Ecology of elephant (*Elephas maximus*) in South-West Bengal including population dynamics, migratory pattern, feeding habits and human-elephant conflict

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Salim Ali Centre for Ornithology and Natural History
(A Centre of Excellence under the Ministry of Environment
Forest and Climate Change, Govt. of India)
Anaikatty Post, Coimbatore-641108, Tamil Nadu

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TABLE OF CONTENTS

TOPIC	PAGE NO.
1. Background and habitat characteristics of South West Bengal	
1.1 Introduction	3
1.2 Objectives	5
1.3 Study Site	5
2. Stand structure and species composition of vegetation in South Bengal	
2.1 Introduction	11
2.2. Methods	12
2.3 Results	16
2.4 Discussion	23
3. Range expansion of elephants in South Bengal	
3.1 Introduction	25
3.2 Methods	25
3.3 Results	26
3.4 Discussion	40
4. Population status and social organization of elephants in South Bengal	
4.1 Introduction	42
4.2 Methods	44
4.3 Results	49
4.4 Discussion	51
5. Path length and habitat use by elephants in South Bengal	
5.1 Introduction	55
5.2 Methods	57
5.3 Results	57
5.4 Discussion	66
6. Feeding ecology of Asian elephants in South Bengal	
6.1 Introduction	68
6.2 Methods	68
6.3 Results	70
6.4 Discussion	76
7. Human and Elephant interactions in South Bengal	
7.1 Introduction	82
7.2 Methods	83
7.3 Results	86
7.4 Discussion	105
8. People and their perception on elephants in South Bengal	
8.1 Introduction	108
8.2 Methods	109
8.3 Results	109
8.4 Discussion	114

9. Carrying capacity of elephants in Mayurjharna elephant reserve	
9.1 Introduction	118
9.2 Methods	118
9.3 Results	120
9.4 Discussion	121
10. Conclusion	124
Annexure -1: Management Plan	153
Appendices	
Chapter I. Background to the Management Plan	128
Chapter II. Population Monitoring	130
Chapter III. Resource Management	136
Chapter IV. Conflict Management	140
Chapter V. Management of Crucial Crossing Points and Corridors	148
Chapter VI. Overview of Current Mitigation Measures	154
Chapter VII. Management of Mayurjharna Elephant Reserve	163
References	167

LIST OF FIGURES

Figures	Page No.
Figure. 1.1 Forest Divisions in South Bengal including Mayurjharna Elephant Reserve	9
Figure. 1.2 Forest cover of South Bengal including Mayurjharna ER	9
Figure. 1.3 Average rainfall in different districts of South Bengal (data of the year 2017)	10
Figure. 1.4 Average temperature in different districts of South Bengal (data of the year 2017)	10
Figure 1.5 Average humidity in different districts of South Bengal (data of the year 2017)	11
Figure. 2.1 Forest cover in Mayurjharna ER and different Forest Divisions of South Bengal	16
Figure 2.2 Location of sampling plots for vegetation assessment in South Bengal	17
Figure 2.3 Comparison of stand density (stems per ha) and basal area in different girth class of tree species (line)	20
Figure 2.4 Distribution of tree families in South Bengal	21
Figure 2.5 The species accumulation curve using Chao-2	22
Figure 2.6 Comparison of stand density (stems per ha) and basal area in different girth class of tree species in Mayurjharna ER	25
Figure 2.7 Distribution of tree families in Mayurjharna Elephant Reserve	25
Figure 3.1 Overlay of grids (10 X 10 km) on forest cover of South Bengal	29
Figure 3.2 Overlay of grids on a map of forest cover of Mayurjharna ER	30
Figure 3.3 Locations of Mayurjharna Elephant Reserve and Dalma Wildlife Sanctuary	31
Figure 3.4 Area used by elephants in Mayurjharna ER between 1950 and 60	32
Figure 3.5 Area used by elephants in Mayurjharna ER between 1960 and 70	32
Figure 3.6 Area used by elephants in Mayurjharna ER between 1970 and 80	33
Figure 3.7 Area used by elephants in Mayurjharna ER between 1980 and 90	33
Figure 3.8 Area used by elephants in Mayurjharna ER between 1990 and 2000	34
Figure 3.9 Area used by elephants in Mayurjharna ER between 2000 and 2010	34
Figure 3.10 Area used by elephants in Mayurjharna ER between 2010 and 2018	35
Figure 3.11 Dalma Wildlife sanctuary, Mayurjharna ER, and other locations in South Bengal	37
Figure 3.12 Area used by elephants in South Bengal between 1950 and 1960	38
Figure 3.13 Area used by elephants in South Bengal between 1960 and 1970	39
Figure 3.14 Area used by elephants in South Bengal between 1970 and 1980	40
Figure 3.15 Area used by elephants in South Bengal between 1980 and 1990	41
Figure 3.16 Area used by elephants in South Bengal between 1990 and 2000	42
Figure 3.17 Area used by elephants in South Bengal between 2000 and 2010	43
Figure 3.18 Area used by elephants in South Bengal between 2010 and 2018	44
Figure 3.19 Route followed by elephants while traveling from Dalma Wildlife Sanctuary, Hazaribagh area and Ranchi in Jharkhand state	45

Figure 4.1 Different dung stages for scoring to estimate the dung decay rate	52
Figure 4.2 Belt transects in Rupnarayan and Medinipur Forest Divisions	53
Figure 4.3 Transect line/belts in Mayurjharna ER	54
Figure 4.4. Belt transect for dung count	54
Figure 5.1 The intensity of habitat use by elephant herd-1 in Kharagpur Forest Division	65
Figure 5.2 The intensity of habitat use by elephant herd-7 in Kharagpur Forest Division	66
Figure 5.3 The overall intensity of habitat use by both the elephant herds in Kharagpur Forest Division	66
Figure 5.4. The intensity of habitat use by elephants in Rupnarayan Forest Division	67
Figure 5.5. The intensity of habitat use by elephant herd-1 in Medinipur Forest Division	67
Figure 1.6. The intensity of habitat use by elephant herd-7 in Medinipur Forest Division	68
Figure 5.7. The intensity of habitat use by all the elephant herds in Medinipur Forest Division	68
Figure 5.8. The intensity of habitat use by elephant herd-1 in three forest divisions of Kharagpur, Medinipur and Rupnarayan	69
Figure 5.9. The intensity of habitat use by herd-7 in the three forest divisions of Kharagpur, Medinipur and Rupnarayan	69
Figure 5.10. The intensity of habitat use by both the herds in Kharagpur, Medinipur and Rupnarayan Forest Divisions	70
Figure 5.11. The movement pattern of local elephant herds in Rupnarayan, Medinipur and Kharagpur Forest Divisions	71
Figure 5.12. The relationship between elephant path length and their herd size	72
Figure 5.13. Mean path length of the elephants in different months	72
Figure 5.14. The path length of elephants in different conditions in South Bengal	73
Figure 6.1. Location of plots taken for feeding by elephants inside the forest in the three divisions of Rupnarayan, Medinipur and Kharagpur Forest Divisions	78
Figure 6.2. Location of plots taken for crop feeding by elephants in the three divisions of Rupnarayan, Medinipur and Kharagpur Forest Divisions	79
Figure 7.1 Human death locations due to elephants in South Bengal from 2010 to 2018	94
Figure 7.2 Mean number of human deaths due to elephants at South Bengal in different years	95
Figure 7.3 Mean number of human deaths due to elephants in different forest divisions of South Bengal	95
Figure 7.4 Mean number of men and women deaths due to elephants in different years at South Bengal (blue bar: men; green bar: women)	96
Figure 7.5 Mean number of men and women deaths due to elephants in different forest divisions of South Bengal (blue bar: men; green bar: women)	96
Figure 7.6 Number of human deaths due to elephants in different months of the	97
years between 2010 and 2018.	

Figure 7.7 Number of human deaths due to elephants in different months of the year at South Bengal	97
Figure 7.8 Human deaths due to elephants in different timings of the day (24-hour cycle) at South Bengal	98
Figure 7.9 Cold and hot spots (forest range level) of human death in the study site during 2010-2012.	101
Figure 7.10 Cold and hot spots (forest range level) of human death in the study site during 2013-2015.	102
Figure 7.11 Cold and hot spots (forest range level) of human death in the study site during 2016-2018.	102
Figure 7.12 Cold and hot spots (forest range level) of human death (Overall) in the study site during 2010-2018.	103
Figure 7.13 Three-year interval (i.e., 2010-2012, 2013-2015 and 2016-2018) spatiotemporal clusters (circles) of human death across the study site analyzed by SaTScan (R=Radius). Values within or next to each circular cluster describing the characteristics of each cluster, where R is the radius of the cluster and bellow that the year when the outbreak started.	104
Figure 7.14 Activists of the deceased were engaged while their death occurred due to elephants.	105
Figure 7.15 Hotspot analysis of human deaths due to elephants in South Bengal: A. While traveling to or from the village, B. while had gone out for open defecation, and C. Overall deaths.	107
Figure 7.16 Location of human injuries due to elephants between 2010 and 2018 in South Bengal.	108
Figure 7.17 Percent of human injuries due to elephants in different divisions of South Bengal.	109
Figure 7.18 Percent of human injuries in different months in South Bengal	109
Figure 7.19 Percent of circumstances in human in injuries occurred due to elephants in South Bengal.	110
Figure 8.1 Locations (red dot in the map) of the interview in South Bengal	117
Figure 8.2 Locations (black dot in the map) of the interview in Mayurjharna ER	117
Figure 9.1 Map showing distribution of above ground biomass in Mayurjharna ER	128

LIST OF TABLES

Tables	Page No.
Table 1.1 Details of the forest divisions and their ranges	6
Table 2.1 Calculating quantitative structure and composition of plant communities	16
Table 2.2 Community structure of woody trees in South Bengal	18
Table 2.3 Importance Value Index of tree species in South Bengal	19
Table 2.4 The stand density, species richness and basal area under various girth	20
classes of tree species	

Table 2.5 Community structure of woody trees in Mayurjharna Elephant Reserve	22
Table 2.6 Important Value Index of tree species in Mayurjharna ER	23
Table 2.7 The stand density, species richness and basal area under various girth classes of trees in Mayurjharna ER	24
Table 3.1 Area used by elephants and their entry and exit locations in Mayurjharna ER	31
Table 3.2 Area used by elephants in South Bengal over a period of six decades (1950 to 2018)	35
Table 4.1 Estimates of elephant density using dung count method for Rupnarayan and Medinipur forest divisions and Mayurjharna ER	56
Table 4.2 Sampling effort and detection of elephants in Mayurjharna ER	57
Table 4.3 Details of the elephant herds in South West Bengal	57
Table 4.4 Estimate of Asian elephant density from other parts of the country	60
Table 4.5 Herd size and age-sex ratios of Asian elephants from protected areas in India	61
Table 5.1 Number of days the focal herds were followed and the grids utilized in the forest Divisions of Rupnarayan, Medinipur and Kharagpur	65
Table 6.1. Preference index (PI) for the most important species in the diet of elephants	79
Table 6.2. Preference index (PI) for the most important species in the diet of elephants according to different seasons	80
Table 6.3. Total Estimated crop damage by elephants according to different seasons in Medinipur Forest Division	80
Table 6.4. Total Estimated crop damage by elephants according to different seasons in Kharagpur Forest Division	81
Table 6.5. Total Estimated cro p damage by elephants according to different seasons in Rupnarayan Forest Division	82
Table 6.6. Total Estimated crop damage by elephants according to different seasons in the study area	83
Table 7.1. Description of the activities or circumstances of the victim during the accident considered to group them under a broader category of activity.	92
Table 7.2. Number of human deaths due to elephants in different forest divisions of South Bengal between 2010 and 2018.	93
Table 7.3 The percent human deaths in forest and non-forest area and awareness of the presence of elephants in different forest divisions	99
Table 7.4 Variation in human death hotspots between 2010 and 2018	99
Table 7.5 Name of beats falling under human death hotspots	100
Table 7.6 Indicating ratios within and between hot-and cold-spot eclusters based on the sum of square estimates in every three years (K-means Cluster (2) performed in GeoDa software	101
Table 7.7. Details of outbreak clusters across the study period	103
Table 7.8 Details of the human deaths due to elephants in Mayurjharna ER	106
Table 7.9. Details of the elephant deaths that occurred in South Bengal	111

Table 7.10. Seasonal crop depredation by elephants in Medinipur, Rupnarayan and Kharagpur Forest Division	112
Table 8.1 Socio-economic characteristics of respondents	119
Table 8.2 Views of respondents on elephants	120
Table8.3 Respondents' views on the reasons and the response of the department towards elephants	120
Table 9.1 Biomass availability of food species and their estimated consumption by Elephants in Mayurjharna ER.	127

LIST OF PLATES

Tables	Page No.
Plate 1	85
Plate 2	86
Plate 3	87
Plate 4	114
Plate 5	123
Plate 6	130

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Extended summary

In the recent past, the range expansion of Asian elephant is noticed in South West Bengal from the Dalma Wildlife Sanctuary in the adjoining state of Jharkhand. Now, elephants have become almost residents and their increased presence in the landscape of South Bengal has led to severe human-elephant conflict. Thus, to understand the ecology of elephants and associated issues in South Bengal to provide inputs for the conservation action plan, we conducted this study with the following objectives:1) study the elephant ecology including its demography, population trend, migratory pattern, resident population movement patterns, elephant corridors, and habitat utilization, 2) study the habitat of Mayurjharna Elephant Reserve in South-West Bengal and assess its carrying capacity and develop an Elephant Management Plan for the South-West Bengal including Mayurjharna Elephant Reserve, and 3) study and analyze the human-elephant conflict in South-West Bengal including preparation of conflict map and suggest mitigation measures to minimize the conflict.

The understanding of the vegetation and its probable effects on the fauna in an areais a requisite for appropriate conservation and management plans. Our findings in South Bengal and the Mayurjharna Elephant Reserve (Mayurjharna ER) show that *Shorea robusta* is the most dominating tree species in the landscape. The practice of plantations of *S. robusta*and associated species, for timber, has decreased the diversity and species richness in the forests and that has a major impact on the natural habitat of elephants forcing them to strayout to agriculture fields and human habitations.

The movement of elephants from Dalma Wildlife Sanctuary towards the Mayurjharna ER due to severe land mining in the latter has increased considerably in the last few decades. Elephants, which were earlier confined to certain pockets of Mayurjharna ER,have now expanded into the other parts of South Bengal i.e. Medinipur, Kharagpur, Jhargram, Rupnarayan, Panchet, Bankura North, and Bankura South forest divisions. Despite the absence of continuous forest patches, the expanse of the area utilized by the animals has increased. The presence of ample land under agriculture to feed on has lured the elephants to this region, and though the movement is restricted to specific areas, the time spent there has increased due to the barricades erected by the Odisha government along the borders.

Estimation of elephant population was made using two field techniques- dungcount surveys (Rupnarayan and Medinipur Forest Divisions and Mayurjharna ER) and distance sampling (Mayurjharna ER). Dung count surveys in Rupnarayan and Medinipur forest divisions, provided the density of 0.518 and 0.003 elephants/ km^2 respectively. In the Mayurjharna ER, density could not be estimated due to no detection of elephants despite 620.40 km of transect walk. The elephant population in this area is continuously on the move;unnatural movement as they are being regularly driven out for long distances, and that makes estimating their populations using the above two methods all the more difficult. However, a good number of immatures in the population indicates that the population is reproductively fit and thriving in the area.

The identified elephant herds (Herd-1 and Herd-7) were followed between August 2017 and December 2018 and their habitat use and feeding ecology were documented. Although elephants spent the daytime in the forests, usually closeto agricultural fields, they stray out in the night to agriculture fields for crop raids. The high presence of cropspecies in their diet revealed their dependency on agriculture and the lack of adequate fodder species in the forests. The agricultural crops, being rich in nutrients, are preferred by the elephants despite the high risk of human interactions. The natural movement of elephants is highly influenced by the *hula* drives, the local drives conducted to reduce the crop depredation by elephants, thereby completely altering their natural movement pattern.

Conflict in south Bengal is inevitable due to the lack of continuous and sufficiently rich forest patches and the presence of vast expanses of agricultural land. Thereby, a high number of human deaths and injuries occur in non-forested areas. Continuous driving of elephants agitates and irritates them,and that leads to more conflicts. Medinipur forest divisions suffered maximum loss of human lives due to restriction of movement of elephants to other areas by barricades, thus forcing them to limit their natural tendency to move out and agitating them leading to more human-elephant conflicts. The retaliatory killing of elephants either by poisoning or electrocuting is common in the area for the excessive human life and the economic losses incurred due to elephants. The livelihood of the local people is dependent on the single crop that they grow in a year. If the elephants depredate croplandsit is the major reason for people in the area not to accept them in their agriculture fieldssince these animals make their survival difficult. Although they have respect for elephants, the loss incurred overrides theirsympathy for it.

The carrying capacity for any region provides us with the equilibrium between the population of a species and its resources in an area and the same was also assessed for Mayurjharna Elephant Reserve.

The study area is a fragmented and landscape dominated with sal trees with very sparse population of fodder plants for elephants, and the unusual and violent behaviors of local people are the inherent constraints to hold the elephant population in South Bengal.

The present study provides detailed information regarding elephant population structure, movement pattern, theirdependency on agricultural crops to gratify their dietary requirements, problems of increasing conflicts in the area, and the management possibilities in the landscape of South Bengal including Mayurjharna ER.

TECHNICAL CHAPTER

Ecological profile ofsouthern West Bengal

1.1.Introduction

Asian elephants, once abundant from West Asia to the Indian subcontinent, South-East Asia and China spread over 9 million km² (Sukumar 2003),are now extinct in West Asia, Java, and most of China.They presently occur in 13 countries, with an approximate range area of 4,86,800 km²that include Bangladesh, Bhutan, India, Nepal and Sri Lanka in South Asia, and Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand, and Vietnam in South-East Asia. Even within theirpresent range the species is decliningand existsonly as fragmented populations (Sukumar 2003; Blake and Hedges 2004). In India, there are four major populations- north-eastern, central, north-western, and southern. The north-easternpopulation extends through northern West Bengal,western Assam, and Arunachal Pradesh, Assam, Nagaland and Meghalaya. The central population is found in the states of Odisha, Jharkhand, and southern West Bengal.The north-westernpopulation occurs in Uttaranchal andUttar Pradesh. The southern population occurs in the hilly terrains of the Western Ghats and parts of the Eastern Ghats in Karnataka, Kerala, Tamil Nadu, and Andhra Pradesh. An earlier estimate of the global population of Asian elephant was 41410 - 52345 animals, of which 26390- 30770 are in India (Sukumar 2003).

Asian elephants have always been an integral part of Indian culture andmythology.The elephant-headed god Ganesha is one of the most widely adored Hindu gods in the subcontinent. Many Harappan seals depict elephants on them (Narain 1991). Elephants have been an integral part of our society and culture especially on any grandiose occasions, as illustrated by the role ofelephants in wars by Rajput kings and Mughal rulers (Digby 1971), mass elephant hunting festivals during the British rule (Lahiri-Choudhury 1999), and even the contemporary use of elephants in temple functions in South India (Sukumar 2003). Apart from the cultural importance, the Asian elephants being the keystone species (Chatterjee 2016) and one of the mega-herbivores have remarkable ecological importance due to their high impact on the habitat through their feeding and other activities (Sukumar 2003). However, despite their coveted role in Indian culture, their life in the wild is not trouble-free; habitat loss and incessant fragmentation of the habitats in recent years has forced them to trudge towards human habitations and depredate croplands. These depredationslead to high conflict between humans and elephants . Such confrontations give rise to increasing animosity between humans and elephants, further leading to them getting slaughtered (Sukumar 2003).

Historically, reports on elephants in South West Bengal dates back to the early 1900, where large elephant herds were reported in dense sal forests of West Medinipur and adjoining areas during the colonial period (O'Malley 1911). In consecutive years, due to the loss of forests in SouthWest Bengal, elephants probably disappeared from the landscape (Palit 1991). By 1955 when private forests were transferred to the forest department, barely any resident wild elephants were known to be present in the region (Palit 1991). Later on,until the mid-1980s elephants got limited only to the border areas of West Bengal and Bihar witha few individualsscattered in Ajodhya hill, Bandawan, Banspahari, and Ranibandh area (Chatterjee 2016). However, in the late 80sas vast areas of these degraded forests regenerated through Joint Forest Management (JFM) (Malhotra and Poeffenberger 1989), the elephants started getting attracted into the area (Palit 1991; Malhotra 1995; Panda 1996). In addition, land mining in the Singhbhum district of Jharkhand adjoining Dalma Wildlife Sanctuary that led to severe disturbances in the once flourishing forests (Singh and Chowdhury 1999) probably forced the elephants to move out towards forests of Mayurjharna in South West Bengal. Herds from Dalma Wildlife Sanctuary started moving in the months between October and December attracted by the paddy crop fields,but they were restricted only until the west of Kangsabati River (Dey 1991). Shahi (1980) reports the visit of 42 elephants in 1976 into Purulia District from Dalma to Sindri, wherein they stayed for 20 days and damaged paddy fieldskilling two people.He also reported elephant movement through the Banspahari and Belpahari region in September and some incidences of crop damage in West Medinipur during the same time. The first long-distance movement by elephants from Dalma Wildlife Sanctuary to East Medinipur district beyond the Kangsabati river was recorded in the year 1987 (Dey 1991; Datye and Bhagwat 1995).

According to a study by Dey (1991), 50 elephants from the Motgoda range of Bankura district crossed the river Kangsabati in 1987 and moved southward to enter the Lalgarh Range of East Midnapore Forest Division. Such movement of elephants in successive years continued and expanded to the east, exploring new areas, which resulted in prolonged stays of elephants in south-West Bengal. The use of the Mayurjharna region by elephants as an entry point from Dalma Sanctuary, their increased stay in South West Bengal and to minimize man-elephant conflict in the zone of influence led to the development of Mayurjharna as an Elephant Reserve under the Governmentof India's 'Elephant Project' scheme. On 24th October 2002, 414 km^2 of forest area falling in the district of Purulia, Bankura, and East Medinipur was declared as 'Mayurjharna Elephant Reserve'.

In the context of the escalating human-elephants conflicts the current study was undertaken with the following objectives:

1.2. Objectives

1. To study the elephant ecology in SouthWest Bengal (Paschim, Medinipur, Bankura, Purulia, Birbhum, and Burdwan districts), including the elephant demography, population trend, migratory pattern, resident population movement patterns, elephant corridors, habitat utilization, and related aspects.
2. To study the habitat of Mayurjharna Elephant Reserve in South-West Bengal and assess its carrying capacity and develop an Elephant Management Plan for the South-West Bengal including Mayurjharna Elephant Reserve.
3. To study and analyze the human-elephant conflict in South-West Bengal including preparation of conflict map and suggest mitigation measures to minimize human-elephant conflict in a participatory manner.

1.3.Study area

The study covered the districts of Paschim Medinipur, Bankura, Jhargram, Purulia, Birbhum, Paschim Bardhaman and Purv Bardhaman in southern West Bengal. The western part of the study area is hilly and undulating being an extension of Chota Nagpur plateau, while the eastern part consists of flat Gangetic plains. Geologically, the western part of south West Bengal has the oldest rocks, the granites, and schist from Precambrian age (Dasgupta 1989). The area comprises of 13 forest divisions namely, Kharagpur, Medinipur, Jhargram, Rupnarayan, Panchet, Bankura South, Bankura North, Kangsabati South, Kangsabati North, Purulia, Durgapur, Burdwan, and Birbhum (Fig. 1.1). The geographic areas of the forest divisions and their ranges are given in Table 1.1.

Table 1.1 The forest divisions and ranges in the study area

Divisions	Ranges	Area (in km^2)
Rupnarayan	Amlagora Garhbeta Goaltore Hoomgarh Mahalisai	845
Purulia	Ajodhya Arsa Bagmundi Balarampur Jhalda Joypur Kotshila Matha	1948
Panchet	Bankadaha Bishnupur Joypur Onda Taldangra	1246
Medinipur	Arabari Bhadutala Chandra Chandrakona Godapeasal Lalgarh Medinipur Nayabasat Pirakata	1852
Kharagpur	Belda Chandabilla Egra Ghatal S.F Hijli Kalaikunda Keshorekha Nayagram Panskura	4484
Kangsabati South	Bandwan-I Bandwan-II Barabazar Jamuna Manbazar-I Manbazar-II	1487
Birbhum	Bolpur Mahammadbazar Rajnagar Rampurhat Sainthia Suri	4553

Divisions	Ranges	Area (in km^2)
Kangsabati North	Hura Kashipur Para Puncha Raghunathpur	2888
Jhargram	Banspahari Belpahari Bhulaveda Gidhni Gopiballabhpur Hatibari Jamboni Jhargram Lodhasuli Manikpara Parihati Silda	2155
Durgapur	Asansol Ukhra	1336
Burdwan	Burdwan Durgapur Guskara Memari Panagarh	5689
Bankura North	Bankura (N) Barjora Beliatore Gangajalghati Jhantipahari Mejhia Patrasayer Radhanagar Saltora Sonamukhi	2985
Bankura South	Bankura Fulkusma Indpur Jhilimili Kamalpur Khatra-I Khatra-II Motgoda Pirargari Ranibandh Sarenga Simlapal	2639

The Mayurjharna ERis located at the tri-junction of the districts of West Medinipur, Purulia, and Bankura between 23°27′ N and 22°23′ N and 86°27′E and 87°32′ E bordering Jharkhand. The area comprises of Belpahari, Banspahari, and Bhulabheda forest ranges of Jhargram Forest Division, and Bandwan-I, Bandwan-II, Manbazar-II and Jamuna forest ranges of Kangsabati (South) Forest Division; and Jhilimili, Fulkusma, Ranibandh, and Motgoda forest ranges of Bankura (South) Division totalling to 473.23 km^2.

Topography and Soil: The topography of the landscape is gently undulating, with hillocks on the western side and a stretch of flatlands towards the east, and it varies in altitude from 200m to 670m. Contour spacing reveals that the eastern elevation is still gentler. Elevation becomes prominent as it approaches the Chotanagpur plateau. The Ajodhya hill is the highest peak reaching an altitude of 670 m. The second highest peak, Lakaisini Pahar, reaches an altitude of *ca*. 500 m and it is located westward on Jharkhand-Bengal border. The soil is the red, sandy, lateritic, and alluvial type with red and black soils in a few pockets.

Hydrology: There are four major river systems in the area under study *viz*., Subarnarekha, Kangsabati, Silabati, and Darakeswar. There are also a few minor rivers and perennial streams such as Kumari, Totko, Tarafeni, Tamal, and Kubai. The region also hasnumerous man-made water bodies and ponds in the villages. The canal networks of the Kangsabati dam atMukutmanipur in Bankura district is a major source of irrigation in the region (Singh et al. 2002)

Climate:There are three distinct seasons i.e., summer, monsoon, and winter. The summer is extreme and lasts from the middle of March to the middle of June with April, May, and June being the hottest months. The maximum temperature fluctuates between 42˚C and 46˚C and the minimum temperature varies between 8˚C and 13˚C. The monsoon period is from mid-June to end of the September with moderate rainfall. The average annual rainfall varies in the region with 1428 mm in Midnapore, 1271 mm in Bankura, and 1180 mm in Purulia (Ghosh 1992). The rainfall decreases October onwards and dry winter sets in November and lasts up to February.

Vegetation: The vegetation type in the area in general is tropical dry deciduous dominated bysal *(Shorea robusta)*. According to Champion and Seth (1968), the forests belong to category 5B of group 5 and are represented by types C1/1C, C2, DS1,E5, E7, and 2S1. Based onthe composition, the forest types can be divided into four broad categories i.e. sal-coppice, open scrub forests with sporadic saland thorny bushes, and plantations. The composition of forests varies from 82% sal in the western hilly tract to 95 % sal in the eastern undulating plains (FSI 1985). Many associate species found here include *Pterocarpus marsupium, Diospyrosmelanoxylon, Madhuka latifolia, Schleichera trijuga, Adina cordifolia, Terminalia tomentosa, Terminalia bellirica, Soymida febrifuga, Anogeissus latifolia* (Santra et al. 2008)

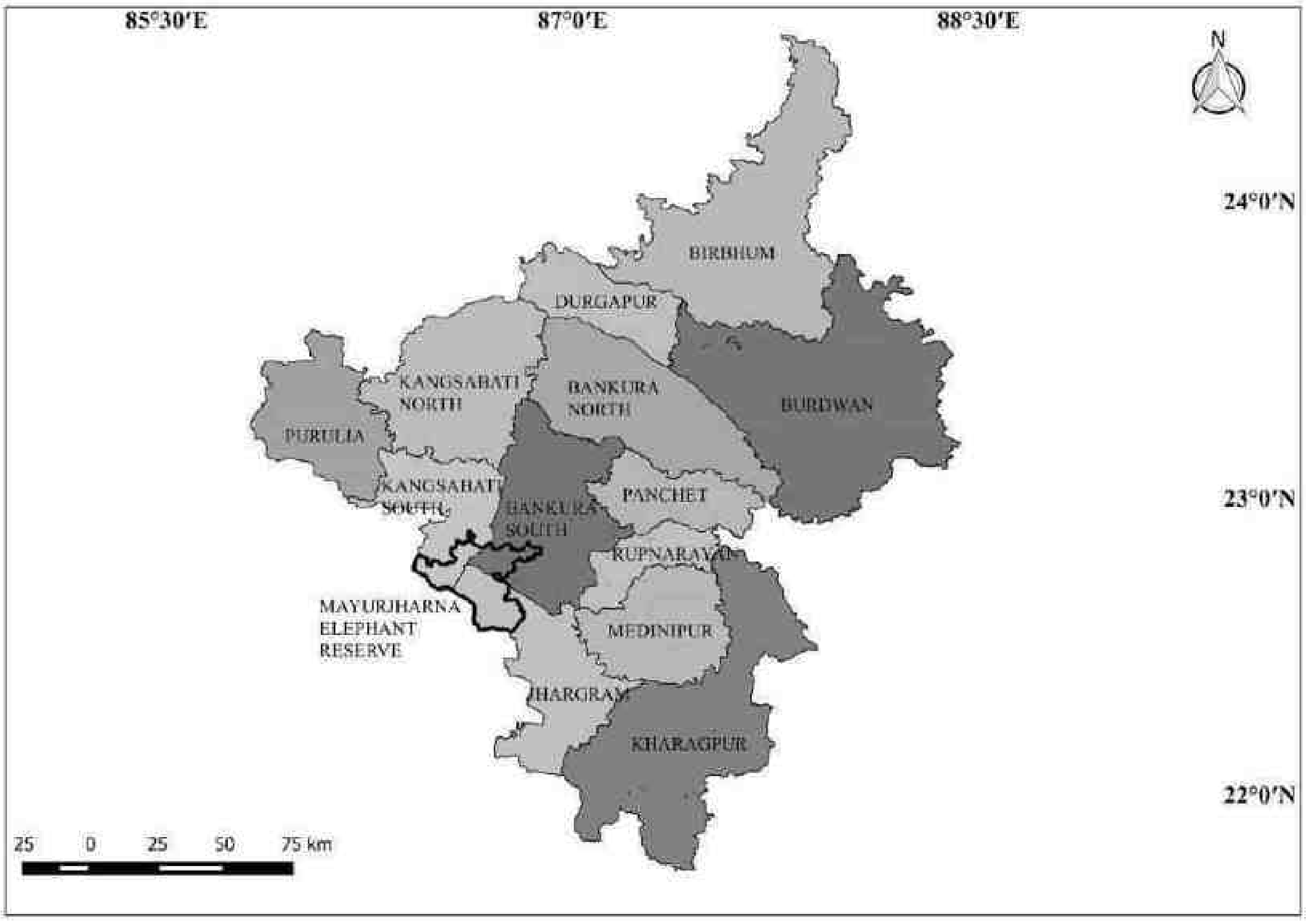

Figure1.1 Forest Divisions in South Bengalincluding Mayurjharna ER

People: The number of villages in Bankura is 3585, 2242 in Birbhum, 7600 in Paschim Medinipur, 2459 in Purulia, and 7024 in Bardhman district. Some part of the landscape is inhabited mostly by Santal, Lodha, Sabar, Kheria tribes, intermixed with local Bengali people as well as migrants from Odisha, Jharkhand, and Bihar. These districts are densely populated with523 people/ km^{2}in Bankura, 771 in Birbhum, 631 in Medinipur, 468 in Purulia, and 1100 in Bardhman Districts (Chandramouli and General 2011). Some of the villages practice farming almost throughout the year with the help of irrigation facilities; however, most of the areas still grow one crop in a year during the monsoon. The major crop grown in the landscapeis paddy which is grown once or twice a year depending on water availability.Potato is also grown in many parts of the study area, and it is one of the important cash crops for south Bengal. Other vegetables are also grown in this area such as brinjal, bitter gourd,and snake gourd. In some parts of areas like Kharagpur sugarcane is also grows to some extent.

CHAPTER-II

Vegetation composition

2.1. Introduction

The principal aim of a study on quantitative vegetation is to define the vegetation, and explain the pattern, categorize and organize it in a significant manner (Ilorkar and Khatri 2003). The characteristics of vegetation play an important role in determining the distribution and diversity of animals in a particular habitat (MacArthur 1972). The herbivore population, in turn, is known to affect the forest composition of an area (Nuttle et al. 2013). The increasing human activity in and around forests changes the total biodiversity of the region (Swaine et al. 1987; Abdulhadi et al. 1987). Such changes cause massive impacts on ecological and ecosystem services such as prevention of soil erosion, maintenance of hydrologic and nutrient cycles, decomposition, and productivity of soil (Loreau et al. 2001). The effective management of dynamic plant communities requires an understanding of the basic processes involved in vegetation change (Niering 1987). A sound understanding of species diversity is necessary for appropriate conservation and restoration of biological diversity.

There has been uncontrolled forest destruction in South Bengal during the expansion of the Bengal Nagpur railway line in 1889 followed by the railway tracks through Medinipur district in 1903 (Palit 1991). Such massive destruction of forests pressed the government to establish a committee in 1938, which led to the Bengal Private Forest Act of 1945mandating the landowners to plant and restore the forests that they have felled. In 1981, under the joint forest management (JFM) programme, the Social Forestry Project was launched with the objective of planting fast-growing tree species on public and private lands to meet the fuel demands of the local people (Malhotra and Poffenberger 1989) e.g. *Eucalyptus* sp., akashmoni (*Acacia auriculiformis*), and mahua (*Madhuca longifolia*). However, these regenerated forests of sal and other fast-growing species replaced the indigenous plant species of lateritic tracts. Thus, within the last one and a half-century, the forests were modified due to the replacement of the indigenous species by largely exotic speciesand hence that have been classified as sal dominant deciduous forest (Champion and Seth 1968). Given the possible impacts of such drastic changes in vegetation on the animals living in the area, it is indeed essential to document the present species composition and vegetation of South Bengal.

Also, in south Bengal, elephants have been known to raid the crops to a great extent and it is important to understand that crop-raiding by elephants is triggered by nutritional stress caused by a decline in the quality and nutritive value of natural forage (Osborn 2004). Documenting the vegetation structure is valuable for continuing ecological research, management, and conservation of elephants. Therefore, to understand the natural forests and food resource availability, the stand structure and tree species composition was assessed

2.2. Methods

Major forest areas in Bankura North, Bankura South, Kangsabati North, Kangsabati South, Purulia, Panchet, Medinipur, Rupnarayan, Jhargram, and Kharagpur forest divisions in South Bengal including Mayurjharna ER were identified and categorized (Fig. 2.1). The forests of the region fall under category 5B of group 5 and are represented by types C/1C, C2, DS1, E5, E7, and 2S1 based on species composition (Singh 2006).

In the select forest patches, 10 x 10 m quadrats were randomly laid and woody plants in 708 quadrats (119 quadrats in Mayurjharna ER and 589 quadrats in total in other divisions: Fig. 2.2) were sampled. In each quadrat, all the stems with >10 cm of GBH (Girth at Breast Height) were considered as woody species (Hall and Okali, 1979) and assessed. Each stem was recorded with the name of the species and their girth (GBH) measured at 1.3 m height from ground level (Fig. 2.3).

Analysis: Quantitative community characteristics (Table 2.1) such as frequency, density, abundance, relative frequency, relative density, relative abundance, relative dominance, Importance Value Index (IVI), and composition of plant communities were computed following Curtis and McIntosh (1950), Philips (1959) and Muller-Dombois and Ellenberg (1974). The Shannon diversity index (H′) was also calculated (Mori et al.1983).

Frequency, the number of quadrats in which a species occurs, expressed as a percentage of the total number of quadrats examined (Curtis and McIntosh 1950).

Density, the number of plants of a certain species per unit area, was expressed by converting the number of individuals per plot into per hectare using appropriate conversion factors (Goldsmith et al. 1986).

Abundance denotes the average number of individuals of a species per quadrat considering all the quadrats in which it occurs.

Basal area (BA) was calculated based on the diameter measurements of the tree stems with GBH of ≥ 10 cm and expressed in square meter per hectare.

The *Importance Value Index* (IVI) permits a comparison of species in a given forest and depicts the sociological structure of a population in its totality in the community. It often reflects the extent of the dominance, occurrence, and abundance of a given species in relation to other associated species in an area (Kent and Coker 1992).

