CONSERVATION OF THE ELEPHANT POPULATION IN THE ANAMALAIS - NELLIYAMPATHIS & PALANI HILLS (PROJECT ELEPHANT RANGE 9), SOUTHERN INDIA

FINAL REPORT
to
UNITED STATES FISH AND WILDLIFE SERVICE

Assistance Award Number: 98210-4-G892

by

ASIAN NATURE CONSERVATION FOUNDATION
c/o CENTRE FOR ECOLOGICAL SCIENCES
INDIAN INSTITUTE OF SCIENCE
BANGALORE - 560 012, INDIA

Indian Institute of Science | Asian Nature Conservation Foundation | U.S. Fish & Wildlife Service

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Citation

Baskaran, N. Kannan, G and Anbarasan U. 2007. Conservation of the elephant population in the Anamalais – Nelliyampathis & Palani hills (Project Elephant Range 9), Southern India. Final Report to United States Fish & Wildlife Service. Asian Nature Conservation Foundation, c/o Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, INDIA.

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ACKNOWLEDGEMENTS

We thank the **United States Fish and Wildlife Service** (US FWS) for financial support to carry out this study. We are extremely grateful to Programme Officers **Dr. Karl A. K. Stromayer** and **Dr. Meenakshi Nagendran**, US FWS who consistently provided encouragement to this project.

We sincerely thank the Tamil Nadu and Kerala State Forest Departments, especially the Chief Wildlife Wardens **Dr. Sukh Dev [Indian Forest Service - IFS]** (present Chief Wildlife Warden - CWLW), **Shri. C. K. Sridharan [IFS]** (former CWLW) of Tamil Nadu and **Shri. Gopinathan [IFS]** (former CWLW) of Kerala State for permitting us to carry out the present study and providing the necessary support. We also extend our sincere thanks to all the **Conservators of Forest**, **District Forest Officers**, **Wildlife Wardens**, **Assistant Conservators of Forest**, **Range Officers** and **all the Field Staff** of Forest Divisions of Elephant Range 9 belonging to Tamil Nadu and Kerala states for their co-operation and support to complete this study successfully.

We are obliged to **Dr. P. S. Easa**, former Director (Conservation) of Wildlife Trust of India, New Delhi, for extending his valuable services during the Training Programmes conducted for the field personnel of the Kerala Forest Department.

We thank **Mr. Thomas Mathew** Executive Director, Asian Nature Conservation Foundation, Indian Institute of Science, Bangalore for his critical inputs to the report.

We also thank **Mr. K. Sudhakar**, **Mr**. **K. Karunanithi**, **Mr**. **P. Thilagar, Mr. K. Venkatesh** and **Mr**. **K. Rajkumar,** Post Graduate students from A.V.C. College, Mayiladuthurai, Tamil Nadu and **Mr**. **Sumin, G. Thomas,** M. Sc. [Ecology and Environmental Science] student from Pondicherry University, Pondicherry, for volunteering their services during our surveys.

We appreciate the assistance of our other GIS members: **Mr**. **Vikas Deverjankar**, Late **Mr. Narendra Babu**, and **Mr. Santanu Dutta** in processing the GIS data for the present study.

We are thankful to our field assistant Mr. **M. Mohan** and our driver Mr. **M. Selvam** for their hard work and co-operation throughout the study period.

EXECUTIVE SUMMARY

Project Elephant Range 9 'the Anamalai hill ranges' (~5700 km^2) located in the Western Ghats to the south of the Palghat gap in southern India is one of the potential areas for the long-term conservation of the Asian elephant. This population is genetically more diverse and distinct from the much larger elephant population further north in the Ghats. The landscape is also known for its rich biodiversity along a rainfall and topographic gradient. On the other hand, extensive developmental activities such as hydroelectric and irrigation projects with open-cut canals, large areas under commercial plantations and expanding townships have resulted in an increase in fragmentation of natural habitats and elephant- human conflicts. Despite the high conservation potential and the threats facing the elephant in this landscape, information on the status of elephant population and the habitats that are essential for their long-term conservation is generally scanty. This study evaluated elephant habitats including corridors, land use and vegetation patterns, the status of elephant populations and elephant-human conflict in the landscape. Additionally, we conducted workshops on elephant census techniques in order to build capacity among officers and field level staff of the Forest Department.

Some key facets of the project:

- Elephant habitats and corridors were assessed through extensive field surveys and the data analyzed using Geographical Information System software. In total we estimated that ~ 4000 km^2 of habitat is available to elephants in this landscape, with five corridors arising mainly from developmental activities (commercial plantations & hydel projects) and topographic constraints (steep gradients).

- Although a major part of the elephant habitat in the landscape remains intact, a smaller region (Idukki Wildlife Sanctuary and part of Kothamangalam) with ~5% of the total population of elephants is already isolated due to constraints imposed by developmental activities and topography.

- Detailed GIS analyses of data on non-forest land-use attributes show that the eastern side of the landscape with 61% of the total settlements /cultivated lands and 88% total non-forest area is subject to higher levels of habitat fragmentation as compared to the western side of the landscape.

- Vegetation and land use patterns assessed by incorporating ground truthing data into satellite imagery show that the study area consists of nine landscape elements, including five diverse natural vegetations types (4000 km^2) ranging from tropical dry thorn forest to dry deciduous forest, moist deciduous forest, evergreen forest and montane *shola*-grassland forest, with moist deciduous habitat (1217 km^2) dominating the landscape. The natural vegetation has been transformed in many places by monoculture forest plantations (594 km^2 -mainly teak) and non-forest plantations (614 km^2 – such as tea, cardamom, rubber) along with settlement/cultivation (382 km^2) and hydel dams.

- Elephant population size estimated using the indirect, dung count method from 367 km of line transect, walked during dry and wet seasons showed a mean density of ~1 elephant/km^2 for the landscape.

- Population structure of elephants arrived at from a sample of 89 individuals shows a moderately skewed sex ratio towards females in the adult segment (1 male: 9 females) indicating a moderate level of ivory poaching.

- Data on spatial distribution of elephants in relation to season showed a higher abundance of elephants in the closed canopy habitats such as evergreen and moist deciduous forests during the dry season and in the open/semi-open canopied habitats of grasslands, dry deciduous and thorn forests during the wet season.

- Elephant-human conflict assessed through rapid questionnaire survey of 466 farmers from 176 villages across 19 Forest Divisions revealed that conflict is significantly higher in Forest Divisions along the eastern part than the western part of the landscape.

Similarly, the secondary data on elephant-human conflict (human casualties, elephant mortality and capture due to conflict, and compensation amount paid towards elephant damage) collected from all the forest divisions also showed a similar trend. Farmers in the eastern part of the landscape cultivated significantly more annual crops (such as paddy, maize, sugarcane and banana) compared to the farmers on the western part of the landscape. The higher degree of landscape transformations by human activities (settlements/cultivations, commercial plantations and hydro-electric projects) resulting in loss and fragmentation of elephant habitats along with the high levels of biotic pressure and cultivation of highly palatable crops in Forest Divisions on the eastern side of the landscape, seemed to be the possible reasons for the high degree of elephant - human conflict here as compared to the western part of the landscape.

- As part of capacity building, about 150 forest officers and field staff from Kerala part of the Elephant Range were trained in various techniques used for elephant population estimation.

- We make a number of recommendations for conservation of the elephant population of this landscape. These include:
  a) widening of corridors in the Indira Gandhi WLS and NP,
  b) converting monoculture forest plantations gradually into natural vegetation,
  c) capturing the few elephants ranging into the isolated Theni Forest Division and causing extensive damage to crops,
  d) enhancing anti-poaching efforts through field patrols and intelligence,
  e) detailed study on population dynamics and
  f) extensive training for the forest department field staff on habitat survey and population studies.

PROFILE OF THE REPORT

This report provides consolidated information on elephant habitats of Project Elephant Range 9 or Anamalai Hill Ranges carried out between January 2005 and June 2006 with financial support from U. S. Fish and Wildlife Service. The report contains six chapters: **Chapter 1** deals with the background and objectives of the project, and description of the study area; **Chapter 2** provides a description of the elephant habitats including elephant distribution area, land use, vegetation types and corridors; **Chapter 3** provides details of population size and structure of elephants of this region; **Chapter 4** presents the extent of human-elephant conflict across this landscape; **Chapter 5** gives details of the training programme conducted for the Forest Department staff on the Techniques used in elephant population estimation; **Chapter 6** deals with recommendations derived from the study for the management of this Elephant Range.

CHAPTER 1

PROJECT BACKGROUND

1.1. INTRODUCTION

India holds the world's largest population of Asian elephants (*Elephas maximus*) in the wild. With 28 states and 7 union territories, it is the seventh largest and second most populous country in the world. Despite this large human population, India harbours two of the 25 "biodiversity hotspots" designated across the globe (Myers *et al.* 2000), with diverse vegetation types and wide varieties of endemic fauna and flora.

In recent decades, the country has enacted several laws such as the Wildlife Protection Act 1972 and the Forest Conservation Act 1980 to establish several hundred National Parks and Wildlife Sanctuaries (Protected Areas – hereinafter referred to as PAs) as well as to conserve the forest cover and protect its wildlife. But such a PA network is still inadequate to conserve a wide-ranging species like the elephant. Elephants have large home ranges that stretch across Reserved Forests and other land use categories apart from PA (Desai 1991, Baskaran *et al*. 1995 and Baskaran 1998), which do not come under the protected area network. Further, the Asian elephant, listed as "Endangered" in the IUCN Red List, is under threat mainly due to fragmentation, degradation and loss of habitat, and poaching for ivory and meat (Daniel 1980, Sukumar 1989).

The Government of India launched 'Project Elephant' in February 1992 to initiate comprehensive measures for elephant conservation. Under this scheme, traditionally important elephant habitats have been designated as Elephant Ranges across the country. Most of these Ranges are spread across more than one state. Elephant Range areas falling under each state have been notified as Elephant Reserves (Bist 2002). There are presently 11 Elephant Ranges and 25 Elephant Reserves in 12 states, spread across 58,000 km^2, supporting more than 20,000 elephants or about two-third of the elephant population of the country (Project Elephant 2004).

Project Elephant Range 9, popularly known as Anamalai (meaning 'Elephant hill' in Tamil), Nelliyampathy and Palani Hill Ranges is situated in the southern part of Western Ghats to the

south of the Palghat Gap, and extends over 5700 km^2. This area is believed to harbour nearly 2000 elephants and has been identified as one of the potential habitats for the long-term conservation of Asian elephants. It has an elephant population that is genetically more diverse and distinct from the population north of Palghat gap in southern India (Vidya *et al*. 2005). This area is also known for its variety of endemic and endangered fauna (Stonor 1946, Umapathy and Kumar 2000, Kannan 1998, Raman 2001).

Despite the high potential of this region for the long-term survival of elephants and biodiversity, information on the status of the elephant population and its habitats is either scanty or isolated and no comprehensive data necessary for the long term planning for elephant conservation exist. In this context, a survey of the elephant habitat, including mapping of present elephant distribution, land use patterns and identification of corridors within these habitats, assessing population size and structure of elephants, and documenting the extent of human-elephant conflict was carried out, in order to make comprehensive conservation recommendations. The present survey was carried out between January 2005 and June 2006 with the following objectives.

1.2. OBJECTIVES

1. To identify and map the habitat contiguity, vegetation types, and land use patterns in Project Elephant Range 9 and superimpose information on elephant habitat utilization on this to obtain insights into the use of corridors and critical habitats.
2. To determine population size of the elephant and assess its demographic health in the light of ivory poaching and other threats in the Range.
3. To categorize the levels of elephant - human conflict within the Range.
4. To provide training on population estimation methods to the Kerala Forest Department field staff, in order to build capacity for future monitoring of the population and management of the Elephant Range.
5. To prepare a comprehensive report of this study in a format that could be incorporated into elephant management plans.

1.3. STUDY AREA

The Western Ghats, one among the 25 global Biodiversity Hotspots (Myers *et al.* 2000), runs in a north - south direction over 1600 kilometers along the west coast of peninsular India (Fig. 1.1). Elephant Range 9 popularly known as Anamalai, Nelliyampathy and Palani Hill Ranges (Fig. 1.2) is situated in the southern Western Ghats (76.34° E and 10.44° N to 77.55° E and 10.34° N) to the south of the Palghat Gap, extending over an area of 5700 km^2. The landscape is known for its wide altitudinal gradient ranging from as low as 100m above MSL on either side of the Ghats to as high as 2694m at Anaimudi Peak, the highest elevation in southern India. The remarkable altitudinal gradient results in significant variation in the amount of precipitation across the landscape, with the western face and crest-line of the hills enjoying higher rainfall (mean annual rainfall up to 3500 mm), and the eastern sides in the rain shadow region receiving lower annual rainfall (mean rainfall about 800 mm) (Fig. 1.3).

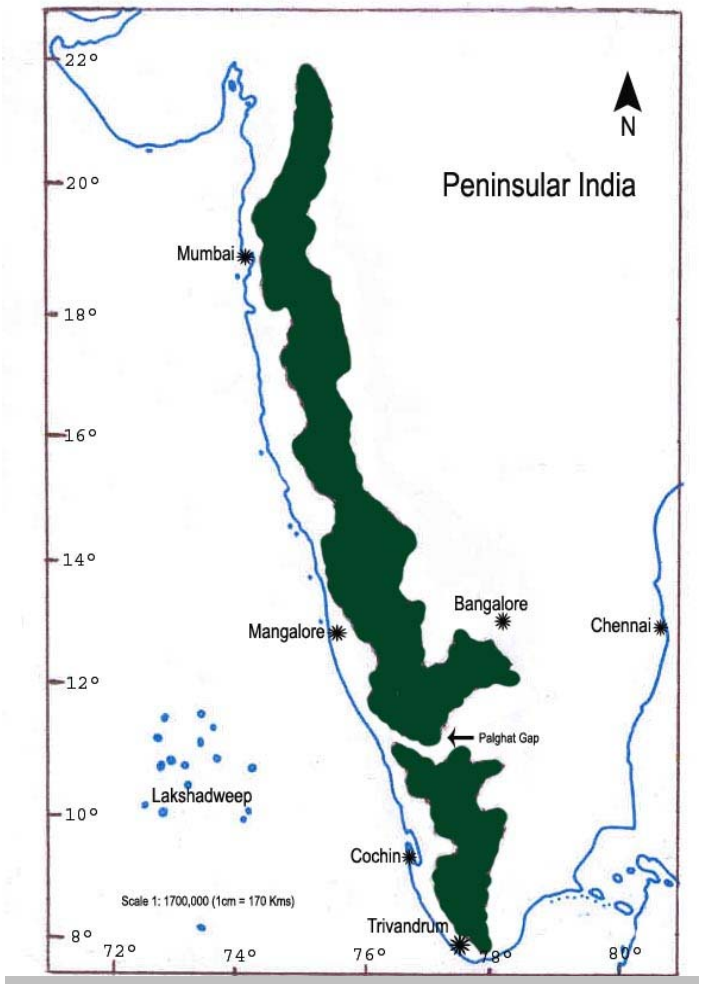


Figure 1.1. The Western Ghats in India

Figure 1.2. Map of Elephant Range 9 showing various forest divisions

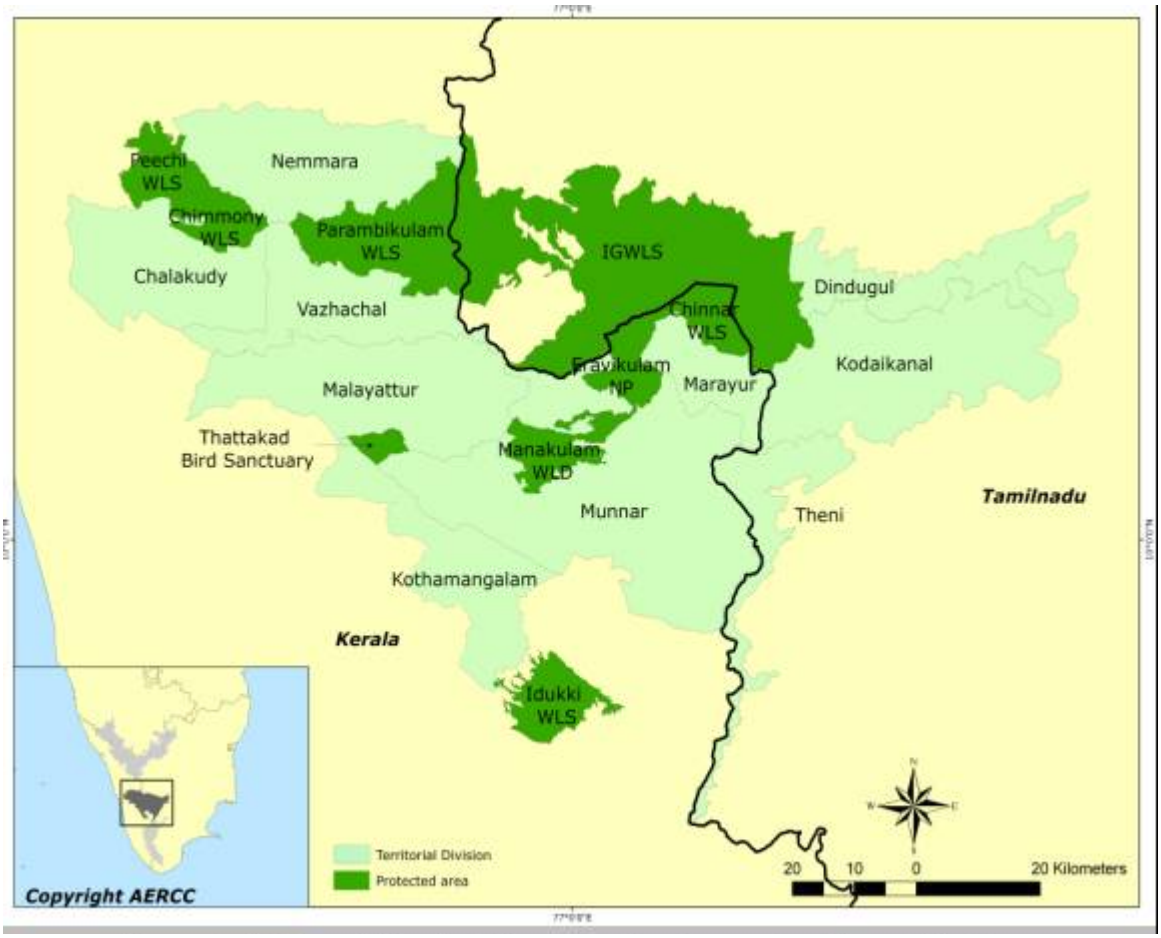
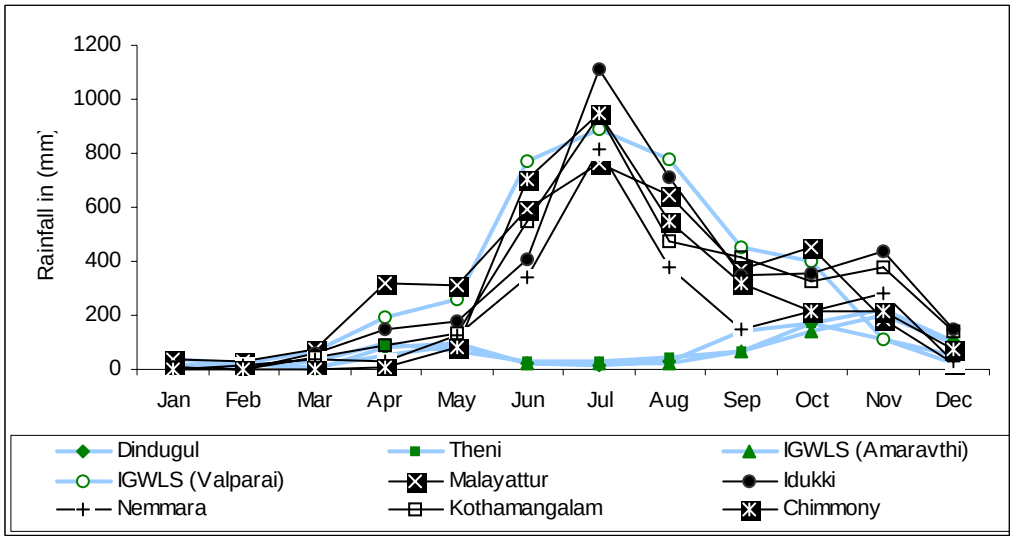


