period of 1999-2005. From a total of 463 compensations claimed, Biliganakuppe was found to have claimed 338, which is 73% of the total compensation claims. The reason being its location which is at a distance of 1.75 kilometres from the boundary of the elephant corridor and a very significant factor being that it has 80% of its land area under cultivation which would have attracted the elephants. The trend in compensation claims from 1999 to 2005 has shown a gradual increase in the number of claims for the focus villages; with the maximum of 167 claims in the year 2005 and a minimum of 22 claims in 2001. From Figure 14, it is clear that except for 1999 to 2001 there was a gradual increase in compensation claims. The pattern of less number of claims for compensation during 1999-2001 may be due to the farmer's poor awareness on the compensation scheme.

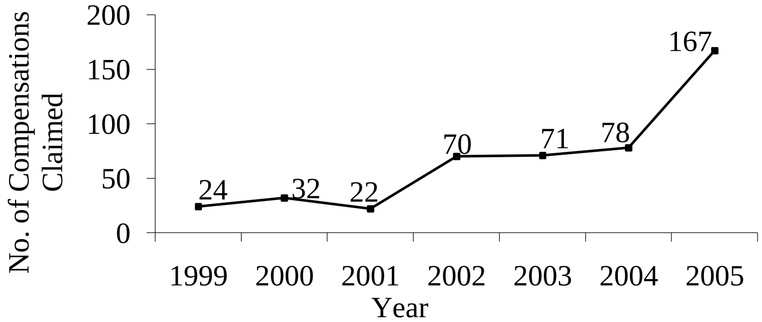


Figure 14: Compensation Claims for Crop Damage: The number of compensation claims is plotted against the year of compensation claimed, assessed and paid

Peak conflict months

Crop depredation occurred throughout the year with the minimum being in both March and June (4%),the other months, September, accounted for 5% followed by January, April, May, July and October with 6%, February with 7% and August with 8%. Inspite of the conflict being reported throughout the year, November and December together accounted for 40%, reflecting to be the peak conflict season. The ground surveys also suggests similar results, as the period of harvesting, storing and processing of crops correlates with the peak period of conflict.

Conflict in relation to pattern of cultivation and distance from the corridor

With regard to the conflict in relation to the percentage area cultivated for each village, the villages located close to the corridor reported damage to an area of 0.0046 to 0.01 (Table 6) acre and villages located away from corridor reported 0.001 to 0.013 acre of damage.

Table 6: Pattern of conflict around corridor and non-corridor villages

Sl. No.	**Village name**	**Distance from the Corridor (km)**	**% Natural forest around the village**	**Percentage cultivated land around the village**	**Crop damage/ year/ha**	**Damage in relation to % area cultivated**
1*	Biliganaguppe	1.75	10	80	0.374	0.0046
2*	Jaipurdoddi	0.5	5	60	0.246	0.0041
3*	Shivanahalli	2.85	0	50	0.354	0.0071
					Mean	**0.00526**
					SE	**0.00114**
					% CV	**21.7**
4**	Buthanahalli	18	30	60	0.79	0.013
5**	Thattiguppe	15	10	80	0.078	0.001
6**	Ragihalli	10	10	80	0.16	0.002
					Mean	**0.00533**
					SE	**0.00471**
					% CV	**88.4**

*Corridor villages; ** non Corridor villages

Mean damage for both the regions appeared to be similar; however the level of conflict for 2 villages away from the corridor was very low as compared to villages located close to the corridor. The percentage precision around the mean damage for the corridor villages was high and it was low for villages away from the corridor.

Conclusion

The results depict the corridor region to be an area of high plant diversity, the forest cover within the region covered only about 2 km^2, but was represented by 41 species and 18 species were represented by only one individual, which could also reflect that the region is an area of higher species rarity. There was more similarity between sites 1 and 3 compared to sites 2 and 3. The diameter distribution across the 3 sites was not significantly different. With this ecological significance, if the region is annexed to the corridor region, it may increase the width of the corridor by another 150m to 200m.

The major anthropogenic disturbances observed at the study site varied from firewood cutting to cattle grazing. Among the signs of human disturbance in the study site, manmade paths accounted for 35%, which was followed by firewood cutting and collection which accounted for 24% of the signs. These anthropogenic disturbances may influence the viability of the Karadikall-Madeshwara corridor for usage by elephants.

The survey of the settlements around the Karadikall-Madeshwara corridor shows agriculture to be the major land use practice. An analysis of the crop compensation claims records also suggest agriculture to be the major occupation of the communities living around the corridor area. Further, it is inferred that the crops cultivated are rain fed. The dependency of the community on the natural vegetation in the study area appeared to be high. It was also found that Ragi, Paddy and Coconut were cultivated more, indicating the cultivation pattern to be rain fed. So, in order to sustain themselves, the local communities appear to be accessing the vegetation around the Karadikall-Madeshwara corridor area for subsistence use.

The results indicate that the status of human–elephant conflict around the corridor appears to be high compared to other villages located away from corridor. The pattern of conflict in relation to the percentage of area cultivated in a village suggests that the villages located closer to the corridor have higher conflict status when compared with other villages located away from corridor. Considering the narrowness of the corridor (length being 1 km and width 0.3-0.4 km), if the corridor usage by elephants is high, the human-elephant conflict in the surroundings can be expected to increase further.

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Appendix -I

Additional figures giving details of the investigation of landscape elements and land use pattern around the corridor region

a b

c d

e f

a: Corridor terrain and land cover, b: Firewood collection in the forest adjoining the corridor, c: Research team enumerating the vegetation, d: Agricultural farming in the corridor region, e: Interviewing the local community, f: Mapping of landscape elements within the village

Section 5
Part 1
Human-Elephant Conflict

Assessment of the Extent of Human-Elephant Conflict and Economic Loss due to Crop Depredation by Elephants

Introduction

An uncontrolled increase in habitat fragmentation, human settlements and their crop fields and changes in land use patterns around elephant habitats have brought the elephants closer to humans more than ever before (Sukumar 1989; Easa & Shankar 1999; Nath & Sukumar 1998; Prabal *et al.* 2008). Elephants today are losing not only their habitats but also their migratory corridors at an alarming rate. Human induced developments over the period of years have resulted in the fragmentation and degradation of elephant habitats and have restricted these animals into ever shrinking islands of habitation; forcing populations into greater contact with human populations, resulting in increased conflict (Basappanavar & Kaveriappa 2007). Some proximate causes of crop raiding suggested by previous studies are: compression of elephant populations (Ratnam 1984; Hoare 1997), rainfall patterns (Hoare 1997), increase in cultivated area and human movement in elephant habitats (Blair *et al*. 1979) and natural preference of crops by elephants (Sukumar 1989).

The human-elephant conflict is deleterious to both the parties involved, initially harmful to humans as their crops, property and at times even lives are lost due to elephants and then to the elephants as humans retaliate. This is also a cause for concern as it threatens to erode the local support for conservation in conflict areas (Williams & Johnsingh 1997). An increase in the conflict is a clear indication of the increasing pressure on an already strained human-elephant relation. This is especially true for the subsistence farmers of India who are a majority and are the most affected too.

Bannerghatta National Park is a fragmented elephant habitat surrounded by 117 revenue villages located within 5 km radius from the park boundary with a human population of around 1,07,082 people (Anand *et al.* 2006). The highly fragmented nature of this national park, coupled with a relatively high density of elephants and the cultivation of elephant preferred crops such as paddy (*Oryza sativa*), banana (*Musa paradisiaca*) and ragi (*Eleusine coracana*) has resulted in an epic battle between the 'crop cultivators' and the 'crop raiders' with the 'crop raiders' (elephants) being looked at as the antagonist. Although the park is one among the high conflict regions in India, no scientific studies have been carried out on a full scale or at least on a scale of selected villages; there was opportunity to investigate the conflict in detail.

Objectives

The main objectives are as follows
Assess the status of human- elephant conflict in selected villages
Assess the economic loss due to the conflict, more specifically due to crop damages

The objectives were evolved through the following concept
Although the land use pattern surrounding the elephant habitat and the foraging requirements of elephants may be the proximate causes for crop raiding by elephants, the exact cause/s are yet to be unravelled. Answers to these queries will allow us to address the role that loss and degradation of habitat plays in forcing elephants to seek forage requirements from cultivated lands, as opposed to elephants resorting to crop raiding simply because crops are more palatable and nutritious than wild fodder (Sukumar 1989).

Around 83.7% of the population living around the park area are marginal, subsistence and small farmers prone to chronic poverty and suffer from enormous economic losses in the event of raids by elephants. Even though an ex-gratia amount is paid to the farmers by the State Forest Department, the amount does not always fully compensate the loss which could be owed due to the lack of information on the actual economic losses incurred by the farmers. The assessment of the economic losses due to crop depredation by elephants is expected to fill up the gaps in the knowledge on the economic loss.

Methodology

To understand the status of conflict, seven villages namely Buthanahalli, Thattiguppe, Ragihalli, Biliganaguppe, Chudahalli, Linganapura and Shivanahalli were selected (Figure 1).

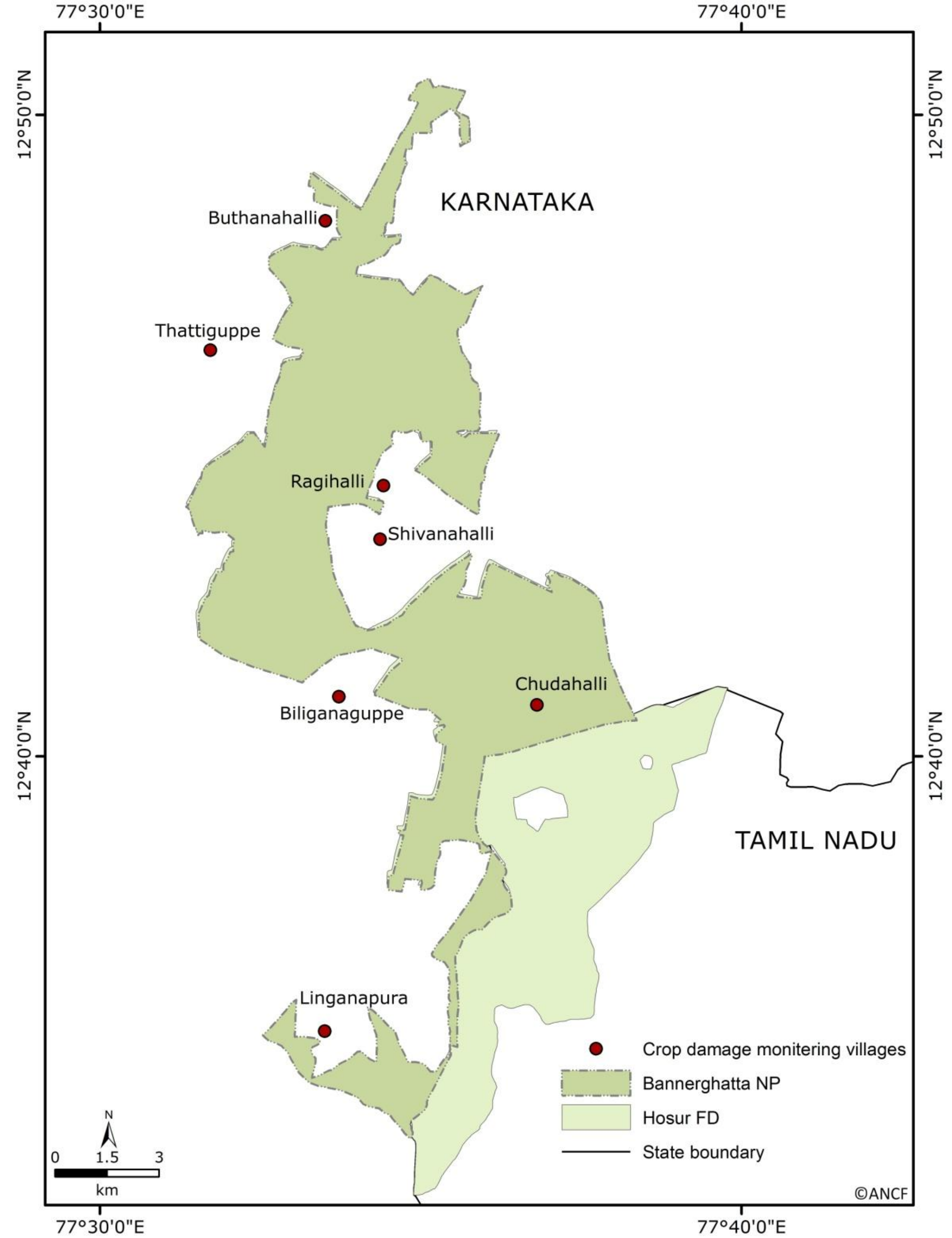


Figure 1: Map showing locations of the villages selected for crop damage monitoring (Source ANCF)

The selection was based on the intensity of conflict in these villages which was assessed from the crop compensation claim records and direct observations of crop damages. The selected villages were geographically well distributed covering different regions of BNP.

An informer was appointed in each of these villages to work as a local resource person to the researcher. The villages were monitored once in a week by the researcher irrespective of the elephant visit (Figure 2; see Appendix I for additional figures related to crop damage incidents and their assessment).

Data relating to elephant village visit such as: number, type of crops cultivated, total area of cultivation, damaged crop, total area of damage, infrastructural damage, economic loss, etc., were quantified and recorded on a specially designed data sheet (see Appendix-II). Although the monitoring was initiated in 2005, the status of conflict for the period January 2007 to March 2008 alone is being presented here.


Figure 2: Assessment of crop damage by a researcher

To understand the economic loss due to crop damages, the crop compensation claim records and data on actual crop damages for the seven study villages were assessed. The data relating to 1) name of crop damaged, 2) total area of crop cultivated, 3) total area of crop damaged, for the seasonal crops were quantified. The data on average yield per acre of cultivation for different crops were collected from the University of Agricultural Sciences (Anonymous 2007). The market price of the cultivated crops was collected from the Department of Agricultural Marketing and Karnataka State Agricultural Marketing Board’s online Agricultural Price Information System.

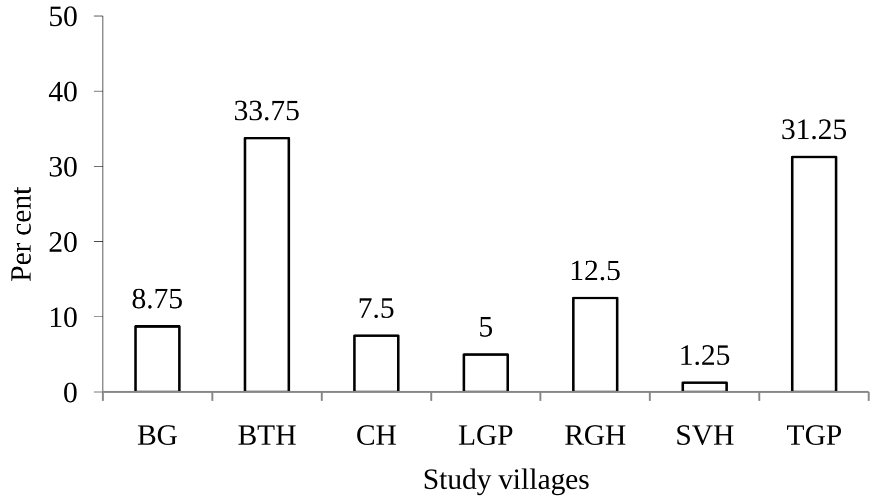
Results and Discussion

Status of human-elephant conflict

Village wise elephant visits

An assessment of the number of elephant visits to each village will give a clear indication of the extent and intensity of conflict. The results (Figure 3) indicate that Buthanahalli (BG) and Thattiguppe (TGP) have recorded the most number of elephant visits during the study period followed by Ragihalli (RGH), Biliganaguppe (BG), Chudahalli (CH), Linganapura (LGP) and Shivanahalli (SVH).

As mentioned earlier, the villages of Buthanahalli and Thattiguppe being primarily agriculture based have been the most visited villages too. The availability of food crops and plantations throughout the year seems to be the most likely reasons for this pattern of visit. These villages also bordered the forest and according to Sukumar, 1989, crop fields bordering the forest bear the brunt of damage. The frequency of crop raiding in the villages during different months was proportional to the area of land under cultivation (Sukumar, 1989).

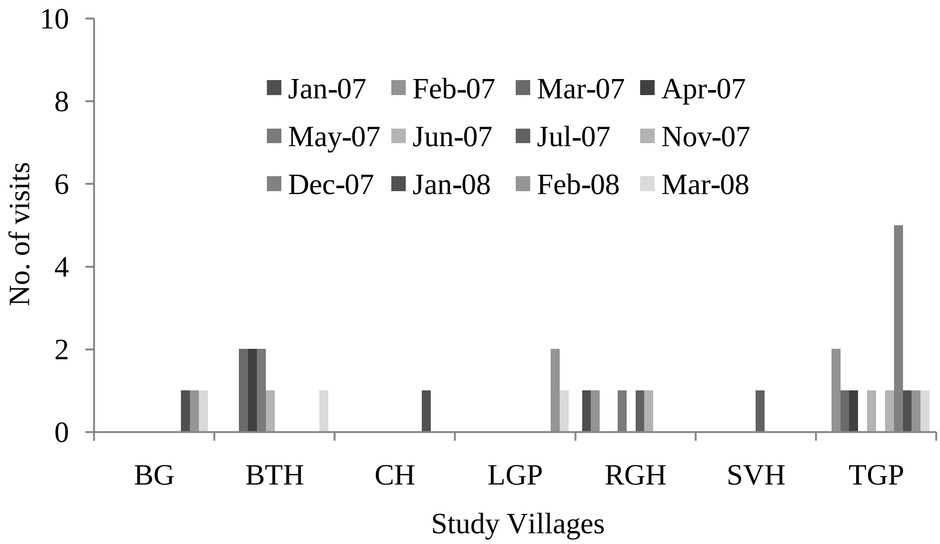


BG: Biliganaguppe, BTH: Buthanahalli, CH: Chudahalli, LGP: Linganapura, RGH: Ragihalli, SVH: Shivanahalli, TGP: Thattiguppe

Figure 3: Percentage of elephant visits to each of the study villages

Month wise visits of elephants to the study villages

The monthly visit of elephants to the study villages were documented in order to see if any seasonal pattern of visits exists. From the results (Figure 4a) it was known that no regular seasonal pattern exists in the village visits and the villages were visited at random throughout the year. Out of the study villages, Thattiguppe (TGP) and Buthanahalli (BTH) had the most number of elephant visits and the former village recorded visits during nine out of the twelve months followed by Ragihalli (RGH) and other villages.



BG: Biliganaguppe, BTH: Buthanahalli, CH: Chudahalli, LGP: Linganapura, RGH: Ragihalli, SVH: Shivanahalli, TGP: Thattiguppe

Figure 4a: Month-wise elephant visits to the study villages

The villages of Thattiguppe, Ragihalli and Buthanahalli had elephant visits almost throughout the year due to availability of crops throughout the year. These villages also fall under the high conflict zones (formulated using the compensation claim records). Thattiguppe has been one of the worst affected villages.

This may be due to the fact that the villagers here brew country liquor (Figure 4b) which attracts elephants, apart from the cultivation of elephant preferred crops. Most of the visits of elephants to crop lands have been in the month of December which is the harvest season for most of the crops.

Figure 4b: Remnants of illegal brewing of country liquor

In Buthanahalli a high number of elephant visit was registered during the summer months which coincide with the fruiting season of mango (*Mangifera indica*) and jackfruit (*Artocarpus heterophyllus*) trees, which are extensively grown in this village.

The villages Chudahalli (an enclosure) and Shivanahalli (located next to a large patch of forest) have recorded the least number of visits by elephants, which could be due to the minimal agricultural activities taking place in these villages.

Patterns of crop damage

Seasonal Crops

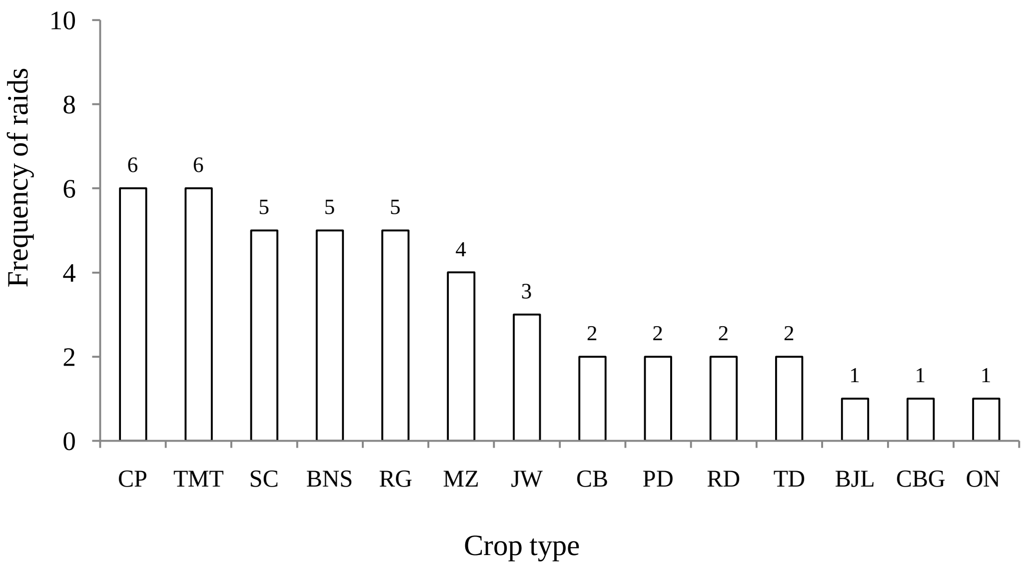
Crops damaged: During the study period, 14 different seasonal crops were found to be damaged by the elephants (Table 1, see Figure 5 for some of the crop damaged).

Figure 5: Some of the seasonal crops raided by the elephants. Top row- Left to right): Ragi, Paddy & Radish. Bottom row (Left to right): Tomato, Cluster beans & Maize)

Among the crops, Tomato and Cow pea, Sugar cane, Ragi, Beans, Maize and Jowar were frequently raided followed by, Toor dal, Radish, Paddy, Cluster beans, Onion and Cabbage (Figure 6).

Table 1: Seasonal crops damaged by the elephants

Sl. No.	Name of the crop	Scientific Name
1	Beans	*Phaseolus vulgaris*
2	Brinjal	*Solanum melongena*
3	Cabbage	*Brassica oleracea*
4	Cluster beans	*Cyamopsis tetragonoloba*
5	Cow pea	*Vigna unguiculata*
6	Jowar	*Sorghum bicolour*
7	Maize	*Zea mays*
8	Onion	*Allium sepa*
9	Paddy	*Oryza sativa*
10	Radish	*Raphanus sativus*
11	Ragi	*Eleusine coracana*
12	Sugarcane	*Saccharum officinarum*
13	Tomato	*Lycopersicon esculentum*
14	Tur dal	*Cajanus cajan*



TMT: Tomato, CP: Cow pea, SC: Sugar cane, RG: Ragi, BEN: Beans, MZ: Maize, JW: Jowar, TD: Toor daal, RD: Radish, PD: Paddy, CB: Cluster Beans, ON: Onion, CBG: Cabbage and BJL: Brinjal

Figure 6: Frequency of crop raids: Shows the number of times each crop raided during the study period

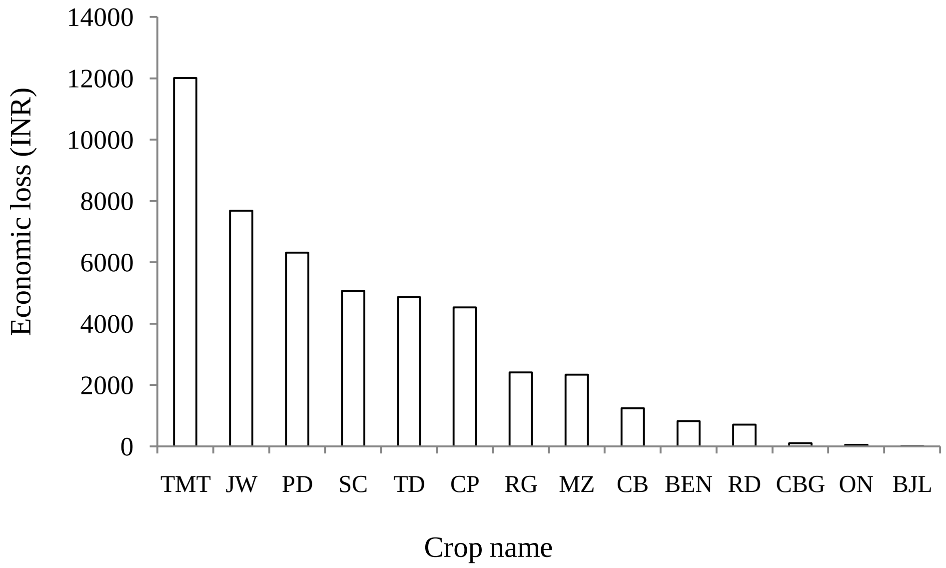
Total area of crop cultivation and damage: A total of 6 acres of crop land was damaged out of 53 acres of cultivated crop lands that were under study. This area of damage accounts for 11% of the total area of crop cultivation.

Village wise crop damage: The results of the crop damage assessment shows that villages, Thattiguppe (56%) and Ragihalli (29%) had the highest area of damage followed by Chudahalli, Biliganaguppe and Buthanahalli (Table 2). Thattiguppe is an agricultural based village with majority of the community involved in crop cultivation throughout the year. The village Shivanahalli had no damages at all. This may be due to noise disturbance in the locality caused by stone crushers, which is believed to have kept the elephants away.

Table 2: Percentage area of crop damage in the study villages

Sl. No.	Village Name	Total area under cultivation (acres)	Total area of damage (acres)	% area of damage (of total across all villages)
1	Thattiguppe	34.93	3.25	56.40
2	Ragihalli	3.80	1.65	28.70
3	Chudahalli	14.00	0.52	9.00
4	Biliganaguppe	0.42	0.24	4.20
5	Linganapura	0.05	0.06	1.00
6	Buthanahalli	0.05	0.04	0.70
7	Shivanahalli	0.00	0.00	0.00
	Total	**53.24**	**5.76**	**100.00**

Economic loss: The study on the economic loss due to crop depredation reveals that the farmers had lost an overall sum of INR 48,116/- during the study period. The farmers incurred major economic losses through Tomato (*Lycopersicon esculentum)*, Jowar (*Sorghum bicolour)*, Paddy (*Oryza sativa*), Sugarcane (*Saccharum officinarum),* Tur dal (*Cajanus cajan)*, Cow pea (*Vigna unguiculata*), Ragi (*Eleusine coracana*) and Maize (*Zea mays*). The top six crops raided by the elephants alone accounted for 84% of the economic loss (Figure 7 & Table 3).

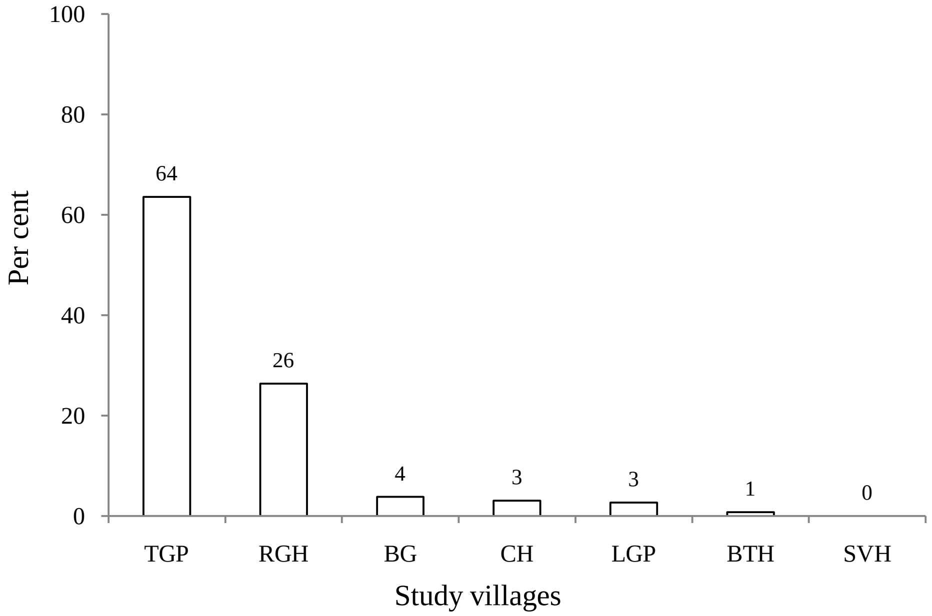


TMT: Tomato, CP: Cow pea, SC: Sugar cane, RG: Ragi, BEN: Beans, MZ: Maize, JW: Jowar, TD: Toor daal, RD: Radish, PD: Paddy, CB: Cluster Beans, ON:Onion, CBG: Cabbage and BJL: Brinjal

Figure 7: Economic loss incurred through each crop by elephant crop depredation

The villages Thattiguppe (64%) and Ragihalli (26%) recorded maximum economic loss among the study villages, followed by Biliganaguppe, Chudahalli and Buthanahalli.

Combination of Thattiguppe and Ragihalli accounted for about 90% of the economic loss in the study villages (Figure 8). These two villages had crops cultivated throughout the year during the study period.



BG: Biliganaguppe, BTH: Buthanahalli, CH: Chudahalli, LGP: Linganapura, RGH: Ragihalli, SVH: Shivanahalli, TGP: Thattiguppe

Figure 8: Percentage of economic loss recorded in the study villages

The maximum economic loss occurred during the harvest stage (86%) of the crops, which was followed by the reproductive stage (13%). The crops in the vegetative stage also recorded economic loss during the study period (Figure 9).

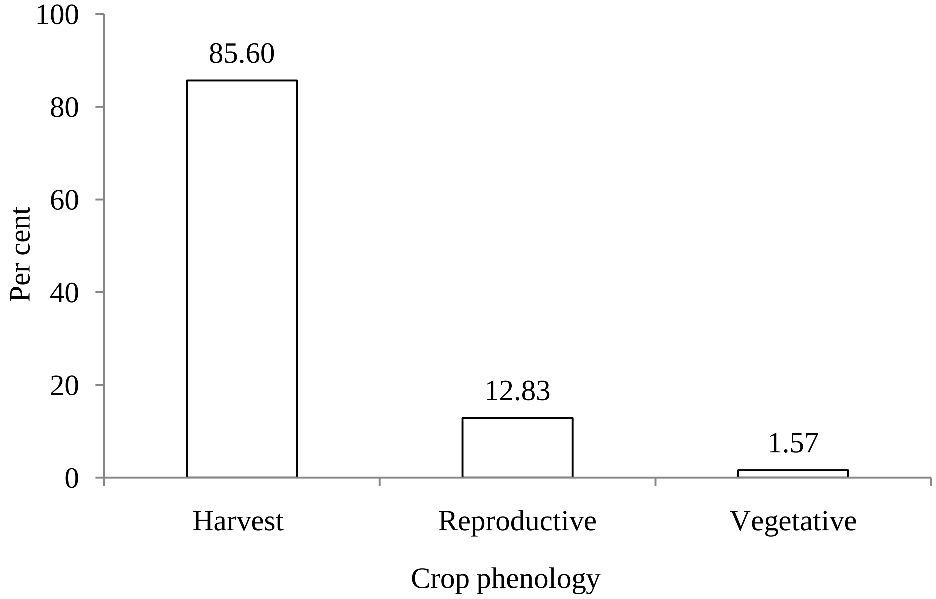


Figure 9: Percentage loss of economy distributed across different stages of crop phenology

Table 3: Crops damaged, area of cultivation, expected yield, market price of the yield, expected income, area of damage, loss of yield, loss of income and percentage loss of income for the crops raided by elephants

Sl. No.	Name of the crop damaged	Total area of cultivation (Acres)	Expected yield from cultivation (Quintal)*	Market price of the yield (INR/ Quintal)**	Expected income from cultivation (INR)	Total area of damage (Acres)	Loss of yield due to crop depredation (Quintal)	Loss of income due to crop depredation (INR)	% loss of income due to crop depredation (INR
1	Beans	0.97	4.56	885.00	4039.75	0.20	0.92	815	1.7
2	Brinjal	0.10	1.47	500.91	736.34	0.00	0.01	6	0.01
3	Cabbage	1.50	17.19	354.00	6084.38	0.03	0.29	104	0.2
4	Cluster beans	1.53	7.63	1375.00	10484.38	0.18	0.90	1239	2.6
5	Cow pea	6.62	24.83	1966.50	48818.36	**0.61**	2.30	**4525**	**9.4**
6	Jowar	2.50	18.75	994.71	18650.89	**1.03**	**7.73**	**7686**	**16.0**
7	Maize	6.53	88.36	860.24	76010.48	0.20	2.71	2333	4.9
8	Onion	0.03	0.21	552.27	115.06	0.01	0.09	47	0.1
9	Paddy	4.00	129.17	861.17	111234.03	0.23	**7.33**	**6316**	**13.1**
10	Radish	0.56	3.47	394.29	1367.68	0.29	1.79	707	1.5
11	Ragi	5.19	81.09	706.87	57322.47	0.22	3.40	2405	5.0
12	Sugarcane	11.00	2062.50	100.00	206250.00	0.27	**50.63**	**5063**	**10.5**
13	Tomato	4.07	105.91	293.24	31057.48	**1.57**	**40.94**	**12005**	**25.0**
14	Tur dal	0.56	3.14	3928.33	12333.25	**0.22**	**1.24**	**4867**	**10.1**
	Sum	**45.14**			**5,84,504.53**	**5.05**		**48,116**	**100.0**

* Source – Anonymous (Director of extension), Package of practices, 2007, University of agricultural sciences, Bangalore

**Source – Krishi Marata Vahini, Online Agricultural Price Information System, 2008 (http://maratavahini.kar.nic.in)

The results further suggests that out of the total economic loss of Rs. 48116/-; a sum of INR 27,954/- (58%) was due to trampling of the crop while the remaining INR 20,161/- (42%) was due to actual consumption by the elephants (Figure 10).

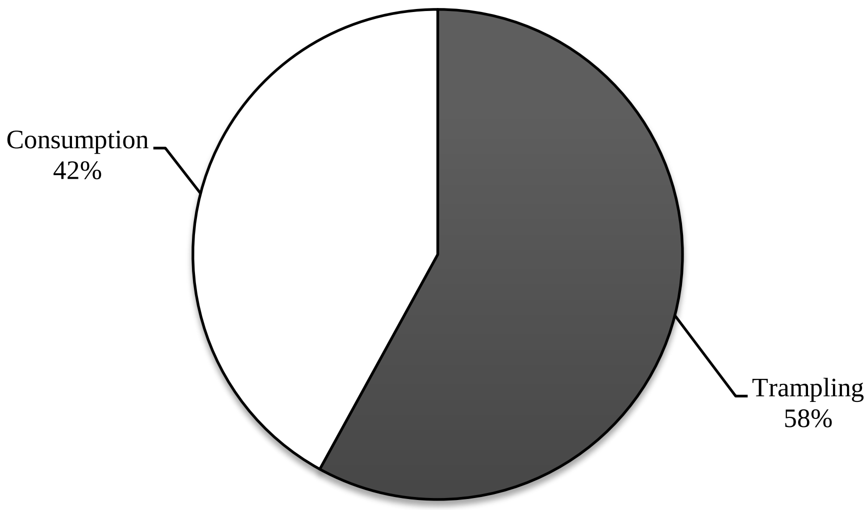


Figure 10: Proportion of loss of income due to trampling and consumption by elephants

Phenology of the seasonal crops damaged

An assessment of the phenology of the seasonal crops damaged may be an indicative of the vulnerability of the crops to damage and also the phenology based preference of crops by elephants. The results (Figure 11) suggest that of the total number of crops damaged nearly 51% were ready for harvest, followed by reproductive and vegetative stages.

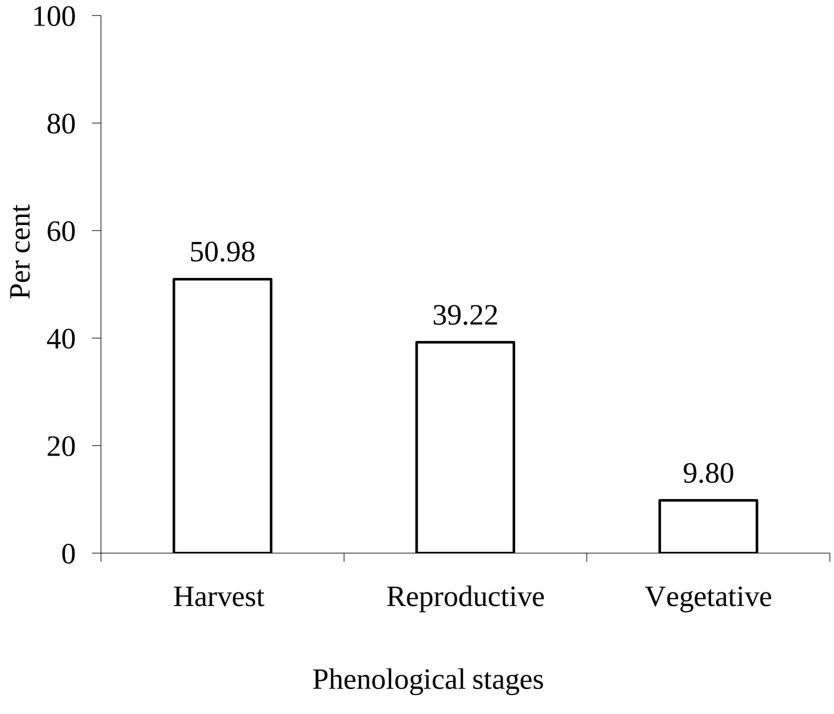
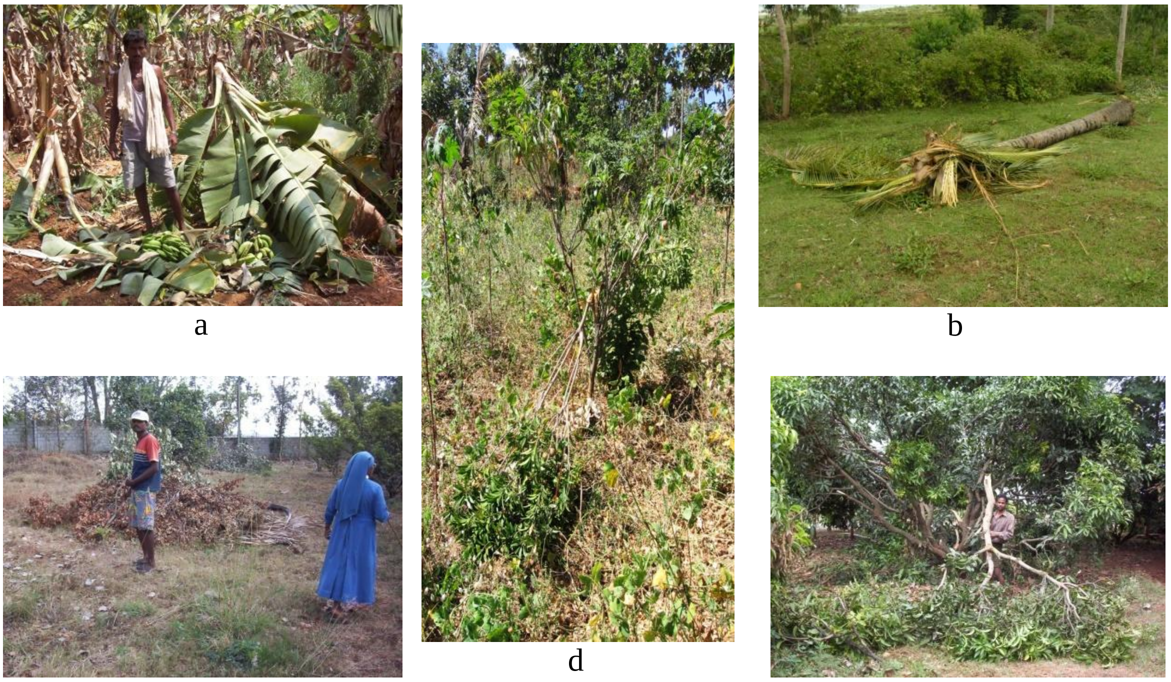


Figure 11: Phenology of the seasonal crops damaged expressed in percentage.

It was found that elephants prefer standing crops that are ready for harvest. This may be due to the fact that the crops are the most palatable and nutritious at this stage. Sukumar (1989) suggests a strong selection by elephants, for fields with robust plant growth, high density of standing crop and plants in inflorescence or grain stage.

About seven different annual crops (Figure 12) were found to be damaged by the elephants during the study period (Table 4). An assessment of the phenology of the annual crops damaged is an indicative of the vulnerability of these crops to elephant raids and also the phenology based preference of crops by elephants.



a b

d

c e

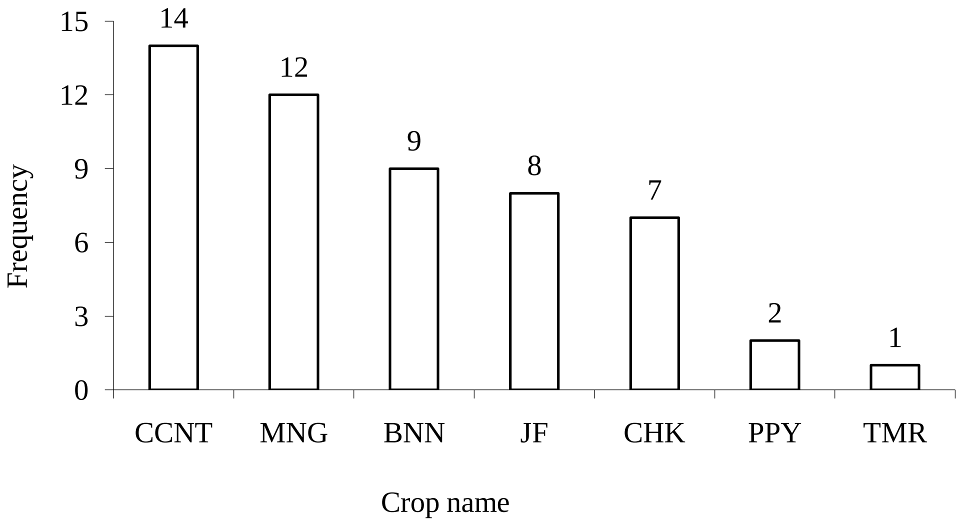
Figure 12: Some of the annual crops damaged by the elephants
Banana (a), Coconut (b), Jack fruit (c) Sapota (d) and Mango (e)

Table 4: Annual crops damaged by the elephants

Sl. No.	Name of the crop	Scientific Name
1	Banana	*Musa paradisiacal*
2	Chikkoo (sapota)	*Achras zapota*
3	Coconut	*Cocos nucifera*
4	Jack Fruit	*Artocarpus heterophyllus*
5	Mango	*Mangifera indica*
6	Papaya	*Carica papaya*
7	Tamarind	*Tamarindus indica*

Annual crops

Crops damaged: During the study period annual crops were damaged in the study villages due to elephant crop raids, in the following order: Coconut, Mango, Banana, Jack fruit, Sapota, Papaya and tamarind (Figure 13). The results also showed that the crop banana (55%) was damaged more among the seven crops followed by mango (24%) and coconut (11%).



CCNT: Coconut, MNG: Mango, BNN: Banana, JF: Jack Fruit, CHK: Chikoo, PPY: Papaya and TMR: Tamarind

Figure 13: Frequency of crops damaged by the elephants during the study

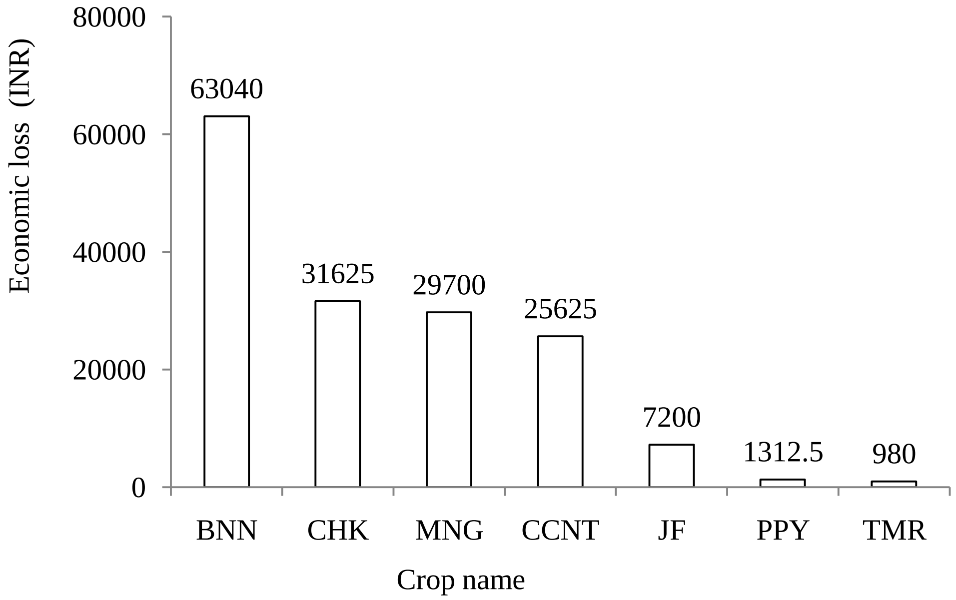
Total area of crop cultivation and damage: A total of 368 trees/plants were damaged out of the 6962 trees/plants that were cultivated during the time of study. This area of damage accounts to 11% of the total area of crop cultivations.

Village wise crop damage: The results of the crop damage assessment shows that the village Buthanahalli (60%) had the maximum damages followed by Linganapura (14%), Biliganaguppe (12%) and Thattiguppe (10%). Buthanahalli had maximum number of annual crop cultivation and Chudahalli had the least number of annual crop cultivations during the study. Both Chudahalli and Shivanahalli had no elephant depredations during the study period (Table 5).