The *Simpson's Index* is a measure of diversity, which takes into account the number of species present as well as the relative abundance of each species. As species richness and evenness increase, so does the diversity. To determine the adequacy of the sample size, species accumulation trajectory was examined using Estimate-S software.

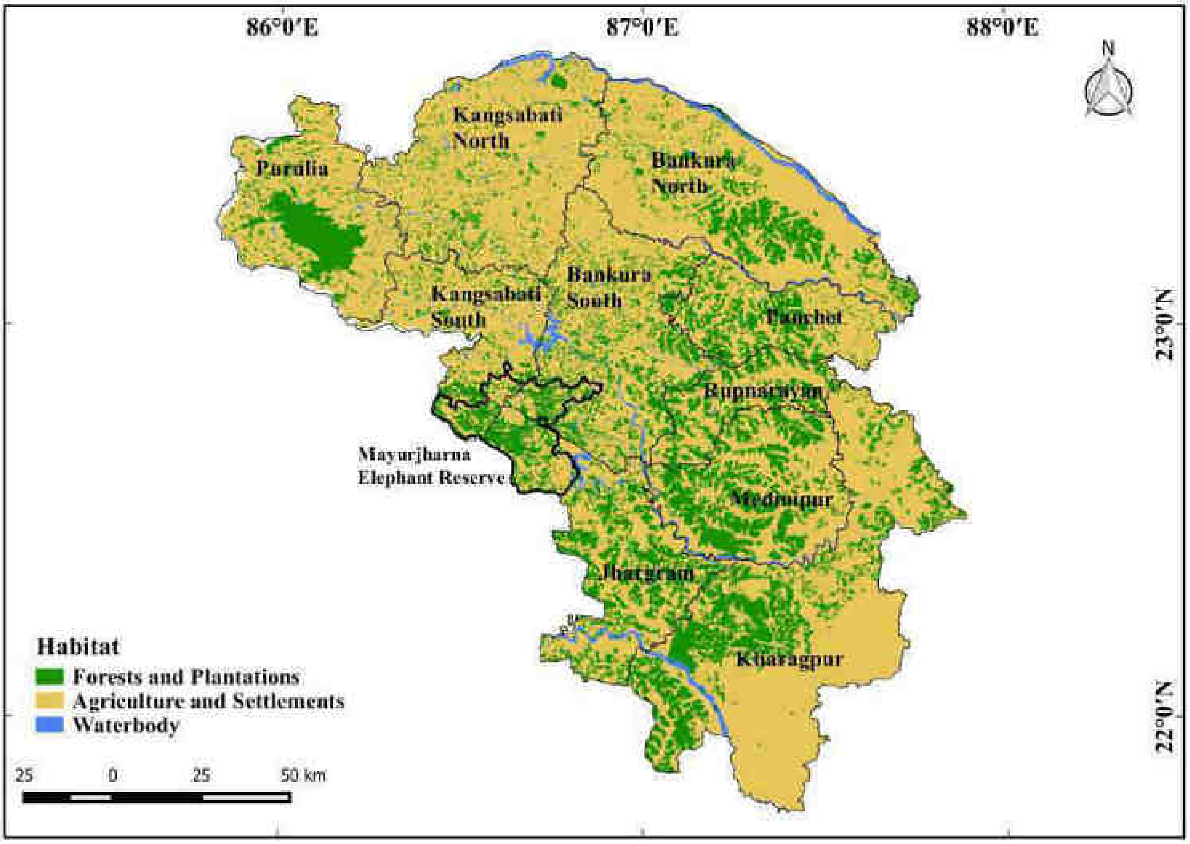

Figure 2.1 Forest cover in Mayurjharna ER and different Forest Divisions of South Bengal

Table 2.1 Calculating quantitative structure and composition of plant communities

Parameters	Formula adopted
Frequency (%)	(No. of quadrats in which a species occurred /total no. of quadrats examined) X 100
Abundance	Total number of individuals of a species /no. of quadrats in which the species occurred
Density	Total no. of individuals of a given species/total no. of quadrats examined
Relative density	(No. of individuals/no. of individuals of all Species) X 100
Relative abundance	(Abundance of species X 100) /sum of all abundances
Relative frequency	(Number of quadrats occurring /total no. of quadrats) X 100
Basal area	$(\text{GBH in m})^2/4\pi$

Relative basal area	(Total basal area of individuals /total basal area of all species) X 100
Importance Value Index (IVI)	Relative density + relative dominance + relative frequency
Simpson Index (SI)	$D = \Sigma (n_i/N)^2$ (where, n_i = IVI; N = total IVI of all species)
Shannon–Wiener's Index	$H' = \Sigma(n_i/N) \ln(n_i/N)$
Species Occurrence Rate	Species richness/ species density, where species richness is no. of species in each group
Stand Density	Total individuals/unit area

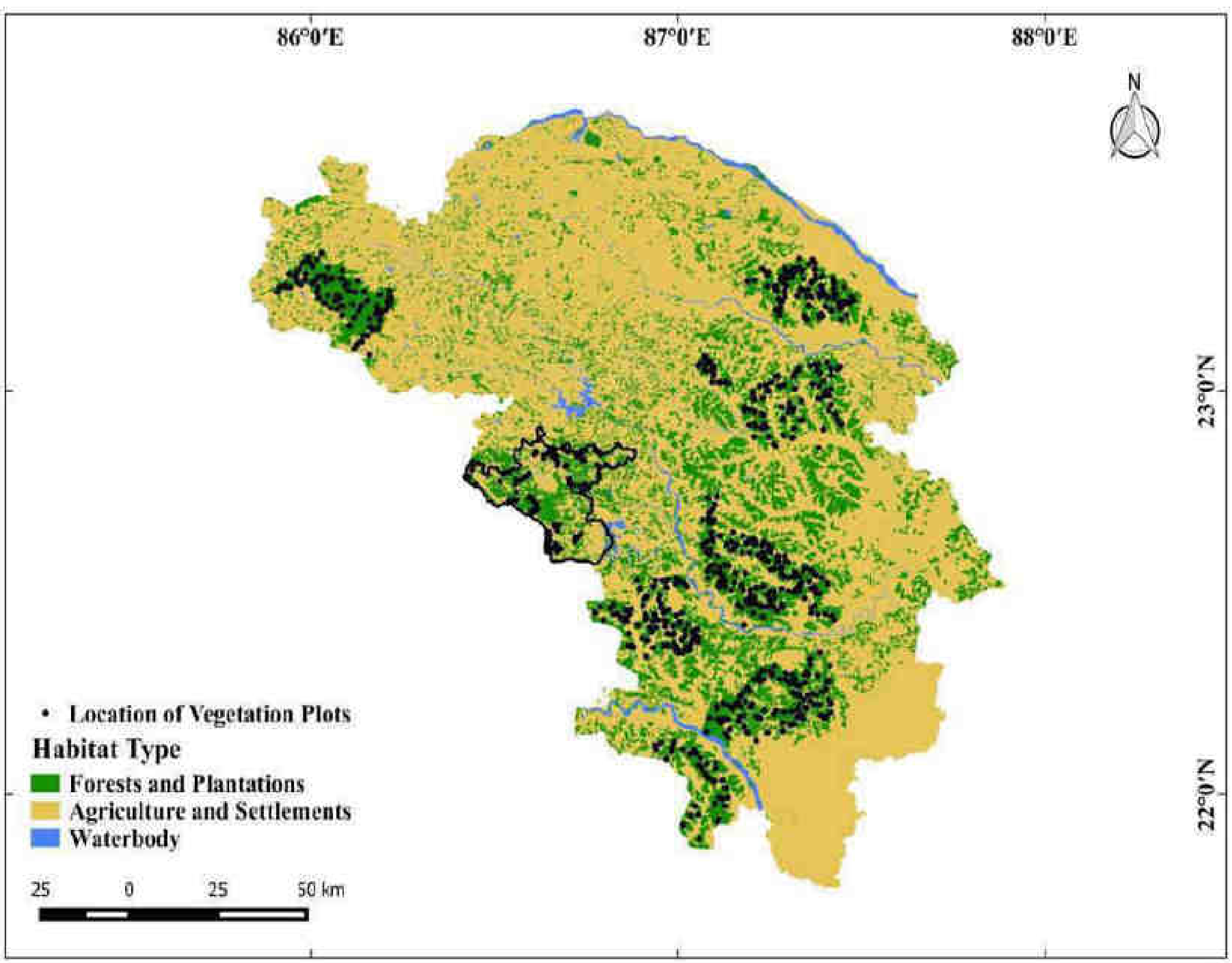

Figure 2.2 Location of sampling plots for vegetation assessment in South Bengal

2.3. Results

South Bengal

In total, 9642 trees belonging to 27 species were recorded in 589 quadrats (Table 2.2). Among them, *Shorea robusta*was the highest inthe number of individuals (80.93%, n=7804, Table 2.3), which was followed by *Madhuca longifolia* (n=308), *Lannea grandis* (n=108),and *Terminalia elliptica* (n=108). Furthermore, *S. robusta* (IVI=227.26, SDI=0.57) is the most dominant species followed by *M. longifolia* (IVI=23.62, SDI=0.01).

The stand density decreased as the girth class increased, with a maximum density of 991.46 trees ha^{-1} in the girth class of 10-29 cm and the lowest density of 2.44 trees ha^{-1} in the girth class of 110-129 cm (Table 2.4). The highest tree species richness was found in the girth class of 10-29 cm followed by the 30-49 cm girth class (Table 2.4). Also, the 10-29 cm girth class contributed to the greatest basal area (Fig. 2.4). Similarly, the occurrence rate of species decreased as the girth class increased (Table 2.4).

Familial Composition: The number of tree families in the sampled area was 17 (Fig. 2.5). Among them, the families Combretaceae and Anacardiaceae were represented by three species each dominating the forest canopy followed by Rubiaceae (2 species). Based on the density, family Dipterocarpaceae (n=7804) represents the highest number followed by Sapotaceae (n= 308) and Anacardiaceae (n=108).

Table 2.2 Community structure of woody trees in South Bengal

Species composition variables	Value
No. of species	27
No. of family	17
Stand density (Individuals/ ha)	1637.01
Basal area (m^2 ha^{-1})	16.66 m^2 ha^{-1}
Shannon Diversity Index	2.39
Simpson Index	0.21

Table 2.3 Importance Value Index of tree species in South Bengal

Tree species	Family	TI	D	BA	Rel. BA	IVI	SDI	SI
Aegle marmelos	Rutaceae	58	0.01	0.07	0.2	0.91	-0.02	0
Anogeissus latifolia	Combretaceae	87	0.02	0.01	0.04	1.49	-0.03	0
Annona squamosa	Annonaceae	68	0.04	0.11	0.31	2.45	-0.04	0
Artocarpus heterophyllus	Moraceae	98	0.04	0.05	0.15	1.65	-0.03	0
Buchanania cochinchinensis	Anacardiaceae	68	0.07	0.09	0.26	1.34	-0.02	0
Casearia tomentosa	Salicaceae	39	0.04	0.03	0.09	2.23	-0.04	0
Cleistanthus collinus	Phyllanthaceae	89	0.05	0.03	0.1	1.03	-0.02	0
Diospyros melanoxylon	Ebenaceae	47	0.09	0.44	1.28	4.36	-0.06	0
Eucalyptus tereticornis	Myrtaceae	54	0.17	0.71	2.08	5.02	-0.07	0
Gardenia gummifera	Rubiaceae	85	0.01	0.01	0.03	0.74	-0.01	0
Gymnema sylvestre	Asclepiadaceae	1	0.01	0.01	0.03	0.75	-0.01	0
Lannea grandis	Anacardiaceae	108	0.1	0.13	0.39	4.82	-0.07	0
Madhuca longifolia	Sapotaceae	308	0.88	1.66	4.88	23.62	-0.2	0.01
Neolamarckia cadamba	Rubiaceae	65	0.01	0.04	0.11	0.82	-0.02	0
Pterocarpus marsupium	Fabaceae	68	0.01	0.02	0.05	0.76	-0.02	0
Schleichera oleosa	Sapindaceae	41	0.01	0.06	0.17	0.89	-0.02	0
Semecarpus anacardium	Anacardiaceae	85	0.02	0.03	0.09	0.87	-0.02	0
Shorea robusta	Dipterocarpaceae	7804	14.68	29.82	87.8	227.26	-0.21	0.57
Syzygium cumini	Myrtaceae	98	0.05	0.06	0.17	3.03	-0.05	0
Tectona grandis	Lamiaceae.	92	0.01	0.04	0.12	0.84	-0.02	0
Terminalia bellirica	Combretaceae	38	0.04	0.11	0.33	2.47	-0.04	0
Terminalia elliptica	Combretaceae	108	0.21	0.29	0.86	8.51	-0.1	0
Unidentified		46	0.01	0.01	0.03	0.74	-0.01	0
Unidentified		29	0.02	0.05	0.14	0.93	-0.02	0
Unidentified		1	0.01	0.07	0.22	0.93	-0.02	0
Unidentified		56	0.01	0.02	0.05	0.76	-0.02	0
Unidentified		1	0.01	0.01	0.04	0.75	-0.02	0

TI= total individuals, D= density, BA= basal area, Rel. BA= relative basal area, IVI= importance value index, SDI= Shannon Diversity Index, SI= Simpson Index

Table 2.4 Stand density, species richness, and basal area under various girth classes of tree species

Girth class (cm)	Stand density (stems ha^{-1})	Species richness	Basal area (m^2 ha^{-1})	Species occurrence rate
10-29	991	23	4.44	0.04
30-49	389	10	4.54	0.03
50-69	186	7	3.76	0.02
70-89	81	6	2.09	0.01
90-109	13	4	1.27	0.003
110-129	2	2	0.56	0.001

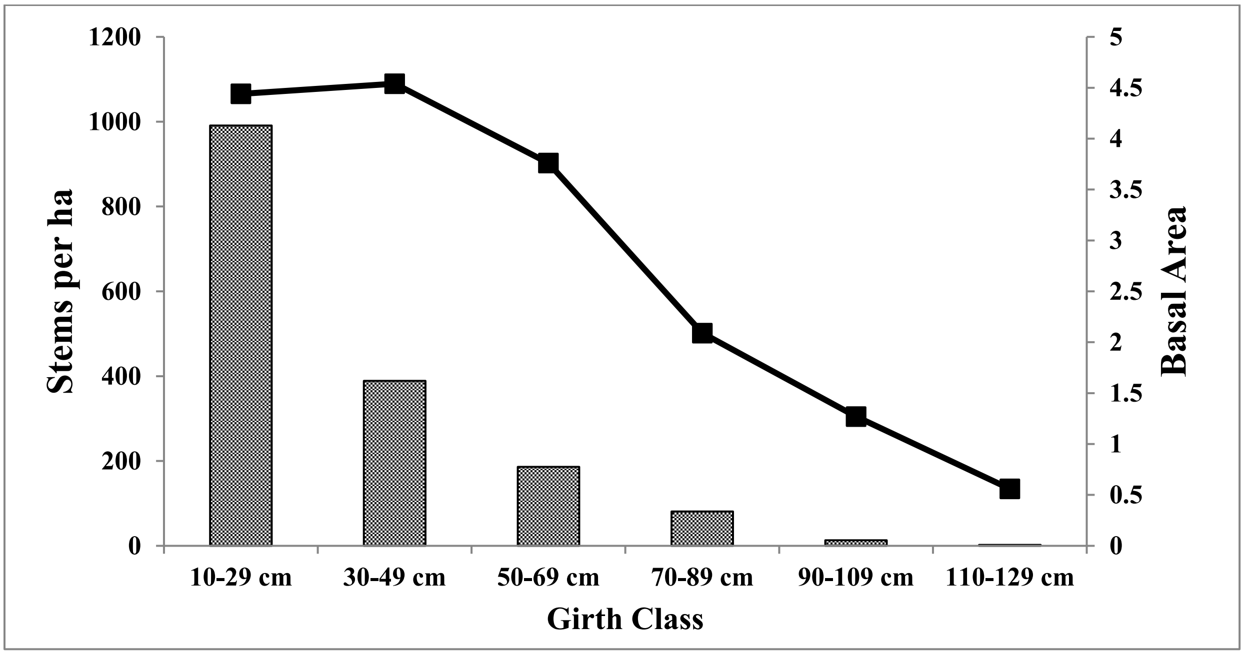

Figure 2.3Stand density (stems per ha, bars) and basal area in different girth class of tree species (line)

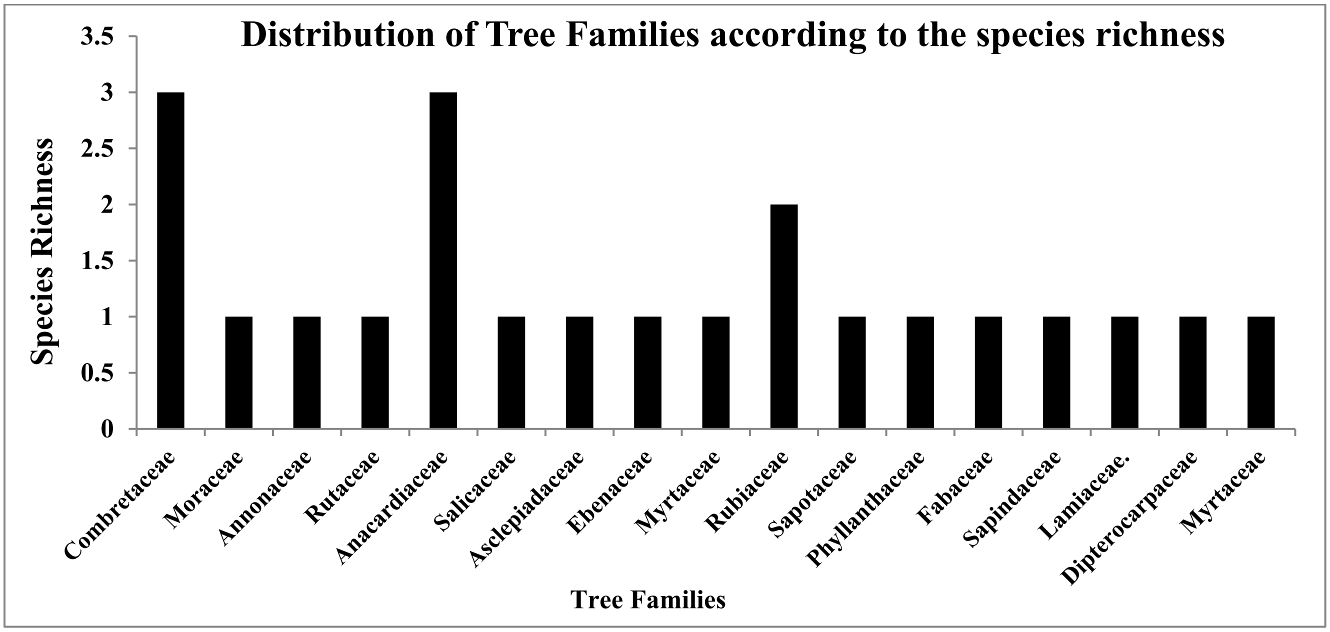

Figure 2.4 Distribution of tree families in South Bengal

Mayurjharna Elephant Reserve

In total, 2574 trees belonging to 58 species (Table 2.5 and 2.6) were recorded in 119 quadrats (1.19 hectares) in Mayurjharna ER. Among them, *Shorea robusta* accounted for the highest number of individuals (54.47%, n=1402), followed by *Madhuca longifolia* (n=213), *Buchanania cochinchinensis* (n=163), *Diospyros melanoxylon* (n=156), *Terminalia alata*(n=121) and *Semecarpus anacardium* (n= 100). *S. robusta* (IVI= 127.46, SDI=0.18) was the most dominant species followed by *M. longifolia* (IVI= 25.31, SDI= 0.01), *B. cochinchinensis* (IVI= 22.00, SDI= 0.01), and*D. melanoxylon* (IVI=21.63, SDI=0.01). The Shannon diversity index of the tree species in the study area was 2.39, and the Simpson index of diversity was 0.21. The mean density was 2163.03 individuals ha^{-1} and the mean basal area was 21.28 m^2 ha^{-1}.

The species accumulation curve, estimated using Chao-2 providing a least biased estimate of species richness (Fig. 2.6), which depictthe species accumulation it did not reach the asymptote, as the expected number of species was 72 that was higher than the observed number of species (58).

Table 2.5 Community structure of trees in Mayurjharna ER

Species composition variables	Value
No. of species	58
No. of genus	45
No. of family	25
Stand density (Individuals/ ha)	2163.03
Basal area (m^2 ha^{-1})	21.28 m^2 ha^{-1}
Shannon Diversity Index	2.39
Simpson Dominance Index	0.21

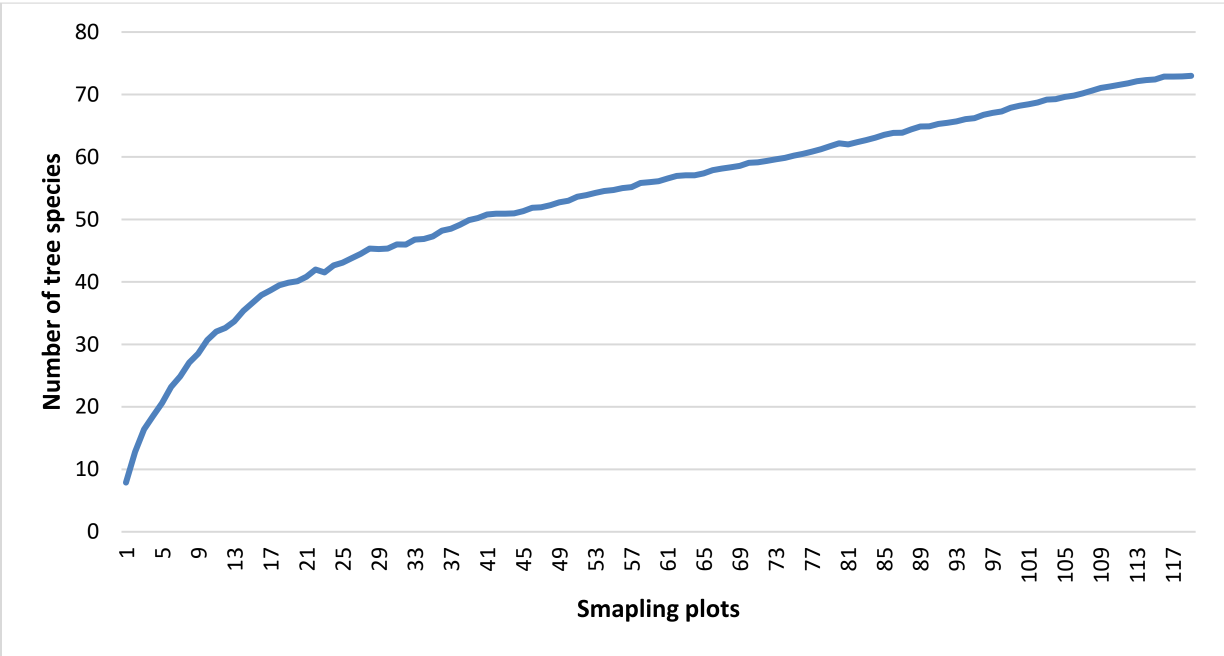

Figure 2.5Plant species accumulation curve using Chao-2

Table 2.6 Important Value Index of tree species in Mayurjharna ER

Tree Species	Family	TI	GBH	D	BA	Rel. BA	IVI	SDI	SI
Acacia auriculiformis	Fabaceae	1	0.17	0.01	0.170	0.02	0.21	-0.04	0.00
Acalypha indica	Euphorbiaceae	2	0.3	0.02	0.004	0.04	0.26	-0.09	0.00
Alangium salvifolium	Cornaceae	1	0.13	0.01	0.001	0.02	0.20	-0.01	0.00
Albizia lebbeck	Fabaceae	9	4.06	0.08	0.193	0.54	1.61	-0.01	0.00
Anacardium occidentale	Anacardiaceae	4	1.65	0.03	0.058	0.22	0.81	0.00	0.00
Annona Squamosa	Annonaceae	4	0.92	0.03	0.213	0.12	0.86	-0.03	0.00
Anogeissus latifolia	Combretaceae	49	10.43	0.41	0.216	1.38	6.90	-0.02	0.00
Bauhinia purpurea	Fabaceae	1	0.75	0.01	0.045	0.10	0.28	-0.02	0.00
Bombax ceiba	Bombacaceae	1	0.83	0.01	0.055	0.11	0.29	-0.01	0.00
Buchanania cochinchinensis	Anacardiaceae	163	47.3	1.37	1.513	6.25	22.00	-0.01	0.01
Butea monosperma	Fabaceae	12	4.87	0.10	0.287	0.64	2.27	-0.19	0.00
Cassia fistula	Fabaceae	4	1.53	0.03	0.080	0.20	0.94	-0.04	0.00
Casearia tomentosa	Salicaceae	9	1.18	0.08	0.013	0.16	1.38	-0.01	0.00
Ceriscoides turgida	Rubiaceae	1	0.13	0.01	0.001	0.02	0.20	-0.02	0.00
Cleistanthus collinus	Phyllanthaceae	53	10.28	0.45	0.177	1.36	7.47	-0.02	0.00
Croton persimilis	Euphorbiaceae	9	1.64	0.08	0.028	0.22	1.58	-0.09	0.00
Cochlospermum religiosum	Bixaceae	1	0.41	0.01	0.013	0.05	0.24	0.00	0.00
Desmodium oojeinense	Fabaceae	2	0.33	0.02	0.005	0.04	0.41	-0.01	0.00
Diospyros exsculpata	Ebenaceae	4	1.21	0.03	0.053	0.16	0.75	-0.03	0.00
Diospyros melanoxylon	Ebenaceae	156	44.36	1.31	1.705	5.86	21.63	-0.01	0.01
Ficus racemosa	Moraceae	1	0.7	0.01	0.039	0.09	0.28	-0.19	0.00
Ficus religiosa	Moraceae	1	0.37	0.01	0.011	0.05	0.23	-0.01	0.00
Flacourtia indica	Salicaceae	1	0.16	0.01	0.002	0.03	0.20	-0.01	0.00
Gardenia gummifera	Rubiaceae	41	6.49	0.34	0.087	0.86	5.93	-0.01	0.00
Gymnema sylvestre	Asclepiadaceae	4	1.15	0.03	0.033	0.15	0.89	-0.01	0.00
Haldinia cordifolia	Rubiaceae	12	3.29	0.10	0.118	0.43	2.35	0.00	0.00
Holarrhena antidysenterica	Apocynaceae	22	3.99	0.18	0.075	0.53	3.56	-0.02	0.00
Holoptelea integrifolia	Ulmaceae	2	0.44	0.02	0.008	0.06	0.28	-0.01	0.00
Joannesia princeps	Euphorbiaceae	9	2.99	0.08	0.135	0.39	1.61	-0.05	0.00
Kydia calycina	Malvaceae	18	4.28	0.15	0.097	0.57	2.86	0.00	0.00
Lannea coromandelica	Anacardiaceae	38	17.72	0.32	0.863	2.34	7.73	-0.09	0.00
Madhuca longifolia	Sapotaceae	213	60.95	1.79	1.965	8.05	25.31	-0.21	0.01
Mallotus nudiflorus	Euphorbiaceae	4	0.56	0.03	0.007	0.07	0.52	-0.01	0.00
Mitragyna parvifolia	Rubiaceae	11	4.46	0.09	0.228	0.59	2.18	-0.04	0.00
Myristica fragrans	Myristicaceae	1	0.38	0.01	0.012	0.05	0.23	-0.01	0.00
Nyctanthes arbortristis	Oleaceae	3	0.42	0.03	0.005	0.06	0.61	-0.01	0.00
Phyllanthus acidus	Phyllanthaceae	6	1.24	0.05	0.027	0.16	1.12	-0.02	0.00
Phyllanthus emblica	Phyllanthaceae	2	0.29	0.02	0.002	0.04	0.41	-0.01	0.00
Pterocarpus marsupium	Fabaceae	4	0.73	0.03	0.011	0.10	0.83	-0.02	0.00
Sapindus emarginatus	Sapindaceae	1	0.14	0.01	0.002	0.02	0.20	-0.03	0.00
Sapindus mukorossi	Sapindaceae	8	1.55	0.07	0.024	0.20	1.10	-0.02	0.00
Schleichera oleosa	Sapindaceae	1	0.15	0.01	0.002	0.02	0.20	0.00	0.00
Semecarpus anacardium	Anacardiaceae	100	31.42	0.84	0.010	2.94	13.25	-0.14	0.00
Shorea robusta	Dipterocarpaceae	1402	425.36	11.7	14.025	56.18	127.46	-0.36	0.18
Streblus asper	Moraceae	2	0.57	0.02	0.014	0.05	0.30	-0.01	0.00
Strychnos nuxvomica	Loganiaceae	1	0.14	0.01	0.002	0.02	0.20	-0.08	0.00
Symplocos racemosa	Symplocaceae	3	0.62	0.03	0.010	0.08	0.34	-0.01	0.00
Syzygium cumini	Myrtaceae	8	2.5	0.07	0.082	0.33	1.80	-0.03	0.00
Terminalia alata	Combretaceae	121	41.71	1.02	1.752	5.51	19.34	-0.18	0.00

Terminalia arjuna	Combretaceae	4	0.59	0.03	0.007	0.08	0.67	-0.01	0.00
Terminalia bellirica	Combretaceae	12	3.07	0.10	0.082	0.41	2.47	-0.04	0.00
Terminalia chebula	Combretaceae	10	2.38	0.08	0.053	0.31	2.15	-0.04	0.00
Goti		2	0.39	0.02	0.006	0.05	0.27	0.00	0.00
Lepsi		1	0.32	0.01	0.008	0.04	0.23	-0.01	0.00
Lulajhangri		1	0.16	0.01	0.002	0.02	0.20	0.00	0.00
Merai		1	0.14	0.01	0.002	0.02	0.20	0.00	0.00
Tetalia		2	0.25	0.02	0.003	0.03	0.26	-0.01	0.00
Tilai		15	2.54	0.13	0.037	0.34	1.93	-0.03	0.00

TI= total individuals, D= density, BA= basal area, Rel. BA= relative basal area, IVI= importance value index, SDI= Shannon Diversity Index, SI= Simpson Index

The stand density decreased as the girth class increased, with a maximum density of 1395 trees ha^{-1} in the girth class of 10-29 cm and the lowest density of 2 trees ha^{-1} in the girth class of 110-129 cm (Table 2.7). The highest tree species richness was found in the girth classes of 10-29 cm GBH followed by 30-49 cm GBH; also, the girth class 30 - 49 cm GBH contributed to the highest basal area (Fig. 2.7). Similarly, the occurrence rate of species decreased as the girth class increased (Table 2.7).

Table 2.7 Stand density, species richness, and basal area under various girth classes of trees in Mayurjharna ER

Girth class (cm)	Stand density (stems ha^{-1})	Species richness	Basal area (m^{2}ha^{-1})	Species occurrence rate
10-29	1395	51	4.07	0.04
30-49	**488**	**27**	**5.67**	**0.06**
50-69	165	14	4.34	0.09
70-89	68	15	3.14	0.22
90-109	38	10	2.78	0.26
110-129	4	3	0.45	0.71
130- 149	3	4	0.52	1.19
150-169	2	1	0.31	0.60

Familial Composition: The number of tree families in the sampled area was 25 (Fig. 2.8). Among them, Fabaceae was represented by seven species dominating the forest woody trees followed by Combretaceae (5 species), Anacardiaceae (4 species), Euphorbiaceae (4 species), and Rubiaceae (4 species). Based on the density, family Dipterocarpaceae (n=1402) represents the highest number followed by Sapotaceae (n= 213), Anacardiaceae (n=163), and Ebenaceae (n=156).

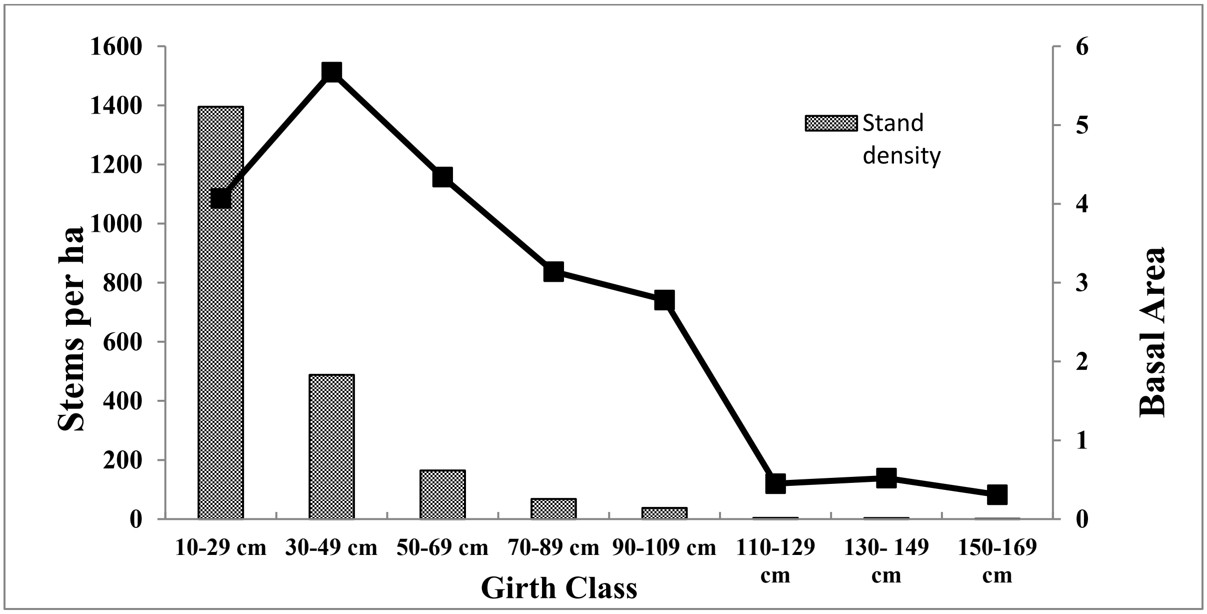

Figure 2.6Stand density (stems per ha) and basal area in different girth class of tree species in Mayurjharna ER

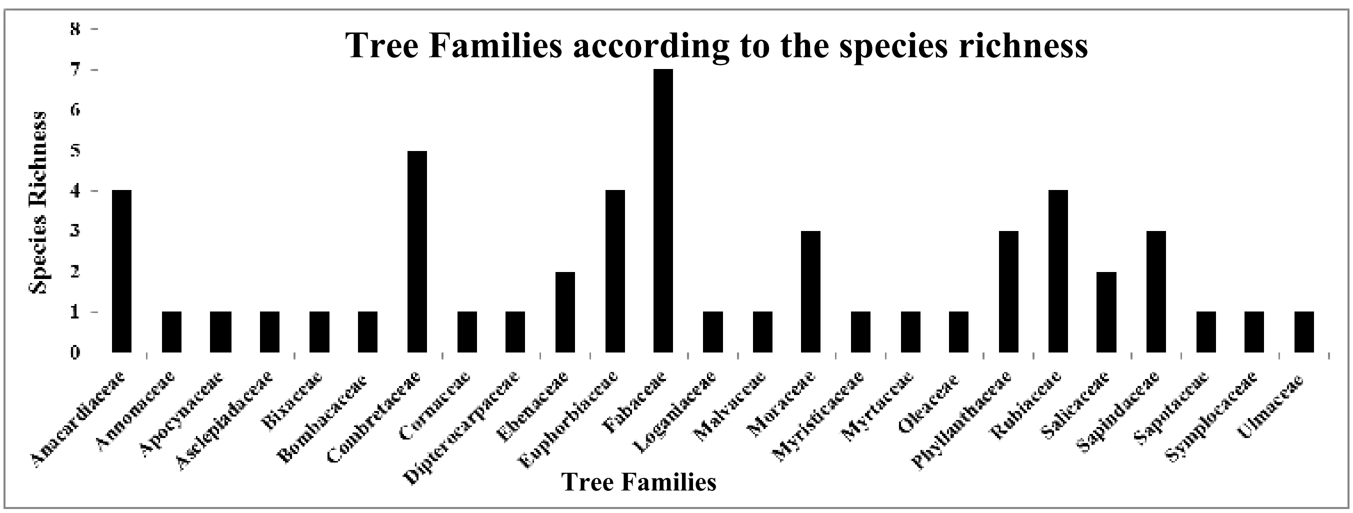

Figure 2.7 Distribution of tree families in Mayurjharna ER

2.4. Discussion

The study provides quantification of stand structure and tree species composition for the entire South Bengal and Mayurjharna ER. The mean density and basal area of trees were more in Mayurjharna ER (mean density: 2163.03 trees ha^{-1}; basal area: 21.28 $m^2 ha^{-1}$) than in other forest divisions of South Bengal (mean density: 1637.01 trees ha^{-1}; basal area: 16.66 m^2 ha^{-1}). Although, *Shorea robusta* dominates both the regions, other forest divisions studied had more *S. robusta*in number than Mayurjharna ER.