Figure 1.3. Mean annual rainfall in various Forest Divisions in the eastern and western sides of the Landscape

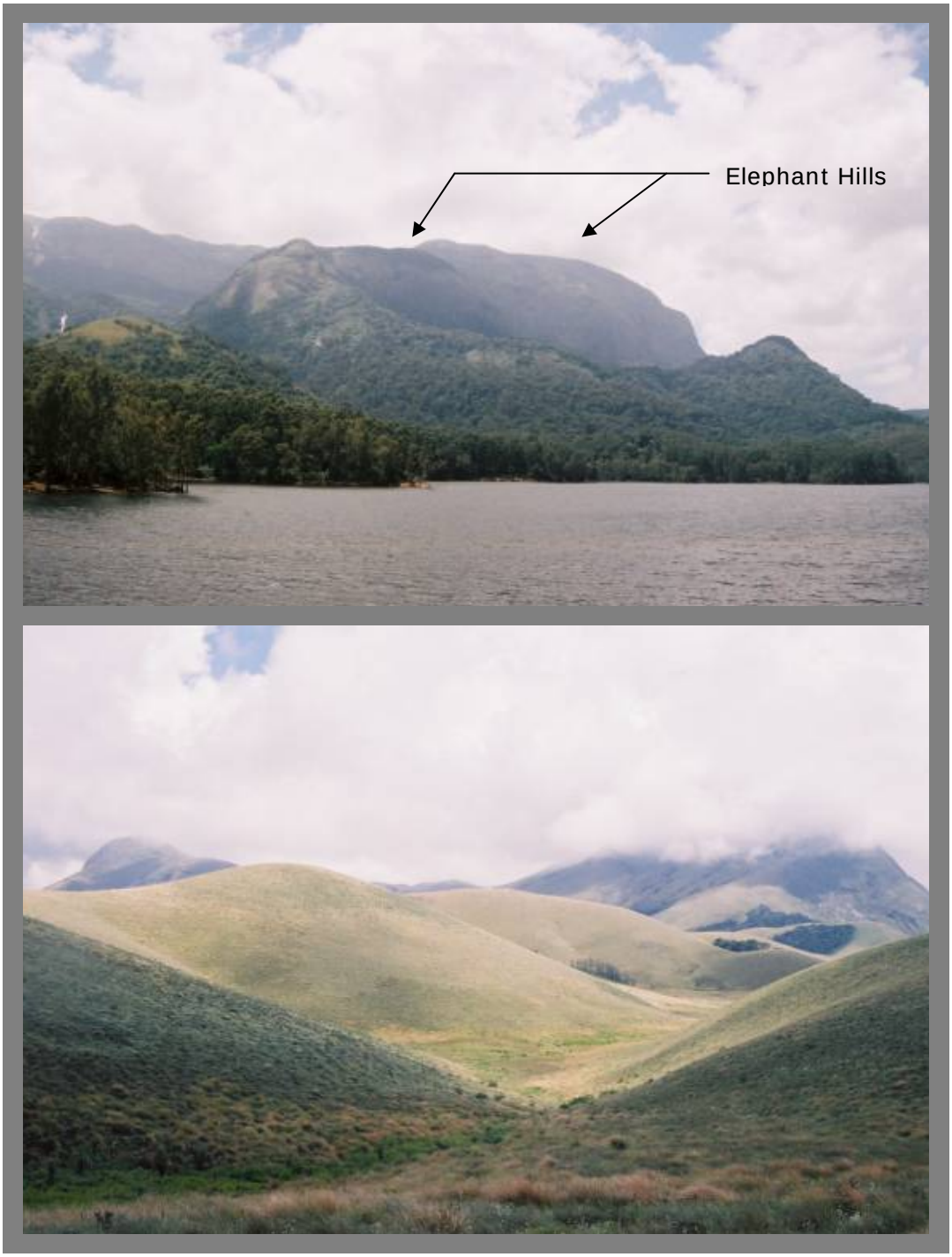


Thicker lines with blue (or lighter colour) indicate areas from the eastern side of the landscape with relatively lesser rainfall (except IGWLS Valparai), and thinner lines with black colour indicate areas from the western side of the landscape with higher rainfall.

The varied rainfall from east to west coupled with the complex topography results in heterogeneous vegetation types: from lowland tropical dry thorn forest mostly on the eastern sides, mid-elevation tropical dry and moist deciduous forests, high elevation tropical semi-evergreen and evergreen forests to high elevation stunted montane forests (locally known as *shola*) and grasslands (Subramanyam and Nayar 1974).

The landscape being heterogeneous, the vegetation supports diverse faunal communities, including several endemic and endangered fauna (Stonor 1946, Kannan 1998, Umapathy and Kumar 2000, Raman 2001). The notable endemic fauna include limbless amphibians (caecilians), burrowing snakes (uropeltids), and mammals such as lion-tailed macaque (*Macaca silenus*), Malabar civet (*Viverra megaspila*), Nilgiri tahr (*Hemitragus hylocrius*) and Nilgiri langur (*Semnopithecus johnii*) (Gadgil and Meher-Homji 2003). This landscape with an approximate population of 2000 elephants (Bist 2002) has been identified as one of the potential habitats for the long-term conservation of Asian elephants. The elephant population here is genetically more diverse and distinct from the much larger population to the north of the Palghat gap in southern India (Vidya *et al*. 2005).

Plate 1. A view of hills resembling elephant backs [top]. In Tamil *Anai* is elephant and *malai* is hill], the Sanctuary is named after these hills as Anaimalai. View of grass hills in the Anaimalai Sanctuary [bottom].



CHAPTER 2

THE ELEPHANT HABITATS IN ELEPHANT RANGE 9

2.1. INTRODUCTION

Habitat loss and fragmentation continues to be one of the major threats to the existence of Asian elephants across Asia (Santiapillai and Jackson 1990, Leimgruber *et al*. 2003, Hedges *et al*. 2005), resulting in conflicts between elephants and humans. The present scenario of increasing conflict and decreasing population size of elephants in many parts of its range has been due to the unplanned expansion of developmental activities in the forest areas in the past, resulting in extensive loss and fragmentation of elephant habitats. The future conservation of Asian elephants is expected to present even more difficult challenges. Thus there is a need to develop suitable conservation and management strategies for each isolated population, so as to protect this umbrella species along with the biodiversity its range harbours. As stated by Hedges (2006) baseline data on elephant populations, and their habitats, including corridors are, essential to plan strategies for effective management of this wide ranging species.

Elephant Range 9, has a variety of developmental activities such as commercial tea, coffee and cardamom plantations, and a large number of hydel projects and other forms of infrastructure development that impede the movement of elephants (Davidar 1987, Sukumar 1989, Easa 1990). As elephants are known to show high fidelity to home ranges and the seasonal corridors that they use traditionally (Baskaran *et al*. 1995), such developmental activities across the corridor areas have caused an increase in elephant-human conflict in some parts of their ranges (Kumar *et al*. 2004).

The Asian Elephant Research and Conservation Centre (AERCC) a division of Asian Nature Conservation Foundation (ANCF) maintains a database on elephant numbers and distribution, threat levels, vegetation types, land-use patterns and extent of forest boundaries of elephant-bearing forest divisions in southern India (www.asiannature.org). This includes spatial and textual data of the present study area. However, this database needed to be updated for two reasons. (1) The database was nearly 10 years old and there have been further developmental activities after the last documentation. (2) The old database was based on low-resolution

maps. A more detailed database with higher resolution data (1:50,000 scale) on spatial variation in elephant densities, habitat contiguity, major vegetation types and land use patterns, critically needed for management, is lacking.

Therefore, the present survey was undertaken with the following objectives:

1. To identify and map elephant habitats available under various forest divisions within the landscape in order to know the present status of the habitat, its contiguity and total area available to support the existing elephant population,
2. To identify and map elephant corridors and assess their status in order to develop and prioritize the management actions for protecting or strengthening such crucial corridors,
3. To evaluate vegetation types and land use patterns of Elephant Range 9 in order to understand the elephant density that each habitat supports, thereby identifying the critical habitats, and
4. Using all these attributes, developing a GIS database of the landscape for planning the effective management of elephant habitats.

Plate 2. Developmental activities like hydroelectric power project [top] and commercial tea plantation [bottom] within the Elephant Range 9

2. 2. METHODS

2. 2. 1. Mapping of elephant habitats and corridors

To identify and map elephant habitats and corridors, a systematic field survey of forest divisions in Elephant Range 9 was carried out across the landscape. During the survey, the layout of various administrative areas such as division and range boundaries for each forest division were traced on topographic maps in consultation with the concerned forest officials. Further, within each division the actual area used by elephants was identified by field surveys and also through interviews with the concerned forest officials and local people. Eventually, the identified elephant area was delineated on division maps to estimate the elephant distribution areas / habitats available within the landscape.

By noting the forest boundaries on maps and from field visits, the constrictions of forest areas or corridors were identified and marked on the topo sheet. An assessment of the corridor was carried out based on direct sightings, and indirect signs of elephants such as tracks, dung piles and feeding signs and also by enquiry with the local people in the adjoining areas. While assessing the corridors, information on the legal status and extent of the land where connectivity presently exists, was also collected for future reference in case the lands were to be acquired (in the case of private land) or upgraded to protected area status (if the link was through government land controlled by the Revenue Department).

Information on boundaries of forest divisions and ranges within each division, elephant distribution areas and the elephant corridors identified within the landscape were marked out on topo sheets and digitized using Geographical Information System Software (Arc view version – 3.3). Additionally, incorporating the major rivers, highways, railway lines and contour lines (as these are known to fragment the habitat contiguity), a detailed GIS database on elephant habitats for the Anamalai landscape was created.

Elevation contours were extracted from Shuttle Radar Topography Mission (SRTM) data taken in 2001 from the Global Land Cover Facility (GLCF) website. Global Mapper v 4.78 was used to generate elevation contours from SRTM data at intervals of 100m. Contours were then extracted as shape files to be used in ArcView. In ArcView, contours from all degree tiles were merged and sub-setted for the study area. Arc View extension 3D Analyst was used for all 3D analysis functions. Triangular Irregular Network (TIN) surface was created from

the contours. Slope of the terrain was then derived from this TIN surface. Finally the image mosaic was overlaid on the TIN surface to have a 3D view of the terrain topography.

2. 2. 2. Mapping of vegetation and land use patterns

Intensive surveys were carried out in all the forest divisions of the landscape to classify the land cover of Elephant Range 9. The landscape elements (LSE) were identified using differences in canopy structure, phenological characteristics, land use pattern and degree of disturbance in the landscape. The earlier classification by the French Institute (Pascal *et al*. 1982) was used as a guideline for this exercise. The ground truthing for various landscape elements in the natural forest areas was carried out using 20 x 20 m plot (Ground Truthing Plot - GTP); for the non-forest areas and forest plantations, this was done without laying any plot for a given point (Ground Truthing Point - GTP) at multiple locations. For all the ground-truthing plots and points, variables such as (1) latitude and longitude details (using Global Positioning System - GPS) (2) type of landscape element (3) biotic pressure, were recorded. Based on this survey, the following landscape elements were differentiated: (1) Grassland (2) Evergreen forest (3) Semi-evergreen forest (4) Moist deciduous forest (5) Dry deciduous forest (6) Dry thorn forest (7) Forest plantations of (a) Teak (*Tectona grandis*) (b) Eucalyptus (*Eucalyptus* spp.) (c) Wattle (*Acacia spp*) (8) Non Forest plantations of (a) Tea (*Camellia sinensis*) (b) Coffee (*Coffea arabica*) (c) Cardamom (*Elettaria cardamomum*) (d) Rubber (*Ficus elastica*) (9) Water bodies, and (10) Cultivation/Settlements.

Satellite Imagery

Indian Remote Sensing (IRS) satellite (IRS - P6, sensor: LISS III) images (spatial resolution 23.5 obtained in Jan-Feb, 2004), with following details were used for mapping land use and land cover.

Scene 1 = Path: 99	Row: 66	Date of Pass: February 14, 2004
Scene 2 = Path: 100	Row: 66	Date of Pass: February 19, 2004
Scene 3 = Path: 100	Row: 67	Date of Pass: February 19, 2004

Image-to-image geo-registration was performed using ground control points (GCPs) obtained from topographic sheets. GCPs were collected in such a way that points were spread uniformly over the entire scene. Points such as the intersection of roads and railway lines were identified on the topographic sheets as GCPs. Geographic Lat/Long with datum and

spheroid as WGS 84 was used for the projection type. The process was re-sampled with nearest neighborhood algorithm. The geo-registered images were then sub-setted covering Elephant Range 9 and its surrounding areas from the scene using standard techniques in ERDAS Imagine 8.3.1.

Supervised classification was done on the mosaiced image. A total of 102 training sites were generated for landscape element types shown in Table 2.1 using information of 204 Ground Truthing Plots and 517 Ground Truthing Points (GTPs) collected from the study area. Finally, the pixels were re-sampled using the Maximum Likelihood algorithm. From the spectral information obtained from each of these signature files using supervised classification, different LSE types were delineated for each forest division and similar LSE types belonging to various forest divisions were pooled together to obtain the LSEs for the landscape.

Table 2.1. Details of landscape element types used for vegetation and land use classification

Forest cover elements		**Non forest cover elements**	
Natural vegetation	**Forest plantation**	**Non-forest plantation**	**Others**
Grassland	Teak (*Tectona grandis*)	Tea (*Camellia sinensis*)	Cultivation / settlements
Evergreen forest	Eucalyptus (*Eucalyptus* spp.)	Coffee (*Coffea arabica*)	Water bodies
Moist deciduous forest	Wattle (*Acacia* spp.)	Cardamom (*Elettaria cardamomum*)	-
Dry deciduous forest	-	Rubber (*Ficus elastica*)	-
Dry thorn forest	-	Cashew (*Anarcardium occidentale)*	-
-	-	Others	-

2.3 RESULTS AND DISCUSSION

2.3.1. Status of elephant habitats in the landscape

Elephant Range 9 located in southern Western Ghats comprises 19 forest divisions spread over 5657 km^2 (Table 2.2). However, only 4421 km^2 area falls within the elephant distribution range while the remaining area is not used by elephants due to various reasons. The 4421 km^2 area is broken up into different fragments, with the majority (~70%) of the area within a single patch and the rest of the area isolated with a maximum distance of <10km from the other forest patch.

Table 2.2. Total forest area and elephant habitat available under various Forest Divisions in Elephant Range 9

Division	Extent of Area (km^2)	
	Total	**Elephant habitat**
Chinnar WLS	94.7	92.9
Dindugul	182.9	172.9
Eravikulam NP	119.8	119.7
IGWLS	958.3	790.1
Kodaikanal	82.3	82.3
Marayur	193.8	159.2
Munnar	1206.5	667.9
Theni[$]	279.2	235.6
Landscape Eastern side	***3117.6***	***2320.6***
Chalakudy	229.9	164.5
Chimmony WLS	95.2	95.2
Idukki WLS	128.0	125.4
Kothamangalam	165.9	33.2
Malayattur	637.4	600.6
Manakulam Wild Life Div	91.3	85.9
Nemmara	373.2	217.1
Parambikulam	288.2	283.9
Peechi WLS	106.6	103.9
Thattakad Bird Sanctuary	29.7	24.6
Vazhachal	393.8	366.2
Landscape Western side	***2539.3***	***2100.5***
Entire Landscape	**5656.9**	**4421.1**

[$] Part of Theni forest Division falls with Elephant Range 9

Although the elephant habitat is fragmented into many forest patches, only about 5% of the elephant population (found in the Idukki Wildlife Sanctuary and parts of Kothamangalam Forest Division adjoining the Idukki WLS) is isolated from the main landscape (Fig. 2.1). The

settlements coupled with the steep terrain in between the southern part of Munnar Division (Neriyamangalam Range) and the northern part of the Kothamangalam Forest Division (Thodupuzha Range) act as barriers to elephant movement although forest contiguity exists between these two areas. Due to greater fragmentation in the Munnar Forest Division, its contiguity to Theni Forest Division is presently cut-off by the non-forest plantations of tea and cardamom. However, elephants still move through these areas. The eastern part of the landscape has relatively more fragmented forest patches compared to the western part of the landscape.

2.3.1a. Legal status of elephant habitats in the landscape

The 4421 km^2 of elephant habitat under various Forest Divisions legally falls under two major categories: (1) Protected Areas (PAs) and (2) Reserved Forests (Territorial Divisions), which belong to the Forest Department (Table 2.3). National Parks (exclusively conservation oriented) and Wildlife Sanctuaries (also conservation oriented but permitting some level of human-activity such as cattle grazing) come under the Protected Area network of Wildlife Division. Reserved Forest areas come under the Territorial Division of Forest department are meant for both conservation and human use like cattle grazing, fire wood and non-timber forest-produce collection. Reserved Forest areas are sometimes diverted for developmental activities like formation of new roads, railway lines, hydel power projects, etc.

Nearly two-thirds of the elephant habitat in the landscape is under Reserved Forest (65%) status, while the rest (35%) is protected under the PA network (Table 2.3) of which, National Parks contribute 5% and Wildlife Sanctuaries 30%. The eastern part of the landscape has a relatively higher area of PAs (66%) compared to the western part (34%).