Table 5: Shows the percentage of the annual crops damaged in the study villages

Sl. No.	Village Name	Total number of trees/plants cultivated	Total number of trees/plants damaged	% of trees/plants damaged
1	Biliganaguppe	409	44	11.96
2	Buthanahalli	4266	219	59.51
3	Linganapura	1009	53	14.40
4	Ragihalli	61	17	4.62
5	Thattiguppe	1217	35	9.51
6	Chudahalli	0	0	0.00
7	Shivanahalli	0	0	0.00
	Total	**6962**	**368**	**100**

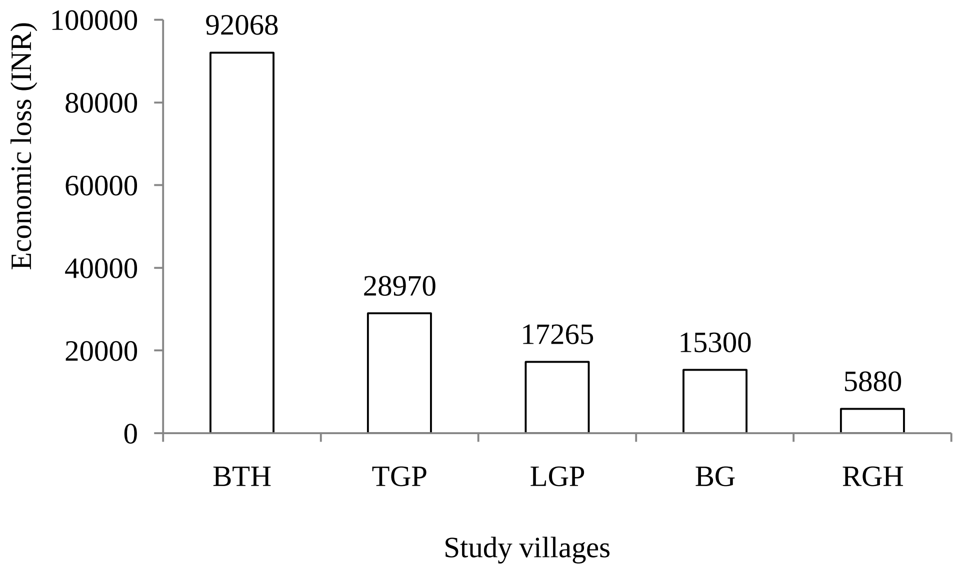
Economic loss: The study on the economic loss due to crop depredation reveals that the farmers had lost an overall sum of INR 1, 59,483/- during the study period. The farmers incurred major economic losses through banana, sapota, mango, and coconut. The top four crops raided by the elephants, alone accounted for 91% of the economic loss (Figure 14 & Table 6).



CCNT: Coconut, MNG: Mango, BNN: Banana, JF: Jack Fruit, CHK: Chikoo,
PPY: Papaya and TMR: Tamarind

Figure 14: Crop wise economic loss incurred due to elephant raids

During the study period, among the study villages, Buthanahalli recorded the maximum economic loss (INR. 92,068/-) due to crop raids. The villages Thattiguppe, Linganapura, Biliganaguppe and Ragihalli also showed a significant loss in economy (Figure 15).



BTH: Buthanahalli, TGP: Thattiguppe LGP: Linganapura,
BG: Biliganaguppe and RGH: Ragihalli

Figure 15: Village wise economic loss recorded for study villages

Table 6: Crops damaged, number of plants cultivated, average yield per plant/tree, expected yield, market price of the yield, expected income, number of trees/plants damaged, loss of yield, loss of income and percentage loss of income for the crops damaged by elephants

Name of the crop damaged	Total number of plants cultivated	Average yield per plant or tree (Kg)*	Expected yield from cultivation (Kg)	Market price (INR/ Kg)**	Expected income from total cultivation (INR)	Total number of plants damaged	Loss of yield due to crop depredation (Kg)	Loss of income due to crop raid (INR)	% Loss of income
Banana	2398	20	47960	16	767360	**197**	**3940**	63040	**39.5**
Sapota	375	125	46875	11	515625	23	2875	31625	**19.8**
Coconut	1124	125	140500	51	702500	**41**	**5125**	25625	**16.1**
Jack fruit	39	500	19500	1	23400	12	**6000**	7200	4.5
Mango	3000	30	90000	11	990000	**90**	2700	29700	**18.6**
Papaya	6	87.5	525	5	2625	3	262.5	1312.5	0.8
Tamarind	20	17.5	350	28	9800	2	35	980	0.6
Sum	**6962**				**3011310**	**368**		**159482.5**	100

* Source – Anonymous (Director of extension), Package of practices, 2007, University of Agricultural Sciences, Bangalore
**Source – Krishi Marata Vahini, Online Agricultural Price Information System, 2008 (http://maratavahini.kar.nic.in)

The maximum economic loss occurred during the reproductive stage (Rs. 1, 25,143/-) of the crops, which was followed by the vegetative stage (Rs. 24,390/-). The crops in the harvest stage also recorded significant economic loss during the study period (Figure 16). According to Sukumar (1989) elephant shows preference for mango trees from the time of flowering until fruiting (reproductive stage), such shoots being selectively eaten.

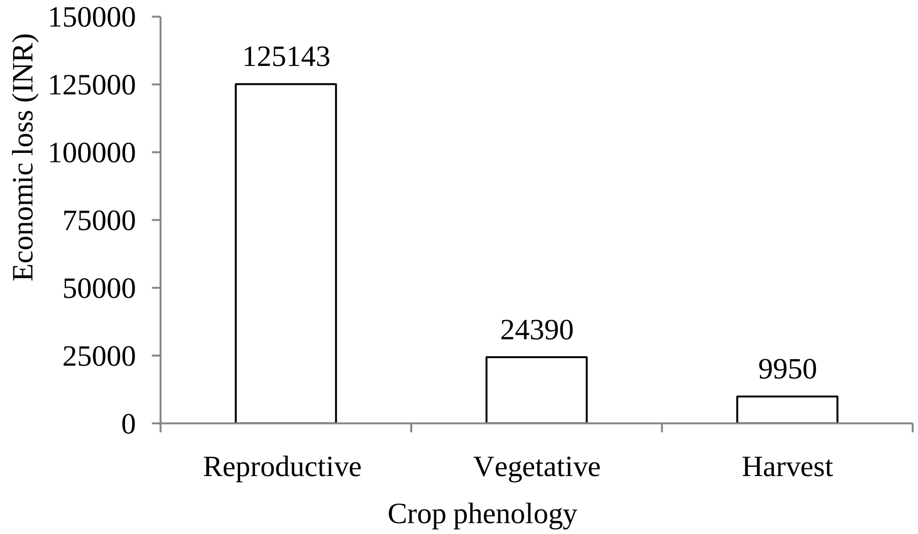


Figure 16: Economic loss across the phenological stages of the crops due to elephant raids

The results further suggests that out of the total economic loss of Rs. 1,59,483/-; a sum of INR 1,05,464/- was due to trampling of the crops while the remaining was due to consumption by the elephants (Figure 17).

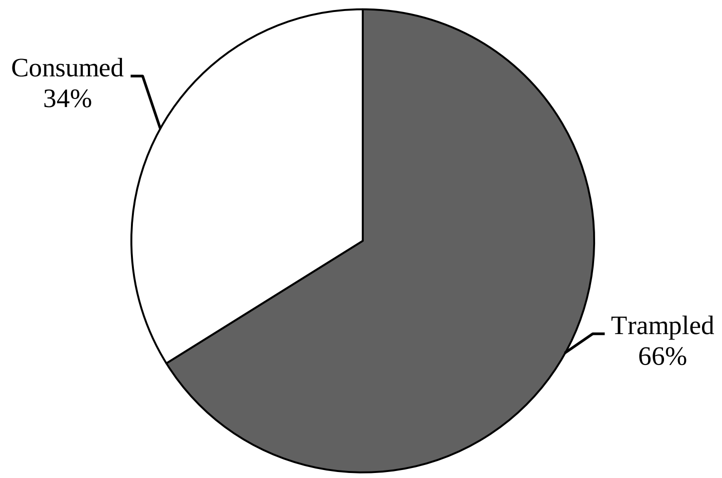


Figure 17: Proportion of loss of income in INR due to trampling and consumption by elephants

Phenology of the annual crops damaged

The results (Figure 18) indicate that, of the total number of crops damaged, nearly 71% were in the reproductive stage followed by vegetative and harvest stages.

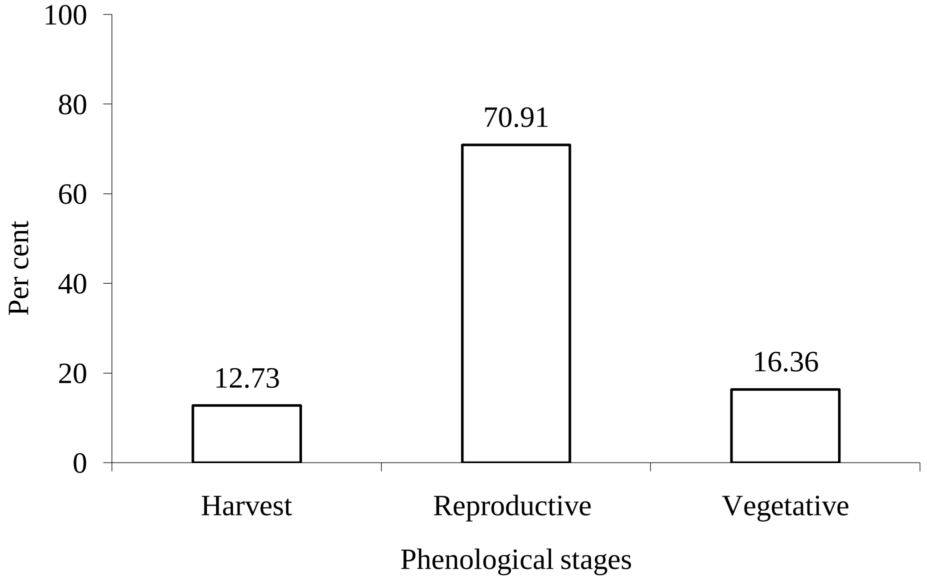


Figure 18: Proportion of different Phenology of the annual crops damaged

According to Sukumar (1989) preference by the elephants to annual crops in the reproductive stage of phenology was observed.

Elephants preferred time for raid

An insight into the preferred time of arrival of elephants to the villages may be immensely useful to the farmer for being prepared for the raid. Although elephants are known to visit the villages randomly at any time, the results (Figure 19) indicate that most of the times elephants have visited between 0021 hrs to 0023 hrs and again between 0024 hrs to 0200 hrs. Sukumar (1989) mentions that bulls were often seen entering between 19.00 hrs and 22.00 hrs and departing before sunrise.

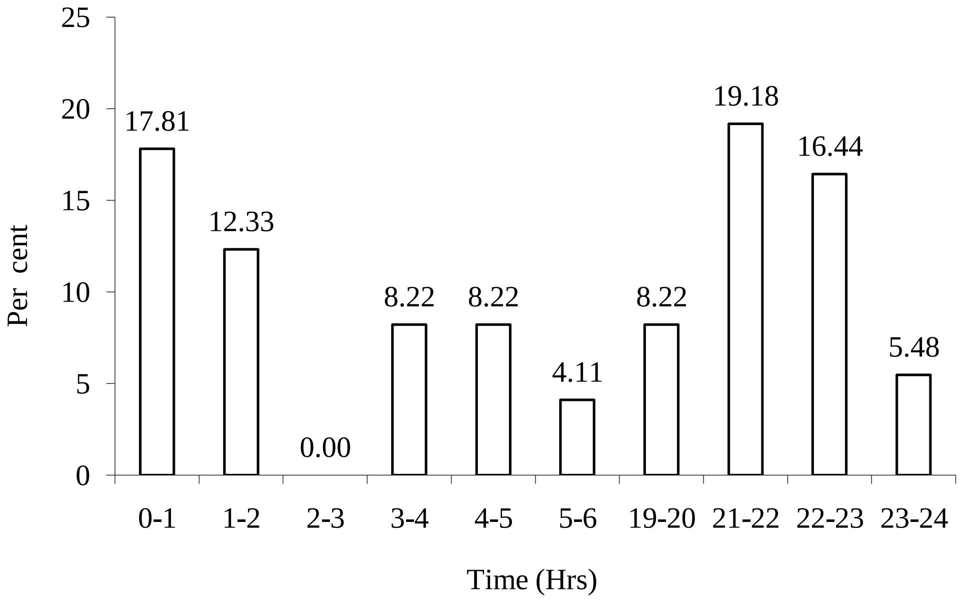


Figure 19: Preferred time of arrival of elephants to the villages, expressed in percentage

Elephants involved in crop raids

The results, (Figure 20) obtained by doubling the circumference of the pad marks of crop raiders, indicates that elephants of all age classes had raided the crops. Most of the elephant raiders belong to the adult age class (83%) followed by sub adults, juveniles and calves in the decreasing order of number of elephants.

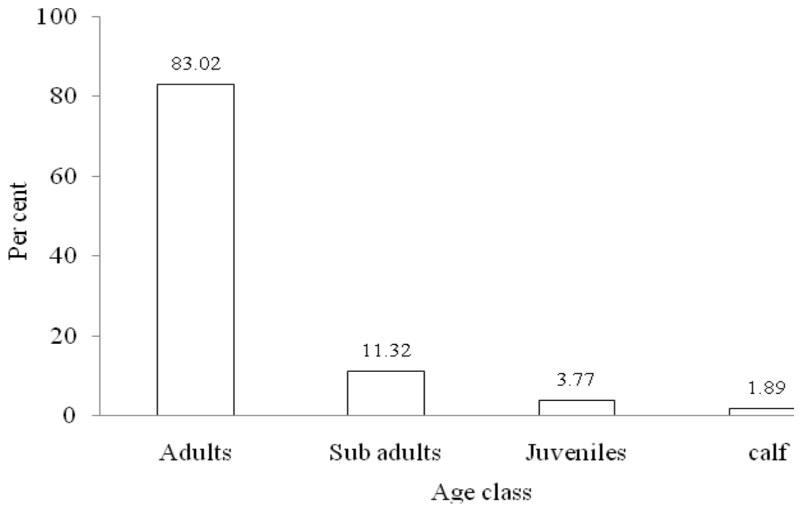


Figure 20: Percentage of individuals belonging to each age class that have raided crop fields

Group size of elephants involved in crop raids

From the results (Figure 21) it can be concluded that most of the raids have been by solitary elephants followed by group sizes of 4 and 2. The raids by large group sizes are less when compared to the smaller group sizes of 2 to 8 elephants. This reveals that elephants with varied group sizes had been raiding the crops during the study period.

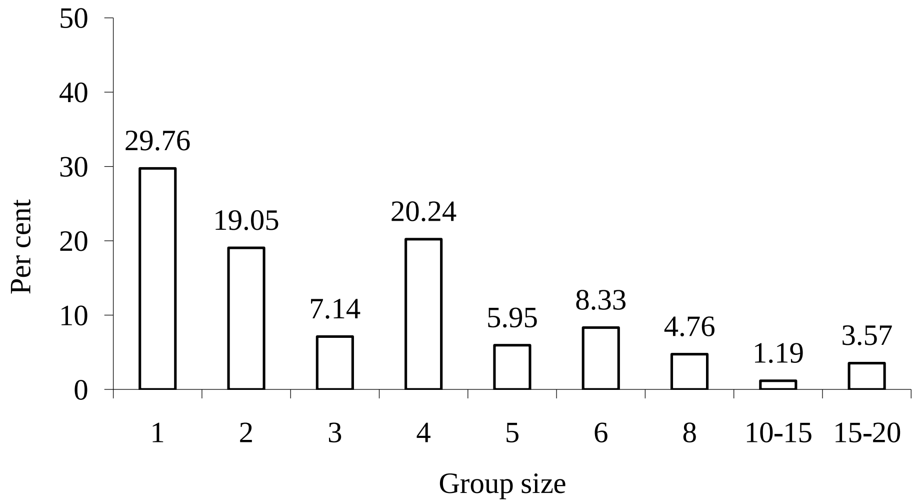
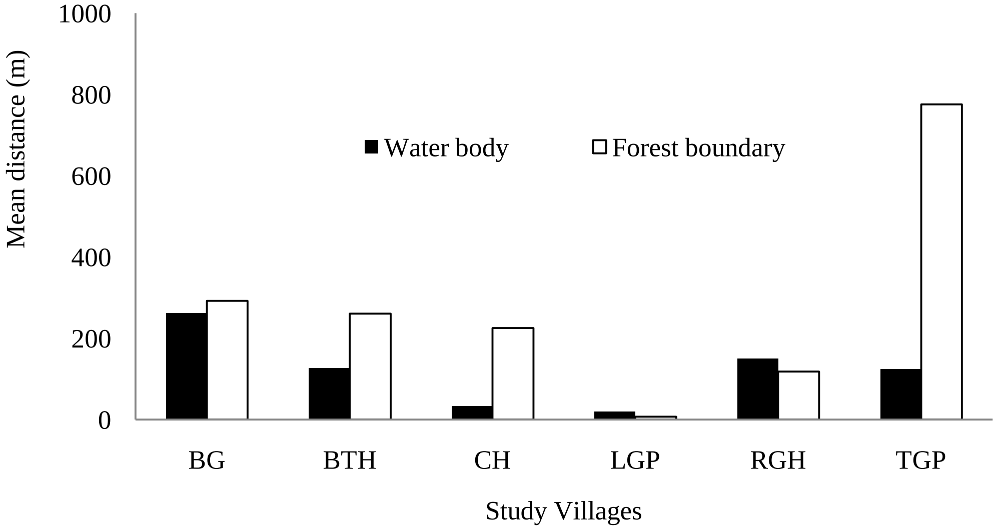


Figure 21: Percentage of visits or raids by elephants of different group sizes

Sukumar (1989) observed that raids by single bull per day were the most common in all the villages in his study area. Elephants were raiding the crops in smaller group sizes of 2 to 8 animals, which could be to optimize co-operation while raiding and at the same time avoid competition which may arise in larger herd sizes. An observation by the farmers suggest that elephants enter in small groups to avoid attracting attention that inevitably arises when the group size is large and composed of young individuals.

Proximity of crop fields to the forest boundary and water bodies

The results (Figure 22) show that the distance of the forest boundary from the damaged crop fields was found to be at a distance range of 8m to 776m. The water bodies were found to be located at a distance range of 20m to 261m from the damaged crop field. The crop fields located both close and away from the forest boundary were observed to be affected irrespective of their proximity.



BG: Biliganaguppe, BTH: Buthanahalli, CH: Chudahalli, LGP: Linganapura, RGH: Ragihalli, SVH: Shivanahalli, TGP: Thattiguppe

Figure 22: Average distance of the raided crop fields from the forest boundary and the nearest water body

Conclusion

The investigation on the status of human-elephant conflict and loss of economy due to elephant crop depredation reveals that both seasonal and annual crops were prone to raids and subsequent loss of economy. The villages of Buthanahalli and Thattiguppe are primarily agriculture based and the visit of elephants to these villages was also very high. The availability of food crops and plantations throughout the year in these villages seems to be the most likely reasons for this pattern of visit.

These villages also bordered the forest. Among all villages, Thattiguppe has been one of the worst affected as the local people brew liquor which may attract elephants apart from the cultivation of elephant preferred crops. It was found that elephants prefer standing crops that are ready for harvest. This may be due to the fact that crops are very palatable and nutritious at this stage. The seasonal crops suffered a lesser amount of economic loss compared to the annual crops. This could be more due to the commercial value of the crops rather than the extent of damage.

The seasonal crops were raided the most during the harvest stage resulting in maximum economic loss; whereas in the case of annual crops, the reproductive stage of crop phenology suffered the maximum raids and economic loss. The economic loss due to trampling was more compared to consumption by the elephants for both seasonal and annual crops. More meaningful patterns can be expected if farmer-wise crop loss and its implication on the economic loss are studied.

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Appendix –I

Additional figures showing the status of human-elephant conflict

a b

c d

e f

Elephant damage to - a: Maize, b: Banana, c: Paddy field, d: Damage assessment by a researcher to the Sorghum crop , e: Elephant entry point through a compound wall, f: Elephant sign inside a crop land cultivated with ragi

Appendix-II

Monitoring and Assessment of Elephant crop raids around Bannerghatta National Park

Data Sheet

Date:

Observer's Name:

Village Name:

Range Name:

Elephant visits: Yes/ No

If No give reason and stop

If Yes Continue…….otherwise stop

Farmer's Name:

Farmer's Father Name:

Crop damage details:

Sl. No.	Name of the crop cultivated	Total area of cultivation (in acres)	Area of damage (Length (L) x Breadth (B))			Crop Phenology (Vegetative/ Reproductive/ Harvest stage	Trampled (%)	Eaten (%)
			Site 1 (m)	Site 2 (m)	Site 3 (m)			
1								
2								
3								
4								
5								

Tree damage details:

Sl. No.	Name of the Tree/ Plant	Total number/ area of cultivation (in acres)	Total number of plants damaged	Crop Phenology (Vegetative/ Reproductive/ Harvest stage	Trampled (%)	Eaten (%)
1						
2						
3						
4						
5						

Survey number of crop damaged:

Location (GPS Readings):

Point of entry:

Elephant Responsible:

Sl. No	Number	Min	Max	A	B	C	D	E	F	Remarks
1										
2										
3										
4										
5										

Min: Minimum, Max: Maximum, A: Male/ Female/ Calf/ Un- identified, B: Time of arrival, C: Time of departure, D: Duration of stay, E: Elephant signs (Track/ Dung), F: Status of sign (VF/ F/ O/ VO; V. Fresh (Previous night), Fresh (1-2 days), Old (3-5 days), V. Old (>5 days))

Elephant sign details:

Sl No	Track/ Pad marks (Yes/ No)	If yes, Circumference (in meters)		Dung (Yes/ No)	If yes, Circumference (in meters)			Remarks
		Length	Width		C1	C2	C3	
1								
2								
3								
4								
5								

Is there a water body nearby: Yes / No
If yes approximate distance?
Approximate distance of damaged crop from the forest boundary:

Introduction

Crop raiding by elephants is a major conservation concern in many elephant habitats both in India and Africa (Bell 1984; Sukumar 1989; Tchamba 1996; Hoare 2000; Low 2000; Sitati 2003; Sitati et al. 2003; Basappanavar & Kaveriappa 2007). Inclusive details on the status of human-elephant conflict in a given forest region is essential for developing conservation strategies for the region (Blair et al. 1979; Barnes et al. 1995; Tchamba 1996; Nath & Sukumar 1998; Newmark & Hough 2000; Rajeev 2002). The pattern or extent of conflict could be studied through many approaches such as, systematic long term investigations or through investigating specific issues related to human-elephant conflict and researching the patterns that cause the conflict. This can be also achieved through rapid surveys, or one season or one time investigations.

Many protected areas in India or elsewhere maintain systematic records. These records include elephant census, mortality and crop damage payment data; they also contribute specific knowledge about the human-elephant conflict. In addition to this, the distance elephants travel from forest to croplands, extent of property damage, human injury and deaths by elephant, and elephant deaths due to conflict related causes could be obtained from compensation payment records (Nath & Sukumar 1998; Rajeev 2002). These records may provide indication of the status of conflict; however, this depends on many factors: interest of people claiming the compensation, availability of funds during the specific period, the effort and interest concerned departments put to assess the damage, claimants' honesty and other aspects.

The value of exploring patterns of conflict from compensation payment records is little explored or often criticized. However, long-term scientific investigations are very expensive, time consuming and may not provide scope for understanding the pattern of conflict for all or majority of villages at one time. Any attempts to process the data obtained through crop compensation claims may help in reviewing the merits and demerits of this approach, and this review could be additionally supplemented by actual ground investigations of the status of human-elephant conflict.

Objectives

The objective of this investigation was to assess the following aspects;
To identify the indicators of patterns of human-elephant conflict through assessing compensation claims for crop damages and other conflict related issues.
To identify different conflict zones based on intense, high, moderate, low and minimal categories of damage accounted during the study period among the study villages.
To understand the pattern of conflict through systematic protocol followed for obtaining conflict insights for seven years from compensation records (from 1999 to 2005) and compare the summary results of 2 years, i.e., 2006 & 2007 using the same records.
Develop a digital data base of villages affected, frequency, amount claimed, pattern of claims across months and years, major and frequency of crops targeted, estimation of differences between actual claim, assessment and the payment and other aspects related to it. It is assumed that this would give opportunity to understand the value of such data base to the forest department in effectively using the information for their requirement.

The objectives may have the following insights
As seen elsewhere, compensation claims and payments processes are complicated by many factors. It is expected that, the processes associated with compensation payment

may reduce the number of claims and actual status of the extent of the problem, and inference from the compensation claim may not reflect the actual conflict status. There are about 120 villages located in or 5 km radius of Bannerghatta National Park.

It is also important to note that not all the villages (120) were subjected to human-elephant conflict problem. The actual data available on compensation claim may reflect the existing pattern in 85 to 90 % villages. On an average 595 (SE = 98.3, n=7, ranging from 227 to 938) claims are reported/year. If we convert each claim as individual farmer family, about 600 families claim compensation per year. It would be interesting to know the percentage of families that do not ask for compensation due to the factors discussed above. It is also assumed such families would form a negligible percentage in the study area; hence the available number of villages claiming the compensation may reflect the status of the conflict.

With this opportunity, many aspects of conflict and underlying patterns could be derived. Comparison of the pattern of conflict across years could be made through systematic protocols. The results of systematic approaches (1999- 2005) could be also compared with the summary results of 2006-2007. Eventually, a digital or GIS data base for affected village, frequency, amount claimed, pattern of claims across months and years, total area, major crops and frequency of crops targeted, differences between actual claim, assessment and the payment given and other aspects related to it could be made. This data can then be used for drawing inferences and appropriate conflict mitigation measures. This may also help in assisting the forest department in effectively using the information for their requirement.

Methodology

Initially, discussions were held with experts and forest department officials, and a format for data extraction from the crop compensation records was evolved. A two pronged approach was followed to collect data. Firstly, data of compensation claim and other associated factors were systematically collected for years 1999 to 2005. Secondly, the summary data set of crop compensation claims for the year 2006, and 2007 was collected. Range wise details for each village was extracted, details such as name, date and time of crop damage, crop types, compensation claimed, assessed and paid, affected area/size, land status/area, loss of human life and livestock and property damage were collected (see appendix I for the format used to extract details from the forest department records). Specific survey was made in those villages appearing in the compensation claims, and their geo coordinates were obtained to create GIS and digital data base environment. The data was analyzed to know the spatial trends in conflict, number of incidents across the years and the distance from the nearest forest to villages that reported conflict.

Collecting data on elephant incursions into human habitations and resulting damage to property is a very difficult task, especially in areas with high levels of HEC. Data collection is constrained by lack of trained man power, non-claimant of crop damage compensation or simply due to non-detection of raids by elephants. However, claim by a farmer asking for compensation towards crop damage by elephants submitted to the forest department can be considered as a definite visit by the elephant to the crop field however high or low the damage may be. This is reliable as the farmer's claim is assessed by the forest department by visiting the raided crop field. However, the estimation of crop damage and assessment of economic loss are contentious.

This data on definite elephant visit to the village can be used in programme Home Range Estimator (generally used for estimating home ranges of animals and intensity of use of an area based on their geographic locations) and applied to the estimation of intensity of conflict by taking cluster of villages that have reported elephant visitation. A probabilistic map, identifying cluster of villages experiencing varying levels of conflict can then be generated. Animal movement extension to Arcview 3.2a (Hooge and Eichenlaub, 2000) was used for this purpose. The zonation was done using Fixed Kernel Home Range Estimator, which considers probabilistic techniques for home range estimation (Hooge et al. 1999; Hooge & Eichenlaub 2000). The estimate makes it possible to locate the core area, i.e., the zones used most intensively by the animal.

The intensity of usage was obtained based on the incidents of crop damages. Data on incidents of crop damage was categorized using natural breaks based on Jenk's optimization (Brewer 2006). Here the classification was based on 5 different categories such as, the highest, second highest, third highest, fourth highest and fifth highest (Figure 1) and these categories highlight the intensity of the incidents of crop damages presented in some of the figures dedicated for the distribution of conflict status across the villages.

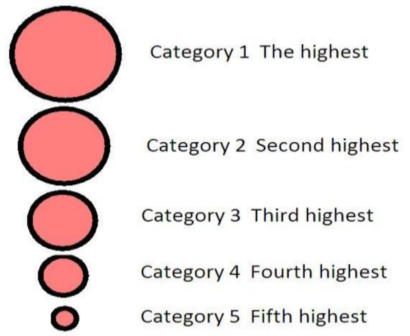


Figure 1: Classification of the crop damage intensity

Results and Discussion

Procedures, constraints and patterns of compensation claims

In the event of crop or physical property damage due to the elephant straying into human habitations, the victim of the damage appraises the forest watcher of that particular beat about the incident and registers a 'written claim' called "Arji" for compensation with the 'Office of Range Forest Officer'. The forest guard in-charge of that particular beat along with the Forester in turn pays a visit to the damage site to assess the economic loss and prepares a damage assessment report called "*Mahzar Report*". The victim must produce the land records called "*Pahani*" in order to get his request for compensation processed.

It was found that some of the agricultural lands, though affected due to elephant damage, legally are not entitled for the claim, as the land is not legally owned by them, or it may be a part of encroached land. If the crop is shared or taken on lease from other farmers, for the damage incurred in such lands, only the original or legal owners (of the land and not the produce) are entitled for the compensation. It was understood that the damage assessed by the forest department is usually much less than the actual, assessment protocols are very complex and time consuming. Lack of knowledge about the claims, protocols and other associated aspects limit the compensation availability to some farmers. Some farmers felt, the special favors some of the concerned department staff receives from some of the influential farmers also bias the claims.

The claim amount is not paid as cash but as cheque, and many farmers do not have transaction with any banks, many of the farmers do not have the knowledge to understand the need for using banks or to have an account in banks. The distance of the administrative offices (where the compensation amount is processed or paid) is relatively far away from the villages, and farmers reported to spend money to reach there or wait hours or days for processing and receiving the claim. Elephants are considered as God and worshiped. Specific rituals (locally called *aane para*; Figure 2a and b) are conducted during the cropping season.

a b

Figure 2a and b: Photograph showing the worshipping of elephants by the farmers called *Aane para*

The worship may primarily be focused towards the prayers to God to prevent damage by elephants. Some of the farmers who follow the ritual, even after being subjected to damage/loss, do not make any claim for compensation with the belief that the damage was subjected by their God, claiming compensation may lead to more damage to their crops. Some farmers accept the damage as an offering to God, and for such damages, claiming compensation is not acceptable. Even with all the issues, an average of 595 (SE 98.3, N=7, range from 227 to 938) compensation claims per year was reported from 117 villages for the period of 2000-2005.

Elephant visit to the crop fields in relation to the distance from the forests

The result of elephants' visit to 100 villages in relation to the distance from the forests shows that elephants move up to 20 km from the forest (Figure 3a and b).

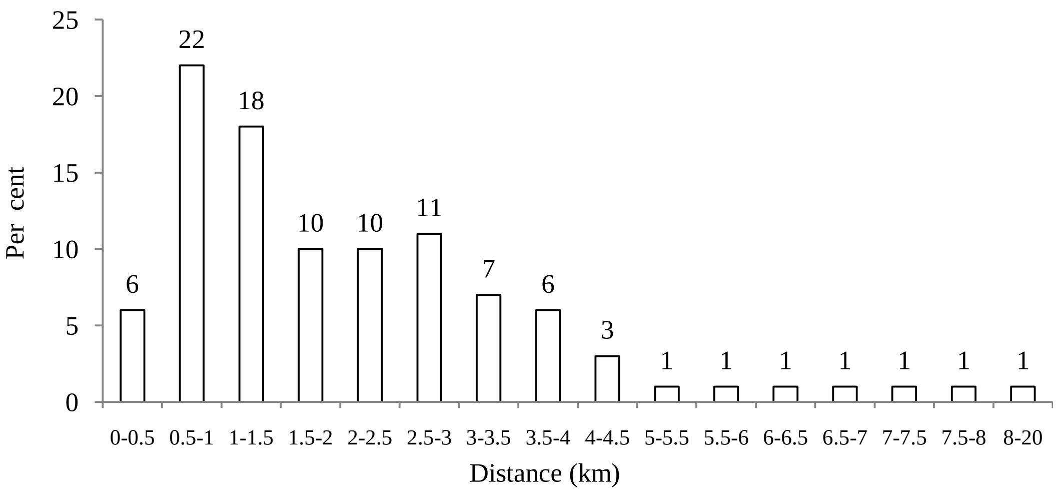


Figure 3a: Percentage of incidents of elephant damage to crop reported across different distances

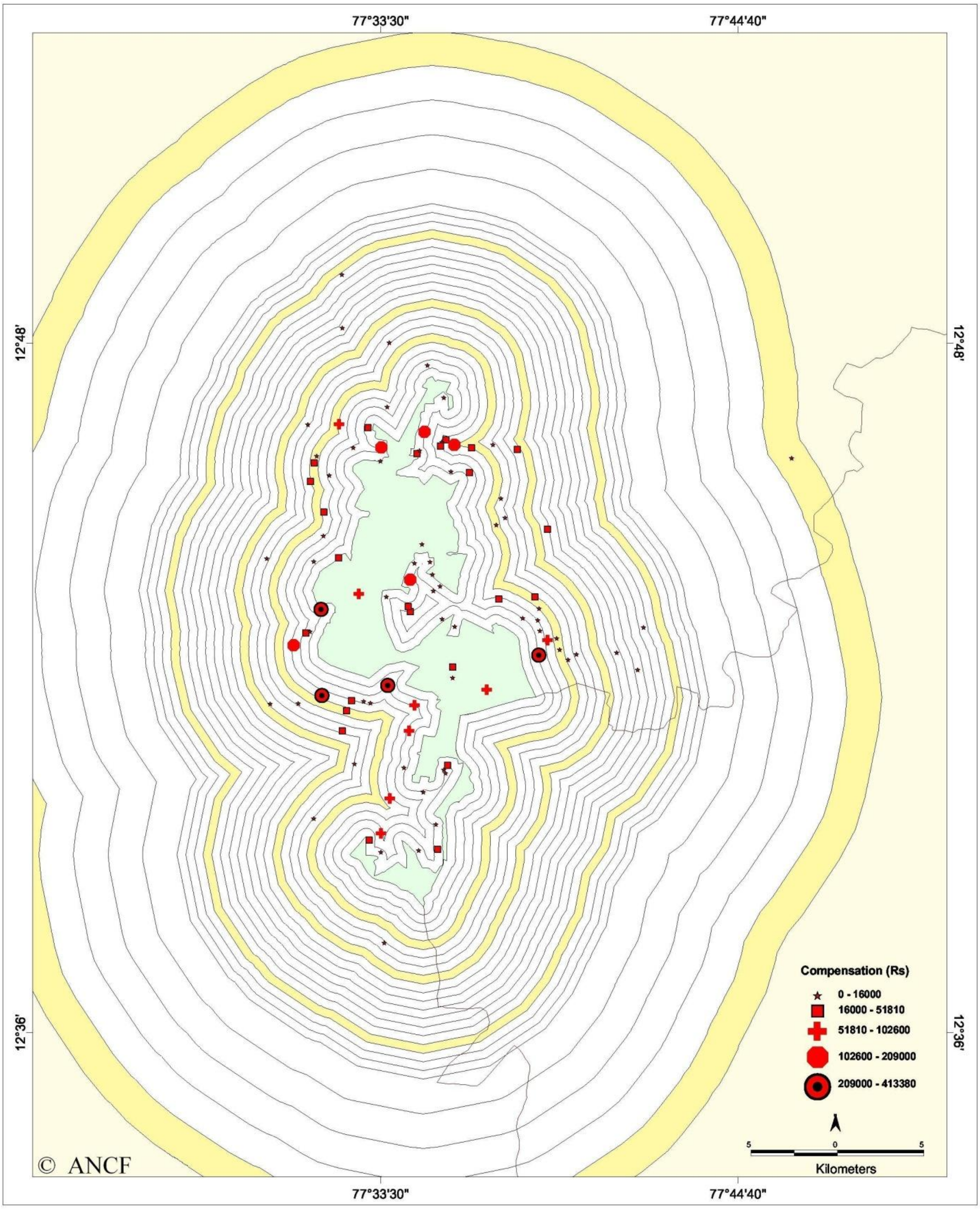


Figure 3b: Map showing distances from forest to villages that report conflict incidents
(Source: ANCF)

Elephants travel a mean distance of 2 km (SE=0.2, N=100) ranging from 0-20 km. The distance range of 0.5-1 km shows highest incidents of damage followed by 1.5-2 km and 1-1.5 km. About 80% of the visits fall within 3 km from forest.

Spatial distribution of compensation claims and payments

Figure 4 shows the spatial distribution of villages that claimed crop compensation from the forest department. The villages Gottigehalli, Kaadujakkasandra, Biliganaguppe located in Harohalli Range and Thammanayakanahalli located in Anekal Range of the park fall under the highest category. The spread of crop damage incidents observed almost everywhere around the park fall under the high category. Both occurrence and intensity of conflict in the North-West region of the park decreased over the years, while the pattern for North-East shows consistent conflict across the years and the intensity appears to remain more or less constant. The human settlements dotting the boundary in the middle portion of the park have been affected the most followed by the settlements surrounding the narrow patch of forest in the northern tip of the park.Some villages appear to be visited by elephants regularly. This is reflected by the occurrence and the magnitude of the crop damages. The villages Ragihalli, Sampigehalli and Buthanahalli located in Bannerghatta range, Gottigehalli, Kaadujakkasandra, Biliganaguppe and Maralawadi located in Harohalli range and Thammanayakanahalli located in Anekal range have been affected by the conflict consistently across the years.

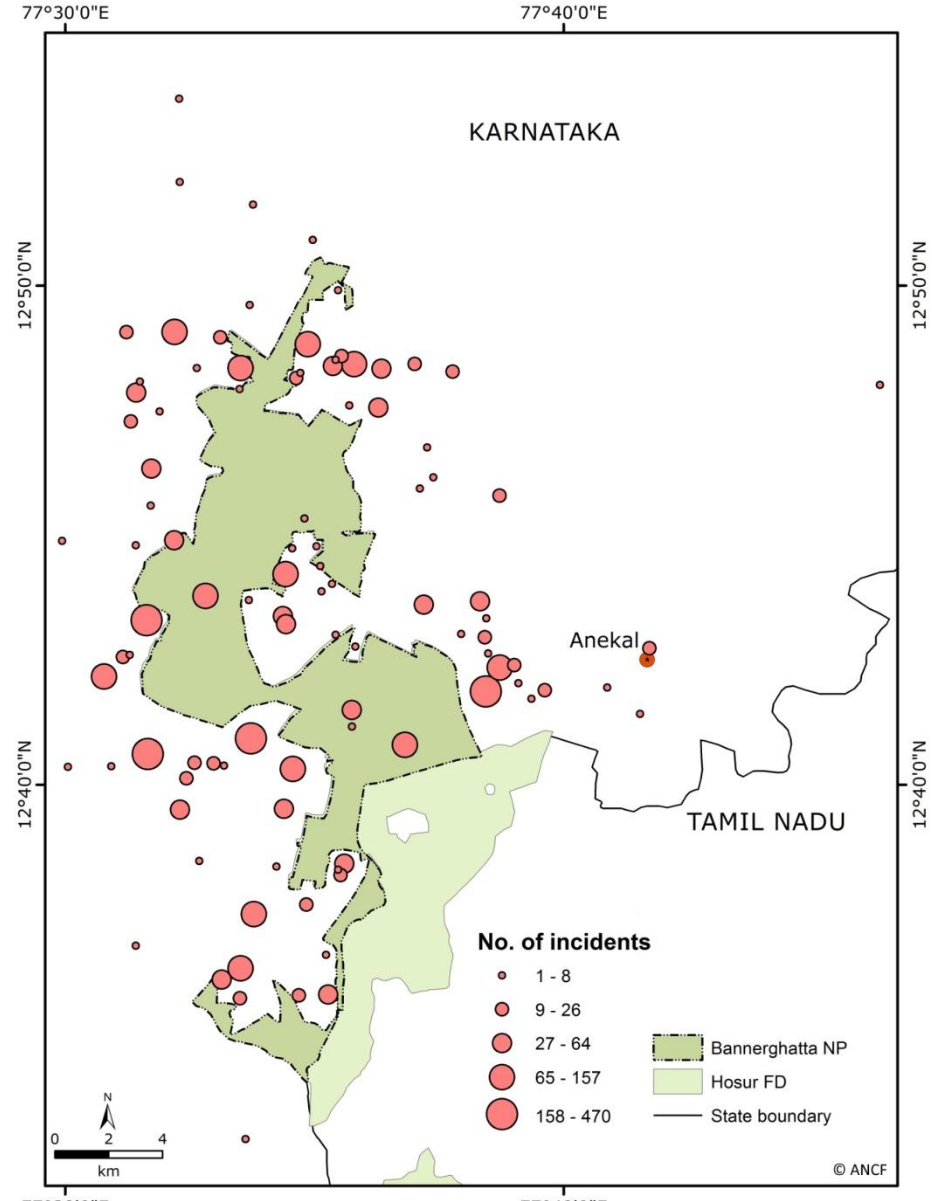
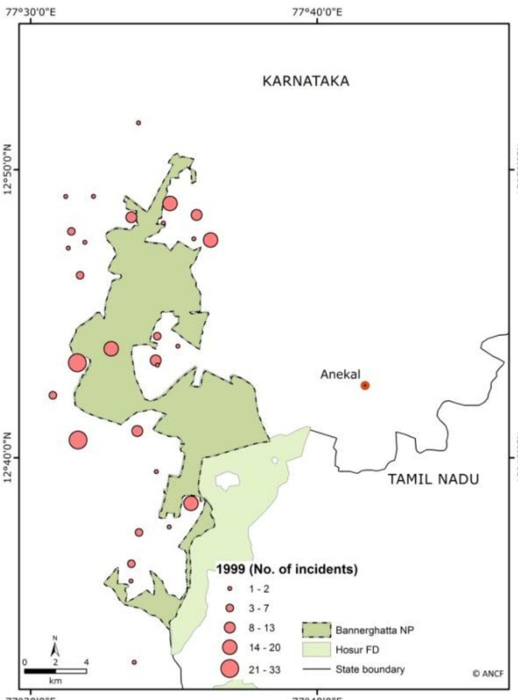
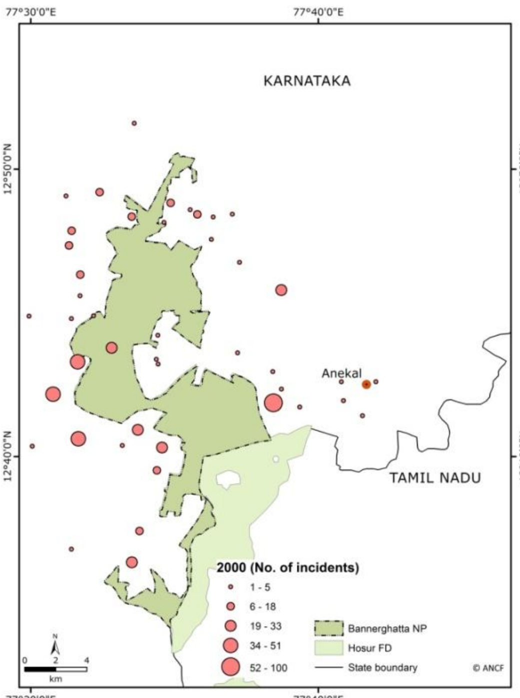


Figure 4: Maps showing the incidents of crop damage from 1999 to 2005(Source: ANCF)

Among these villages Kaadujakkasandra, Biliganaguppe report crop damage for all seven years, Gottigehalli, Ragihalli, Sampigehalli and Thammanayakanahalli for six years and Gullahattikaval for four years. The presence of conflict incidents is very obvious in the enclosures. There is a clear trend of increase from 2004 to 2005. Some villages stopped cultivating due to the elephant problems. Absence of conflict incidents for such villages during 2004 and 2005 are indication of no cultivation. Patterns for other villages across different years (1999 to 2005) are given in the figures 4a, b, c, d, e, f and g.



a



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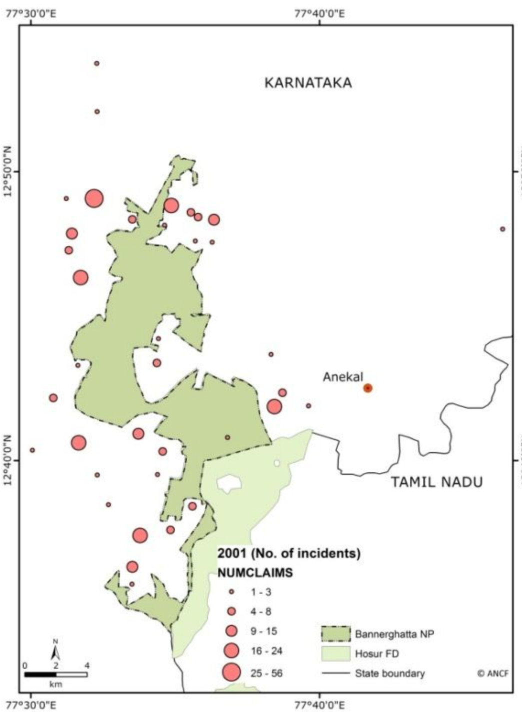

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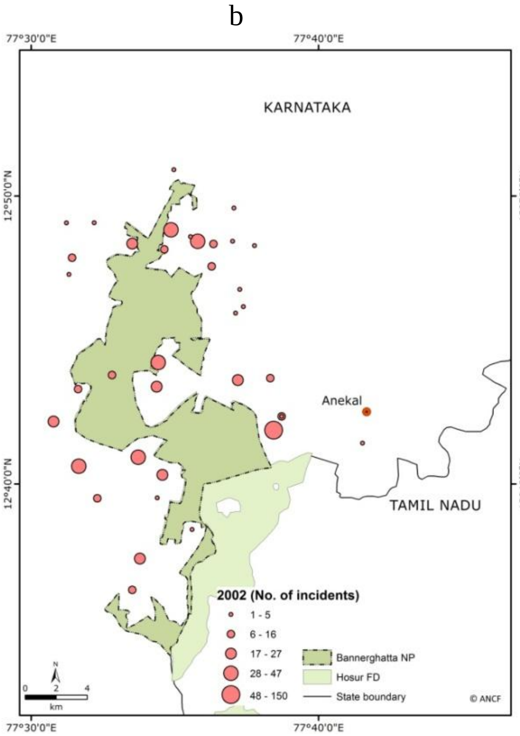

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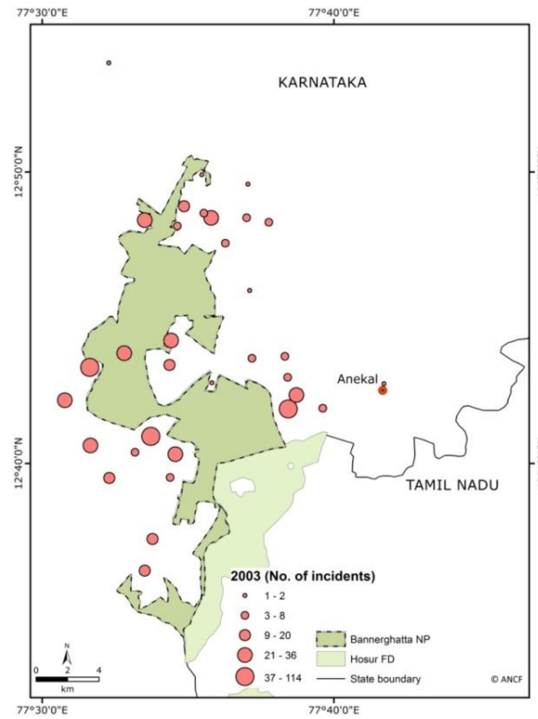

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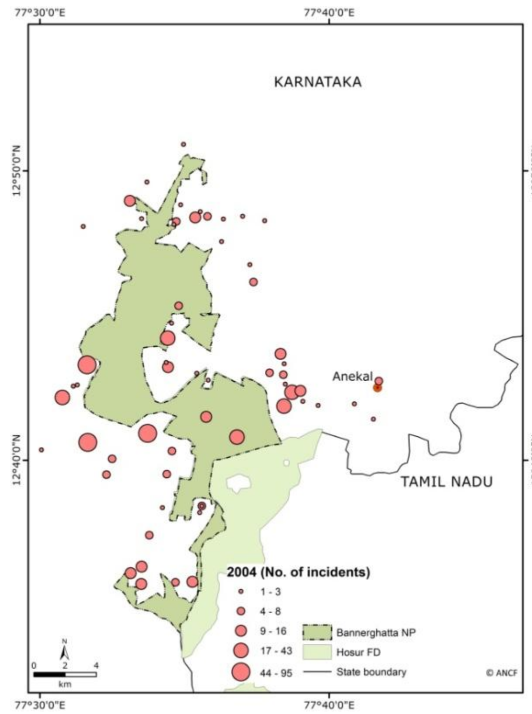
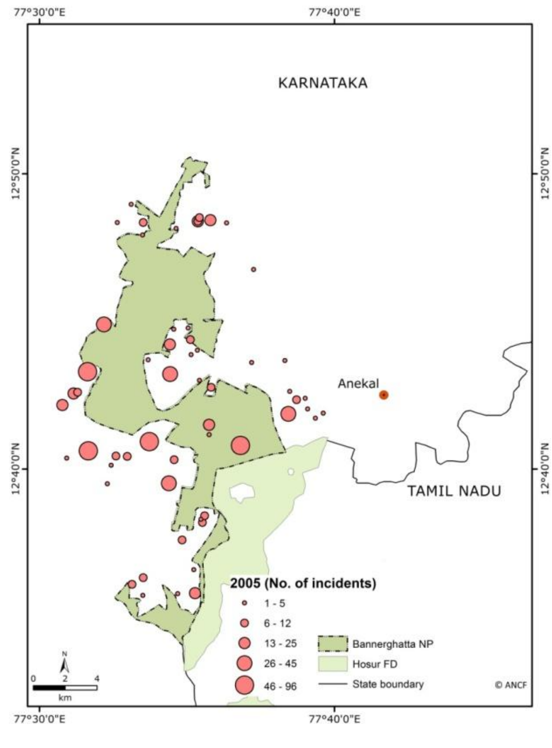


f



Figures 4a,b,c,d, e, f and g: Maps showing the incidents of crop damage during 1999 (a), 2000 (b), 2001 (c), 2002 (d), 2003 (e), 2004 (f) and 2005 (g) (Source: ANCF)

Spatial distribution of different villages in relation to amount of compensation paid

The results from the spatial data also shows (Figure 5) the distribution of villages with amounts claimed in INR as compensation for the period 2000 –2005.