Vegetation studies analyzing the stand structure or species compositions from entire South Bengal have not been found. However, a study on the 25 sacred groves (SG) covering an area of 60,500 m^2 in Paschim Medinipur District has been done by Pandit (2011) recording 139 species of angiosperms belonging to 51 families. A similar study was done by Basu (2009) in Bankura District wherein 26 sacred grooves with a total area of 83167 m^2 had 114 species. According to the study, *Shorea robusta* (0.069 individuals ha^{-2}) was found to be the most dominant species followed by *Butea monosperma* (0.031 individuals ha^{-2}) and *Alangium salvifolium* (0.023 individuals ha^{-2}). These studies also indicate the sal dominated deciduous forest landscape.

The species richness in the present study (58 species) is closer to the species richness of the Bhadra Wildlife Sanctuary (46 species, Krishnamurthy et al. 2010) and forests in Puerto Rico (50 species, Murphy and Lugo 1986). A mean basal area of 16.66 m^2 ha^{-1} in the present study area is comparable to the mean basal area of 18.2 m^2 ha^{-1} recorded in the Bhadra Wildlife Sanctuary and 15 m^2 ha^{-1} basal area of the dry forests of St. Lucia (Gonzalez and Zak 1996). The lower basal area is indicative of the small numbers of larger sized individuals (Gonzalez and Zak 1996). The Importance Value Index revealed that the area is dominated by five species similar to Bhadra Wildlife Sanctuary where only seven species are most dominant. Similarly, in dry forests in Puerto Rico (Murphy and Lugo 1986) and St. Lucia (Gonzalez and Zak 1996), similar observations were made with the seven most common species dominating the forests.

The forests in the area are being continuously exploited due to the frequent visits by people from the nearby villages for their daily requirement of fuelwood and other non-timber forest produce. This has led to the fragmentation of the forests, thereby causing damage to the plant diversity. Continuous monitoring and educating the local people towards decreasing the depletion of natural forest produce is a major requisite to reduce damage to this fragile ecosystem inhabited by Asian elephants.

CHAPTER-III

The story of range expansion of elephants

3.1. Introduction

The expansion of range by animals is influenced by several natural and human-induced factors (Hoare 1999). Distribution of quality vegetation and food resources and water availability are Natural factors influencing range expansion. Human-induced factors such as encroachment by agriculture and other developmental activities that result in habitat fragmentation and alteration of traditional routes of elephants' cause range expansion or shrinkage (Conybeare 1991). Animal populations primarily expand their range to get better accessibility to food resources and shelter as their survival depends on the spatial distribution of suitable habitat. Besides, species expansion is controlled by any competition for ecological resources (Sexton et al. 2009; Wiens 2011). In absence of such competition, the species distribution and range proliferate at a high rate (Diamond 1975; Price and Kirkpatrick 2009).

Migration and range expansion by large mammals like African elephants is well-documented (Buechner et al. 1963; White 1994). The availability of water and forage has played a major role in such movements and expansions (White 1994). In addition, anthropogenic activities also play a significant role in bringing such changes for some species (Graham et al. 2009). In the case of Asian elephants, the range expansion was reported in South Bengal from the Dalma Wildlife Sanctuary in the adjoining state of Jharkhand (Palit 1991; Singh and Chowdhury 1999; Dey 1991; Shahi 1980). However, systematic documentation of that range expansion was not available, and that prompted us to map the range expansion of elephants in South Bengal in the last six decades.

3.2. Methods

In total 456 grids of 10 x 10 km (100 km^2) were laid on the entire landscape of South Bengal (Fig. 3.1) and 250 grids of 2 x 2 km (4 km^2) were laid on Mayurjharna ER (Fig. 3.2) using QGIS platform (v 2.18). In each grid cell, we identified the people of the age 50 yr and above, owing to their experiences and familiarity with the area, and they were contacted through personnel from the forest department. We interviewed them using an open-ended questionnaire, between January

2018 and February 2019, after their informed consent. A minimum of five such interviews (with different respondents) were done for each grid cell. The data on range expansion was collected for the last six decades (i.e., 1950-60, 1960-70, 1970-80, 1980-90, 1990-2000, and 2011-18) through the past sightings of elephants in the South Bengal and Mayurjharna ER. We asked respondents about their first memory of an elephant encounter or any accounts of elephants and their movements from the past. Also, archival records from the forest department were collected to get the data on elephant movement and sightings. Field visits were made along with the forest department personnel and local people to understand and identify the movement pattern, sighting locations, or areas used by the elephants. The data was recorded using a handheld global position system (Garmin GPSMap 64s). The geo-coordinates of these records for each decade were overlaid on the grids to obtain grid wise usage of the area by the elephants.

To understand the current routes used by the elephants, information about recent movements was collected from local inhabitants and the forest officials. Information regarding the areas crossed, barricades made if any, and the exact villages where the elephants cross the state boundaries were collected. This information was then organized in a structured spreadsheet and routes were mapped on the QGIS platform.

3.3. Results

Initially, elephants started entering South Bengal through Mayurjharna from adjoining Dalma Wildlife Sanctuary in Jharkhand (Fig. 3.3). Thus, the range use and expansion of elephants was mapped first on smaller grid cells in Mayurjharna ER and later on larger grid cells in South Bengal.

Few elephants started to enter through Kankrajhore to Mayurjharna during 1950-60 (Fig. 3.4); they used to cover *ca*. 80 km^2. During 1960-1970, elephants extended their range to 260 km^2 and started to use the northern periphery of the Mayurjharna ER (Fig. 3.5); yet the major activity was confined to the reserve. In the next decade (1970-1980), the use of area increased to 376 km^2 (Fig. 3.6). In the subsequent decades (1980-1990 and 1990-2000), area used became more extensive and was about 448 km^2 and 572 km^2 respectively (Fig. 3.7 and 3.8). During this time

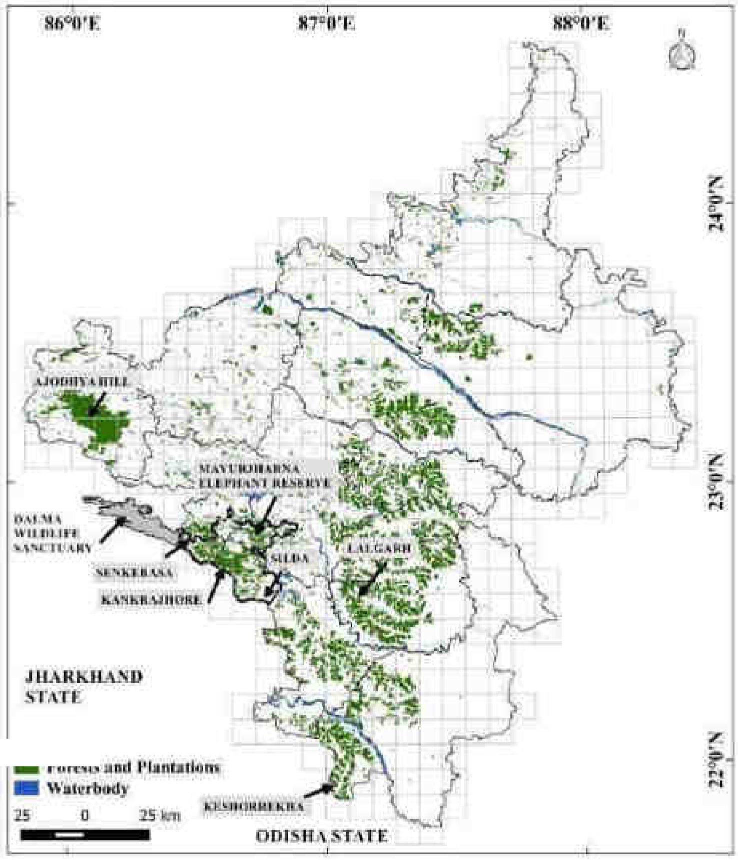

Figure 3.1 Overlay of grids (10 x 10 km) on forest cover of South Bengal

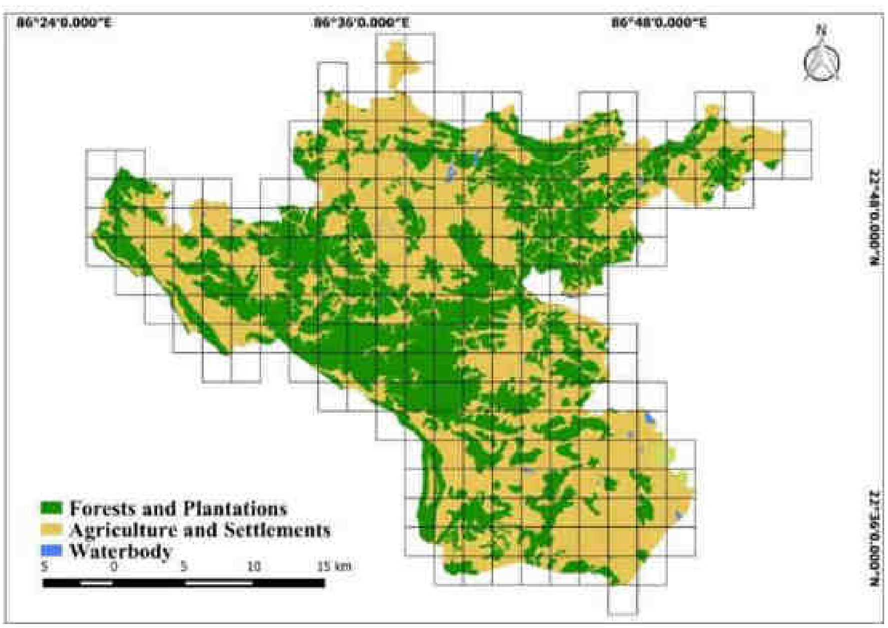

Figure 3.2 Grids overlaid on a map of forest cover of Mayurjharna ER

(between 1980-1990), the elephants started moving out of Mayurjharna and started exploring parts of Medinipur beyond Kangsabati River (Fig. 3.7). In the subsequent decades, the usage ofarea decreased, and during 2000-2010 (Fig. 3.9) elephants were limited to 208 km^2. The current usage is about 144 km^2 of the Mayurjharna ER (Fig. 3.10).

Elephants were confined to Purulia Forest Division (near Ajodhya Hill) during the 1950-60s, and only a few elephants used to enter South Bengal through Mayurjharna ER via Kankrajhore region and used *ca*. 1200 km^2 area (Table 3.2; Fig. 3.11 and 3.12). Elephants expanded their range to 1600 km^2 and started using the northern periphery of the Mayurjharna ER during the 1960-70s (Fig. 3.13); yet the major activity was confined to Ajodhya Hills and the Mayurjharna ER. Elephants expanded their range to 2100 km^2 by the 1970-80s (Fig. 3.14), and 3800 km^2 by the 1980-90s (Fig. 3.15). Use of the landscape by elephants increased multifold (from 3800 km^2 to 17400 km^2) during the 1990-2000s (Fig. 3.16). In the following decade, the usage area increased to 18500 km^2 (2000-10s, Fig. 3.17); however, the elephant range now has shrunk to 13200 km^2 (2010-18, Fig. 3.18). The present routes followed by elephants are provided in Fig. 3.19.

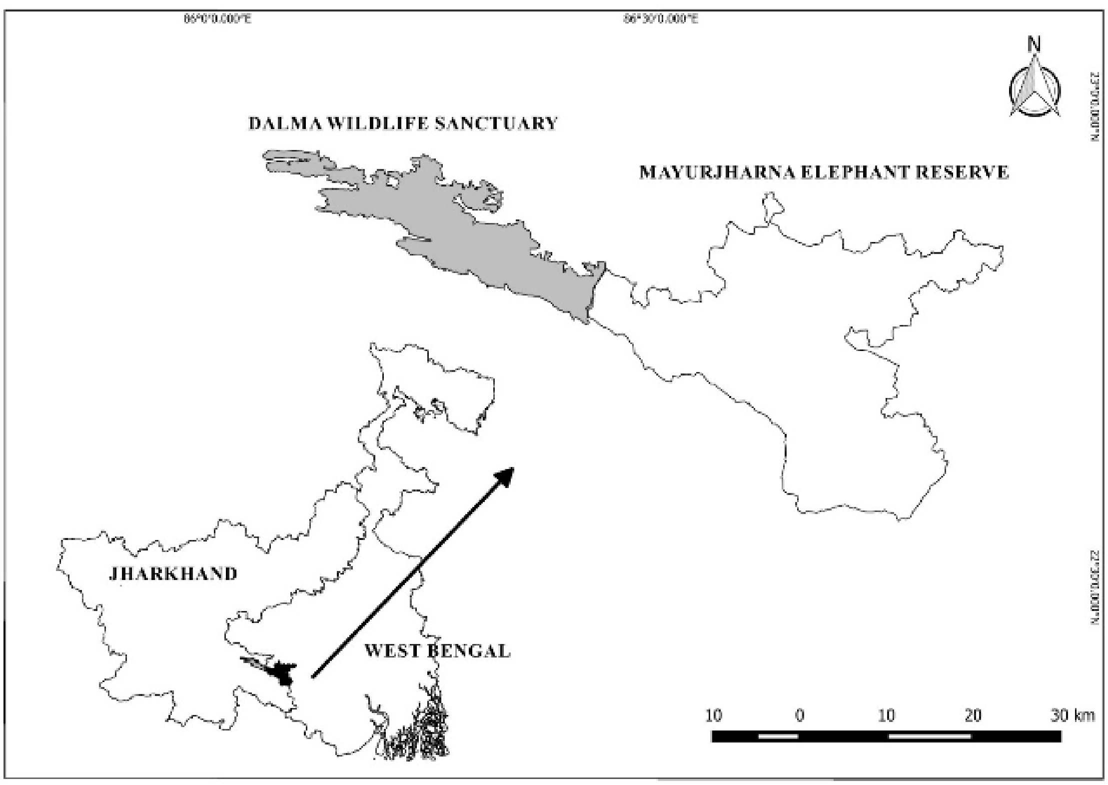

Figure 3.3 Locations of Mayurjharna ER and Dalma Wildlife Sanctuary

Table 3.1 Area used by elephants and their entry and exit locations in Mayurjharna ER

Period	Entry Point	Exit Point	Total number of grids used	The area used (km^2)	Figure number
1950 - 1960	Kankrajhore	Kankrajhore	20	80	3.4
1960 - 1970	Kankrajhore	Senkebasa	65	260	3.5
1970 – 1980	Kankrajhore	Senkebasa	94	376	3.6
1980 – 1990	Kankrajhore	Senkebasa	112	448	3.7
1990 – 2000	Kankrajhore	Silda	143	572	3.8
2000 – 2010	Kankrajhore	Silda	52	208	3.9
2011 - 2018	Kankrajhore	Silda	36	144	3.10

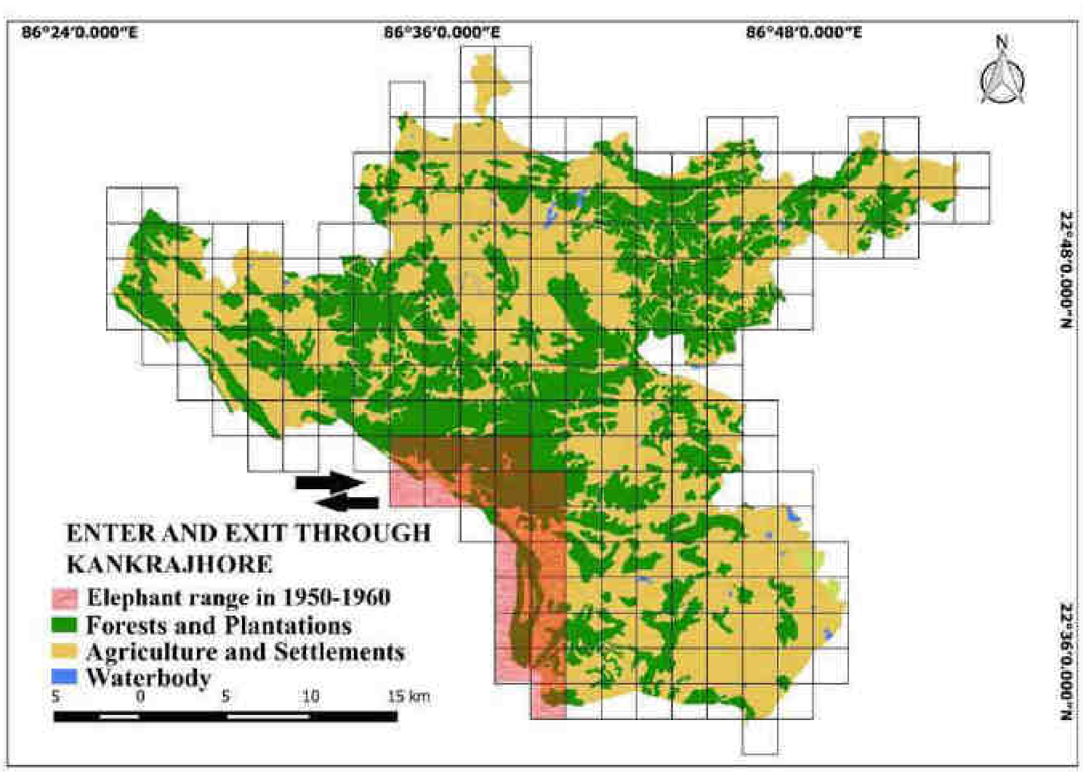

Figure 3.4 Area used by elephants in Mayurjharna ER between 1950 and 60

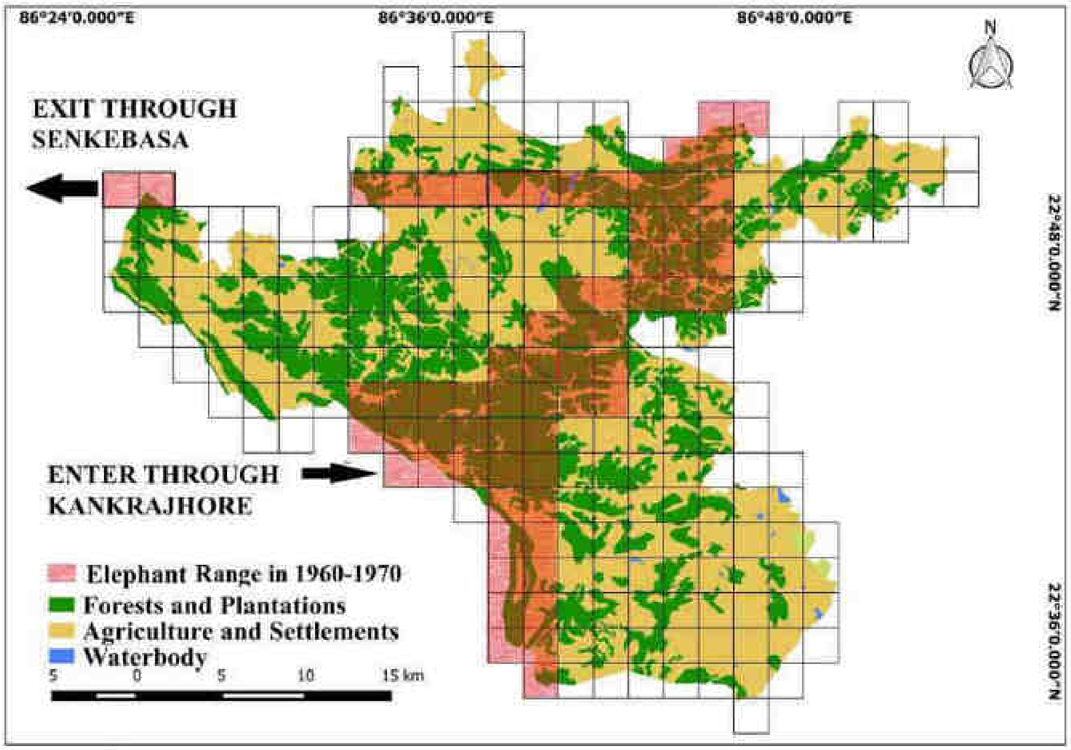

Figure 3.5 Area used by elephants in Mayurjharna ER between 1960 and 70

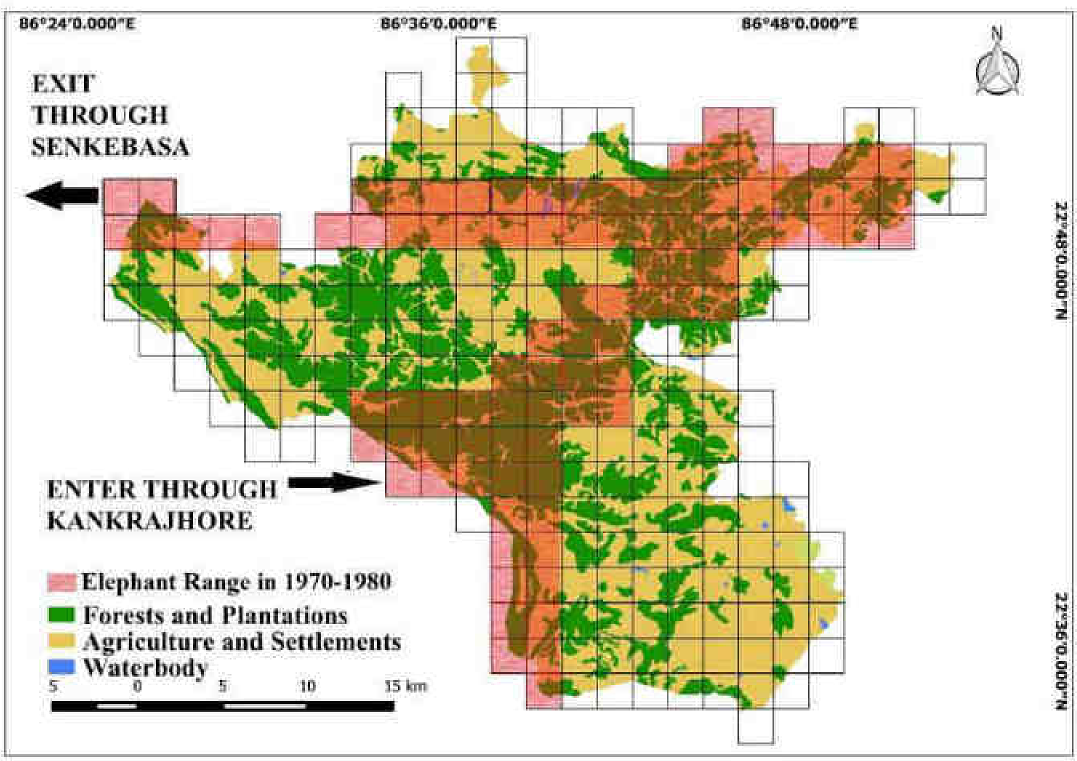

Figure 3.6 Area used by elephants in Mayurjharna ER between 1970 and 80

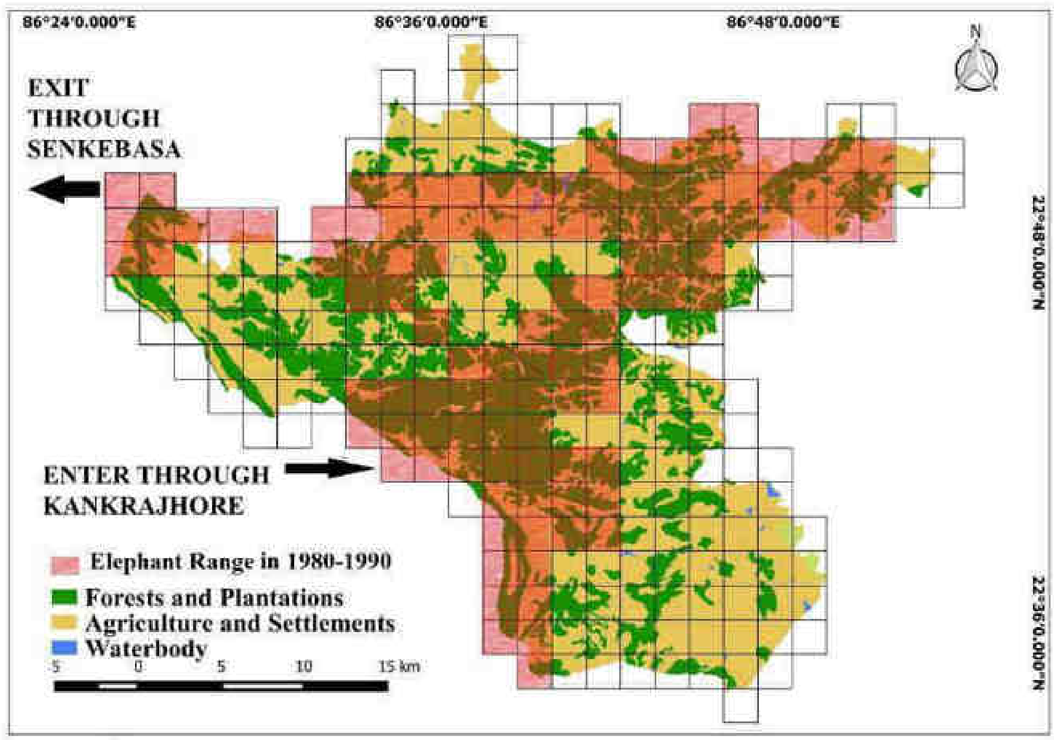

Figure 3.7 Area used by elephants in Mayurjharna ER between 1980 and 90

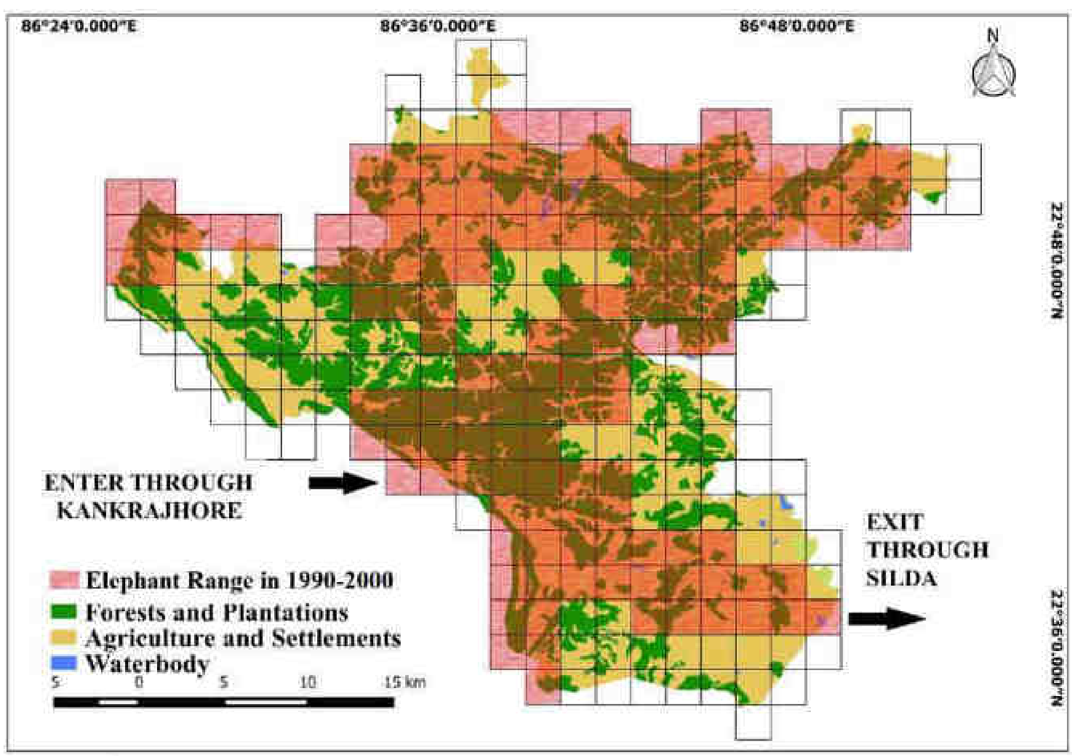

Figure 3.8 Area used by elephants in Mayurjharna ER between 1990 and 2000

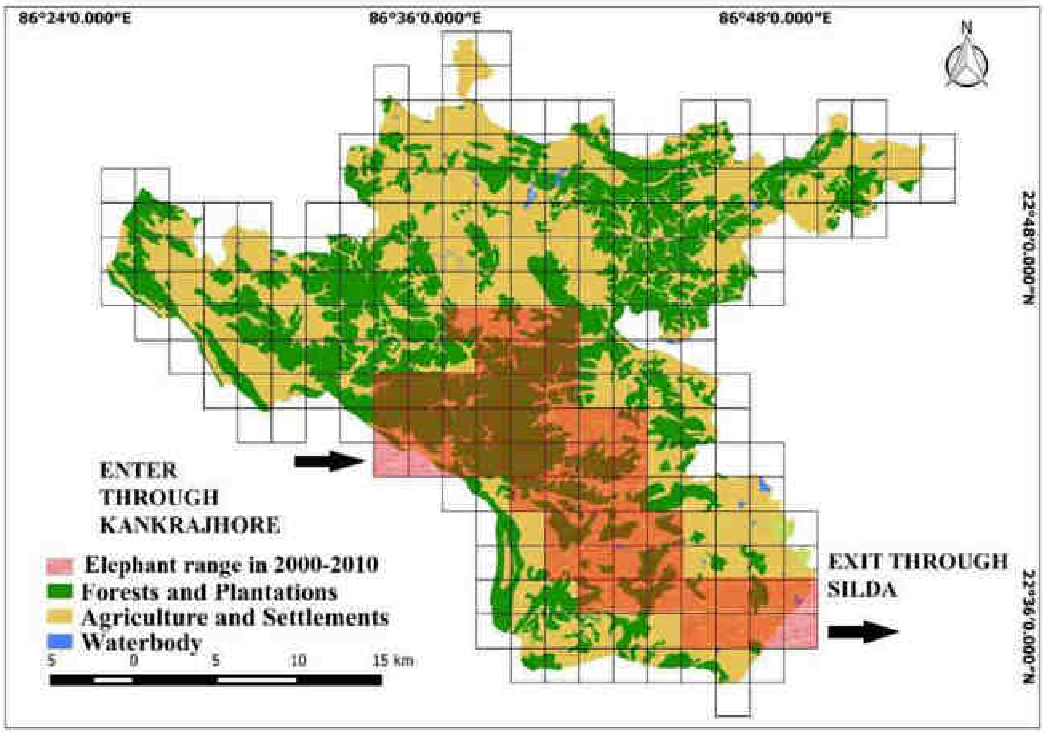

Figure 3.9 Area used by elephants in Mayurjharna ER between 2000 and 2010

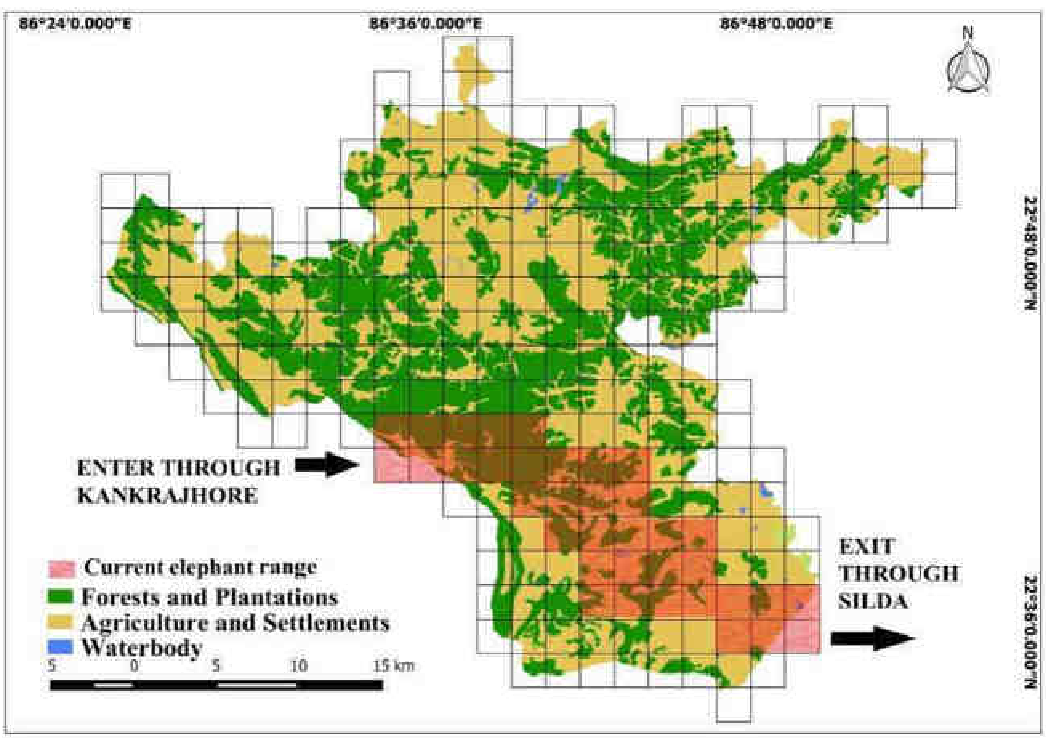

Figure 3.10 Area used by elephants in Mayurjharna ER between 2010 and 2018

Table 3.2 Area used by elephants in South Bengal for six decades (1950 to 2018)

Period	Entry Point	Exit Point	Total number of grids used	Area used (km^2)	Figure number
1950 - 1960	Kankrajhore	Kankrajhore	12	1200	3.12
1960 - 1970	Kankrajhore	Senkebasa	16	1600	3.13
1970 – 1980	Kankrajhore	Senkebasa	21	2100	3.14
1980 – 1990	Kankrajhore	Senkebasa	38	3800	3.15
1990 – 2000	Kankrajhore	Kankrajhore towards Jharkhand and Keshorekha towards Odisha	174	17400	3.16
2000 – 2010	Kankrajhore	Kankrajhore towards Jharkhand and Keshorekha towards Odisha	185	18500	3.17
2011 - 2018	Kankrajhore	Kankrajhore towards Jharkhand and Keshorekha towards Odisha	132	13200	3.18

1950: The movement of elephants started in the 1950s from Dalma Wildlife Sanctuary in Jharkhand towards Mayurjharna ER. Elephants first crossed through the Kankrajhore forest region in Jhargram, went southwards towards Amlasol and Jamaimari region (in Jhargram) within the Mayurjharna reserve, and then again moved upwards to exit from the Kankrajhore area.

1960: They started moving towards Sutan (Bankura south) located inside the reserve through Orali (Jhargram) to reach Ranibandh in Bankura during the mid-1960s.

1970: Elephants then used to move towards Bundwan (partly outside the reserve) to exit from the Jorsya forest area near Senkebasa (Kangsabati south, inside the reserve) to reach the Jharkhand.

1980: Elephants started utilizing more areas within Mayurjharna and started spreading to Banspahari, Kuilapal, and Jhilimili regions of Bankura south within the reserve.

1990: Elephants started exploring other areas in Jhargram too and started moving towards Bhulaveda to enter Silda located towards the south-western side of the Mayurjharna ER. After Silda, they started moving out of the reserve towards Malabati forest, crossed Kangsabati River at Sijuaghat, and entered the Lalgarh region in West Medinipur.

After the 1990s: Elephants started moving to other parts of Medinipur through Goaltore, Hoomgarh, Garhbeta, Dhadka, and finally Shayamnagar. From there they entered Bankura

District via Bankadaha and moved towards Patrasayar, Sonamukhi, Brindabanpur, and Barjora. Through Barjora, they move back towards Dalma Hills taking a little different route where they covered Sonamukhi, Radhanagar, Bishnupur, Nayabasat, Arabari, Mirga, Moupal, Chandra, and then again moving towards Lalgarh, finally crossing Sijuaghat, to reach Malabati forest. From Malabati the elephants move towards Silda and then cross Kankrajhore to reach Dalma hills of Jharkhand. A routetaken by the animals while going towards Odisha is after Chandra move through Kalaikunda, Patina, Nayagram and then cross Keshorrekha and reach Odisha State.