Figure 2.1. Map showing various non-forest elements within the elephant habitats of Elephant Range 9

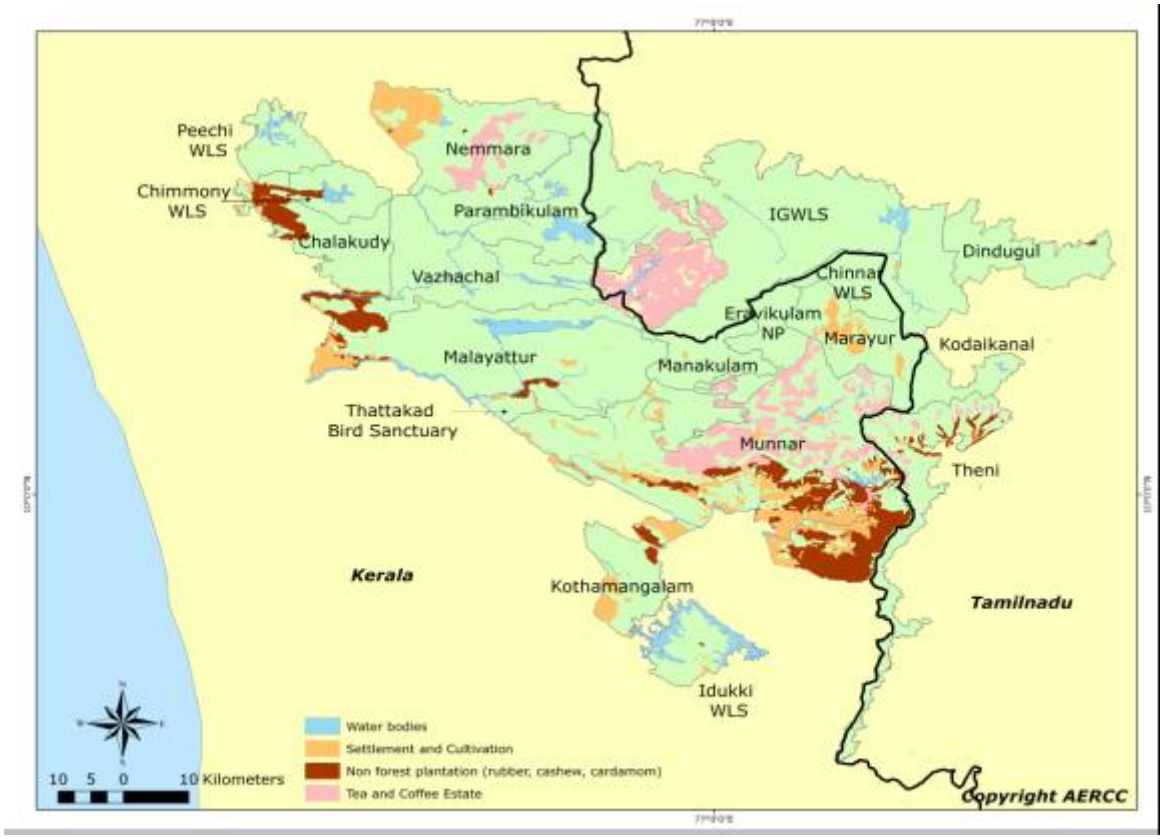


Table 2.3. Legal status of elephant habitat under various Forest Divisions within the elephant Range 9

Division	Protected Area (km^2)		Territorial Area (km^2)	Total Area (km^2)
	National Park	Wildlife Sanctuary	Reserved Forest	
Chinnar WLS	-	92.9	-	92.9
Dindugul	-	-	172.9	172.9
Eravikulam NP	119.7	-	-	119.7
IGWLS	108	682.1	-	790.1
Kodaikanal	-	-	82.3	82.3
Marayur	-	-	159.2	159.2
Munnar	-	-	667.9	667.9
Theni	-	-	235.6	235.6
Eastern Region	***227.7***	***775.0***	***1317.9***	***2320.6***
Chalakudy	-	-	164.5	164.5
Chimmony WLS	-	95.2	-	95.2
Idukki WLS	-	125.4	-	125.4
Kothamangalam	-	-	33.2	33.2
Malayattur	-	-	600.6	600.6
Manakulam Wild Life Div	-	-	85.9	85.9
Nemmara	-	-	217.1	217.1
Parambikulam	-	283.9	-	283.9
Peechi WLS	-	103.9	-	103.9
Thattakad Bird Sanctuary	-	24.6	-	24.6
Vazhachal	-	-	366.2	366.2
Western Region	***0***	***633***	***1467.5***	***2100.5***
Landscape	**119.7**	**1408**	**2785.4**	**4421.1**

2.3.1b. Non-forest lands in the elephant habitats of the landscape

Non-forest lands comprising human settlements and cultivated lands found inside the elephant habitat were identified and mapped, as the corresponding activities are known to increase elephant-human conflict. In total, 129 (major) human settlements / cultivated lands covering about 403 km^2 were located within the elephant habitats under various forest divisions (Table 2.4). Similarly 168 (major) non-forest plantations of tea, coffee, cardamom and rubber occupying nearly 700 km^2 of area have also been identified within the elephant habitats of the landscape. The forest divisions on the eastern part of the landscape, with 61% of the total settlements / cultivated lands and 88% of the total area of non-forest plantations are highly prone to elephant-human conflict as compared to forest divisions on the western part of the landscape.

Further, the eastern side of the landscape also has a large number of forest fragments compared to the western side, which possibly results in more conflict in the former region.

Table 2.4. Details of non-forest land use attributes in different Forest Divisions of Elephant Range 9

Division	Settlements / Cultivation		Non-forest plantations*	
	Numbers	Area (km^2)	Numbers	Area (km^2)
Chinnar WLS	5	1.7	0	0
Dindugul	0	0.9	1	9.09
Eravikulam	0	0.0	0	0
IGWLS	2	1.6	2	166.5
Kodaikanal	0	0.0	7	16.7
Theni	3	3.2	35	40.2
Marayur	9	34.6	0	3.5
Munnar	60	159.5	73	379
Landscape Eastern side	***79***	***201.5***	***118***	***615***
Chalakudy	9	17.6	3	47.7
Malayattur	9	12.0	14	24.6
Nemmara	1	76.7	21	79.4
Parambikulam	1	0.003	3	4.2
Vazhachal	3	2.4	4	25.0
Peechi & Chimmony	4	0.5	0	2.0
Thattakad BS	3	2.7	1	2.3
Mankulam	7	5.3	1	0.07
Idukki WLS	5	2.3	1	0.3
Kothamangalam	8	82.1	2	50.5
Landscape Western side	***50***	***201.6***	***50***	***236.0***
Landscape	**129**	**403.1**	**168**	**851**

* Includes plantations of tea, coffee, rubber and cardamom

A divisionwise estimate on non-forest attributes reveals that forest divisions such as Munnar followed by IGWLS and Marayur on the eastern side of the landscape, and Nemmara, Malayattur, Chalakudy and Kothamangalam on the western side, have greater levels of non-forest activities within them (Table 2.4)

2.3.2. Elephant corridors in Elephant Range 9

2.3.2.1 Status of elephant corridors

The forest cover of the landscape Elephant Range 9 is linked by five corridors at present. These are: (1) Monkey falls – Navamalai (2) Attakatti – Upper Aliyar (3) Aiyarpadi – Waterfalls (4) Siluvaimedu – Kadamparai, and (5) Mattupatti – Mathikettan *Shola* (Fig. 2.2. & Table 2.5). Additionally there is a corridor between Elephant Range 9 and 10. Of the six corridors, four lie within IGWLS and one each in Munnar and Theni Forest Divisions.

Figure 2.2. Map showing the corridors in Elephant Range 9

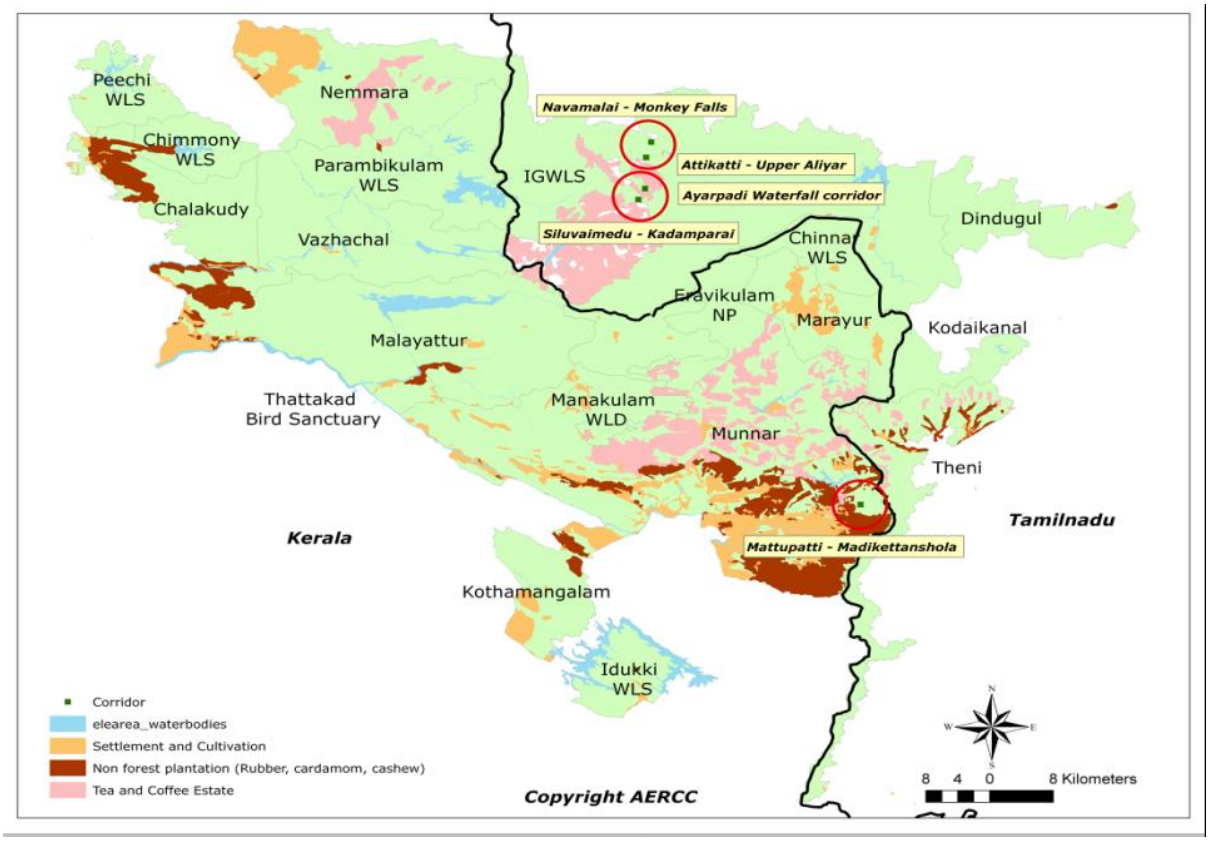


Table 2.5. Details of Corridors identified in Project Elephant Range 9

S. No.	Division	Name of the corridor	Status	Connecting habitats	Threats
1	IGWLS	Monkey falls-Navamalai	RF	Between Anamalai RF and Punachi RF. Connecting the IGWLS western part with eastern part	Tourism
2	IGWLS	Attakatti-Upper Aliyar	RF	Between Anamalai RF and Punachi RF. Connecting the IGWLS western part with eastern part	Roads
3	IGWLS	Ayerpadi-Waterfalls	RF& PL	Between Anamalai RF and Amaravathi RF. Connecting the IGWLS western part with eastern part	Roads & Tea estates
4	IGWLS	Siluvaimedu-Kadamparai	RF& PL	Between Anamalai RF and Amaravathi RF connecting the IGWLS western part with eastern part	Roads & Tea estates
5	Munnar – Theni Forest Div.	Mattupatti - Mathikettan Shola	RF& PL	Between Cardamom Hill RF, Mathikettan shola RF and Kamban valley west RF. Connecting Munnar and Theni Divisions via private lands	Roads & Human habitation

* IGWLS = Indira Gandhi Wildlife Sanctuary, RF = Reserved Forest, RL = Reserved Land and PL = Private Land

2.3.2.2. Corridors in IGWLS

Elephants move between the western part of IGWLS (Ullandy, Pollachi and Manampalli Ranges – the Anaimalai Reserve Forest and further west from Thunakadavu and Nelliyampathy Reserve Forests) and the eastern part of the IGWLS (the Udumalapet and Amaravathy Ranges – the Punnachi Reserve Forest) through the Valparai plateau that acts as a corridor. The extensive developmental activities such as cultivation of non-forest plantations mainly tea, settlements across the Valparai plateau along a north-south axis along with the topographical features, and the hydro-electric project's contour canal have split the once vast contiguous habitat into four different bottleneck corridors (Fig. 2.3.) between the eastern and the western parts of IGWLS and beyond. The vehicular traffic on the Pollachi-Valparai highway also affects the free movement of elephants through these corridors. Some of the existing bottleneck corridor areas being inaccessible terrain, elephants use the adjoining tea estates instead of the forested corridor areas. More detailed descriptions of individual corridors are given below.

2.3.2.2a. Monkey falls – Navamalai corridor

This corridor is located in the northeastern part of Pollachi Range in IGWLS connecting the Anamalai Reserved Forest with Punachi Reserved Forest through a narrow strip of forest. Aliyar reservoir and the private lands in the northern side, and the contour canal in the southern side coupled with steep escarpments create a bottleneck between the two RFs mentioned above. Water availability in the reservoir coupled with flat terrain invites frequent elephant movement in the corridor. The Pollachi-Valparai highway cuts through the corridor. The major threats to this corridor include the large tourist influx into Monkey Falls and vehicular traffic on the highway.

2.3.2.2b. Attakatti – Upper Aliyar corridor

Attakatti- Upper Aliyar corridor is one of the crucial elephant corridors in IGWLS. This corridor connects Punachi Reserved Forest and Anamalai Reserved Forest through a narrow strip of forest that is a teak plantation. Elephants use this corridor frequently. Steep escarpments and the contour canal on the northern side, and a tea estate (northern side of Waterfalls Tea Estate) on the southern side form this corridor. The Pollachi-Valparai highway cuts through this corridor as well. Major conservation problems in this corridor include the rapid development of Attakatti settlement and highway traffic.

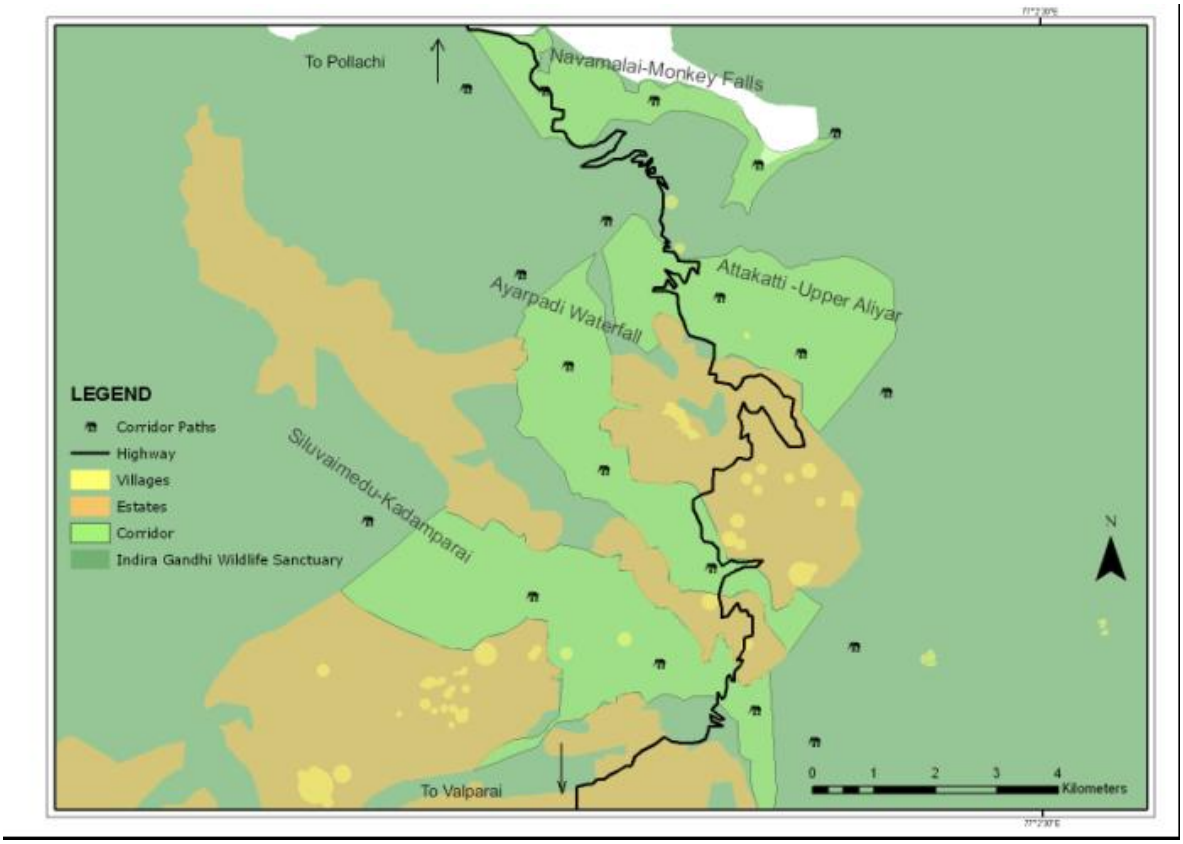
2.3.2.2c. Aiyarpadi – Waterfalls corridor

This corridor connects Anamalai and Tunakadu Reserved Forest with Amaravathi Reserved Forest through a narrow forest patch. On either side of the corridor are private tea estates (Waterfalls Estate to the northern side and Mount Stuart Estate to the southern side). The narrow forest patch connecting the two Reserved Forests is steep with a mean elevation of 1500 meters making it unsuitable for elephant movement. Hence, elephants use the more gently undulating lands of the tea estates. Use of this corridor is very seasonal (eastward movements during the wet season and westward movements during the dry season). The Pollachi-Valparai highway cuts through the corridor. Major threats are highway traffic and disturbances from tea estates. High elephant-human conflict exists in the tea estate settlements of this corridor.

2.3.2.2d. Siluvaimedu – Kadamparai corridor

Elephants use this corridor occasionally. This corridor connects Tunakadavu and Anamalai Reserved Forests with Amaravathi Reserved Forest through a narrow forest patch. On either side of the corridor are private tea estates (Mount Stuart Estate in the northern side and Aiyarpadi Estate in the southern side). The narrow forest patch connecting the two Reserved Forests is steep with a mean elevation of 1000 meters, which is not suitable for the free movement of elephants. Therefore elephants use the more gently undulating lands of tea estates. Major threats to this corridor are highway traffic and disturbances from the tea estates. Conflict between elephants and humans is high especially in the tea estate settlements of this corridor.

Figure 2.3. Map showing corridors within the IGWLS



2.3.2.2e. Mattupatti – Mathikettan Shola corridor

This corridor is already broken, but elephants still travel from Cardamom Hill Reserve Forest of Munnar Forest Division (Kerala) to Kambam Valley West Reserve Forest of Theni Forest Division (Tamil Nadu) through private cardamom estates (Fig. 2.4). Elephants from Munnar Forest Division during their seasonal movement use Mattupatti elephant corridor to reach Anaiyarangal reservoir through Pachakadu and Silent valley tea estates. From Anaiyarangal reservoir through cardamom estates they cross (Pupara - Bodimettu road) at Thondimala entering into Mathikettan shola RF. From here they move into K.R. Vijaya cardamom estates and Kudampara estates using the Tamil Nadu - Kerala interstate boundary as a corridor. Major threats include vehicular movement and private lands in the corridor.

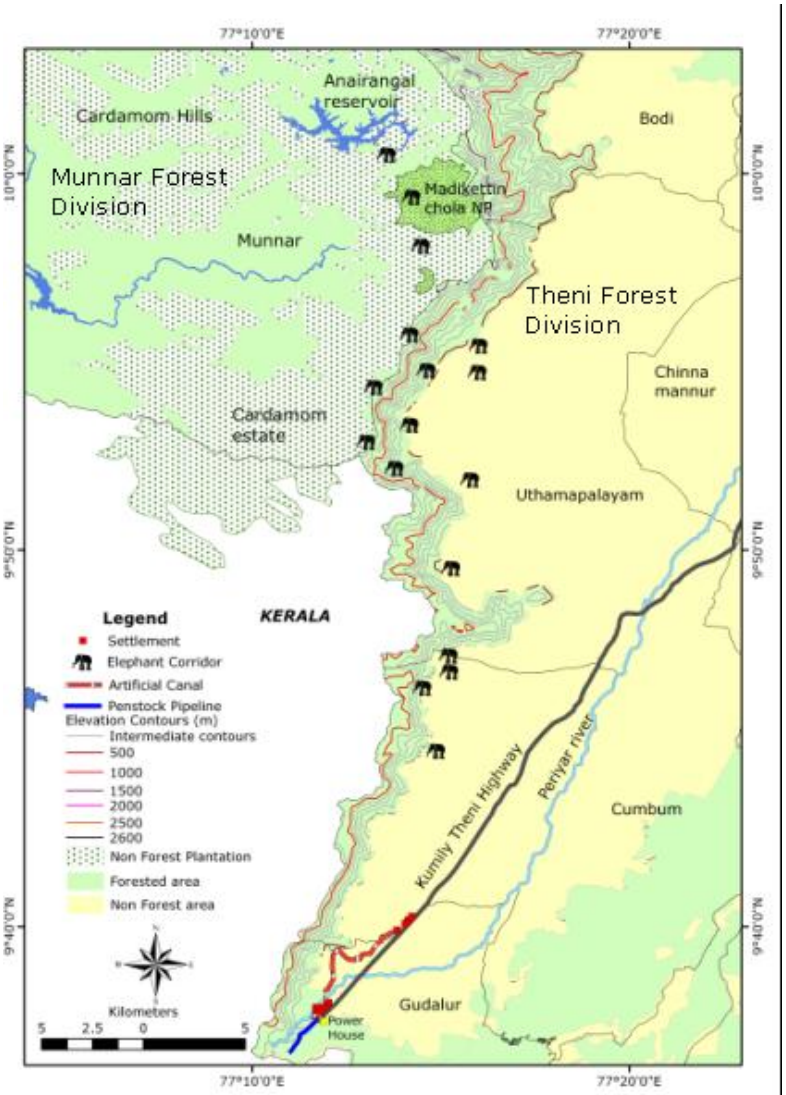


Figure. 2.4. Map showing corridor between Munnar and Theni Forest Divisions in Elephant Range 9

2.3.2.3. Corridor and habitat contiguity between Elephant Ranges 9 & 10

The Theni-Kumily interstate highway cutting across the Theni Forest Division bifurcates it into two patches. The patch to the western side of the highway comes under Elephant Range 9 while that on the eastern side is part of Elephant Range 10. Theni western part (which is part of Elephant Range 9) is physically connected with Theni eastern part (which is part of Elephant Range 10) by forest cover. However, elephant movements have been reported from

the eastern part of Theni division - Vannathiparai Reserved Forest of Gudalur Range and further from Periyar Tiger Reserve, to the western part of Theni division – the Suranganar Reserved Forest of Gudalur Range, only until the construction of the Periyar Hydro-electric Dam (Theni Management Plan 1972). Elephant movements between the two Reserved Forests (Suranganar and Vannathiparai) have been cut-off by the penstock pipes of the Periyar Hydro-electric Project since 1959. Our population survey (during 2005) also showed no evidence of elephants using the Suranganar Reserved Forest. Therefore, elephants do not move from Theni eastern part (*i.e.* Elephant Range 10) to Theni western part (*i.e.* Elephant Range 9).