The cumulative compensation payment across villages ranged from INR 1000 to 300000 and the range of 1000 to 16000 dominated. In relation to the number of incidents the amount of compensation claimed by the conflict villages is in proportion to the number of conflict incidents.

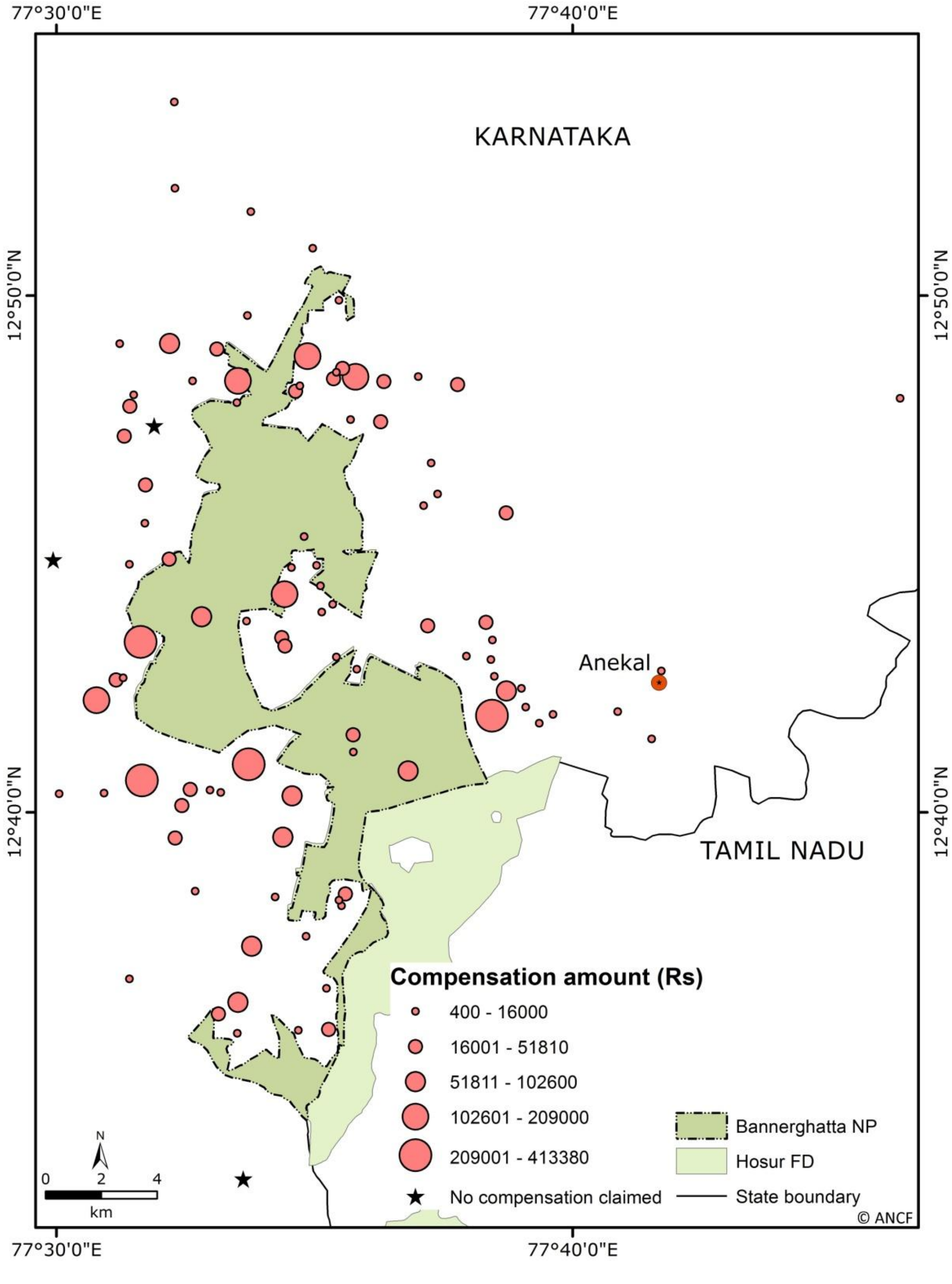


Figure 5: Spatial distribution of the villages that have claimed compensation payment (Source: ANCF)

The trend in compensation claims for the period 1999 to 2005, showed gradual increase in the number of compensation claims; with the maximum of 938 claims for the year

2005 (Figure 6). This pattern need not necessarily reflect the trend or the status of conflict since only the farmers who were aware of the compensation scheme, initiated in 1999 availed of the payments.

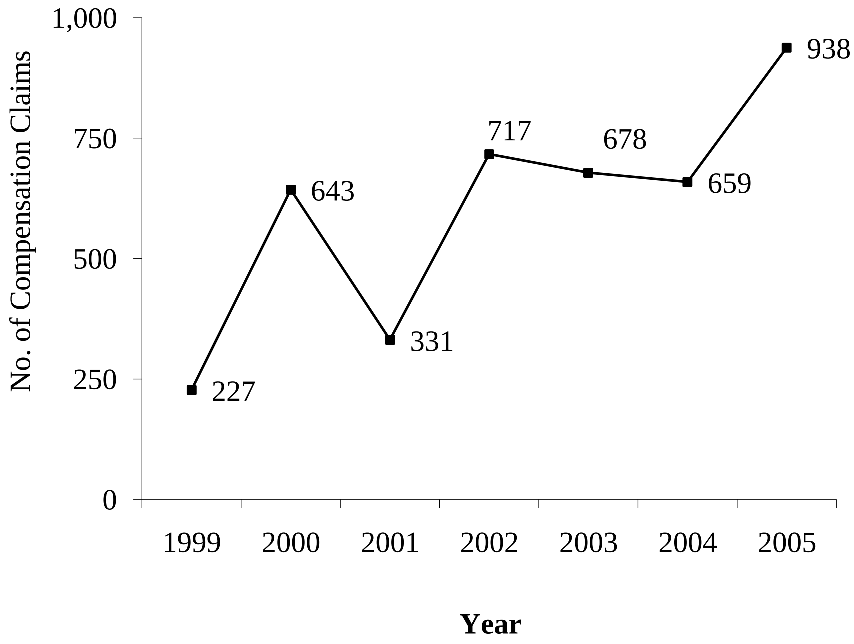


Figure 6: Shows the year wise compensation claims for crop damage from 1999 - 2005

Conflict zones

Conflict zones were identified using the home range estimator and these zones were allocated as intense, high, moderate, low and minimal. Number of villages, mean number of crop damage incidents, mean compensation amount paid/village and mean distance from the forest for each zone have been presented in table 1.

If both intense and high conflict zones are combined, 34 villages have both intense and high status of conflict; villages such as Ragihalli, Mantapa, Bannerghatta, Thammanayakanahalli and Buthanahalli come under these two zones of conflicts. Figure 7 gives the details of the distribution of conflict zones for the study area.

Table 1: Status of conflict in conflict zones that have been qualitatively assigned as "intense, high, medium, low and minimal"

Sl. No.	Status of conflict	Number of villages	Mean incidents (SE)	Mean compensation amount (SE)	Mean distance from forest- in km (SE)
1	Intense	15	37.7 (12.0)	39875.3 (12934.1)	1.5 (0.2)
2	High	19	43.8 (25.1)	37367.1 (17770.8)	1.5 (0.2)
3	Medium	28	41.4 (16.8)	42345.4 (17678.2)	1.5 (0.2)
4	Low	24	39.6 (13.1)	41258.3 (14266.1)	1.5 (0.2)
5	Minimal	14	13.2 (7.8)	13914.3 (7494.1)	5.4 (1.3)

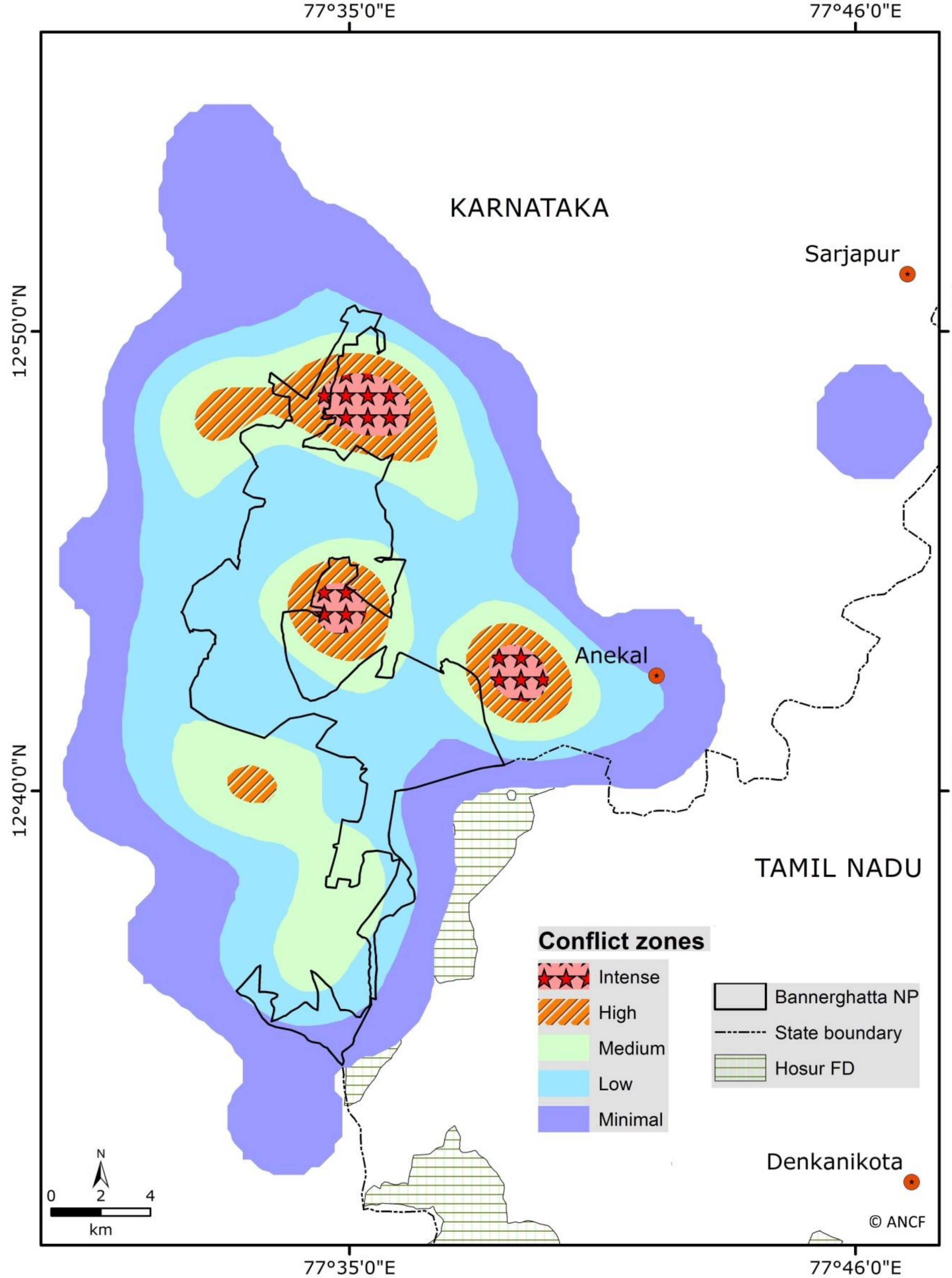


Figure 7: Map showing conflict zones delineated as intense, high, medium, low and minimal of the volume of the probability distribution derived from the kernel estimation (Source: ANCF)

Peak conflict months

The months between October and January appeared to be the peak period of conflict (Figure 8). There is more number of crop types (the scientific names were referred from Gurudeva 2001; see Appendix II for scientific names) cultivated during this period and it also coincides with the peak cropping season in the area.

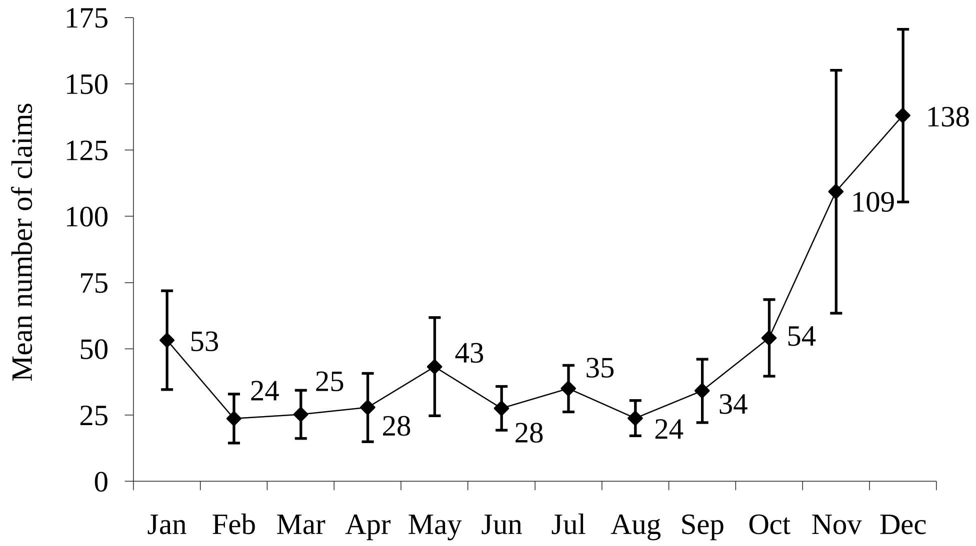


Figure 8: Month wise compensation claims for the period 1999 to 2005

Further, the crop compensation records analyzed shows a maximum of 23 crop types raided by the elephants during the month of November. The ground surveys also suggests similar results, as the period of harvesting, storing and processing of crops especially Ragi (a major crop cultivated along with Sorghum, Cluster beans and Wild sesame as a mixed crop) correlates with the peak period of conflict.

Pattern of crop cultivation and damage

The crop compensation records suggest that a minimum of 37 different crop types are cultivated around the national park. About 8 crop types are perennial (Tree crops), 2 are annual and the rest 27 are seasonal in cultivation. On an average 15.5 (SE=1.29, n=12, ranging from 9 to 23) crop types are raided by the elephants around the national park per month. The month November tops the list with 23 crop types raided by the elephants. About 414 compensation claims were registered for the combined months of November and December indicating the severity of the conflict in the park (Table 2a and b).

The crop Ragi is raided the most each year and maximum raids are reported between September and December. This period also happens to be the peak cropping season in the area. The crop Banana is the second most raided crop by the elephants and this crop is available all through the year as it is a 12 month crop. The third most raided crop is paddy and paddy is also found to be cultivated throughout the year. However, large scale cultivation of this crop is restricted to only one season (December-April) and the other seasons it is cultivated on a lower scale by only those farmers who have irrigation facilities like bore wells

.

Table 2a**:** Average elephant raids crop wise per month per year (during 1999, 2000 & 2005)

Sl. No.	Crop name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Almond	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.7**
2	Areca	0.0	0.3	0.3	0.0	0.3	0.3	0.5	0.0	0.0	0.3	0.0	0.0	**2.2**
3	Banana	1.3	14.3	11.7	10.7	12.0	6.7	27.3	3.3	3.3	1.7	1.3	8.0	**101.7**
4	Beans	2.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.3	0.7	0.7	1.0	**5.3**
5	Betel leaf	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	**0.7**
6	Bitter gourd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.0	**1.3**
7	Brinjal	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	**0.7**
8	Cabbage	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	**2.3**
9	Chilli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	**0.3**
10	Chintamani flower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	**0.3**
11	Cluster bean	0.3	0.0	0.0	0.0	0.0	0.0	0.3	1.7	5.0	17.5	28.7	6.3	**59.8**
12	Coconut	1.0	5.0	8.0	2.0	12.3	11.3	16.0	9.0	6.0	3.3	3.3	9.0	**86.3**
13	Great millet	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.7	4.0	0.7	1.3	2.0	**11.0**
14	Green pea	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.3	0.0	0.0	0.0	**1.7**
15	Ground nut	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.0	0.3	0.0	**3.0**
16	Huchu ellu	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.7	**1.3**
17	Jackfruit	1.0	3.0	1.5	0.7	6.7	3.7	6.0	0.7	2.0	0.0	0.0	0.3	**25.5**
18	Jowar	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	1.0	3.7	**8.3**

Table 2b**:** Average elephant raids crop wise per month per year (during 1999, 2000 & 2005)

Sl. No.	Crop name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
19	Karamani kai	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.0	**1.0**
20	Maigold flower	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	1.3	**4.3**
21	Maize	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	10.0	38.0	19.7	**68.3**
22	Mango	0.3	3.7	3.7	3.7	8.3	2.7	6.7	1.7	3.3	0.0	1.7	1.0	**36.7**
23	Mulberry	0.0	0.0	0.7	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	**1.3**
24	Napier	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.3	0.0	**1.0**
25	Nilgiri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	**1.0**
26	Paddy	3.3	1.0	2.7	4.0	18.0	10.3	3.0	2.3	4.7	5.7	22.0	23.7	**100.7**
27	Peas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	**0.3**
28	Pigeon pea	3.3	0.0	0.3	0.0	0.3	0.3	0.5	0.7	0.3	3.0	3.3	5.0	**17.2**
29	Potato	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	**0.3**
30	Ragi	12.3	5.0	1.7	1.7	10.3	2.0	0.7	2.7	21.3	47.0	125.0	80.0	**309.7**
31	Ridge gourd	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.7	0.0	0.0	0.0	0.0	**2.0**
32	Sapota	1.0	0.0	0.7	0.7	0.3	0.0	0.7	0.0	0.7	0.0	0.7	0.3	**5.0**
33	Sugarcane	0.0	0.3	1.0	1.0	1.7	4.7	2.3	0.0	3.3	0.0	0.0	1.7	**16.0**
34	Tamarind	0.3	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.3	**1.3**
35	Teak tree	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.7	0.3	0.0	0.0	0.0	**1.7**
36	Tomato	2.0	1.5	1.0	0.3	0.3	1.0	1.7	0.7	0.7	0.7	0.7	1.7	**12.2**
37	Toor daal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	10.3	4.7	**19.3**

The fourth most raided cop is coconut which is available all through the year as it is a perennial crop and is targeted the most during May to July. This period happens to be the end of dry season; the vegetation all around may be dry and poor in nutrients as well as moisture content. The crop sorghum is the fifth most raided crop in the park and is one of the crops cultivated with Ragi as a mixed crop.

This crop is the most preferred crop by the elephants after the harvest of Ragi as it will be in the reproductive stage at that point of time. The elephants feed only on the grains as they are very nutritious. The sixth most raided crop is Cluster beans and is raided the most during October and November (Figure 9). The crop, cluster beans is grown as a mixed crop with Ragi and is observed that the elephants does not consume this crop but trample it as they visit these crop fields for the crop Sorghum cultivated alongside.

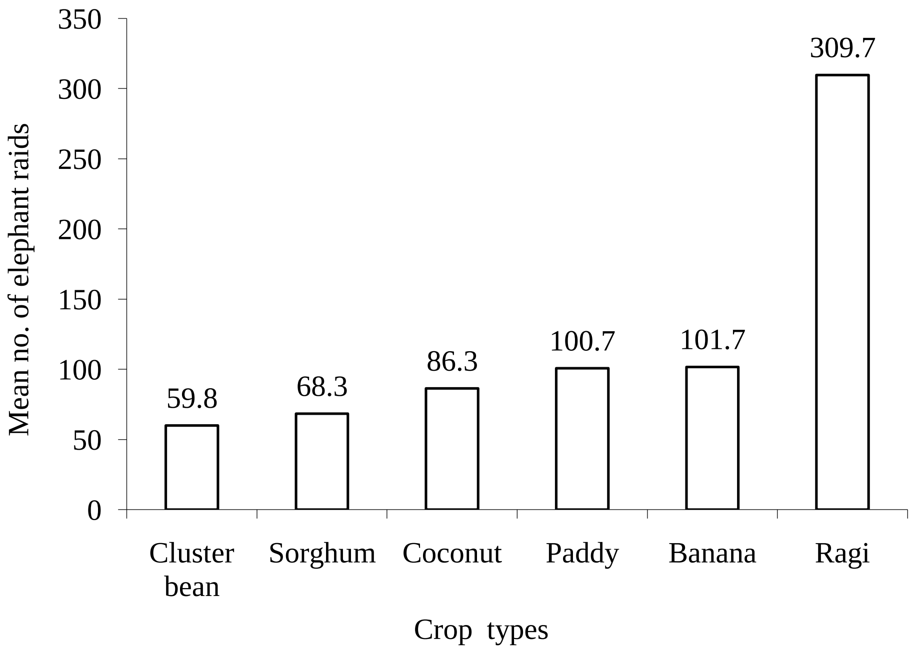


Figure 9: The mean number of elephant raids was potted against the top raided crops

Comparison of compensation claimed, assessed and paid

The percentage difference between the compensation amounts claimed and the assessed value for crop damage is given in figure 10. The figure also shows the percentage difference between the assessed value and the actual payment made to the farmers. The average percentage difference for the period 1999 to 2005, between compensation claimed and assessed was 36% (SE=8.86) and the average percentage difference between compensation assessed and paid was 9.5% (SE=6.2).

The average percentage difference between compensation claimed and paid was 42% (SE=7.7). Thus the actual compensation paid was only 58% of the claimed amount. This result indicates that an average of only 58% of the actual value of crop lost is paid as compensation to the farmers, reflecting the magnitude of the economic loss incurred by the farmers due to crop raiding by elephants.

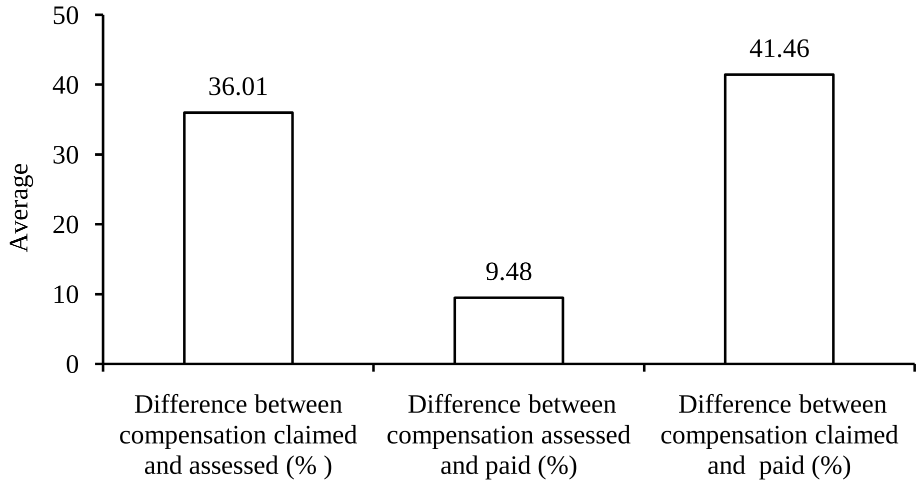


Figure.10: Differences between compensation claimed, assessed and paid for the period 1999 to 2005

Comparison of the results of the patterns of crop damage incidents of 1999-2005 with 2006-2007

The compensation claim records for the period 1999-2005 were collected for the calendar years following a systematic protocol, while for the period 2006-2007 the summary for the financial years available were collected. The numbers of claims for compensation across the years were tabulated to understand the trend. The comparison of values shows a decreasing trend in the conflict (Table 3).

Table 3: Number of compensation claims registered with the park authority between 1999 and 2007

	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006***	**2007***
April	13	16	0	31	90	1	44		
May	28	128	1	68	59	13	6		
June	49	56	11	15	38	21	3		
July	22	34	21	22	40	25	81		
August	21	31	25	53	24	0	13		
September	6	86	50	23	48	3	23		
October	35	33	67	58	12	51	123		
November	8	49	84	70	58	152	344		
December	38	128	58	258	100	196	188		
January	2	57	11	71	110	108	14		
February	2	6	0	25	45	29	59		
March	3	19	0	14	41	60	40		
Total	**227**	**643**	**328**	**708**	**665**	**659**	**938**	**825**	**500**

*****For the years 2006 and 2007 only the summary of compensation claimed available was collected and given in the table

Conclusion

The results suggest that elephants move up to 20 km from the forest and the distance range of 0.5-1 km show the highest incidents of crop damage. The pattern of compensation claimed by the local community for the duration 1999-2005 towards damages caused by elephants indicates that the human-elephant conflict is high and steadily increasing in the study area. The spatial distribution of the conflict villages as well as the compensation amount paid suggests that the villages located close to the narrow strips of the park area are affected to a larger extent as compared to the other villages in the park area. An interesting result emerging from the compensation claim records analysis is that the maximum damages occurred during the period October-January which coincides with the peak cropping season in the park area. The arrival of the migratory elephant population also overlaps with this season (Gopalakrishna pers. obs).

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Appendix-I

Assessment of compensation claims towards elephant damages in Bannerghatta National Park

I Area				**II. Crop details**		**III. Compensation**			**IV. Damage details**				
Sl. No	Range	Village Name	Date & time of damage	Crop type	age (Y-I-M)	INR claimed	INR assessed	INR paid	Affected Area	Farmer's name	Survey No	Location	Farmers Total Land
1													
2													
3													
4													
5													
6													

	V. Other Damage				VI. Elephant information			VII. Additional	Notes
Sl. No	House-person / Other property	INR claimed	INR assessed	INR paid	Seen (Yes / No)	How many	Deterrents (exist / used)		
1									
2									
3									
4									
5									
6									

Appendix II

Scientific names of crops (Gurudeva, 2001)

Sl. No.	Crop name	Scientific Name
1	Almond	*Prunus dulcis*
2	Areca	*Areca catechu*
3	Banana	*Musa paradisiaca*
4	Beans	*Phaseolus vulgaris*
5	Betel leaf	*Piper betel*
6	Bitter gourd	*Momordica balsamina*
7	Brinjal	*Solanum melongena*
8	Cabbage	*Brassica oleracea*
9	Chilli	*Capsicum sps.*
10	Chintamani flower	*Tagetes erect asps.*
11	Cluster bean	*Cyamopsis tetragonoloba*
12	Coconut	*Cocos nucifera*
13	Great millet	*Sorghum vulgare*
14	Green pea	*Pisum sativum*
15	Ground nut	*Arachis hypogeal*
16	Huchu ellu	*Guizotia abyssinica*
17	Jackfruit	*Artocarpus heterophyllus*
18	Jowar	*Sorghum bicolour*
19	Karamani kai	*Vigna unguiculata sps.*
20	Marigold flower	*Tagetes erecta*
21	Maize	*Zea mays*
22	Mango	*Mangifera indica*
23	Mulberry	*Morus alba*
24	Napier	*Pennisetum purpureum*
25	Nilgiri	*Eucalyptus globulus*
26	Paddy	*Oriza sativa*
27	Peas	*Pisum sps*
28	Pigeon pea	*Cajanus sps*
29	Potato	*Solanum tuberosum*
30	Ragi	*Eleusine coracana*
31	Ridge gourd	*Luffa acutangula*
32	Sapota	*Achras zapota*
33	Sugarcane	*Saccharum officinarum*
34	Tamarind	*Tamarindus indica*
35	Teak tree	*Tectona grandis*
36	Tomato	*Lycopersicon esculentum*
37	Tur daal	*Cajanus cajan*

Part 2
Conflict Mitigation Measures

Introduction

The management of conflict is a multifaceted and logistically demanding problem (Hoare 1995; Barnes *et al*. 1995; Mehta & Kellert 1998; Ogutu 2002). Human-elephant conflict problem is tackled by many mitigation measures, and the choice for mitigation of conflict between elephants and people have been recognized by many investigations (Sukumar 1991; Barnes *et al*. 1995; Hoare 1995). Government sponsored conflict mitigation measures encourage tolerance towards the problem species, however, if conflict mitigation measures fail, the concept of conserving problem species, even if it is highly endangered is lost (Tchamba 1996; Mitchell & Slim 1991; Mehta & Kellert 1998; Ogutu 2002; Prabal *et al*. 2008). Initiating or executing conflict mitigation measures requires a detailed understanding of underlying patterns and processes (Sitati *et al*. 2003; Prabal *et al*. 2008; Varma & Prabal 2008). With fluctuating densities of elephants, loss and fragmentation of habitats, elephants have been forced to enter human dominated landscapes and, it is imperative that more scientific and systematic methods of conflict mitigation have to be tried and monitored for their effectiveness.

Damage by elephants is prevented by fencing, (wooden or electric or any other fencing), or excavating barriers (Treves 1998; Hoare 2000; Low 2000; Varma *et al*. 2008). Digging steep sided trenches may reduce conflict initially, but soon become ineffective; in some cases the trenches are concrete lined, or rubble walls are erected. However, such vigorous approaches are very costly or not practical or feasible considering the lengthy boundaries of parks (Hoare 1995; Barnes *et al*. 1995; Sukumar 1990; Sukumar 1991; Prabal *et al*. 2008). The Forest Department, custodian of wildlife in India uses active methods such as elephant capture and scaring and passive methods such as elephant-proof trenches, electrified fences and rubble walls towards conflict mitigation (Nath & Sukumar 1998).

These methods have been used in many parts of Asia and Africa (Hoare 1995; Tchamba 1996; Newmark & Hough 2000; Sitati *et al*. 2003; Sitati 2003; Prabal *et al.* 2008), but there are few studies that provide detailed investigations of the current status of the conflict mitigation measures (Nath & Sukumar 1998; Prabal *et al*. 2008). The investigation of the current status of these elephant proof barriers in terms of their location, total length, breakage points, cause of breakage, cost of maintaining or fixing the breakage points and other aspects have to be carried out. A specific investigation of assessing past and current status of some of the elephant proof barriers were carried out in Bannerghatta National Park.

Objective

To assess the status of existing elephant proof barrier
To identify the spatial factors and the distribution of breakage points
To compare status of the barriers from two different years, 2005 and 2008
To estimate the cost of repairing the barriers

The objectives were developed through the following concept
As part of conflict mitigation, elephant proof trenches, electric fences, rubble wall, and scaring squads are used in the Bannerghatta region**.** In spite of the use of these barriers, the conflict situation appears to be unabated in the study area, which is evident from the continuous rise in compensation claims over the years. The reasons could be manifolds, but primarily it is due to lack of understanding on the efficacy of each elephant barrier as well as participation from the local communities in its maintenance.

Managing human-elephant conflict is difficult and may be logistically taxing, with unpredictable densities and movement of elephants, reduction in and destruction of existing habitats, elephants have become more destructive and, new conflict mitigation measures have to be tried. Correspondingly, testing the status and efficacy of existing conflict mitigation measures have to be done. The task is very difficult, fixing the problems of existing mitigation measures, and issues created due to changing land use patterns, reduction in forest cover and increasing elephant densities. This requires an absolute understanding of the status and efficacy of accessible mitigation measures. This is a never ending process, has to be done periodically or at different time intervals, equally importantly, investigation has to be carried out with more scientific and systematic methods.

Even with several mitigation measures, elephants are increasingly damaging crops and properties, and injuring or killing people, leading to a soaring conflict and maximum financial sufferings to those residing close to elephant habitats (Hough 2000; Mitchell & Slim 1991; Varma & Prabal 2008). A survey of the different elephant barriers at the Bannerghatta National Park was needed to assess their current status. This assessment was carried out for the entire park, of the existing 143 km elephant proof barriers and 138 km of barrier was investigated for its efficacy in 2005. In 2008, 23% of the total barrier mechanisms, amounting to 35 km in length were surveyed. The prime aspects considered for investigation was to identify each barrier's location, distance from village or crop land, total length and breakage points and their causes. During both periods, a systematic approach was followed. This provided a scope for comparing the status across two different periods, in estimating the cost of fixing the barriers and in projecting the scope and constraints of fixing the breakage points for a given barrier mechanism.

Methodology

Mapping and assessment of elephant barriers

An assessment of the elephant barriers was undertaken to assess the status of different barrier mechanisms such as the Elephant Proof Trenches, Electrified Fences and Rubble Walls (Figure 1; see Appendix I for additional figures related to the status of barriers). This assessment was done in all the three ranges namely the Bannerghatta range, Harohalli range and Anekal range, of 143 km elephant proof barriers, 138 km (97%) barriers were investigated for their efficacy in 2005.

Figure 1: Assessment and mapping of traditional elephant barriers in BNP

The different barriers were surveyed by foot and mapped with the help of Global Positioning Systems (GPS). While mapping, at each breakage/damage point, a geo coordinate was taken. Apart from the coordinates, information such as type of damage, cause of damage, status of damage, year of execution of the barrier, status of forest, the distance to nearest cultivation, type of cultivation, distance to nearest village were also recorded. Irrespective of the breakages, the status of forest, distance to nearest cultivation, type of cultivation, status of elephant barrier and the distance to nearest village were also collected for every half an hour. This was done to know the effect of human activities on the barriers (see Appendix-II for data sheet). The data collected was processed in the Geographical Information System (GIS) environment.

In 2008, the random sampling method was used for the survey where 23% of the total barrier mechanisms, amounting to 35 km in length were surveyed. The barriers were surveyed by foot and mapped with the help of a Global Positioning Systems (GPS). While surveying, at each breakage/damage point, a geo-coordinate was taken.

Apart from the coordinate readings, information such as the type of damage, cause of damage, status of damage, details of the nearest village were also recorded. Irrespective of the damage at every half an hour interval, the distance of the barrier to nearest cultivation/village and the status of the barrier at that point were also collected. This was documented to ascertain the anthropogenic pressure on the barriers.

Results and Discussion

Mapping and assessment of elephant barriers

Status of elephant barrier in 2005

Three types of barriers were identified during the mapping and assessment of the elephant barriers. The barriers observed were Rubble Walls (RW), Elephant Proof Trenches (EPT) and Electrified Fences (EF). Predominantly EPT were found to be in use at the time of survey. Electrified fences (erected but not in use) were present in 0.83 % (1.18 km) of the total length of barriers that were surveyed. The EPT was used in 67% (95.3 km) of the total length and rubble walls were found to be erected in 33% (46.9 km) of the total barrier length.

Basic design and the dimensions of the barriers

The Elephant proof trench has an average depth of 2.16 (SE=0.05, n=26) m, average top width of 2.97 (SE=0.04, n=26) m and a bottom width of 1.17 (SE=0.07, n=26) m. The Rubble wall is a solid structure with an average top width of 1.25 (SE=0.06, n=22) m, average bottom width of 2.05 (SE=0.07, n=22) and an average height of 2.06 (SE=0.08, n=22) m. The Electric fence observed was a 5 line drawn on the stone pillars with a height of 1.5 m (Figure 2).

a b c

Figure 2a, b and c: Design of Elephant proof trench (a), Rubble wall (b)and Electrified fence (c) in BNP

Barrier location, villages and cultivation

About 35% of the total length of the barrier sampled was located at about 50m distance from the villages and about 17% of the barrier surveyed was located at about 500m (Figure 3) from the villages with an average distance of 53.88m (SE=41.4, n=18) from the village (this sample was based on every 30 minutes interval investigation on the presence and absence of villages and their distance from the barrier surveyed).

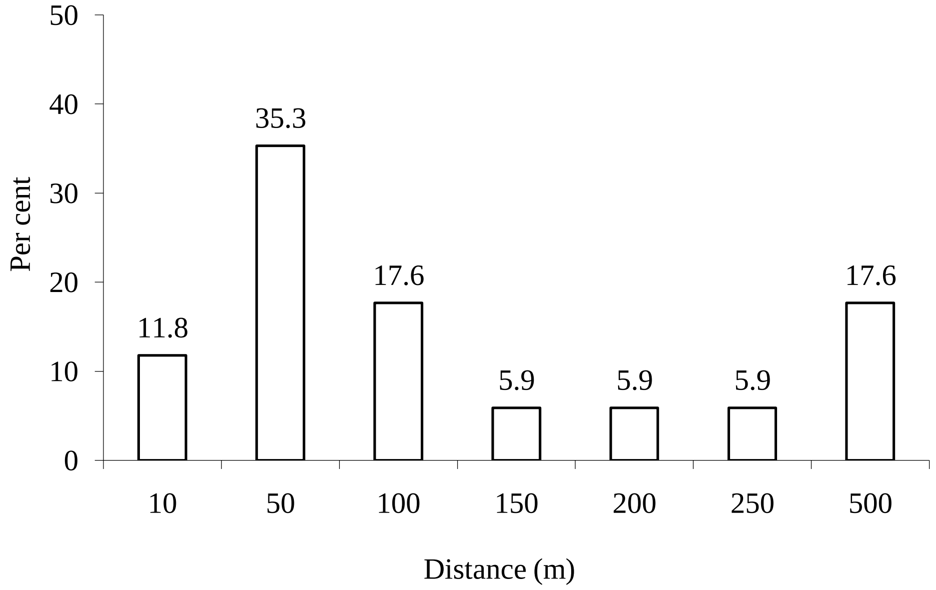
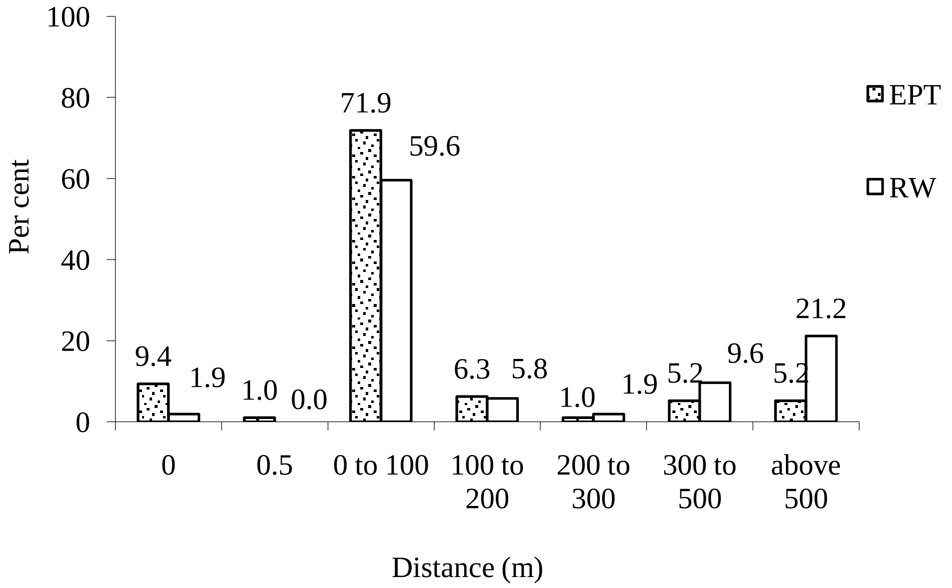


Figure 3: Percentage of barriers v/s their distance from the villages during 2005

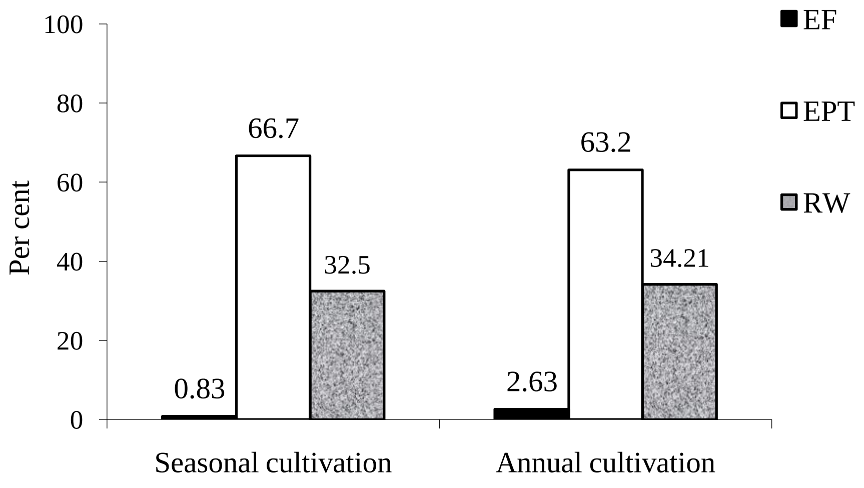
About seventy two percent of the EPT and 60 % of RW surveyed were located within 0-100 m distance from the crop land (Figure 4).



EPT-Elephant Proof Trench, RW-Rubble Wall

Figure 4: Percentage of barriers v/s their distance from the crop cultivation during 2005

All the above mentioned barriers were found to be used in seasonal crop cultivation areas. However EPT was found to be used predominately in both seasonal and annual crop cultivated areas (Figure 5).



EF-Electric Fence, EPT-Elephant Proof Trench, RW-Rubble Wall

Figure 5: Proportion of occurrence of elephant barriers in seasonal and annual crop cultivation lands during 2005

Status of breakages

The assessment of status of different barriers showed a total of 882 breakage points in 138 km stretch of the barrier. The damages were classified into 4 types, namely, very fresh (4-5 days old), fresh (5-10 days old), old (> month) and very old (>2 months). Old damages were found more (84%) during the survey period, followed by very old damages in 13% of the total damage. The signs of fresh damages were less accounting for only 3% of the total damages and very fresh damages accounted for only 0.5% of the total damage points (Figure 6).

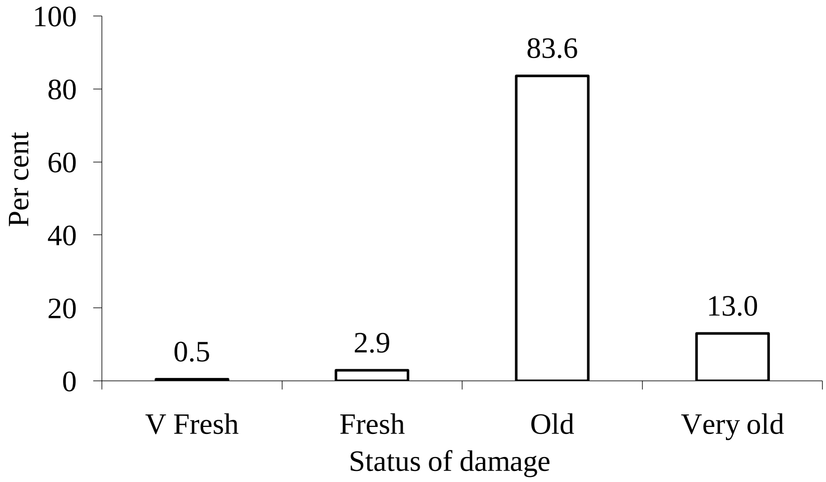


Figure 6: Status of damage points during 2005

The results showed many causes for the damage of the barriers. These causes were broadly classified into 28 categories. The number of causes for the damage of the elephant proof trench (EPT) was found to be 19, 13 for Rubble walls and cause of damage to electric fence was not ascertained as the fence was discarded (Table1; Note table 1 provides only 15 causes and 12 causes of damages for EPT and RW respectively).

The causes 'discontinuity' and 'land fill' for EPT are further divided into 2 more categories. The man made causes for RW has been further classified into one more category. The causes range from cattle related, road or stream, drains or pathways cutting across barriers, natural collapse, encroachment, soil or wall erosions and damage due to wildlife.

Table 1: Causes of elephant proof barrier damage

	Elephant proof trench		Rubble wall		Electric fence
1	Width not maintained	1	Cattle path way	1	Elephant - Not maintained*
2	Cattle pathway	2	Cutting across of roadway		
3	Depth not maintained	3	Cutting across of stream		
4	Discontinuity [1, 2, 10]	4	Discontinuity[9]		
5	Cutting across of drain	5	Elephant path		
6	Elephant path	6	Height not maintained.		
7	Encroachment	7	Manmade [8, 6]		
8	Erosion	8	Natural collapse		
9	Landfill [3, 4, 5]	9	Sheet rock obstruction		
10	Hard soil	10	Sunken and unpacked		
11	Cutting across of pathway [6]	11	Width not maintained		
12	Rocky outcrop	12	Wildlife [7]		
13	Sheet rock obstruction				
14	Cutting across of stream				
15	Wild boar pathway				
	Total number of damage points = 575		Total number of damage points = 307		

1= Due to legal dispute over land, 2 = Due to hard soil surface, 3 = Due to manmade sand filter, 4 = Due to inner wall collapse (loose soil), 5 = Due to silt deposition by drainage, 6 = Man made illegal pathway for accessing bordering settlements, 7 = Unpacked by sloth bear for honey collection, 8 = Unpacked by man for honey collection, 9 = Due to sloppy terrain, 10= Due to filling up of rain water in the EPT. * Cause of damage for electric fence was not ascertained as the fence was discarded

The various causes mentioned above can also classified into natural cause, execution error, elephant made and human interference. Dominant among the categories was natural causes accounting for 49.8% of the total breakages. This was followed by the execution errors, which accounted for 23.0% of the breakages. The damage caused by elephants accounted for only 14.8% of the total breakage. Human interference was observed in 12.3% of the breakages.