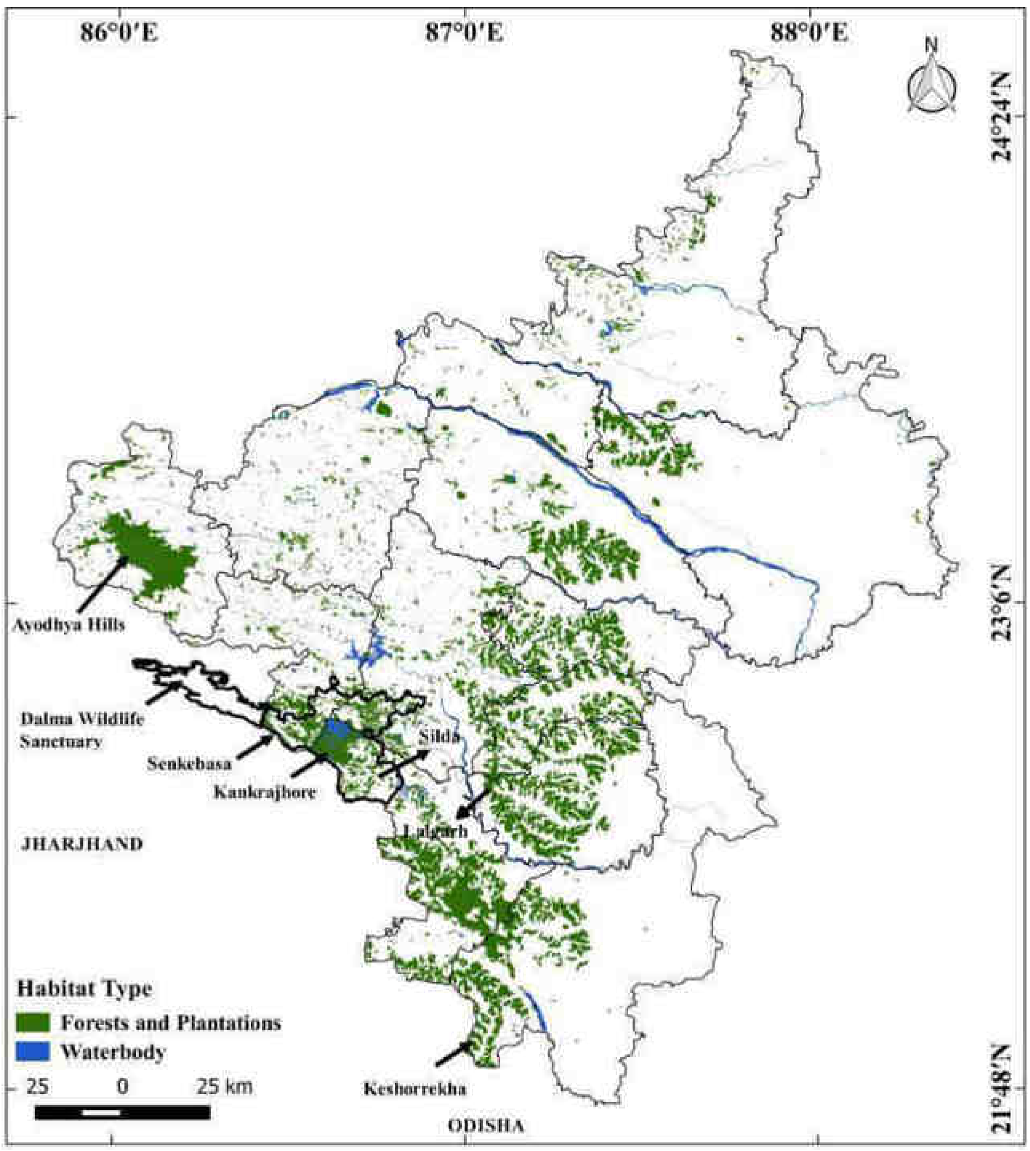

Figure 3.11 Dalma Wildlife sanctuary, Mayurjharna ER, and other locations in South Bengal

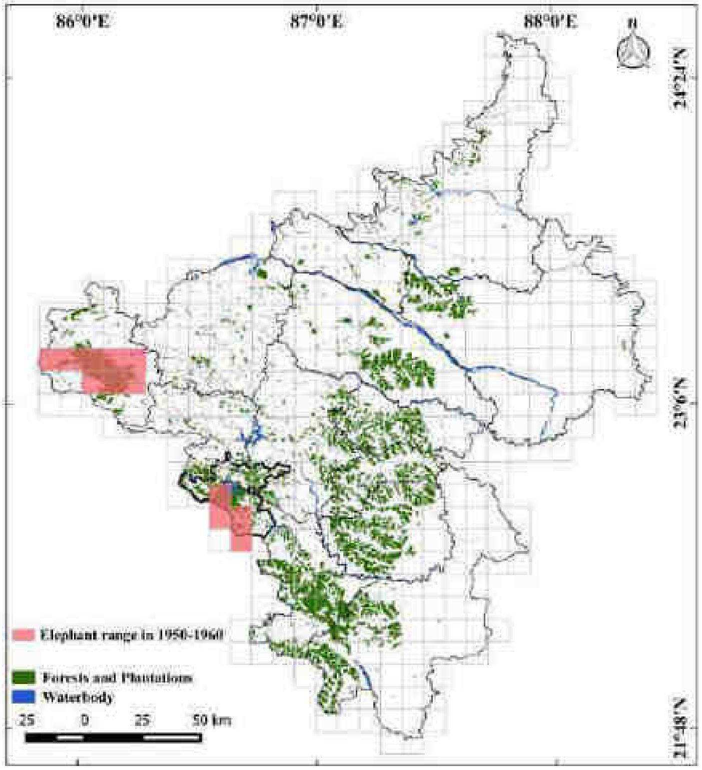

Figure3.12 Area used by elephants in South Bengal between 1950 and 1960

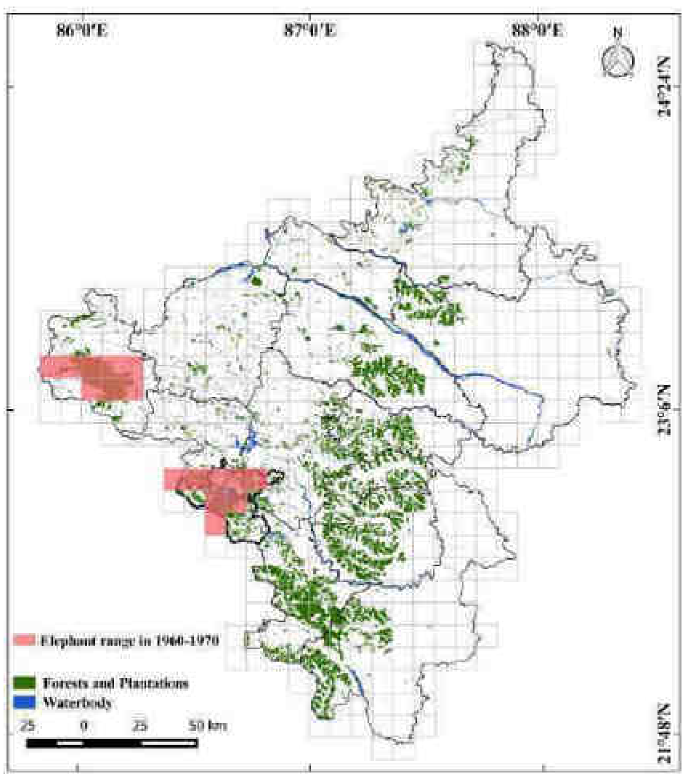

Figure 3.13 Area used by elephants in South Bengal between 1960 and 1970

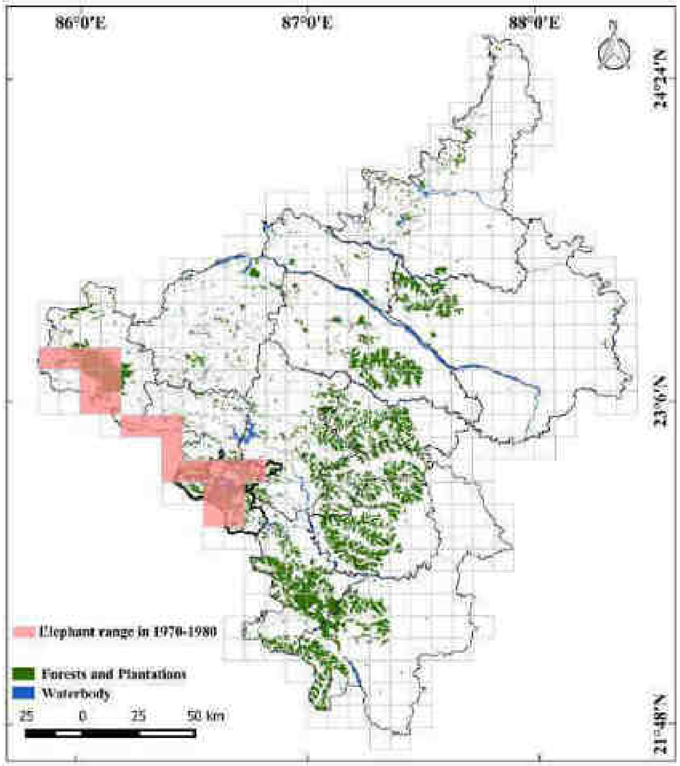

Figure 3.14 Area used by elephants in South Bengal between 1970 and 1980

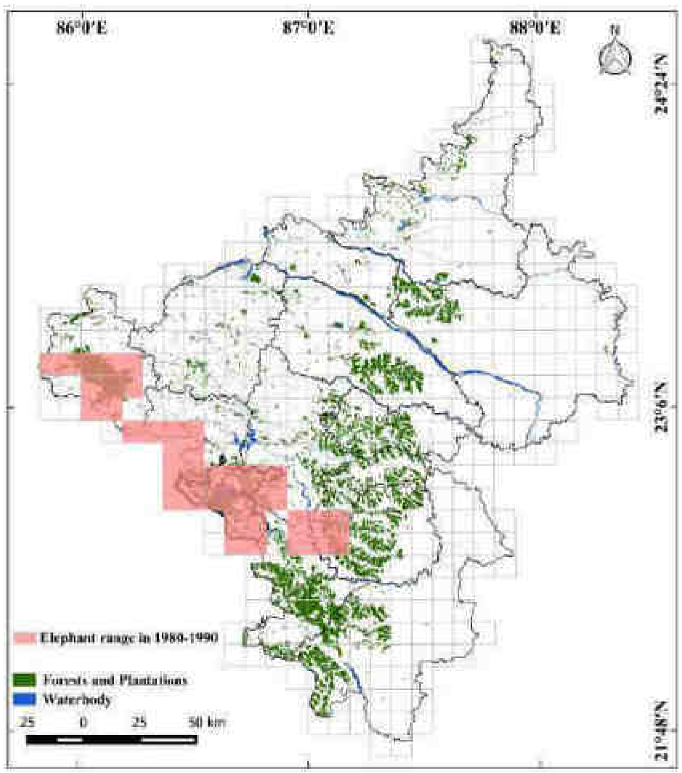

Figure 3.15 Area used by elephants in South Bengal between 1980 and 1990

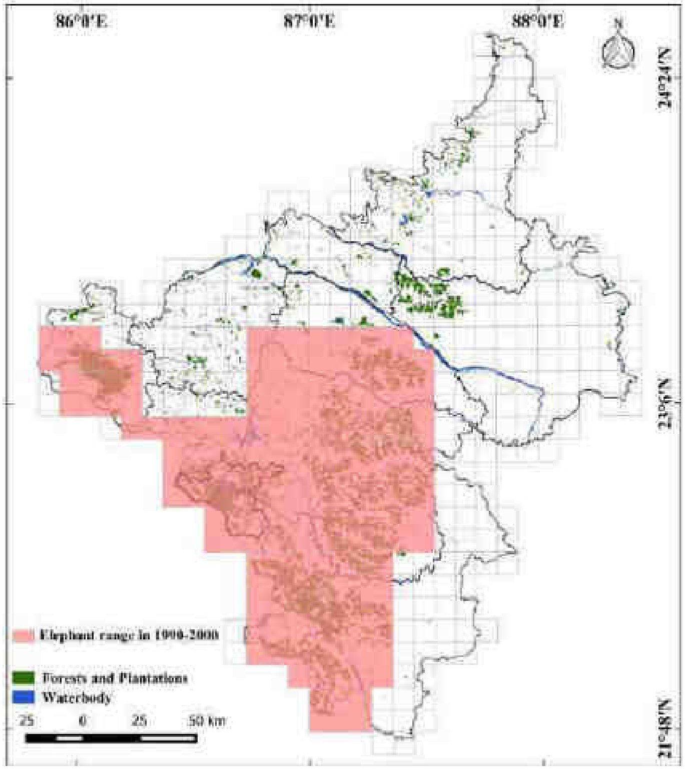

Figure 3.16 Area used by elephants in South Bengal between 1990 and 2000

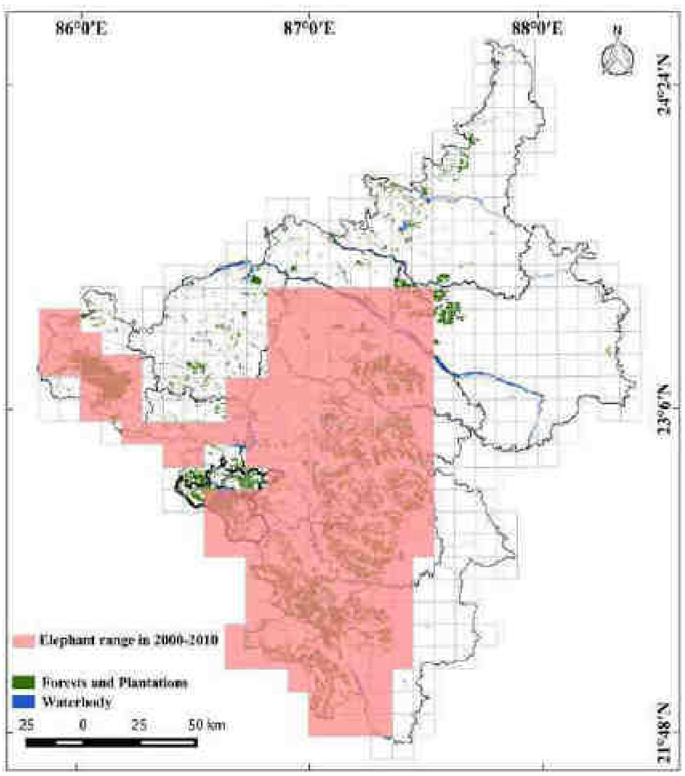

Figure 3.17 Area used by elephants in South Bengal between 2000 and 2010

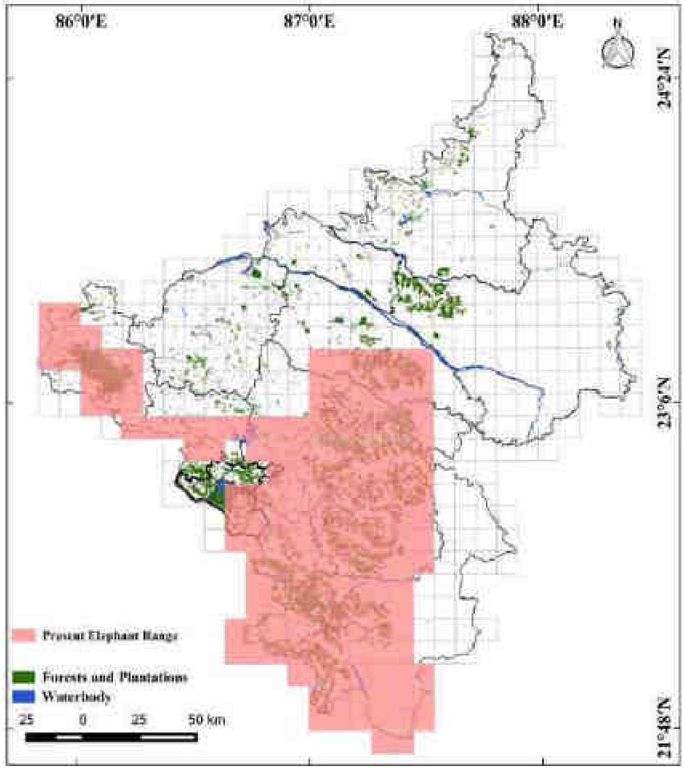

Figure 3.18 Area used by elephants in South Bengal between 2010 and 2018

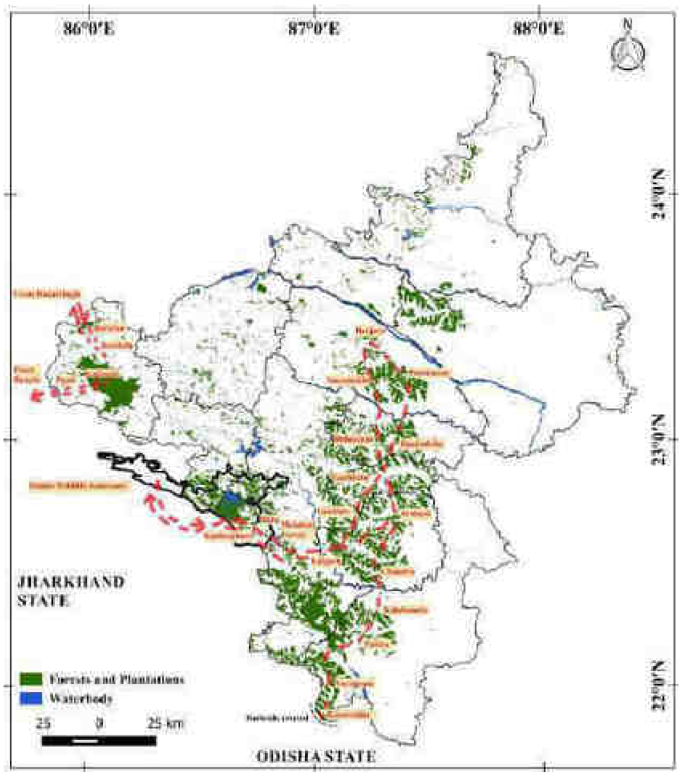

Figure 3.19 Route followed by elephants while travelling from Dalma Wildlife Sanctuary, Hazaribagh area, and Ranchi in Jharkhand state

3.4. Discussion

Sand mining in the Singhbhum district of Jharkhand adjoining to Dalma Wildlife Sanctuary led to severe disturbances in the forests (Singh and Chowdhury 1999) that probably has made the elephants move towards Mayurjharna in south West Bengal. Herds from Dalma Wildlife Sanctuary started moving towards Mayurjharna ER in the months between October and December due to the availability of Kharif season paddy crop but were restricted till west of Kangsabati River (Dey 1991). By the mid-1970s, elephants started moving into Purulia District (Shahi 1980) wherein they stayed for 20 days and damaged paddy fields. Shahi (1980) have also reported elephant movement in the month of September and some incidences of crop damage in West Medinipur during the same time.

The first long-distance movement by elephants from Dalma Wildlife Sanctuary to East Medinipur district beyond the Kangsabati river was recorded in the year 1987 (Dey 1991; Datye and Bhagwat 1995). This was probably due to the large expanses of agricultural land that lured the elephants to the area. The presence of huge croplands and no competition or threat from any other wild animals might have been a reason for the elephants to increase their range in the area. Another major reason for this change in movement was the forest degradation in the Mayurjharna ER that necessitated their range expansion. Further, the movement of Maoist groups in the region during the mid-1990s led to further degradation in the quality of the forests. Large numbers of big trees including many fruiting trees were illegally cut down, which caused severe destruction of elephant habitat.

Since then the rich agricultural land in West Medinipur has become the major foraging ground. Currently, the elephants only use Mayurjharna as a corridor to pass through to reach Jhargram and Medinipur forest divisions and spend a maximum of their time in Medinipur, Rupnarayan, and Bankura districts to feed on the agricultural crops. Over the year’s elephants have been observed to return to the same areas and use them as foraging grounds. The absence of continuous forest patches and the presence of agricultural land on peripheries of the forest fragments have led to the depredation of agricultural land. This, in turn,has given rise to human-elephant conflict in the region. To mitigate this conflict, the Forest Department has undertaken various precautionary measures and actions such as erecting electric fences, digging trenches,and also regular driving of elephants through *hula* (a practice of driving away the elephants using a torch made of rags and cloth put on fire using any flammable oil) parties. The use of North and South Bankura Forest Divisions by elephants has decreased considerably in the last few years due to construction of barricades and forceful *hula* driving to protect dense cultivation dominant lands of Burdwan district. Also, the movement of elephants from the Odisha border has been disturbed due to the presence of concrete-lined irrigation canals and other barricades. Elephants are prevented from entering the state by these barricades as well as by using *hula*. Nevertheless, a few animals manage to cross the border and enter Odisha state and spend time there before returning to South Bengal. The movement of elephants is now restricted to certain pockets of South Bengal; but the duration of their stay has increased due to the various barricades in the Odisha state and the degraded forests in Jharkhand state.

CHAPTER-IV

Population status and social organization of elephants in South Bengal

4.1. Introduction

Estimating the abundance of a species is an indispensable parameter for monitoring and assessing conservation programs (Sharma et al. 2010). The periodical monitoring of animal populations is always emphasized in the management plans of protected areas (Alexander 1996). Various methodologies including observations from direct and indirect evidence have been used to determine animal populations (Eggert et al. 2003; Jathanna et al. 2003; Sharma et al. 2010). Count of dung, nests, trails, calls, and direct observations along transects have been widely used to estimate the abundance and density of animals (Eberhardt and van Etten 1956; Gannon and Foster 1996; Fragoso 1991; Fashing and Cords 2000; Barnes 2001; McNeilage et al. 2001; Kumara et al. 2012). More recently, photo-capturing has been widely used to estimate the population of large mammals, e.g., tiger (Karanth and Nichols 1998) and bear populations (Crooks et al. 1998; Mace et al. 1994). Capture-recapture models using photo-marked individuals have been used for monitoring purposes (Mace et al. 1994; Karanth and Nichols 1998). In the case of elephants, the commonly used methodologies include line-transect surveys direct detections (Caughley and Goddard 1975; Jathanna et al. 2015; Kumara et al. 2012), dung count techniques (Baskaran et al. 2013; Madhusudan et al. 2015), mark-recapture method (Goswami et al. 2007), waterhole count (Jennifer et al. 2010), and use of acoustic sensors (Thompson et al. 2009; Thompson et al. 2010). However, the distance sampling methodology along with the dung count surveys remains to be the most widely used and reliable technique for estimating elephant populations. Hence, we employed the line transect method for direct detection and the belt transect method for dung count to estimate the elephants in South Bengal.

Distance Sampling:Line-transect models allow estimates of density to be made under a few assumptions (Buckland et al. 1993), often with greater accuracy (Buckland et al. 2001). The three basic assumptions of line transect sampling include (1) objects on the line are always detected; (2) objects are detected at their initial location before they move in a non-random fashion in response to the observer, and (3) distances and angles are measured accurately. A best-fit model is usually picked based on Akaike's Information Criterion (AIC) value and goodness of fit tests generated by the program DISTANCE. In addition, the encounter rate, the average probability of detection, cluster density, cluster size, and animal density are chosen using the selected model.

Dung Count Method:Dung count is the estimate of dung pile density in an area using the line transects or belt transects (Burnham and Anderson 2002). This method has been used (Barnes and Jensen 1987; Dawson and Dekker 1992) for surveying elephants in Africa as well as in Asia (Short 1983; Merz 1986; Dawson 1990; Barnes et al. 1995; Santosh and Sukumar 1995; Varman et al. 1995; Baskaran et al. 2013; Madhusudan et al. 2015). In this method, the density of dung piles in an area is estimated using the line transects or belt transects (Burnham and Anderson 2002). It requires estimates of three variables, i.e., dung-pile abundance on the ground, defecation rate, and dung decay rate that gives the dung density, which is then converted into elephant density (Baskaran et al. 2013; Varman et al. 1995).

In addition to an estimate of the population, understanding their social organization is crucial to know the viability of the population. The social organization of an Asian elephanthas been studied very little as compared to their African counterparts. There have been many long-term studies on African elephants (Douglas-Hamilton 1972; Moss and Poole 1983; Moss 2001) where their multi-tiered social organization has been studied and defined. Studies on the Asian elephant shows the existence of basic social units (mother and dependent offspring; Sukumar 1989), family groups comprising of two or more mother-offspring units (Fernando and Lande 2000), and clans (larger associations of family groups; Sukumar 1989, 1994; Baskaran et al. 1995). Usually, the males disperse on reaching adulthood (de Silva et al. 2011; Eisenberg et al. 1990; Fernando and Lande 2000; Vidya and Sukumar 2005) and join the social groups only during mating. Always a division-union dynamickeeps on taking place in the social units (de Silva et al. 2011). The photographic capture-recapture to estimate population sizes for both Asian and African species is one of the most widely used techniques nowadays (Goswami et al. 2007; Morley and van Aarde2007). A photo taken on the first encounter is considered as an initial 'capture' and subsequent photographs are considered as 'recaptures'. The photographs can be taken by camera traps (Karanth et al. 2006) or by human observers (Goswami et al. 2007). As most adult elephants can be identified through natural markings, the identification becomes easy and subsequent identification of the entire herd could be made. In this study, we have attempted to provide the social structure of the herds in our study area and broadly categorized the herds based on the different age-sex categories. In this chapter, we discuss different techniques used to estimate the population status of elephants and their social organization in South Bengal.

4.2. Methods

The dung count technique involves the estimation of three factors, i.e., the estimate of the dung decay rate, dung density, and defecation rate.

Dung Decay Rate: To determine the dung density, we first determined the dung decay rate in the landscape. The dung decay rate is the rate at which the dung disappears under natural conditions (Fig. 4.1). The decay rates can highly vary between different sites due to differences in climatic conditions, especially rainfall. Inter-site differences in rainfall regime, weather conditions, elephant diet, and vegetation type have major implications for dung-based surveys, and thus the decay rate from other sites may not be used. It is preferred to estimate the decay rate for each site while determining elephant densities. We adopted categorization of the decay stages as defined by Dawson (1990) since insects like termites attack the boli from within; thus, the breakdown of eachbolus is not readily evident. These stages are defined below:

A: Boli intact, very fresh (<1 day old); moist with odour.

B: Insect activity commenced from beneath (detected by the fact that dung was cemented to the substrate), but all boli still intact.

Cl: Less than 50% of the boli consumed by the termites.

C2: More than 50% of the boli consumed by the termites

D: All boli disintegrated as a result of termite activity, but not necessarily turned into a flat amorphous mass.

E: Only mud left (in the shape of boli); no dung left except for a few fibers.

To determine the dung decay rate, in total 28 fresh dung piles were selected and marked in the Goaltore range in the Rupnarayan division. The GPS locations were recorded for each dung pile. Visits were made once every seven days to check the piles for decomposition and the decay stages were recorded. The visits were made until the dung piles fully decomposed.

STAGE A

STAGE B

STAGE C1

STAGE C2

Figure 4.1 Different dung stages for scoring to estimate the dung decay rate

To calculate the decay rate, the survival method was adopted (Dawson 1990). It derives the "life expectancy" of a dung pile from a life table of dung surviving at the end of each week (Armitage and Berry 1987). In this method, dung piles are monitored until the last dung pile disappears and the mean expected survival time is calculated. The reciprocal of this survival time gives the decay rate (r). This means that: $r = 1 / T$, where T is the mean survival time per dung pile.

Belt transect for elephant dung count: In total 25 belt transects (Fig. 4.4)were laid in Rupnarayan and Medinipur forest divisions (Fig. 4.2) and 28 belt transects in Mayurjharna ER (Fig. 4.3). The length of transects varied between 1 km to 3 km adding to 42.3 km (42300 m) in Rupnarayan and Medinipur forest divisions and 51.7 km (51700 m) in Mayurjharna spatially representing the larger landscape by covering all the major forest areas (Fig. 4.3).

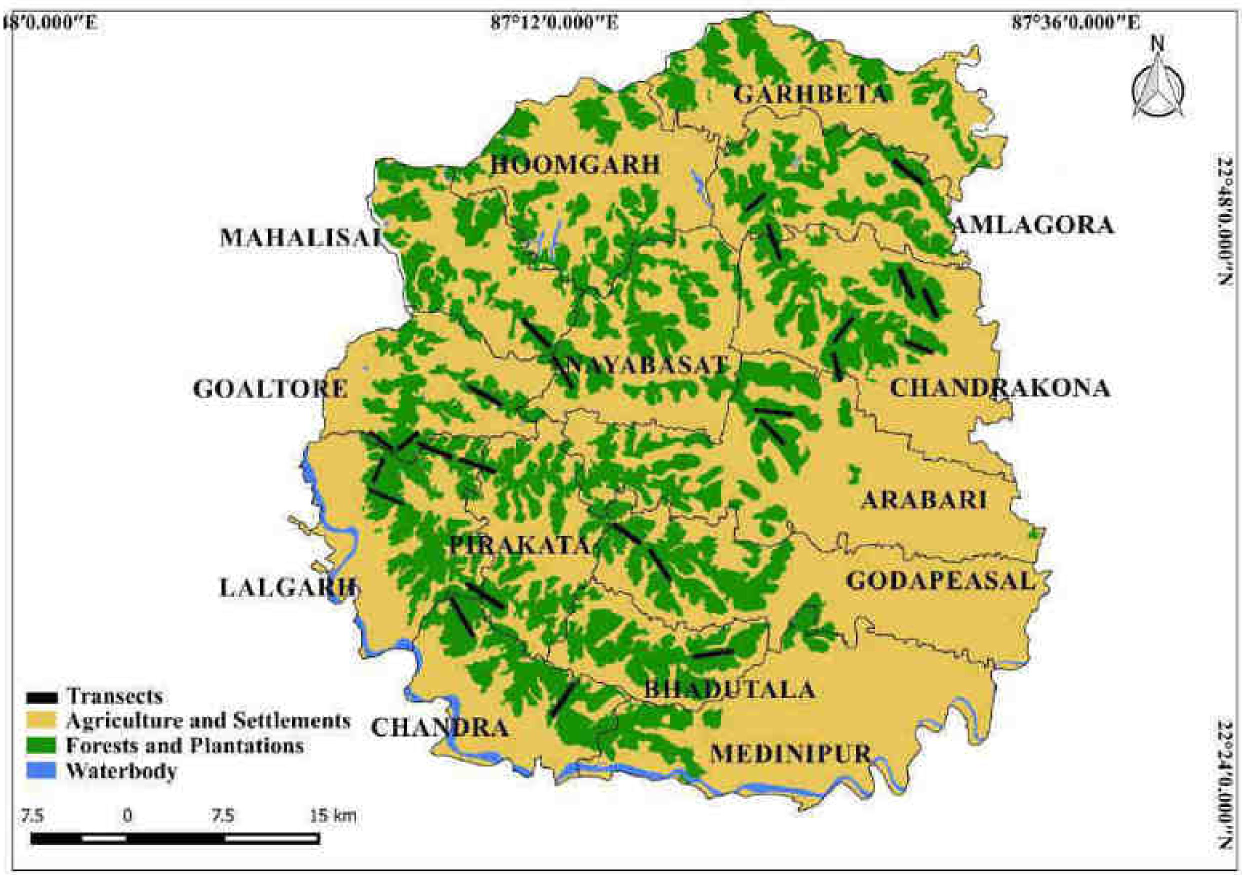

Figure 4.2 Belt transects in Rupnarayan and Medinipur Forest Divisions

For counting the dung piles, a transect belt width of 4 m (2 m on each side) was considered. The belt transects were walked and all dung piles observed within 2 m on both sides of the transect were recorded (Fig. 4.4). The assumption was that all the dung piles within 4 m of the belt are detected. On sighting dung piles, the GPS readings and dung stages were recorded.

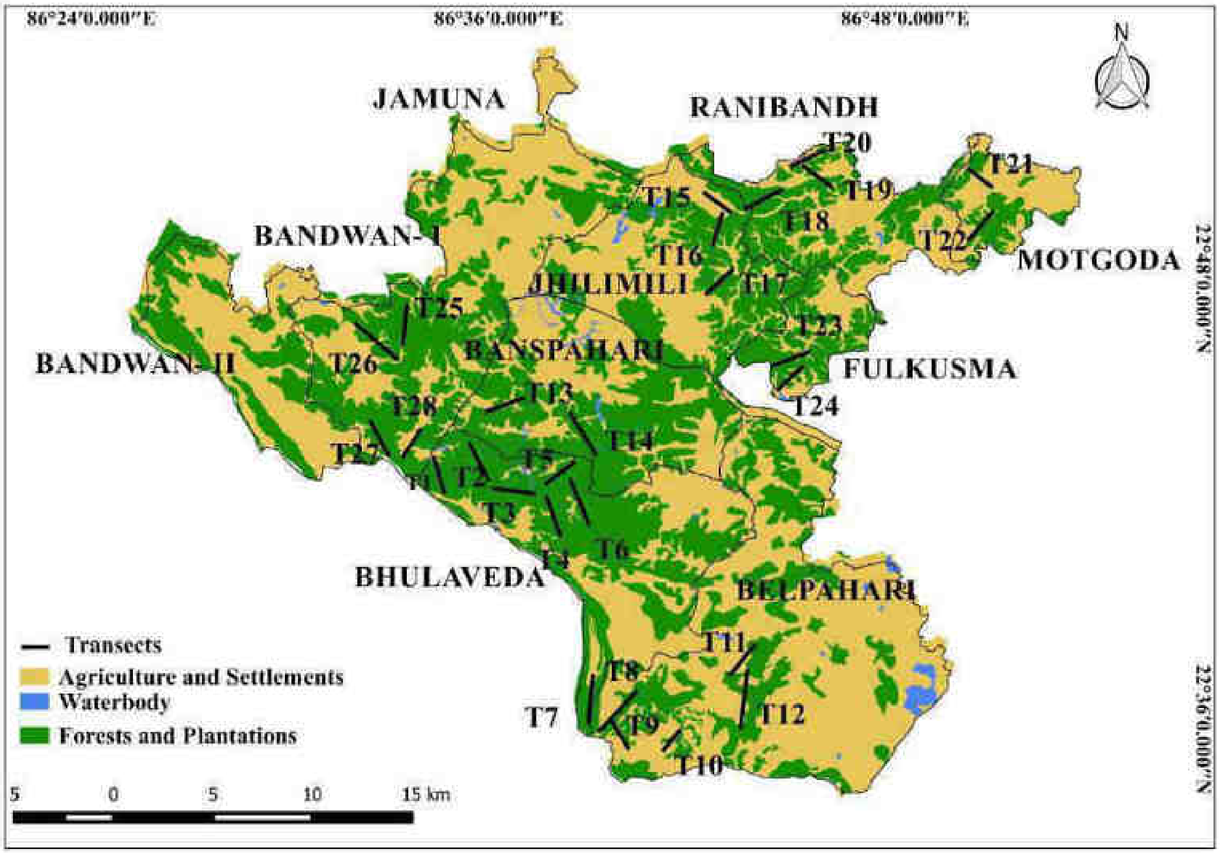

Figure 4.3 Belt transects in Mayurjharna ER

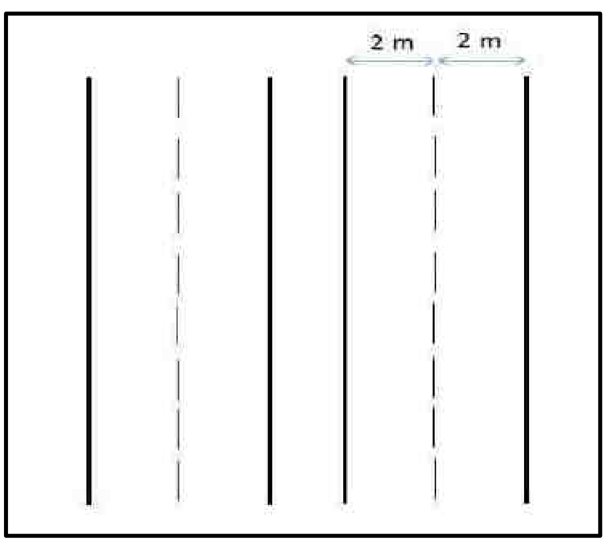

Figure 4.4 Belt transect for dung count

Line transect for direct detection of elephants: Line transects were laid only in Mayurjharna ER and not in other areas due to the continuous movement of elephant populations away from those areas. A total of 28 transect lines were laid in Mayurjharna ER (Fig. 4.3). Initially, each transects lines were determined on the ground and mapped using a handheld global position system (Garmin eTrex). The transect length varied between 1 km and 3 km, maintaining a minimum gap of one kilometer between each transect line. All the transect lines spatially represented the entire landscape and major forest types of Mayurjharna ER.

Each transect line was walked 12 times in the morning between 0600 and 1130 hrs between December 2016 and March 2017 (Table 4.1). Thus, in total 620.4 km of transect walk was made. The date and time at the start and endpoint of the transect walk were recorded.

Social Organization: Elephant herds were photographed whenever possible; videos and photographs of elephants were also collected from the villagers and the forest staff on a regular basis. By comparing various photographs and videos, herds were identified and the number of elephants in each herd was counted. The elephants were then categorized into different age-sex classes following the figure description in Varma et al. (2012). The elephants were also classified into various age-sex categories based on relative height and morphological characteristics (Daniel et al. 1987; Sukumar 1989). Younger elephants (<15 years) were classified by comparing their height to the oldest adult female in the group. The elephants were grouped as calves (<1 year), juveniles (1-5 years), sub-adults (5-15 years), and adults (>15 years).

Elephant density estimation: It requires estimates of three variables, i.e., dung-pile abundance on the ground, defecation rate, and dung decay rate that gives the dung density which is then converted into elephant density using the formula (Baskaran et al., 2013; Varman et al., 1995) given below.

$$E = Y \times r / D$$

Where E is the density of elephants, Y is dung density, r is the decay rate, and D is the number of dung piles deposited (defecation rate) per elephant per day.

4.3. Results

In Rupnarayan and Medinipur forest divisions, 72 dungpiles were recorded on the belt transects (Table 4.1). The total area of sampling was 0.17 km^2. That gives a dung density of 423.53 dungs/ km^2. Similarly, in Mayurjharna ER, in the total area of 2.07 km^2sampled 5 dung piles were recorded giving a dung density of 2.42 dungs/ km^2.

Dung decay rate: It took 49 days for 20 dung piles to decompose and 56 days for the rest of the 8 dung piles to decompose.

For Decay rate: Mean time (T) = [(20*49) + (8*56)] / 28 = 51 days, therefore, Decay rate (r) = 1/T = 1/51= 0.0196. The decay rate was estimated to be **0.0196 perdung per day.**

The defecation rate (D) in Indian conditions was taken as 16.33 dungs per day.