2.3.3. Vegetation and land use pattern in the landscape

In total, the landscape has about 5690 km^2 of land area within the elephant distribution area (Table 2.6). Out of this, 81% (4598 km^2) is effective forest cover area and the rest 19% consist of non-forest area predominantly occupied by plantations of tea, coffee, cardamom, and rubber. Although the major part of the effective forest cover area consists of natural forest (87% - 4004 km^2), a substantial part is under monoculture forest plantations (13% - 594 km^2) of teak, eucalyptus, wattle and pine (Fig. 2.5).

The elephant population in this landscape has access to a wide variety of forest types ranging from tropical climax grassland habitats at high altitudes to tropical evergreen and semi evergreen forests at high altitudes, tropical moist and dry deciduous forests at mid-elevations and tropical dry thorn forest in the lower, eastern part of the landscape. The western part of the landscape is more moist compared to the eastern part due to topographic features favouring higher rainfall from the southwest monsoon. Therefore, the western side is mostly occupied by evergreen and moist deciduous habitats, while the lower elevation in the eastern side is dominated by tropical dry thorn forests. Further, the bulk of the non-forest area of the landscape that is occupied by plantations of tea and cardamom (that are perennial in nature, with some canopy cover) are still being used by elephants for moving between forest patches, with negligible damage to these crops.

Table 2.6. Details of various landscape elements identified and their extent within the elephant habitats in Elephant Range 9

S. No	Division	Forest type (km^2)						Non -Forest (km^2)			Total
		GL	EGF	MDF	DDF	DTF	FPL	NFPL	W	Cu/Se	
1	Chalakudy	20.5	23.3	97.2	9.1	0.0	23.0	53.6	0.3	5.1	232.1
2	Chimmony	2.9	22.8	49.7	4.0	5.7	4.4	1.7	4.8	0.0	96.0
3	Chinnar WLS	8.4	11.7	12.0	23.5	35.5	0.8	0.0	0.0	1.8	93.8
4	Dindugul	19.0	19.2	38.5	63.5	40.1	1.8	0.8	0.0	0.7	183.6
5	Eravikulam	71.1	31.9	11.1	6.2	0.0	0.2	0.0	0.0	0.0	120.4
6	Idukki WLS	28.8	10.1	36.9	15.4	0.0	5.6	0.3	30.0	2.4	129.4
7	IGWLS	73.0	124.0	106.3	359.7	201.9	87.2	0.0	2.6	5.6	960.3
8	Kodaikanal	32.3	5.5	1.9	0.1	2.0	42.3	0.0	0.2	0.0	84.3
9	Kothamangalam	9.8	30.2	52.0	13.6	0.0	17.7	10.2	0.4	33.3	167.1
10	Malayattur	26.5	93.0	344.9	28.0	0.0	68.6	24.2	25.2	29.5	639.9
11	Mankulam	3.6	38.7	28.0	8.5	6.0	1.8	0.0	0.0	5.4	92.0
12	Marayur	20.7	58.6	23.5	18.8	27.4	9.5	0.0	0.0	34.7	193.4
13	Munnar	63.3	139.9	210.9	63.2	71.8	76.5	405.7	4.2	181.9	1217.4
14	Nenmara	11.1	46.2	102.8	66.9	0.0	28.9	49.8	4.4	66.2	376.3
15	Parambikulam	0.0	77.0	47.7	18.2	0.0	130.9	4.8	12.5	0.3	291.3
16	Peechi	3.0	89.9	2.5	9.7	0.0	0.0	0.0	2.4	0.6	108.1
17	Thattekad BS	3.8	4.3	4.8	2.1	0.0	8.9	2.5	1.3	2.8	30.5
18	Theni	21.2	34.0	24.2	49.8	94.7	10.9	35.0	0.0	9.2	279.0
19	Vazhachal	10.7	231.2	21.5	21.2	0.0	75.1	25.0	8.1	2.6	395.5
	Landscape	**429.7**	**1091.6**	**1216.5**	**781.5**	**485.0**	**594.0**	**613.6**	**96.4**	**382.0**	**5690.3**

GL - Grassland EGF - Evergreen and semi-evergreen
MDF - Moist deciduous forest DDF - Dry deciduous forest
DTF – Dry thorn forest FPL - Forest plantation (Teak, Eucalyptus, Wattle & Pine)
W – Water Bodies NFPL - Non-forest plantations (Tea, Cardamom, Coffee & Rubber)
Cu/Se – Cultivation & Human Settlements

2.3.3a. Vegetation and land use patterns of forest divisions

Two among the 19 forest divisions found in the landscape, support a major part (~50%) of the elephant population. These are (1) IGWLS, with topographically contiguous habitats on the western side (Parambikulam WLS) and eastern side (Dindugul and Chinnar forest divisions), and (2) Malayattur Forest Division with a relatively larger area and with predominantly secondary forest habitats such as tropical dry thorn, tropical moist and dry deciduous habitats (Table 2.6). IGWLS, Eravikulam, Idukki and Munnar with considerable area of grassland habitat, support a medium to high density of elephants especially during the first wet season (south-west monsoon – June to August).

Figure 2.5. Vegetation and land use patterns within the elephant habitats of Elephant Range 9

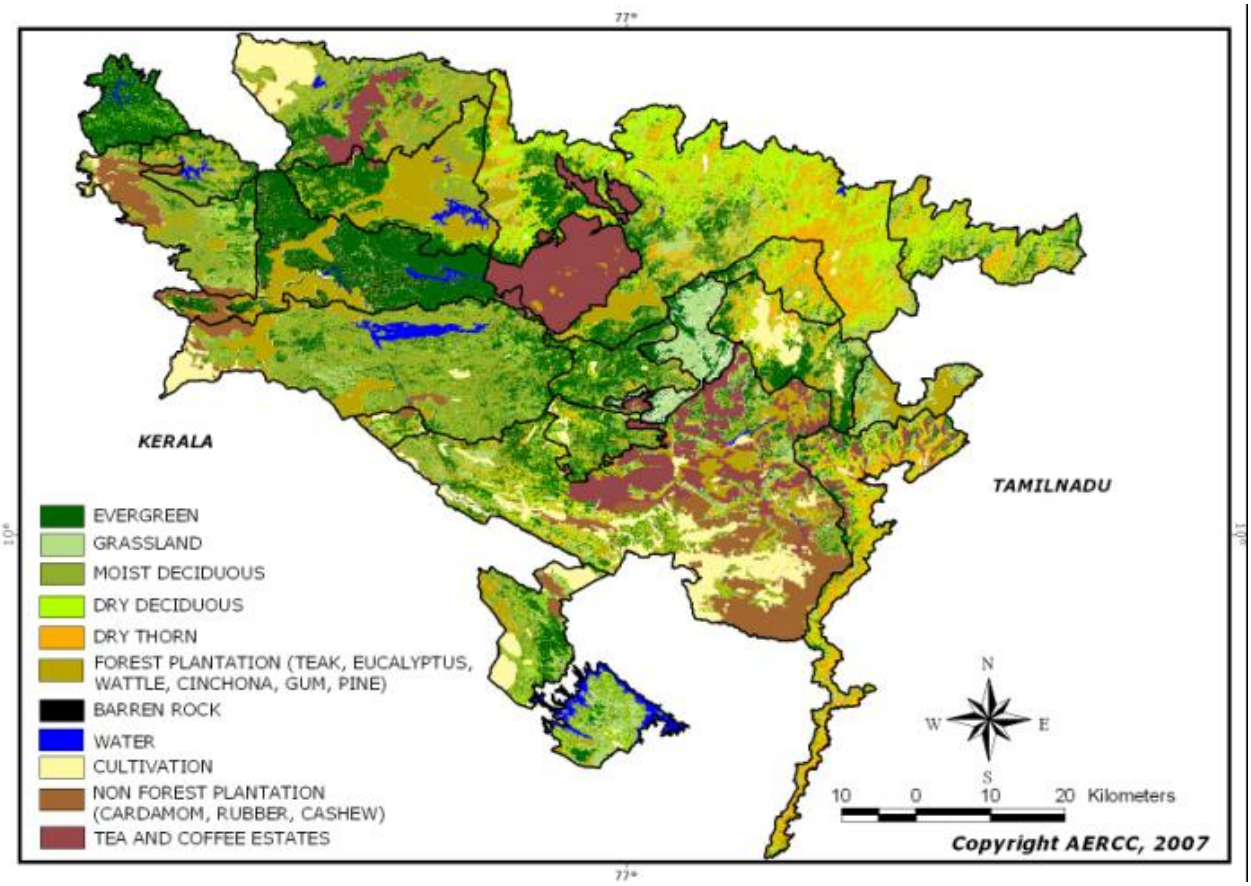


Plate 3. Types of natural vegetation and teak (*Tectona grandis*) plantation present in the Elephant Range 9

In the tropical region, resource quality and quantity changes significantly within a season between habitats. Therefore, availability of more diverse habitats within the population range could provide sufficient resources round the year than what a single habitat or less diverse habitats could. This is vital for wide ranging species like elephants that are known to move seasonally between habitats due to their large nutritional requirements (Sukumar 1985 and Baskaran 1998). The presence of diverse habitat types ranging from climax shola-grassland to evergreen, deciduous and dry thorn forests in the landscape could fulfill different types of resource requirements for elephants in different seasons.

A considerable area (>400km^2) under grassland habitat is an added advantage for the elephant population in the landscape as elephants have seasonal preference for grass, which constitutes >70% of the wet season diet of elephants in southern India (Sukumar 1989, Sivaganesan and Johnsingh 1995, Baskaran 1998). Therefore the presence of grassland habitats can provide suitable food resources to elephants during the wet season.

Similarly, the closed canopy habitats such as moist deciduous and evergreen forests are important in terms of shade and browse requirements, and play an important role in the dry season distribution of elephants (Sivaganesan and Johnsingh 1995, Sukumar *et al*. 2003).

The Munnar forest division with large area under non-forest activities especially plantations of tea and cardamom, has not only fragmented the contiguity of forest areas in the division but also the contiguity with the Theni forest division. However, elephants are still moving between the Theni and Munnar forest divisions through some of these tea and cardamom estates. Thus, some of these estates need to be reverted back to forests (in case of government lands leased out to private agencies for commercial purposes) or acquired (in case of private lands), in order to maintain forest contiguity and to reduce elephant-human conflicts.

CHAPTER 3

THE ELEPHANT POPULATION IN ELEPHANT RANGE 9

3.1. INTRODUCTION

A reliable estimate of population size and assessment of the population structure as related to demography are important for planning the long-term conservation of a species (Sukumar 1989, Baskaran and Desai 2000, Hedges 2006). The elephant population in Elephant Range 9 has been estimated using various methods in the past by the State Forest Departments. The total count method was used extensively from late 1970s until late 1980s mostly in the protected areas of Wildlife Sanctuaries and National Parks. But poor visibility due to dense vegetation coupled with the hilly terrain of the landscape makes the total count an inappropriate method. Thus during the 1990s the Tamil Nadu Forest Department used the line transect (direct count) method that was also hampered by the lack of equipment and trained personnel needed to ensure accuracy of estimates. In 2002, the synchronized elephant census conducted throughout southern India by the State Forest Department in co-ordination with regional research institutions, used sample block count and line transect based dung count methods. Three years down the line in 2005 while this research project was ongoing, a similar synchronized census was conducted using the same methodology as in 2002. Although this exercise yielded a reliable density estimate for many divisions, due to different administrative jurisdictions (states of Tamil Nadu and Kerala) data were compiled using different software and analysis, thus leaving room for ambiguity and uncertainty. Further, results on population structure, collected during synchronized census, were not comparable with results obtained from the research projects, which could be due to the lack of experience among the field staff of the forest department in collecting such information. Thus the present study undertook population studies to obtain better insights into the structure and demography of this elephant population with the following objectives.

1. To estimate population density of elephants across the landscape,
2. To assess the population structure and evaluate its demographic status in the light of poaching and other threats in the landscape, and
3. To assess the spatial variation in the distribution pattern of elephants with reference to season and vegetation types.

3.2. METHODS

3.2.1. Elephant density estimation

The dense vegetation coupled with hilly terrain in the Anamalai landscape did not permit our small research team to use direct count methods. Therefore, the indirect–dung count method pioneered by Barnes & Jenson (1987) on African elephants and later used by several researchers in Asia (Dawson 1990, Varma *et al*. 1995) on Asian elephants was employed in the present study. This method estimates the density of dung piles in a given area using the line transect method and converts the dung density into elephant density using defecation and decay rates with the following formula.

E = (Y x r) / D

where, E = Density of elephants, Y = density of dung, r = daily rate of decomposition and D = the number of dung piles deposited per elephant per day.

The line transect method described by Burnham *et al*. (1980) was used to estimate the dung density. A total of 233 transects covering 367.4 km with varying lengths of 1 to 2 km were laid, covering all forest divisions and vegetation types in the landscape. All transects were traversed along a straight line placed across the altitude gradient or perennial water sources. Dung piles seen from the transect line at any distance were recorded and for each dung pile, the perpendicular distance from the transect line to the center of the dung pile was measured by using a measuring tape. During analysis the dung piles recorded as outliers that varied in the distance between seasons and habitats, were discarded. Total number of transects was higher during the dry season than during the wet season (described in detail in the results section of this chapter). The transects were surveyed twice: once between February and April (dry season enumeration) and another between October and December (wet season enumeration). The dung density was calculated from the line transect data using '*Distance Version Beta 5.0'* software for each forest division.

In order to estimate the rate of dung decomposition, very fresh dung piles were located by following fresh wild elephant tracks and marked by a peg on which date and sample number were indicated. In total, 36 and 34 fresh dung piles representing various habitats were marked and monitored between January and April, and September and December 2005, respectively.

Additionally, dung decay data collected by the Forest Department was also used in the present exercise.

As earlier studies have shown similar elephant defecation rates between Southern India (Watve 1992) and Northeastern India (Baskaran *et al*. 2004), the present study used a defecation rate estimated at Mudumalai Wildlife Sanctuary in southern India (Watve 1992 - defecation rate 16.33/day).

There are several statistical problems in estimating an unbiased variation on the mean elephant density through the basic formulation of the indirect count method (Ramakrishnan *et al*. 1991). There are also problems with assuming a "steady state assumption of dung" in different habitats as well as estimating the dung decay rate (Sukumar 1998). Our research group has been developing Monte Carlo simulation methods (Santosh and Sukumar, 1995) to overcome the problem of estimating variance in elephant density, the present study adopts this method. For estimating elephant density, incorporating the three variables (dung density, daily defecation rate, and daily dung decay rate), we used a Monte Carlo simulation method (*GAJAHA 1.1* Archana and Sukumar unpublished – download available at www.asiannature.org). This method has the advantage of being robust to variations from normality in the distributions of the three variables. We believe that it provides more realistic statistical confidence limits on the estimates of the mean elephant density.

3.2.2. Elephant population structure evaluation

Data on age-sex were collected whenever an elephant herd or bull was sighted during fieldwork. For every sighting, information such as date and place of sighting, group size and age-sex composition were recorded. Characteristic features of individual elephants (if any) were also recorded in order to differentiate individual herds and bulls.

Age estimation was done based on shoulder height described by Sukumar *et al*. (1988). All elephants that were sighted were classified into calf (<1 year old; 90-120 cm), juvenile (1-5 years old; 120-180), sub-adult (5-15 years; old 180-210 cm for female and 180-240 cm for male) and adult (>15 years old; above 210 cm for female and above 240 cm for male). Sex differentiation was not possible for elephants below 2 years and thus assumed equal, as

studies on captive elephants have shown the sex ratio to be equal at birth (Sukumar *et al*. 1997). A special effort was made to identify tuskless males (*makhnas*) based on characteristics such as trunk musculature, presence of penis sheath and the social context of the individual (sub-adults or adult solitary elephants without tusks were assumed to be *makhnas* and an effort was made to confirm this). This was only reliable in the case of adults and sub-adult age classes, as differentiating a *makhna* from a female at the juvenile stage is not always possible due to poor visibility.

3.2.2a. Types of classification

All elephant herds or solitary animals sighted were classified under three types *viz*.:

Type I: Sightings in which all the individuals in the herd were aged and sexed,

Type II: Sightings in which all the individuals in the herd were not classified but it was sure that there was an adult male or no adult male, and

Type III: Sightings in which all the individuals in the herd were not counted or aged and sexed.

Data from Type I sightings were used to derive the age and sex composition of the total population; Type I and Type II sightings were then used to derive the proportion of adult males in the population. Type III sightings were excluded from the analysis because their inclusion could cause bias in arriving at estimates for age-sex composition (typically, only larger animals would have been visible) even though these would have added to the overall sample size.

3.2.3. Seasonal distribution of elephants in various habitats

Seasonal variations in the distribution of elephants in relation to major habitats available within the landscape were studied both for dry and wet seasons, to understand which habitat is crucial to the elephants during a given season. The seasonal distribution pattern of elephants can be studied by estimating elephant abundance in different habitats using direct sighting method or using indirect evidence such as dung piles, feeding signs and tracks signs in places where the visibility is poor and population density is low. We used the indirect method *i.e*., relative abundance of dung piles in different habitats due to the poor visibility and low density of elephants in the study area, as a measure of habitat utilization. A systematic survey was carried out both during dry and wet seasons to estimate the relative abundance of dung piles in all the habitats.

Plate 4. Line transect being laid by ANCF researchers to carry out elephant dung based estimation of the population size of elephants in Elephant Range 9

3. 3. RESULTS AND DISCUSSION

3.3.1. Elephant population density

The exercise of population estimation was carried out in two seasons. For the dry season between February and April (2005 and 2006) and the second one for the wet season between October and December (2005) to estimate the seasonal density or distribution of elephants across the landscape.

3.3.1a. Dry season count

Before the dung count exercise, we started the dung decay rate experiment in January 2005 to know the age of dung piles, which appeared during the count. Due to the hilly nature and poor visibility of the landscape coupled with relatively low density of elephants across the landscape, we were able to mark and monitor only 36 dung piles during the dry season. However, during the same period the Tamil Nadu Forest Department also carried out the decay rate experiments for the synchronized elephant census that was conducted in May 2005. The decay rate data collected by the forest department was also included in our analysis in order to obtain a better dung decay rate representing diverse macro and microhabitats of the landscape. Thus in total, dry season dung decay rate was obtained from 1298 dung piles, which showed a daily decay rate of 0.01 with a small standard error of 0.000018. The analysis of decay rate was performed using the *Gajaha* software. As mentioned in the method section, in the present exercise we used the dung defecation rate of 16.33 dung piles / day with a standard error of 0.8 estimated by Watve (1992).