Figure 6 shows the current status of the various elephant proof barriers across the national park as well as the breakage points. The breakage points on the map (Figure 7) appear as continuous lines reflecting the highly porous status of the barrier.

Figure 8a & b provide a pictorial representation of the breakage points for both EPT and Rubble Wall.

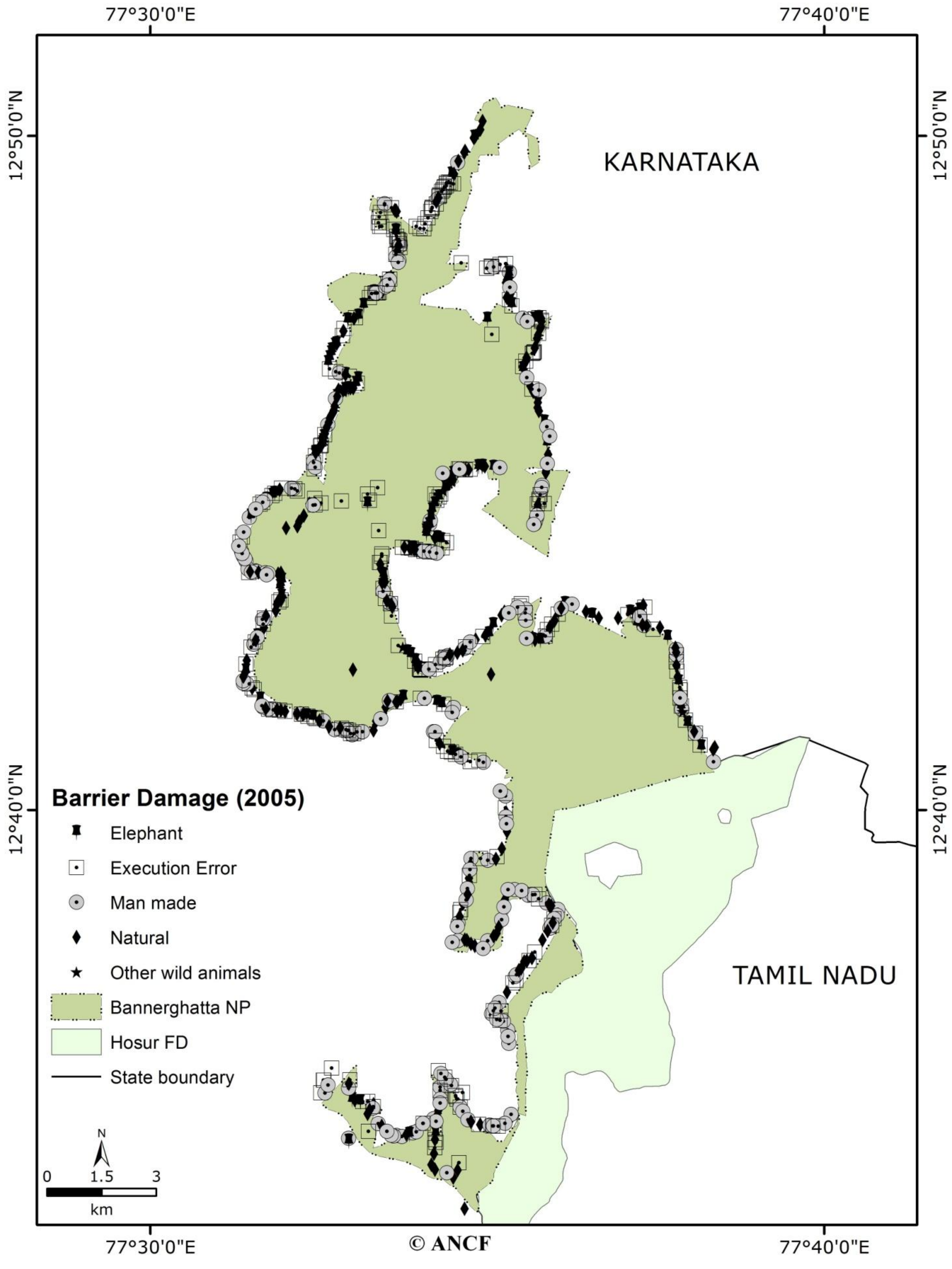


Figure 7: Status of elephant proof barriers as observed during 2005 in BNP
(Source: ANCF)

Patterns of breakages

Elephant Proof Trench (EPT): A total of 575 breakage points for EPT were encountered, for 433 breakages actual distances (or size) of breakage was available and the results suggests that, the breakage length of EPT varied from 1m to 600m (with an average of 32.9, SE=3.4, n=433).

Figure 8a & b: Status of the rubble wall and elephant proof trench during the survey

Frequency of size (or distance) of breakage dominated for 10 m (22 %) followed by 20 meters (12%), 5 meters (10%) and 15 and 30 m (9%), and about 80% were within the 30 m size class. As size of the damages increased, the frequency of occurrence decreased (Figure 9, r = 0.62).

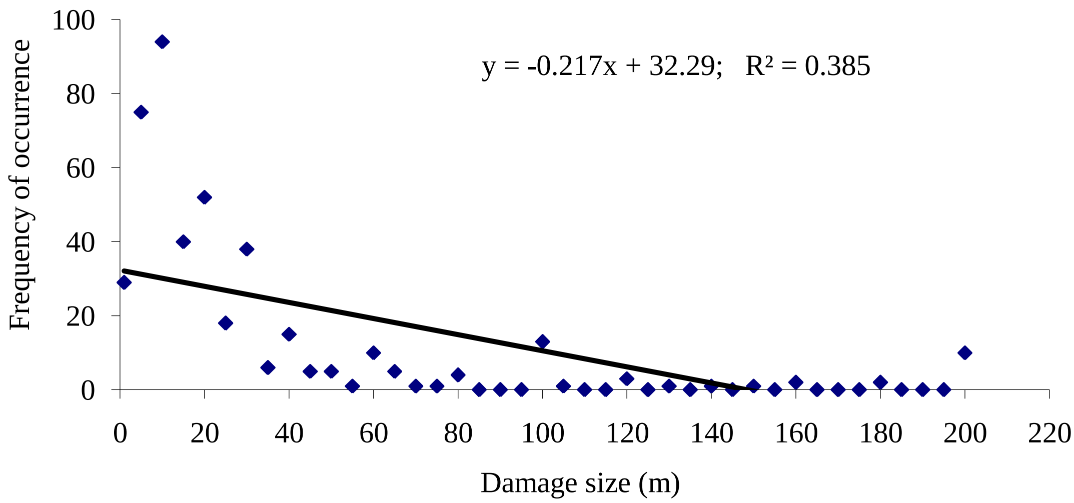


Figure 9: Shows the frequency of occurrence of different size classes of damages in EPT during 2005

Cost of repair

The status of breakage points or damages to EPT provide an opportunity for estimating the expected cost of fixing these breakage points, individually or collectively, depending on the location, budget and other aspects. Data on actual cost of fixing or repairing each point (depending on the size or distance) is not available and the total cost of repairing EPT per km is considered. Per km rate has been converted into per meter and depending on the size (or distance) of the breakage, cost of fixing breakage has been arrived.

The cost of repairing EPT worked out to be INR 40,000.00 (US$ 889) per km in 2005 and the cost arrived per point for fixing EPT was 40 INR per meter. Based on the size (distance in meter), cost of each breakage was calculated. The total length of breakages (total of 433 breakages) was 14,246.5 m (or 14.246 km) and a total of INR 5, 69,860.00 would be required for repairing the breakage points.

Rubble Wall: A total of 307 breakage points were encountered for Rubble Wall. The data available (184 points) for actual size (distance) of brakage suggest that the breakage length varied from 0.5m to 200m (with an average of 18.2, SE=1.9, n=184). Frequency of size (or distance) of breakage dominated for 10 m (22 %) followed by 3 meters (12%), and 6 m (10%), and about 78% fall within the 20 m size class, and like EPT, as size of the damages increase, the frequency occurrence decreases (Figure 10, r = 0.64).

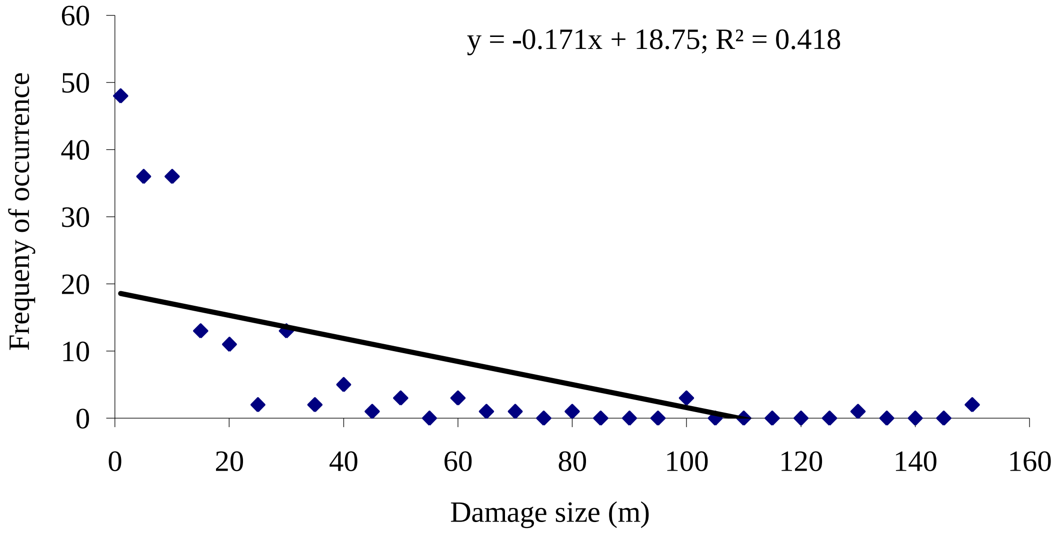


Figure 10: Shows the frequency of occurrence of different size classes of damages in RW during 2005

Cost of repair

The cost of repairing Rubble Wall was estimated to be INR 1, 38, 000.00 (US$ 3067) per km in 2005. This value was arrived at as 1 running meter is estimated to be 3.33 m^3 and for 1 meter repair at a cost of INR 41.00 per m^3, a total amount of INR 138.00 was arrived at for repairing of 1 running meter of rubble wall. The total length of breakages (total of 184 breakages) was estimated to be 3361.5 m (or 3.3615 km), thus a total of INR 4, 63, 887.00 (Table 2) would be required for repairing the breakage points.

The actual cost fixing individual breakage points for both EPT and Rubble Wall may go up further due to other factors (distance to the breakage point to administrative boundary, cost of transport, labour, materials and other aspects). Our attempt is to provide a conservative estimate and from this estimate specific plan or insights could be arrived. This attempt is to project the cost of fixing the breakage points and to identify the magnitude of the problem, providing scope of estimating specific budget and other related aspects.

The frequency of occurrences of breakage size (distance) for each breakage point for both EPT and Rubble Wall are given in the table 2a and 2b; the table also summarizes the amount of money needed to repair each or collective breakage points during 2005.

Table 2a: The frequency of occurrences of breakage size (distance) for both EPT and RW and the amount of money needed to repair each or collective breakage points during 2005

Sl. No.	Elephant Proof Trench				Rubble Wall			
	Distance of damage (m)	**Frequency**	**%**	**Total cost of the damage**	**Distance of damage (m)**	**Frequency**	**%**	**Total cost of the damage (INR)**
1	1	2	0.5	80	0.5	1	0.5	69
2	2	8	1.9	640	1	8	4.3	1104
3	2.5	1	0.2	100	2	11	6.0	3036
4	3	14	3.3	1680	3	22	12.0	9108
5	4	4	0.9	640	4	6	3.3	3312
6	5	43	10.1	8600	5	10	5.4	6900
7	6	28	6.6	6720	6	19	10.3	15732
8	8	4	0.9	1280	8	7	3.8	7728
9	10	93	21.9	37200	10	31	16.8	42780
10	13	1	0.2	520	12	5	2.7	8280
11	15	38	8.9	22800	15	11	6.0	22770
12	16	1	0.2	640	16	2	1.1	4416
13	18	1	0.2	720	20	11	6.0	30360
14	20	51	12.0	40800	25	2	1.1	6900
15	23	1	0.2	920	30	13	7.1	53820
16	25	18	4.2	18000	35	2	1.1	9660
17	30	38	8.9	45600	36	1	0.5	4968
18	35	5	1.2	7000	40	4	2.2	22080
19	36	1	0.2	1440	43	1	0.5	5934
20	40	15	3.5	24000	50	3	1.6	20700
21	45	4	0.9	7200	60	4	2.2	33120
22	48	1	0.2	1920	65	1	0.5	8970
23	50	5	1.2	10000	70	1	0.5	9660
24	55	1	0.2	2200	80	1	0.5	11040
25	60	10	2.4	24000	100	4	2.2	55200
26	65	1	0.2	2600	130	1	0.5	17940
27	70	4	0.9	11200	150	1	0.5	20700
28	74	1	0.2	2960	200	1	0.5	27600
29	75	1	0.2	3000				
30	80	4	0.9	12800				
31	100	13	3.1	52000				
32	105	1	0.2	4200				
33	120	3	0.7	14400				
34	130	1	0.2	5200				
35	140	1	0.2	5600				
36	150	1	0.2	6000				
37	160	2	0.5	12800				
38	180	2	0.5	14400				
39	200	5	1.2	40000				
40	250	1	0.2	10000				
41	500	1	0.2	20000				
42	600	1	0.2	24000				
43	800	2	0.5	64000				
Total		**433**		**569860**		**184**		**463887**

Table 2b: The mean of frequency of occurrences of breakage size and mean cost of the damage for both EPT and Rubble Wall

Sl. No.	Elephant Proof Trench		Rubble Wall	
	Frequency	**Cost of the damage (in INR)**	**Frequency**	**Cost of the damage (in INR)**
Mean	32.9	1316.1	18.3	2521.1
SE	3.5	139.8	1.9	275.3
CV%	10.6	10.6	10.9	10.9

Status of elephant Barriers in 2008

The barriers observed during the survey were the Elephant Proof Trenches (EPT), Rubble Walls and Electrified Fences. Like 2005, predominantly the EPT was found to be in use at the time of survey. The EPT was used in 42% of the total length surveyed and Rubble walls were found to be erected in 35% of the total barrier length. Electrified fences were present in 23 % of the total length of barriers that were surveyed.

Basic design and the dimensions of the barrier

The Elephant proof trench had an average depth of 2.5 (SE=0.10, n=6) m, average top width of 2.9 (SE=0.05, n=6) m and a bottom width of 1.55 (SE=0.08, n=6) m. The Rubble wall had an average top width of 1.8 (SE=0.18, n=9) m, average bottom width of 2.38 (SE=0.51, n=6) m and an average height of 1.8 (SE=0.18, n=9) m. The Electric fence had an average height of 1.8 (SE = 0.12, n =3) m and an average of 6.33 (SE = 0.4, n = 3) lines were drawn on the flexible iron poles supported by the firm iron poles erected.

Barrier location from villages and cultivations

The barriers surveyed were located on an average of 575 (SE=104, n=20) m from the villages (this sample was based on every 30 minutes interval investigation on the presence and absence of villages and their distance from the barrier surveyed). About 75% of the total length of the barrier sampled was located within 500m distance from the villages (Figure 11).

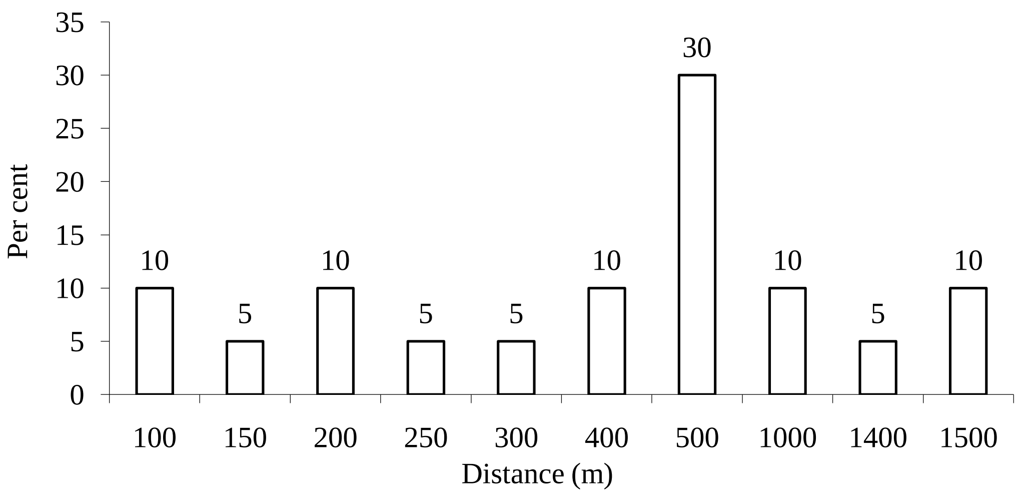
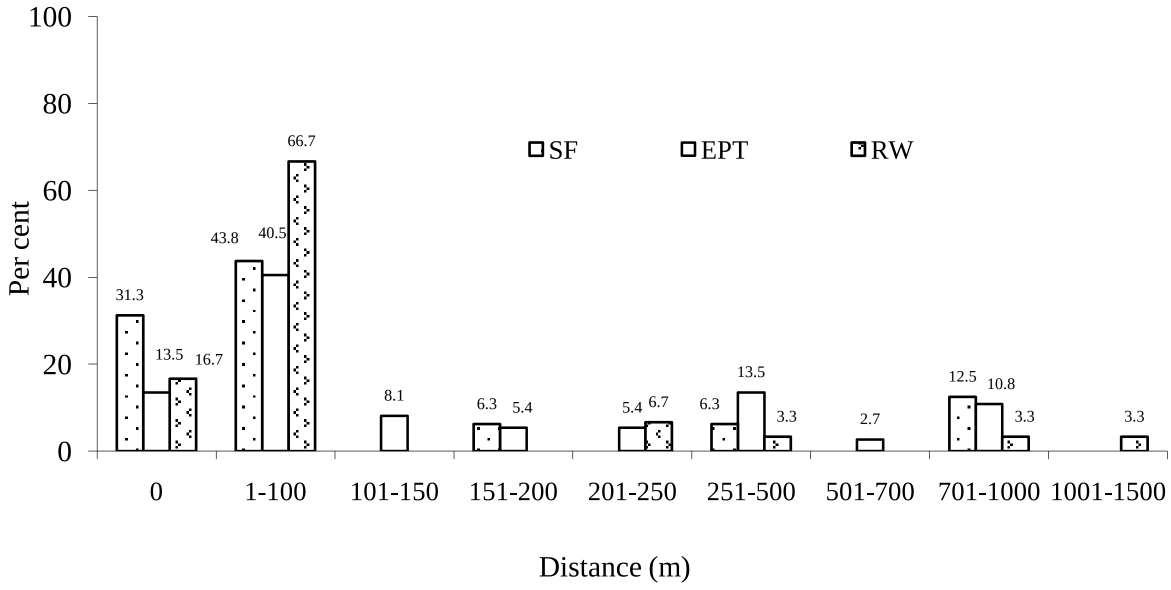


Figure 11: Shows the proportion of barriers v/s their distance from the villages during 2008

Sixty seven percent of the RW, 44 % of the Electric (solar) fencing and 41 % of EPT surveyed were located within 1-100 m distance from the crop land (Figure 12).



EF-Electric Fence, EPT-Elephant Proof Trench, RW-Rubble Wall

Figure 12: Shows the proportion of barriers v/s their distance from the crop cultivations during 2008

Status of breakages

The assessment of status of the barrier mechanisms showed a total of 235 breakage points in the 35 km stretch of barrier surveyed. The damages were classified into 4 types namely very fresh (4-5 days old), fresh (5-10 days old), old (> month) and very old (>2 months). Very old damages were found more (82%) during the survey period, followed by old damages in 12 % of the total damages.

The signs of fresh damages were less accounting for only 6 % of the total damages and that of very fresh damages were nil during the survey period (Figure 13a). The distribution of the patterns of the breakage points are given in the Figure 13b.

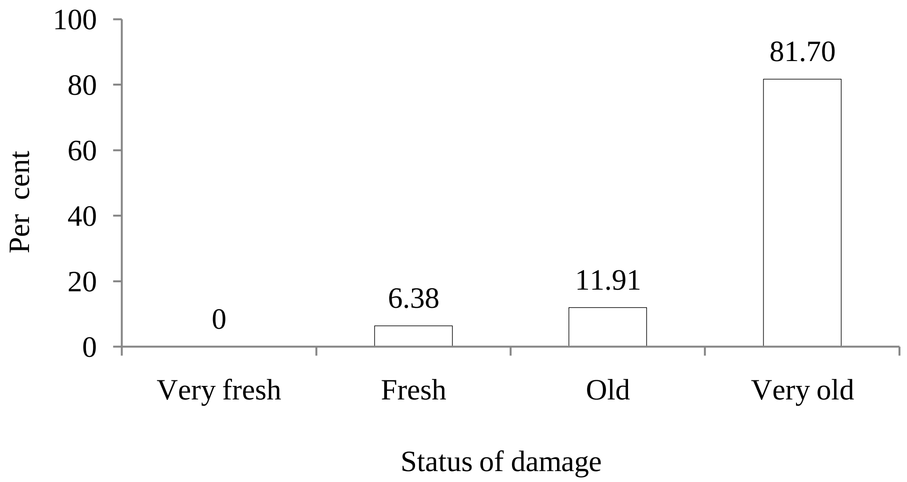


Figure 13a: Status of damage points during 2008

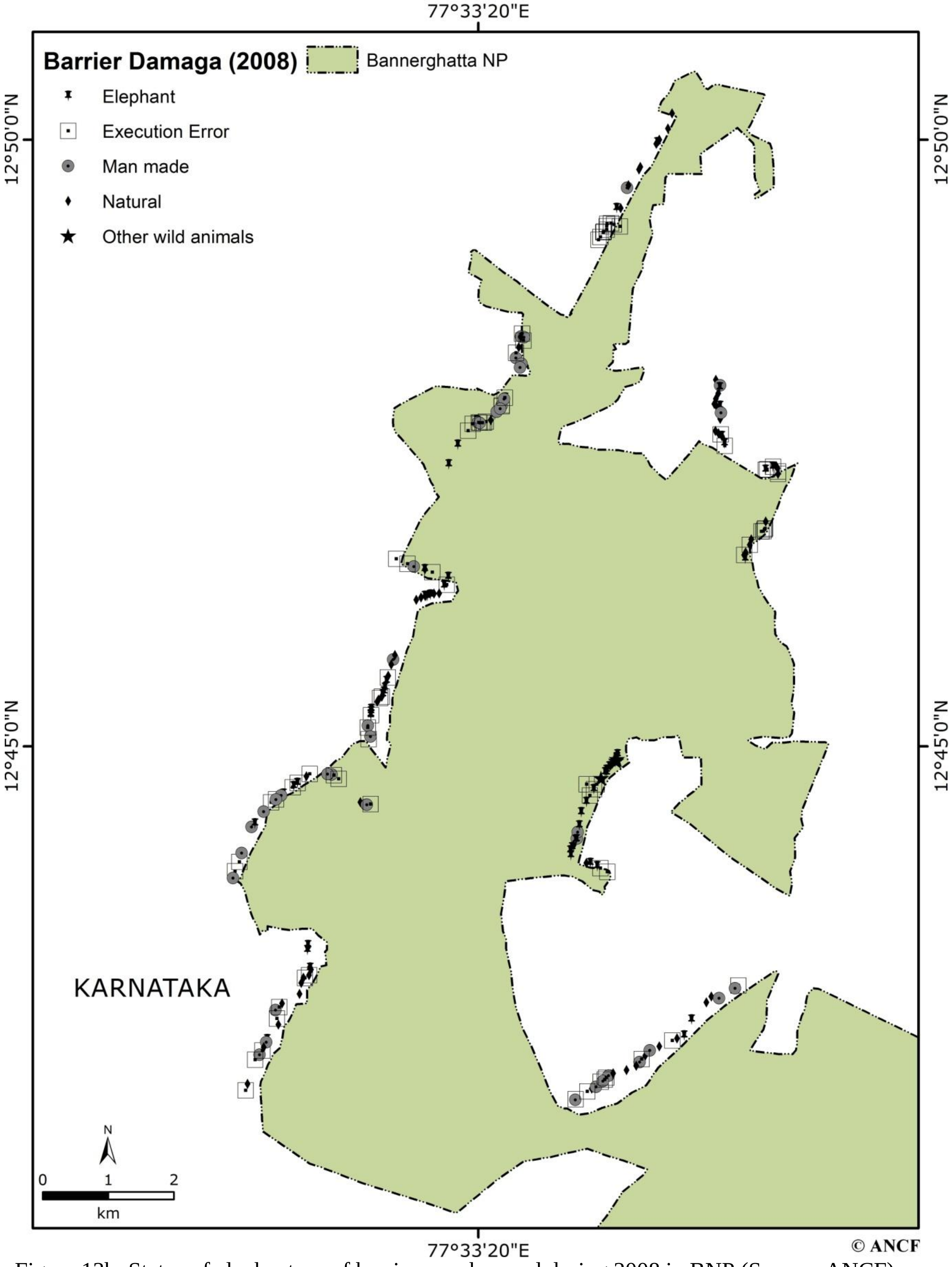


Figure 13b: Status of elephant proof barriers as observed during 2008 in BNP (Source: ANCF)

The results further reveal a variety of causes for the breakage of the barriers. The number of causes for the damages of the EPT was found to be 9 and this was 10 for Rubble walls (Table 3). The cause for the damage of Electric fence was found to be only 1. (Note: Table 3: provides only 8 causes for the Rubble wall. The cause of human interference is further divided into 2 more categories). The average length of a breakage point in the EPT was found to be 19.87 meters (SE=0.48, n=121 and range 1-150) where as the average length of a damage point in the rubble wall was 9.8 meters (SE=0.35, n=114 and range = 0.7-100)

Table 3: The different causes for the damages in the elephant proof barriers during 2008

Sl. No.	Electric fence	Sl. No.	Elephant proof trench	Sl. No.	Rubble wall
1	Elephant caused	1	Cattle path way	1	Elephant caused
		2	Discontinuous due to sheet rock	2	Cattle path way
		3	Depth not maintained	3	Collapsed due to gradient
		4	Discontinuous due to rocky outcrop	4	Man made[1, 2, 3]
		5	Filled up due to erosion	5	Height not maintained
		6	Man made[1]	6	Roadway cuts across
		7	Roadway cuts across	7	Rubble wall sunken and height decreased
		8	Stream cut across	8	Stream cut across
		9	Width not maintained		
	Total number of damage points = 1		**Total number of damage points = 120**		**Total number of damage points = 114**

1= Foot path ways to access the bordering settlements located other side of the park, 2= Broken by humans to access the forest, 3= Rubble wall unpacked by local community for personal use.

The various causes mentioned above can also be classified into natural causes, execution errors, elephant made and human interference. Dominant among the categories was ‘elephant caused’ accounting to 40% of the total breakages recorded. This was followed by the natural causes, which accounted for 34% of the breakages. The damages due to execution errors accounted for 14% of the total breakages. Human interference was observed in 13% of the breakages. The finding shows that about 13% of the breakage points were frequently damaged by the elephants even after being repaired (Figure 14a, b and c).

a b c

Figure 14: Breakage points in elephant traditional elephant proof barriers Viz. EPT (a), RW(b) & SF(c)

The overall status of the different elephant barriers shows that electric fences were well (100% of the total length) maintained throughout its length and similarly the rubble walls were (98% of the total length) also maintained well, whereas the EPT was moderately (only 59% of the total length) maintained (Figure 15).

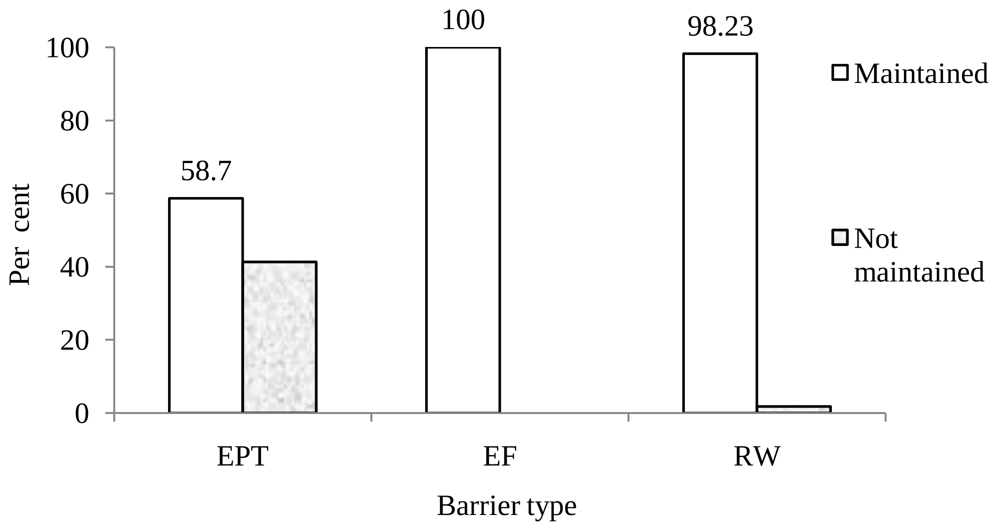


Figure 15**:** Maintenance status of different elephant proof barriers in BNP

Patterns of breakages

Elephant Proof Trench (EPT)

A total of 120 breakage points for EPT were encountered and the length of the damage varied from 1 m to 150 m (with an average of 19.8, SE=0.48, n=120). Frequency of size (length) of breakage dominated for 1m (24%) followed by 10m (19%), 5m (18%), 20m (13%), and 15m (11%) and about 95% of the breakages were within the 20m size class. As the size of the damage increased, the frequency of occurrence decreased (Figure 16, r = 0.65)

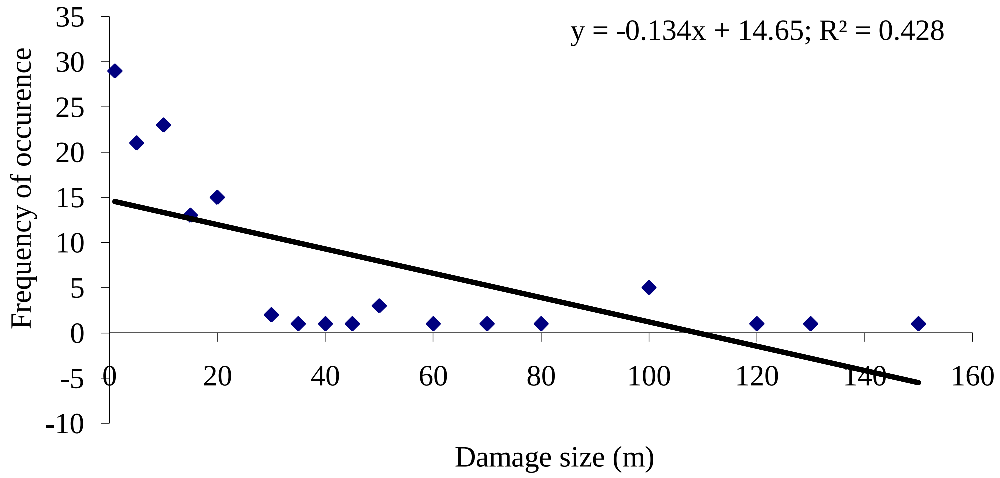


Figure 16: The frequency of occurrence of damages in EPT was plotted against the different size class of damages

Cost of repair

The data on actual cost of fixing or repairing each point (depending on the size or distance) was not available and the total cost of repairing EPT per km is considered. Per km rate has been converted into per meter and depending on the size (or distance) of the breakage, total cost of fixing the breakage has been arrived. The cost of repairing EPT worked out to be INR 62,500.00 (US$ 1389) per km during 2008 and the cost arrived per point for fixing EPT was 62.50 INR per meter. Based on the size (distance in meter) cost of each breakage was arrived at. The total length of breakages (total of 120 breakages) accounts for 2385 m (or 2.385 km) and a total of 1, 49, 062.50 INR would be required for repairing all the breakage points.

Rubble wall

A total of 114 breakage points were encountered for Rubble Wall during the survey period. The results suggests that the size (length) of breakage varied from 0.7m to 100m (with an average of 9.8, SE=0.35, n=114). The frequency of breakage size (length) dominated for 1m (41%) followed by 5m (24%), 10m (17%), 15m (7%) and 20m (6%) and about 95% of the breakages were within the size class of 20m. As the size of the damage increased the frequency of occurrence decreased (Figure 17, r = 0.64).

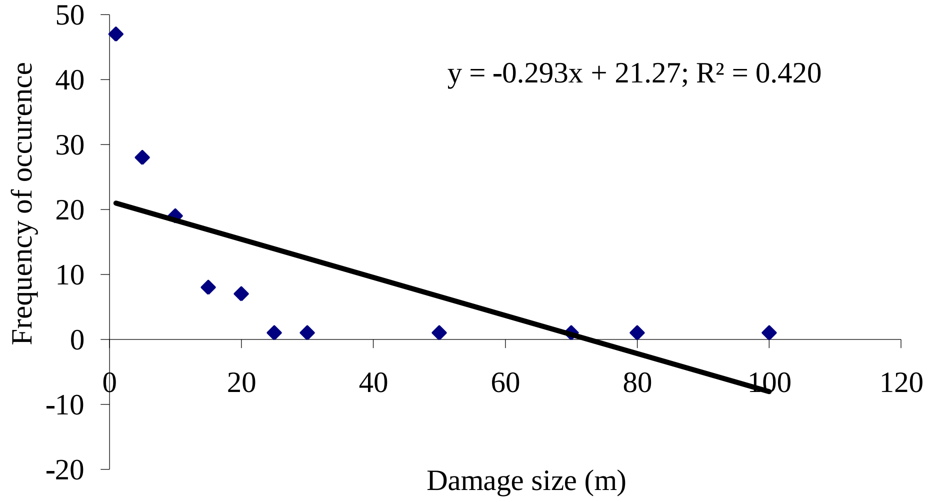


Figure 17: The frequency of occurrence of damages in RW was plotted against the different size class of damages

Cost of repair

The cost of repairing Rubble Wall was estimated to be INR 2, 00, 000.00 (US$ 4445) per km during 2008. This value was arrived at considering 1 running meter is equal to 3.33 m^3. Based on 1 m^3 re-construction cost of INR 59.34, a total amount of INR 200.00 was arrived at for the construction of 1 running meter of rubble wall.

The total length of breakages (total of 114 breakages) was estimated to be 1118.1 m (or 1.1181 km) in 2008, and a total of INR. 2, 23, 620.00 (Table 4) would be required for repairing these breakage points. The actual cost of fixing individual breakage points for both EPT and Rubble Wall may go up further as mentioned earlier (see cost estimation for 2005).

The frequency of occurrences of breakage for each breakage point for both EPT and Rubble Wall is given in the table; the table also summarizes the amount of money required for each or collective breakage points. The frequency of occurrences of breakage size (distance) for each breakage point for both Elephant proof trench and Rubble Wall are given in the table 4 the table also summarizes the amount to be spent for each or collective breakage points during 2008.

Table 4: The frequency of occurrences of breakage size (distance) for each breakage point for both EPT & RW and the amount of money required to repair each or collective breakage points during 2008

Sl. No	Elephant Proof Trench				Rubble Wall			
	Distance of damage (m)	**Frequency**	**%**	**Total cost of the damage (INR)**	**Distance of damage (m)**	**Frequency**	**%**	**Total cost of the damage (INR)**
1	1	5	4.17	313	0.7	1	0.88	140
2	1.5	1	0.83	94	1	2	1.75	400
3	2	6	5.00	750	1.9	1	0.88	380
4	3	15	12.50	2813	2	11	9.65	4400
5	4	2	1.67	500	2.3	1	0.88	460
6	5	5	4.17	1563	2.5	2	1.75	1000
7	5.5	1	0.83	344	2.7	1	0.88	540
8	6	8	6.67	3000	3	11	9.65	6600
9	7	2	1.67	875	3.3	1	0.88	660
10	8	4	3.33	2000	3.7	1	0.88	740
11	9	1	0.83	563	4	10	8.77	8000
12	10	18	15.00	11250	4.5	2	1.75	1800
13	12	4	3.33	3000	4.7	2	1.75	1880
14	14	1	0.83	875	5	13	11.40	13000
15	15	12	10.00	11250	5.6	1	0.88	1120
16	18	1	0.83	1125	6	9	7.89	10800
17	20	15	12.50	18750	6.5	1	0.88	1300
18	30	2	1.67	3750	7	1	0.88	1400
19	35	1	0.83	2188	8	2	1.75	3200
20	40	1	0.83	2500	9	1	0.88	1800
21	45	1	0.83	2813	10	14	12.28	28000
22	50	3	2.50	9375	11	2	1.75	4400
23	60	1	0.83	3750	12	3	2.63	7200
24	70	1	0.83	4375	15	4	3.51	12000
25	80	1	0.83	5000	16	3	2.63	9600
26	100	5	4.17	31250	19	1	0.88	3800
27	120	1	0.83	7500	20	7	6.14	28000
28	130	1	0.83	8125	25	1	0.88	5000
29	150	1	0.83	9375	30	1	0.88	6000
30					50	1	0.88	10000
31					70	1	0.88	14000
32					80	1	0.88	16000
33					100	1	0.88	20000
Total		**120**		**149062.5**		**114**		**223620**
Mean		**4.14**		**1242.18**		**9.81**		**1961.6**
SE		**0.45**		**164.51**		**1.33**		**266.6**
%CV		**10.78**		**13.24**		**13.59**		**13.6**

Comparison of status of barriers during 2005 and 2008

Three types of barrier mechanisms viz. Elephant Proof Trench, Rubble Wall and Electric Fence were found to be in use during both 2005 and 2008 (Figure 18). The results of the barrier survey show a breakage point encounter rate of 6.37/km and 6.71/km during the years 2005 and 2008 respectively. This suggests a slight increase in the number of breakage points over the time.

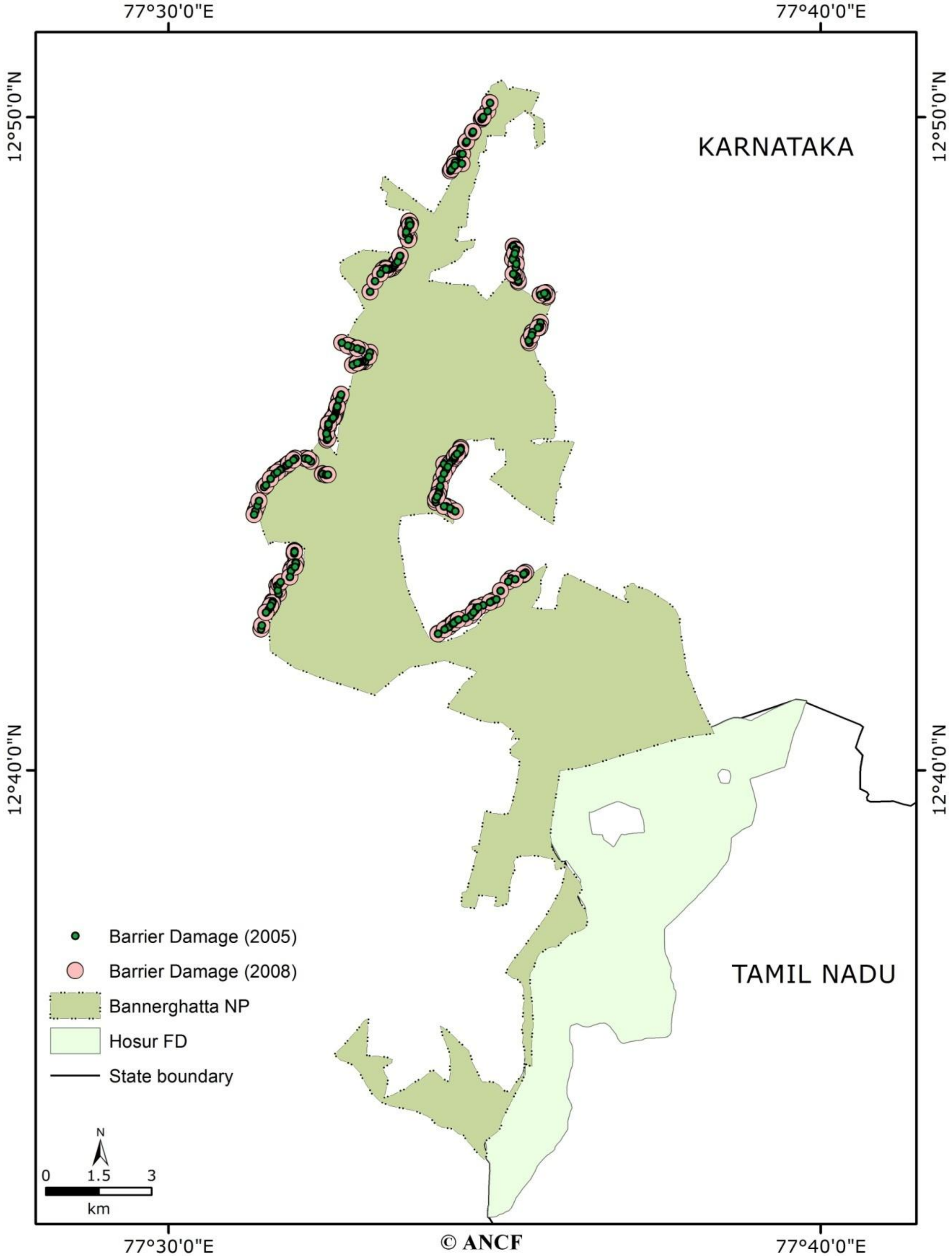


Figure 18: Comparison of status of elephant proof barriers as observed during 2005 and 2008 in BNP (Source: ANCF)

The number of breakages caused by elephants increased from 15% to 40% and the breakages owing to natural causes and execution errors have decreased (50% to 34% for natural causes and 23% to 14% for execution errors) where as the breakages caused due to human interferences remained the same. During 2005, about 72% of the EPT and 60 % of RW surveyed were located within 0-100 m distance from the crop lands where as during 2008, about sixty seven percent of the RW, 44 % of the electric (solar) fencing and 41 % of EPT surveyed were located within 0-100 m distance from the crop land.

During 2005, old breakages dominated where as during 2008 very old breakages dominated. The approximate cost of repair of breakage points of EPT and RW within 138 km during the year 2005 was found to be INR 5, 69, 860.00 and INR 4, 63, 887.00 respectively. Whereas, during the year 2008, the approximate cost of repair of (breakages within 35 km) EPT was INR 1, 49, 062.50 and for RW was INR 2, 23, 620.00 only.

The increase in elephant caused breakages may not be an actual increase but increase in proportion as the number of breakages due to elephants remains more or less the same whilst that of other causes were reduced. This reduction in the natural causes and execution errors may be due to the erection of electric fence for about 8km of the total length of the barriers surveyed during 2008 which was found to be only about 1.14 km during 2005. Even the electric fence was broken on several occasions but was rectified immediately as observed during the field visits. The cost of repair of elephant proof barriers is escalating every year.

Conclusion

A total of three different types of elephant proof barrier mechanisms viz. Elephant Proof Trench (EPT), Rubble Wall (RW) and Electric Fence (EF) were found to be in use in the park during the study. The EPT was found to be predominantly used followed by RW and EF. The barriers were highly porous with an average of 6 breakage points per kilometer. Most breakages were under the size class of 0-30m and as the size of the breakage increased the frequency of their occurrence decreased. About 92.0% of the breakages were old in nature. The EPT and RW have showed the maximum breakages. Even EF was broken at several points frequently but was rectified immediately as observed during the survey. Majority of the breakages were due to natural causes and execution errors followed by elephant caused and human caused. The cost of fixing these breakages especially EPT and RW is increasing over the years. Further fixing the breakages in EPT and RW is labor intensive when compare to EF.

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Appendix I

Additional figures showing the status of elephant proof barriers in BNP

a

b

c

d

e

f

a: Elephant proof trench (EPT) damaged due to soil erosion, b: EPT filled up due to silt deposit, c: Human foot path cutting across the rubble wall, d: Cattle path damaging the rubble wall, e & f: Electric fence damaged by the elephants

Appendix-II

Assessing the efficacies of the elephant proof barriers in Bannerghatta National Park

I. Profile of the barrier

1. Date: Name of the Observer:
2. Name of Elephant proof barrier:
3. Range: Name of the tracker:
4. Location:
5. Forest beat / Nearest Village:
6. Terrain and Soil type:
7. Specification:

Elephant Proof Trench	Electric Fence	Rubble Wall	Remarks
	Materials used	Materials used	
Top width:	1.	1.	
Bottom with:	2.	2.	
Depth:	3.	3.	
Length:	4.	4.	
Description:	5.	5.	
Remarks	Height:	Height:	
	Length:	Length:	
	Design:	Top width:	
	Remarks	Bottom width:	
		Remarks	

1. Date/year of establishment:
2. Amount spent:

Sl. No.	Cycle of maintenance	Cost of maintenance	Source of funds
1			
2			
3			
4			
5			

3. If not maintained or ignored why? (Reasons):
4. Name of starting point:
5. Name of end point:

6. GPS Readings: 1.Starting Point:
   2. Ending point:

7. Status of land:
8. Current status: Maintained/ Not maintained/ Ignored/ No more viable
9. Maintained by: Forest Department/ Local Village/ Individual/ NGO/ Others ______

Sl. No.	Forested Yes/ No – (Distance from the barrier 0-100, 100-200, 200-500, above 500mt)	Status of Forest	Cultivated Yes/ No – (Distance from the barrier 0-100, 100-200, 200-500, above 500mt)	Status of cultivation (Cultivated/ abandoned/ seasonal cultivation)	Remarks
1					
2					
3					
4					
5					

II. Damage detail of barrier:

Sl. No	Time Interval	GPS Location	A	B	C	D	E	Status of sign	Remarks
1									
2									
3									
4									
5									

A; Status of the barrier (Broken/ Not broken), B: Distance of Nearest Cultivation/ Village, C: If village found, Name of the Village, D: Elephant signs observed (yes/ No), E: If yes, type of sign

III. Damage detail of barrier found within time interval

Sl. No.	Time	Location	GPS Readings	Reasons for damage	Status of damage	Status of repair
1						
2						
3						
4						
5						

Use of Chilli-Tobacco Barrier (CTB) as a Human-Elephant Conflict Mitigation Measure

Introduction

Many species face escalating hostility with people for space and resources (Pimm *et al*. 1995; Balmford *et al*. 2001) and as a result many of the large mammals come into increasing conflict with people. Conflict between elephants and humans is a major conservation concern. The majority of crop raiding incidents involve elephants destroying mature food crops (Sitati 2003; Tchamba 1996; Treves 1998; Smith & Kasiki 1999). Elephants generally require a large wilderness area for their survival, and tend to visit human settlements to raid crops and for other attractants (Bell 1984). Farmers' source of revenue can be badly impacted by crop damage where subsistence cultivation occurs. Human-elephant conflict problem is addressed by many mitigation approaches and the options for reducing conflict between elephants and people have been acknowledged in numerous studies (Bell 1984; Sukumar 1990; Barnes *et al*. 1995; Hoare 1995; Tchamba 1996; Smith & Kasiki 1999; Gadd 2005).