Therefore, elephant density in Rupnarayan and Medinipur forest divisions (E) = Y× r / D

= 423.53 *0.0196 / 16.33 = **0.52** elephants/ km^2

Elephant density in Mayurjharna ER (E) = 2.42 *0.0196 / 16.33 = **0.003** elephants/ km^2

The estimated elephant density in Rupnarayan and Medinipur forest divisions was 0.52 (Table 4.1). If the area of the two divisions taken together is 2697 km^2, then the minimum population size of elephants is 1348 elephants. Similarly, the estimated elephant density in Mayurjharna ER was 0.003 elephants/ km^2. If the area of the reserve is 414 km^2, then the minimum population size of elephants in Mayurjharna ER is 1.2 elephants.

Table 4.1 Estimates of elephant density using dung count method for Rupnarayan and Medinipur forest divisions and Mayurjharna ER

Area	No. of Transects	Dung piles found	Area (km^2)	Density (elephants/ km^2)
Rupnarayan and Medinipur	25	72	0.17	0.518
Mayurjharna ER	28	5	2.07	0.003

Detection of elephants on line transect: A total of 620.40 km of transect walk was carried out in Mayurjharna ER (Table 4.2) with no elephant detection. Hence, the density could not be computed.

Table 4.2 Sampling effort and detection of elephants in Mayurjharna ER

Forest Range	No. of transect lines	The total distance of transect lines (km)	Number of replications	No. of detections
Bhulaveda	7	15.2	12	0
Belpahari	5	6.8	12	0
Banspahari	2	4.4	12	0
Jhilimili	3	4.4	12	0
Ranibandh	3	6.3	12	0
Motgoda	2	3.8	12	0
Fulkusma	2	3.4	12	0
Jamuna	4	7.4	12	0

Table 4.3 Details of the elephant herds in South West Bengal

HERD ID	≥ 30 yr. MALE	≥ 30 yr. FEMALE	≥ 15 yr. MALE	≥ 15 yr. FEMALE	≤15 yr. MALE	≤15 yr. FEMALE	JUV	CALF	UN	TOTAL
1	1	2	0	1	1	3	1	1	0	10
2	0	5	0	4	2	2	1	3	0	17
4	1	4	1	6	3	1	6	4	0	26
6	1	2	2	1	0	1	0	2	3	12
7	1	6	4	7	2	2	3	0	0	25
								TOTAL		**97**

Social organization: We have identified seven herds in South West Bengal from which demographic data on five herds with a total sum of 97 individuals have been collected. The herds were classified into different age-sex classes (Table 4.3). The mean group size was 17 animals; the adult female: calf ratio was 1:0.51 while the adult female: adult male ratio was 1:0.31.

4.4. Discussion

The study attempted to estimate the elephant density using direct detection on line transects and dung count on belt transects. The elephants were not detected on line transects, despite 620.4 km of walk-on spatially representing line transects in Mayurjharna ER. During the dung count survey, 72 dung piles were detected in 0.17 km^2 sampling in Lalgarh and Medinipur forest divisions and five dung piles in 2.07 km^2 sampling in Mayurjharna ER.Thus, we could estimate the density of elephants only from the belt transect sampling, i.e. 0.51 elephants/ km^2 in Lalgarh and Medinipur forest divisions and 0.003 elephants/ km^2 in Mayurjharna ER.

A minimum of 40 detections is required to use DISTANCE software to compute the density of an animal using the line-transect technique (Buckland et al. 1993), otherwise causing bias due to the high confidence interval. To use detection-based estimation using the DISTANCE program, there should be some resident and evenly distributed minimum population of a species to obtain minimum required detections to estimate the density. However, that was not the case in the current study and hence estimation could not be made. There are many factors that affect elephant density estimation, such as the defecation rate and other spatial and temporal factors. One basic assumption of the dung survey is that all the elephants in a habitat defecate in the same rate, which, however, is not true. According to Wanghongsa (2004), there is a substantial difference in the defecation rate between ages and sexes of elephants. Elephants are also known to defecate more in humid zones (Sivaganesan and Kumar 1994), than elephants in a dry zone. The deterioration rate also acts as a major variable. Nchanji and Plumptre (2001) found that the deterioration rate was faster in the wet season than in the dry season which may be due to the higher activity of insects in the wet season, which accelerates the deterioration process of dung piles.

An estimate of densities using similar field techniques was available for several protected areas and landscapes in South Asia (Table 4.4). In Sri Lanka, the population density was estimated to be between 0.10 and 0.46 elephants/ km^2 (Eisenberg and Lockhart 1972).Sukumar (1989) reported 0.56 elephants/ km^2 in the deciduous forests of Chamarajanagar, Kollegal, and

Satyamangalam Forest Divisions in South India. Population densities as high as 3.10 elephants/ km^2 in Mudumalai Tiger Reserve (Tamil Nadu Forest Department 2010), 2.60 elephants/ km^2 in Kaziranga National Park, 2.40 elephants/ km^2 in Nagarhole Tiger Reserve, 2.10 elephants/ km^2 in Bandipur National Park (Jathanna et al. 2015), 1.75 elephants/ km^2 in Wayanad Wildlife Sanctuary (Kerala Forest Research Institute 2007), 1.70 elephants/ km^2 in Biligiri Rangaswamy Temple Tiger Reserve (Kumara et al. 2012) were reported based on dung count/transect surveys. Varman et al. (1995) reported 1.54 elephants/ km^2 for Mudumalai Wildlife Sanctuary and Baskaran et al. (2007) reported a density of 1.10 elephants/ km^2 for Anamalai Hills. These estimates indicate that line transects and dung surveys have provided robust estimates. On comparing our estimates with the other areas in the country, the density of elephants in Mayurjharna ER is insignificant while in the forest divisions of Rupnarayan and Medinipur is comparable but questionable. Making direct comparisons of density estimates may not be appropriate because elephants in South Bengal appear to be a moving population. At any given point of time, one or two herds would be present in the landscape; however, their movement pattern is unnatural due to the regular driving of them for long distances by people. Thus, determining the density using the line-transect technique using direct detections of the animal from transect walk or through dung count would be complicated. Our interaction with the local people and forest department personnel during our survey revealed that elephant herds were not recorded in Mayurjharna ER. Further, they revealed that elephants used the Mayurjharna ER for a day or two, and then they would move out. In the absence of a resident population, the possibility of zero detection was obvious in Mayurjharna ER. Even, very low detection of fresh dungs during the dung count made it difficult for us to estimate their density using the dung count method. The presence of a few herds of elephants in the entire landscape of South Bengal, and herds always being driven from one forest patch to the other, results in elephants venturing into new areas, making it more complicated to estimate the area of suitable habitat for elephants in the study area. Thus, estimating the population size for the entire landscape including Mayurjharna ER would be biased if the dung count method or 'line transect' method is followed. The formation of groups and their sizes are highly influenced by the availability of forage (Jarman 1974) and predation (Geist 1998). Usually, the elephants have huge resource requirements; hence, smaller groups are formed to avoid competition within a family unit (Sukumar 2003). Living in small groups during foraging can be a good approach to avoid competition, especially when there is a shortage of food or food availability is patchy. The group sizes of elephants are based on strong social connections/bonds, which are also influenced by factors like avoiding competition for food. Elephants live in groups of 5 to 20 animals who interact and communicate with each other as one family unit (Sukumar 2006). Similar observations were made in the present study too where group sizes of 12 to 20 elephants were recorded. Similar mean herd sizes have been observed in other parts of the country too (Table 4.5).

Table 4.4 Estimate of Asian elephant density from other parts of the country

Area	**Elephants/ km^2**	**Method**	**Source**
Mudumalai Wildlife Sanctuary	1.54	Dung count	Varman et al. 1995
Buxa Tiger Reserve	0.35		Sukumar et al. 2003
Wayanad Wildlife Sanctuary	1.75	Dung count	Kerala Forest Research Institute, 2007
Kalakad–Mundanthurai Tiger Reserve	0.10- 0.20	Dung count	Varma 2008
Bannerghatta National Park	0.70	Dung count	Varma et al. 2009
Mudumalai Tiger Reserve	3.10	Dung count	Tamil Nadu Forest Department, 2010
Nilgiri North	0.50	Dung count	Tamil Nadu Forest Department, 2010
Satyamangalam Tiger Reserve	0.30	Dung count	Tamil Nadu Forest Department, 2010
Biligiri Rangaswamy Temple Tiger Reserve	1.70	Distance sampling	Kumara et al. 2012
Anamalai Hills	1.10	Dung count	Baskaran et al. 2013
Bandipur National Park	2.10	Distance sampling	Jathanna et al. 2015
Bhadra Tiger Reserve	0.30	Distance sampling	Jathanna et al. 2015
Kaziranga National Park	2.60	Distance sampling	Jathanna et al. 2015
Nagarahole Tiger Reserve	2.40	Distance sampling	Jathanna et al. 2015
Mayurjharna Elephant Reserve	0.0029 and 0.50	Dung count	Current study

Table 4.5 Herd size and age-sex ratios of Asian elephants from protected areas in India.

Area	Mean Group size	Adult female: calf ratio	Adult female: adult male ratio	Source
Mudumalai, India	4.6	1:0.26	1:0.11	Ramesh et al. 2012
Bandipur	7.8	1:0.37	1:0.40	Johnsingh 1983
Nagarhole	3.5	1:0.20	1:0.18	Arivazhagan 2005
Hasanur- Biligiri Ranga Hills	7.6	1:0.20	1:0.20	Sukumar 1985
Periyar	-	1:0.16	1:0.02	Arivazhagan 2005
Parambikulum	7.9	1:0.32	1:0.14	Easa and Balakrishnan 1995
Rajaji	6.8	1:0.41	1:0.54	Williams et al. 2007
South West Bengal	17	1:0.51	1:0.31	Current study

The ratio of females to calves in a herd is an important parameter that influences the population growth rate of elephants (Ramesh et al. 2012). The high number of calves and juveniles shows the tremendous reproductive health of elephant females in South Bengal. The reported adult male to female ratio is comparable to other areas in the country (Table 4.5) which could be attributed to the lack of competition among males for mating and hence,the survival of males becomes easy. Although the loss of habitat in the entire landscape is an alarming situation when it comes to the survival of the elephant population, elephants are thriving in terms of reproduction and maintaining population size.

CHAPTER-V

Path length and habitat use by elephants in South Bengal

5.1. Introduction

Animal movement is one of the many significant ecological processes considered crucial for a better understanding of population dynamics and animal behavior (Horne et al. 2007). It is a complex process controlled by various factors acting at different spatial and temporal scales (McClintock et al. 2014). Studying animal movement patterns allows ecologists to determine the distribution of species, both in space and time, especially the migrating wildlife populations. For successful conservation and management of migrating wildlife populations, it is crucial to understand when and how animals move (Berger 2004; Thirgood et al. 2004; Schick et al. 2008) and the factors that influence their movements in different environments (Pinaud 2008). The movement of animals is controlled by the spatial dispersion of the forage and their success in the exploitation of such resources (Viswanathan et al. 1999;Bartumeus et al. 2005). The strategies adopted by animals have always been the center of focus due to the significance of the interactions between the movement patterns of animals and the environmental heterogeneity (Turchin 1998; Viswanathan et al. 1999; Zollner and Lima 1999; Bartumeus et al. 2005). For a migrating population, availability of resources, predation risks, habitat conditions, and the risk of interactions with humans play an important role in determining their movement paths and feeding grounds (Hunter 2007). Since the availability of resources varies a lot seasonally influencing the large mammalian populations, forcing them to use part of an area more than the other (Dunham 1994). The effort any animal population putsin by adjusting to changing habitat conditions in terms of movement, diet, and other necessities regulate their population survival and reproductive success (Morales et al. 2010). Hence, an understanding of the movement pattern is a prerequisite for the long-ranging animals (Bolger et al. 2008; Harris et al. 2009).

Initially, elephants in South Bengal were visitors; however, in recent times they have almost become residents. Therefore, understanding their movement patterns and habitat use is crucial to assist the conservation and management of elephants in the human-dominated landscape of South Bengal.

5.2. Methodology

The data on elephant movement was collected between August 2017 and December 2018. To study the path length and habitat use, two herds, Herd 1 (10 individuals) and Herd 7 (25 individuals) were selected. The herds were recognized based on some key individuals identified by their body characters, tail shape, body wounds, tail length and cuts. Possible attempts were made to follow the herds both in the day and night hours. Since the *hula*drive is a common practice in the landscape, we accompanied them on many such occasions. The elephants are usually agitated due to continuous driving and tend to become aggressive. Thus, maintaining the distance from the herd, we followed the track and collected the data on movement patterns using handheld global position system. The geo-coordinates were recorded at every 100 m of the path taken by the focal herd. The daily movement of the herd was recorded along with the data on herd size, and driving type (if occurs) i.e. *hula*drive conducted either by the forest department or by the local villagers. The day-wise data on 24 hr scale was segregated and loaded into Ranges 7 Software to compute the path length (PL) of the animals. The movement records for less than six hours were not considered for analysis.

The selected sites of the two herds were overlaid with 2 x 2 km grids on the QGIS platform. The geo-coordinates obtained were plotted on the gridded select sites on the QGIS platform. The number of geo-coordinates falling into each grid is considered as an indicator of the intensity of the habitat use. The extent of usage of each grid in different divisions was depicted by color gradients, greater was the usage where darker the color.

5.3. Results

*Habitat use:*1268 grids of 2 x 2 kilometers were laid in Kharagpur Division, 533 grids in Medinipur, and 268 grids in Rupnarayan Forest Division. Of these, 92 grids were utilized by the elephants in Medinipur, 64 in Kharagpur, and 22 in Rupnarayan Forest Divisions (Table 5.1). Most of the used grids are found on the margins of the forest area close to agricultural fields (Fig. 5.2 to 5.10)

Table 5.1 Number of days local herds were followed and the grids utilized by them in Rupnarayan, Medinipur and Kharagpur forest divisions

Habitat use	Rupnarayan Forest Division	Medinipur Forest Division	Kharagpur Forest Division	No of days followed
No. of grids utilized by Herd 1	22	53	24	170
No. of grids utilized by Herd 7		30	64	82
Total no. of grids utilized by all herds combined	22	56	64	

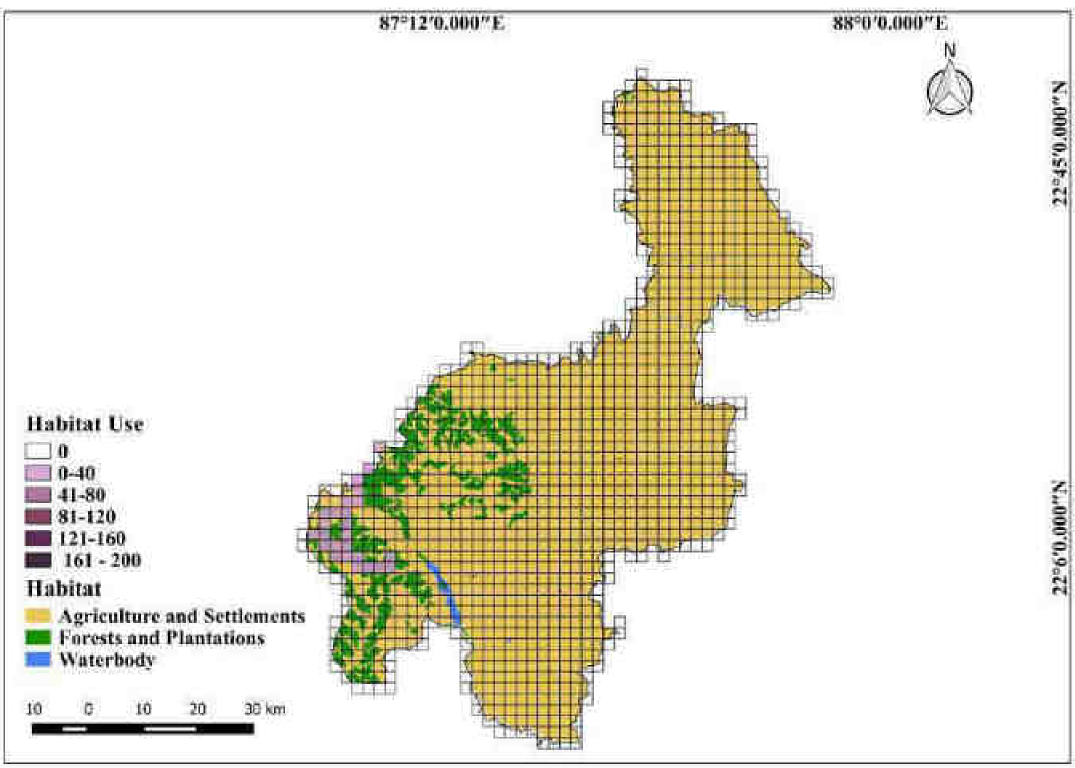

Figure 5.1 Intensity of habitat use by elephant herd-1 in Kharagpur Forest Division

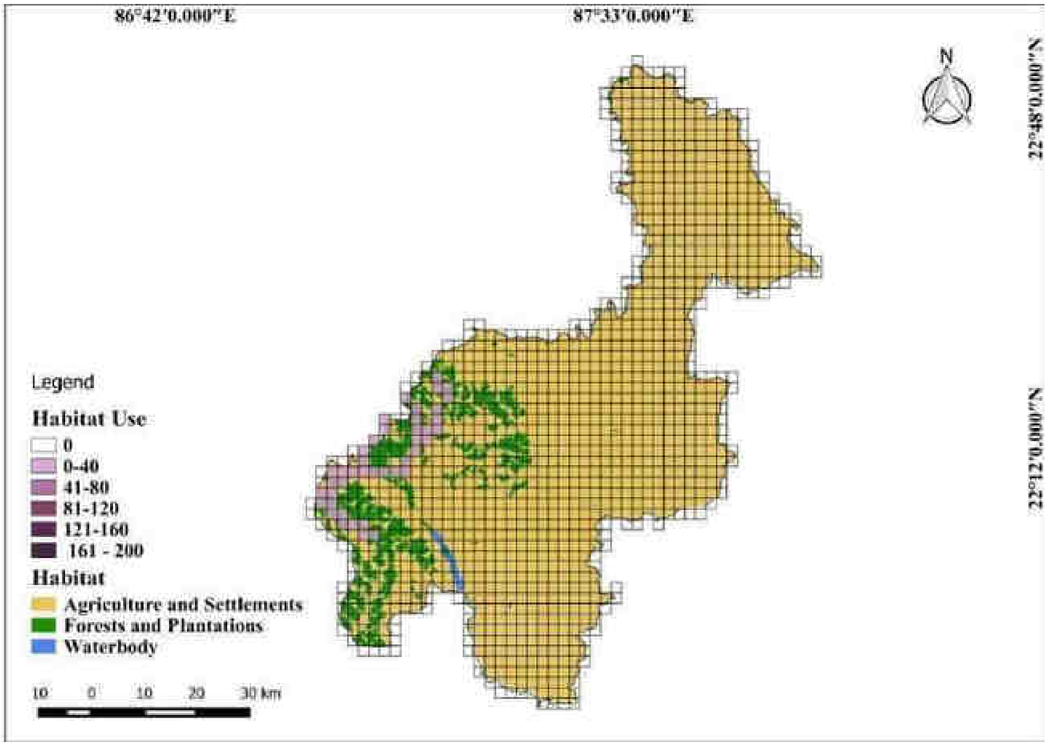

Figure 5.2 Intensity of habitat use by elephant herd-7 in Kharagpur Forest Division

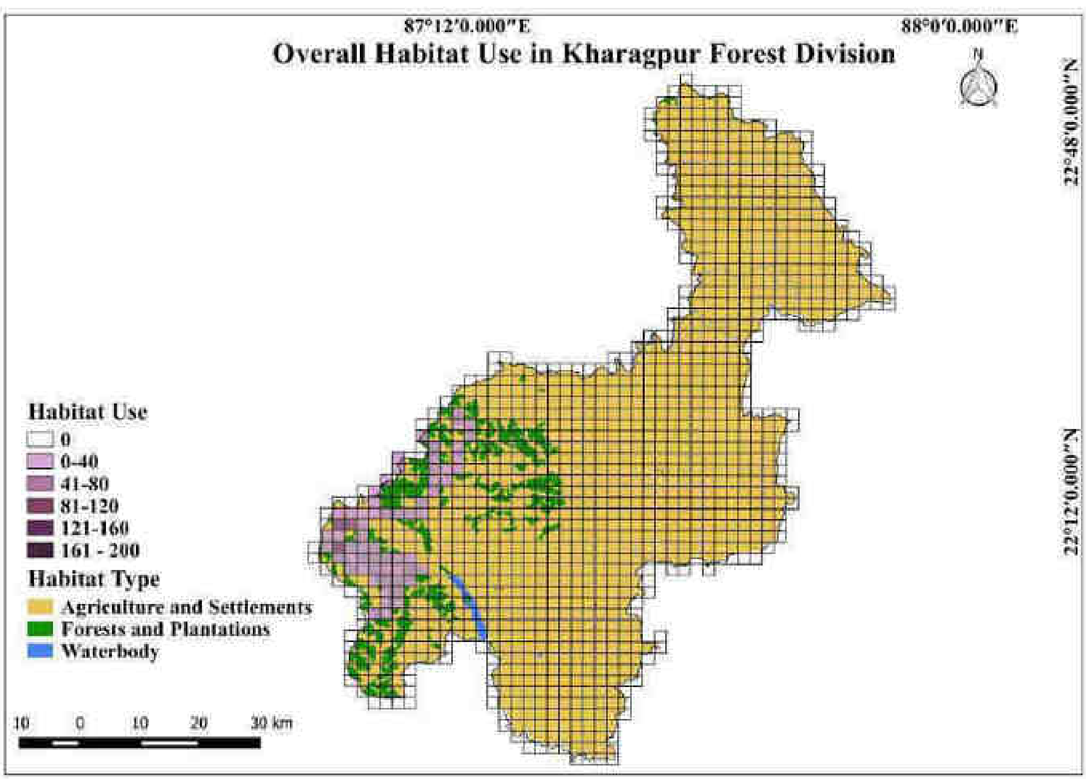

Figure 5.3 Overall intensity of habitat use by both the elephant herds in Kharagpur Forest Division

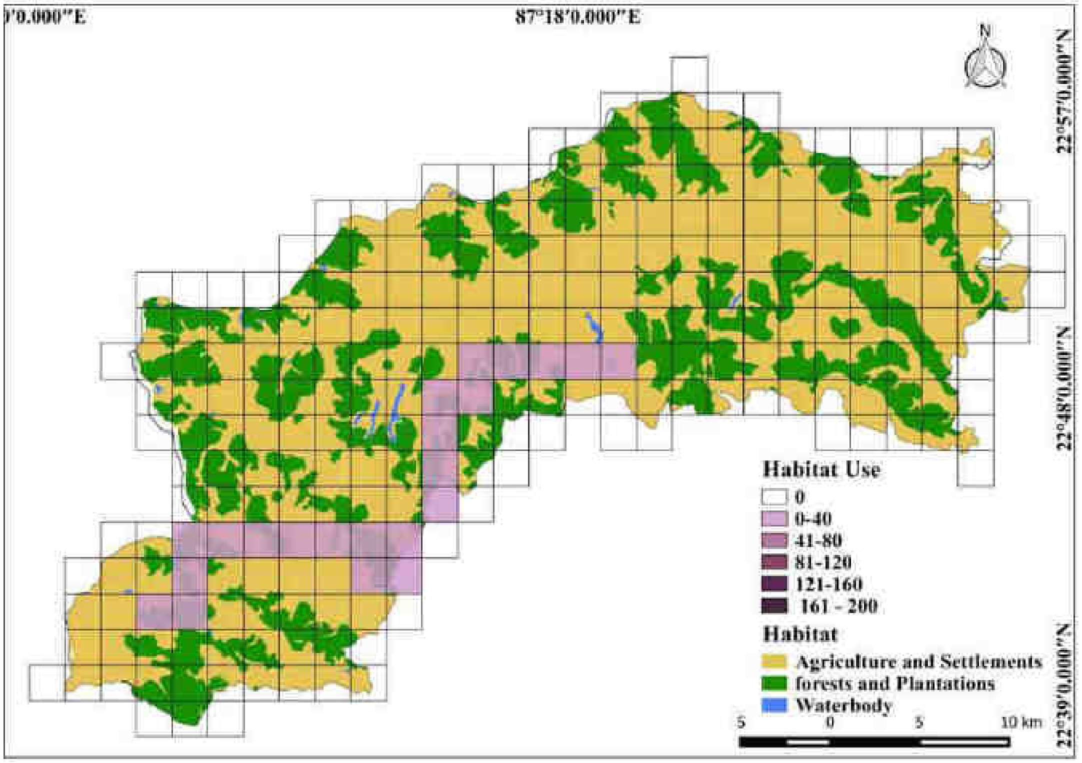

Figure 5.4 Intensity of habitat use by elephants in the Rupnarayan Forest Division

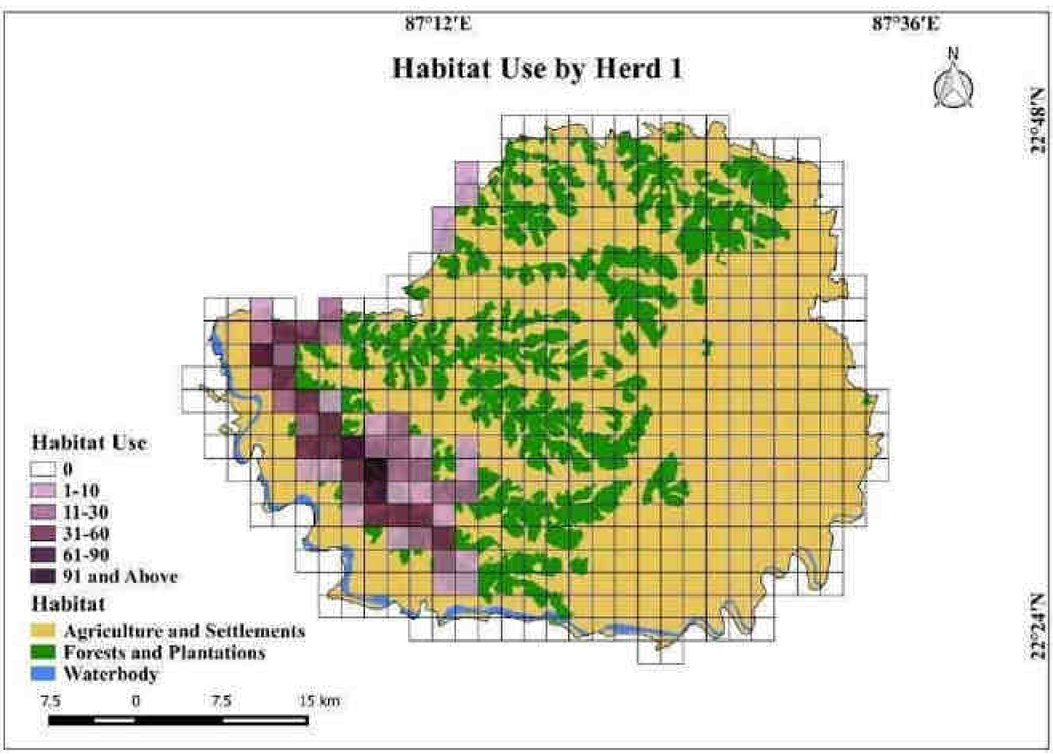

Figure 5.5 Intensity of habitat use by elephant herd-1 in Medinipur Forest Division

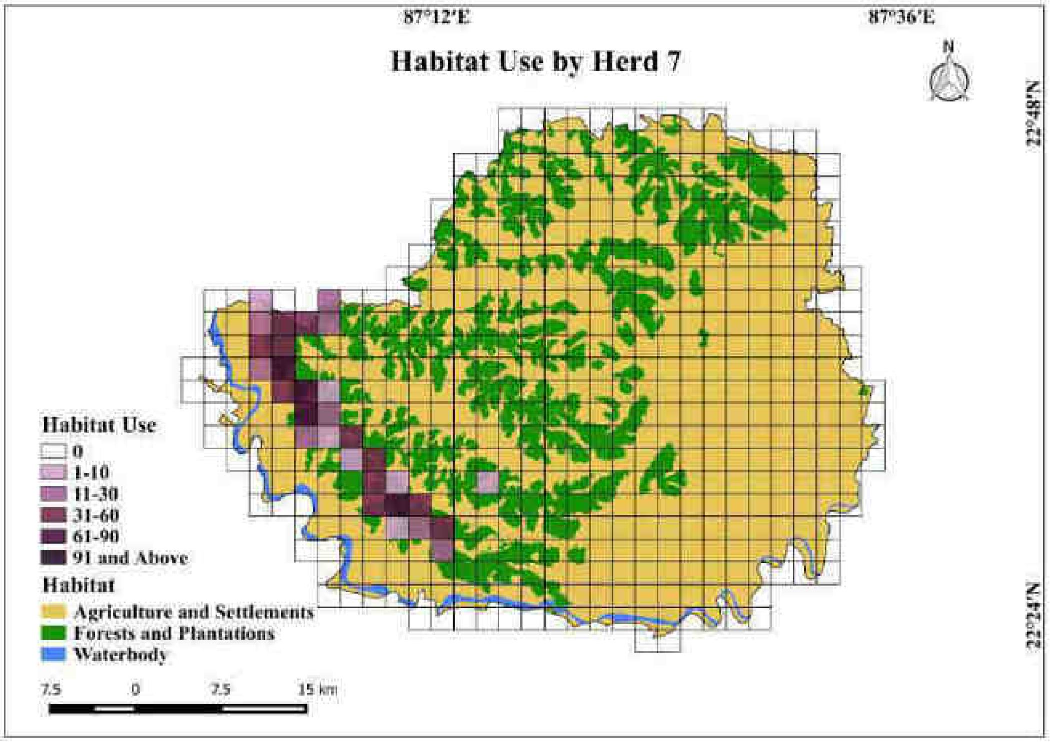

Figure 5.6 Intensity of habitat use by elephant herd-7 in Medinipur Forest Division

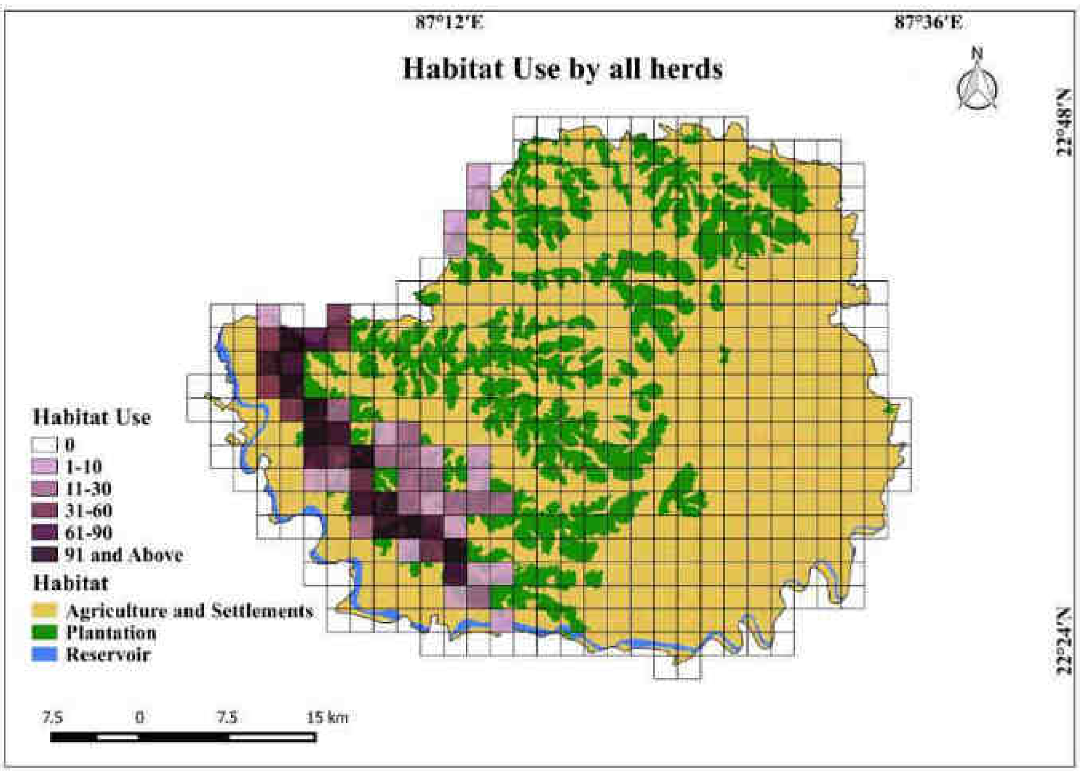

Figure 5.7 Intensity of habitat use by all the elephant herds in Medinipur Forest Division

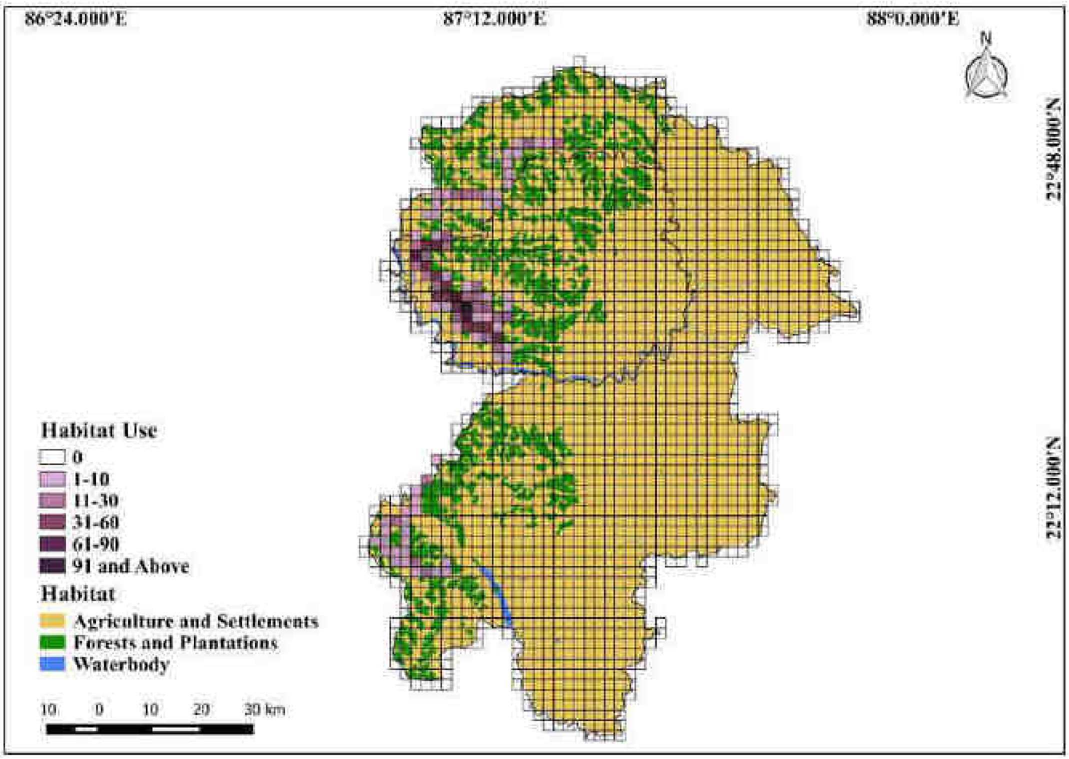

Figure 5.8 Intensity of habitat use by elephant herd-1 in three forest Divisions of Kharagpur,Medinipur, and Rupnarayan

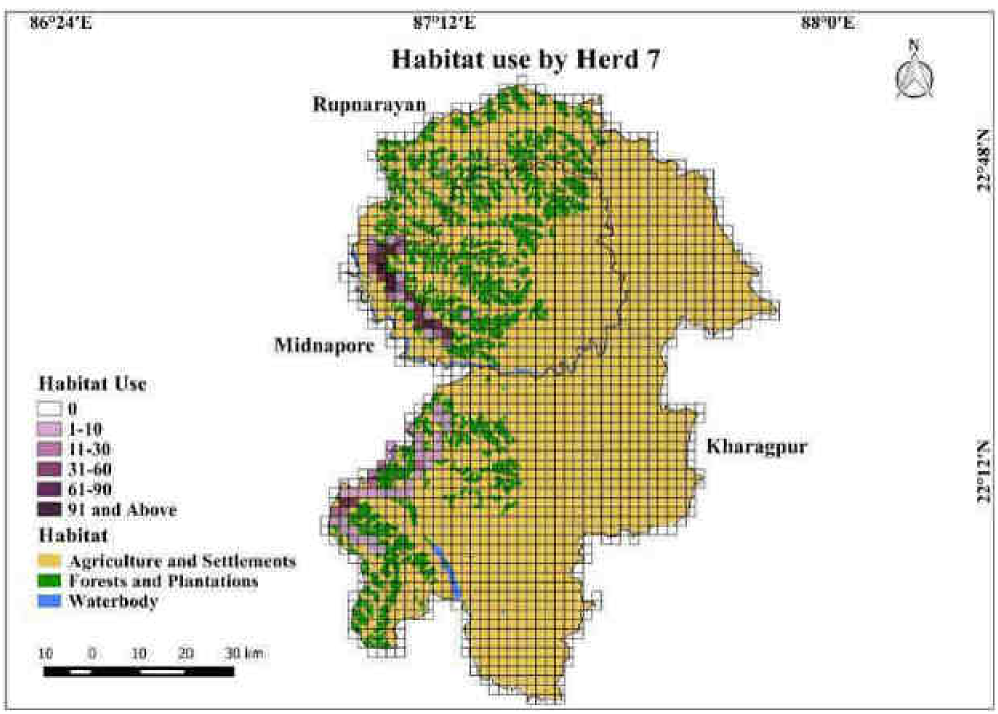

Figure 5.9 Intensity of habitat use by herd-7 in the three forest divisions of Kharagpur, Medinipur, and Rupnarayan

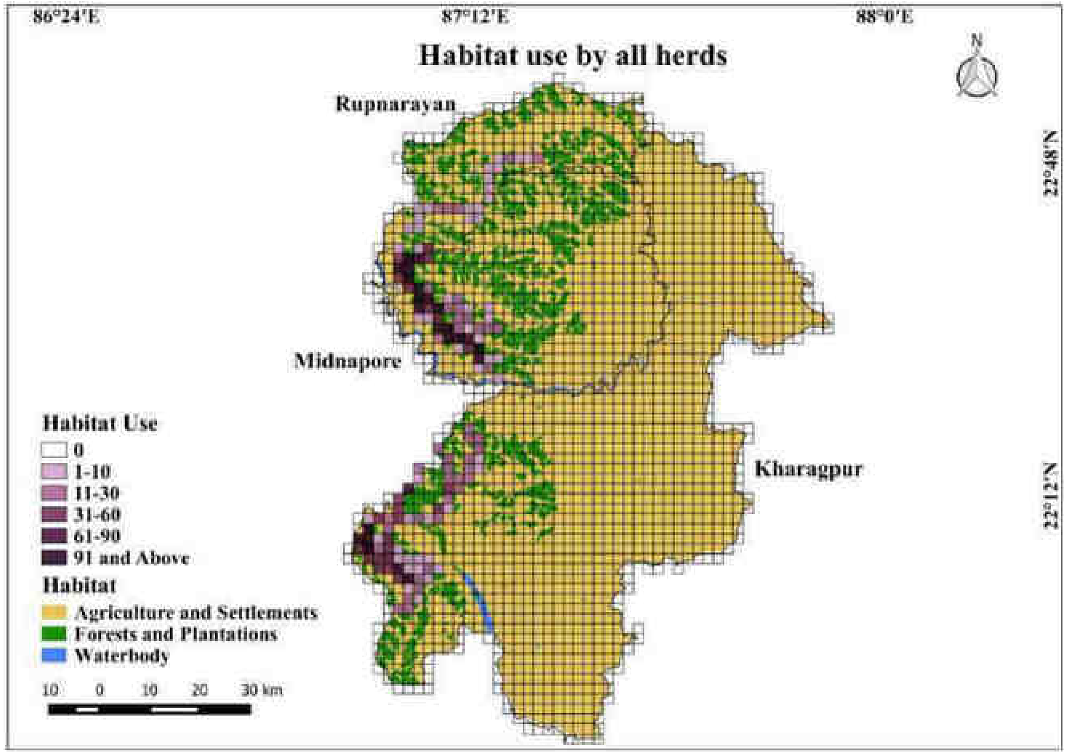

Figure 5.10 Intensity of habitat use by the herds in Kharagpur, Medinipur, and Rupnarayan Forest Divisions

Path length: Day-wise movement by the elephants was calculated in terms of daily path length for the whole of 224 days. The path length of the elephants was negatively related to their herd size (r_s =-0.171, N= 190, $p < 0.05$; Fig. 5.12). Although the mean path length varied between 5518.6 ± 2524.17 SDand 9599.4 ± 3348.99 SD (Fig. 5.13), that did not differ across the months ($F_{10, 179}$ = 0.690, p =0.733). However, the mean path length was significantly higher during the *hula*drive (9467.0 ± 4300.4 SD; Fig. 5.14) ($F_{2, 187}$ = 21.776, $p < 0.001$) than the drives by the local people (4927.1 ± 2217.4 SD) or natural movement (6860.1 ± 5324.7 SD).