Table 3.1. Details of the elephant dung decay rate used in the present exercise

Season	Sample size	Dung decay rate (dung/day)			
		Mean	Standard Error	LCL	UCL
Dry (Jan – May 2005)	1298*	0.011	0.000018	0.0116	0.0136
Wet (Sep – Dec 2005)	34	0.015	0.000565	0.0142	0.1164

* Sample size includes data collected from synchronized elephant census by the Tamil Nadu Forest Department, LCL = Lower Confidence Interval and UCL = Upper Confidence Interval

The dry season dung count was carried out in two phases. The first phase was between February and April 2005 and the second phase during same period in 2006 so as to cover the entire landscape and obtain a sufficient sample size. Thus our effort for the dry season count was greater and, in total, we laid nearly 140 transects covering a distance about 275 km. Over

this distance, nearly 3600 dung piles were encountered during the dry season and thus the encounter rate of dung piles was 13.1 / km. The analysis was carried out either separately for each division or by pooling the data from adjoining divisions with similar elephant dung density so as to fulfill the minimum sample size requirement to analyze the data using the programme *Distance*. Using the three variables (1) mean dung density obtained from distance sampling analysis, (2) dung decay rate obtained by the present study, and (3) defecation rates obtained by Watve (1992), the Monte Carlo simulation was performed using *Gajaha* 1.1 to arrive at elephant density for each division. The total number of elephants for each division was estimated using mean elephant density and elephant habitat available in each division. From these, the total number of elephants and total elephant habitat available for the landscape was arrived at by pooling elephant numbers and elephant habitats from individual divisions. Finally, the total number of elephants calculated for the landscape was divided by the total area of elephant habitats available in the landscape to arrive at elephant density for the landscape (weighted average method) taking account of the fact that the sampling intensity was higher in high and medium density areas than in low density areas. The results of the dry season dung count showed a mean density of over 1 elephant / km^2 for the landscape (Table 3.2).

Table 3.2. Elephant density estimated using line transect dung count method for various Forest Divisions and landscape of Elephant Range 9

Forest Division	**Distance walked - km (*n**)**	**Dung Density**		**Elephant density (individuals) / km^2**		
		Density (km^2)	**Standard Error**	**Mean**	**LCL**	**UCL**
Dindugul	19 (310)	1660.4	131.64	1.1	0.9	1.3
Anamalai (IGWLS)	57.75 (1789)	2935.8	108.02	1.9	1.7	2.2
Theni and Kodaikanal	33.95 (92)	410.28	67.86	0.3	0.2	0.4
Chalakkudy	16 (109)	1382.2	202.15	0.9	0.6	1.2
Chimmony and Peechi	10 (31)	272.7	60.89	0.2	0.1	0.3
Chinnar and Eravikulam	18 (44)	378.49	65.34	0.3	0.2	0.4
Idukki	7.0 (73)	2021.6	337.61	1.4	0.9	1.9
Kothamangalam	8.0 (67)	1332.2	229.40	0.9	0.6	1.2
Malayattur	24.0 (286)	3144.1	283.79	2.1	1.7	2.6
Munnar	31.1 (216)	1269.5	114.96	0.9	0.7	1.1
Nemmara	8.75 (49)	1738.1	433.22	1.2	0.6	1.8
Parambikulam	18.0 (202)	1946	196.61	1.3	1.0	1.6
Vazhachal	22.98 (335)	2915.2	196.00	2.0	1.7	2.3
Landscape	**274.53 (3603)**	**1646.7**	**-**	**1.11**	**0.84**	**1.40**

n* Sample size obtained, **LCL** = Lower Confidence Interval and **UCL** = Upper Confidence Interval

3.3.1b. Wet season count

During the wet season, a total of 34 dung piles were marked between September and October 2005 and monitored up to January 2006 for decay rate estimation; the analysis of these 34 dung piles showed a mean decay rate of 0.015 (SE = 0.000565), which is much higher than the decay rate estimated for the dry season. Although we used this decay rate in our wet season analysis, there is a need for estimating the wet season dung decay rate with a larger sample size of dung representing the diverse habitats in the landscape, as dung piles in the grassland habitat were not adequately represented in our decay experiment.

The higher rainfall during the 2005 wet season resulted in field logistical problems and lower effort in line transect sampling (92.9 km of distance in 93 transects). Parallel analyses were carried out for the wet season as was done for the dry season, which yielded similar elephant density for the landscape (1.09 elephant / km^2 – Table 3.3).

Table 3.3. Elephant density estimated using line transect dung count method for various Forest Divisions and landscape of Elephant Range 9

Division	**Distance walked - km (*n**)**	**Dung Density**		**Elephant density (individuals) / km^2**		
		Density (km^2)	**Standard Error**	**Mean**	**LCL**	**UCL**
Anaimalai (IGWLS) and Dindugul	25.0 (259)	1250.4	96.42	1.1	0.93	1.37
Theni	5.0 (36)	625.0	133.98	0.6	0.31	0.84
Kodaikanal	2.0 (0)	0.0	-	0.0	0.0	0.0
Chalakkudy, Chimmony, Peechi and Nemmara	10.9 (27)	484.64	110.56	0.4	0.22	0.65
Chinnar, Eravikulam and Munnar	15.5 (69)	732.91	104.55	0.7	0.46	0.89
Idukki	3.0 (42)	2788.7	521.33	2.6	1.6	3.5
Kothamangalam	1.0 (0)	0	-	0.0	0	0
Malayattur	14.5 (161)	2264.5	271.21	2.1	1.49	2.62
Parambikulam	9.0 (88)	1566.8	283.93	1.4	0.87	2.01
Vazhachal	7.0 (72)	2168.7	489.41	2.0	1.03	2.88
Landscape	**92.9 (754)**	**1188.2**	**-**	**1.09**	**0.7**	**1.5**

n* Sample size obtained, **LCL** = Lower Confidence Interval and **UCL** = Upper Confidence Interval

Considering the densities estimated for the landscape during dry (1.11 elephant / km^2) and wet (1.09 elephant / km^2) seasons are similar, it is realistic to assume a mean density of 1.1

elephant / km^2 for the landscape. The synchronized elephant census conducted during May 2005 in southern India using dung count method estimated a mean density of 0.82 elephant / km^2 for the Kerala side of the landscape (Sivaram *et al*. 2006). Therefore, the present study estimated density marginally higher (0.2 elephant / km^2), which could be attributed to sampling time because the present study was conducted during the dry season between February – April while the synchronized elephant census was conducted in May which is the beginning of the first wet season (southwest monsoon). If density figures of synchronized elephant census for the Tamil Nadu side of the landscape were available, these differences could have easily been confirmed; unfortunately the data has not been available. However, the consistency in the density figure estimated for the landscape during the second wet season (northeast monsoon) by the present study, further confirms the probability of one elephant / km^2 or between 0.8 to 1 elephant / km^2 on the basis of dung count method. However, the density estimated by dung count method by the present study (1.1 elephants /km^2) and also the synchronized census (0.82 elephant/km^2) appears far higher than the 0.55 elephants / km^2 estimated by the synchronized census using the direct sighting, block count method in May 2005 for the Forest Divisions of Kerala in Elephant Range 9. This could be due to poor visibility in the study area resulting in under-estimation of elephant density.

The study based on the habitat survey and mapping, estimated a total of 4421 km^2 of elephant habitats across the landscape. However, within these elephant distribution areas, a large chunk of ~600 km^2 area consisted of several small patches which are inaccessible to elephants (being rocky) or rarely used by elephants (being very steep terrain) for which extrapolating the estimated elephant density is inappropriate. Such areas need to be excluded in computing available habitats for elephants by incorporating additional details like contours, barren rocks etc into the GIS database. We therefore excluded 600 km^2 inaccessible area from the landscape and considered only 3820 km^2 as effective elephant habitat in the landscape similar to the figure estimated by Ramesh *et al*. (2003) for the Kerala Forest Divisions (2818 km^2), which was also adopted by the Kerala Forest Department for extrapolating elephant density estimated during 2005. Therefore, in total, an area of 3820 km^2 was considered as elephant habitat for the landscape. Considering the mean density of 1.1 elephants / km^2 in dry season or 1.09 elephants/ km^2 in the wet season (Table 3.4), it translates to around 4200 elephants (after excluding the captive elephants of Anamalai whose dung piles were also sampled inevitably during dry season) for the total landscape. The synchronized elephant census

(2005) by the Forest Divisions of Kerala in Elephant Range 9 estimated 2300 elephants (Sivaram *et al*. 2006). The Anamalai Wildlife Sanctuary and Dindugul Forest Division are together spread over about 1000 km^2 with elephant density more or less similar to Parambikulam (as can be seen in Tables 3.2 and 3.3). Assuming Anamalai and Dindugul also had density of 1.9 elephants/km^2 during May 2005 census (similar to the elephant density estimated for Parambikulam -1.9 elephants/km^2 during synchronized census May 2005, shown in Sivaram *et al*. 2006), these two divisions, with approximately 1000 km^2 of elephant habitat, translates to 1900 elephants. These 1900 elephants for the Tamil Nadu side of the landscape and 2300 elephants estimated for the Kerala part of the Elephant Range during May 2005 (Sivaram *et al*. 2006), adds up to around 4200 elephants for the landscape, similar to the population size estimated by the present study.

Table 3.4. Population density and size estimated using line transect dung count method for the landscape of Elephant Range 9

Season	Distance walked (km)	Sample size (*n*)	Elephant Density			Population size		
			Mean	UCL	LCL	Mean	Min.	Max.
Dry	274.53	3603	1.11	0.84	1.40	4237	3192	5350
Wet	92.9	754	1.09	0.69	1.48	4161	2634	5650

n Sample size obtained, **LCL** = Lower Confidence Interval and **UCL** = Upper Confidence Interval

The elephant habitats in the landscape are discontinuous (Theni Forest Division in the southern side, and Idukki and part of Kothamangalam Forest Divisions in the western side) due to physical barriers such as steep escarpments and commercial plantations, although forest contiguity still exists. Therefore, of the 4200 elephants, about 225 elephants ranging in the Idukki and western part of Kothamangalam Forest Division were isolated from the rest of the elephants in the landscape. The Theni Forest Division, although, did not have forest contiguity in plains with the adjoining forest division on the northern side, so elephants from this Forest Division were moving to Munnar Division and vice versa through private cardamom and tea plantations. Therefore, only ~225 elephants ranging in Idukki Wildlife Sanctuary and western part of Kothamangalam could be treated as an isolated population as these elephants could not move to the larger landscape on the eastern side, due to physical barriers coupled with the presence of settlements and cultivation. The estimated population size of 4200 elephants for the landscape is higher compared to ~2000 elephants earlier believed to be present in the landscape (Bist 2002). Thus the landscape with large elephant population possessing higher genetic diversity than that of the larger Nilgiri population

(Vidya *et al*. 2005) appears viable for long term conservation according to criteria of Leimgruber *et al*. (2003) provided future developmental activities do not hamper the contiguity of the habitats anymore.

3.3.2. Elephant population structure

Data on age-sex composition of elephant herds and bulls were collected on the basis of 30 sightings consisting of 147 elephants, recorded between January 2005 and April 2006. Of the 30 sightings, 19 were Type 1 sightings/ classification (where all the 89 individuals were aged/sexed), 9 were Type 2 sightings (where not all elephants were aged/sexed but presence or absence of adult male/s was confirmed) and 2 were of Type 3 classifications (where no elephants were either counted or aged/sexed) (Table 3.5) that were excluded from analysis.

Table 3.5. Details of direct sightings of elephants recorded between January 2005 and April 2006 in Elephant Range 9

Details	Type of sighting			Total
	Type 1	Type 2	Type 3	
Number of sightings	19	9	2	30
Number of animals counted	89	50	8	147
Number of animals aged/sexed	89	39	6	134
Percentage of animals aged/sexed	100	78	75	91

3.3.2a. Proportion of adult males in the population

Proportion of adult males was computed using Type 1 and Type 2 classifications of data. In total 139 elephants were recorded in Type 1 & Type 2 classifications during the study period. Out of these 139 elephants, 4 were adult males. Therefore, proportion of adult males was 0.029 (3%) of the total population.

3.3.2b. Percentage of major age classes of elephants

The age structure of the 89 elephants recorded in Type 1 classification showed that the population consisted of 46% adults with the rest in younger age classes (juveniles and sub-adults) (Fig. 3.1). On the other hand, the age structure in relation to sex (Fig. 3.2) showed that the proportion of males appeared to decline gradually from sub-adult class (5 years old) onwards reaching very low values in the >20 years age class, there were very few adult males (3%) above 20 years age, resulting in a considerable bias towards females in the upper age segments (Fig. 3.2) indicating a moderately skewed sex ratio.

Plate 5. Elephant herd sighted with a young calf and a young adult male in Elephant Range 9

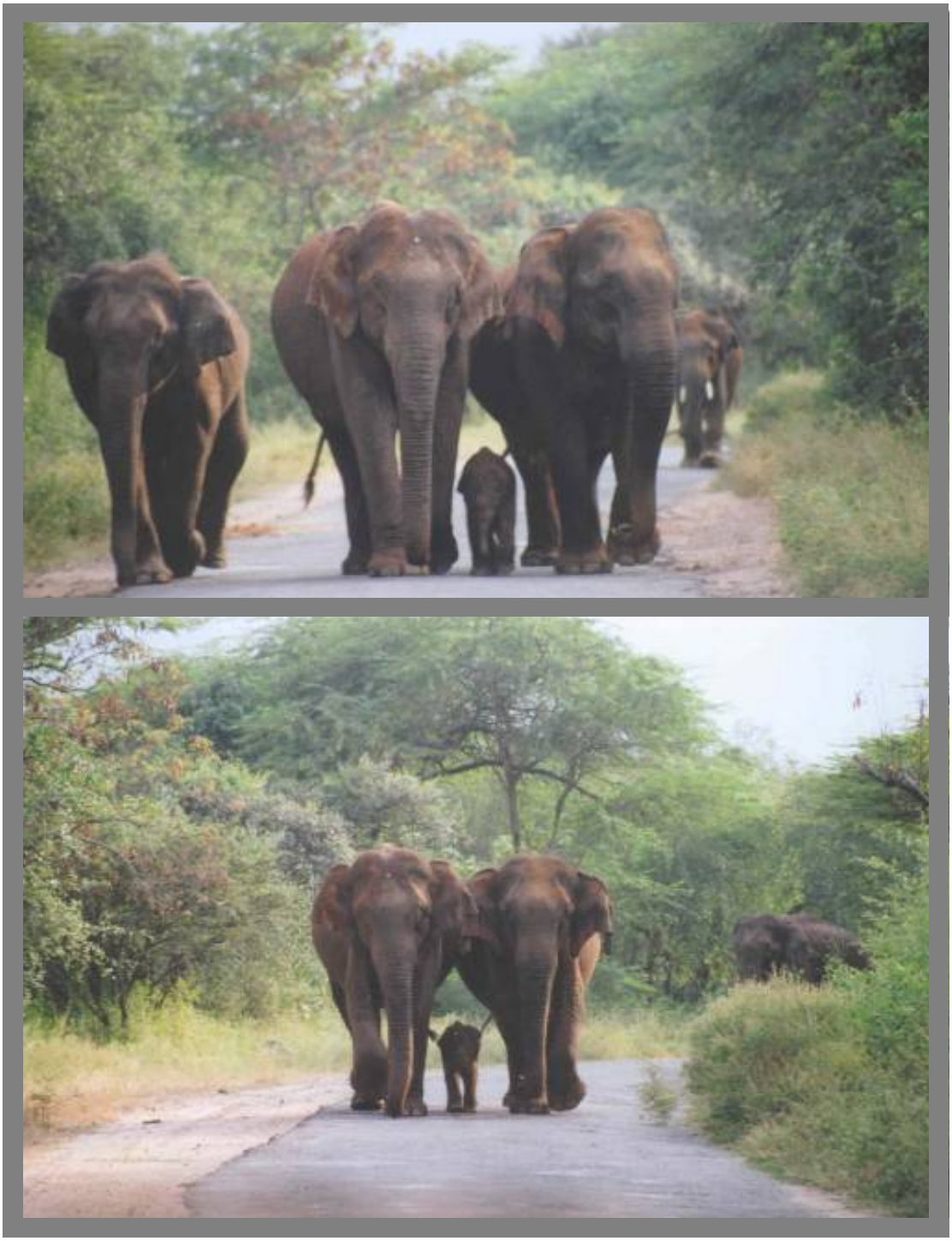


Fig 3.1. Percentage of various age classes of elephants recorded in the study area (n = 89) January 2005 and April 2006

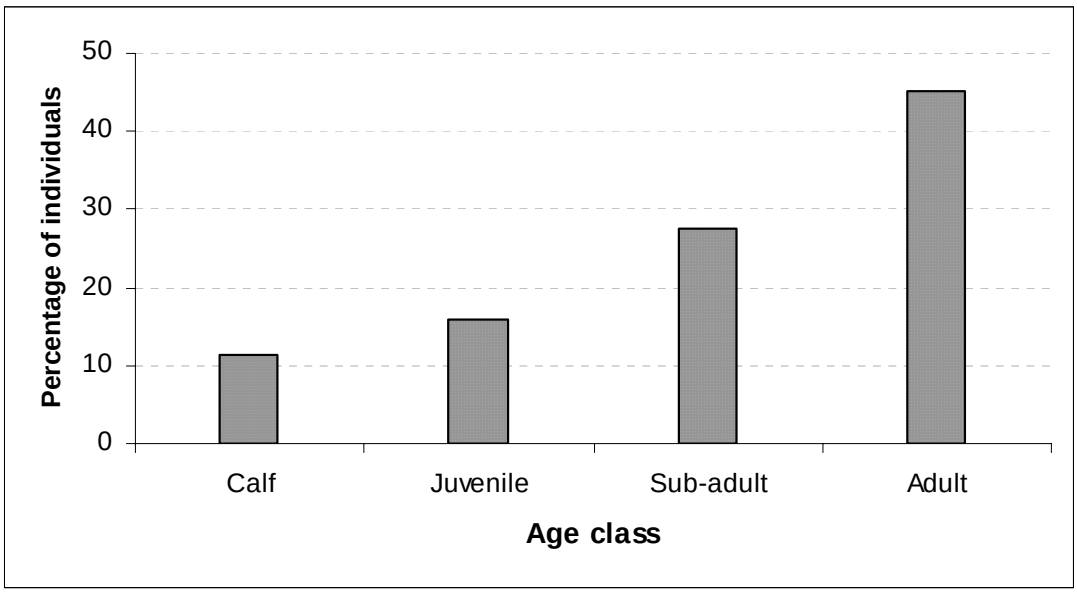
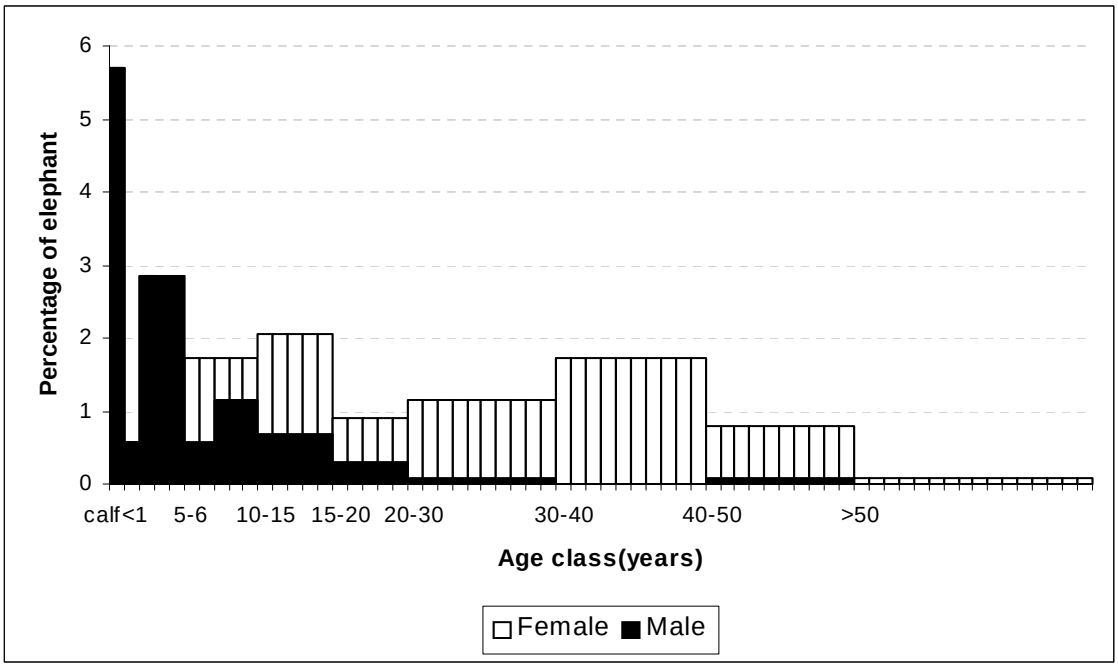


Fig 3.2. Age-sex classes of elephants recorded in the study area (n = 89) between January 2005 and April 2006



The sex ratio estimated for major age classes (Table 3.6) also show a gradual skew towards females from juvenile (1: 1.8) to sub-adult (1: 2.4) and adult (1: 9) indicating higher mortality of males in the upper age segment of the population that could likely be due to poaching for tusks. The present finding is based on a small sample size (n = 89); a larger sample size of 100 to 200 individuals would give us a better understanding about the age-sex composition of the population. However, Kumar *et al*. (2004) also reported a higher skew towards female at adult level (1:38) based on larger sample size of 162 elephants (including re-sightings of same herds) from the *Valparai Plateau*, a smaller part of the landscape. On the other hand, the synchronized elephant census for the Kerala part of Elephant Range 9 estimated the sex ratio of adult male to female as 1:4.0 and 1:4.7 respectively in 2002 (Easa *et al*. 2002) and 2005 (Sivaram *et al*. 2006). Such large difference in sex ratios among the three studies (Kumar *et al*. 2004, Sivaram *et al*. 2006, and the present study) emphasizes the need for detailed long-term sampling for determining the demographic parameters of the population.