The methods in mitigating conflict can be classified into passive and active approaches (Barnes *et al*. 1995; Hoare 1995; Tchamba 1996; Parker & Osborn 2006; Prabal *et al.* 2008). Passive systems attempt to prevent the target species into areas of human settlements and crop lands. Barriers such as electric fences, elephant proof trenches (EPT), and thorny branches, wooden or stone fences are normally used in many locations. Active systems involve driving the target animals away or the use of resistance mechanism such as scaring by banging on tins or drums, shouting and throwing objects. In some areas guns are fired into the air to scare animals (Prabal *et al*. 2008). Compensation schemes are also intended to offset the financial losses and thereby encourage people to protect wildlife.

However Prabal *et al*. (2008) suggest that the conflict mitigation measures, passive or active, are becoming increasingly costly, lack special skills, and proper monitoring system. The non-conventional Chilli Tobacco Barrier (CTB) prepared using a combination of chilli and tobacco powder, mixed with used engine oil in a certain ratio, smeared on a rope encircling crop fields was found to be effective in deterring the elephant crop raids in some parts of Africa (Parker & Osborn 2006). The concept is new and is in basic experimental stages in India. Its application, viability and cost-benefits in the Indian context are not known. Thus, the efficacy and the viability of this method was investigated for Asian elephants in the Bannerghatta National Park during the peak cropping season, including the reproductive, harvesting and processing stages of some of the major crops cultivated.

Objectives

To establish presence or absence of elephants close to the crops with the CTB
To ascertain crop damage in test plots and adjacent crop lands irrespective of the presence or absence of elephant preferred crops
To assess the economic viability of the CTB in relation to crop economy and net profit and to establish cost of establishment and maintenance of the CTB

The following assumptions have been made to study the efficacy of this deterrent mechanism.

- If the presence of elephant is established within proximity of the CTB barrier with no damages made to the chilly tobacco barrier and the crop within it, then the barrier effectively deters elephants.

- If there are instances of the barrier being broken and elephants entering the test plots, then barrier does not deter elephants.

- If smaller herds or lone tuskers avoided the fence and large herds break the fence, then the CTB may prove effective for small herds or lone elephants.

Methodology

Three villages with high conflict were chosen for the establishment of the barrier, based on the high probability of elephant visits to these villages.

Two villages of medium conflict were chosen based on the assumption that elephant visits would be relatively less. The above mentioned villages were also geographically well distributed covering different regions of the park.

Figure 1: CTB test plot

At each village, the location of the experiment plots was chosen (see Figure 1 for one of the test plots) based on accessibility to elephants, type of crop and cropping stage. A total of 8 CTB experiment plots were established. The CTB plots were monitored for a period of 52 days (November and December 2007)

Study villages and their conflict status

The following villages (Table 1) were selected for this experiment. The villages were selected on the basis of the extent of conflict by rating them on a scale of 1-10. This rating was based on the history of conflict derived from the crop compensation claim records (1999 – 2005) maintained by the Forest Department as well as the village surveys carried out by the research team from June 2004 to October 2007.

Table 1*:* The villages selected for the CTB experiment and their human-elephant conflict status

Sl. No.	***Village Name***	***Conflict Rate***	***Range***
1	Biliganaguppe	10/10	Harohalli
2	Chudahalli	10/10	Anekal
3	Ragihalli	8/10	Bannerghatta
4	Thattiguppe	6/10	Bannerghatta
5	Jaipurdoddi	5/10	Harohalli

Materials used

The process of establishing the chilli tobacco barrier required procurement of the following materials in adequate quantity: 1) Cotton rope of diameter 3.2 mm. 2) Chilli powder – initially the processed and marketed brand of MTR (a popular brand) was used, which was subsequently replaced by sun dried and ground red chillies (mud coated variety). 3) Tobacco – initially processed tobacco leaves bought directly from the market, were dried on a ‘Tava’ (vessel) and ground to powder.

This was replaced by sun dried and ground tobacco leaves and 4) Used engine oil – procured from the automobile garages/service centres.

i) Smear preparation

Smear-I: The smear was prepared by mixing 1kg of chilli powder and 1kg of tobacco powder with 10 litres of used engine oil to cover a length of 1 km rope.

Smear-II: The smear was prepared by mixing 1 kg of Tobacco powder with 10 litres of used engine oil to cover a length of 1 km rope (Figure 2).

ii) Barrier establishment

Initially a cotton rope of adequate length was soaked in the smear before being taken to the experimental plots. Subsequently it was decided to apply the smear on the rope at the experimental plot itself, as the earlier method was time intensive. The cotton rope was tied around trees or to specially erected wooden posts and it was ensured that the entire test plot was enclosed within the rope (Figure 3; see appendix I for additional figures related to establishment of CTB & Appendixes-II and III for the data sheet).

Figure 2: Preparation of smear

Figure 3: CTB Establishment

Each village had two experimental plots, one enclosed with smear-I and the other with smear-II. Manpower for the smear application was sourced from the village and the forest department (see Appendix IV for case studies as capacity building exercise for the research team and testing efficacy using captive elephant).

iii) Re-application of Smear

The re-application cycle of the smear was initially assumed to be 3 days, which was later (after the 4th re-smearing) changed to once in 2 weeks. This was done as the smear lasted for longer than expected. The smear was prepared at the experimental site by mixing the ingredients in appropriate proportions and applied on the rope manually

iv) Crop economics

This was assessed through both direct observations and by interviewing the farmers to arrive at the economical viability of this barrier mechanism.

Results and Discussion

Efficacy of CTB in deterring elephants

The efficacy of the method was established through the following 4 distinct approaches:

1. Presence or absence of elephants and or their signs close to the crops with the CTB
2. Pattern of crop damage in adjacent crop lands
3. Ascertaining crop damage in test plots and adjacent crop lands irrespective of the presence or absence of elephant preferred crops
4. Farmer’s experiences in using the CTB as an elephant deterrent

Presence or absence of elephants and or their signs close to the crops with the CTB

During the study period about 43 elephant signs were recorded close to the test plots. The combination of elephant signs noticed on different days at different CTB plots suggest that a minimum of 19 times, elephants were found visiting within the vicinity of the CTB during the experiment period. These distances ranged from 0 to 110 meters from the crop within CTB. Of this about 27 % of time elephants came within 0 to 1 m of the CTB, 9 % from 2 to 3 meters, 36 % of time they came within 3 to 5 meters and about 73 % of times elephants came within 0 to 5 meters. The rest 27 % of the times elephants were found to have come within 6 to 10 meter distance of the CTB (Figure 4).

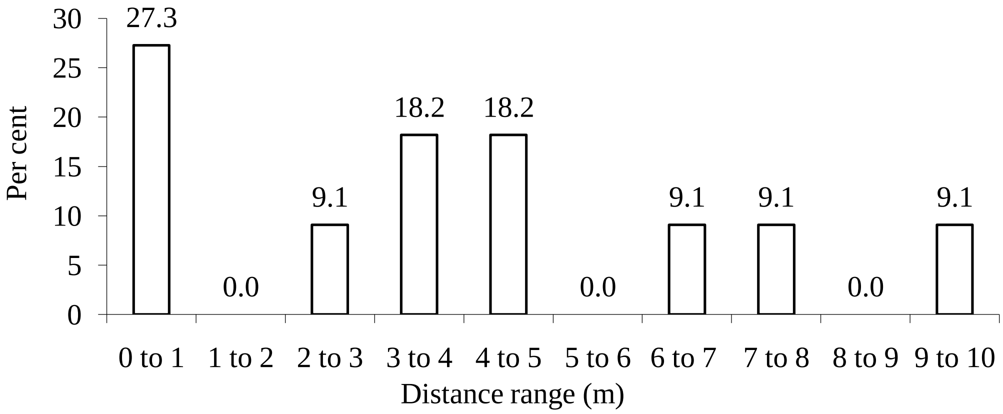


Figure 4: Proportion of elephant visits Vs their proximity to the CTB test plots

When the elephant signs (dung and track circumference) were converted into different age classes (based on known captive animals' (n=52) height and dung circumference measurements), it was found that elephants visited the CTB 32 times. Of this, 17 times elephants were believed to have come within 5 m distance of CTB. Looking at the sizes of the dung bolus and track, animals between 30 cm and 47cm circumference of dung bolus and the track measurement of 80 cm to 150 cm circumference were recorded within 10m distance from the test plots. There was no correlation (r = 0.21) between the elephant age class and their approach distance (Figure 5) to the CTB, and it is clear from the distribution of different dung and track circumferences that elephants of all ages have come close to the experimental plots.

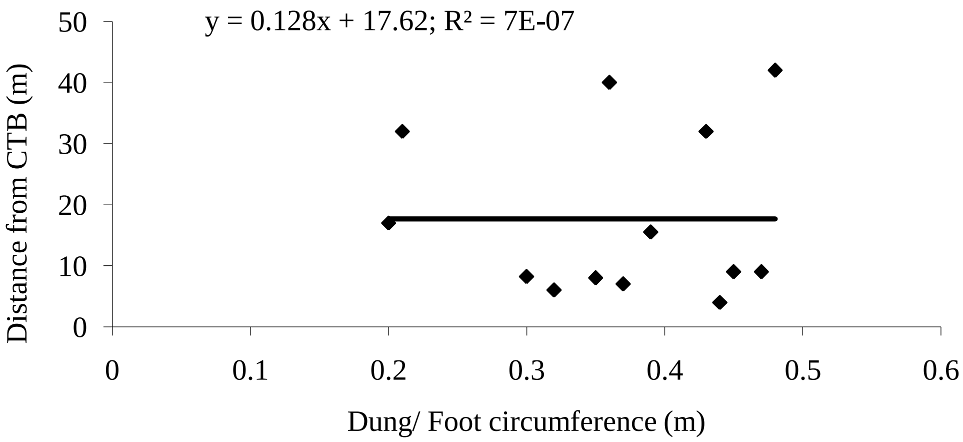


Figure 5: Elephant visits to the test plots. Proximity of elephant (different age class) visits to the test plots arrived from the circumference of pad and dung bolus signs

Although elephants came as close as 0 meters to the CTB, no damage to barrier or crop was reported during 52 days of monitoring.

Pattern of crop damage in adjacent crop lands

The efficacy of the CTB could be assessed based on the crop damage pattern reported for the agricultural lands close to the CTB test plots. This can be done by comparing the patterns of cultivation and different phenological stages of crops cultivated within the CTB and adjacent crop lands where crop damages were reported. During the study period, totally, 9 times crops were damaged by elephants in the adjacent cultivated lands. This damage accounted for a total of 8447 m^2 (mean = 938.61, SE= 494.6, ranged from 17 to 4080 m^2). The damage was recorded within 0 to 80 m (mean 25.1, SE = 12.2 m) distance from cropland within CTB. About 44% of these croplands were located within 0-5 m distance from cropland within CTB, and these lands alone accounted for 43% of the total extent of damages.

Corp phenology and the patterns of damages

With reference to the phenology of the crops, elephants were found to select crops in reproductive stages as these crops are considered to be less fibrous, juicy and tasty. During harvesting stage the crop becomes more fibrous and only the grains of the crops are nutritious. With this background on crop phenology, both the CTB test plots and the adjacent cultivable lands where crop damages were recorded were investigated for the phenological stages. It was found that, crop lands where the damages occurred had 70% of the crops in harvesting stage and the rest 30% were in reproductive stage. While in the CTB test plots, 64 % of crops were in reproductive stage and the rest 36% were in the harvesting stage.

Sukumar (1990) says that even in the reproductive stage, elephants were found to have an order of preference; ragi, sorghum, paddy, maize and horse gram. The elephants are also known to select some crops in the harvesting stage rather than the reproductive stage. For example, the harvesting stages of ragi or sorghum or paddy are preferred more over horse gram in the reproductive stage. With this insight, a comparison of the preferred crops in reproductive stages (Table 2) suggests that about 64% of crops in the test plots were in the reproductive stage while it was only 26% in the adjacent damaged crop lands.

Table 2: Shows the phenological stages of crops present both in test plots and in adjacent crop lands during the elephant raids

Sl. no	Crops in adjacent crop lands	Phenological stages in adjacent crop lands	Crops in test plot	Phenological stages in test plot
1	Maize	Reproductive	Ragi/Sorghum	Harvest/ Reproductive
2	Ragi/Sorghum	Harvest/ Reproductive	Sorghum	Reproductive
3	Sorghum	Harvest	Sorghum	Harvest
4	Ragi	Harvest	Ragi/Sorghum	Reproductive / Reproductive
5	Paddy	Harvest	Ragi/Sorghum	Reproductive/ Reproductive
6	Paddy	Harvest	Sorghum	Reproductive
7	Ragi	Harvest	Ragi/Sorghum	Reproductive/ Reproductive
8	Horse gram	Harvest	Ragi/Sorghum	Harvest / Harvest
9	Sorghum	Harvest	Sorghum	Harvest

In the damaged crop lands, 100% of the crops were in harvesting stage and none in the reproductive stage. While in the CTB test plots, 86% of the crops were in the reproductive stages and only 14 % were in the harvesting stage. The presence of elephant preferred crops in reproductive stage were nil in adjacent damaged lands, while 86% were present in the CTB test plot (Figure 6).

This clearly indicates that the crops within the CTB test plots, irrespective of the distance from adjacent crop damaged lands or having more preferred species, had no damage to crops showing that the CTB clearly had prevented the entry of elephants and the resultant damages.

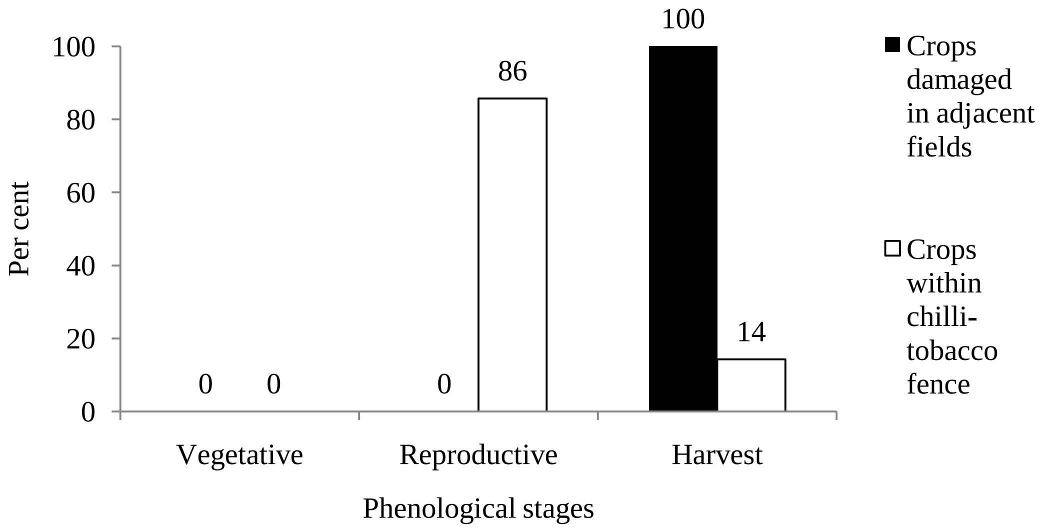


Figure 6: Proportion of various phenological stages of crops within the test plot and the adjacent elephant raided crop fields during the experiment period

Insights from the farmer's experiences

According to the farmers, during the study period 10 times elephants were found to have come to the crop lands close to the CTB test plots. These elephant visits were spread across three weeks (22 days). About 50% of the visits were recorded within the first 7 days followed by 40% between 8^{th} and 15^{th} day and the remaining 10% between 16^{th} and 22^{nd} day. Of the total 8 test plots, 5 plots had elephants coming close to the plots (Table 3) during the experiment period. The test plot BHJD1 had the maximum visits (30%) followed by BHJD2 (20%), BHBG1 (20%), BBTG2 (20%) and BBRH2 (10%).

(The first alphabet B: Bannerghatta National Park and the second alphabet B: Bannerghatta Range and H: Harohalli Range. JD1: Jaipurdoddi plot-1, JD2: Jaipurdoddi plot-2, BG1: Biliganaguppe plot-1, TG2: Thattiguppe plot-2 and RH2: Ragihalli plot-2)

Table 3: Shows percentage of elephant visits across the test plots

Sl. No.	Test plots	% of elephant visits to the test plots
1	BHJD1	30
2	BHJD2	20
3	BHBG1	20
4	BBTG2	20
5	BBRH2	10

According to the farmers, about 78 elephants have come close to the CTB. Among the elephants visited, about 50% were solitary, 20% were in groups of 5 to 10 individuals, 20% were in the group of 10 to 15 elephants and the remaining 10% of visits were by relatively big groups (25-30). This also suggests that animals of all the group size and age class have come close to the CTB test plots.

An interesting observation is that about 70% of the elephants visits were close to the crop lands (with CTB) that were located about 200 meters from the Karadikall–Madeshwara elephant corridor (Varma *et al*., 2005). It is clear from farmers' observations that collectively about 64% of the times elephants have come to the crop lands adjoining the CTB test plots between late evening and early morning (Figure 7).

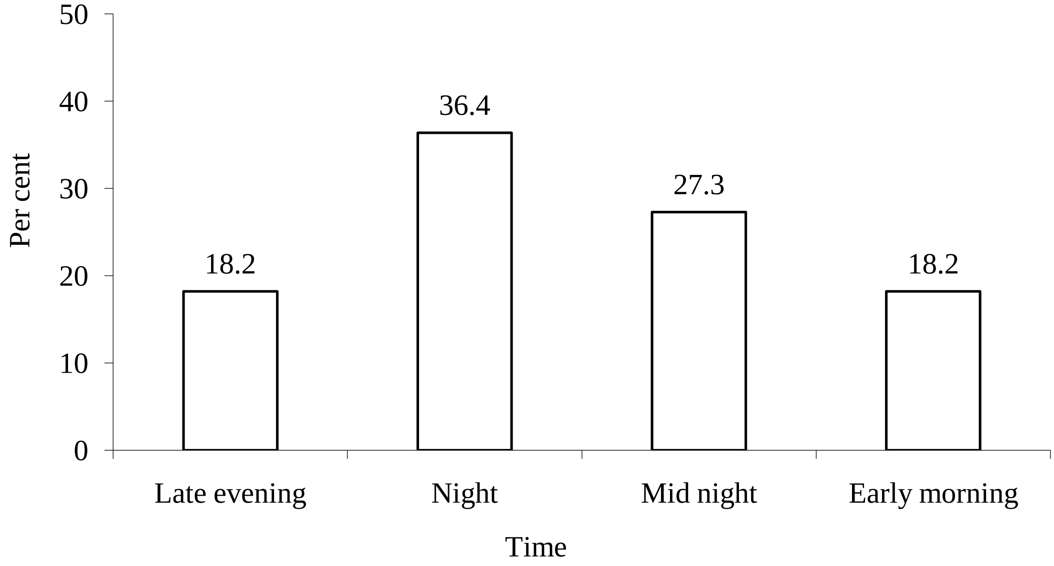


Figure 7: Time of elephant crop raids- Preferred time of elephant visits to the crops adjacent to the CTB plot (Late evening: 18:00-21:00, Night: 21:00-23:00, Mid night: 23:00-3:00, Early morning: 3:00-6:00 hrs)

Two out of 8 farmers continued the CTB with the subsequent crops cultivated in their land such as paddy and vegetables and the other farmers have stored the CTB rope safely for the next cropping season. These farmers are reported to cultivate crops only during monsoon season as they lack irrigation facilities. All these insights also reflect the effectiveness of the CTB.

Viability of CTB

The viability of the CTB basically depends on the crop economy, barrier economy (amount spent on the CTB) and the human efforts (man power and time budget).

Crop economy

The test plots established, measured on an average 0.45 acre (SE = 0.15, ranging between 0.2 acre and 0.7 acre) accounting to a total of 3.6 acre (from 8 test plots) which were under the cultivation of the major crop Ragi (*Eleusine coracana)*.

The plots had ragi as a major crop (Mean =91%, SE = 0.99, ranging from 80% to 100%), along with sorghum (*Sorghum bicolor*) for about 3.6%, cluster beans (*Cyamopsis tetragonoloba)* for about 2.4%, wild gingelli for about 0.8%, chilli (*Capsicum sps.*) for about 1.3% and castor (*Ricinus communis*) for about 0.8% as minor crops (Figure 8).

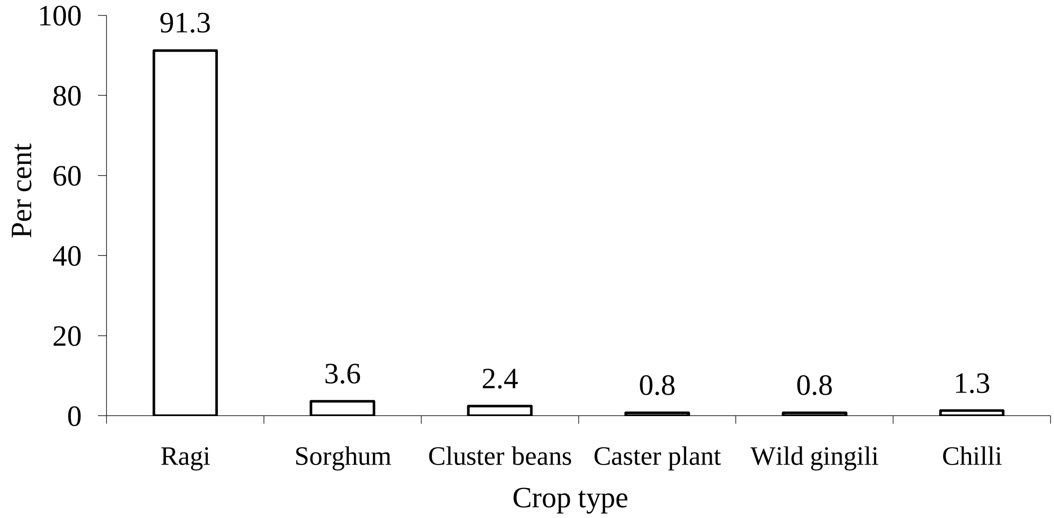
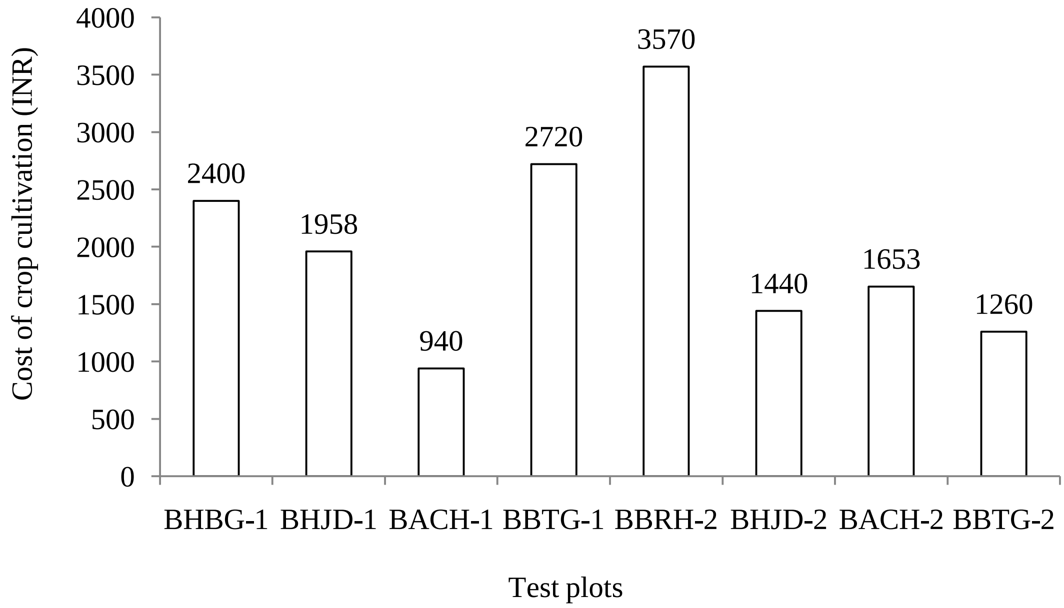


Figure 8: Major crops cultivated in the CTB test plots

Cost of crop cultivation

The cultivation of the crop involves financial investment during several stages such as ploughing, seeds procuring, sowing, fertilizing, de-weeding, harvesting, shifting and processing. An average of 1992/- (SE = 11.12) INR was spent on each plot. This accounts to a total of 15942/- INR for all the eight plots (Figure 9).



The first alphabet B: Bannerghatta National Park; Second alphabet B: Bannerghatta Range; H: Harohalli Range; A: Anekal Range. BG-1: Biliganaguppe plot-1, JD-1: Jaipurdoddi plot-1, CH_1: Chudahalli plot-1, TG-1: Thattiguppe plot-1, JD-2: Jaipurdoddi plot-2, TG-2: Thattiguppe plot-2, CH-2: Chudahalli plot-2 and RH-2: Ragihalli plot-2

Figure 9: Test plot wise cost of crop cultivation in INR

Of the total amount spent, the purchase of chemical fertilizers amounted to 27%, ploughing of land was 22.3%, harvesting 14.0%, processing of harvest was 12.0%, de-weeding amounted to 9.0%, sowing 8.0%, purchase of seeds 5.3% and the transport of harvest for processing accounted for 2.2% (Figure 10).

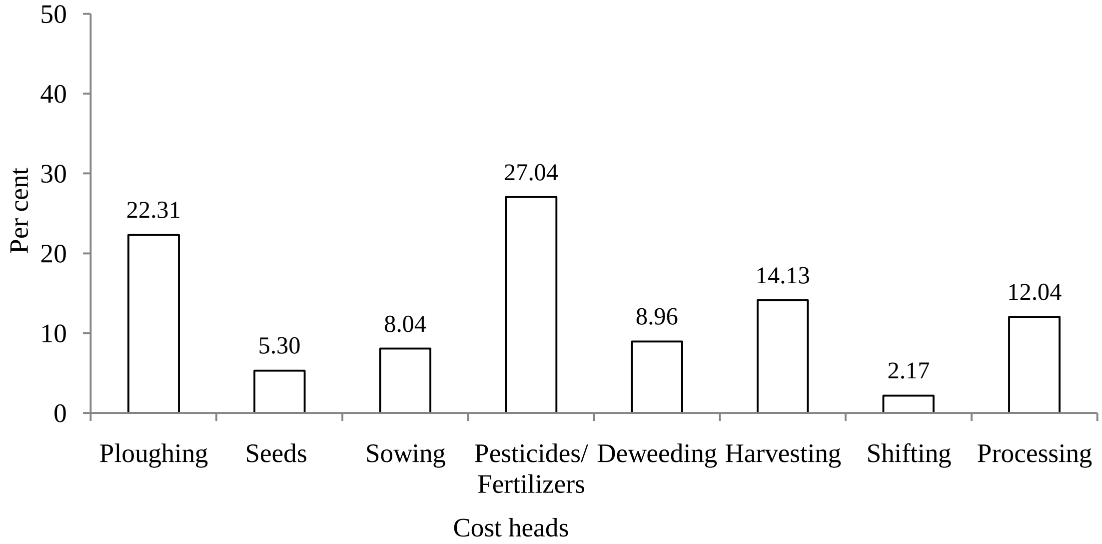
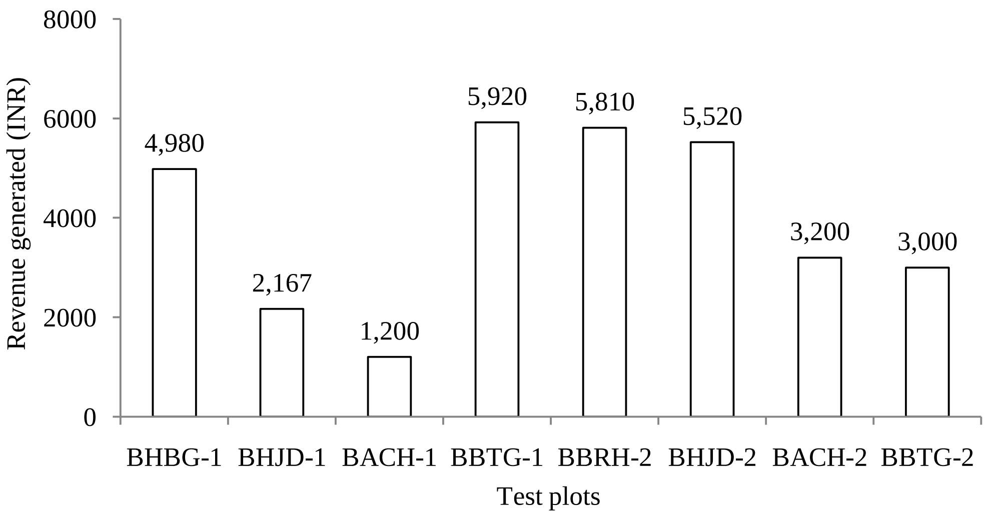


Figure 10: Cost of crop cultivation. The percentage of total cost involved in the processes of crop cultivation is plotted against different CTB test plots

Income generated

The income generated per CTB test plot was quantified by taking into account the total quantity of grains and the straw produced. The crop generated an average income of 3,974/- (SE=16.10 and ranged from 1,200.00 to 5,920.00) INR which amounts to a total of 31,797.00 INR from all the eight plots (Figure 11).

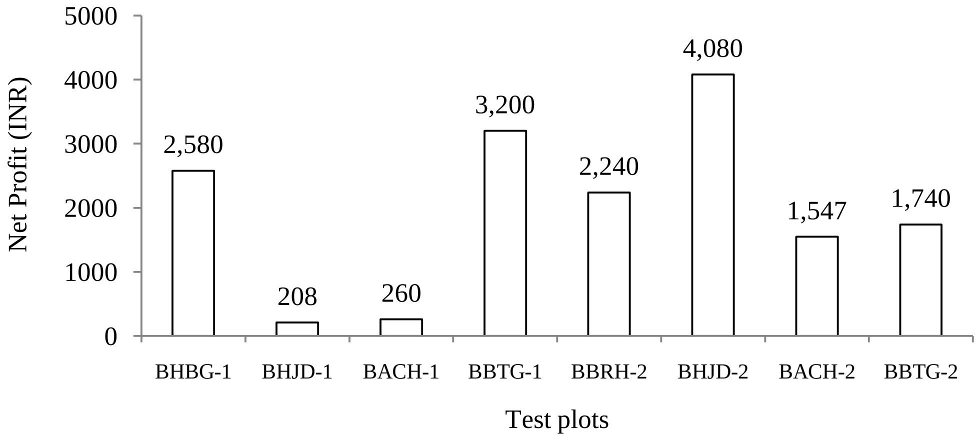


The first alphabet B: Bannerghatta National Park; Second alphabet B: Bannerghatta Range; H: Harohalli Range; A: Anekal Range. BG-1: Biliganaguppe plot-1, JD-1: Jaipurdoddi plot-1, CH_1: Chudahalli plot-1, TG-1: Thattiguppe plot-1, JD-2: Jaipurdoddi plot-2, TG-2: Thattiguppe plot-2, CH-2: Chudahalli plot-2 and RH-2: Ragihalli plot-2

Figure 11: Revenue generated exclusively by the crops cultivated within CTB

Net Profit

Based on the cost of crop cultivation and income generated, the average net profit per CTB test plot was found to be 1,982/- (SE = 13.86 and ranged from 208.00 to 4,080.00) INR. This accounts to a sum of 15,855.00 INR for all the eight test plots (Figure 12).



The first alphabet B: Bannerghatta National Park; Second alphabet B: Bannerghatta Range; H: Harohalli Range; A: Anekal Range. BG-1: Biliganaguppe plot-1, JD-1: Jaipurdoddi plot-1, CH_1: Chudahalli plot-1, TG-1: Thattiguppe plot-1, JD-2: Jaipurdoddi plot-2, TG-2: Thattiguppe plot-2, CH-2: Chudahalli plot-2 and RH-2: Ragihalli plot-2

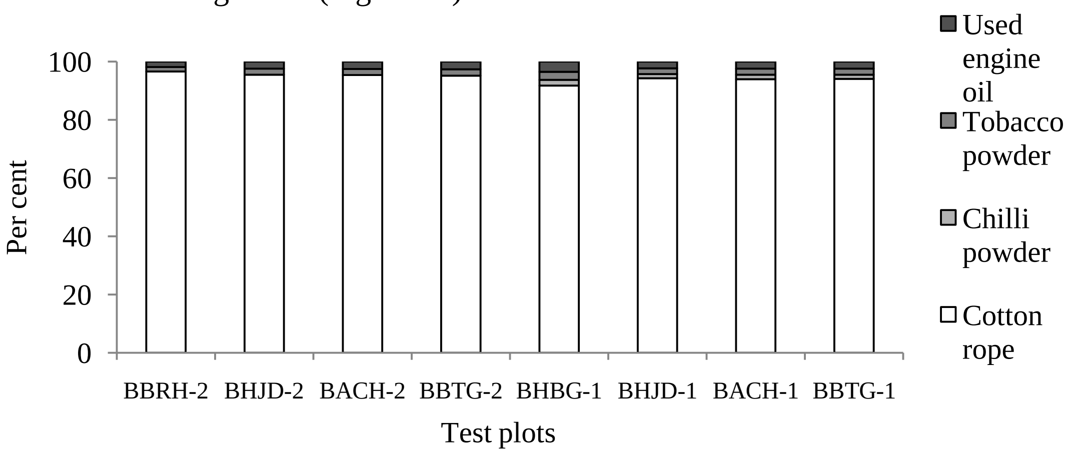
Figure 12: Net profit generated by the crops cultivated within CTB

Barrier economics

This constitutes the cost of cotton rope, chilli powder, tobacco powder and used engine oil. The barrier economics has two components 1) the cost of establishment and 2) the cost of re-smearing (i.e. maintenance). Out of the eight test plots four were smeared with Smear-I and the remaining with smear-II.

Cost of CTB Establishment

The establishment of just tobacco barrier (Smear-II) cost around 4,743.00 (Mean = 1,186.00 and SE = 8.0) INR while the chilli tobacco barrier (Smear-I) cost around 5, 121.00 (Mean =1,280.00 and SE = 9.34) INR. The cost of establishment of chilli-tobacco fence was found to be more than the tobacco barrier. Per plot cost of establishment was found to be 1,233.00 (SE = 5.6) INR. Thus the overall cost of 9,865.00 INR was assessed for all the 8 plots. About 95% of the cost of establishment went towards the cotton rope whilst only 5% went towards chilli powder, tobacco powder and used engine oil (Figure 13).

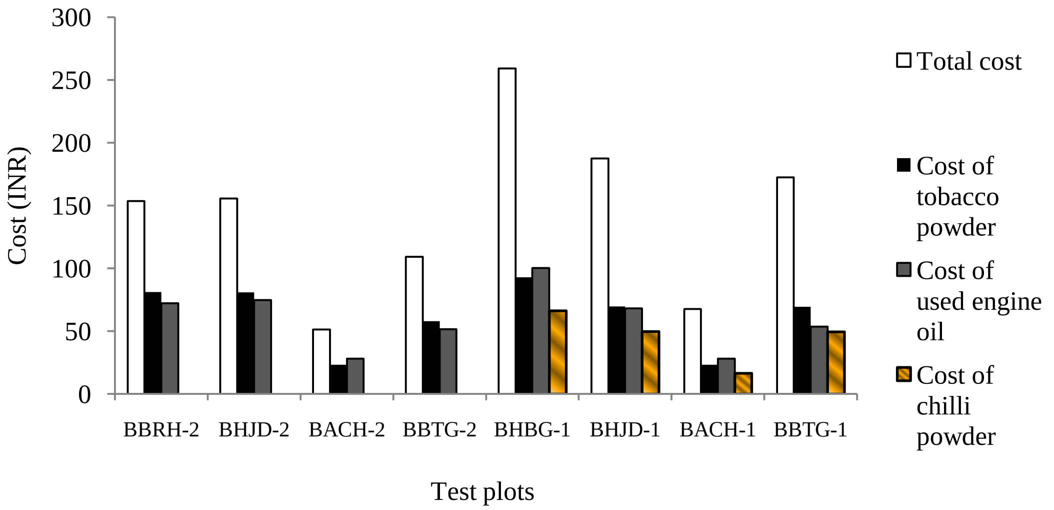


The first alphabet B: Bannerghatta National Park; Second alphabet B: Bannerghatta Range; H: Harohalli Range; A: Anekal Range. BG-1: Biliganaguppe plot-1, JD-1: Jaipurdoddi plot-1, CH_1: Chudahalli plot-1, TG-1: Thattiguppe plot-1, JD-2: Jaipurdoddi plot-2, TG-2: Thattiguppe plot-2, CH-2: Chudahalli plot-2 and RH-2: Ragihalli plot-2

Figure 13: Percentage cost of different raw materials used in the establishment of the CTB

Cost of re-smearing

During the study period a total of 35 times re-smearing was carried out (includes all the 8 CTBs). The average cost of re-smearing per CTB plot was found to be 145.00 (SE = 3.10) INR and the total cost of re-smearing was 1, 156.00 INR(Figure 14).



The first alphabet B: Bannerghatta National Park; Second alphabet B: Bannerghatta Range; H: Harohalli Range; A: Anekal Range. BG-1: Biliganaguppe plot-1, JD-1: Jaipurdoddi plot-1, CH_1: Chudahalli plot-1, TG-1: Thattiguppe plot-1, JD-2: Jaipurdoddi plot-2, TG-2: Thattiguppe plot-2, CH-2: Chudahalli plot-2 and RH-2: Ragihalli plot-2

Figure 14: Total cost of re-smearing along with the cost of each ingredient for each of the CTB test plots

On an average each plot was re-smeared for 4.3 times during the study period. Another interesting observation made was that the cost of re-smearing reduced gradually with the increased number of re-smearing (Figure 15).

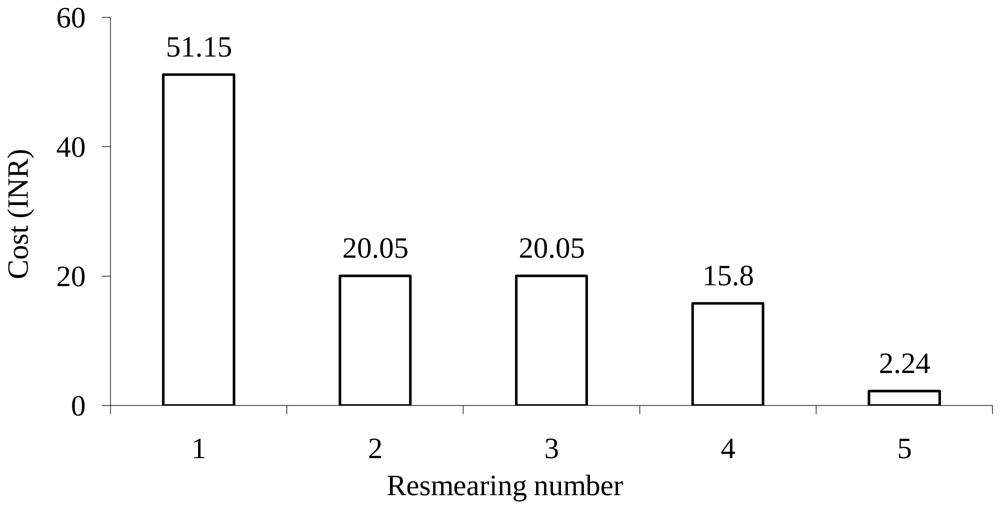


Figure 15: The cost of re-smearing is plotted against the re-smearing number which depicts the gradual decrease in the cost

The average cost of re-smearing was only 145.00 INR (Table 4) and if the same rope is used for the subsequent crop cultivations the profit will go up further assuming the same amount of revenue they generate.

Table 4: Frequency of re-smearing, days of monitoring and overall cost of re-smearing

Plot code	Frequency of re-smearing	Days of monitoring	Overall cost of re-smearing (INR)
BBRH-2	6	40	154
BHJD-2	6	40	156
BACH-2	1	16	51
BBTG-2	5	38	109
BHBG-1	6	46	259
BHJD-1	5	42	187
BACH-1	1	16	68
BBTG-1	5	38	172
		Mean	**145**

Overall cost of establishment and re-smearing of the CTB

The average cost of CTB per test plot was found to be 1,378.00 INR covering an area of 0.45 acre of cultivated crop lands for a period of 52 days. This accounts to a total sum of 11,021.00 INR for all the eight test plots.

Cost benefit of CTB

The average cost of crop cultivation per test plot was found to be 1, 992/- INR and the average cost of CTB per plot was found to be 1, 378.00 INR only. The additional cost of the CTB raised the overall cost of crop cultivation in the test plots to 3,370.00 (SE = 12.31) INR. With the use of the CTB the average net profit from the crops cultivated within the test plot was reduced to 596.00 (SE = 13.93 and ranges from 402.00 - to 2,800.00) INR. Some farmers even incurred a loss at an average of 1,141.00 INR by opting for this barrier mechanism (Figure 16).

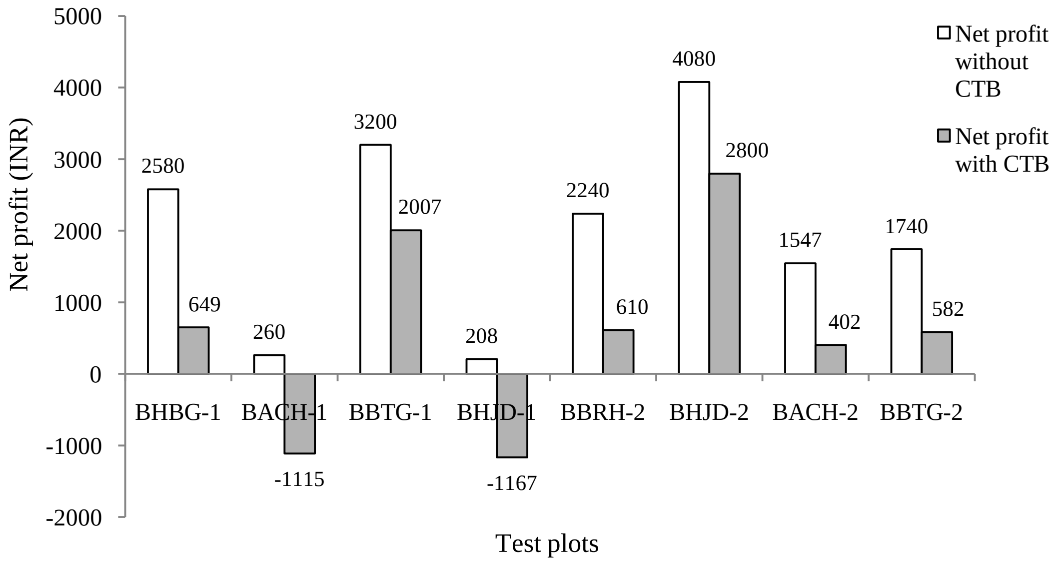


Figure 16: Net profit generated by the experiment plots with and without CTB

The average percentage loss due to elephant raids was calculated from the crop compensation record data and was found to be 38.48%. This finding suggest that the average net profit per plot after the loss due to elephant raids was only 757.00 (SE= 10.4

and ranged from 160.00 to 1,971.00) INR (Figure 17). On a comparison, the values of net profit after use of CTB and the net profit after the loss due to elephant raids appear to be similar. This suggests that there is no substantial profit made by the farmer after the use of CTB for the first crop. The subsequent crops will result in significant profits even if they yield the same quantity of produce as there is no cost of establishment involved. Only the cost of maintenance needs to be taken care, which is negligible.

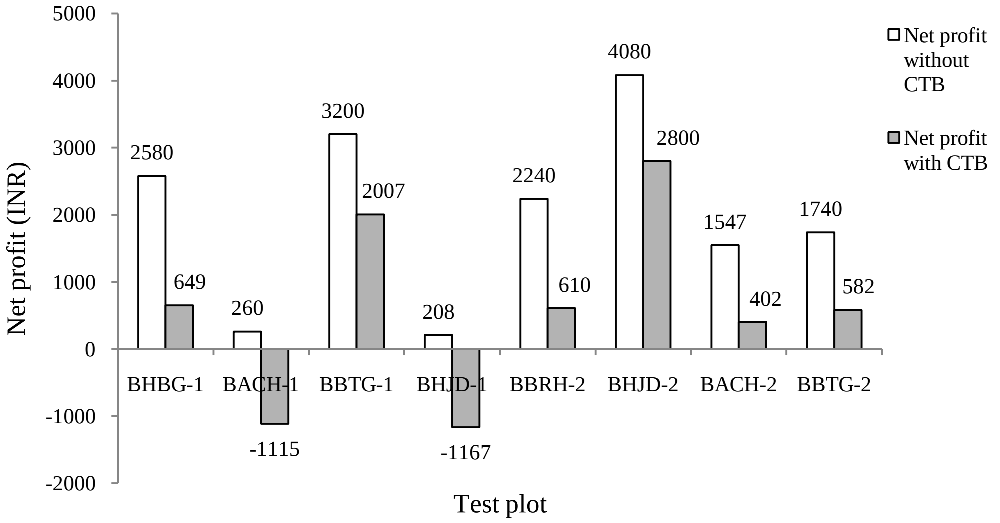


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Figure 17: Profit in INR is plotted against net profit test plot wise, with and without the CTB

Manpower requirement

Establishment of CTB

During the establishment of eight CTB test plots, a total of 33 people (Mean = 4.12 people and SE = 0.34) were used for 11 hrs (Mean = 1 hour & 22 minutes and SE = 0.05) towards the erection of the rope. A total of 14 people (Mean = 2 people and SE = 0.31) were used for 1 hour and 13 minutes (Mean = 9 minutes and SE = 0.015) towards the preparation of smear and a total of 29 people (Mean = 3.6 and SE = 0.36) were used for 8 hrs and 26 minutes (Mean = 1hour & 3 minutes and SE = 0.02) towards application of the smear (Figure 18).

Figure 19: Labour involved in CTB establishment

Re-smearing

During 35 times of re-smearing spread across a period of 52 days, a total of 14 people (Mean = 2.8 people and SE = 0.52) were used for 1 hour and 25 minutes (Mean = 17 minutes and SE = 0.03). A total of 67 people (Mean = 1.86 people and SE = 0.35) were used for 3 hrs and 22 minutes (Mean = 5 minutes and SE = 0.02) towards smear preparation and a total of 93 people (Mean = 2.58 and SE = 0.4) were used for 18 hrs and 43 minutes (Mean = 31 minutes and SE = 0.06) towards application of the smear.

It was also observed that the time interval of re-smearing increased as the number of re-smearing increased. For example, first re-smearing was done at an interval of 3 days after the establishment of the CTB, the second re-smearing was done after 5 days (instead of 3). The third re-smearing was done after 7 (instead of 5) and the fourth one was done after 10 days (instead of 7) and the last (fifth) re-smearing was done after 12 days (instead of 10).