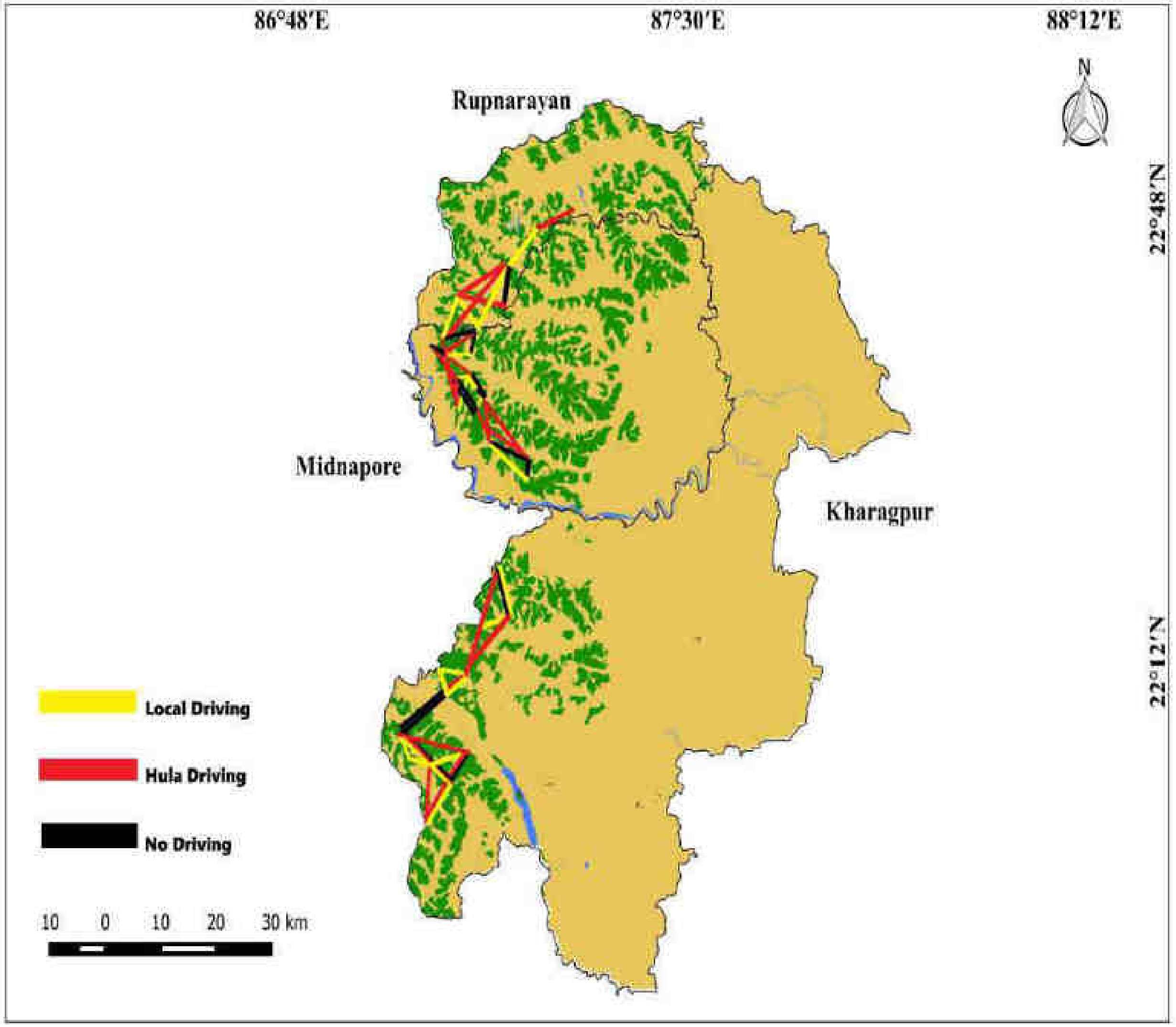

Figure 5.11 Movement pattern of local elephant herds in Rupnarayan, Medinipur, and Kharagpur Forest Divisions

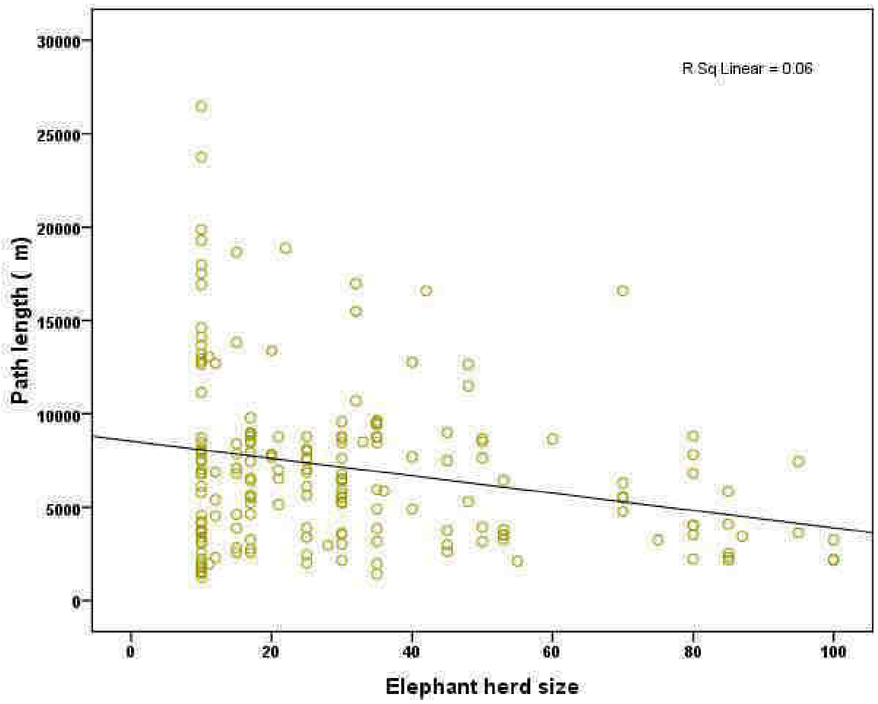

Figure 5.12 The relationship between elephant path length and their herd size

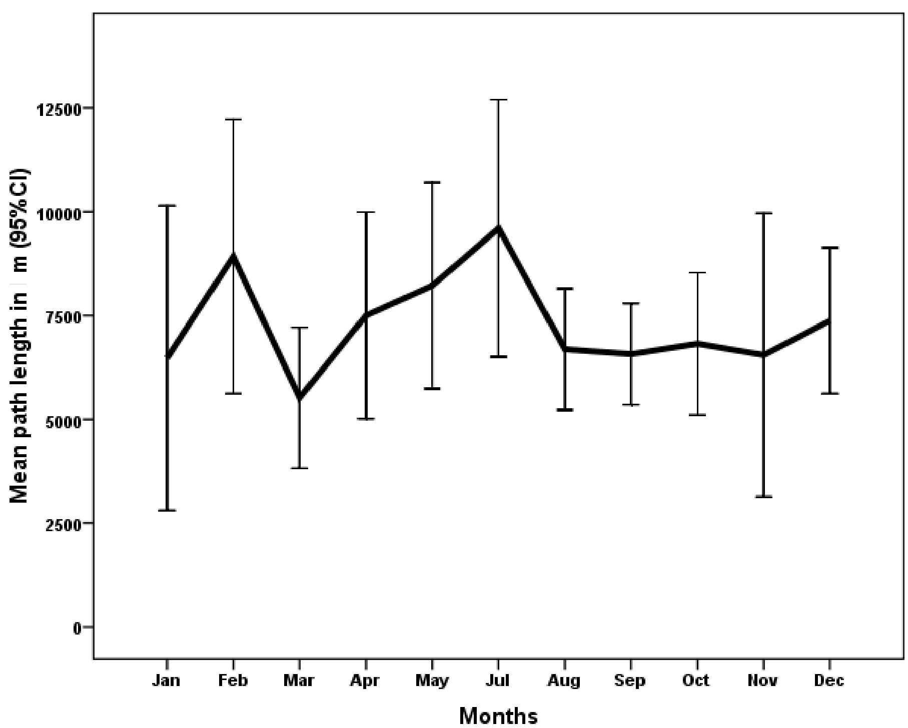

Figure 5.13 Mean path length of elephants in different months

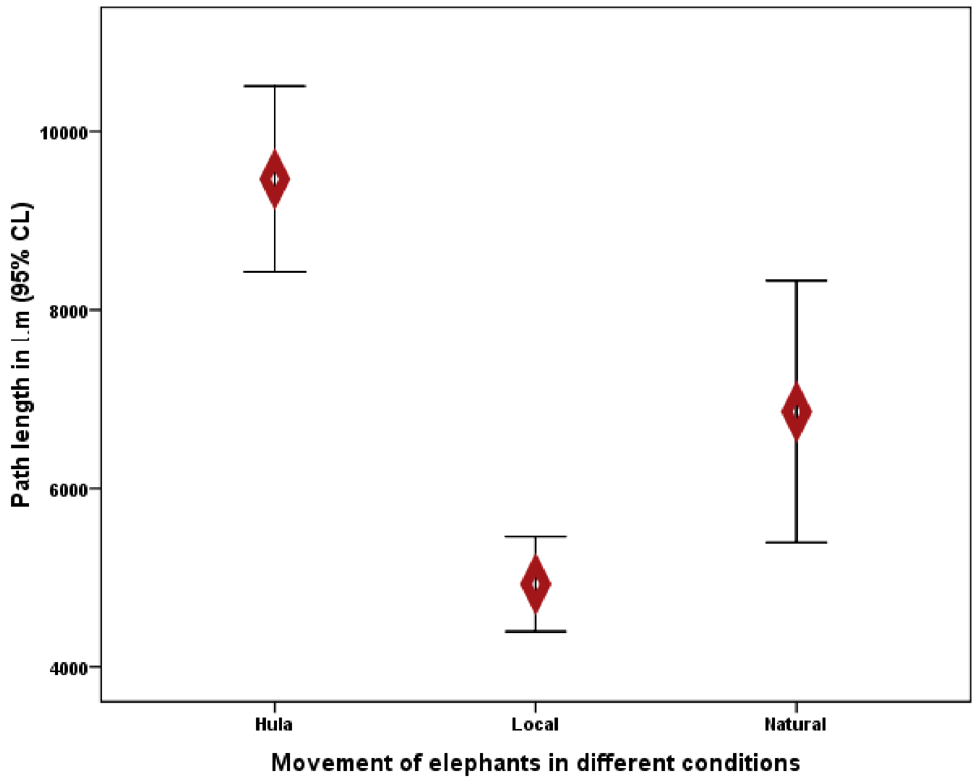

Figure 5.14 The path length of elephants in different conditions in South Bengal

5.4. Discussion

In total 92 grids were utilized by the elephants in Medinipur, 64 in Kharagpur, and 22 in Rupnarayan Forest Divisions. Although the mean path length of elephants across the months was the same, the distance traveled due to *hula*driving was significantly more than the natural movement or when driven by the local people. The herd size of elephants was negatively related to the path length.

The elephants showed an inclination towards mixed forests and areas surrounding the agricultural land, which is consistent with other studies for elephants in Indonesia (Rood et al. 2010), India (Sukumar 1989; Areendran et al. 2011), Sri Lanka (Fernando et al. 2008b) and China (Zhang et al. 2015). A large number of grids used by the elephants had both forests and agriculture fields or were associated with agriculture fields largely in marginal areas, similar to the reports from Nepal (Steinheim et al. 2005; Pradhan and Wegge 2007), India (Sukumar 1989, 1990), and China (Zhang and Wang 2003). Marginal areas are generally rich in elephant feed

(Sukumar 1989, 1990; Zhang and Wang 2003) and are close to the crop fields owing to their high nutritional values compared to other vegetation types (Anderson and Briske 1995; Steinheim et al. 2005). Elephants retreat to forests for cover and/or shade when not feeding on grasses, and/or may travel through these areas while searching for food or for avoidingan encounter with humans while traveling. The sal forest provides low-quality food (Steinheim et al. 2005) and elephants use sal vegetation considerably less compared to other vegetation types in India (Williams et al. 2008). However, the sal forest is the only forest in the entire landscape, and therefore the use of the available forest is inevitable for elephants there.

Due to a high degree of human-elephant conflict, the *hula*drive is often practiced in the landscape to avoid over-depredation of crops, thereby altering the natural movement pattern (direction and path length) of elephants. The local drives (the practice of driving the elephants done by the local villagers in which they usually drive the elephant from one village to another to save their crop) by the villagers drivethe elephants awayonly for short distances; and hence, the mean path length was much lesser than the *hula*drive. The mean path length in different months did not vary across the months because elephants almost have become residents and driving them have become a regular event in South Bengal. The incessant driving (both local and *hula*) of elephants leave only a small window for the natural movement of elephants.

CHAPTER-VI

Food and feeding ecology of Asian elephants

6.1. Introduction

Elephants cover a large distance to satisfy their dietary needs (Sukumar 1989) and utilize an array of plant species and are generalized feeders (Sukumar 1990). As megaherbivores,they consume up to 150 kg of plant matter per day (McKay 1973). Hence, food availability is the chief factor determining the carrying capacity of elephants in a given area (Samansiri and Weerekoon 2007). Elephants largely depend on browse and forage, and are sometimes selective of the plant or plant part consumed (Owen-Smith and Chafota 2012). The content of secondary metabolites in particular tissues also has a major influence on their diet (Bryant and Kuropat 1980;Cooper et al. 1988). Moreover, the decrease in the availability of palatable food resources owing to habitat loss has led to unavoidable challenges for elephant survival (Sukumar 1990). Such decrease in natural food resources leads to crop-raiding by elephants and ultimately leads to conflict between human populations and elephants (De Boer and Baquete 1998). Further, they raid crops for high nutrient content (Sukumar 1990; Osborn 2004; Rode et al. 2006), especially in areas where cultivated lands border the forests.

In the case of south Bengal, the major movement of elephants happens in and around the fragmented forestland (chapter V), and they are continuously in close proximity to the agricultural land. Therefore, to understand the extent of the dependency of elephants on agricultural produce, a study on the feeding pattern of elephants was conducted.

6.2. Methods

Data on the food preferences of elephants was collected while following herd-1 and herd-7. GPS locations of the spots where signs of feeding were found while following the elephants were taken and 360 plots of 10 x 10 m area were laid. The tree species with clear signs of feeding like chewed vegetation, debarked and broken twigs and branches, scratched posts, foot and body marks on soil were identified and recorded (White 1994; Demeke and Bekele 2000; Shoshani et al. 2004; Chen et al. 2006). For each plot, a number of food plants and parts eaten by the animals were documented. For each species, the presence or absence of feeding sign was recorded but the amount consumed could not the quantified, as the feeding observations were not direct (Santra et al. 2008). Due to regular *hula* driving by the forest department or local community, elephants used to be very aggressive in the area.

The data were pooled according to different Forest divisions and were analyzed separately for the division. Analysis of the data includescomputing the relative frequency of different plant species observed in the diet, their relative abundance in the study area, and thus calculating preference indices. The preference index was calculated for each food item using the formula (Uresk 1984; De Boer et al. 2000; Kassa et al 2007) given below.

$$PI = \frac{u}{ab}$$

Where, *u* is the relative frequency of a food item in diet, and *ab* is the relative frequency of plant species in the study area.

PI score >1 indicates that the plant was utilized proprtionatly more than its occurrence in the environment and PI score<1 indicates that the plant was used proprtionatly less than its presence in the environment(Uresk1984). For any species where the abundance is not available, the relative abundance value of the least abundant species present in the observations is considered the value for the unavailable species and PI is calculated accordingly in the way (Uresk 1984) mentioned above.

Similarly, plots of 10 x 10 m were laid in cropland where elephants were observed feeding. In total 247 plots were laid in Medinipur, 45 plots in Kharagpur, and 55 plots in Rupnarayan Forest Division. A visual approximation was made of the percent crop depredated in each plot. The data were pooled and segregated according to different seasons as well as different forest divisions. For quantification of crops fed by the elephants, per hectare production for different crops was obtained from the official site of the Agricultural Department of India, and the total damage was calculated based on the percentage of the crop destroyed by the elephants during the study. The total quantities of crops consumed per day by elephants were calculated using the crop damage data collected during the study period and accordingly their contribution to the diet was calculated.

6.3. Results

Elephants were observed to feed on 13 wild plant species belonging to 12 families. Elephants showed a positive PI score for 9 out of the 13 utilized plant species (Table 6.1). Plant species that had relatively high PI scores ranged from 1.28 to 2.93. The strongest preference was for *Lannea grandis* (PI= 2.93), *Pterocarpus marsupiumRoxb*(PI= 2.67), and *Gardenia Gummifera* (PI= 2.56). Percent availability of highly preferred species like *L. grandis,P.marsupiumRoxb,*and *G. Gummifera* is 2 in the south Bengal while that of *Terminalia elliptica* and *Diospyros melanoxylon* is 3. However, the percent availability of *Shorea robusta* is 25 while its PI is 1.57.

Preference for *Aegle marmelos* (PI=1.57)*, Syzygium cumini* (PI=1.56), and *T. elliptica* (3.13) increase during the pre-monsoon period (Table 6.2), while consumption of *S. robusta* (PI=1.86)increases during the monsoon spell. However, consumption for *Artocarpus heterophyllus* (PI=1.05)*, Buchanania cochinchinensis* (PI=0.74), and *D. melanoxylon* (PI=1.85) is highest during the post-monsoon period.

The total area sampled in Medinipur Forest Division for paddy damage was 0.98 ha wherein 0.27 ha was damaged by elephants and the total estimated damage was 121500 kg. Similarly, for potato, 0.98 ha of cropland was sampled, of which 0.27 ha was damaged by elephants with a total loss of 14850 kg of potato. In the case of vegetables, 0.51 ha of cropland was sampled wherein 0.14ha was destroyed by elephants and the total loss incurred was 9500 kg of vegetables. Sugarcane crop was not sampled in the area due to lack of crop availability during the sampling time.

The total area sampled in Kharagpur Forest Division for paddy damage was 0.28 ha, of which 0.08 ha was damaged by elephants and the total damage was 36000 kg of rice. Similarly, for sugarcane 0.22 ha of cropland was sampled, of which 0.09 ha was found damaged by elephants with a total loss of 2700 kg of sugarcane. No potato and vegetable crops were sampled in this area.

The total area sampled in Rupnarayan Forest Division for paddy damage was 0.55 ha wherein 0.15 ha was damaged by elephants and the total damage was 67950 kg of rice. No potato, vegetables, and sugarcane cropland were sampled in the area

The total consumption for paddy per day per elephant was calculated to be 0.0002 ha which equals to around 100 kg of paddy per night. In the case of potato, total consumption was calculated to be around 60 kg of potato per night, in the case of vegetables it is around 65 kg per night and for sugarcane, it is around 50 kg per night. As the average requirement of food for elephants is around 150 kg, paddy makes around 66.66 % of their diet when in season, and the rest is fulfilled by forest produce. While potato makes around 40% of the diet when it is available and rest of the diet comprises of forest produce. Vegetables account for 43.3% of their diet when available and sugarcane makes around 33% of their diet when available.

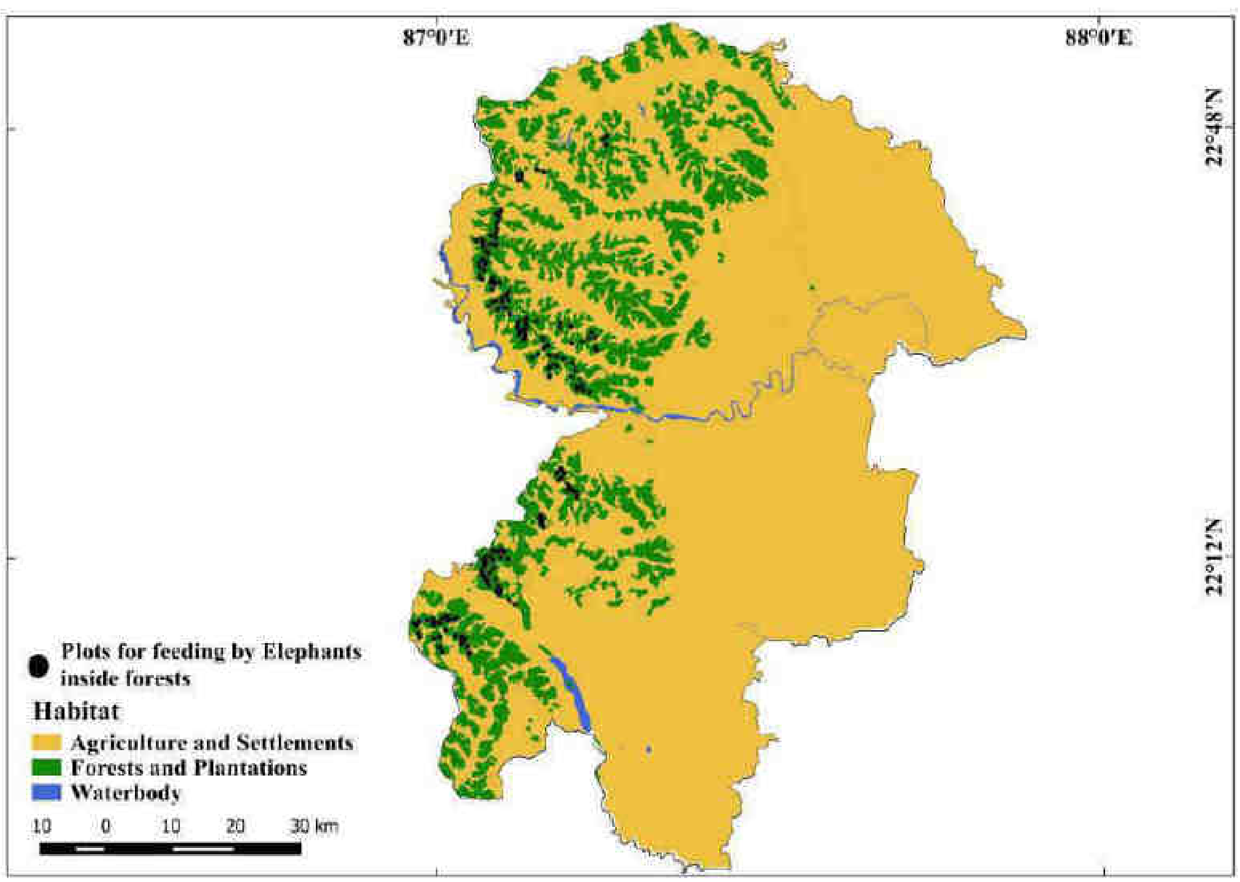

Figure 6.1 Location of study plots for feeding by elephants inside the forest in Rupnarayan, Medinipur, and Kharagpur Forest Divisions

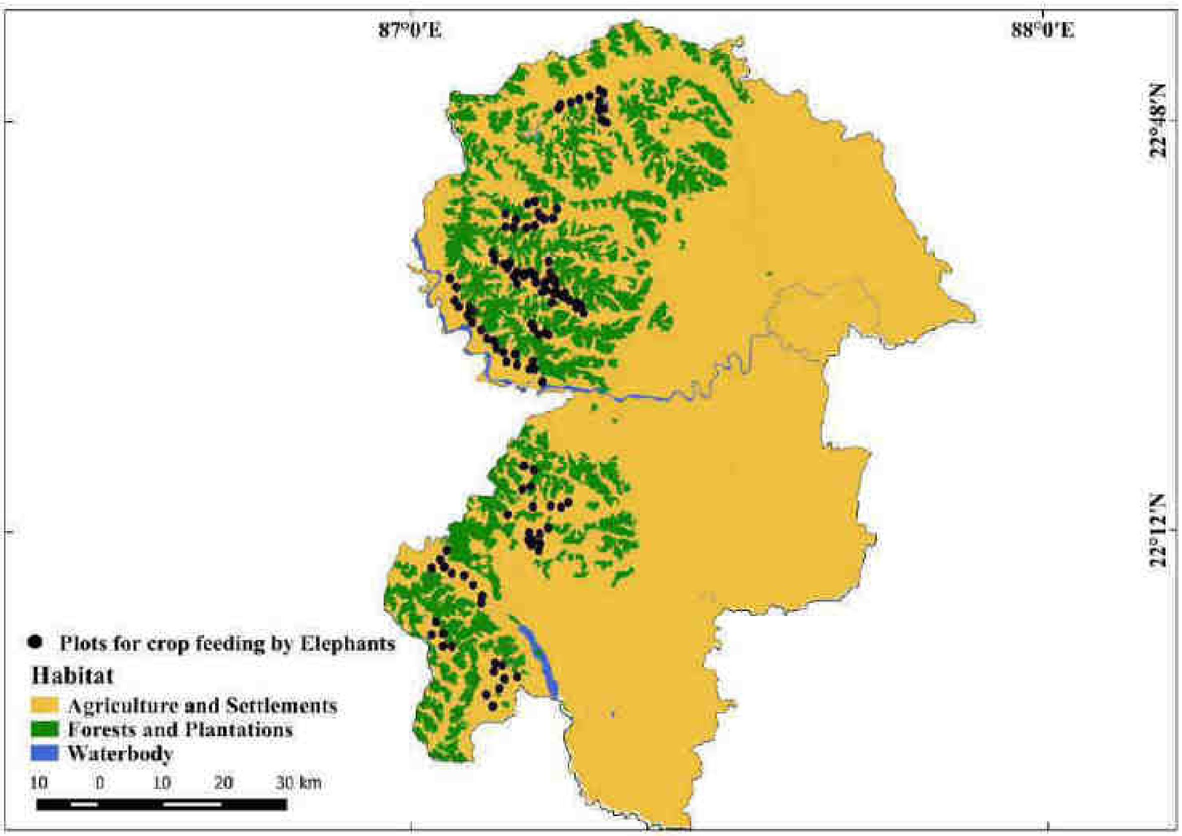

Figure 6.2 Location of study plots for crop feeding by elephants in Rupnarayan, Medinipur, and Kharagpur Forest Divisions

Table 6.1 Preference indices (PI) for the most important species in the diet of elephants

Species	Plant Part Consumed	Relative Frequency (% Utilization)	Relative Abundance (% Availability)	PI
Aegle marmelos	Fruit	2.56	2	1.28
Artocarpus heterophyllus	Fruit	2.24	3	0.75
Buchanania cochinchinensis	Foliage	6.18	10	0.62
Diospyros melanoxylon	Foliage and fruit	5.01	3	1.67
Gardenia gummifera	Foliage	5.12	2	2.56
Lannea grandis	Foliage	5.86	2	2.93
Madhuca longifolia	Flowers	10.23	6	1.71
Pterocarpus marsupium Roxb	Foliage	5.33	2	2.67
Phoenix sylvestris	Pith and fruits	2.13	1	0.21
Shorea robusta	Foliage and bark	39.34	25	1.57
Syzygium cumini	Fruit	2.67	2	1.33
Terminalia bellirica	Foliage and fruit	7.68	17	0.45
Terminalia elliptica	Foliage	5.65	3	1.88

Table 6.2 Preference Index (PI) for the important species in the diet of elephants according to different seasons

Tree species	Relative Frequency (% Utilization)			Relative Abundance (% Availability)	PI		
	Pre Monsoon	Monsoon	Post Monsoon		Pre Monsoon	Monsoon	Post Monsoon
Aegle marmelos	0.02	-	0.03	0.02	1.57	-	0.78
Artocarpus heterophyllus	0.00	0.01	0.03	0.03	0.00	0.40	1.05
Buchanania cochinchinensis	0.06	0.04	0.07	0.1	0.63	0.44	0.74
Diospyros melanoxylon	0.03	0.05	0.06	0.03	1.04	1.57	1.85
Gardenia Gummifera	0.06	0.06	0.04	0.02	3.13	3.01	2.21
Lannea grandis	0.05	0.06	0.06	0.02	2.34	3.14	2.95
Madhuca longifolia	0.11	0.10	0.11	0.06	1.82	1.61	1.75
Phoenix sylvestris	0.02	0.02	0.02				
Pterocarpus marsupium Roxb.	0.06	0.05	0.05	0.02	3.13	2.56	2.68
Shorea robusta	0.36	0.47	0.37	0.25	1.44	1.86	1.46
Syzygium cumini	0.03	-	-	0.02	1.56	-	-
Terminalia bellirica	0.11	0.07	0.08	0.17	0.64	0.41	0.47
Terminalia elliptica	0.09	0.06	0.05	0.03	3.13	2.01	1.66

Table 6.3 Total Estimated crop damage by elephants according to seasons in Medinipur Forest Division

Parameters	Season	Paddy	Potato	Vegetables	Sugarcane
No of Plots	Pre-Monsoon	18	0	20	0
	Monsoon	26	0	0	0
	Post Monsoon	54	98	31	0
Total plots		**98**	**98**	**51**	**0**
Total area sampled (ha)	Pre-Monsoon	0.18	0	0.20	0
	Monsoon	0.26	0	0	0
	Post Monsoon	0.54	0.98	0.31	0
Total		**0.98**	**0.98**	**0.51**	**0**
Average crop % destroyed	Pre-Monsoon	23	0	19	0
	Monsoon	30	0	0	0
	Post Monsoon	26	28	19	0
		26.33	**28**	**19**	**0**
Total Area destroyed (in ha)	Pre-Monsoon	0.04	0	0.04	0
	Monsoon	0.08	0	0	0
	Post Monsoon	0.14	0.27	0.06	0
Total area		**0.27**	**0.27**	**0.14**	**0**

Average production (kg per ha)		450000	55000	95000	30000
The estimated quantity of crop depredated (kg per ha.)	Pre-Monsoon	22500	0	3800	0
	Monsoon	36000	0	0	0
	Post Monsoon	63000	14850	5700	0
Total		**121500**	**14850**	**9500**	**0**

Table 6.4 Total Estimated crop damage by elephants according to seasons in Kharagpur Forest Division

Parameters	Season	Paddy	Potato	Vegetables	Sugarcane
No of Plots	Pre-Monsoon	0	0	0	15
	Monsoon	0	0	0	0
	Post Monsoon	28	0	0	2
Total		**28**	**0**	**0**	**17**
Total area sampled (ha)	Pre-Monsoon	0	0	0	0.15
	Monsoon	0	0	0	0
	Post Monsoon	0.28	0	0	0.17
Total		**0.28**	**0**	**0**	**0.22**
Average crop % destroyed	Pre-Monsoon	0	0	0	31
	Monsoon	0	0	0	0
	Post Monsoon	29	0	0	25
		29	**0**	**0**	**28**
Total Area destroyed (in ha)	Pre-Monsoon	0	0	0	0.05
	Monsoon	0	0	0	0
	Post Monsoon	0.08	0	0	0.04
Total area		**0.08**	**0**	**0**	**0.09**
Average production (kg per ha)		450000	55000	95000	30000
Estimated quantity of crop depredated (kg per ha)	Pre-Monsoon	0	0	0	1500
	Monsoon	0	0	0	0
	Post Monsoon	36000	0	0	1200
Total		**36000**	**0**	**0**	**2700**

Table 6.5 Total Estimated crop damage by elephants according to seasons in Rupnarayan Forest Division

Parameters	Season	Paddy	Potato	Vegetables	Sugarcane
No of Plots	**Pre-Monsoon**	1	0	0	0
	Monsoon	24	0	0	0
	Post Monsoon	30	0	0	0
Total		**55**	**0**	**0**	**0**
Total area sampled (ha)	**Pre-Monsoon**	0.01	0	0	0
	Monsoon	0.24	0	0	0
	Post Monsoon	0.30	0	0	0
Total		**0.55**	**0**	**0**	**0**
Average crop % destroyed	**Pre-Monsoon**	10	0	0	0
	Monsoon	23	0	0	0
	Post Monsoon	29	0	0	0
		21	**0**	**0**	**0**
Total Area destroyed (in ha)	**Pre-Monsoon**	0.001	0	0	0
	Monsoon	0.06	0	0	0
	Post Monsoon	0.09	0	0	0
Total area		**0.151**	**0**	**0**	**0**
Average production (kg per ha)		450000	55000	95000	30000
Estimated quantity of crop depredated (kg per ha)	**Pre-Monsoon**	450	0	0	0
	Monsoon	27000	0	0	0
	Post Monsoon	40500	0	0	0
Total		**67950**	**0**	**0**	**0**

Table 6.6 Total Estimated crop damage by elephants according to different seasons in the study area

Parameters	Season	Paddy	Potato	Vegetables	Sugarcane
No of Plots	Pre-Monsoon	19	0	20	15
	Monsoon	50	0	0	0
	Post Monsoon	112	99	31	2
Total		**181**	**99**	**51**	**17**
Total area sampled (ha)	Pre-Monsoon	0.19	0	0.20	0.15
	Monsoon	0.50	0	0	0
	Post Monsoon	1.12	0.99	0.31	0.02
Total		**1.81**	**0.99**	**0.51**	**0.17**
Average crop % destroyed	Pre-Monsoon	19	0	19	31
	Monsoon	27	0	0	0
	Post Monsoon	28	28	19	25
		24.66	**28**	**19**	**28**
Total Area destroyed (in ha)	Pre-Monsoon	0.04	0	0.04	0.05
	Monsoon	0.14	0	0	0
	Post Monsoon	0.31	0.28	0.06	0.005
Total area		**0.49**	**0.28**	**0.10**	**0.055**
Average production (kg per ha)		450000	55000	95000	30000
Estimated quantity of crop depredated (kg per ha)	Pre-Monsoon	18000	0	3800	1500
	Monsoon	63000	0	0	0
	Post Monsoon	139500	15400	5700	150
Total		**220500**	**15400**	**9500**	**1650**

6.4. Discussion

Out of the 13 wild plant species that elephants were feeding on, the availability of most of the species is very low in the study area.The presence of sufficient fodder species for elephants in the forests is a requisite to support the population of elephants in an area. Basu (2009) reported *S. robusta* to be the dominant species followed by *Butea monosperma* and *Madhuca longifolia* in the Bankura district. Pandit (2011) also recorded *S. robusta* to be the dominant species in the Medinipur district. Santra et al., (2008) recorded 52 plant species in four plots of 1500 m^2 in West Medinipur, Bankura, and Purulia districts. Of that, 22 species preferred by elephants were identified, and among them,*D. melanoxylon* and *P. marsupiumRoxb* were found utilized to the maximum, an observation similar to that of our study.