Table 3.6. Sex ratio at different age classes of elephants recorded in the study area (n = 9) between January 2005 and April 2006

Age class	Male: Female
Juvenile	1: 1.8
Sub-adult	1: 2.4
Adult	1: 9.3

3.3.3. Seasonal distribution of elephants in different habitats

3.3.3a. Dry season

In order to know the importance of various vegetation types for supporting the elephant population, the number of dung piles per km (dung encounter rate) and elephants dung density per km^2 were estimated for the major habitats of the landscape separately for the dry and wet seasons. The results of dung encounter rate in dry season show that dry thorn forest habitat had the highest occurrence of elephant dung piles/km of walk and moist deciduous habitat had the lowest (Table 3.7). The dung pile encounter rate in any area is a function of visibility, which changes between habitats within a season. Therefore, dung density that does take visibility or width of sampling area into account reflects more closely the variation in the intensity of use of various habitats within a season. Interestingly, evergreen forests had the highest dung density (2642/km^2) followed by moist deciduous forest (2358/km^2), while it was lowest was in grasslands and plantation habitats (Table 3.7).

Table 3.7. Details of elephant dung encounter rate and dung density recorded during the dry season in various habitat types of Elephant Range 9

S. No.	Habitat type	Distance walked (km)	Sample size	Encounter rate/km	Dung density (km^2)	
					Density	Standard Error
1	Dry deciduous forest	51.10	1060	20.7	2254.0	114.33
2	Evergreen forest	52.03	548	10.5	2641.7	201.02
3	Grassland	30.65	313	10.2	1303.2	119.37
4	Moist deciduous forest	35.75	316	8.8	2357.6	279.64
5	Plantation	77.50	703	9.1	1635.8	92.856
6	Dry thorn forest	27.50	663	24.1	2006.7	100.28

3.3.3b. Wet season

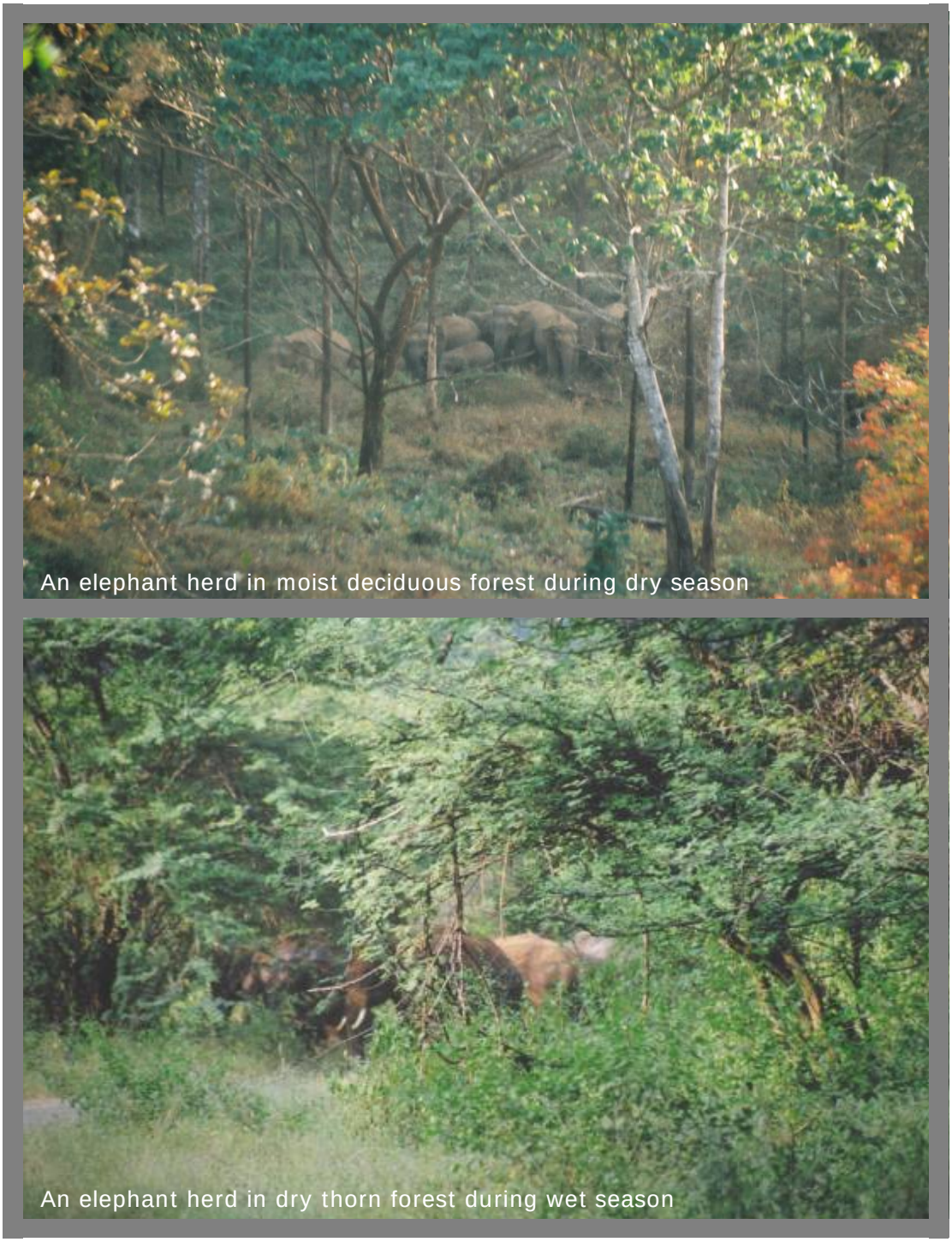
In contrast to the dry season, higher densities of elephant dung piles appeared during wet season in the dry and moist deciduous forests, and in the open canopied grassland habitats. This indicates higher usage of these habitats by elephants compared to closed canopy browse dominated evergreen habitat (Table 3.8).

Table 3.8. Details of elephant dung encounter rate and dung density recorded during wet season in various habitat types of Elephant Range 9

S. No.	Habitat type	Distance walked (km)	Sample size	Encounter rate/km	Dung density (km^2)	
					Density	Standard Error
1	Dry deciduous forest	13.60	168	12.4	1836.9	247.29
2	Evergreen forest	26.15	168	6.4	1367.0	170.59
3	Grassland	07.30	44	6.0	1594.2	315.73
4	Moist deciduous forest	14.00	156	11.1	1700.0	153.48
5	Plantation	23.65	147	6.2	987.43	103.34
6	Dry thorn forest	8.20	71	8.7	1464.3	217.46

Further, the presence of a relatively large number of dung piles in all the habitats during the dry season compared to the wet season could be due to the lower dung decay rate during the dry season (0.011/day) as compared to the wet season (0.015/day).

Plate 6. Elephant herds using moist deciduous [top] and dry thorn forests [bottom] respectively during dry and wet seasons in Elephant Range 9



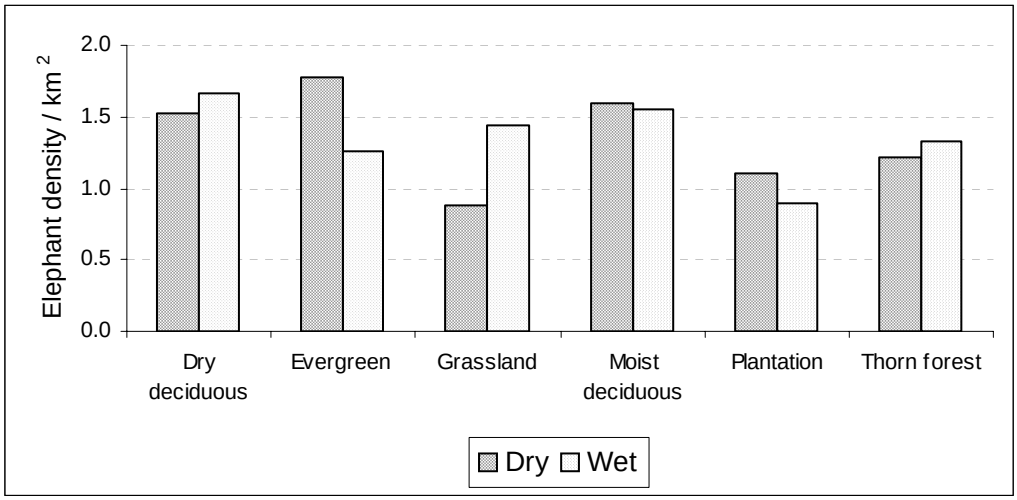
An elephant herd in moist deciduous forest during dry season

An elephant herd in dry thorn forest during wet season

3.3.3c.Comparison of elephant density between seasons in various habitats

Since dung decay rate is known to be lower during dry the season compared to wet season (as observed earlier in the section on population size), resulting in a relatively higher dung density in the dry season compared to wet season in all the habitats (see Table 3.7 and 3.8), direct comparison of dung density in a given habitat between dry and wet seasons does not reveal the actual variation in usage pattern. Therefore to compare the relative usage of a given habitat in two different (dry and wet) seasons, the observed dung density in various habitats was converted into elephant density and the results are presented in Fig. 3.3. The habitats such as evergreen forest, moist deciduous forest and plantations supported higher elephant density/km^2 or were used more during dry season compared to wet season. On the other hand, habitats such as grasslands, dry deciduous and dry thorn forests supported higher elephant density during the wet season than during dry season. These results highlight the importance of evergreen and moist deciduous forests during dry season and grasslands, dry deciduous and dry thorn forests during wet season in supporting higher densities of elephants across the landscape.

Fig. 3.3. A comparison of elephant density within various habitats between season



The elephants found in seasonal heterogeneous habitats of Asia and Africa are known to show distinct seasonal use of various habitats due to varied availability (including nutritive quality) of fodder resources like grasses or woody plants and also changes in water and shade availability (Field and Ross 1976, Barnes 1979, Sukumar 1989, Baskaran 1998). A predominantly grass diet during the wet season and a browse diet during the dry season are

indicated in several studies. Mineral content may also influence choice of certain plant species and parts such as bark.

The more distinct seasonality observed in the use of evergreen and grassland habitats could be attributed to the seasonal variation in resource quantity and quality and also their requirements by the elephants. For instance, grasslands have relatively low shade and food resources with less nutritive quality (dry grass) to elephants during the dry months, while the evergreen habitat is still quite moist with sufficient shade, water and protein rich browse food at this time. Therefore, evergreen habitat could have supported a higher elephant density during the dry season. On the other hand, relatively higher use of open habitats such as grasslands, dry deciduous and dry thorn forest habitats during the wet season compared to dry season could be due to availability of freshly growing grass species as the other two crucial resources such as water and shade are abundantly available in all habitats. Such influence of availability of food, water and shade on elephant movements has been well documented elsewhere in Asia (Eisenberg and Lockhart 1972, Sivaganesan 1991, Baskaran 1998, Sukumar *et al*. 2003) and in Africa (Buss 1961, Buechner *et al*. 1963, Western 1975).

It is to be noted that among the six different habitats, relatively lower density of elephants was seen in forest plantations (such as Teak, Eucalyptus and Wattle) both during dry and wet seasons compared to the other five habitats indicating an avoidance of monoculture plantations. Similar lower usage pattern of monoculture forest plantations over the natural forest habitats by elephants has also been observed in the northeastern region in India (Sukumar *et al.* 2003). The possible reason for such lower usage of monoculture plantations could be the absence or lack of diverse food resources. Such monoculture forest plantation habitats occupying 536 km^2 of the total landscape results in a lower overall elephant density than what can otherwise be supported by the landscape; these sub-optimal habitats need to be taken into account for future management of the elephant habitats. Thinning of existing monoculture forest plantations needs to be considered to improve regeneration of diverse endemic plants so as to improve the food availability to the elephant population in such areas.

CHAPTER 4

ELEPHANT – HUMAN CONFLICT IN ELEPHANT RANGE 9

4.1. INTRODUCTION

Conflicts between elephant and agricultural communities dates back to as early as the fifth or sixth century BCE (Sukumar 2003). The extent of conflicts increased over time across the geographical range of Asian elephants as natural habitats traditionally used by elephants have gradually been converted into agricultural lands and settlements, resulting in a large number of elephants in contact with humans leading to increase in human-elephant conflict (Santiapillai and Jackson 1990, Balasubramanian *et al*. 1995). A continental study on the evaluation of Asian elephant habitats (Leimgruber *et al*. 2003) states that only 51% of the geographic range (estimated at < 500,000 km^2 by Sukumar 2003) of Asian elephants consisted of unfragmented wild lands in 1990. India, which holds the largest Asian elephant population in the wild has ongoing developmental activities in all the elephant ranges with the exception of a part of the northeastern region (Leimgruber *et al*. 2003); thus the future of elephant conservation remains severely challenged. The present scenario of decreasing elephant population with increasing conflicts is largely due to unplanned developmental activities of elephant ranges in the past. Documentation of the existing status of conflicts and their causes is vital to plan the future management of this landscape dwelling species.

Elephant Range 9 is no exception, as it also experiences increased human-elephant conflicts in some parts of the landscape such as the *Valparai plateau* of Anamalai Wildlife Sanctuary (Kumar *et al*. 2004), Theni (Baskaran *et al*. 2006) and Dindugul Forest Divisions. A study by Kumar *et al*. (2004) that looked at human-elephant conflict in a small area of the landscape, attributes lack of cover and forage as well as the presence of villages in and around the elephant migratory route as the main cause for such conflicts. However, little data are available on the conflict scenario or the causes of conflict in the remaining areas of the landscape. Therefore, rather than focusing on a detailed study on the ecology of crop raiding, a rapid survey was carried out across the landscape to understand the status of human-elephant conflict and its causes, in order to broadly understand variation in conflict levels across the landscape with the following objectives.

1. To evaluate the human-elephant conflict across various forest divisions in the landscape,
2. To assess the possible causes of conflicts, and
3. To overlay the intensity and the causes of conflicts over the division map using GIS in order to portray the elephant-human conflict across the landscape.

4.2. METHODS

4.2a. Data Collection

A rapid survey was carried out during January 2006 covering 40-70% of the villages abutting the forest areas across the landscape, to assess the intensity of conflicts. During the rapid survey in each village, farmers were interviewed from the outskirts of the village (bordering the forest areas) towards the interior (up to the extent where elephant intrusions occurred) in order to maximize coverage of the farmers who were affected in a given village keeping in view the constraints of time and manpower. During the interviews, information such as the farmer's name, cultivated area owned, details of various crops cultivated and their extent, elephant damage to each crop and its extent, damage to other properties (house, pipe line, pump sets, etc), economic loss incurred and month of damage were collected from every farmer for the year 2005 using a questionnaire. The geographical locations of crop fields belonging to each farmer interviewed were obtained using a Global Positioning System (GPS). If a given village was not affected by elephants, only one or two farmers were interviewed. Additionally for each village, details such as Forest Division and Range within the division under which a given village is administered, manslaughter by elephants and elephant mortality due to conflict and their location were also noted down. Also, secondary data pertaining to human-elephant conflict available with the Forest Department were collected to supplement the results of rapid assessment.

4.2b. Analysis

The data were compiled for each division separately so as to obtain the percentage of villages, farmers, and crops affected and economic loss due to elephant damage to crops and other properties, etc. Additionally the location data of various farmers surveyed and affected, manslaughter by elephants and elephant mortalities by conflict were superimposed on the map of Elephant Range 9 to depict the intensity of conflict across the landscape. The secondary data collected from each forest division were also summarized for each division as supplementary detail to the rapid assessment.

4.3. RESULTS AND DISCUSSION

4.3.1. Cropping pattern

The rapid survey carried out in various forest divisions showed that the perennial crops (cultivated and harvested within a year) dominated (64%) cultivated land as compared to annual crops (36%). However, significant variations in cropping patterns were observed between the eastern side and the western side of the landscape (Table 4.1). For example, the farmers in the eastern part of the landscape cultivated significantly more annual crops compared to those in the western part of the landscape (M-W U = 4 $P<0.05$). The farmers living in the fringe and enclave areas of forest divisions, especially Dindugul, Theni and Chinnar cultivated more annual than perennial crops. The reason for this variation in cropping pattern across the landscape could be due to the variation in rainfall coupled with local topography. The eastern part being in the rain shadow area, receives significantly lower rainfall (mean annual rainfall 1596 mm) compared to the western side (mean annual rainfall 3344 mm); thus farmers predominantly grow annual crops in the former region.

Table 4.1. Cropping pattern observed in different Forest Divisions and parts of landscape in Elephant Range 9 during 2005

S. No	Forest division	Percentage of crops cultivated	
		Annual crops	Perennial crops
1	Dindugul	63	37
2	IGWLS	47	53
3	Theni	66	34
4	Chinnar	83	17
5	Munnar	4	96
6	Marayur	37	63
	Eastern side Total	***50***	***50***
7	Kothamangalam	0	100
8	Malayattur	28	72
9	Nemmara	14	86
10	Vazhachal	19	81
11	Peechi	0	100
12	Chalakudy	0	100
13	Idukki WL	25	75
	Western side Total	***12.3***	***87.6***
	Landscape Total	**36.3**	**63.7**

4.3.2. Degree of elephant – human conflict

Through rapid surveys to assess the degree of human elephant conflict in various divisions, 466 farmers belonging to 176 villages in and around the forest areas of the landscape were sampled. The assessment revealed that the degree of elephant-human conflict varied remarkably across the landscape (Table 4.2 & Fig. 4.1).