Challenges in the use of the CTB

- Establishment is labour and time intensive. This may bring down the viability as majority of are marginal farmers and live in nuclear families. Organizing man power especially during the cropping season will be a great challenge as everyone in the community would be busy working in their own crop fields.
- The cost of cotton rope is high which may not be affordable to all the farmers considering their marginal economic status.
- Procurement of used engine oil will be a challenge for the farmer as it would require the farmer to go after the automobile garages for collection of used oil. This exercise will also result in the additional cost of travelling to the garages.
- Smear preparation requires skills to get the right concentration which may be difficult for the farmer considering their educational background.
- Smear preparation and application is a cumbersome job and spoils the clothing.
- Deciding on the time interval for re-smearing could be another challenge to the farmer due to lack of necessary skills.
- The impact of rain on the efficacy of the CTB is not known.
- A high level of interest and cooperation among the local community is an important factor for the CTB to be efficient. This may be a great challenge considering the poor interrelationships the members of the community share among themselves.

Conclusion

The CTB mechanism was found to be effective in deterring the elephants. For instance, at one of the experimental plots more than 35 elephants had visited destroying the entire crop except the crop within the CTB test plot. Sometimes lonely bulls and also herds had visited the crop fields adjacent to the CTB test plot but were not able to enter the test plots. During the 52 days of monitoring, only twice elephants had entered the CTB test plots. In one of the test plots a tusker and in another plot, a herd of 5 elephants upon entering rushed out of it by distressful trumpeting causing no damages to the crops. The overall observation is that the CTB mechanism is effective to about 99% in deterring the elephants from raiding the crop fields. Farmers have developed a very high faith in the CTB mechanism and in two of the study villages; the farmers are continuing the CTB on their own.

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Appendix I

Additional figures showing the components involved in using chili-tobacco fence in deterring elephant damage to cultivated crops

a

b

c

d

e

f

a: Chilli and Tobacco stored in bags, b: Forest staff carrying the materials to one of the experimental plots for erection, c: Smear preparation, d: Application of smear on to the rope, e: Dimensions of the experiment plot as mapped in the GPS instrument, f: Data collection at one of the experimental plots during the monitoring

Appendix-II

Chilli-Tobacco elephant barrier

Status of experiment plot at the time of establishment of barrier

Date: Observer's Name:

Village Name:
Experiment plot code:
GPS Readings:
Farmer Name:
Total area of the test plot:
Total length of Perimeter (GPS on Track mode):
Crop Type: Single crop / multiple crops

Sl. No.	Name of the crop	Total area (in sq mtrs)	Relative proportion of each crop (%)	Crop Phenology (Vegetative/ Reproductive/ Harvest stage)	Remarks
1					
2					
3					
4					
5					

Crop damage: Yes or No
If Yes

Sl. No.	Name of the crop	Total area of damage (m^2)	Trampled (%)	Eaten (%)	Remarks
1					
2					
3					
4					
5					

Status of crop damage: Fresh (1-2 days), Old (3-5 days)

Elephant signs details:

Sl. No.	Track/ Pad marks	If Yes, Circumference (In meters)	Dung	If Yes, Circumference (In meters)	Remarks
1					
2					
3					
4					
5					

Material used

Sl. No.	Type of Material	Quantity	Amount spent	Remarks
1	Cotton Rope (in mtrs)			
Smear Preparation				
2	Chilli powder (in gms)			
3	Tobacco powder (in gms)			
4	Used engine oil (in ltrs)			

Man power utilized

Sl. No.	Establishment of barrier (No. of persons involved)	Time taken (In Hrs)	Smear preparation (No. of persons involved)	Time taken (in Hrs)	Smear applying (No. of persons involved)	Time taken (in Hrs)	Remarks
1							
2							
3							
4							
5							

Explain in brief the procedure followed in establishing the chilli barrier:
Explain in brief the procedure of Smear preparation being followed:
Explain in brief the method of smearing being followed:

Appendix-III

Chilli-Tobacco elephant barrier

Smear Re-application and monitoring of chilli barrier

Date: Data Sheet Observer's Name:

Visit Number:
Village Name:
Experiment plot Code:
GPS Readings:
Crop Type: Single crop / multiple crops

Sl. No.	Name of the crop	Total area (m^2)	Relative proportion of each crop (%)	Crop Phenology (Vegetative/ Reproductive/ Harvest stage)	Remarks
1					
2					
3					
4					
5					

Barrier (Crop) damage: Yes/ No
If Yes

Sl. No.	Name of the crop	Total area of damage (m^2)	Trampled (%)	Eaten (%)	Remarks
1					
2					
3					
4					
5					
6					
7					

If no but to neighbor crops (within 25m)/ No elephant presence

Sl. No.	Name of the crop	Crop Phenology (Vegetative/ Reproductive/ Harvest stage)	Area of damage (L x B) (m^2)	Total area of damage (m^2)	Remarks
1					
2					
3					
4					
5					
6					
7					

Crop Damage to: (   ) Experiment plot
(   ) Adjacent plot (within 50 mtrs from experiment plot)
Status of crop damage: Fresh (1-2 days), Old (3-5 days)
Source of information: Direct observation/ Farmer
Point of entry (GPS Readings):
Point of exit (GPS Readings):
Time of Damage: Day/ Evening/ Late evening/ Night/ Mid night/ Early morning

Elephants Responsible:

Sl. No.	Number	Minimum	Maximum	Male/ Female/ Calf	Elephant signs (Track/ Dung)	Status of the sign (VF/ F/ O)	Remarks
1							
2							
3							
4							
5							

VF: Very Fresh; F: Fresh; O: Old

Elephant signs details:

Sl. No.	Track/ Pad marks	Circumference (m)	Distance from barrier (m)	GPS Readings	Dung	Circumference (m)	A	B
1								
2								
3								
4								
5								

A: Distance from barrier (m), B: GPS Readings

BARRIER ECONOMICS

Re-application Number:
Reason for re-application of smear:

Sl. No.	Materials used	Specification of materials used (means of procurement)	Quantity used	Amount spent	Remarks
1	Rope (in mtrs)				
Smear preparation					
2	Chilli powder (in gms)				
3	Tobacco powder (in gms)				
4	Used engine oil (in ltrs)				

MAN POWER

Sl. No.	Re-erection of barrier (No. of persons involved)	Time taken (In Hrs)	Smear preparation (No. of persons involved)	Time taken (In Hrs)	Smear applying (No. of persons involved)	Time taken (In Hrs)
1						
2						
3						
4						
5						

Explain in brief the procedure followed in establishing the chilli barrier:
Explain in brief the procedure of Smear preparation being followed:
Explain in brief the method of smearing being followed:

Appendix IV

Capacity Building Exercises

Exercise 1
Establishment of Chilli Tobacco Barrier
A research team consisting of Scientific Advisor, Senior Researcher, Research Assistant and Field assistant were involved in this capacity building exercise along with two farmers and two forest watchers helping in the physical work.

Site Selection
The village Ragihalli located at the fringes of eastern part of the park was selected for the experiment. The major crop cultivated in this village was Ragi (*Eleusine coracana*). This village also falls under high conflict zones as per the crop compensation records maintained at the office of Deputy Conservator of Forests, BNP.

- Ragihalli village was chosen for the establishment of chilli barrier first among all the villages as it is easily accessible by good roads at the same time a high conflict village.
- Farmers (especially of the experimental plot) in this village were well known and co-operative during our previous studies.
- Ragihalli was one of the five villages chosen for the experiment.

Materials used
1. Coir rope (24.5mm) = 158.2 meters
2. Chilli powder (MTR brand) = 330 gm
3. Tobacco powder (processed tobacco leaves) = 330 gm
4. Used engine oil (mixture of Engine, Gear & differential oil) =3.3 liters

Material procurement
A thorough market investigation was under taken on all the materials about their different forms and availability before procurement. Tobacco leaves were bought from a shop and dried on Tava (vessel) before grinding it to powder. Chilli powder (MTR brand) was bought from a shop. Used engine oil was collected from the automobile garage. A 24.5mm thick coir rope was purchased from the local coir rope dealer.

Establishment of chilli barrier
The experimental plot was chosen based on its strategic location and vulnerability to elephant raid by visiting the village prior to establishment of the barrier. The boundaries of the experimental plot was fixed using GPS (global positioning System) instrument. The total area and perimeter of the plot were recorded along with the geo-coordinates. The coir rope was drawn on pre-erected poles with the help of our regular informer and forest watchers from the village. Erection of poles and drawing of rope took 1 hour for 4 people participating in the action. Smear was prepared by mixing 330 grams of chilli powder and 330 grams of tobacco powder in 3.3 liters of used engine oil in the field itself. Smear preparation took 15 minutes for 2 people. Smear application on rope of length 158.2 meters took 1 hour 45 minutes for 3 people participating in the action.

Local people's participation
The farmer and our local resource person walked with us and showed the crop field for the experimental plot during site selection. The local community was helpful during the establishment. The local resource person and 2 forest watchers drew the rope on pre-erected poles and the former helped us by erecting the additional poles required. During

the establishment, around 10 villagers including few women passed by the plot as there was a cause way next to the experiment plot. These people showed very little interest to know about the experimental deterrent mechanism.

Outcome of the activity

- The 24.5mm thick Coir rope used was found to be very unfriendly during both erection and smearing
- The smear absorption rate of the rope was very poor
- The MTR brand chilli powder used was found to be less pungent and decided to change to more pungent variety
- People were reluctant to participate in smear application because it had engine oil as one of the constituents which was considered to be repulsive and stained clothes

Exercise 2:
Method adopted
Two different chilli barrier designs were tested on captive elephants to see their responses towards the experimental deterrent mechanism at two different locations.

Location-1: Safari area (Semi wild)
Location-2: Biological Park (Zoo)

Design I: Soaked & Smeared tested in forest environment
Number of individuals with age and sex
2 adult females
1 juvenile female

Test 1: Soaked and tested with uneven surface & Soaked and tested with even surface
Soaked and tested with uneven surface
A 24.5mm thick coir rope of length 3 meters was soaked overnight in the smear prepared by mixing Chilli powder, Tobacco powder and used engine oil in 1:1:10 ratio. The rope was tied between two trees located 3 meters apart on the two ends of an uneven surface. Three female captive elephants including a juvenile were made to cross the barrier.

Soaked and tested with even surface
A 24.5mm thick coir rope of length 3 meters was soaked overnight in the smear prepared by mixing Chilli powder, Tobacco powder and used engine oil in 1:1:10 ratio. The rope was tied between two trees located around 3 meters apart on the two ends of an even surface. The 3 female captive elephants and juvenile were made to cross the barrier.

Test 2: Smeared
A 24.5mm thick coir rope of 3 meters length was tied on two trees located around 3 meters apart on the two ends of an uneven surface and smeared manually at the time of experiment. The smear was prepared by mixing the Chilli powder, Tobacco powder and used engine oil in 1:1:10 ratios. The 3 female captive elephants and juvenile were made to cross the barrier.

Design II: Smeared and tested at the enclosure & soaked and tested outside the enclosure with food as a bait

Number of individuals with age and sex
1 Tusker
2 adult females
1 sub adult female
1 juvenile female
1 calf

Smeared and tested at the enclosure: A 24.5mm thick coir rope of 3 meters length which was already smeared manually was tied on two poles of the entrance of an enclosure in the biological park. The smear was prepared by mixing Chilli powder, Tobacco powder and used engine oil in 1:1:10 ratios. Six elephants including a tusker, calf and juvenile were made to cross the barrier.

Soaked and tested outside the enclosure with food as a bait: A 24.5mm thick coir rope of length 3 meters was soaked overnight in the smear prepared by mixing Chilli powder, Tobacco powder and used engine oil in 1:1:10 ratio. The rope was tied between two trees located around 6 meters apart on the two ends of an even surface by using additional rope. The six elephants─ tusker, calf and juvenile─ were made to cross the barrier.

Outcome of the exercise
Location-1: Safari area (Semi wild)

Design-I	Negative effect	Positive effect	Remarks
Soaked with uneven surface		Juvenile female -1 Adult female-2	
Soaked with even surface	Juvenile female -1 Adult female-1	Adult female-1	
Smeared (with uneven surface)		Juvenile-1 Adult female-2	

Location-2: Biological Park (Zoo)

Design-II	Negative effect	Positive effect	Remarks
Smeared and tested at the enclosure	Tusker-1 Adult female -1 Sub adult female -1 Calf -1 Juvenile female -1	Adult female-1	
Soaked and tested outside the enclosure with food as a bait	Tusker-1 Juvenile female -1 Sub adult female -1	Adult female -2 Calf -1	

Assessing Local Community Participation in Conflict Mitigation Measures: Experiences and Insights through Investigating the Efficacy of Chili-Tobacco Barrier (CTB) Mechanism

Introduction

Conflict between wildlife and people can wear down local support for conservation (Gadd 2005; Mehta & Kellert 1998). Government sponsored conflict mitigation measures are intended to compensate costs and promote tolerance towards the target species. However, where the conflict mitigation fails or is not understood by local community or the tolerance level is low or linkage between benefits and wildlife is not understood, benefits may be ineffective at reinforcing conservation (Mitchell & Slim 1991; Mehta & Kellert 1998; Ogutu 2002). It's known that, normally local community do not come forward to participate in any conflict mitigation measures; however, as they develop confidence in the efficacy of the new conflict mitigation mechanism, the level of participation increases (Treves 1997; Osborn & Parker 2003). Local people's participation in conflict mitigation measures is one of the important components of any wildlife conservation effort (Boonzaier 1996; Gadd 2005; Prabal *et al* 2008).

People's participation would be at different levels, some levels are considered to be more important for the success of any conflict mitigation measures (Hoare 2000; Sitati 2003; Osborn & Parker 2003; Parker & Osborn 2006). Investigations on people participation or their perception of the issue of elephant – human conflict or conflict mitigation measures adopted have immense value in understanding the status of conflict and also the efficacy of conflict mitigation measures adopted (Prabal *et al*. 2008). A Chili-Tobacco based conflict mitigation method was found to be effective in reducing elephant-human conflict (Parker & Osborn 2006) in Africa. A detail investigation of its efficacy and the viability was carried out for Asian elephant in Bannerghatta National Park; this provided an opportunity to investigate the knowledge, the method, participation and perception of the local community. The process involved in this investigation initially may only document the pattern or basic definition or layers of participations. It may later be a driving force or act as capacity building exercise for local community to understand, accept and execute the method for their benefits.

Objective

To test the level of awareness, interest, involvement, participation (negative or positive) of the local community during different stages of the establishment of the chilli-tabacco barrier as well as to monitor the barrier in Bannerghatta National Park.
To motivate people to understand the concept and efficacy of this method, and encourage them to adopt the method as one of the conflict mitigation measures

Levels of people's participation

Like other elephant proof barriers, the chilli barrier experiment also has to have local people's participation and this could be defined by different aspects: a) Awareness b) Interest c) Involvement d) Negative response and e) Appreciation.

1) Awareness

Here the objective is to see how awareness influences the efficiency of this deterrent mechanism. We assume awareness to have critical impact on the efficiency of any deterrent mechanism which could be positive or negative. The awareness could lead to interest and participation. The participation may lead to negative or positive consequences, depending on the level of confidence that the local community develop over time in the experiment and it's outcome.

Awareness could be defined as local people's knowledge about the chilli deterrent mechanism. i.e. If they are aware (Yes) or not (No). Once this is established the degree of awareness could be classified as Low, Medium & High. This could be further explained as below.

Low: Heard about the method but do not know any further information.
Medium: Heard about the method with some information.
High***:*** Heard about the method with full details.

Awareness is only a one-time event (i.e fixed). It is directly dependent on the sample size (n) of the establishment. In the present experiment the sample size (n) of establishment of CTB is 9. So awareness could be captured to a maximum of 9 times. But the variance of awareness is dynamic, which varies with the sample size, i.e. it could move from low to high.

2) Interest

Interest could be defined as being curious and coming forward to experiment the chilli deterrent mechanism. Interest is a dynamic event, which varies with the sample size (n). The variance of interest could be classified as Low, Medium & High**,** which could be further defined as follows.

Low: Showing visible interest before the start of the experiment but does not participate while the physical activity of the experiment takes place.
Medium: Showing willingness and eagerness towards physical activity of the experiment.
High: Fully participate in all the physical activity involved in the experiment.

3) Involvement

Involvement could be defined as taking part in different activities of the experiment at different stages of the experiment. Involvement is also a dynamic event, which varies with the sampling size (n). Variance in involvement could be classified as Low, Medium & High**,** which are further defined as follows.

Low: Involving in selective activities which are less strainful and less labor intensive.
Medium: Involving in most of the activities with some amount of strain.
High: Involving in all the activities related to the experiment.

4) Negative response

Negative response could be defined as the period when people work against the experiment. The negative participation could include people ridiculing the experiment, stealing of experiment materials, discouraging the research efforts and physically assaulting the research team. Negative response is also a dynamic event, which could vary with the sample size (n).

5) Appreciation

Appreciation could be defined as people's contentment about the experiment. The mode of appreciation could include conveying their best wishes, blessings, being hospitable to the research team. Appreciation is considered to be a dynamic event. This may also vary with the sample size (n).

Methodology

The researcher observed and assessed the responses of local people at different stages of the experiment during each visit to the experimental plot (Figure 1; see Appendix I for additional figures of different levels of people participation in CTB experiments). The responses were documented on a specially designed data sheet (see Appendix-II) and analyzed.

In this experiment, the participation of the people was assessed at 4 different stages, viz. a) Establishment, b) Re-smearing, c) Data collection and d) Crop economy assessment.

The number of data points available for each stage are as follows

1) Establishment (9): Each plot is considered as one data point irrespective of the number of people sampled for each plot (number may vary as a single person or group of people belonging to a family or neighbors of each CTB plot). This approach was followed to maintain consistency.
2) Smear application (41): A total of 41 re-smearing were made for all the test plots.
3) Data collection (50): A total of 50 times, data was collected for all the plots put together.
4) Crop economy assessment (8): This stage has data for only 8 plots. Though 9 plots were established the 1st plot was not considered for the monitoring due to the difference in the materials used.

A total of 540 responses were considered to assess the awareness, interests, involvement, negative response and appreciation. In each category a total of 108 responses (9 for establishment, 41 for smear application, 50 for data collection and 8 for crop economy assessment) were obtained

Figure 1: Local people participation in various stages of the chilli tobacco barrier (CTB) experiment

Results and Discussion

Awareness

During the establishment (n=9), 33% of people were found to be aware of the chilli deterrent mechanism but the level of awareness was low, where as the remaining 67% of people were not at all aware. During re-smearing (n=41), 64% of people reflected low level of awareness and remaining 36% of people reflected medium level of awareness. During data collection (n=50) about 57% of people were moderately aware of the chilli barrier and the other 43% of people reflected low degree of awareness. During crop economy assessment 100% (n=8) of people were aware of the chilli barrier. If we review the overall patterns of awareness during different stage of CTB experiment, the results suggest that the awareness level was very low (Figure 2) during establishment and it reached 100% (the degree of awareness was also high) during crop economy assessment stage.

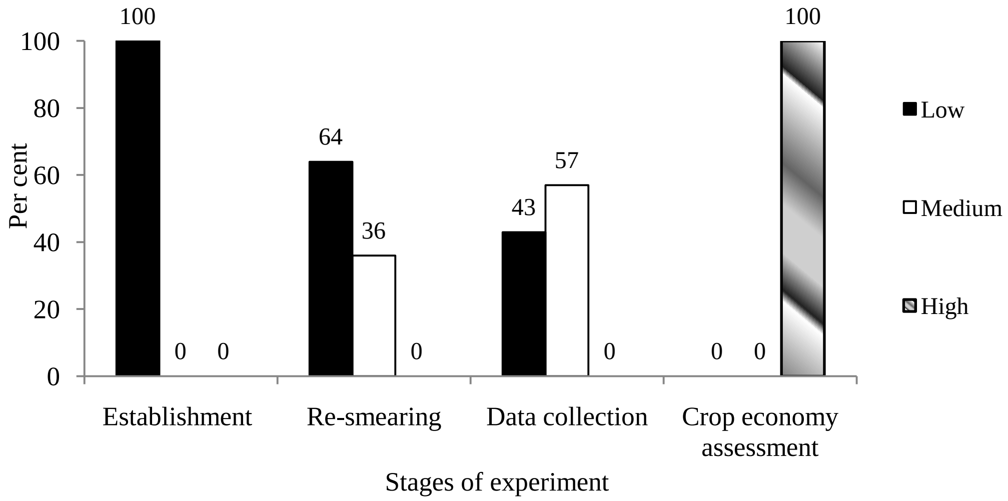

Figure 2: Levels of awareness towards the CTB experiment among the local people during different stages of the experiment

This result is also related to the knowledge they gained and the confidence they developed over a period of time on the experiment. The local people were aware about chilli being used as deterrent, but the details about the experiment, procedures and efficacy of this mitigation measures among locals was very low. It was observed that, there was a distinct increase in their knowledge about the concept and its applicability during different stages of the experiment.

Interest

During establishment (n=9) 100% of people showed interest. Among them, 67% showed high degree of interest. The other 33% showed medium degree of interest. While re-smearing (n=41), 93% of people showed interest. Among them 21% showed low degree of interest. About 34% showed medium degree of interest and the rest 45% showed a high degree of interest. During data collection (n=50), 98% of people showed interest. Among them 39% showed high degree of interest.

About 47% showed medium degree of interest and the other 14% of people showed low degree of interest. During crop economy assessment (n=8), 100% of people showed interest. Among them about 87% showed high degree of interest and the other 13% of people showed medium degree of interest. There is clear pattern of high level of interest of local people in all the stages (Figure 3), and it was very high during the crop assessment stage.

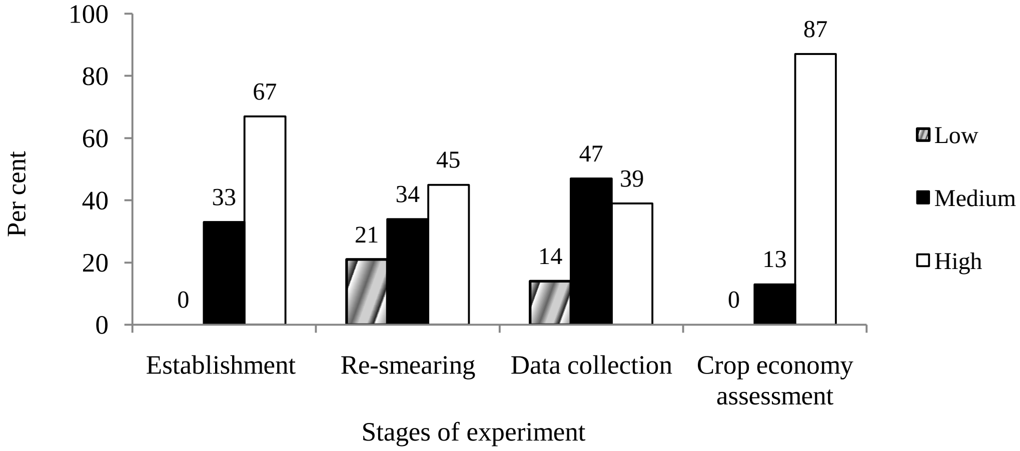

Figure 3: Levels of interests towards the CTB experiment among the local people during different stages of the experiment

Local people's interest toward the experiment is an interesting aspect to review— it may be linked, or be an independent event, to the other stages of the CTB experiment, more specifically to the aspect of awareness. The results showed that the high level of interest dominated in all the stages, however, re-smearing and data collection stages showed low interest and the low interest level was high in re-smearing stage.

Involvement

People showed 100% (n=9) involvement during establishment stage. Among them 11% showed high degree of participation. The other 89% showed medium degree of participation. About 76% (n=41) of people participated in the experiment during re-smearing. Other 24% did not get involved. Among the people who were involved, 13% showed high degree of involvement, 42% showed medium degree of involvement and the other 45% showed a low degree of involvement. During data collection (n=50), about 88% of people showed involvement. Among them 21% of people showed high degree of involvement. About 55% of people showed medium degree of involvement. The rest 25% showed low degree of involvement. About 12% showed no involvement at all. During crop economy assessment (n=8) 100% of the people were involved. Among them about 75% of people showed high degree of involvement while the other 25% of people showed medium degree of involvement. Involvement reflects actual participation of the community in the experiment; in all the stages, low and medium levels dominated (Figure 4).

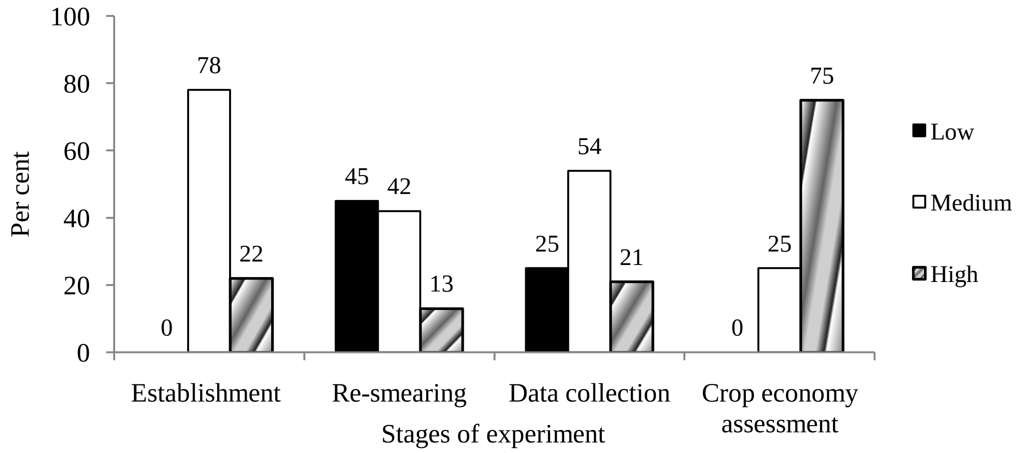

Figure 4: Levels of involvement in the CTB experiment among the local people during different stages of the experiment

During the establishment and re-smearing stages, low level of involvement was noticed. Establishment stage involves participating in the process physically but smearing or re-smearing was found to be disgusting to handle as the smear was'used engine oil' based which was found to stain cloth permanently. The lack of confidence in the efficacy of the new barrier mechanisms may also be one of the reasons for the low level of involvement during the initial stages, but by crop economy assessment stage, the level of interest attained was high.

Negative response

The Establishment stage (n=9) recorded no negative response at all (0%) but about 12% of people showed negative response during re-smearing stage (n=41). During data collection, about 10% (n=50) of people showed negative response. Crop economy assessment stage (n=8) also recorded no negative response (0%).

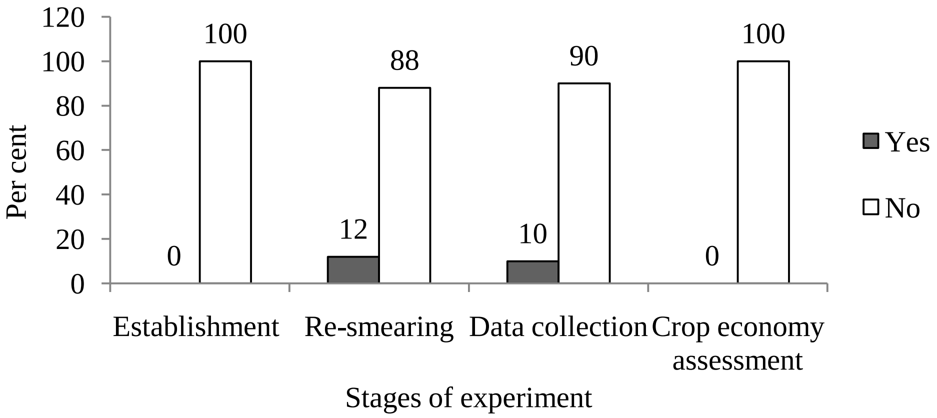

Figure 5: Levels of negative response towards the CTB experiment among the local people during different stages of the experiment

The negative response during re-smearing stage was very distinct; this included stealing of experiment materials and ridiculing the efficacy of the barrier and the efforts. The ridiculing was to such an extent that, the local people started laughing at the research team efforts and told us that "a big elephant with huge tusks approached the CTB and fainted in front of it due to the effect of chilli barrier" when we enquired about elephant visitis to the experiment plot. During data collection, about 10% (n=50) of people showed negative response by ridiculing the effort (Figure 5).

Appreciation

During establishment stage, about 89% (n=9) of people appreciated the research efforts. The rest 11% of people showed no response. About 76% (n=41) of people appreciated the research efforts during re-smearing stage. The rest 24% of people did not show any appreciation. During data collection stage (n=50), 84% of people appreciated the research efforts. The rest 16% of people did not appreciate (Figure 6). Crop economy assessment stage (n=8), recorded 100% of people appreciating the research experiment.

Local people's appreciation of the experiment was good since the establishment stage itself. But their appreciation dropped during the smearing as mentioned earlier as the smear was not user friendly, but the response was not significant. Farmers offered tender coconuts, butter milk and some places even food as their token of appreciation to the Chilli-tobacco barrier experiment. In one of the experimental plots, a farmer from the neighbouring village approached the research team and requested them to put up the CTB in his field admitting he was impressed by the appreciation it was getting in the experimental villages. Two of the farmers who cultivated crops throughout the year continued the CTB in their crop fields maintaining on their own.

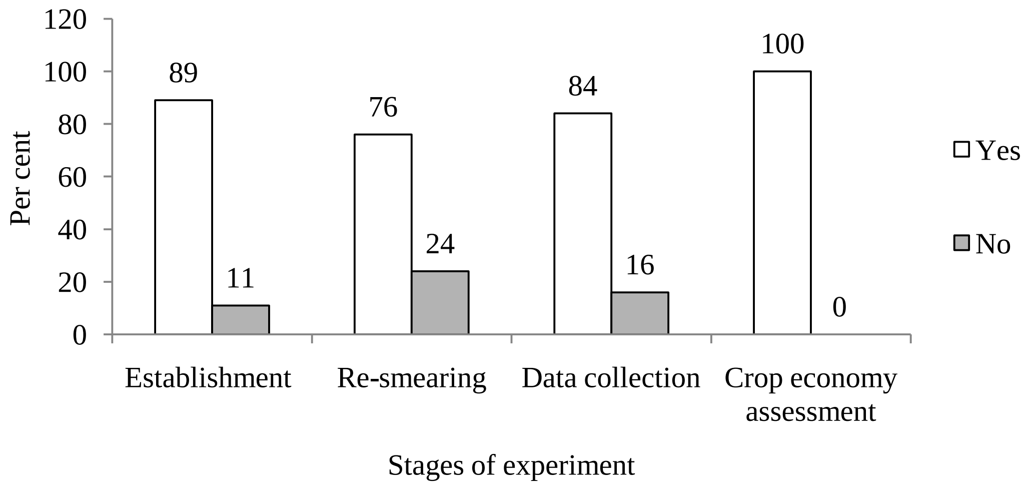

Figure 6: Levels of appreciation of the CTB experiment among the local people during different stages of the experiment

Correlations of people participation in different stages of experiment

During the establishment stage the awareness among the local community about the CTB was low, interest was high but unfortunately, only medium level of involvement by local people was observed. Negative response was nil and high degree of appreciation was noticed. During re-smearing stage, awareness and involvement was very low, and the involvement and interest levels were lower than establishment stage. During data collection stage, medium levels of awareness, interest and involvement dominated. The trend changed in crop economy assessment stage; high levels of awareness, interest and involvement dominated and there was no negative response, interestingly a high level of appreciation was received (Figure 7) by the research team.

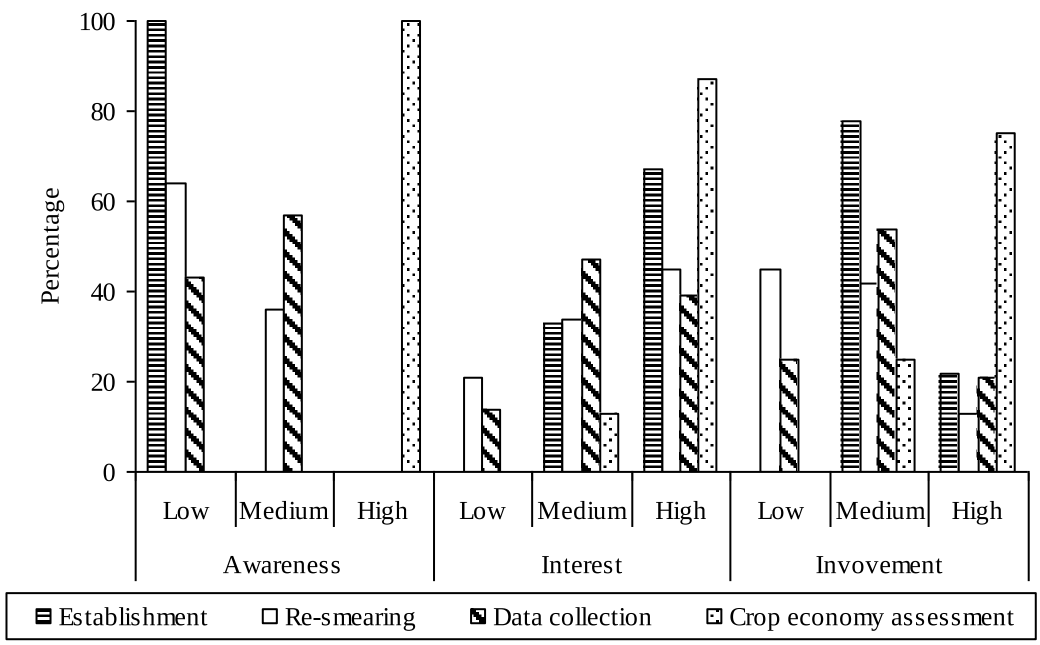

Figure 7: Levels of negative response among the local people during different stages of CBT experiment

In our study region, the local community's awareness level on many aspects of their life appeared to be poor as the landscape was very remote, and the community had limited exposure to many aspects. This is evident from their low awareness on the chilli-tobacco based elephant deterrent mechanism. The farmers said that they had heard about the chilli powder being used as a deterrent to keep the elephants away from the crop raids but the details of the procedure were vaguely known to them.

The local people were very curious and sought information such as the ingredients, proportions used, cost of materials, availability of the ingredients in the local market, etc., suggesting a moderate to high interest. It was observed that their interest levels dropped during the smearing/ re-smearing stage as they were not excited about the activity but were again found to be very interactive during the data collection about the elephant visits and damages to the CTB. During the crop economy assessment stage, they were very cooperative to share the information on the different aspects of economy of the crops in the CTB. This reveals the high degree of interest in the CTB among the local community.

The farmers took part in activities such as digging the pits, organizing the wooden post, erecting the posts in the pits and drawing the rope on the erected posts and also organized water to wash hands at some locations during the establishment of CTB which reflects a high involvement by the local people. During the smearing stage of the experiment, they were reluctant to apply the smear but were found tightening the drooped rope as well as re-erecting the wooden posts firmly; suggesting a moderate involvement. Further during data collection stage (about elephant visits, crop damages, barrier damage) and crop economy assessment stage the local people shared their time and information assisting the CTB experiment. This indicates a high involvement of the local people during these two stages of the experiment.

The local people were arrogant initially towards the CTB but as the experiment progressed and the results begin to emerge they developed confidence in the efficacy of the CTB, they started getting involved. During the CTB experiment, as the awareness and interest levels increased, there was a direct involvement of local people. This was in the form of local people helping the research team physically, by lending a hand to tighten the cotton rope which slacked from the CTB posts due to wind and other climatic conditions.

As seen from the results, there was no negative response observed during establishment stage, data collection stage and crop economy stage of the experiment. Negative response such as stealing of experimental materials was noticed during the re-smearing stage of the experiment at two of the locations which could be attributed to the existing conflict among the villagers (neighbouring farmers). At one of the places of CTB experimental plot, the efficacy of the CTB was ridiculed by the adjacent crop field farmer (one of 10 people who were harvesting the crop). However, as the experiment progressed and elephants were found to be effectively deterred by the CTB, more and more local people started appreciating the CTB experiment in the villages by praising and wishing the research team. At two places the farmers themselves moved the CTB from the experimental plot to the crop storage place (for processing) after the crop was harvested. Farmers at two other places continued the CTB on their own for the subsequent crops.

People's participation is important in all the stages, however, establishment and re-smearing stages necessitates high level of physical participation of the local people.

These two stages along with data collection stage recorded low level of participation by the local people. People's co-operation was high during crop economy assessment stage. This may be related to no physical participation by them in this stage and also due to the confidence the local community developed in the efficacy of the CTB. Data collection stage also involved no physical participation, but the crop economy assessment stage is the last stage of the experiment, and it appears that before reaching that stage, people found the value of the experiment and showed their high level participation in this stage. It appears that, participation of people was not only related to the awareness and interest but confidence, benefits and faith developed as the experiment progressed as there were no damages to the crops guarded by chilli-tobacco barrier mechanism.

Conclusion

The awareness about the deterrent mechanism was low during establishment stage which gradually moved towards medium and high degree of awareness with time. People showed low degree of interest during the re-smearing stage compared to the other two stages of the experiment as smear application was found to disfigure their clothes. The deterrent mechanism recorded a low degree of negative participation and a high degree of appreciation. Overall participation of people was found to be very good. People were open to participate to experiment the alternative elephant deterrent mechanisms. The active participation (positive) of local community in this experiment was also related to the confidence local people developed towards this mechanism and its efficacy.

Overall, from their point of view, the chilli barrier mechanism was found to be effective in deterring elephants. The initial positive results have given a promising insight towards openness to experiment new deterrent mechanisms. The incidents of bulls (who are considered to be causing severe damage to the crops and very difficult to scare away) and big female groups had been effectively prevented by CTB gave a strong fillip in this mechanism to the local community. Over all, according to the local people, the Chilli based deterrent mechanism is more than 90% effective in blocking the elephants from raiding the crop fields, farmers have developed a very high faith and trust in the new barrier. As they started developing confidence in this experiment, their level of participation increased.

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Appendix-I

Additional figures showing the different levels of people participation in the establishment of a chilli–tobacco fence


a b


c d


e f

a: Local people involvement in identifying the location to set up experimental plot, b & c: Erection of the rope, d & e: People participation in the smearing process, f: People participation in the crop economics assessment survey

Appendix-II

Local people participation in Chilli-tobacco elephant barrier efficacy assessment in Bannerghatta National Park

Date: Observer:

1. Whether the people aware of the chilli barrier? : Yes/ No
   If Yes,
   Level of awareness: Low/ Medium/ High

2. Whether the people showed interest in chilli barrier experiment? : Yes/ No
   If Yes,
   Level of awareness: Low/ Medium/ High

3. Whether the people participated in the chilli barrier experiment? : Yes/ No
   If Yes,
   Level of awareness: Low/ Medium/ High

4. Whether the people participated negatively in the experiment? : Yes/ No
   If Yes,
   Type of negative participation: Discouraging/ridiculing/stealing of experiment materials/ Beating/ others
   Describe the type of negative participation:

5. Whether people appreciated the chilli barrier? : Yes/ No
   If Yes,
   Describe the mode of appreciation:

Assessing the Efficacies of Farmers and Forest Watchers in the Mitigation of Human-Elephant Conflict*

Introduction

Though conflict appears to be inevitable, mitigation measures can play a role in reducing the intensity of conflict (Bell 1984; Sukumar 1990; Tchamba 1996; Smith & Kasiki 1999). Any conflict mitigation will have local community at the fore front supported by the forest department which is legally entrusted with the responsibility of protecting and conserving the species along with various interest groups (Ogutu 2002; Gadd 2005). Farmers have many traditional methods designed such as crop guarding, airborne missiles, simple barrier mechanisms, and decoy food techniques to prevent elephants from entering human habitations (Hoare 2000; Parker & Osborn 2006; Prabal *et al.* 2008). These approaches are oriented towards protecting their life, property and cultivated crops. With an ultimate aim of protecting the species (Sukumar 1990; Prabal *et al.* 2008), forest department follows suit in order to prevent farmers from developing any negative attitude towards elephants which may threaten the existence of the Asian elephant.

In Bannerghatta National Park, Elephant Scaring Squads, Elephant Proof (physical) barriers and other traditional method of crop guarding are used. The 'elephant scaring squads' comprise forest watchers. The idea of constituting these squads, equipped with firecrackers, guns, shoes, torch etc., is to drive elephants to deeper parts of the habitat, keep vigilance in the peripheral region during the day to avert any elephant incursions into human habitations and joining the farmers during night to guard the crop fields (Rajeev 2002). The farmers, during crop guarding, are required to remain awake throughout the night, positioning themselves in strategic locations such as tree platforms, farm houses, pump houses and open areas in order to keep watch over elephant incursions.

When they sight or perceive sound of elephants they beat drums, burst crackers and make loud noise to drive them away. In spite of the use of these methods, the conflict situation appears to be unabated in the study area, which is evident from the rise in compensation claims over the years. No study has ever been done to understand the efficacy of these local mitigation methods in the study area. About 70% of the land in the villages was under cultivation of subsistence crop ragi (*Eleusine coracana*) during the study period. This same crop happens to be the most frequently and extensively damaged crop by elephants. This crop is highly prone to damage between reproductive and processing stage through harvest stage. The investigation was focused during the period of harvest and processing stage. In this context, an attempt has been made in Bannerghatta to understand the overall efficacy of watcher and farmer with the following specific objectives:

Objectives

Studying and assessing the efficacy of:
Watcher's efforts towards mitigation of human-elephant conflict.
Farmer's efforts towards mitigation of Human-elephant conflict.

The objectives are based on the following concept
As mentioned earlier, farmers are the front runners in conflict mitigation as it is their livelihood which is at stake.

*With inputs from Ashok Kumar, A. MSc, Wildlife Biology, AVC College, Manampandal, Mayiladuthurai, Tamil Nadu and A Rocha India, # 23 Anjaneya Street, Austin Town, Bangalore-560 047

Watchers appointed by the forest department may complement the farmer's efforts in mitigating the conflict by acting as the first line of defence. Their efficiency has a direct impact on the losses local communities incur due to elephant depredations. For effective conflict mitigation these two layers have to act complementary to one another by way of sharing information and actively participating in preventing elephant incursions. Opposing each other depending on the level of interest and morale may prove to be disastrous on both the fronts. This in turn depends on the frequency, pattern and intensity of elephant visits. As a consequence, it is important to establish elephant visits to the study villages and resulting damages to study the above objectives.

Profile of study villages

Two villages' viz. Thattiguppe (a fringe village) and Choodahalli (an enclosure) were selected for this study. These villages come under different administrative ranges viz. Bannerghatta range and Anekal range of the park which were classified under high conflict zones of the park.

Figure 1: A farm house and landscape at Thattiguppe

Thattiguppe: The study village 'Thattiguppe' is located in the western part of the National Park. The total area of the village is 50.3 km^2 with the human population of 4000. The village is agriculturally viable and consists mostly of marginal farmers. 18 families were found to live in the farm fields itself, very close to the forest boundary (Figure 1) making this village crucial for this study.

The vegetation around this settlement is of mainly dry deciduous type and the major crops cultivated in this village are paddy (*Oryza sativa*), Banana (*Musa spp.*), Ragi *(Eleusine coracana*), Kambu (*Pennisetum typhoides*), Maize (*Zea mays*), Sugarcane (*Saccharum officinarum*) and vegetables (Rajeev 2002). As the crop compensation records of the forest department conclude this village to be one of the high conflict villages, a special elephant scaring squad was constituted by the forest department of the Kagglipura range office (Social forestry division).

Figure 2: Park's vegetation and landscape at Choodahalli

This elephant scaring squad, comprised of watchers who drive elephants deep into the forest during the day as a precautionary measure and join the local farmers to guard the crop fields from elephant raid at night. The elephant squaring squads are normally equipped with guns, shoes, uniforms, torch light and crackers for the operation.

Choodahalli: The study village is an enclosure located towards the south east of the park, within the Madeswara State Forests which falls under the Anekal Range of the Bannerghatta National Park. The range covers an area of 23.84 km^2 and is situated to the east of Karadikal State Forest and to the north west of Tali Reserve Forest of Tamil Nadu also abutting the state boundary of Tamil Nadu. The total area of the village is 800 acres with the human population of 608. The villagers are mainly dependant on agriculture. The vegetation around the village is of a typical dry deciduous (Figure 2) type with fairly dense mixed jungle with Bamboo (*Dendrocalamus strictus*) in abundance (Rajeev 2002). The major crops grown are Ragi (*Elusine coracana*), Banana (*Musa paradisiaca)*, Mulberry *(Morus alba)*, Cabbage (*Brassica oleracea*) and Flat Beans (*Cyamopsia tetragonoloba*). Choodahalli being an enclosure is prone to elephant's ingress from any direction of the village. Since the village is located close to the Tali Reserve Forest of Tamil Nadu bordering the Karnataka boundary, it would also attract many migratory elephants to this village.

Methodology

The first step involved in the assessment of the efficacy of any barrier mechanism is establishing elephant visits. This information quickens the process of understanding the existing patterns of elephant visits and its influence on the efficacy of both farmers and watchers efforts towards the mitigation of the conflict (see Appendix I for figures showing the activities related to watcher and farmer involved in mitigation measures).

1) Establishment of elephant visits

The establishment of elephant visits was achieved by monitoring each of the study villages for a period of 25 days, accounting to a total of 50 days spread across 4 months of peak reproductive and harvesting stage of crops. Information regarding elephant's visits was established by both direct observation and through information from farmers and watchers on a daily basis. The number of elephant herds visited, time of the visit, type of damage caused and causalities, if any, were also gathered. Indirect evidences of elephant's visit such as dung, track and pad marks were also recorded using a data sheet (see Appendix-II) prepared specifically for this activity. The data was digitized and analyzed using basic statistical tools.

2) Watcher's efforts in mitigating human-elephant conflict

The efforts of the watchers in keeping the elephants away from entering the human habitations were studied through both direct observations and questionnaire surveys. The approach here is expected to validate the findings and also capture the missing aspects of each of the methods.

a) Direct Observations

In direct observations, the researcher monitored the watcher's activities by accompanying them for a period of 25 days for each of the village, which accounts to a total of 50 days. To assess their efficacy, information such as the number of watchers involved, units involved, time of operation, duration of operation, mode of locating the elephants, actions made to drive away elephants (physical efforts, bursting of crackers, man-power used etc.) were recorded using a data sheet (Appendix-III). Direct sightings and indirect evidence of elephant presence like dung and pad marks were also documented.

b) Questionnaire surveys

In questionnaire survey, all the 15 watchers involved in the elephant driving operation in the study villages were interviewed for the following information using a specially designed data sheet. Involvement of watchers in the driving operations, number of people involved, duration of driving operation, distance maintained from the elephants during the operation and the reaction of the elephants to their efforts was recorded using a questionnaire (see Appendix-IV).