Various studies have been done on the feeding behavior of Asian elephants in different parts of the world. According to Sukumar (1990) in southern India, elephants consumed around 112 plant species, but 85% of their diet consisted of only 25 species. According to Lahkar et al. (2007), 18 species of flowering plants were found to be part of their diet in the Manas National Park during the dry season. Another study in the Shangyong National Natural Reserve in China reported 106 plant species to be part of the elephant diet (Chen et al. 2006). Another study on the feeding behaviour of wild Asian elephants in Rajaji National park by Joshi and Singh (2008) suggested that elephants consume 50 species, out of which trees represented 74% of the species that elephants fed followed by 14% (grass species), 8% (shrub species) and 4% (climber species).The increase in preference for *A.marmelos* (PI=1.57)*, S.cumini* (PI=1.56), and *T. elliptica* (3.13) during the pre-monsoon period coincides with the fruiting season of these species which is similar to the observation made by Joshi and Singh (2008) where the preference for *A. marmelos*, *Zizyphus mauritiana*,*S. cumini,* and *Ehretia laevis* increased during the fruiting season. The proportion of crops consumed by elephants is indicative of their dependence on agricultural produce in their daily diet. Crops constitute around 50 % of their daily diet and the rest 50% is procured from the forests, even more, difficult when the availability of natural fodder is low.

There is a requirement of a huge amount of food and water for a megaherbivore like an elephant for their day-to-day activities (Owen-Smith 1988). The elephants usually debark or uproot the entire trees while feeding or under stress (Höft and Höft 1995). De-barking the trees or uprooting them terminates that particular tree and that leads to furthermore reduction in the already low number of fodder species in the forests. Hence, the absence of enough fodder in the forests compels the animals to raid nearby agricultural lands. That also makes the animal visit the croplands at regular intervals to feed. Such frequent raiding increases the interaction of the animal with humans and thereby increasing conflict. That means that it is very important to have an optimal amount of fodder in the forests to avoid human-animal interactions.

Certain changes in the habitat of this region like a replacement of the species such as *Shorea robusta* and *Eucalyptus tereticornis* with fodder species such as *Lannea grandis, Aegle marmelos, Madhuca longifolia, Pterocarpus marsupium,* and *Buchanania cochinchinensis* will help in enriching the forests in terms of food availability for the elephants. The presence of adequate palatable fodder in the forests might make the elephant spend longer time within the forests, and thus, they are likely to stay away from agricultural fields for a longer period, eventually reducing interactions and conflicts in the landscape.

a)

b)

Plate 1. Elephants depredation on a) Potato crop; b) Vegetables

c)

d)

Plate 2. c) Elephants in a paddy farm; d) Potato farm depredated by elephants.

e)

f)

Plate 3. e) Bambooate by elephants; f) tree debarked by elephants

CHAPTER-VII

Human-elephant conflicts

7.1. Introduction

A range of direct and indirect negative interactions between humans and wildlife leads to conflicts thatare likely to harm everyone involved, bringing in negative attitude in humans towards wildlife, eventually decreasing appreciation of wildlife that would potentially affect conservation (De Boer and Baquete 1998; Nyhus and Tilson 2000). A wide range of species is involved in the conflict, e.g., primates, rodents, ungulates, lions, leopards, and hyenas (Hill 2000; Naughton-Treves 1998; O'Connel-Rodwell et al. 2000; Saj et al. 2001). Apart from human deaths and injuries, other conflict includes economic losses due to crop depredation and house damages, restrictions on movement, competition for water sources, loss of cattle through predation and psychological stress (Hoare 1995; Naughton-Treves 1998; Sukumar, 1990; Tchamba 1996; Williams et al. 2001). Human-elephant conflict is not a new phenomenon, and crop-raiding has been in place as early as the nineteenth century when farmers cultivating crop in central African forests used to lose entire crops to elephants, while in other areas crop-raiding by elephants caused food shortages and displaced settlements (Barnes 1996; Graham 1973; Parker and Graham 1989; Ville 1995). The elephant crop-raiding pattern has been documented in Asia and Africa (Sukumar 1989; Damiba and Ables 1993; Hoare 1995; Kiiru 1995; O'Connell et al. 2000), and attempts have been made to estimatethe costs of the crop damage (Bell and McShane-Caluzi 1986; O'Connell et al. 2000).

India has the largest Asian elephant population (Daniel 1998), and hence it is apparent that humans and elephants compete for natural resources (Williams et al. 2001). Several factors are responsible for causing human-elephant conflict (Pressey et al. 2007). In India, elephant ranges are now beginning to have greater human density, and the populations in these regions are growing at the rate of 1% to 3% per year (Sukumar 2006), which may lead to greater pressure on elephant landscapes in the future. More than 60% of the elephant population remains outside the protected area in the southern state of Karnataka. The human-elephant conflict is accelerated due to many developmental projects that cause loss of elephant habitat, disruption of elephant movement patterns, and compromised space for elephants (Sukumar 2006). In this context, understanding human-elephant interactions especially the conflict in South Bengal is important to suggest possible mitigation measures to minimize the conflict.

7.2. Methods

The existing data on human-elephant conflicts in entire South Bengal was collected for a period of nine years from 2010 to 2018 from Bankura South, Bankura North, Jhargram, Kharagpur, Medinipur, Panchet, Purulia, and Rupnarayan Forest Divisions. We also collected data on all human-elephant interactions during the study period. The human-elephant conflicts that we considered for the study include human deathsand injuries to humans,elephant deaths, and crop damage due to elephants. The data included the name of a victim, age-sex of the deceased individual, date of the incident, complete address of the victim, type of crop, amount of crop damaged and the compensation paid.

We visited victim's houses or villages and authenticated the death cases from their families. The families were interviewed on the incidents. While interviewing, we recorded the geo-coordinates of the incidents using handheld GPS, time of death, a distance of the incident locations from village and forest, and the family members were also asked about whether the victims were aware of the presence of elephants and the activities involved during the accident. We assigned different time slots (taken on the 24-hour time scale) for human deaths and injuries and data was classified and pooled accordingly. The locations of incidents were plotted on the forest division map.We plotted all the geo-coordinates on the classified image of the South Bengal and created a circle of 500 m radius for each location point of the incident. Then, we extracted the percent forest cover, built-up area and agriculture land, and distance from forest, village, and agriculture field. Using this, we characterized the landscape features and ascertained the pattern of human deaths due to elephants. We broadly pooled the details of circumstances of each human death under eight activities that include activities in the agriculture field, cattle herding, elephant driving, NTFP collection, open defecation, sleeping or activities around the house, traveling through the forest road, and through village road. The description and factors related to each activity are provided in Table 7.1. We calculated the percent of each activity of the victim during the elephant attack and mapped all the human deaths due to elephants. We mapped all the human injuries, crop damages by elephants, and elephant deaths on the map of forest divisions of South Bengal.

Crop depredation: For crop depredation, data from August 2017 to December 2018 was collected from three divisions of Medinipur, Rupnarayan, and Kharagpur. Whenever possible the elephants were observed from a distance while they were feeding and the next morning of their visit to any crop field, the same place was visited to collect data on depredation. We recorded the type of crop depredated and the approximate area of crop field damaged by elephants. The data were pooled according to seasons and kind of crop depredated. Total loss incurred for each crop was calculated using the amount provided to the person claiming for the damage for crop depredation from the Forest Department.

Elephant death: data from 2013- 2017 was collected from the forest Division. Then each such locations/area was visited to record the geocoordinates of the place of death, the circumstances of deaths, age, and sex of the elephant. The data were then pooled together and the frequency of the deaths was calculated according to different forest ranges and reasons for deaths.

*Identify elephant conflict hot spot (High intensity of conflict/human death) between years:*We used nine years (2010-2018) human-elephant conflict data (human death due to human-elephant conflict) to understand the spatial distribution of high-intensity conflict zone in our study site. The entire data (2010-2018) was sub-divided into three three-year temporal classes i.e. 2010-2012, 2013-2015, and 2016-2018. The intensity of human death due to the human-elephant conflict was calculated for each forest beat (N=258) in the study site. As 'forest beat' is the lowest administrative level in Indian Forest Department, beat-wise hot spot analysis would be the high-resolution analysis of conflict data that can further help the Forest Department to implement management plans and policies. The intensity of human death due to thehuman-elephant conflict in each beat in each temporal class and overall period was calculated as the number of human deaths in the forest beat in each temporal period and overall divided by the total area of a beat (km^2).

We used Geographical Data Analysis (GeoDa) 1.12.1.161 software (Anselin 2018) to perform cluster analysis to identify the consistency of beat level spatial distribution of high intensity of human death (hot spot) in the study area between the temporal periods. K means clustering method with two preferred clusters (K=2, hot spot or high-intensity cluster=1, cold spot or low-intensity cluster=2) were used with 999 iterations to define clusters throughout the study period. The ratio between cluster sums of the square error to the total sum of square errors (SSE) was used as the measure of cluster validation. The value of the SSE ratio nearing numerical value 1 reflects high between cluster variance and low within-cluster variance.

Determine outbreak cluster of human death due to human-elephant conflict in study site between 2010 and 2018: Irrespective of the influential factors, the spatiotemporal clusters identify the outbreak or hotspot of human deaths in the study site by comparing locations and times of human death throughout the study period and indicates the high-conflict-risk zone (Packer et al. 2019). The spatiotemporal cluster was determined using SaTScan software version 9.6 (Kulldorff 2018) employing space-time permutation models where the information about the spatial location (Latitude and Longitude) and the time of occurrence (three temporal periods/years) of each incident were used.

Table 7.1 Description of the activities or circumstances of the victim during the accident considered to group them under broader categories of activity.

Broad activity of victim	Description and factors considered
Activities in the agriculture field	Farming activity, field protection during day-night, and resting in the field
Cattle herding	Herding the cattle for grazing to agriculture field or forest or wasteland
Elephant driving	Driving elephant is a common phenomenon in South Bengal. This may be a*hula*drive that is an organised drive involving many people, or local level drive.
NTFP collection	Collection of Sal leaves, firewood from forests
Open defecation	Defecating at village outskirts or out of the house
Sleeping or activities around the house	Household activities around the house and also people have a habit of sleeping outsidenear the house.
Traveling through the forest road	Due to lack of transportation, people had to walk or travel by cycle or motorbike to and from their village to a nearby town or market areas, they had to cross interspersed forest patches on the way. During such travels, if the incident happens at forest patches it is considered under this category
Traveling through the village road	Due to lack of transportation, people had to walk or travel by cycle or motorbike to travel to and from village to a nearby town or market areas, they had to cross interspersed forest patches on the way. During such travel, if the incident happens on village roads, it is considered under this category

7.3 Results

Human deaths due to elephants: In total 268 humans were killed by elephants between 2010 and 2018 in all the forest divisions (Table 7.2; Fig. 7.1). Although human deaths occurred in all the years, the incidences varied from 11 (in 2011) to 52 (in 2015). While the mean number of human deaths highly varied between the years ($F_{8,63} = 2.284$, $p < 0.05$) (Fig. 7.2), it did not vary between the forest divisions ($F_{6,65} = 0.985$, $p = 0.443$) (Fig. 7.3).

Table 7.2 Number of human deaths due to elephants in different forest divisions of South Bengal between 2010 and 2018

Forest Division	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Bankura North	0	0	1	4	9	18	4	6	0	42
Bankura South	1	1	2	2	4	1	6	0	0	17
Jhargram	3	0	0	2	5	4	8	0	8	30
Kharagpur	9	1	1	1	5	8	2	2	11	40
Medinipur	9	1	4	3	5	5	13	5	6	51
Panchet	1	0	2	1	3	4	5	0	3	19
Purulia	2	6	8	1	4	5	3	0	1	30
Rupnarayan	3	2	1	4	7	7	4	9	2	39
Total	28	11	19	18	42	52	45	22	31	268

Of the total human deaths, 214 (79.85%) were men and 54 (20.15%) women. The mean men deaths (2.97 ± 3.08SD) and women deaths (0.75 ± 0.89SD) did not vary between the forest divisions (men: $F_{6,65} = 1.052$, $p = 0.401$; women: $F_{6,65} = 0.643$, $p = 0.685$) (Fig. 7.4). Similarly, the mean men deaths (2.97 ± 3.08SD) and mean women deaths (0.75 ± 0.89SD) did not vary between the years (men: $F_{8,63} = 1.940$, $p = 0.069$; women: $F_{8,63} = 2.077$, $p = 0.051$, Fig. 7.5). The overall men (26.75 ± 10.83SD) and women (6.75 ± 2.05SD) deaths due to elephant significantly varied between forest divisions ($t = 5.130$, $df = 14$, $p < 0.001$). Similarly, overall men (23.78 ± 11.51SD) and women (6.50 ± 3.21SD) deaths due to elephant significantly varied between years ($t = 4.094$, $df = 15$, $p < 0.001$).

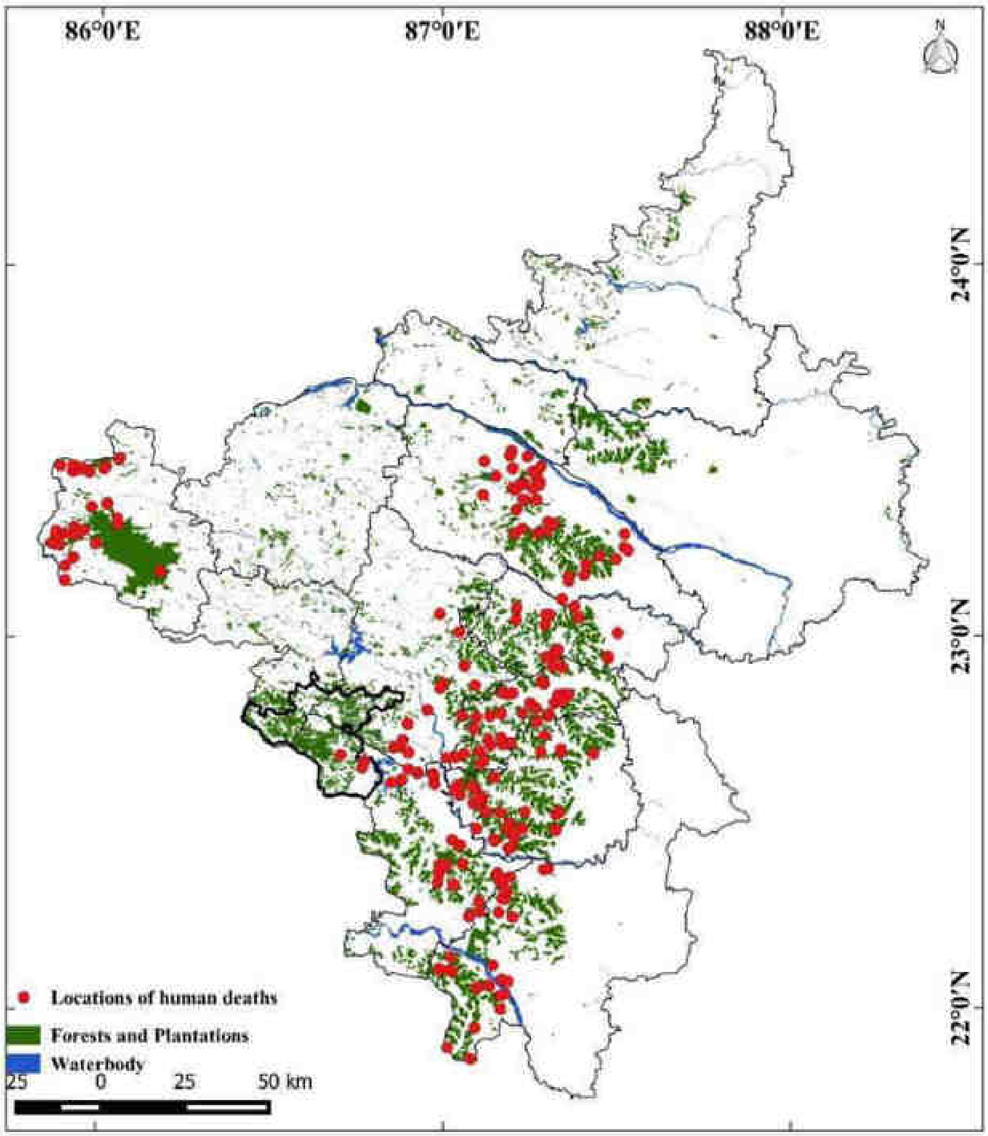

Figure 7.1 Locations of human deaths due to elephants in South Bengal from 2010 to 2018

Human deaths due to elephants occurred in almost all the months in most of the years between 2010 and 2018 except for few months in the years 2011 and 2017 (Fig. 7.6 and 7.7). The number of human deaths was more between January and June than in other months. The mean number of human deaths between January and June (28.00 ± 3.74SD) was significantly more than human deaths in July and December (16.67 ± 2.80SD) ($t = 5.937$, $df = 10$, $p < 0.001$).

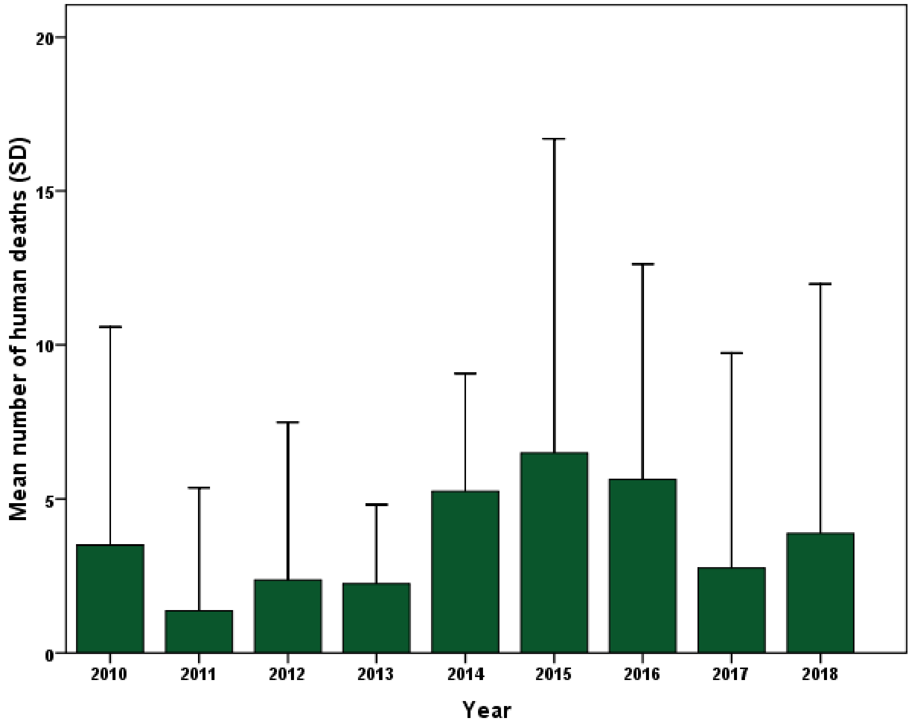

Figure 7.2 Mean number of human deaths due to elephants at South Bengal in different years

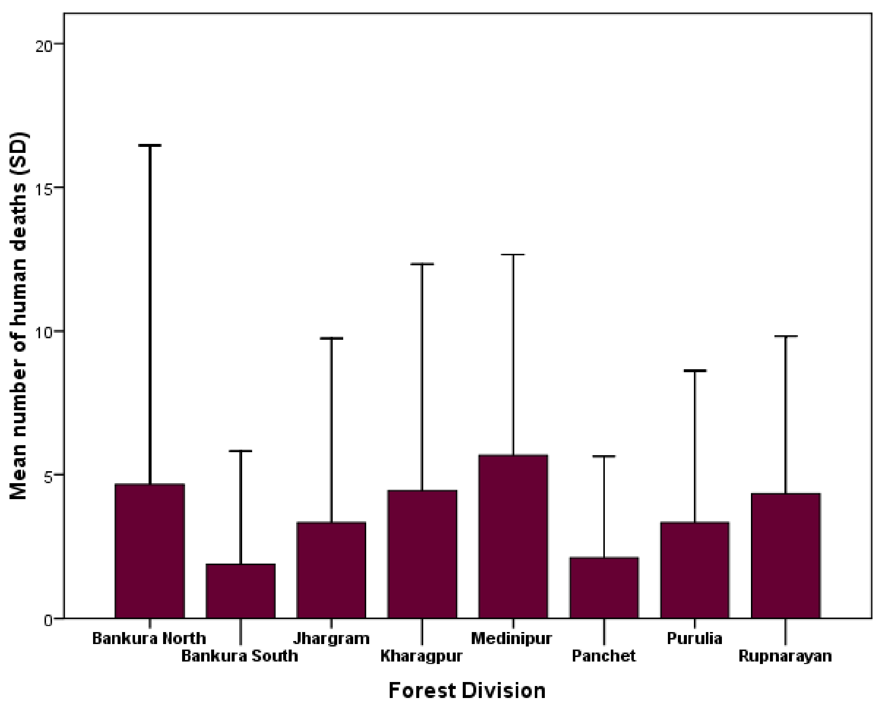

Figure 7.3 Mean number of human deaths due to elephants in different forest divisions of South Bengal

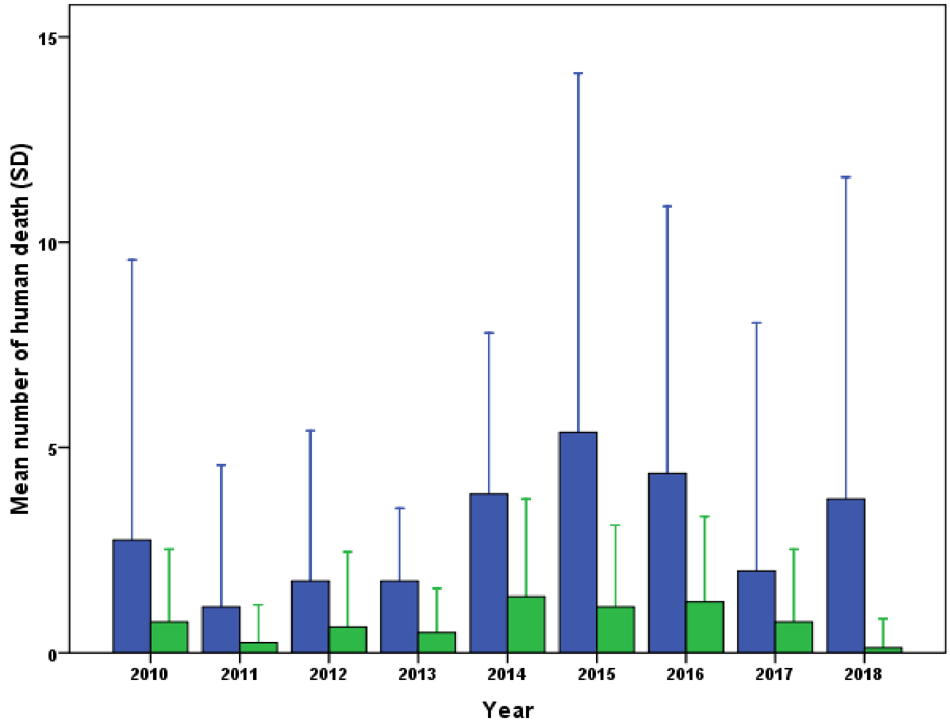

Figure 7.4 Mean number of human deaths due to elephants in different years in South Bengal (blue bar: men; green bar: women)

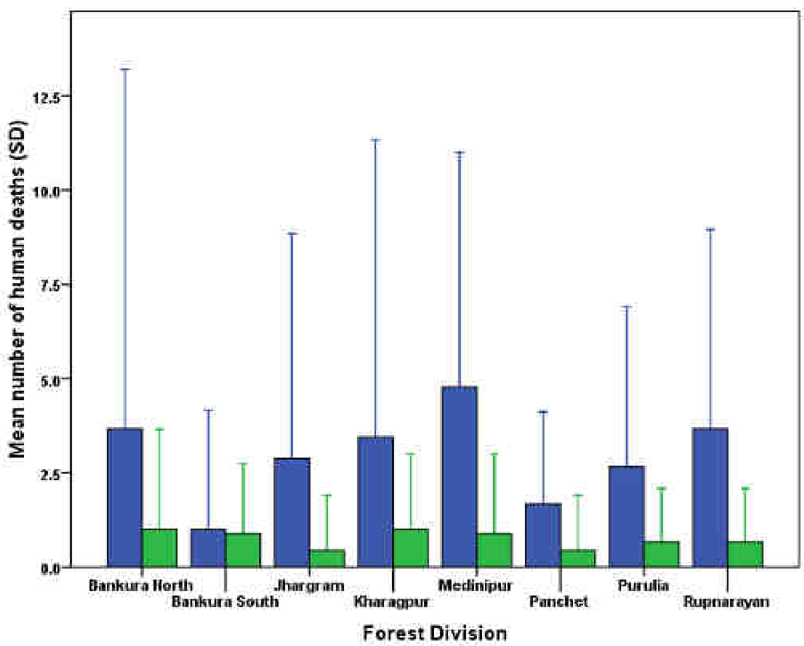

Figure 7.5 Mean number of human deaths due to elephants in different forest divisions of South Bengal (blue bar: men; green bar: women)

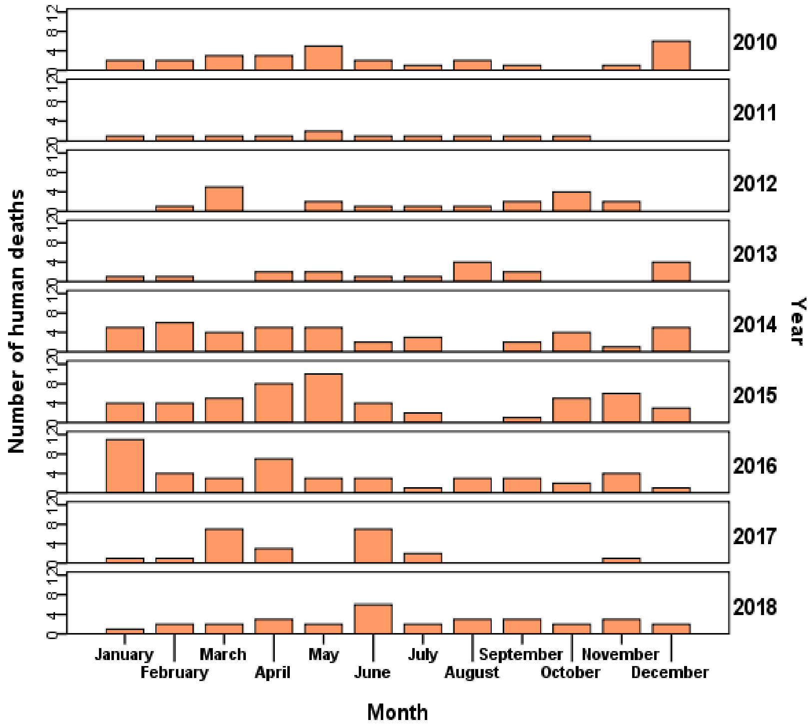

Figure 7.6 Number of human deaths due to elephants in different months of the years during 2010 - 2018.

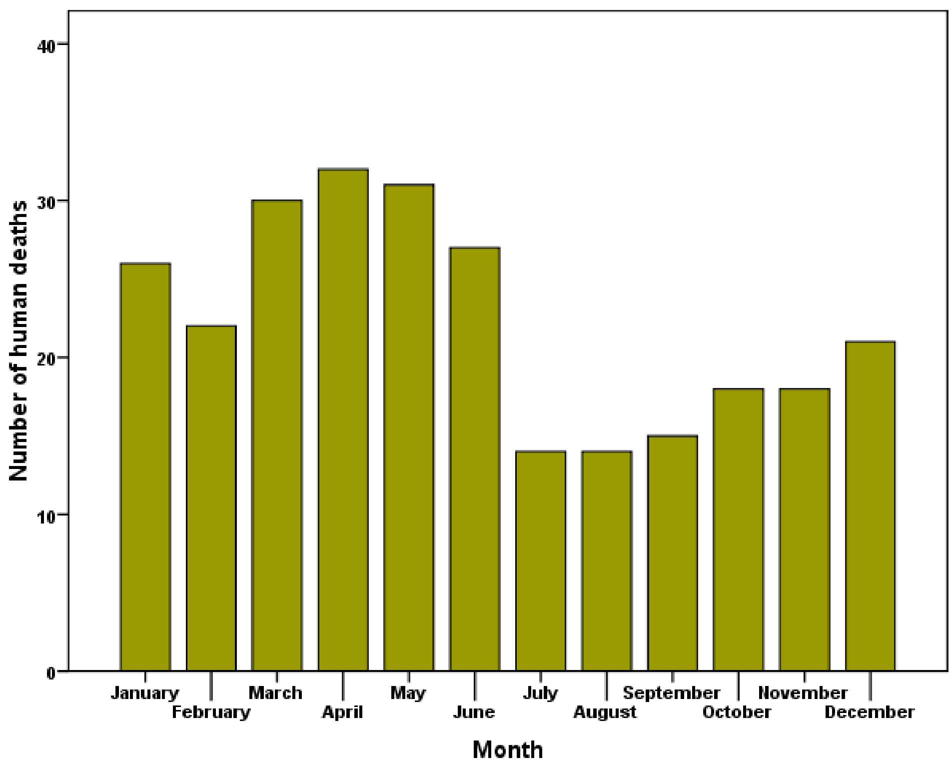

Figure 7.7 Number of human deaths due to elephants in different months of the year at South Bengal

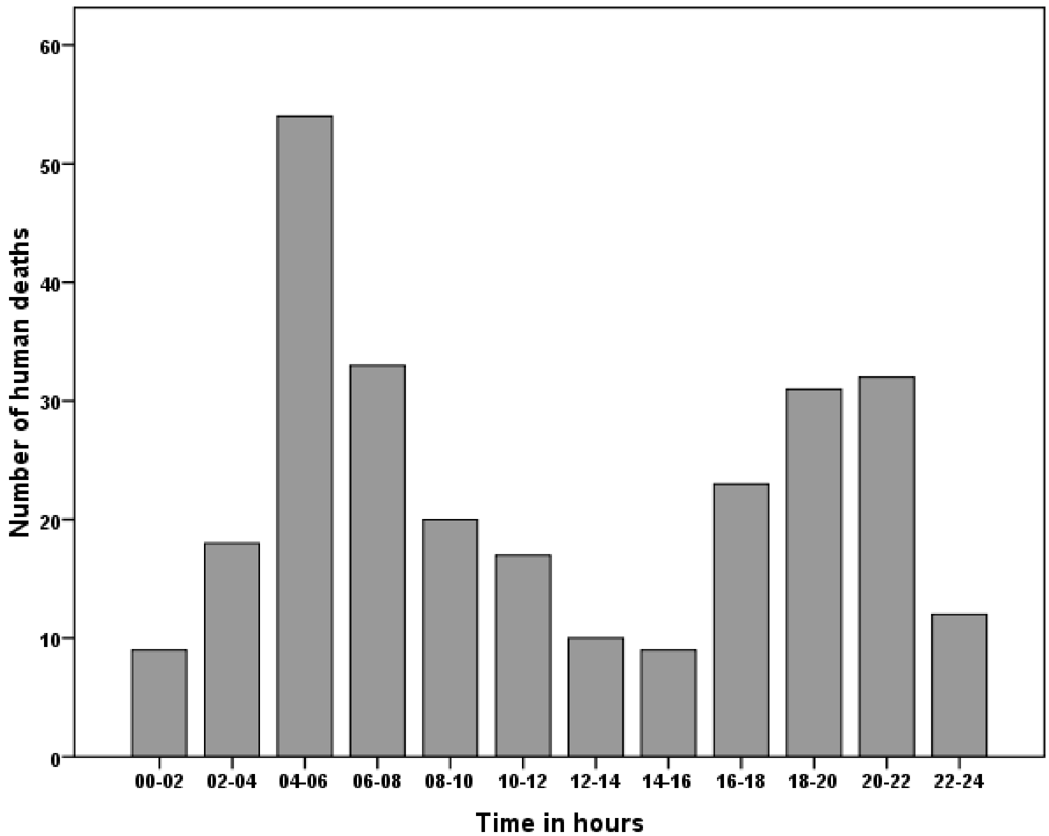

Figure 7.8 Human deaths due to elephants in different timings of the day (24-hour cycle) at South Bengal

Human deaths have occurred all through the day of 24 hours; however, the highest deaths have occurred between 0400 and 0600 hours (Fig. 7.8). Human deaths were more pronounced in two peaks i.e. between 0400 - 0800 hours and 1800 -2200 hours. The lowest human deaths were between 0000 – 0200 hours and 1200 – 1600 hours.

61.92 % of the human deaths due to elephants were in non-forest areas (Table 7.3). The locations of deaths were significantly ($\chi^2 = 13.594$, df = 1, $p < 0.001$) more in non-forest areas ($16.44 \pm 12.10_{SD}$) than in forest areas ($10.11 \pm 6.88_{SD}$). However, the proportions of human deaths between forests and no-forests highly varied between the forest divisions ($t = -2.733$, df = 7, $p < 0.05$). The victims werenot aware of the presence of elephants (66.11% of human death cases) was highly significant against being unaware of the presence of elephants ($\chi^2 = 24.808$, df = 1, $p < 0.001$). But, the proportion of death while aware ofunawareness highly varied between the forest divisions ($t = 3.043$, df = 7, $p < 0.05$).

Table 7.3 The Percent human deaths in the forest and non-forest area and awareness of the presence of elephants in different forest divisions

Divisions	Location of human death		Awareness of the presence of elephants		Total
	Percent in Forest (N)	Percent in Non-Forest (N)	Percent-Yes (N)	Percent-No (N)	
Bankura North	33.33 (14)	66.67 (28)	54.76 (23)	45.24 (19)	42
Bankura South	35.29 (6)	64.71 (11)	29.41 (5)	70.59 (12)	17
Jhargram	36.36 (8)	63.64 (14)	27.27 (6)	72.73 (16)	22
Kharagpur	30.00 (9)	70.00 (21)	33.33 (10)	66.67 (20)	30
Medinipur	35.55 (16)	64.44 (29)	22.22 (10)	77.78 (35)	45
Panchet	50.00 (8)	50.00 (8)	31.25 (5)	68.75 (11)	16
Purulia	33.33 (10)	66.67 (20)	26.67 (8)	73.33 (22)	30
Rupnarayan	54.05 (20)	51.35 (19)	37.84 (14)	62.16 (23)	37
Total	38.08 (91)	61.92 (148)	33.89 (81)	66.11 (158)	239

In total 16, 22, and 3 beats were identified as high intensity of human death hot spots in 2010-2012, 2013-2015, and 2016-2018 (Table 7.4 and 7.5), which clearly suggest that the hotspots varied between years (Fig. 7.9, 7.10, 7.11 and 7.12). SSE data revealed that cluster for the year 2010-2012 and 2013-2015 was more clearly defined than clusters of 2016-2018 and the overall period (Table 7.6). The hotspotsvaried among the temporal classes or years.