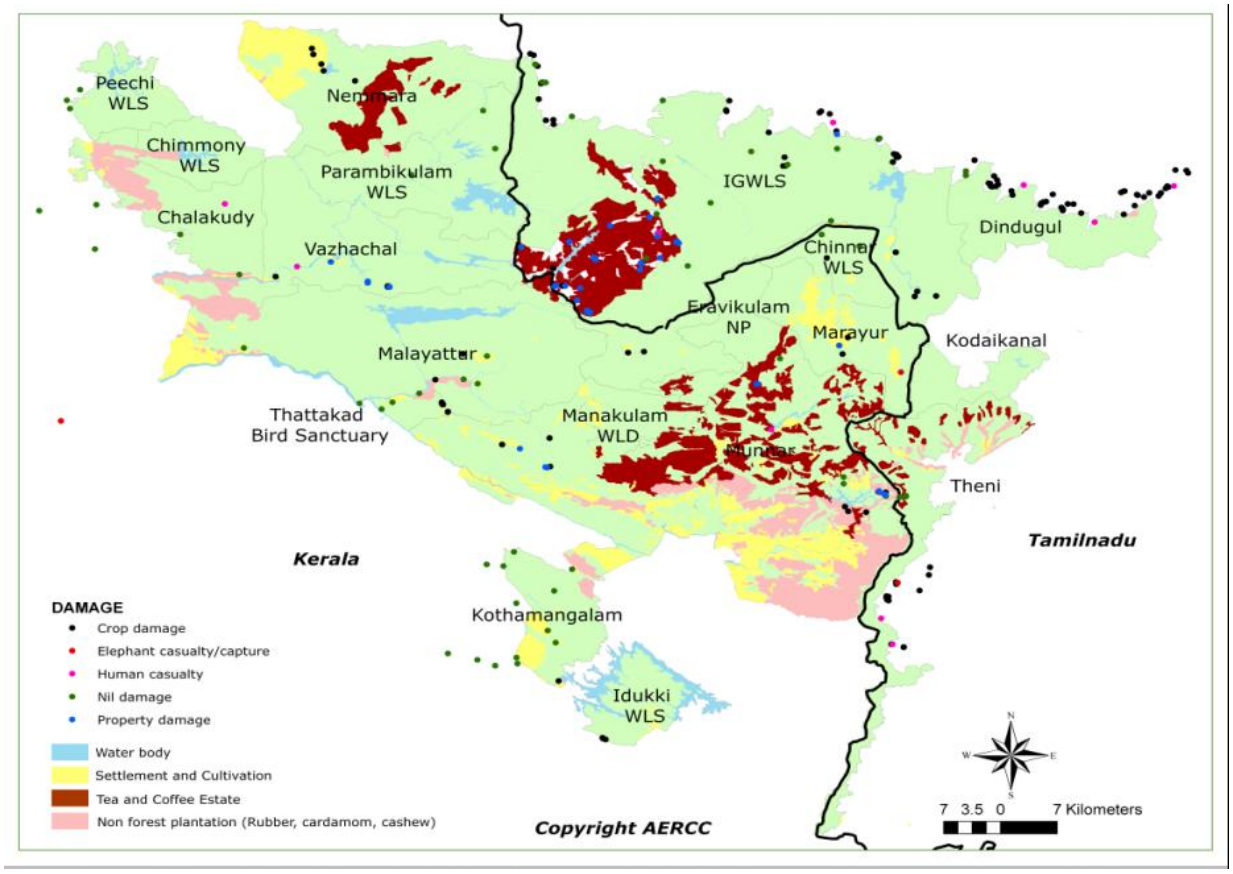
Overall at the landscape level, in 2005, elephants affected 38% of the 176 villages and 38% of the 466 farmers sampled indicating lower level of conflicts compared to other parts of the country such as northern West Bengal (Sukumar *et al*. 2003). However, regional variations in conflict indicate that the eight forest divisions in the eastern part of the landscape experienced significantly higher conflict level compared to ten forest divisions in the western side of the landscape (M-W U = 8 P<0.05), as >50% of the farmers cultivating along the fringes and

Table 4.2. Degree of elephant-human conflict revealed from rapid assessment survey in various Forest Divisions of Elephant Range 9 during 2005

Forest Division	Villages		Farmers	
	Surveyed	**Affected (%)**	**Surveyed**	**Affected (%)**
Chinnar	3	33.3	8	37.5
Dindugul	14	100	69	97.1
Eravikulam NP	*	-	-	-
IGWLS	44	65.9	125	72.8
Kodaikanal	*	-	-	-
Marayur	12	66.7	33	45.5
Munnar	29	72.4	77	37.7
Theni	20	30	62	35.5
Eastern side of landscape	***122***	***61.4 (Avg)***	***374***	***54.3 (Avg)***
Chalakudy	5	20	5	20.0
Idukki WL	2	50	4	25.0
Kothamangalam	12	0	13	0
Malayattur	8	37.5	11	63.6
Mankulam	2	0	2	0
Nenmara	7	71.4	13	46.2
Parambikulam	3	0	3	0
Peechi & Chimmony WL	4	0	4	0
Thattakad BS	4	25	13	76.9
Vazhachal	7	28.6	24	50.0
Western side of landscape	***54***	***23.3 (Avg)***	***92***	***28.2 (Avg)***
Landscape total	**176**	**37.6 (Avg)**	**466**	**38.0 (Avg)**

Villages along the elephant habitats and within village farmers who cultivated immediately next to the forest area were surveyed and therefore % farmers affected need not necessarily be the actual % of farmers affected in each village. * No villages/ cultivation in the elephant distribution areas.

Figure 4.1. Map showing the intensity of elephant-human conflict in 2005 in the surveyed villages of various forest divisions



enclaves of forests) and >60% of the villages surveyed were affected by the elephants in the eastern side forest divisions (Table 4.2).

Five forest divisions, namely Kothamangalam, Mankulam, Parambikulam, Peechi and Chimmony out of 11 divisions in the western part of the landscape, have not experienced any damage by elephants, and that has reduced the number of farmers surveyed to some extent in the western side of the landscape, as we have only sampled one or two farmers if a given village is not at all affected by elephants so as to maximize our sampling. All the forest divisions in the eastern side of landscape have experienced conflict except for Eravikulam and Kodaikanal where there were no villages in the elephant distribution areas.

4.3.3. Nature of conflict

In total, 284 out of the 466 farmers surveyed were affected by elephants during 2005 in Elephant Range 9 (Table 4.3). The nature of conflicts include damage to crops and properties besides human casualties by elephants; there were also elephant deaths and captures as a result of conflict. Between the two damage types caused by elephants, damage to crops was more common (83%) as compared to property (17%). There were also 7 human deaths and 4 elephant captures/deaths due to elephant-human conflict during 2005. Conflict is notably higher in the eastern part of the landscape than in the western part of the landscape (Table 4.3), as five out of seven human deaths and 75% of elephant deaths or capture that took place in the villages surveyed were in the eastern side of Elephant Range 9.

Table 4.3. Nature of elephant–human conflict in Elephant Range 9 during 2005

Regions	**Number of farmers affected (surveyed)**	**% Damage to crops & properties by elephants (*n*)**		**Number of human death**	**Number of elephant death/capture***
		Crop	**Property**		
Eastern side	244 (374)	82.4 (197)	17.6 (42)	5	3
Western side	40 (92)	84.0 (32)	15.8 (6)	2	1
Landscape total	**284(466)**	**83.3 (Avg)**	**16.7 (Avg)**	**7**	**4**

* Number of elephants dead /captured due to conflict.

4.3.4. Economic loss due to elephant-human conflict

The economic loss incurred by individual farmers, due to conflict was reported by 217 farmers whose crop and property were damaged (Table 4.4). The economic loss due to crop

damage by elephants reported by 173 farmers has revealed that an average crop worth of Rs. 13,308 (US $ 296) per affected farmer was lost due to elephant damage. Also, 45 properties were damaged, as reported by the affected people; this worked out to an average of Rs. 9119 (US $ 203) per affected person across the landscape.

Table 4.4. Average economic loss per farmer caused by elephants to crop and property in villages surveyed under different Forest Divisions of Elephant Range 9 during 2005 (Loss in Indian rupees reported by the farmers) – US $ 1 = 45 Indian rupees

S. No	Forest division	Average economic loss / farmer (in Rs.)	
		Crop damage (n)	Property damage (n)
1	Dindugul	19642 (65)	-
2	Theni	5946(13)	2000 (1)
3	Chinnar WL	2750 (2)	5000 (1)
4	Marayur	35312 (8)	6750 (6)
5	IGWLS	29670 (60)	40707 (30)
6	Munnar	9353 (17)	6500 (2)
	Eastern side of landscape (Avg)	***17,112 (165)***	***12,191 (40)***
7	Idukki WL	5000 (2)	-
8	Malayattur	6000 (1)	-
9	Nemmara	6100 (5)	5000 (1)
10	Vazhachal	-	2000 (2)
11	Chalakudy	-	5000 (1)
	Western side of landscape (Avg)	***5700 (8)***	***4000 (4)***
	Landscape (Avg)	**13,308 (173)**	**9119 (44)**

The region-wise analysis showed that the average economic loss due to crop and property per affected farmer or person was far higher in divisions on the eastern side of the landscape compared to divisions on the western side (Table 4.4). Among the divisions in the eastern side, average economic loss due to crop damage by elephants was highest in Marayur Division (Rs. 35,312/affected farmer) followed by IGWLS (Rs. 29,670/affected farmer), while economic loss due to property damage was highest in IGWLS (Rs. 40,707/affected person).

4.3.5. Types of crops damaged by elephants

Elephants damaged crops both by eating and trampling. In total there were 25 different types of crops cultivated across the landscape. Of the 11 annual crops cultivated in the study area, 63% of crop species were damaged with 74% of species being eaten by elephants. In the case of the 14 types of perennial crops cultivated, elephants damaged fewer crops (57 %) with only half the number damaged species being eaten and the rest being trampled (Table 4.5). Most of

the perennial crops, being woody in nature, cannot be easily accessed and could also be less nutritive and palatable to elephants, while most of the annual crops being small in nature with soft texture can easily be accessed and could also be of high nutritive value and thus could be highly palatable to elephants. Therefore, as the majority of the annual crops were palatable to elephants compared to perennial crops, the extent of damage caused to annual crops outweighed the damage to perennial crops.

Table 4.5. Percentage of perennial and annual crop species damaged by elephants in different parts of the landscape in Elephant Range 9 during 2005

Region	Percentage of annual crop	Percentage of perennial crop
East	45.8	39.9
West	4.6	18.4
Landscape	62.6	56.7

4.3.6. Compensation paid by Forest Department towards conflict

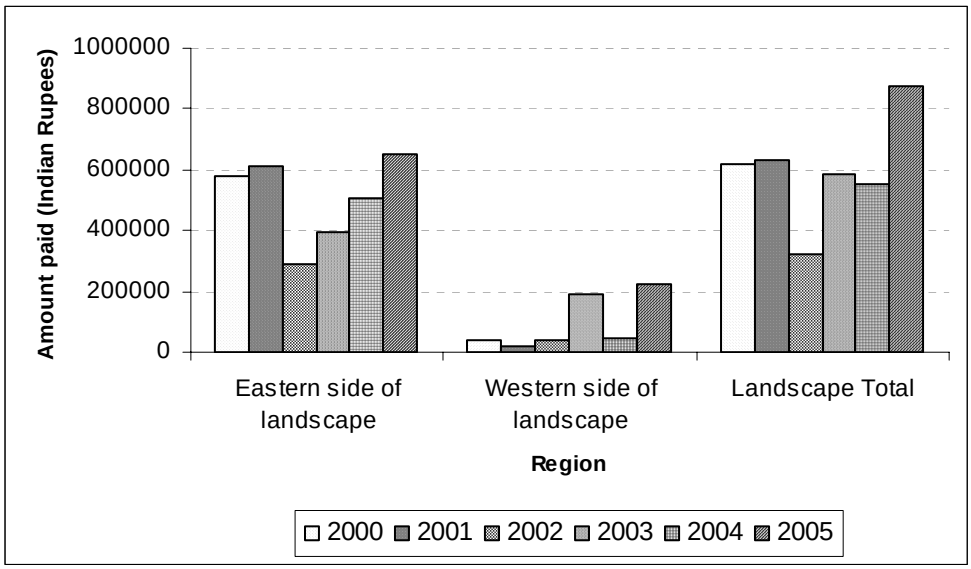
Compensation paid by the forest department towards crop loss, property loss and human death by elephants were collected from each forest division (Table 4.6). There has been a difference in the amount paid as compensation for human death by elephants between Tamil Nadu and Kerala. The forest department in Tamil Nadu paid Rs. 1,00,000/human death that took place in non-forest areas, while the forest department in Kerala paid Rs. 20,000/human death. To overcome this difference, the number of human casualties due to elephants was also recorded. The amount paid as crop compensation by the forest department during 2005 in all the divisions was to the tune of Rs. 5,21,260, and towards human casualty Rs. 3,65,000. The region-wise break-up of compensation amount paid also showed a similar pattern that forest divisions in the eastern side paid more compensation (Rs. 6,82,500 - in total for crop, property and human casualties) compared to those on the western side (Rs. 2,03,760). This indicates that the degree of conflict was higher in the eastern side as revealed by our rapid survey results. The economic loss reported by the affected communities and compensation amount paid by the forest department do not tally. For example, based on the affected community perceived value of the economic loss by elephant damage, the rapid survey has estimated an average crop loss worth Rs. 13,308 / farmer and property loss worth Rs. 9119 / affected family in the 176 villages alone during 2005. But the forest department distributed only about Rs. 5,25,000 in total in all the forest divisions across the landscape. Such discrepancies could be due to two reasons. Firstly, the economic loss reported by affected community is always an

overestimate and secondly, the compensation paid by the forest department is subject to the availability of funds in the state during that period and thus do not represent the actual economic loss caused by elephants to crops and properties. Even for human death, different states pay different amounts of compensation. Further, the compensation amount paid towards elephant damages in the last six years (Fig. 4.2.) shows a rapid increase in the elephant-human conflicts in 2005 across the landscape.

Table 4.6: Compensation paid by various Forest Divisions toward crop damages and human casualties by elephants during 2005 (US $ 1 = 45 Indian rupees)

Divisions	**Compensation paid (Indian Rupees)**	
	Crop / property damage	**Human casualties**
Chinnar WLS	0	0
Eravikulam NP	0	0
Dindugul	3,50,000	50000
IGWLS	24500	0
Kodaikanal	0	0
Marayur	0	0
Munnar	10000	45000
Theni	53000	1,50,000
Eastern side of landscape	***4,37,500***	***2,45,000***
Chalakudy	0	20000
Idukki WLS	37840	0
Kothamangalam	0	0
Mankulam	0	0
Malayattur	35420	0
Nemmara	0	40000
Parambikulam	0	0
Peechi & Chimmony	0	0
Vazhachal	10500	60000
Thattakad Bs	0	0
Western side of landscape	***83760***	***1,20,000***
Landscape total	**5,21,260**	**3,65,000**

Fig. 4.2. Compensation paid by various Forest Divisions towards crop and property damages and human casualties by elephants during 2000 – 2005 (US $ 1 = 45 Indian rupees)



4.3.7. Conflict related human casualties and elephant mortalities in the landscape

The total number of human casualties by elephants, and elephant mortalities and captures, due to conflict, that took place in various forest divisions of the landscape during 2005 is presented in Table 4.7. It supports the fact that elephant-human conflict incidents were higher in the forest divisions on the eastern side of the landscape compared to forest divisions on the western side. In the eastern side of the landscape, Munnar a large forest division with large fragmentation and non-forest activities, and the Dindugul and Theni forest divisions with relatively smaller elephant habitats and numbers, have experienced 10 human casualties by elephants in 2005 alone. Further, the long-term data available on human casualties (Table 4.8) show an overall increase in elephant-human conflict since 2000.

Table 4.7. Elephant mortality and human casualty due to elephant-human conflict during 2005 in different Forest Divisions of Elephant Range 9

Division	Elephant mortality and capture / Human casualty	
	Elephant	**Human**
Chinnar	0	0
Dindugul	2	3
Eravikulam NP	0	0
IGWLS	0	0
Kodaikanal	0	0
Marayur	0	0
Munnar	0	5
Theni	1	2
Eastern side	***3***	***10***
Chalakudy	0	1
Idukki WLS	0	0
Kothamangalam	0	0
Malayattur	0	0
Mankulam	0	0
Nemmara	1	2
Parambikulam	0	0
Peechi & Chimmony	0	0
Thattekad	0	0
Vazhachal	0	3
Western side	***1***	***6***
Landscape	**4**	**16**

Table 4.8. Elephant mortality and human casualty due to elephant-human conflict from 2000 to 2005 in different Forest Divisions of Elephant Range 9

Region	Years												Total	
	2000		2001		2002		2003		2004		2005			
	Em/c	Hc	Em/c	Hc	Em/c	Hc	Em/c	Hc	Em/c	Hc	Em/c	Hc	**Em/c**	**Hc**
Eastern side	0	4	1	4	0	4	0	6	0	9	3	10	4	37
Western side	0	1	1	0	1	0	1	2	0	0	1	6	4	9
Landscape	**0**	**5**	**2**	**4**	**1**	**4**	**1**	**8**	**0**	**9**	**4**	**16**	**8**	**46**

Em/c – Elephant mortality and capture due to conflict, Hc – Human casualty by elephant.

4.3.8 Causes of conflicts

The rapid assessment of elephant-human conflict and the secondary data on crop compensation as well as human casualties and elephant mortalities collected from various forest divisions revealed that conflict intensity varied significantly across the landscape. It was remarkably higher in forest divisions (especially IGWLS, Dindugul, Theni, Marayur and

Munnar) on the eastern side of the landscape compared to the western side of the landscape. The possible reasons for such variation in conflict across the landscape could be, firstly, the variation in the status of elephant habitats and land use pattern. As seen in the second chapter on elephant habitats in the landscape, it was evident that the forest divisions on the eastern side had large number of non-forest elements such as human settlements and cultivations. Such man-made landscape transformations on the eastern side resulted not only in loss and fragmentation of habitats but also brought relatively large number of elephants in contact with agriculture and settlements during their seasonal movements. Secondly, the eastern side being in the rain shadow area, degradation by anthropogenic activities was also high compared to the western side of the landscape. Thirdly, relatively larger cultivation of annual crops in the eastern side compared to the western side of the landscape coupled with the higher palatability of the annual crops could also be a reason for the higher degree of conflict in the eastern part of the landscape.

Plate 7. Indications of elephant-human conflict recorded in various parts of Elephant Range 9

CHAPTER 5

CAPACITY BUILDING PROGRAMME FOR THE FOREST PERSONNEL IN THE ELEPHANT RANGE 9

5.1. INTRODUCTION

In 2002, the synchronized elephant census conducted throughout southern India by the State Forest Departments in co-ordination with regional research institutions used sample block count and line transect dung count methods to estimate the population size of elephants. The results of the two methods yielded comparable figures mostly in Tamil Nadu, but in Karnataka and Kerala the dung count method yielded either far higher or far lower densities as compared to sample block count. This could be due to lack of experience and training in using line transect dung count methods among the field staff of the latter two states as compared to field staff in Tamil Nadu, who were trained intensively through an exclusive research project from A.V.C. College and subsequently through World Wide Fund for Nature India with financial support from the U. S. Fish and Wildlife Service. Thus it was decided to conduct a series of workshops on elephant census techniques and to train the field level staff of Kerala Forest Divisions in Elephant Range 9, especially regarding the line transect direct sighting and dung count methods, through this project.

As part of the project activities, five workshops on Elephant Census Techniques were conducted during the third and fourth week of October 2005 at various forest divisions to scientifically equip the forest department staff for future monitoring of the elephant population and management of the Elephant Range.

The participants included District Forest Officers (DFOs), Assistant Conservators of Forests (ACFs), Range Officers, Foresters, Forest Guards and Forest Watchers. The first workshop was conducted for DFOs, ACFs and Range Officers and the remaining four workshops were for Foresters, Guards & Forest Watchers, at four different forest divisions. In total about 150 persons participated in the workshop (Appendix 1 - 5), out of which about 40 participants were Officers.