3) Farmer's efforts in mitigating human-elephant conflict

A combination of direct observations for a period of 50 days (25 days at each study village) by staying with the farmers (day and night) and interview of 20 farmers were carried out to assess the efficacy of farmers in mitigating the conflict.

a) *Direct observations*

In direct observations, information such as farmer's involvement, the duration of Night Watching Operation (NWO), mode of establishing the elephant presence, type of crop, crop protecting efforts (bursting crackers, beating drums, screaming and shouting, fire, lighting of bulbs, etc.) were recorded and quantified using data sheet (see Appendix-V).

b) *Questionnaire survey*

The farmers who were involved in the NWO were interviewed to collect information on duration of NWO, number of people involved, approaches used to evade elephants, preferred places of positioning in the crop fields, elephant's reaction to their efforts etc using a questionnaire (see Appendix-VI).

Results and Discussion

1) Establishment of elephant visits

During the study period, about 12% of this period, elephants visited the villages. All the visits resulted in crop damages. This clearly indicates that these villages are prone to elephant visits and farmers need to guard their crop fields and forest watchers have to be vigilant in the peripheral region of the park to prevent elephants entering the human habitations.

2) Watcher's efforts in mitigating human-elephant conflict

The watchers were involved in the Elephant Driving Operations (EDO) only during 18% (9 days) of the study period. During this period, on an average of 3 (SE= 0.48) watchers were involved, spending an average of 2 hrs and 37 minutes/day (SE=0.28). On all the 9 days, the watchers located the elephants in the periphery and they attempted to drive them back except once. During 25% of the study period only solitary elephants were encountered and in the remaining period only groups were encountered. About 88% of the time, the watchers were successful in the EDO. The results from both direct observations and questionnaire surveys indicate that solitaries are more troublesome than the groups during driving operations.

i) Mode of locating elephants

During the EDO, watchers located the elephants in the periphery of the park primarily by direct sighting (57%) followed by feeding signs (14%), track/pad marks (14%) and through sound (14%). However, interviews with the watchers indicate that about 38% of the time track marks and 21% of the time feeding signs were used to locate the elephants.

Dung and sounds made by elephants were also used in same proportions as track marks (21% each) by the watchers (Figure 3).

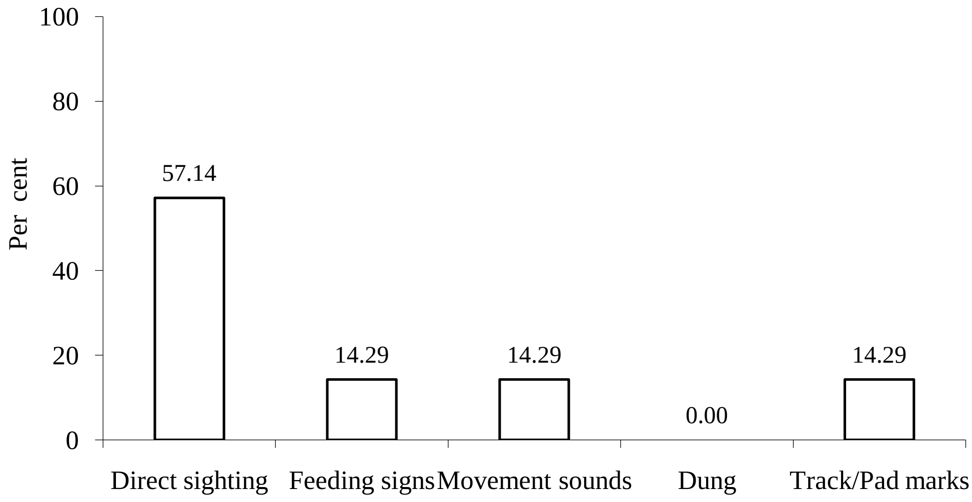

Figure 3: Mode of locating elephants. Percentage of times elephants located by the watchers is plotted against different modes

ii) Preferred approaches in Elephant Driving Operation (EDO)

During the study period, it was observed that watchers on locating the elephants first, resort to vocal scares (screaming & shouting) (50%) followed by bursting of crackers (32%) and beating of drums (18%). The same pattern is seen from the watchers interviews too (Figure 4).

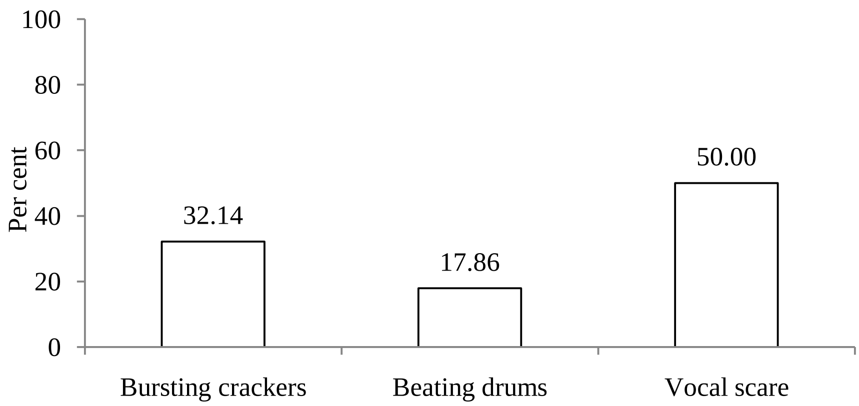

Figure 4: Watchers preferred approaches of EDO. Percentage of times approaches preferred is plotted against type of approach

Watchers, on locating the elephants, first attempt to scare them by shouting and screaming. When the elephants start moving around and are clearly visible, they intensify the driving by bursting of crackers and beating drums. Drums are not used as frequently as crackers in the EDO since crackers are easy to carry and more effective; despite being expensive and harmful. Crackers are used while maintaining an optimum distance (Figure 5). Similarly the drums cannot be used close to the elephants as they are difficult to be carried along.

Figure 5: A firecracker used in the elephant driving operation

iii) Watchers experience in Elephant Driving Operation (EDO)
The results from the questionnaire survey suggest that about 27% of the watchers have an average experience of 2 years, around 33% have 7 years, 20% have 12 years and 20% have 22 years in EDO (Figure 6).

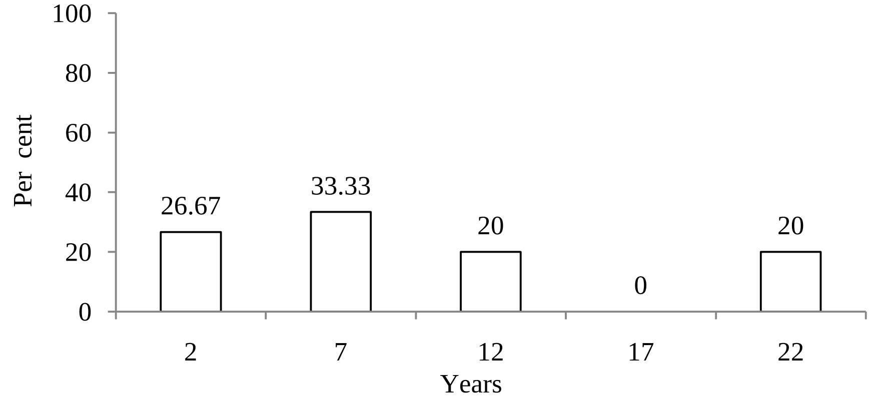

Figure 6: Watchers experience in EDO. Percentage of Watchers is plotted against years of experience

The number of years of experience of the watchers decides the division of labour in the EDO, which is important for the planning and execution of the operation. In the study area, it was observed that the most experienced (22 years) team member coordinates and leads the team by allocating the tasks and giving instructions. The next experienced person (around 12 years) provides the information about the elephant's movement from an elevated region to the leader and other (2 to 7 years) members.

3) Farmer's efforts in mitigating human-elephant conflict
During the study period (n=50 days) only 12% of the days elephants visited the study villages. The assessment of the efficacy of farmer's efforts shows that about 98% of the farmers are involved in the night watching operations (NWO). Most of the time a single farmer (54%) was involved in the operation followed by two farmers (23%), three farmers (15%), four farmers (6%) and 5 farmers (2%). The farmers position themselves on tree platforms (48%), farm houses (29%), pump houses (14%) and raised open areas (10%). The efficacy of NWO depends on efforts such as mode of establishing elephant's presence, approaches followed and time spent.

Figure 7: A tree plat form used during the night watching operation

The NWO is dominated with single farmers participating as most of the families in the study villages are nuclear families (with husband, wife and a children). Farmers with relatively bigger land holdings may form smaller groups as they have more land. Farmers with smaller land holdings form bigger groups as their lands are adjoining. Each farmer associates with his neighbours and forms bigger groups. The forming of groups (small or big) may depend on the level of interest and co-operation between the farmers, which is an important factor influencing the efficacy of NWO.

Farmers normally prefer tree platforms (Figure 7) as it gives a better view of their crop field, facilitates good communication, is economical to construct and safe for positioning during NWO. In the absence of a tree, farm/pump houses may be preferred if they are present at the strategic places. Raised open areas may be inevitable in the absence of the above locations. Only those farmers who have naturally elevated places (sheet rocks/ rocky outcrops) in their crop fields choose open areas for NWO.

i) Mode of establishing elephant presence

Elephants normally visit human habitations during night, which poses a great challenge to farmers in locating them. Farmers may listen to the sounds of elephant movements, dogs barking and actions of neighbour in their respective crop fields to establish elephant presence. Sometimes farmers directly sight elephants or also through information from watchers. A good use of these approaches will enhance the efficacy of the NWO. However the results depicts that most of the times farmers establish elephants presence by the sounds (80%) made by their movements, 16% alerted by dog barking and about 4% by the information given by watchers involved in the elephant driving operation (Figure 8).

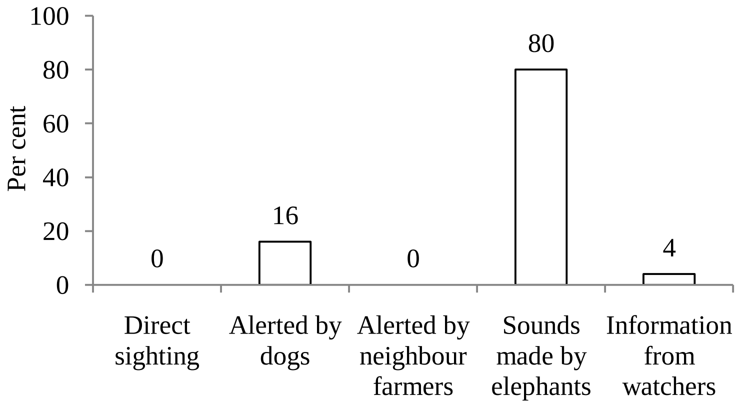

Figure 8: Mode of locating the elephants in the crop fields. Percentage of times elephants were located on the y-axis against mode of establishing on x-axis

ii) Preferred approaches in Night Watching Operation (NWO)

The results indicate that about 64% of the farmers prefer vocal scare (screaming and shouting), followed by bursting crackers (25%) and beating of drums (11%) during the night watching operations (Figure 9) The elephants moved away 100% of the times on bursting of crackers. About 33% of the times elephants moved away in response to the vocal scare (shouting & screaming) made by the farmers.

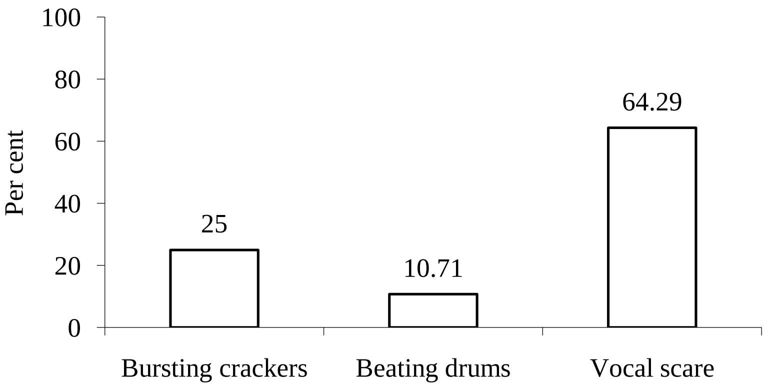

Figure 9: Farmers preferred approaches in NWO. The percentage times approach preferred is plotted against the type of approach

iii) Time spent on Night Watching Operation (NWO)
During the study, 71% of the farmers were awake for about 2 hrs, while 25% were awake for about 4 hrs. Only 4% of the farmers were awake between 6 and 8 hrs (Figure 10).

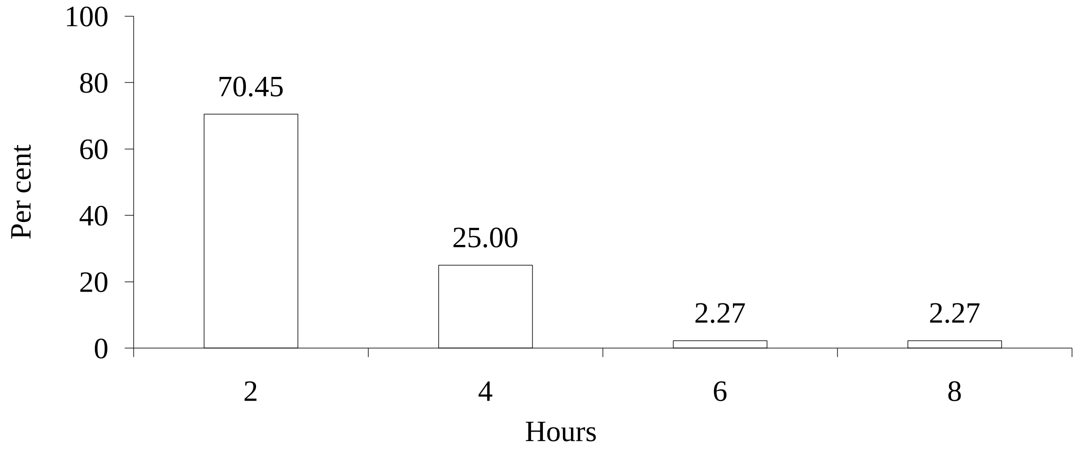

Figure 10: Average number of hrs farmers awake during the NWO. Percentage of farmers on the y-axis against the number of hrs farmers awake on the x-axis

4) Overall efficacy of watcher and farmer through the elephant visit and damage
Incidence of elephant visits and damage to human property are the indicators of efficiency. Elephant visits and damages are linked to the watchers' efficiency and the damages incurred which is exclusively linked to the farmer's efficiency.

Watcher's efficacy
During the study period (lasting for 50 days), watchers were involved in the EDO only for 9 days. This leads to two important questions pertaining to the efficacy of watchers:

1) Does non-participation of watchers for all the days reduce the efficacy?

2) Is it that the watchers are so knowledgeable and experienced that they are able to predict the elephant presence? Hence, they are able to decide up on the need for elephant driving operation on any given day.

The results shows that, of the total days of EDO, 100% of the times elephants were located and the watchers were able to drive them for about 89% of the times. Of the days of successful elephant driving they were able to prevent the elephant visits to the villages for about 63 % of times.

It is not clear if preventing elephants 63% of the times from visiting villages is treated as being effective or that it should be considered as 37% of failure in preventing elephant incursion. This can be addressed only when the extent of damage experienced or not experienced because of the elephants which were prevented or not prevented is known. Assuming that every time elephant enters a village they damage the crops (this is supported by the actual ground data), on an average around 67.5 m^2 of area under crop cultivation is damaged. As watchers have prevented 20 elephants from visiting the village they are able to prevent the damage of about 1350 m^2 of area under crop cultivation. However, irrespective of the success or failure, the conflict issue is continuous and a long lasting process, the watchers have to continue and the factors which motivate them to do so have to be investigated.

Farmer's efficacy

The results of establishing elephant visits to villages suggest that the elephants have visited villages only 6 times (of 50 days of observations), and caused damage to cultivated crops. The farmers participated on all the days in NWO and with all their efforts they were not able to prevent elephants and resultant damages even once. However, the efforts may have crucial value as the extent of crop damage by elephants was only 5 % of the total cultivated area and if there were of no efforts from the farmers, the percentage of crop damages would have increased to a considerable extent. The pattern of elephant visits to villages suggests that about 40 % times, elephant comes to the village with a 10 days gap. Period of interval between elephant raids were found to be erratic which may affect the alertness of farmers in preventing the elephants (See Figure 11).

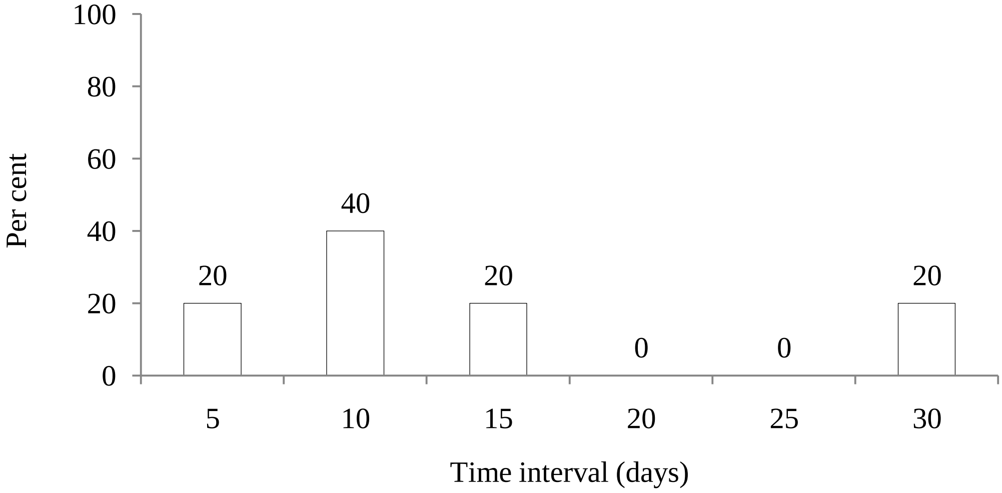

Figure 11: Interval period of elephant village visits: Percentage of interval period is plotted against the time interval (days)

In case of elephant visit not being erratic and was found to be regular (say every night), the effort needed for everyday NWO may be exhausting and de-motivating. Both the erratic and regular visits of elephants to the villages may have a negative effect on their efficacy. Farmers were found to be awake on an average only for 2 hrs during NWO and are not awake during peak elephant visiting hours (see Figure 12). This may be one of the reasons for them being less effective.

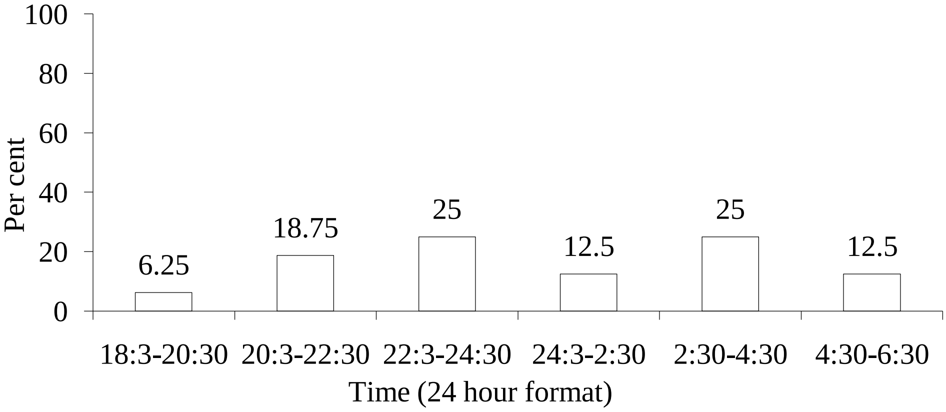

Figure 12: Preferred time of elephant crop raids. The percentage elephant visit is plotted against the preferred time interval (in hrs)

The results of the observation of individual farmers suggest that they did not encounter any elephants during the study period. Therefore no specific conclusions related to their efficacy could be made. However their presence and the different approaches followed by them suggest that they are actively involved in preventing elephants. This participation may play a critical role in the efficiency of the NWO of the farmers in the long run.

Conclusion

The study is oriented towards assessing the efficacy of watchers and farmers who form the two front layers of HEC mitigation mechanism during the peak cultivation sesaon. The observation was focused during harvesting and processing periods of the crop, and this specific time also happens to be peak conflict season. The results suggest that the watchers are effective to a larger extent, while the farmers fail to prevent the elephant entry and the resultant damages.

Watchers appeared to be successful in their operation and this may be due to

1. They operate during day time.
2. They can locate elephants through indirect signs.
3. The team has different experience levels and clear division of labour.
4. Every success of prevention of elephant is rewarded.
5. Every failure of the watcher is taken serious note of as they are ridiculed by the villagers and questioned by their unit officer.
6. The team also earns a heroic status in the village and in their work, which may act as one of the motivating factors.

The failure of farmers to prevent the elephant may be due to the following reasons

1. Farmers operate in the dark (night).
2. No clue of signs is visible to locate the elephant.
3. Strain of being awake during night and working in the day imposed more physical strain on the farmers.
4. Although farmers are knowledgeable and experienced on elephant visits and damages, they are not well trained to deal with such a situation.
5. They do not act as a coherent group to chase the elephants.
6. Farmers are economically weak.
7. Except for the economic loss they are not answerable to anyone.

Overall, our experience in this investigation suggests that both watchers and farmers were not able to prevent elephant from entering crop fields at all times. However, the active and regular involvement of these two layers of defence minimized the damage (mean= 3, SE= 0.7, range from 0.3 to 6.2% of the total cultivation). If there were no efforts from both watchers and farmers, the extent of damage of the cultivated area could have been severe. There appeared to be a coordinated effort between both watchers and farmers. The watcher squad receives regular information about elephant movements from the farmer and farmers also get messages from watchers about elephant presence close to their crop fields. There are incidents of quarrel among them, and this mutual appreciation and criticism plays a critical role in the success or failure of the operation. Even this minimal damage (1 to 7 % of total cultivation) appears to put the farmers in a severe economic loss. This is primarily due to the fact that the study region is dominated by marginal farmers and also the crops cultivated are for their subsistence. These findings suggest a need for critical review of the efforts made by the farmers and watchers in mitigation of conflict and the reasons associated with failures in preventing elephants' entry into the villages.

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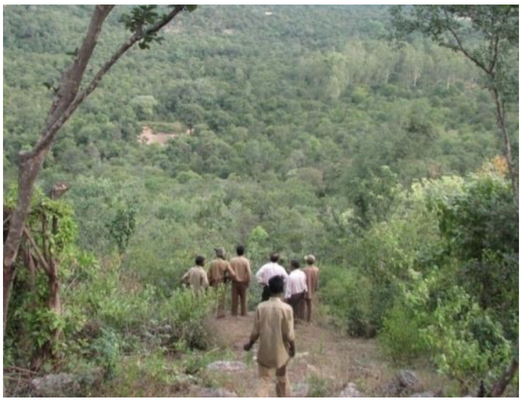
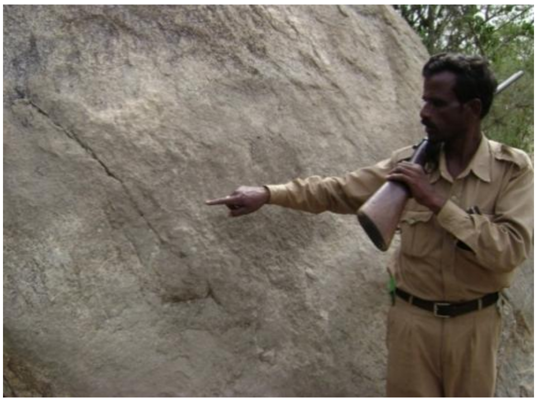
Appendix-I

Additional figures showing the forest watcher's and farmer's involvement in human-elephant-conflict mitigation measures





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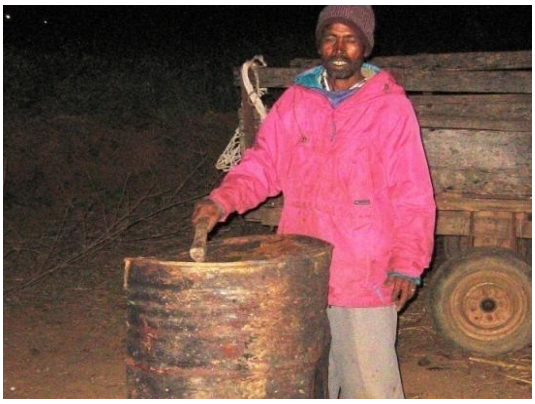


e f

a: Forest watchers in elephant driving operation (EDO), b: Forest watcher identifying elephant presence through elephant sign, c:Village located close to in the park-a potential target for elephants, d: Farmer's family assessing the damage done by elephants. e: Farmer in night watching operation (NWO) , f: Farmer demonstrating their approach of beating a drum to scare away elephants

Appendix-II

Establishing elephant visits to the study villages in Bannerghatta National Park

Observer's name Date:

Village name:

GPS reading:

Elephant visit: yes/no

If no, give reason

If yes:

Elephant visit details: Single/Group

Sl. No.	Time of arrival	Number	Maximum	Minimum	Male	Female	Calf
1.							
2.							
3.							
4.							
5.							

Any crop damage/ elephant human dealt/injury/household/other damage?
Point of entry (GPS reading):
Point of exit (GPS reading):
Source of information: Direct observation /Farmers
If crop is damaged: Crop type (Single/Multiple crop):

Sl. No.	Name of location	Time of arrival	Type of conflict			
			Crop	Infrastructure	Human/elephant/cattle	Injury
1.						
2.						
3.						
4.						
5.						

Sl. No.	Name of the crop	Status of damage			Crop phenology Vegetative/ Reproductive /Mature	Area damage(l*b)	Total area of damage
		Fresh	Old	Very old			
1							
2							
3							
4							
5							

Very fresh (previous night); fresh (1-2days); old (3-4days); very old (5-6days), l: lengh, b: breadth

Elephant signs yes/no:

If yes:

Sl. No.	Tracks/Pad marks	Circumference (m)	Dung	Circumference (m)
1				
2				
3				
4				
5				

Appendix-III

Assessing forest watcher's efficacy in conflict mitigations - by monitoring

Observer name: Data sheet Date:

Name of the village:

Location in the village: N /S /E /W /NE /NW /SE /SW

G p s reading of the location:

Whether watchers involved in Elephant Driving Operation: (E D O): yes /no

If no give reason:

If yes;

Sl. No.	No. of people involved	No. of units involved	Starting time	Closing time	Facilities provided food / vehicle/ shoe/ torch/ uniform/	Remarks
1						
2						
3						
4						
5						

Whether any elephants were located: yes/no

If yes; how many: single /group

Mode of locating elephants: by seeing /track &pad mark signs /dung signs /feeding signs /movement sounds / others specify

Whether watchers followed any approach to drive away elephants: yes /no

If yes;

What are the driving approaches: bursting crackers/ vocal scare/ beating drums/ others specify

Table: 1

Sl. No.	Bursting crackers	No. of people involved	No. of crackers used	Duration of crackers bursting (Hrs)	Elephant response Responded /not responded
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Table: 2

Sl.No	Physical efforts (Causing commotion through vocal scare)	No .of people involved	Duration of vocal scare efforts (Hrs)	Elephant response Responded /not responded
1				
2				
3				
4				
5				

Table: 3

Sl. No.	Beating drums	No. Of people involved	Duration of beating drums (hr)	Elephant response Responded /Not responded
1				
2				
3				
4				
5				

Whether elephants come out of forest: yes /no

Appendix-IV

Assessing watchers efficacy in conflict mitigation-by Interview

Date: Observer name:

Name of the village:

Watchers name:

Age:

Experience in elephant driving operation (EDO):

1. What time you start (E D O) :
2. Time spent, (total number of hrs put in per day) :
3. How many people are involved :
4. How many units are involved :
5. Who heads the team (unit officer ,watcher) :
6. How do you establish elephant's presence? (By seeing/ feeding sign/sounds made by them/track& pad mark/Dung /others specify :
7. What is your first reaction as you establish elephant presence? :
8. What are the approaches made by you like (planning/total time spent for planning approaches in order of priority :
9. Total time spent on this particular operation :
10. What is the distance you maintain from elephants while chasing :
11. Do you chase even in the night :
12. Which one gives more trouble in chasing: (single/group)
13. How many times you successfully drive elephants.
14. At what time you stop (EDO).

Appendix-V

Assessing farmers efficacy in conflict mitigations - by monitoring

Observer name: Date:

Name of the village:
Location in the village: N /S /E /W /NE /NW /SE /SW
GPS reading of the location:
Whether farmers involved in night watching operation: (NWO): yes /no
If no give reason:
If yes;
How many people where involved in (NWO):
Duration of (NWO) in (hrs) Starting time:
Closing time:
How long they are awake (hrs):
Where do they position: farm house /temporary shed /tree platform /pump house /others specify
Whether elephant visits: yes /no
If yes, how many: single /group
Mode of locating elephants: direct sightings /alerted by dogs /alerted by neighbor farmers /others specify
Whether farmers made any approach to block elephants: yes /no
If no give reason:
If yes
What are the approaches: putting fire /bursting crackers /beating drums /loud speakers /lighting up the bulbs/ vocal scare/ others specify

Table: 1

Sl. No.	Putting fire	Number of people involved	Duration of putting fire in (in hrs)	Elephant response	Remarks
				Responded / not responded	
1					
2					
3					
4					
5					

Table: 2

Sl. No.	Bursting crackers	Number of people involved	Number of crackers used	Duration of crackers bursting (in hrs)	Elephant response	Remarks
					Responded /not responded	
1						
2						
3						
4						
5						

Table: 3

Sl. No.	Beating drums	Number of people involved	Duration of beating drums (hrs)	Elephant response	Remarks
				Responded /not responded	
1					
2					
3					
4					
5					

Table: 4

Sl. No.	Loud speakers	Frequency of sound (high /medium /low)	No. of speaker units	Duration of using loud speakers (hrs)	Elephant response	Remarks
					Responded / not responded	
1						
2						
3						
4						
5						

Table: 5

Sl. No.	Lighting up bulbs	Number of bulbs used	Duration of light (hrs)	Elephant response	Remarks
				Responded /not responded	
1					
2					

Table: 6

Sl. No.	Vocal scare (causing commotion through screaming & shouting)	No .of people involved	Duration of vocal scare (hrs)	Elephant response	Remarks
				Responded /not responded	
1					
2					
3					
4					
5					

Whether any damage occurred: yes / no

Appendix-VI

Assessing farmers efficacy in conflict mitigation- by interview

Observer name: Data sheet Date:

Name of the village:

Farmers name :

1. What time you start Night Watching Operation (NWO)
2. How long you are awake in (hrs):
3. Where do you position yourself during (NWO)?
   Farm house/ Temporary shed/Tree plat form/ Open area /Others specify
4. Generally how many people participate in the operation?
5. How do you establish elephant presence?
   By seeing /Alerted by dogs /Alerted by neighbour farmers /Sounds made by them / Information provided by department watchers /others specify
6. What is your first reaction as you establish elephant presence?
7. What are the approaches you generally follow to drive away elephants? (Approaches in the order of priority)
8. Duration of efforts in all approaches:
9. Whether

a. Elephants moved away

b. Elephants did not move but farmers got exhausted

10. Whether any damages happen or not (in %):
11. Is it worthy continuing it: yes /no
    If yes why?
    If no: why are you continuing?
12. What time you stop (NWO):

Part 3
People Perspective on Human-elephant Conflict

Introduction

Crop raiding of subsistence level cultivation by elephants is an issue of great social concern. A single night's raid by a herd can seriously endanger the annual profits of several families. This has made agriculture on the peripheries of several habitats an economically unsuccessful occupation. Even though traditionally farmers in India have been tolerant towards elephant depredation due to the strong religious and cultural symbolism of the elephants, in a society undergoing rapid social, cultural and economic transformations such sentiments are unlikely to be sustained in the future. It has now become essential that proper methods are followed to prevent or reduce elephant depredation of crops and loss of human lives in order to have the cooperation of local communities for the conservation of the Asian elephants and its habitat.

As stated by Prabal *et al.* (2008) human-elephant conflict greatly influence the socio-economy of the local people living close to elephant habitats, creating a pessimistic reaction towards elephants, thus hampering conservation efforts for the species. Most of the elephant landscapes are bordered by human habitation, and accomplishment in conservation effort depends on the people, their awareness, and attitude towards the issues. An investigation on peoples' perception of the issue of human-elephant conflict (Mitchell & Slim, 1991; Boonzaier 1996; Harcourt *et al.* 1986; Ogutu 2002) has an immense value for management strategies for species and developing scope of co-existence. As part of understanding the status of human – elephant conflict issue, an attempt was also made to investigate the level of awareness and attitude of local people towards elephants and the issue of on human-elephant conflict in and around Bannerghatta National Park with the following objectives:

Objectives

To understand the socio–economic status and the perspective of the local community on the issue of human–elephant conflict (HEC) and the conservation of elephants.

To find out the status of economic compensation schemes, current methods of mitigation, suggested methods for mitigation, alternative income sources and the response of Government departments to HEC and people's awareness and participation towards conflict mitigation measures.

The objective was evolved keeping the following concepts in mind;
Bannerghatta National Park (BNP) is surrounded by both productive, well-irrigated as well as dry, unviable rain fed crop lands. Human-elephant conflict, mainly triggered by the cropping pattern and availability of different crops throughout the year, is one of the major conservation concerns in this area as the park has 6 villages within and nearly 104 villages surrounding it. Crop raiding by the elephants is severe between the months of September and December. Forest fires and water scarcity during the dry seasons is characteristic of this place and nearly 7500 cattle are grazed in the forest posing a serious threat to wildlife and natural habitation. Rising human population and the extension of the Information Technology industry in Bangalore have wielded a great deal of stress on land. In addition to this the rural poor who live in and around the national park are also exerting much pressure on the park through cattle grazing, encroachment, fire wood cutting, in addition to mining and quarrying activities.

As part of conflict mitigation, many elephant proof barriers have been widely used in the region. In spite of the use of these methods, the conflict situation appears to be unabated in the study area. Conflict mitigation measures has to have local community at the fore front supported by the government department which is legally entrusted with the responsibility of protecting and conserving the species along with various interest groups (Harcourt *et al.* 1986; Mehta & Kelert 1988; Gadd 2005). Success of conflict mitigation measures are also related to local people's knowledge, awareness, perception, attitude towards conflict issues, or their perspective towards the conservation of large mammalian species like elephants.

Methodology

The survey was carried out in the months of June and July 2005, covering 43 days and 114 people were interviewed (see Appendix I for figures related to data collection and other associated aspects). The survey was restricted to 10 villages, which is 17% of the revenue villages located within an average distance of 0.5 (SE = 0.17) km from the forest boundary. These villages also account for 0.5 % of the total population. Data such as distance of the village from the forest, status of the forest, dependency on forest, elephant raids, reasons for elephant visits, human deaths due to elephants, household damage, crops cultivated and damaged were collected. In addition to elephant deaths, economic losses due to elephants, the status and trend of HEC, the reasons for elephant raids were also collected. The economic compensation schemes, current methods of mitigation, suggested methods for mitigation, alternative income sources and the response of Government departments to HEC were also collected. Data on the traditional value of elephants, schemes which make villagers tolerant to HEC, willingness to participate or support elephant conservation programs were also gathered (see Appendix-II for data sheet).

Results and Discussion

Source of income

The results show that agricultural farming (49%) to be the major source of income for the local community. This was followed by employment as agricultural labourers (22%) and cattle keeping (13%). Employment as casual laborers was found as a source of income for nearly 7.5% of the respondents. Around 4% of the community was involved in business such as running petty shops, cable television network services, carpentry and quarrying. The results also show around 4% of the population was employed in the nearby private small scale industries (Figure 1).

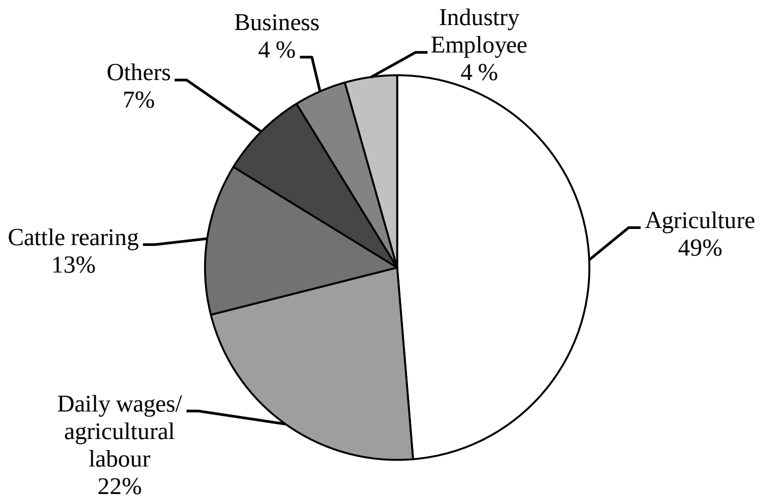


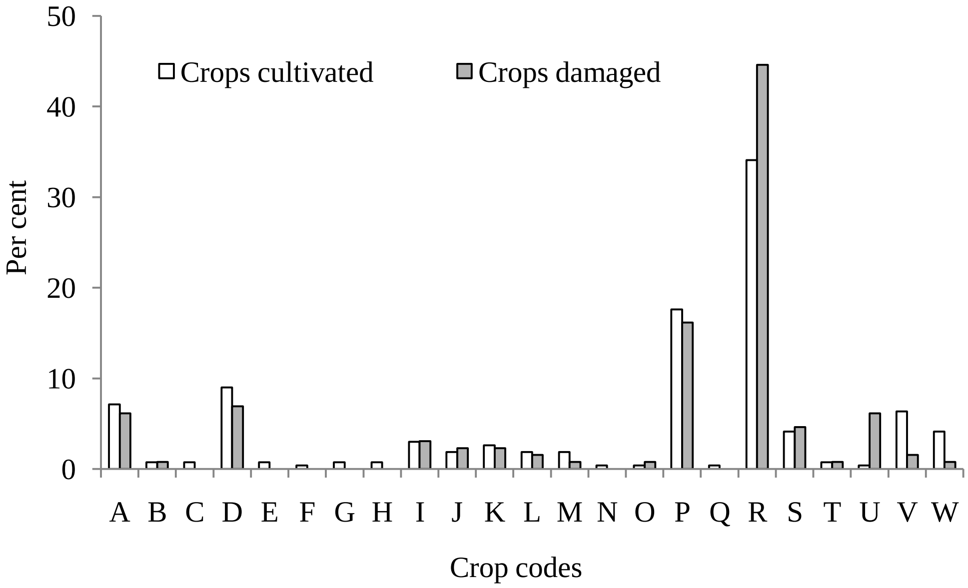
Figure 1: Percentage of various sources of income of the local community

The survey results indicate that 33% of the human population comprises of tribals. It was reported that the tribals had been relocated to these areas decades ago and worked as agricultural laborers. Many of them still work as agri–laborers in the estates of the local landlords. Even though they were given land by the Government, they continue to work as laborers as they have no irrigation facilities.

Crops cultivated and damaged
A total of 23 crops were found to be cultivated in the survey villages during the study period (Figure 2). Among the crops cultivated, Ragi (*Eleusine coracana*) dominated (34%) followed by the cultivation of paddy (*Oryza sativa*) (17%), coconut (*Cocos nucifera*) (8.9%) and banana (*Musa paradisiaca*) (7.11%). It is interesting to note that the crops cultivated in these villages were found to match information on crop type extracted from the compensation claim records for the study area.

People's opinion on reasons for elephant visits to these villages were found to be primarily for water and crops (65.0%), exclusively for crop (33.0%) and for liquor (6.0%), which was reported from only one village. The crop damage data collected showed that Ragi (44.6%) was raided the most among all the cultivated crops (Figure 2), which was followed by paddy (16.5%), coconut (6.9%), banana (6.2%), tamarind (6.2%) and jackfruit (3.1%).

A comparison of the results on elephant visits across the months, to the results from compensation claim records shows that the authenticity of information provided by the people were only for a period of 6 months.



A=Banana, B=Beans, C=Bitter gourd, D=Coconut grove, E= Cow pea, F=Gingili, G= Flowers, H= Guava grove, I=Jack fruit, J= Jowar, K= Maize, L= Mango grooe, M= Mulberry, N= Nursery farm, O= Orchards, P= Paddy, Q= Pulses, R= Ragi, S= Sapota, T= Sugar, U= Tamarind, V= Tomato and W= Other vegetables

Figure 2: Relationship between percentages of crops cultivated and damaged by the elephants

Community dependence on forest
The survey results shows around 74.0% of the respondents claim that they are dependent on the forest and needed access to it.

The reasons for accessibility (Figure 3) to the forest varied from fuel wood collection (65.0%) to cattle grazing (62.0%) to perform rituals at temples (7.0%). Both legal and illegal stone quarries are some of the sources of employment and the quarries depend a lot on the landscape.

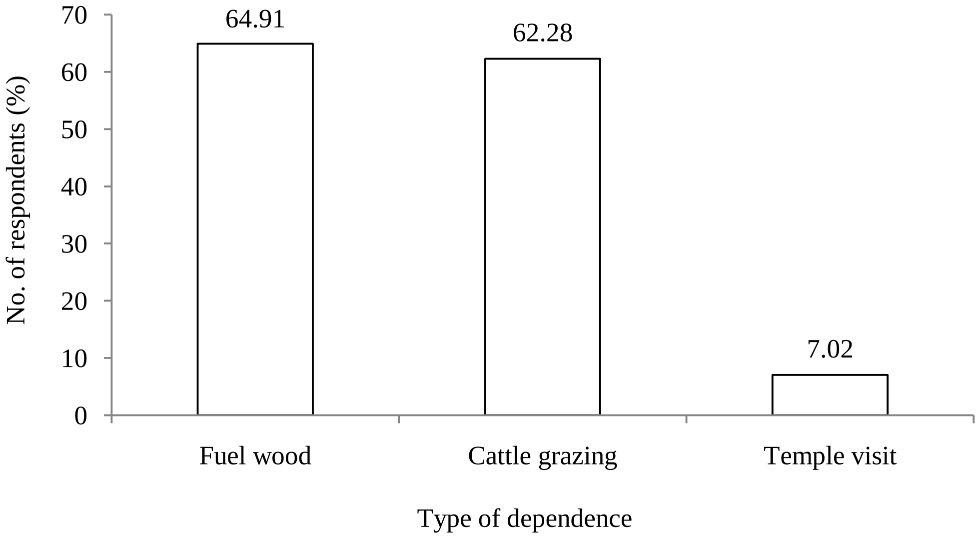
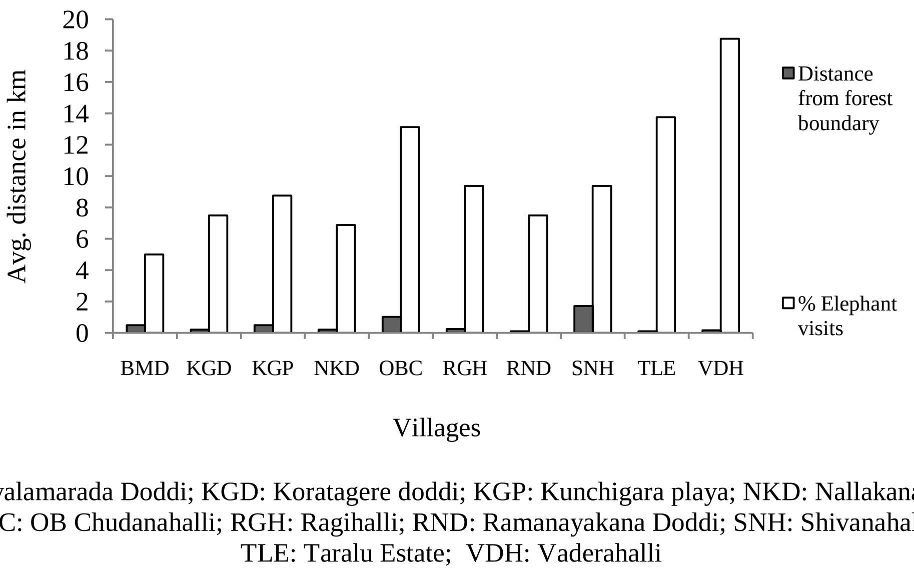


Figure 3: Villagers dependency on forest

Perception of community on elephant visit to villages

It was observed from the survey that elephants visit settlements located close to the forest boundary more frequently (Figure 4). According to the respondents of the survey, the month wise frequency of elephant visits to the villages was more between January and June, with a gradual increase from February onwards.



BMD: Byalamarada Doddi; KGD: Koratagere doddi; KGP: Kunchigara playa; NKD: Nallakana Doddi; OBC: OB Chudanahalli; RGH: Ragihalli; RND: Ramanayakana Doddi; SNH: Shivanahalli; TLE: Taralu Estate; VDH: Vaderahalli

Figure 4: Distance of villages from forest and proportion of Elephant visits

A sudden decline in the number of visits was observed between the months of July and December (Figure 5). The survey suggests that the number of visits after the month of June showed a sharp decline, which contradicts the trend in elephant visit observed from the compensation claim records. However 79.5% of the respondents feel that the number of visits by elephants is steadily increasing.

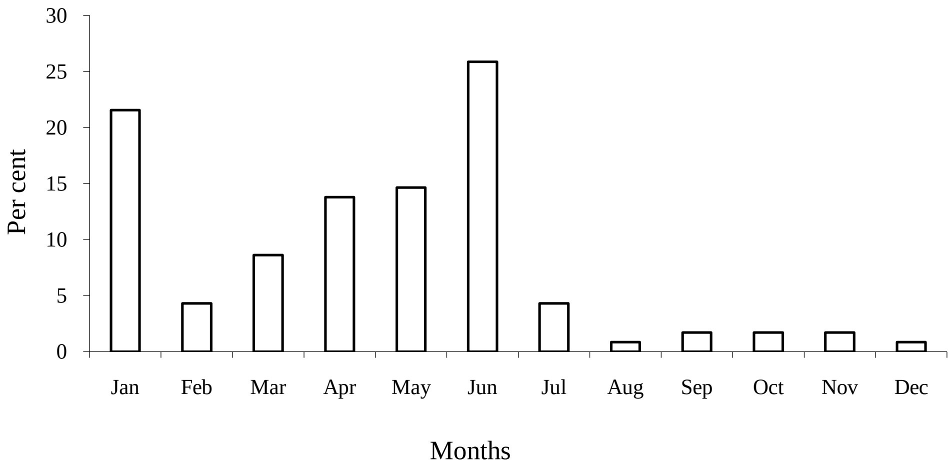
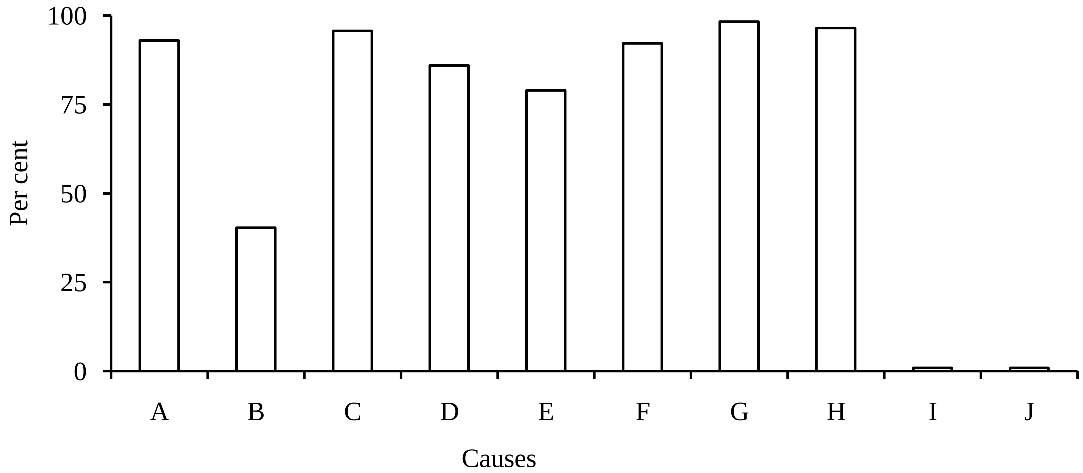


Figure 5: Month wise elephant visits to human habitation

Opinion on the causes of human-elephant conflict

According to the respondents, the reasons for human-elephant conflict, a multifold one with the preference of crops over forest vegetation (98.0%) said to be the major cause for conflict. This was followed by the lack of fear of humans (96.0%). Habitat degradation was also cited equally by 96.0% of the respondents. Increased local availability of vegetation (93.0%) and lack of water (92.0%) along with the increase in elephant population (86.0%) were the other reasons quoted by the people interviewed. The increase in human population was believed by 79.0% of the people interviewed as one of the important causes for conflict. The other reasons for conflict observed through the survey were the decreased availability forest (40.4%), tamed elephants bringing wild elephants (0.9%) and lack of food in the forest in certain season (0.9%) (Figure 6).