The workshop covered in detail three different methods - [1] Sample Block Count, [2] Line Transect Direct Sighting method, and [3] Line Transect Dung Count, as these methods have been widely used for estimating elephant populations reliably. Besides the census methods, techniques for age-sexing elephants were also explained with appropriate photographic examples so as to teach the techniques for monitoring the population structure of elephants. The workshop for officers emphasized more on theoretical and analytical components of the census methods, whereas the workshop for the field staff demonstrated more of the practical components in the field including the Do's & Don'ts of the various census methods. Additionally, course materials relevant to the aspects covered in the workshop were provided to the participants.

5.2. TECHNICAL EXPERTS AT THE WORKSHOP

1. **Dr. P. S. Easa,** Director of Conservation, Wildlife Trust of India, Delhi was invited as a technical expert to talk about the **Sample block count method**. He has worked extensively in the Kerala state forest divisions on elephants and other wildlife and has also been involved in Elephant Census Programmes of the state during his service at the Kerala Forest Research Institute as a Scientist In – charge.

2. **Mr. R. Arumugam,** Biologist, Centre for Ecological Sciences, Indian Institute of Science with a Masters Degree in Wildlife Biology was called to teach the Line Transect Method, as he has been working on Large Mammal Population Monitoring using **Line transect direct sighting method** for the past 10 years in the Tropical Forest of Mudumalai Wildlife Sanctuary.

3. **Dr. N. Baskaran** has extensively applied the Line Transect Dung count method for estimating elephant populations in the North East and Southern India for more than 5 years, and has made a detailed analysis of the lacunae of dung count data collected by the Forest Department staff while compiling the 2002 and 2005 Synchronized Elephant Census Data. This knowledge was used in discussions & training of the participants in **Line transect dung count method** at the workshop.

4. **Mr. C. Arivazhagan,** a Biologist from the Centre for Ecological Sciences with Masters Degree in Wildlife Biology, studying the population structure of elephants since 1998, was called to talk about the **Population Structure and Monitoring of Elephants**.

5. 3. SYLLABUS FOR FOREST OFFICERS

1. Description of sample block counts in comparison with total count method – **Dr. P. S. Easa**
2. Description and theory of Line Transect Direct Sighting Method – **Mr. R. Arumugam**
3. Description and theory of Line Transect Dung Count Method – **Dr. N. Baskaran**

For the above three methods the following aspects were covered in detail.

- Advantages
- Disadvantages
- Stratification
- Sample size and site selection
- Survey team, survey equipments and data sheets
- Survey season and time, and data collection
- Data Analysis and Interpretation of results.

4. Monitoring Population Structure of elephants – **Mr. C. Arivazhagan**
   - Why to monitor?
   - How to monitor?
   - How to age and sex the elephants in the field?

Apart from the field demonstration during the workshop, the field level staff in each forest division were also exposed to the field component of similar techniques during the population estimation survey conducted as part of the present project. Although this short-term programme introduced the basic concepts, applications and field components of the various population techniques, an exclusive training programme with intensive field data collection and analyses like the one conducted for the Tamil Nadu Forest Department staff, would further strengthen the departmental staff of Kerala, a state which supports one third of the southern Indian elephant populations.

5. 4. SYLLABUS FOR FOREST FIELD STAFF

- **Classroom sessions**

1. An overview of Sample Block Count - **Dr. P. S. Easa**
2. Outline of Line Transect Direct Sighting method – **Mr. R. Arumugam**
3. Concept of Line Transect Dung count method **– Dr. N. Baskaran**
4. Age and sexing elephants in the field – **Mr. C. Arivazhagan**

- **Field sessions - [Mr. R. Arumugam and Dr. N. Baskaran]**

1. Map reading
2. Use of Field Compass, Range Finders and Global Positioning System
3. Practical field demonstration of line transect direct sighting and dung count methods.

Plate 8. Workshop on "Elephant Census Techniques" conducted for the officers and field staff of Forest Divisions in the Kerala part of Elephant Range 9

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6. 1. THE STATUS OF ELEPHANT HABITATS IN THE LANDSCAPE

6.1.1. Elephant habitat contiguity and area

- The present survey shows that out of about 5000 km^2 of forest area within the elephant habitats or distribution areas, only about 4000 km^2 area is available to elephants due to constraints from topography, reservoirs, etc. Although a major part of elephant habitat in the landscape remains intact, a smaller region is already severely fragmented due to developmental activities and topographical features. The central part of the IGWLS (Valparai and Manampalli Ranges), Munnar and Marayur Forest Divisions with large area under non-forest activities have brought more elephants in close contact with agriculture and settlements, and therefore conflict between humans and elephants had increased in the eastern part of the region. Such developmental activities have also resulted in loss of contiguity between Munnar and Theni Forest Divisions. Therefore, there is a need for consolidating some parts of elephant habitat especially in the Munnar and Valparai Plateau either by land acquisition (if it is owned by private parties) or by reverting the leased lands of cardamom and tea estates (in case of Government lands leased out to private parties for commercial plantation) to conservation use in order to reduce not only the elephant-human conflicts but also to keep the population from further isolation.

6.1.2. Ongoing Edamalayar – Angamaly hydroelectric project

- The study showed that Malayattur Forest Division is one of the important elephant habitats with high density of elephants in the western part of the landscape. An ongoing hydro-electric project in Malayattur Forest Division involves digging a 44 km contour canal from Edamalayar Reservoir to Angamaly town running ~10 km parallel to Periyar River predominantly cutting through the crucial elephant habitats (Thundathil, Kodanad and Kalady Ranges) of Malayattur Forest Division. Periyar River is the major water source for the elephants and other larger mammals during dry season in Thundathil and Kodanad Ranges. The contour canals will cut off access by large herbivores to Periyar River of Malayattur Forest Division, if the proposed

bridges at the traditional footpaths of wild animals to the river are not constructed. Construction of connecting bridges must therefore be mandatory.

- Proposed hydroelectric project on the Chalakudy River at Vazhachal Forest Division will result in loss of habitat affecting the high density of elephants it supports, which could lead to increase in elephant-human conflict in the adjoining areas.

6.1.3. Corridors and their management implications

- In IGWLS, the first corridor on the northern side (1) Monkey falls - Navamalai with non-forest area and Lower Aliyar Reservoir on the northern side, and contour canal and steep escarpment on the southern side, no simple management action could widen the corridor but tourist movement in Monkey falls especially during the dry season needs to be controlled.
- Elephant movement in the remaining three corridors in IGWLS (1) Attakatti – Upper Aliyar (2) Aiyarpadi – Waterfalls and (3) Siluvaimedu – Kadamparai is being constrained by the tea estates on one or either sides. Acquisition of lands from the tea estates can widen the corridors.
- Mattupatti – Mathikettan Shola and Theni Forest Division are cut off by the tea and cardamom Estates. Purchasing lands from estates in case of private lands or stopping the renewal of lease in case of government land leased out to estates is necessary, to maintain the forest contiguity. The forest contiguity between Elephant Ranges 9 and 10 having been cut off, very few elephants (likely to be one small herd of 4-8 elephants and two bulls) move from Munnar Forest Division to Theni Forest Division, but cause extensive damage to crops, properties and human lives. The compensation paid towards elephant damage takes a larger proportion of the funds (average Rs. 2-4 lakhs / year in the recent past). Diverting funds to protect a small proportion of the population, results in non-availability of sufficient funds for consolidating habitats of larger populations that are presently with minimal conflicts. Therefore there is a need for capturing such a small number of problem elephants and putting them into captivity, and also create a strong barrier between Munnar and Theni to prevent the elephant depredation to crops. Merely driving the elephants back to larger habitats (in Munnar Forest Division) and establishing the elephant barrier would still heighten the elephant-human conflict at the barrier location as elephants

show strong fidelity to their home and seasonal home ranges (Baskaran *et al.* 1995, Baskaran 1998).

6.1.4. Significance of vegetation and land use

- The study has shown that the landscape has diverse habitats ranging from tropical dry thorn forest, dry deciduous forest, moist deciduous forest, semi-evergreen to evergreen and montane climax grassland and shola vegetation, providing diverse resources required for the mega herbivores. However, the forested areas still consist of a large amount of mono-culture plantations of Teak, Eucalyptus, Wattle and Pine, which are relatively less used by elephants in all seasons as shown by the study; thus any more conversion of natural forest for such commercial mono-culture plantations needs to be stopped. Also, the existing monoculture stands need to be thinned out so as to allow diverse endemic plant species to regenerate for effective use of this space.

6. 2. ELEPHANT POPULATION AND ITS SPATIAL DISTRIBUTION

6.2.1. Elephant density and population

- Our density estimates based on the indirect count method shows that the elephant population in the landscape is higher than what was earlier reported (Bist 2002) for this Elephant Range and comparable to that of the Synchronized Elephant Census 2005 conducted by the forest department. The precision of our present estimate is also quite high in statistical terms. Considering the mean density of 1 elephant/km^2 estimated during dry and wet season, the present study estimated about 4000 elephants assuming that this density prevails over 4000 km^2 area of the reserve (the rest being too hilly and inaccessible). The higher numbers indicated by the dung count method for the landscape also means that the elephant population here is likely to be a more viable population in demographic terms.
- However, about 5% of the total population is isolated in the western part of the landscape (Idukki and parts of Kothamangalam) due to developmental activities coupled with topographical features. These isolated elephants are also in conflict with humans. So further planning of any developmental activities in the landscape should take this into account so as to ensure the long-term viability of the elephant population.

6.2.2. Elephant population structure

- Our population structure indicates a healthy birth rate but a skewed sex ratio from sub-adult class onwards based on a smaller sample size of <100 individuals. The sex ratio estimated based on synchronized elephant census data have showed less skew compared to the present study, which could be due to less experience of forest staff in collecting such information. Therefore a long term monitoring of population by trained personnel is required to understand the demographic features in terms of birth, death and growth rates of the population.

6. 3. THE ELEPHANT - HUMAN CONFLICT

- The rapid survey of elephant-human conflict in a sample of 466 farmers belonging to 176 villages in various Forest Divisions across the landscape has revealed that Forest Divisions in the eastern part of the landscape experienced significantly higher level of conflict than the Forest Divisions on the western side. The secondary data on human casualties, elephant mortality and capture due to conflict, and compensation amount paid towards elephant-human conflict also showed a similar trend.
- The higher degree of landscape transformations by human activities such as settlements, agriculture and hydro-electric projects resulting in loss and fragmentation of elephant habitats along with higher level of biotic pressure and highly palatable annual crops cultivated in Forest Divisions on the eastern side of the landscape, seemed to be the possible reasons for the high degree of elephant - human conflict in eastern areas compared to the western part of the landscape.
- Therefore, there is a need for consolidating the fragmented forest patches through acquisition of some private lands as stated in section 6.1.3.

6. 4. FOREST PERSONNEL CAPACITY BUILDING

- More exposure of the forest department field level staff to population estimation techniques, age classification, and ecological and behavioural aspects of elephants, is essential for collecting reliable data on long tem basis.

APPENDICES

Appendix 1. List of participants at the workshop on Elephant Census Techniques conducted for the Forest Officers at Vazhachal Forest Division on 20th October 2005

S. No	Name	Designation	Division
1	V. Sasidharan	Divisional Forest Officer	Kothamangalam
2	M.I. Vargehese	Divisional Forest Officer	Chalakudy
3	V.J. George	Divisional Forest Officer	Nemmara
4	S. Muraleedharan	Divisional Forest Officer	Vazhachal
5	Y. Atsase Thongtsar	Divisional Forest Officer	Malayattur
6	Roy P. Thomas	Wildlife Warden	Munnar
7	P.P. Cheriyan Kunju	Wildlife Warden	Idukki WLS
8	John Augustine Nirmal	Wildlife Warden	Peechi WLS
9	G.R. Mohandas	Asst. Wildlife Warden	Chimmony WLS
10	Saju Varghese	Forest Range Officer	Vazhachal
11	D. Krishnan Nambiar	Forest Range Officer	Munnar
12	B. Santhosh Kumar	Forest Range Officer	Eravikulam National Park
13	V.K. Sailesh	Forest Range Officer	Malayattur
14	N. Rajesh	Forest Range Officer	Nemmara
15	C.K. Vijay Kumar	Forest Range Officer	Mankulam
16	C.T. John	Forest Range Officer	Chalakudy
17	K.V. Mohammed Haneefa	Forest Range Officer	Munnar
18	G. Soman	Forest Range Officer	Malayattur
19	C. Sasikumar	Forest Range Officer	Nemmara
20	M. Venugopalan	Forest Range Officer	Vazhachal
21	K.V. Venu	Forest Range Officer	Vazhachal
22	Mashi Land	Forest Range Officer	Chalakudy
23	P. Satheesan	Forest Range Officer	Malayattur
24	P. Dhanesh Kumar	Forest Range Officer	Chalakudy

Appendix 2. List of participants at the workshop on Elephant Census Techniques conducted for the Forest Field Staff at Vazhachal Forest Division on 21st October 2005

S. No.	Name	Designation	Division
1	T.V. Prakasan	Deputy Range Officer	Chalakudy
2	A. Sasikumar	Deputy Range Officer	Vazhachal
3	D. Edison	Deputy Range Officer	Vazhachal
4	N.R. Rangaraju	Deputy Range Officer	Vazhachal
5	Saji Kumar Rayavath	Deputy Range Officer	Vazhachal
6	M.K. Ramesan	Forester	Chalakudy
7	P.S. Shailan	Forester	Chalakudy
8	M.A. Thomas	Forester	Chalakudy
9	P.K. Thangappan	Forester	Chalakudy
10	T.A. Paul	Forester	Chalakudy
11	K.M. Balan	Forester	Chalakudy
12	R. Sudheer	Forester	Chalakudy
13	C. S. Shaik Sahil	Forester	Vazhachal
14	K.J. Radhakrishnan	Forester	Vazhachal
15	G.G. Ramesan	Forester	Vazhachal
16	S. Hari	Forester	Vazhachal
17	T. Natarajan	Forester	Vazhachal
18	A.T. Thomas Paul	Forester	Vazhachal
19	P.T. Ignatius	Forest Guard	Chalakudy
20	V.K. Paul	Forest Guard	Chalakudy
21	M. A. Prasanth	Forest Guard	Chalakudy
22	P.A. Suresh	Forest Guard	Chalakudy
23	R. Jayakumar	Forest Guard	Chalakudy
24	K.L. Arunan	Forest Guard	Vazhachal
25	P.K. Shakeel Hameed	Forest Guard	Vazhachal
26	P.P. Ajit Kumar	Forest Guard	Vazhachal
27	K.A. Balan	Forest Guard	Vazhachal
28	P.K. Manoharan	Forest Guard	Vazhachal
29	T.J. Azad	Forest Guard	Vazhachal

Appendix 3. List of participants at the workshop on Elephant Census Techniques conducted for the Forest Field Staff at Parambikulam WLS on 22nd October 2005

S. No.	Name	Designation	Division
1	Shrawan Kumar Varma	Wildlife Warden	Parambikulam
2	P.R. Viswanathan	Forest Range Officer	Parambikulam
3	G. Pradeep	Forest Range Officer	Parambikulam
4	Jose Mathew	Forest Range Officer	Parambikulam
5	P. Pavithran	Forester	Parambikulam
6	B. Gopakumar	Forester	Parambikulam
7	P.K. Mujeeb Rahiman	Forester	Parambikulam
8	G. Murugesan	Forest Guard	Parambikulam
9	G. Hari Kumar	Forest Watcher	Parambikulam
10	K. Narayanan	Forest Watcher	Parambikulam

Appendix 4. List of participants at the workshop on Elephant Census Techniques conducted for the Forest Field Staff at Thattekad WLS on 24th October 2005

S. No.	Name	Designation	Division
1	K.M. Vijaya Kumara Nair	Asst. Wildlife Warden	Thattekad
2	D.E. Eshwaran	Forest Range Officer	Konni
3	P.V. Paramasivan	Deputy Range Officer	Malayattur
4	N. Sajeevarathan	Deputy Range Officer	Kothamangalam
5	V.V. Babu Raju	Deputy Range Officer	Kothamangalam
6	K.P. Mathew	Deputy Range Officer	Kothamangalam
7	K.K. Sabu	Forester	Malayattur
8	V.S. Abdul Nazar	Forester	Malayattur
9	V.V. Sarasan	Forester	Malayattur
10	M. K. Mathew	Forester	Malayattur
11	M.A. Paul	Forester	Malayattur
12	K.C. Surendran	Forester	Malayattur
13	P.M. Anil Kumar	Forester	Kothamangalam
14	C.T. Joseph	Forester	Idukki WLS
15	V.O. Mankoke	Forester	Thattekad
16	K.G. Rajesh	Forester	Malayattur
17	K.S. Salim	Forest Guard	Idukki WLS
18	M.M. Basheer	Forest Guard	Idukki WLS
19	A.G. Sunil Kumar	Forest Guard	Idukki WLS
20	K.R. Omprakash	Forest Guard	Malayattur
21	C.K. Rajan	Forest Guard	Idukki WLS
22	E.R. Soran	Forest Guard	Malayattur
23	M. Pushpakumaran	Forest Guard	Malayattur
24	E.B. Shajimon	Forest Guard	Kothamangalam
25	C. Premnath	Forest Guard	Malayattur
26	P.K. Kailasam	Forest Guard	Malayattur
27	P.V. Jacob	Forest Guard	Malayattur
28	K. J. Manju	Forest Guard	Malayattur
29	R. Anil Kumar	Forest Guard	Malayattur
30	T.K. Mahesan	Forest Guard	Malayattur
31	D. Sunil Kumar	Forest Guard	Malayattur
32	K.V. Veldho	Forest Guard	Kothamangalam
33	K.S. Sidhiq	Forest Guard	Thattekad
34	D. Vidhyadharan	Forest Guard	Idukki WLS
35	P.R. Jayaprakash	Forest Guard	Thattekad
36	G. Radhakrishnan	Forest Guard	Kothamangalam
37	T.A. Shaji	Forest Guard	Thattekad
38	Antu Joseph	Forest Guard	Thattekad
39	K.V. Abraham	Forest Watcher	Thattekad
40	Ramachandran	Forest Watcher	Thattekad

Appendix 5. List of participants at the workshop on Elephant Census Techniques conducted for the Forest Field Staff at Peechi WLS on 25th October 2005

S. No	Name	Designation	Division
1	E.P. Norbert Dilip	Asst. Wildlife Warden	Peechi WLS
2	K. Chandamara	Deputy Range Officer	Peechi WLS
3	S. Prasad	Forester	Chimmony WLS
4	V.K. Prasannan	Forester	Peechi WLS
5	P. Housef	Forest Guard	Peechi WLS
6	E. Radhakrishnan	Forest Guard	Peechi WLS
7	C.K. Sadanandan	Forest Guard	Peechi WLS
8	Chakappan	Forest Guard	Peechi WLS
9	T. Chandran	Forest Guard	Peechi WLS
10	Dinakaran	Forest Guard	Peechi WLS
11	V.R. Bose	Forest Guard	Chimmony WLS
12	K.S. Soman	Forest Guard	Peechi WLS
13	B.S. Bhadrakumar	Forest Guard	Nemmara
14	A.J. Frain	Forest Guard	Nemmara
15	Biju Thomas	Forest Watcher	Peechi WLS
16	Santhosh	Forest Watcher	Chimmony WLS
17	P.T. Reji	Forest Watcher	Chimmony WLS
18	M.K. Venugopalan	Forest Watcher	Chimmony WLS
19	K.N. Ravi	Forest Watcher	Peechi WLS
20	M.S. Subran	Forest Watcher	Peechi WLS
21	P.V. Lasser	Forest Watcher	Peechi WLS
22	Siby cheriyal	Forest Watcher	Peechi WLS
23	K.M. Santosh	Forest Watcher	Chimmony WLS
24	N.B. Shabu	Forest Watcher	Chimmony WLS
25	E.S. Suneesh	Forest Watcher	Chimmony WLS
26	M. Sashi	Forest Watcher	Peechi WLS

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