A: Increased local availability of vegetation; B: Decreased available forest area for elephants; C: Habitat degradation; D: Increase in elephant population; E: Increase in human population; F: Lack of water; G: Preference of crops over natural forest vegetation; H: Lack of fear of humans; I: Tamed elephants bring wild elephants and J: Lack of food in the forest in certain season

Figure 6: Causes for human-elephant conflict as opined by the local community

Human pressure on forest

Around 95.0% of the respondents felt that there is human pressure exerted on the forest and main pressure on the forest was found to be for rural demands such as fuel wood collection and cattle grazing. However other activities such as illegal sand mining, fishing, human pathways and illegal bamboo logging were also observed during the survey. Around 3.5% of the respondents felt that there is no human pressure on the forest. About 1.7% of the people interviewed did not have any opinion on this issue (Figure 7).

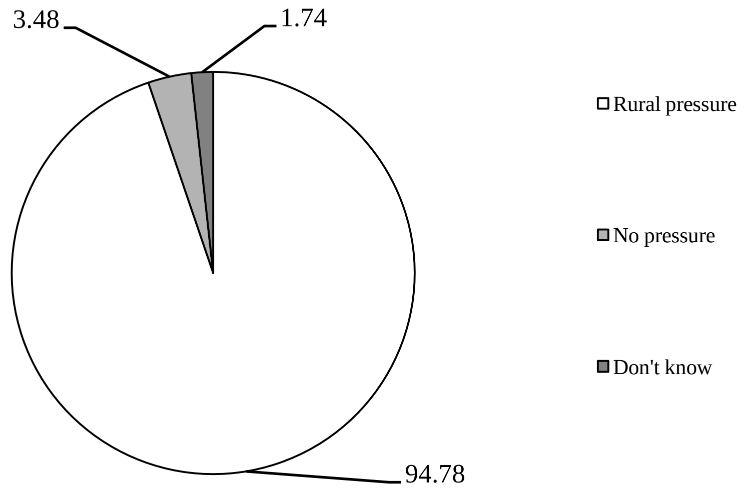


Figure 7: Proportion of human pressures exerted on the forest

Community awareness on crop compensation scheme

About 91.3% of the people interviewed were aware of the compensation scheme to crop loss and household damage provided by the forest department. It was observed that around 4.4% of the people interviewed were not at all aware of this compensation scheme and an equal percentage of people were in a state of confusion about the compensation scheme (Figure 8). Around 91% of the villagers believed that the compensation scheme is complex to deal with. However, it was observed from the compensation claim records that all the claims made were compensated by the state agency even though the amount paid was less compared to the actual loss.

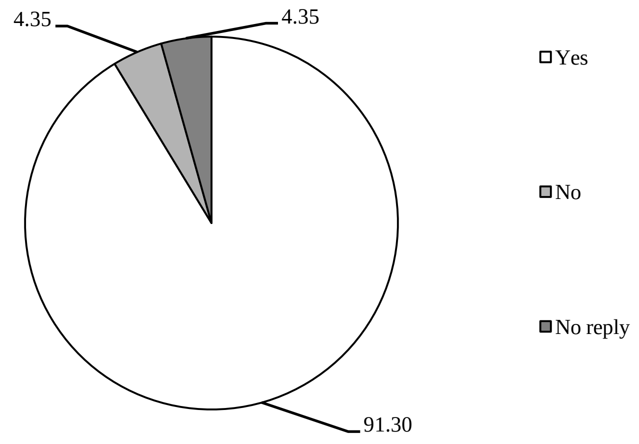


Figure 8: Community awareness about crop compensation scheme

Current use of conflict mitigation methods

The results showed that a combination of different mitigating mechanisms was being used in addition to the use of one type of mitigation measures. About 85.3% of the respondents believed the use of crackers to be effective. Around 66.4% of the respondents used fire. About 83.6% of the respondents believed the method of physically chasing elephants to be very effective. About 88% of the people opined that loud sounds produced by beating drums are effective in driving away elephants during crop raids. Firearms were suggested by 3.5% of the respondents. Only a small proportion of the respondents were found to suggest the use of electrified fence to be effective (1.7%). Around 0.9% believed the use of elephant proof trench as an effective conflict mitigating method and search lights were suggested by 0.9% of the respondents (Figure 9).

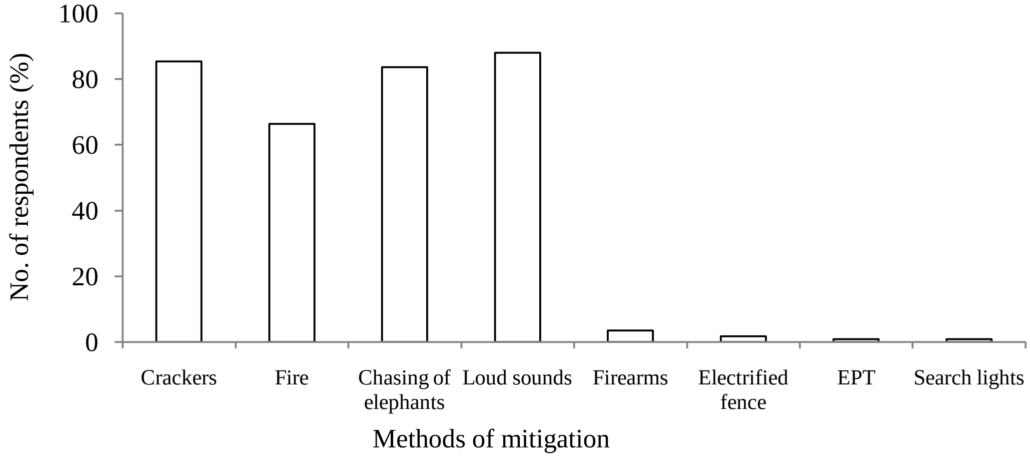


Figure 9: Proportional usage of different conflict mitigation methods

Community opinion on elephant conservation and role of NGO's

The villagers were interviewed for their opinion on elephant conservation and the role of NGOs in conserving elephants. About 85.0% of the respondents felt that it is worth conserving the elephants, among them 97.0% felt that the elephants have the right to live and 27.0% felt they are culturally and religiously important. Around 9.7% of the respondents felt that it is not worth protecting the elephants as they are destructive, and dangerous to human life. About 5.3% did not have any opinion on this (Figure 10). About 98.0% of the people interviewed opined that there had been no initiative by any NGO to mitigate the human-elephant conflict problem in the region. Around 2.0% of the respondents did not have any opinion on this issue (Figure 11).

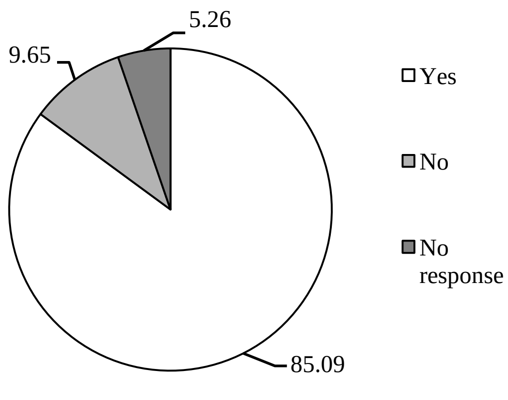


Figure 10: Community opinion on elephant conservation

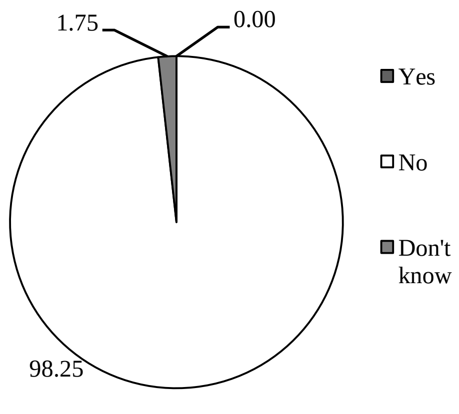
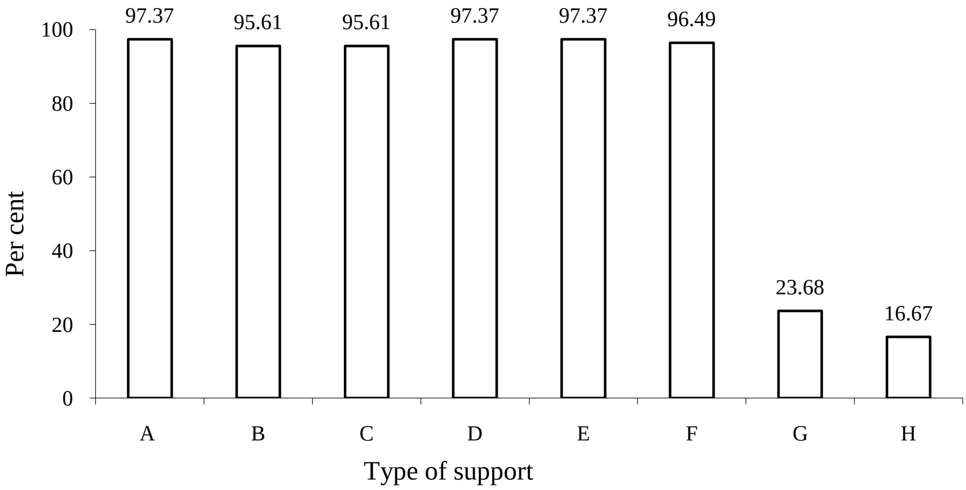


Figure 11: NGO Involvement in mitigating human-elephant conflict

Assistance needed from Government and NGOs in mitigating human – elephant conflict

On a question as to what kind of support is needed from both governmental and non-governmental agencies in mitigating human-elephant conflict, 97.0% of the respondents suggested regular meetings with local people. About 96.0% of the people interviewed said they would seek assistance in executing permanent elephant proof barriers. Around 96.0% preferred information on elephant movements and 96.0% suggested assistance in chasing elephants. Around 97.0% preferred provision for fire crackers and 97.0%



suggested provision for food and compensation for crops damaged. Around 17.0% sought assistance in capture and translocation of frequent raiders (Figure 12).

A: Assistance in chasing elephants; B: Information on elephant movements; C: Assistance in chasing elephants; D: Provision for fire-crackers and others; E: Provision for food and compensation for crop damage; F: Permanent physical barriers; G: Capture and translocation of all elephants and H: Capture and translocation frequent raiders

Figure 12: Assistance required by the local people from the Government and NGO's

Community participation in reducing human-elephant conflict

Around 86.0% of the respondents showed willingness to change their life style in order to reduce human-elephant conflict. About 74.0% among them were willing to change cultivation patterns, 86.0% were willing to change occupation, but only 19.3% of respondents were willing to move to new locality.

Conclusion

The local community living around the Bannerghatta national park is basically dependent on agriculture and agriculture related activities for their livelihood. Further, they cultivate variety of crops extensively during rainy season and sporadically during the other two seasons. These crops are raided by the elephant's in spite of many mitigation measures put in place by the farmers and forest department, resulting in considerable economic loss. The local community sense that the conflict between the humans and elephants is increasing. Furthermore, they feel that the rise in population of both elephants and humans followed by habitat degradation, lack of food in the forest for elephants in certain seasons, increased local availability of the vegetation (in human habitations) are the reasons for the growing conflict in the region. Many strongly consider that the elephants are increasingly preferring the crop fields over the forest and loosing the fear of humans.

The people believe that the elephant has a right to live. The local community also treats the elephant as "God (Lord Ganesha)" but this religious sentiment is gradually fading away with the increasing conflict issues. Most of the people appeared to be aware of the compensation scheme of the State Forest department for the economic loss incurred due to elephants but many of them feel that the procedure is complex and laborious. The local people are willing to change their life style if that brings down the conflict with the elephants and they look up to Government and Non government organizations for assistance in this regard. Overall, the attitude of local people towards the elephants is discouraging but also shows a high scope to make the locals tolerant of elephants through measures which improve economical welfare of the local community in order to conserve the species in this landscape.

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Appendix I

Additional figures showing data collection, status of villages, cultivation patterns and source of income

a

b

c

d

e

f

a, b & c: Interviewing members of the local community, d: Agricultural practices observed in the landscape, e and f: Stone quarry with a crushing unit and brick kiln units as source of income

Appendix-II

Assessment of peoples' attitudes towards elephants, Human-elephant Conflict (HEC) and their contribution to reduce the problem

Date: Observer Name:

Village Name: Name of the Villager:
Total No of villagers: Age:
Tribe/non tribe: Sex:
District: Name of the community:
State:

Details of the villagers

Sl. No.	Number of dependents	Source & Income/yr	Crops (sale/subsistence)	Other source of income
1				
2				
3				
4				
5				

Direction of village (from the forest):
GPS Location:
Distance of village (from the forest):
Forest type:
Status of the forest:
Do you use the forest or collect any forest products regularly? If yes, give details
Do you require access to the forest for products other than timber? (Eg: grazing, water, non-timber products, hunting, etc.)

Elephant visit: Yes/ No (only for last 3 years)

Sl. No.	Date/ Month	Minimum individuals	Maximum individuals	Remarks
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Has the number of visiting increased decreased or remained constant last 3 years?
Reasons for elephant visit: For crop/ salt/ stored rice/ water/ liquor
Others:
Name of the nearest village elephant reported:

Distance of the village from current village:
Direction of the village from current village:
Name of the farthest village elephant reported:
Distance of the village from current village:
Direction of the village from current village:
Human death due to elephants

Sl. No.	Date/ Month	Sex of the person	Age	Cause & Place of the incident/in forest/in settlement/by rogue/others	Remarks
1					
2					
3					
4					
5					

Household damage

Sl. No.	Date/ Month	Name of the structure	No	Remarks
1				
2				
3				
4				
5				

Crops cultivated

Sl. No.	Name of crop	Type of crop/ commercial/ subsistence	Months	Area	Amount spent Crops/season*	Remarks
1						
2						
3						
4						
5						

*classification: <Rs.1000; Rs.1000<x<Rs.2000; Rs.2000<x<Rs.5000; >Rs.5000

Crops damaged

Sl. No.	Name	Month/ year	Frequency of visit/season	Damage/crop/season (Area)	Economic loss/crop/ season	Remarks
1						
2						
3						
4						
5						

Animal responsible (crop damage/human injury/death)

Sl. No.	Sex	Frequency of visit to the settlement/ season	Duration of stay	Remarks
1				
2				
3				
4				
5				

Details of the animal/s responsible

Sl. No.	Frequently seen animal Male/ female/ group/ solitary (specify the sex)	How often	Behaviour of animal*	Detail description of animal (height/ size & length tusk or tail or others **H LT LTa Oh**	Remarks
1					
2					
3					
4					
5					

*category: aggressive; others (specify). H=height; LT=length of tusk; LTa=length of tail; Oh=Others.

Average economic losses suffered due to elephant depredations per year
Average amount of money, time and effort spent on preventing elephant damage to crops and property per year
Is the Human-elephant Conflict very low, moderate or intense in this village?
Has the conflict between human – elephant increased or decreased? If increased why?
If conflict is decreased is it due to problem elephants are captured, died, or shot or elephants stopped reproducing?
Why do elephants come into conflict with humans and raid crops?

- Decreased forest area available for them,
- Increased local availability of forests,
- Habitat degradation,
- Elephant population increase,
- Human population increase,
- Lack of water,
- Preference of crops over natural forest vegetation,
- Loss of fear of humans
- Others/specify

How do you value the following losses (from greatest to least loss)?

- An incident of crop damage
- Human injury
- Human death
- Loss of a night of sleep and energy lost in chasing elephants.

Do human activities inside the forest (movements, fuelwood and timber harvesting, minor forest produce collection, livestock grazing, poaching, etc.) increase or decrease?
Do you think these activities affect the levels of conflict?

Are the main pressures on the forest due to people living inside the forest (usually indigenous tribal's), or from rural demands from the outside?
Does the presence of elephants in the forest deter poaching wild animals and woodcutting?

Compensation

Sl. No.	Compensation available/ not	Amount/ crop/injury/ death/year/ season	Procedure involved Simple or complex	Time/ response taken for procedure/incident	Remarks
1					
2					
3					
4					
5					

Compensation (contd.)

Sl. No.	No. of claims/ season	Received – yes/no	If yes, how much/season	Remarks
1				
2				
3				
4				
5				

Current method used for mitigating the problem

Sl. No.	Name of the method	Used since	Man power response involved	Amount spent/ season	Efficacy/ effective/ mediocre/ no effect	Reason for efficacy	Remarks
1							
2							
3							
4							
5							

Suggested methods (by villagers)

Sl. No.	Name of the method	Reasons for the suggestion	Man power and other resource involved/ for the method	Expected efficacy	Remarks
1					
2					
3					
4					
5					

What is the most effective method for reducing/solving HEC (rate effectiveness of each method as low, medium or high)?

- Avoiding elephants in and near crop fields
- Using fire/fire crackers to scare/chase elephants
- Using noise-making instruments and loud sounds
- Using repulsive sprays/odours or smoke
- Establishing a network of communication providing information on local elephant movements
- Hiring professional elephant scaring squads
- Installing electrified fences
- Installing elephant-proof trenches
- Installing stone or rubble walls
- Capturing all or some elephants and translocate them to a distant forest
- Capture all or some elephants and tame them for work
- Relocate people away from the conflict zone
- Grow crops that are not attacked by elephants
- Cull (kill) only the well-established problem elephants
- Cull all the elephants in the conflict area
- Any other traditionally used methods, or novel suggestions **(**Specify)

Details of the villagers

Sl. No.	Alternative income in case of crop damage	Changes in daily activities (due to elephant)	Remarks
1			
2			
3			
4			
5			

Elephant death

Sl. No.	Month/ Year	Sex	Cause	Remarks
1				
2				
3				
4				
5				

Has the relevant government department been responsive to the HEC-related needs of local people? How often do they interact with local people and what measures have they taken to mitigate conflict?

Forest department response

Sl. No.	Support provided/ not	Response (rapid/ slow)	Details of the support	Suggestion from the villagers	Remarks
1					
2					
3					
4					
5					

Have any other non-government agencies or local groups taken collective steps to mitigate conflict?

Which measures taken by the government and non-government agencies have been effective, and which have been ineffective, in reducing conflict? Give reasons for the effectiveness or failure of each method

Traditional value / status of elephant

Sl. No.	Status changed (Yes/ No)	If yes, how	Worth conserving (Yes/ No)	Explain	Remarks
1					
2					
3					
4					
5					

Do you think elephants should be protected?
Yes, as they have right to live
- Economically useful
- Important source of knowledge (research)
- Culturally and religiously important
- Law protects them
- Others/specify

No, as they are problematic
- Destructive
- Cannot coexist with human beings
- They are no use to humans
- Dangerous to human life
- Others/specify

If Government or associated and concern agencies started a compensation scheme, would that make you tolerant of elephants and their problems?

If given protected status and adequate forests, do you think that elephants can be conserved in or around your area?

Can elephants and humans live together in a landscape consisting of patches of forest and crop fields, or should elephants be conserved in areas far away from contact with humans?

If HEC cannot be reduced, what methods can be used to increase the tolerance of local people towards elephants (rate effectiveness of each method as low, medium or high):

- Crop insurance schemes
- Government subsidies for installation of individually or cooperatively maintained electrified fences or other convenient mitigation methods
- Effective and prompt crop compensation schemes
- Educational programs to increase local support for nature conservation
- Improved transport and other infrastructure facilities to reduce fear of encounters with elephants
- Provisions for occupational retraining and alternative forms of employment
- Promotion of locally controlled ecotourism ventures

What kind of help do you require from government agencies in order to reduce the impact of HEC? (E.g., regular meetings with local people, information on elephant movements, assistance in chasing elephants, provision of firecrackers and other implements for scaring elephants, provision of food or other compensation when crops are destroyed, construction of permanent physical barriers, capture and translocation of elephants, etc.)

What is the best method for providing you with information on elephant movements: radio, TV, local weekly town/village meetings, newspapers, Internet?

What changes in lifestyle would you be willing to make to reduce the conflict (e.g. change cropping patterns, retrain and change occupation, move to a new locality if government provides alternative land or adequate compensation, etc.)?

Are you willing to participate in a joint management scheme, involving government and non-government agencies and local communities, to reduce HEC? If yes, what amount of time, effort and monetary resources are you willing to provide monthly and annually towards such an effort?

If interested in such a scheme in your area, please give your suggestions, recommendations, etc.

Section 6
Capacity Building

Introduction

Lack of trained human resources and institutional capacity to plan, implement and appraise conservation activities is a critical constraint on conservation efforts (Wildlife Conservation Society 2009) around the world. Poor economic security to conservation professionals could be seen as the major reason for the dearth of qualified, trained and committed fulltime manpower available for conservation programs. The situation is worse in developing nations such as India even though there are many people interested to work in the field of conservation. Further, the lack of availability of sufficient funds to achieve the set goals for any conservation programs is another limitation. Therefore, organizations have to utilize the service of volunteers who come from varied professional backgrounds but have an inclination towards conservation of nature and natural resources. Utilization of volunteers in conservation programs is a cost effective strategy but the lack of required skills in them is a disadvantage when it comes to the utilization of their services.

In this scenario, a well designed 'Training and Capacity Building (TCB)' before the beginning of any activity of a research or conservation programme is critical to prepare the volunteers for the role they have accepted within any organization. This orients the volunteers to the organization and their jobs, as well as supporting them with ongoing training opportunities designed to enhance their knowledge and Skills (Kerka 2003). Researchers have found that training gives volunteers the skills and knowledge needed to perform their work well and effectively (Brudney 1990; Culp 1997; Cumming 1998). Volunteers respond better to their assigned jobs when they understand and are trained on the different aspects of the job they are assigned (Hoover & Conner 2001). In addition, training programs for volunteers participating in threatened and endangered species conservation projects foster supportive attitudes in individuals who then become valuable advocates (Thody *et. al*. 2009) of conservation efforts. An effective TCB inspires, motivates as well as increases volunteers' support to further the mission, vision and values of the organization in which they volunteer (Wise & Ezell 2003; Anderson 2005). Studies have shown that TCBP have had a positive impact on volunteer retention, increasing satisfaction and a level of higher commitment (Anderson 2005; VanWinkle *et. al*. 2002) to the conservation programs as well as the organizations.

TCB as part of Asian elephant conservation program at the Bannerghatta National Park (BNP)

The study on ecology, conservation and management of Asian elephant in BNP utilized the services of more than 400 volunteers from varied professional back grounds between 2005 and 2009. The volunteers were taken through a thorough training and capacity building program before the beginning of every field activity in which they were involved.

Target Group

The training programme and the data collection focused around three layers such as research team, forest staff and volunteers.

1. Research staff (for capacity building programs)
2. Forest department staff (Range Forest officers, Forester, Forest guard and Forest watchers)
3. General public as volunteers

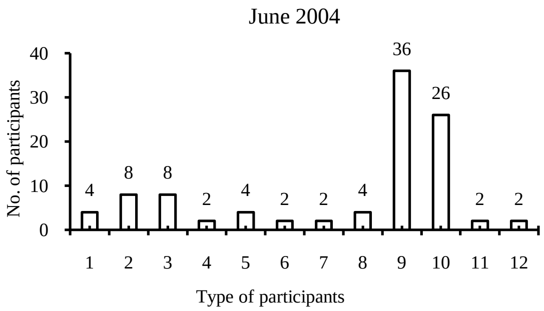
The research team particularly consists of individuals with qualification and experience, work as an employee and always accompanied by forest staff. The need of having uniform data across the landscape, and lack of qualified and experienced researchers influenced the need of looking for the volunteers. Volunteers are accompanied by forest watchers during the data collection. Research team along with the forest ground staff also undergoes training programme. This includes discussions, developing data sheet, reason for including the given parameter for data collection, approach and mode of data collection, field training and report writing.

The forest department staff managing the park was made to involve in the TCB programme with an emphasis on the forest watchers (ground staff on a non transferable job) along with the general public. Most of the forest watchers were from the local community who had a fair knowledge of the landscape and landscape elements of the region. They are however uneducated to understand the need to document the data required for the study. The local knowledge of the forest watchers was utilized and reinforced with the general volunteers from varied professional backgrounds to accomplish specific field invstigation. The training programme was brought under three major training modules

Training Module 1
Elephant habitat utilization assessment through trail survey method
Six training programs were conducted preceding the habitat use surveys. These programmes were conducted in the months of June 2004, January 2005, September 2005, January 2008, June 2008 and January 2009.

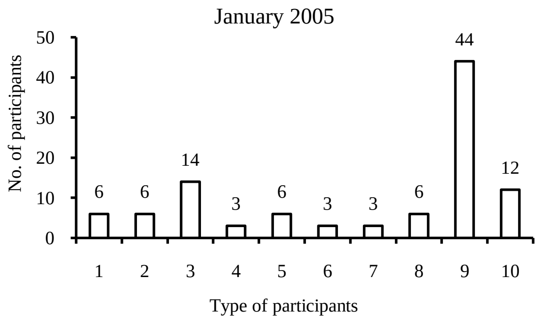
The program was attended by volunteers and forest department staff. The volunteers were from varied professional backgrounds such as researchers, personnel from NGOs, students (undergraduate, post graduate, doctoral and post-doctoral fellows), film-makers, information technology engineers, veterinarians, teachers, stock brokers and customs officers, who were trained on the various aspects of elephant ecology and trail survey method for habitat usage assessment.

The volunteers were taught to identify the different indirect signs of elephants such as track, pad marks, dung, feeding signs, rub marks and debarking. The figures 1a, b, c, d, e and f show the spectrum of professions of the volunteers who attended the training program. Dominant among the categories were students of under and post graduation and forest department personnel.



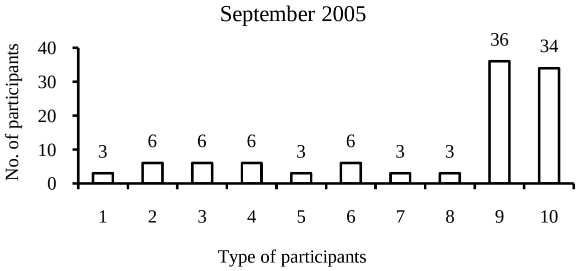
a

1 Doctoral students
2 Researchers
3 Engineers
4 HR trainer
5 Naturalist
6 Travel consultant
7 Airline employee
8 Post-doctoral fellow
9 Forest department staff
10 Under graduate students
11 Bankers
12 Veterinarians



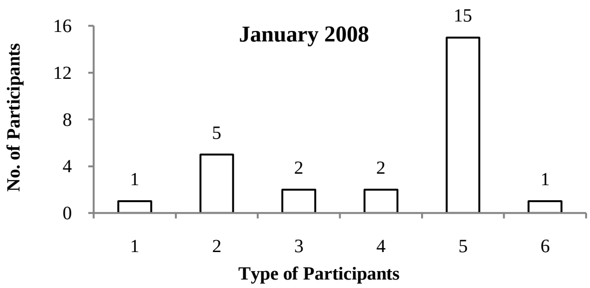
1 Doctoral students
2 Researchers
3 Engineers
4 HR trainer
5 Press reporter
6 Travel consultant
7 Airline employee
8 Post doctoral fellow
9 Forest department staff
10 Under graduate students

b



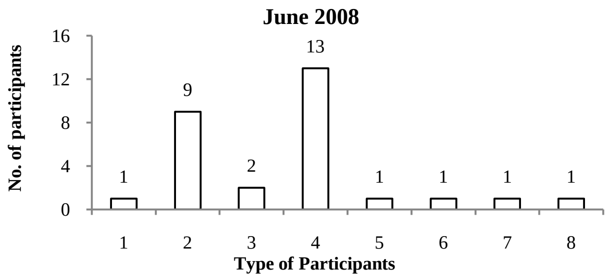
1 Doctoral students
2 Researcher
3 Engineers
4 Post-graduate students
5 Press reporter
6 Naturalist
7 Film maker
8 Post-doctoral fellow
9 Forest department staff
10 Under-graduate students

c



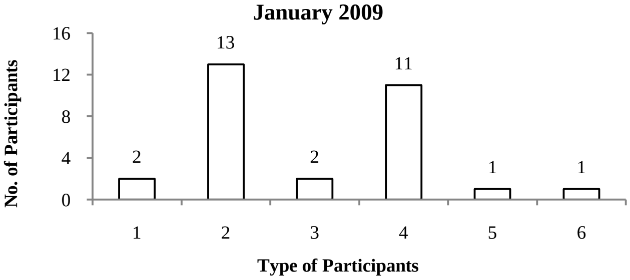
1 Naturalist
2 Post-graduate students
3 Under-graduate students
4 Doctoral students
5 Forest department staff
6 Researcher

d



1 Naturalist
2 Under-graduate students
3 Doctoral students
4 Forest department staff
5 Stock broker
6 Tour operator
7 College lecturer
8 Customs officer

e



1 Post-graduate students
2 Under-graduate students
3 Doctoral students
4 Forest department staff
5 Engineer (Architect)
6 Customs officer

f

Figures 1a, b, c, d, e and f: spectrum of professions of the volunteers who participated in the training program

Training Module 2

Elephant dung decay rate assessment through dung monitoring

Forest department staff was exclusively involved in this training (Figure 2). A team of 24 members (Range Forest Officer, Forester, Forest Guard and Forest watcher) representing all the 3 administrative ranges of Bannerghatta National Park were formed. The team was briefed about the importance of dung decay rate to estimate population density and was trained on the dung decay monitoring procedure in an indoor session.

Later, the trainees were taken to the field and were trained on aspects of the different stages of dung decay such as intact, partially broken, broken, fully broken and burnt-out. After the training, the personnel were asked to mark 35 fresh dung piles per range and monitor them till the dung disappeared. The monitoring cycle was fixed as once in 7 days. The status of the dung pile under monitoring was asked to be recorded periodically on a note book. A field researcher supervised the dung decay rate monitoring activity by visiting each dung pile once in two weeks.

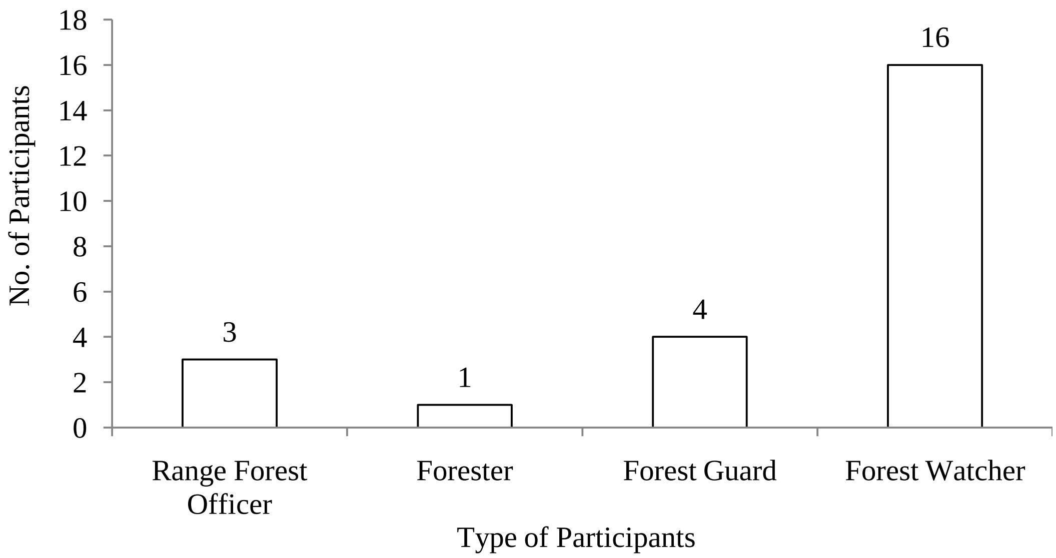


Figure 2: Type and number of forest staff underwent training on dung decay rate monitoring

Training Module 3

Assessment of distribution and extent of weed infestation by trail survey method

A TCBP to assess weed infestation in the study area was organized for the volunteers (Figure 3) during January 2009. A total of 30 volunteers (both forest staff and the general public) were briefed about Lantana and Chromolaena invasive weeds and their impact on the habitat quality. Then the trainees were trained to identify the weed species in different phenological stages (such as vegetative, reproductive and mature) in field conditions.

The trail survey method along with the techniques to estimate the area of a weed patch was imparted in a class room session which was followed by a field session to overcome any real time constraints. The volunteers were also trained on the use of GPS instrument to fix the geo-coordinates of each weed patch encountered on the trail. A data collection form was designed and the volunteers were trained on the usage of the data form.

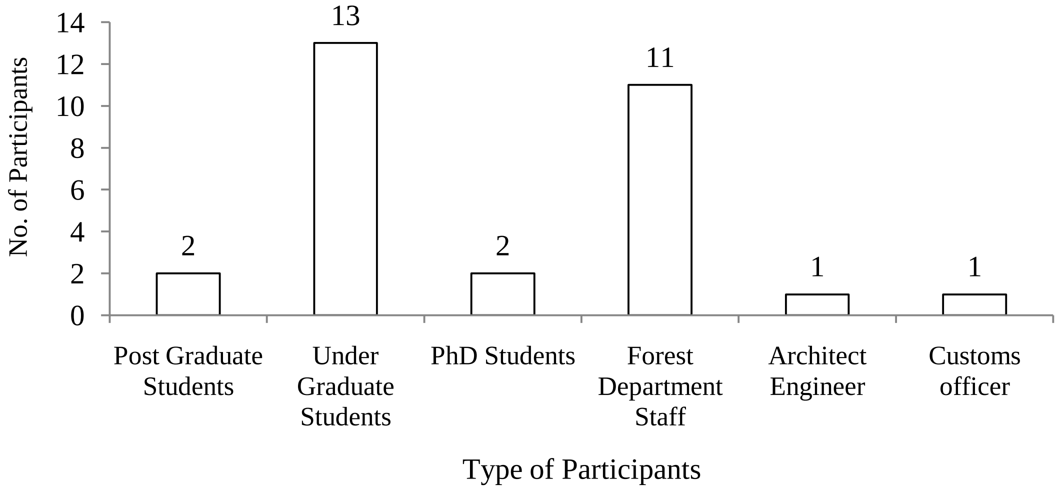


Figure 3: Details of volunteers involved in the TCBP to assess weed infestation in the park

Advantages of using volunteers

- Volunteers come with their own economic resources during deployment in the project, hence they will not add cost to the project
- Volunteers come out of interest, hence are serious and committed to the task assigned to them
- The recruitment of volunteers is done through short message service and e-mail circulation; they are interviewed before deployment in the project which ensures the skill sets required for volunteering
- Most of the volunteers come from multinational companies; hence they are well educated, professionals and bring in professionalism into data gathering
- Apart from this category, a major category of volunteers are undergraduate and post graduate students from different education institutions who have a very high interest, enthusiasm and learning capacity. Hence they undergo training very well, thereby ensure certain degree of quality in data gathering
- Volunteers worked with other similar organisations bring experiences from different landscapes, fostering the quality of the data gathered
- Volunteers get awareness on the subject of study by being a part of the activity which further helps them in creating awareness to others

Disadvantages of using volunteers

- Over enthusiasm of the volunteers many times result in relatively poor quality of data gathered
- Maintaining discipline among volunteers during the field surveys is a factor dealt with difficulties often
- Volunteers come together from varied social, cultural, economic and linguistic background for a short while, which could result in conflict among the group members, defeating the purpose for which they have come
- The inability to converse in local language among some volunteers can become a constraint in the field
- Most of the first time volunteers are over excited about everything they see in the forest, and get distracted which may affect the survey severely
- Arranging and ensuring the accommodation and safety of the volunteers during field surveys is another serious matter of concern

Advantages of using forest watchers

- Watchers are daily wage staff of the forest department, come from the local community and have vast knowledge on the geography and wildlife
- Forest watchers are tough, experienced and have a high adaptability to the field constraints such as lack of food, lack of water, rain, heat, etc., during the course of field surveys
- They are very good at identification of signs of the wild animals
- Watchers are highly sensitive in pursuing threats from the wild animals while in the field
- As forest watchers are non-transferable, the knowledge imparted to them on the area specific conservation problems will immensely benefit them in the long run
- Involving watchers facilitates the community participation in the conservation programs as they form part of the local community
- Their traditional knowledge is utilised to accomplish wider objectives of the research programme

Disadvantages of using forest watchers

- Forest watchers are illiterate, hence cannot document the field data on their own
- Forest watchers are basically from the local community and hence may lack self motivation towards conservation efforts
- Lack of transportation service and incentives de-motivates the watchers participating in centralised training programmes

Motivation for watchers to work with volunteers

- Watchers take pride in guiding the volunteers in the field as they get an opportunity to share their knowledge and feel respected
- They get an opportunity to socialise and network with educated class of people
- The field surveys are a break from their routine jobs
- Working and moving around with the volunteers (well educated class) in their locality earns them more respect among their community members

Role of watchers

- Watchers safely escort volunteers through predefined trails during data collection in the field
- Watchers assist volunteers in identifying the vegetation, wildlife signs and their status
- Watchers help volunteers in carrying the field equipments and clear their path through the forest
- Watchers basically reinforce the quality of the data gathered by providing valuable information to volunteers during the surveys

Role of volunteers

- Volunteers document the data in the field
- Volunteers create mass awareness on the significance of conservation apart from collecting the data during the survey
- Volunteers directly or indirectly boost the morale of the watchers

Who dominates: Watcher or Volunteer?

- Most of the cases both watcher and volunteers complement each other

- Very few cases, the watcher dominates over the volunteers but that does not significantly affect the quality of the data as volunteers are the ones who document it
- Some cases, volunteers dominate over the watcher which affects the quality of the data significantly as they lack experience in identification of most of the signs and their status

Role of logistics

- The logistic planning is an important aspect of any survey programme
- A well planned logistic enhances the efficiency of the manpower used in the survey
- A well planned and co-ordinated drop and pick up of the man power ensures the timely completion of the field work for the given day, in addition to ensuring their safety during the survey
- A well planned and organised accommodation (base shelter, toilet and water facility) food and transportation pleases and encourages both watchers and volunteers to participate in the subsequent surveys

Conflict between research institute's interest and volunteer interest

- Even though care is taken to avoid volunteers with conflict of interest such incidents keep occurring now and then which impacts the quality of data collection badly.

Conclusion

A total of 448 persons have been trained through the above discussed programmes alone and these people were given the opportunity to collect data by accompanying the research team. We found it to be a novel approach and a cost-effective strategy. The forest department staff gained knowledge on methods to assess and respond to conflict on a day-to-day basis. The general public volunteers also learnt about the field techniques to estimate the population, understand the conflict situations faced by the local communities and the wild animals around the forested areas. The objective of the Training and Capacity Building (TCB) programme was not only to utilize the volunteers' service but also to educate them, make them responsible for conserving the endangered Asian elephant and its natural habitat, and encourage them to support the conservation efforts of the organization in the park. The TCBP has greatly contributed towards achieving the objectives of this conservation research program.

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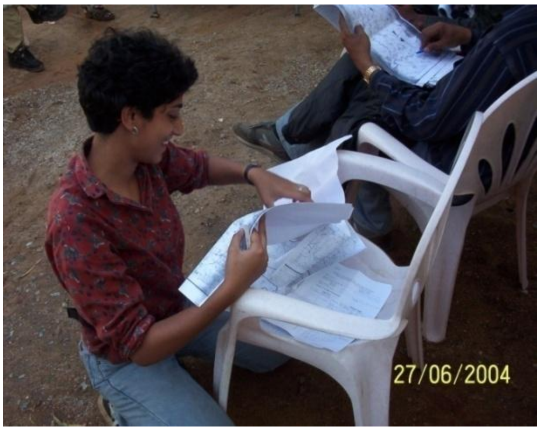
Appendix I

Training and capacity building programme (TCBP) modules

TCBP Module 1



a b

c d

e f

a: Volunteers under training, b:Volunteer familiarising herself with the data collection form, c: Forest guards bieng briefed by the experts, d:Volunteers and forest staff for a photo session after completing the assignment, e & f: Trained volunteer in the field

TCBP Module 2

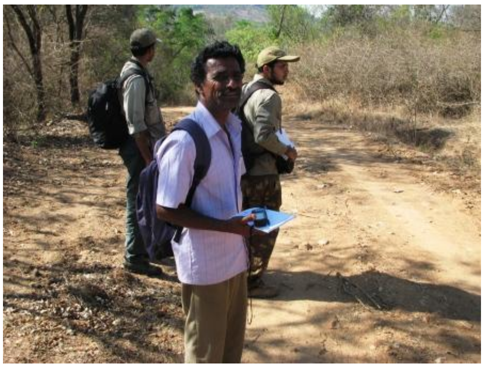
a b

c d

a: Forest staff undergoing training on dung monitoring for decay rate assesment in a class room session, b&c: Identification of elephant dung piles for decay rate monitoring, d: forest staff and the research team for photo session after completing the assignment

TCBP Module-3

a b



c d

a: Volunteers and forest staff undergoing training on weed infestation assessment in a class room, b:*Chromolaena odorata*; one of the weed species, c: Survey team in the field, d: Volunteers and research team after completion of the survey

A Rocha India is a member of the A Rocha network; an international nature conservation organization with a global presence in 20 countries represented in North and South America, Europe, the Middle East, Africa and Asia. A Rocha International is a member of the IUCN-The World Conservation Union and is guided by an eminent team of trustees. A Rocha India was established in 2003 as a registered non-profit organization and works to encourage greater care for creation across the country through scientific research, conservation of key wildlife species and environmental education programs.

Asian Nature Conservation Foundation (ANCF) is a non-profit public charitable trust set up to meet the need for an informed decision-making framework to stem the loss of biological diversity in India and other countries of tropical Asia. The Foundation undertakes activities independently and in coordination with governmental agencies, research institutions, conservation NGOs and individuals, in all matters relating to the conservation of natural resources and biodiversity.

Photo source:
Section I- Chapter 1–Figures 4, 6,7,8,10, Appendix-I: Figures c, d, e; Section 2- Chapter 1- Figures 2,11a,b,Appendix-III: Figures c, d, e; Section 4- Chapter 2- Figures 1,2, Appendix-I: Figures a, b, c, d; Section V-Part 1- Chapter 1- Figures 5 (all), 7(all), Appendix II: Figures a, b, c, e; f; Chapter 2-Figures 2a,b Part 2- Chapter 1- Figures 8b, 14b, Appendix-II: Figures a, b, c, d; Chapter 2- Figure 1; Chapter3- Figures 1b, Chapter 4- Figure 1, Appendix-VI: Figure c; Section V- Chapter 1- TCBP module 2- Figures b, c; TCBP module 3-Figure c: **Gopalakrishna. S.P**

Section I- Chapter 1- Appendix-I: Figure a; Section 2-Chapter 1- Appendix-III: Figures a, b; Section III- Chapter 1- Figure 2; Appendix-II: Figures c, d; Chapter 2- Appendix-I Figure b; Section 5- Part-1- Chapter 1- Figure 1; Part 2- Chapter1- Figures 1,2a,b,c,14a; Chapter 2- Figures 2,3,4; Appendix-IV: Figures b, d, e; Chapter 3- Figures 1a,d,e; Appendix-II: Figures a, e; Chapter 4- Figure 3; Appendix-VI: Figure a; Section VI- TCBP Module 2-a: **Vijay D. Anand**

Section II- Chapter 1- Figures 8a, b, c; Section V- Part 2- Chapter-2: Figure 14c; Appendix-IV: Figures e, f; Chapter 3- Figure 1f; Appendix-II: Figures b and c: **Dina Nisthar**

Section III-Chapter 2-Figures 3a, b, c, d, e, f 6a (all); Appendix-I: Figures a, c, d, e, f; Chapter 3- 2,4,5,6,7,8,9,10,11,12; Appendix-III: Figures all: **Nishant. M.S**

Section III- Chapter 1- Appendix-II: Figures b, e, f; Section IV-Chapter 2- Figures 3;Appendix-I: Figures e, f; Section VI- Chapter 1- TCBP module 1 Figures e, f; TCBP module 2- Figure d; TCBP module 3- Figures a,b,d: **A Rocha India**

Section I- Chapter 1- Figure 5; Appendix-I: Figure b; Section III- Chapter 1- Appendix-II: Figure a: **A .Mani**

Section I- Chapter 1- Figures 11, 12; Section V-Part 1 Chapter 1- Figure 4; Part 2- Chapter 2- Figures 6,8,10: **Ashok Kumar**

Section V-Part II-Chapter 3- Appendix-II: Figure f: **Hari Nair**

Section I-Chapter 1- Appendix-I: Figure f: **Deccan Herald**

Section I-Chapter 1- Figure 9: **Daniel Sukumar Das**

Section V-Part 1- Chapter 1- Appendix-II: Figure d: **M.D. Vinaykumar**

Section VI-Chapter 2- TCBP Module I Figures a, b, c, d: **Baruk S.J**

Section II-Chapter I- Appendix-III: Figure f; Section V-Part 2-Chapter 2-Appendix- IV: Figures a, c, f; Chapter 3-Figure 1c; Chapter 4- Appendix-VI: Figure d: **Surendra Varma**

The survival of the Asian elephant today continues to be threatened by the fragmentation, degradation and isolation of its natural habitat. An uncontrolled increase in habitat fragmentation, human settlements and their crop fields and changes in land use patterns around elephant habitats have brought the elephants closer to humans than ever before. About 85% of the population living around Bannerghatta National Park, southern India, area marginal, subsistence and small farmers prone to chronic poverty and suffer from enormous economic losses in the event of raids by elephants. This study on Ecology, conservation and Management of Asian elephant in mixed deciduous forests of Bannerghatta National Park is first of its kind, and provides an opportunity to understand the habitat status, elephant density, review the appropriate sampling protocols, insights on the population demography, habitat use, elephant-human conflict, conflict mitigation measures and local community perspective on conservation issues.

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