Table 7.4 Variations in human death hotspots during 2010 - 2018

Year	Total No of the beat in the study area	Hot spot beat no	Cold spot beat no
2010-2012	258	16	242
2013-2015		22	236
2016-2018		3	255
2010-2018 (All)		32	226

Table 7.5 Name of beats falling under human death hotspots

Division	Beat			
	2010-2018	2010-2012	2013-2015	2016-2018
Bankura North	Barjora		Barjora	
Bankura North			Beliatore	
Bankura North	Bhara			
Bankura North	Brindabanpur		Brindabanpur	
Bankura North	Shitla		Shitla	Shitla
Bankura South		Fulkusma		
Bankura South	Piragari-1			
Bankura South			Dubrajpur	
Panchet	Adhkata			
Panchet	Bankadaha			
Panchet	Bishnupur-1	Bishnupur-1		
Panchet			Chagulia	
Panchet	Machantala		Machantala	Machantala
Jhargram			Balibhasa	
Jhargram	Balibhasa		Bhulabheda	
Kharagpur	Baradanga	Baradanga		
Kharagpur	Barpat		Barpet	
Kharagpur			Kalnapukuria	
Kharagpur			Chandrabila	
Medinipur	Akchara			
Medinipur	Arabari	Arabari		
Medinipur	Bhadutala			
Medinipur	Bhaudi			
Medinipur	Chandra	Chandra		
Medinipur	Dherua			
Medinipur	Godapeasal		Godapeasal	
Medinipur	Lalgarh	Lalgarh	Lalgarh	
Purulia		Kalma		
Purulia	Khamar	Khamar		
Purulia	Murguma	Murguma	Murguma	
Purulia	Simni	Simni	Simni	
Rupnarayan	Amlasuli		Amlasuli	
Rupnarayan	Dhadika	Dhadika		
Rupnarayan	Hoomgarh		Hoomgarh	
Rupnarayan	Kadasol	Kadasol		
Rupnarayan	Mahalisai-1		Mahalisai-1	Mahalisai-1
Rupnarayan	Mahalisai-2		Mahalisai-2	
Rupnarayan	Nahori	Nahori	Nahori	
Rupnarayan	Pathrisol	Pathrisol	Pathrisol	
Rupnarayan	Ramgarh	Ramgarh	Ramgarh	

Table 7.6 Indicating ratios within and between hot and cold-spot clusters based on the sum of square estimates in every three years (K-means Cluster (2) performed in GeoDa software)

Years	Cluster	Centroid	Within-cluster SSE	Between-cluster SSE	SSE ratio
2010-2012	CL 1: Cold spot	-0.226681	18.3966	159.547	0.710214
	CL 2: Hot spot	3.42856	38.0884		
2013-2015	CL 1: Cold spot	-0.254501	41.5256	179.262	0.697519
	CL 2: Hot spot	2.73011	36.2119		
2016-2018	CL 1: Cold spot	-0.084538	65.2249	156.726	0.609831
	CL 2: Hot spot	7.18573	35.0486		
2010-2018	CL 1: Cold spot	-0.295907	21.6021	159.547	0.620806
	CL 2: Hot spot	2.08984	75.8507		

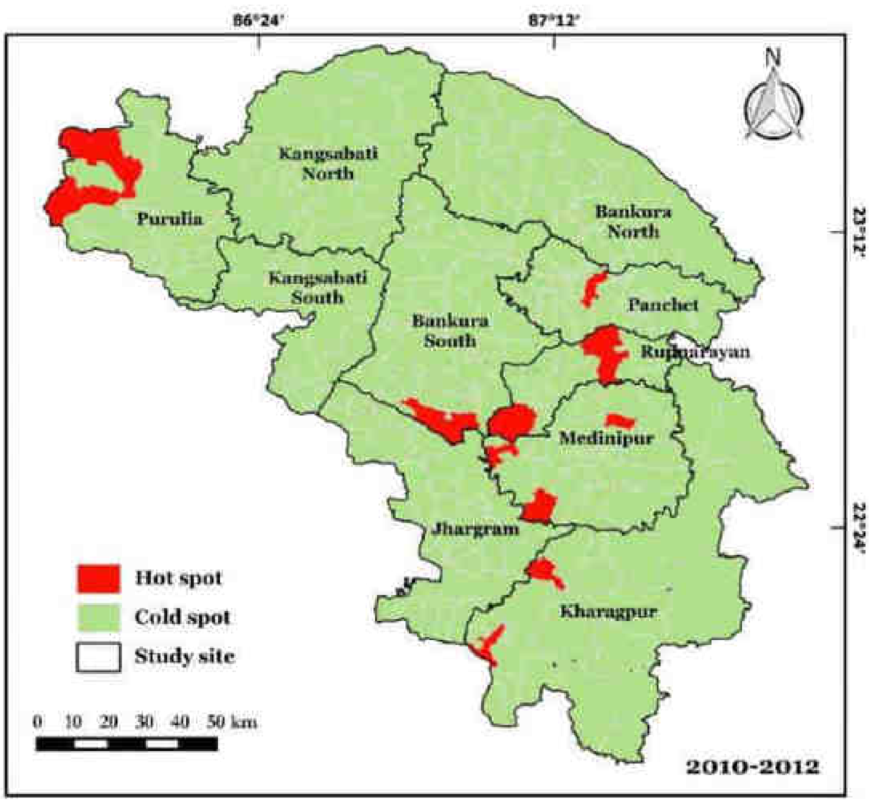

Figure 7.9 Cold and hot spots (range level) of human death in the study site during2010 - 2012

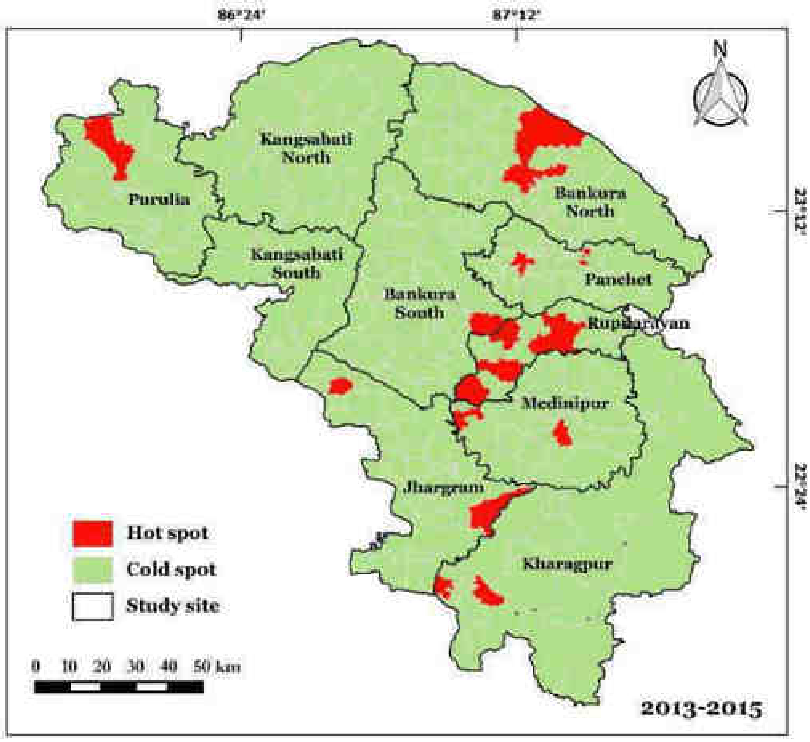

Figure 7.10 Cold and hot spots (forest range level) of human death in the study site during 2013 – 2015

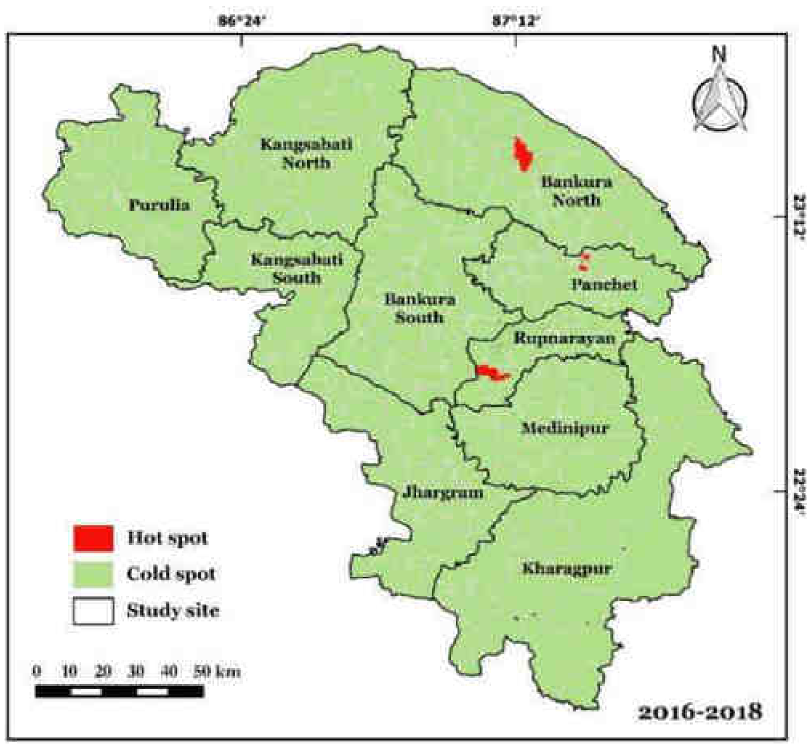

Figure 7.11 Cold and hot spots (forest range level) of human death in the study site during 2016 - 2018

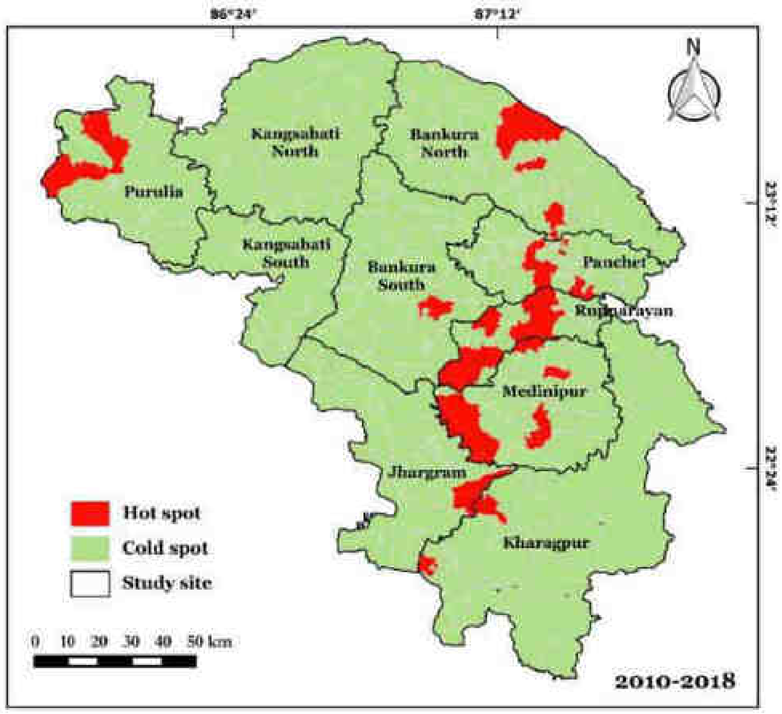

Figure 7.12 Cold and hot spots (forest range level) of human death (Overall) in the study site during 2010 – 2018

We have identified high-risk clusters by comparing an observed number of attacks in three three-year temporal windows (Fig. 7.13). The five clusters shown include three in the 2010-2012 period and one each in 2013-2015 and 2016-2018. Among 239 human deaths during 2010-2018, 143 were included forming the clusters. The radius of clusters ranges from 49 (2013-2015) to 12 km (2010-2012) (Table 7.7). About 60% of human deaths due to the human-elephant conflict were classified as belonging to a discrete outbreak with an average radius of 24±15 km.

Table 7.7 Details of outbreak clusters across the study period

No.	Radius (km)	Year	No. of locations
1	23	2010-2012	19
2	22	2016-2018	52
3	49	2013-2015	44
4	12	2010-2012	14
5	16	2010-2012	14

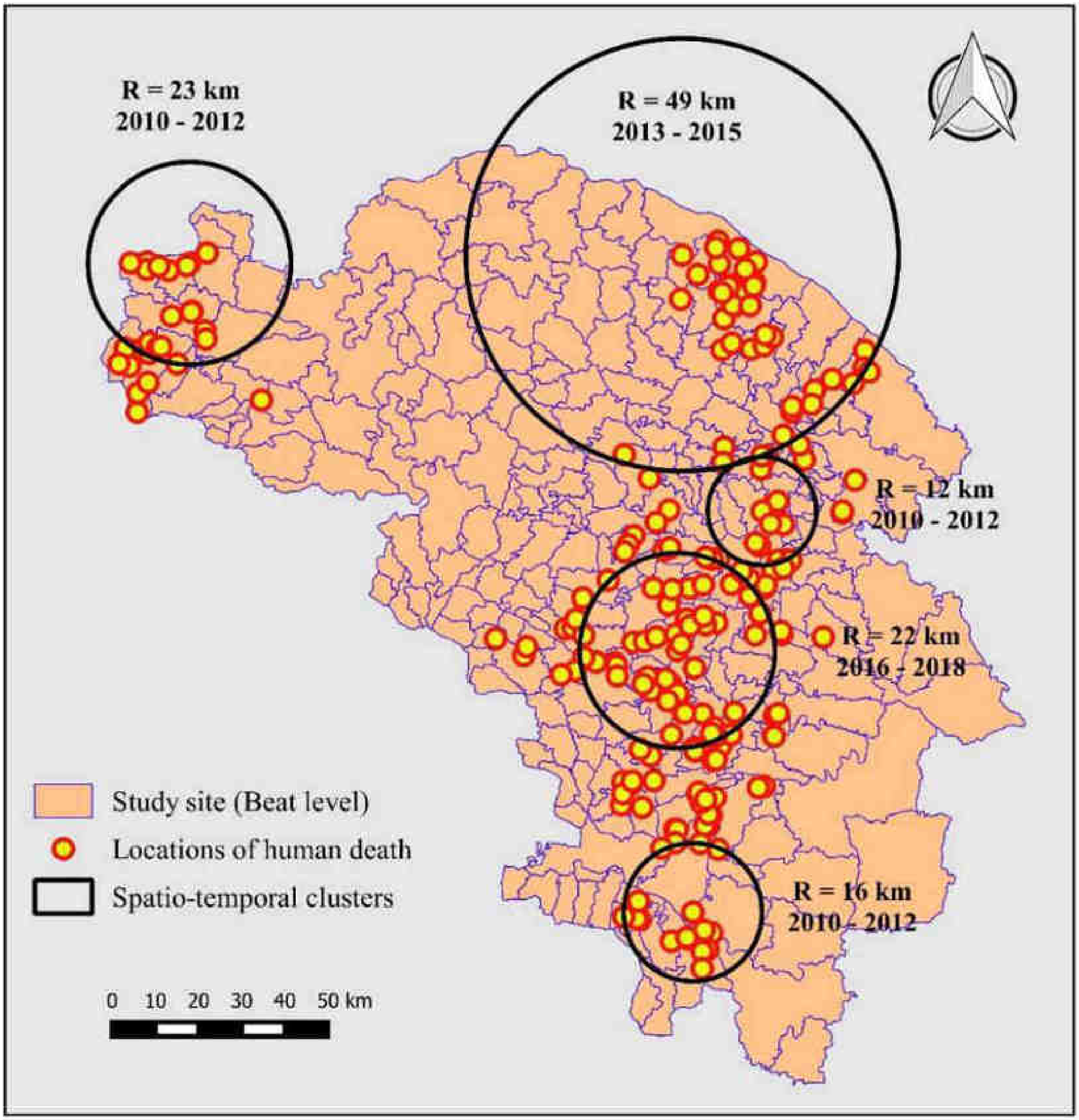

Figure 7.13 Three-year interval (i.e., 2010-2012, 2013-2015, and 2016-2018) spatiotemporal clusters (circles) of human death across the study area analyzed by SaTScan (R=Radius). Values within or next to each circular cluster describe the characteristics of each cluster, where R is the radius of the cluster and followed bythe year when the outbreak started

Circumstances of human deaths due to elephants:

Of all the activities of the deceased due to elephants, the highest (17.91%) was when people had gone out for defecation. That was followed by incidences when people were engaged in agricultural activities (15.67%) or when people had gone for collecting the NTFP (14.93%) or when the victims were sleeping or doing some household work around their houses (14.18%) or while traveling through forest patches on the road (21.64%, Fig. 7.14).

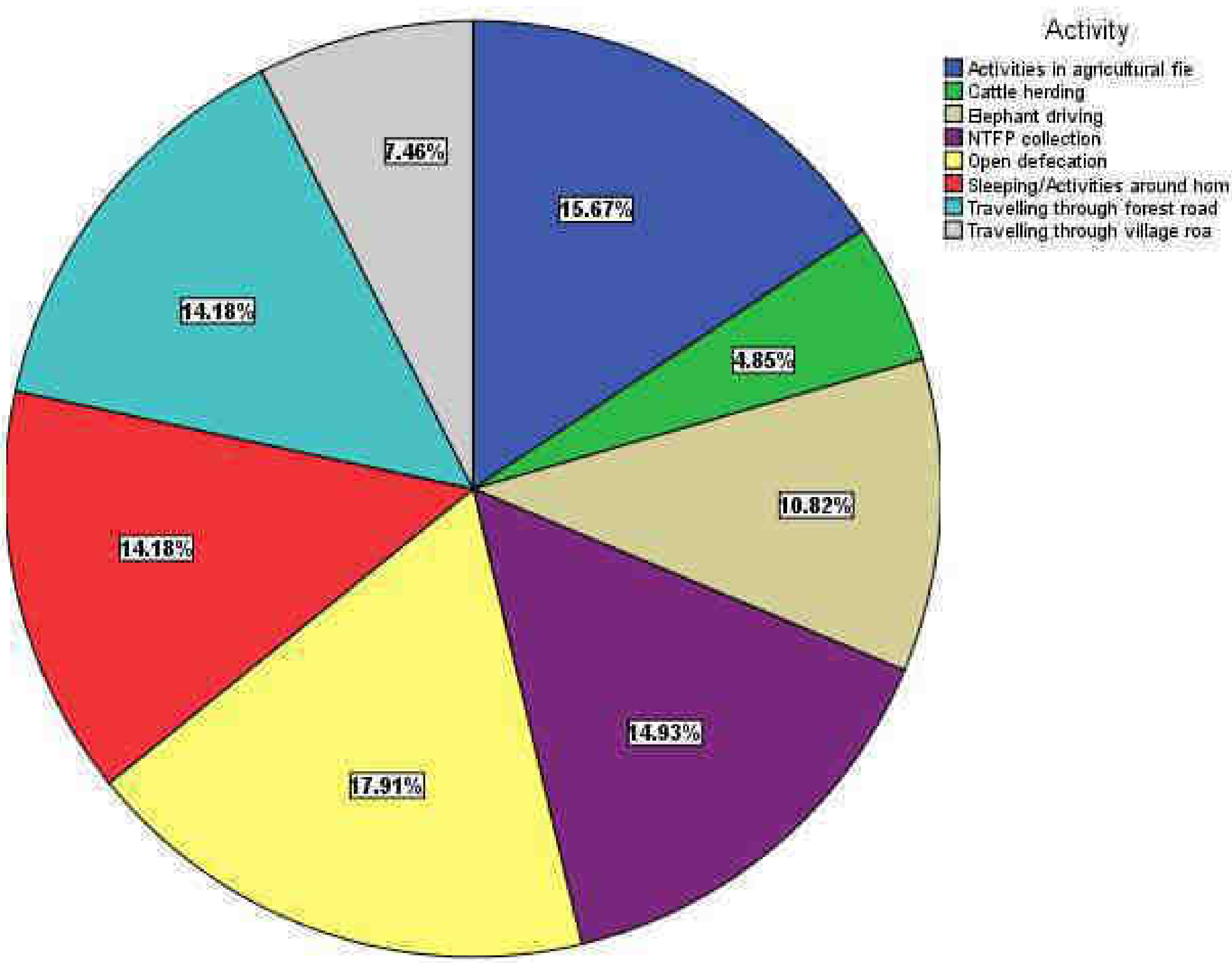

Figure 7.14 Activities the deceased were engaged in while death occurred due to elephants

We developed a hotspot map using only the locations where people got killed while traveling to and from the village, when they had gone out for open defection, including all the death locations (Fig. 7.15). A few hotspots emerged out for each circumstance of deaths, even though circumstances of human deaths remain widespread. The two major hotspots due to open defection were in Rupnarayan and North Bankura. The identified hotspots for deaths while traveling to or from the village were in two locations in North Bankura, one in Rupnarayan, two in Medinipur, two in Kharagpur, and one in Jhargram. All the hotspots of human deaths were certainly at the fringes of the forest or the patch having both forest and agriculture especially at Purulia, North Bankura, Rupnarayan, Medinipur, Jhargram, and Kharagpur Forest Divisions. There are no hotspots in Mayurjharna except for occasional human deaths (Table 7.7). Of all the hotspots, the major ones were in Rupnarayan, Medinipur, North Bankura, and Kharagpur Forest Divisions.

Table 7.8 Details of the human deaths due to elephants in Mayurjharna ER

Human deaths	Mayurjharna ER
Number of human deaths between 2010-2012	0
Number of human deaths between 2013-2015	3
Number of human deaths between 2016-2018	0
Total human deaths -2010-2018	**3**

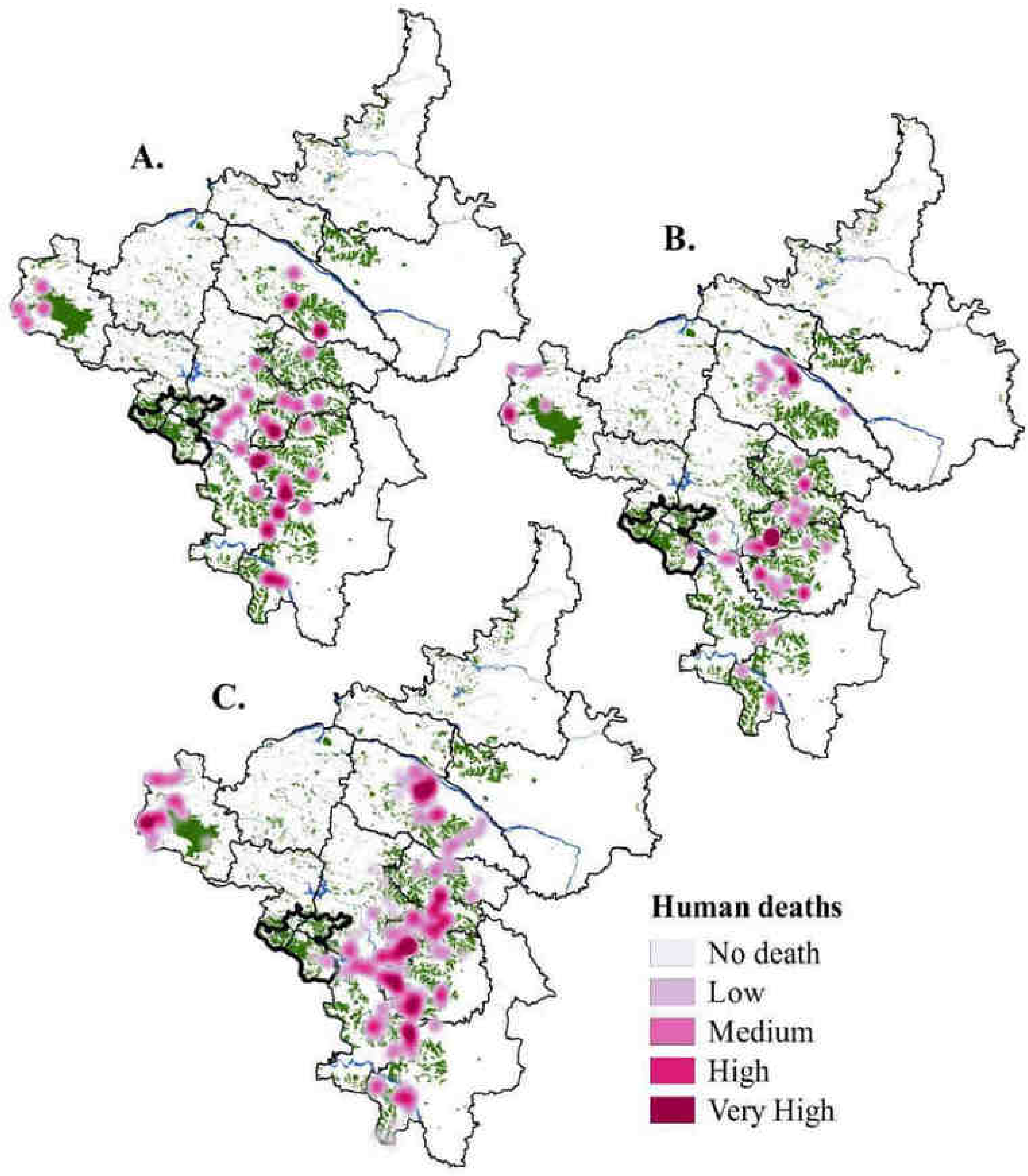

Figure 7.15 Hotspot analysis of human deaths due to elephants in South Bengal: A. While traveling to or from the village, B. while had gone out for open defecation, and C. Overall deaths

Humans' injuries by elephants

In total 372 incidences of human injuries by elephants were recorded between 2010 and 2018 (Fig. 7.16) in the eight forest divisions of the study area. Of these divisions, the highest number of human injuries were recorded in Bankura North (19.35%), followed by Medinipur (19.09%) and Rupnarayan Forest divisions (16.40%) (Fig.7.17).

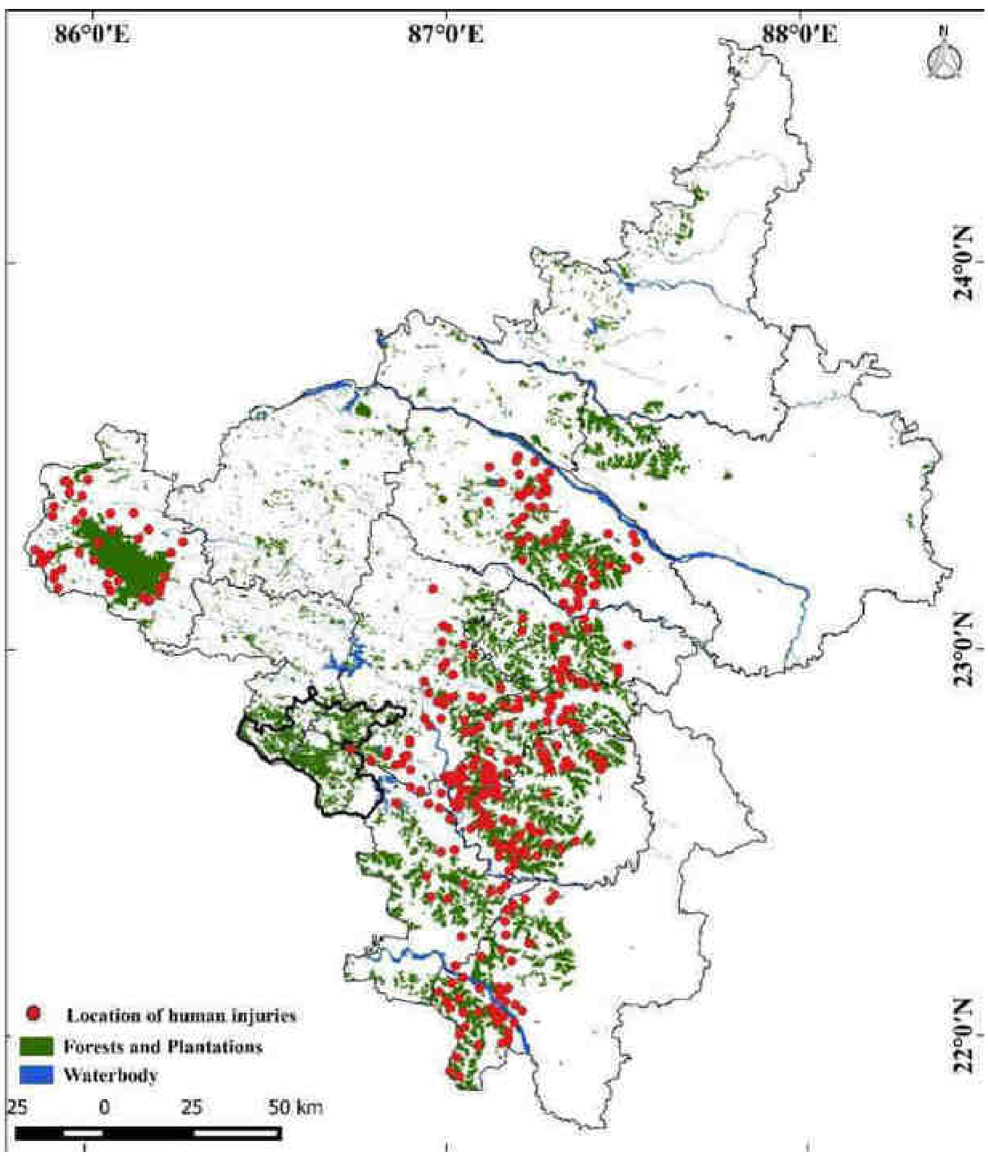

Figure 7.16 Location of human injuries due to elephants during 2010 - 2018 in South Bengal

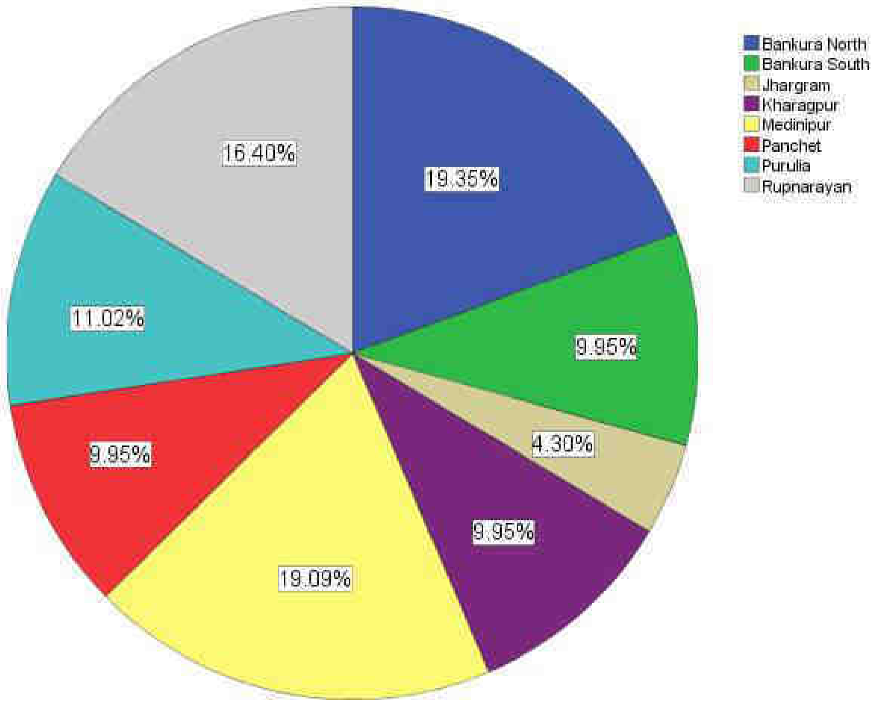

Figure 7.17 Human percent of injuries due to elephants in different divisions of South Bengal

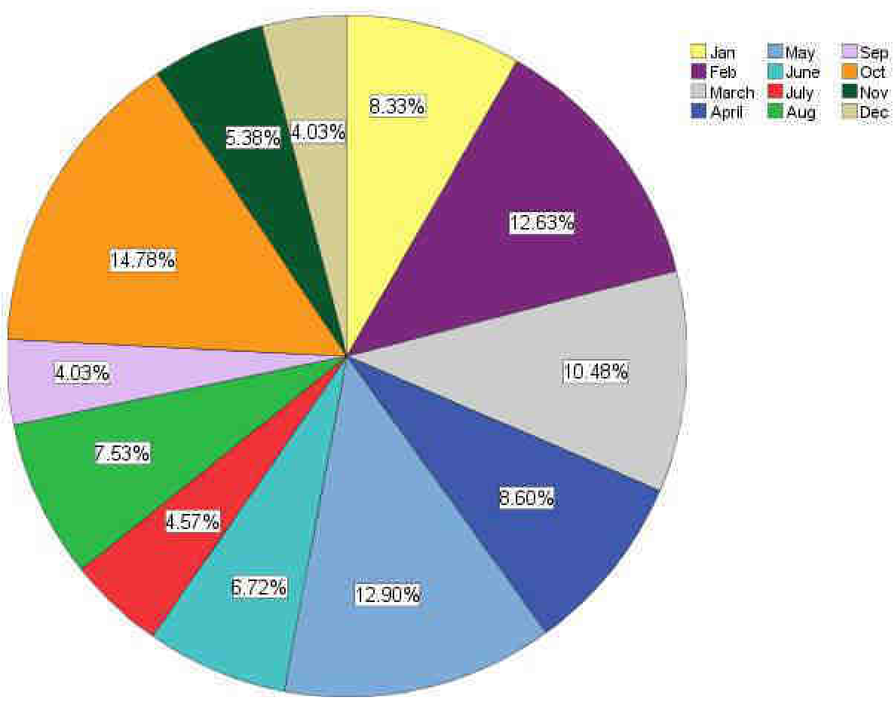

Figure 7.18 Human percent of injuries in different months in South Bengal

Although human injuries due to elephants were recorded all through the year, a high number of injuries were in dry months of the year from January to May, with exceptionally highinjuries being recorded in October (Fig. 7.18). The circumstances of human injuries due to elephant shows that 23.39% of incidence happened while people were traveling to and from the village, which is followed by during the NTFP collection (19.35%), activities in the agriculture field (13.44%) and open defecation (11.02%) (Fig. 7.19).Substantial injuries while watching the elephants, while people were sleeping in their homes or engaged in some household work around the home were also recorded.

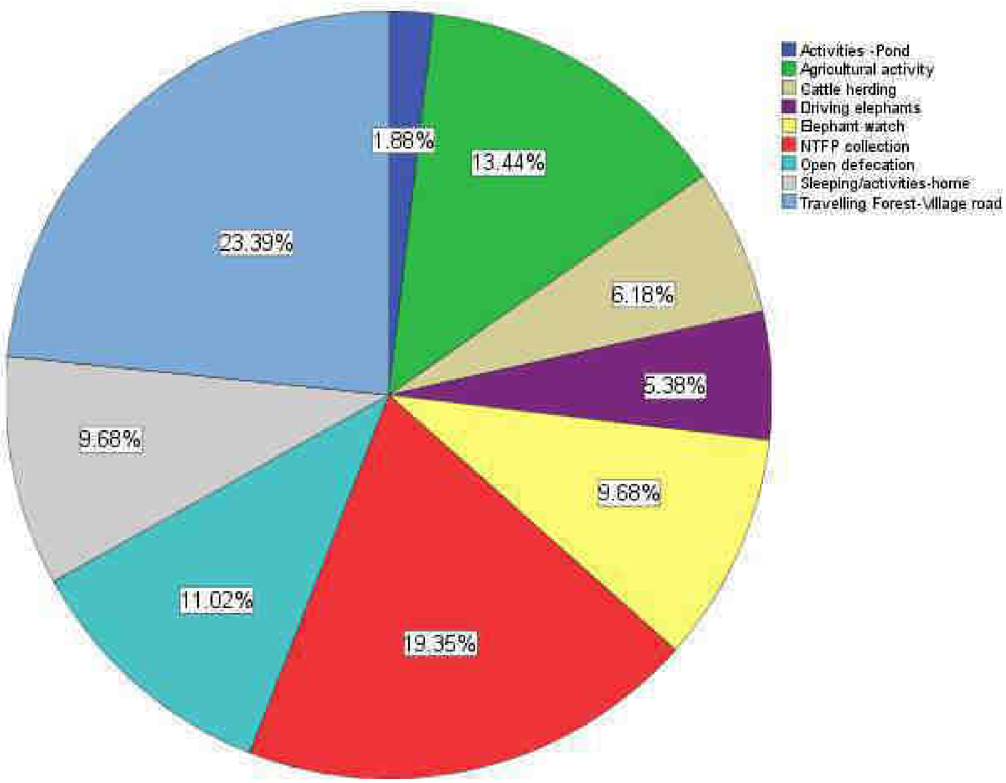

Figure 7.19 Circumstances when human percent of injuries occurred due to elephants in South Bengal

Elephant deaths

In total 23 elephants died during 2013 - 2018, of which 14 were males, eight females and 1 calf was present. Maximum deaths occurred in January (N=6), followed by April, August, and

September (N=3). Among these retaliatory killing was the major reason for elephant deaths (N=10), followed by electrocution (N= 8), and three were from train accidents. Division wise, Bankura North (N= 13) has the highest number of elephant death cases wherein retaliatory killing (N=8) of elephants was the major one. Panchet division has the highest number of deaths due to train accidents (N=2).

Table 7.9 Details of the elephant deaths that occurred in South Bengal

Year	Month	Range	Division	Reason of death	No. of elephants
2013	June	Beliatore	Bankura North	Electrocution	1ADM
	September	Garhbeta	Rupnarayan	Electrocution	1 ADF
	October	Manikpara	Jhargram	Train accident	1SADM
	December	Barjora	Bankura North	Electrocution	1 ADM
2014	April	Mejhi	Bankura North	Electrocution	1 ADF
	December	Bishnupur	Panchet	Train accident	1 ADM
2015	April	Barjora	Bankura North	Retaliatory killing	1 ADM
	September	Bankura north	Bankura North	Electrocution	1 ADM
	October	Sonamukhi	Bankura North	Electrocution	1 ADM
2016	January	Sonamukhi	Bankura North	Retaliatory killing	1 ADM
	January	Beliatore	Bankura North	Retaliatory killing	1 ADF
	February	Sonamukhi	Bankura North	Retaliatory killing	1 ADF
	January	Sonamukhi	Bankura North	Retaliatory killing	1 ADF
	January	Barjora	Bankura North	Retaliatory killing	1 ADM
	April	Bhadutala	Medinipur	Electrocution	1 ADM
	May	Sonamukhi	Bankura North	Retaliatory killing	1 ADM
	August	Bishnupur	Panchet	Train accident	1 ADF, 1 SADF 1 CF
	September	Bagmundi	Purulia	Electrocution	1 ADF
2017	January	Garhbeta	Rupnarayan	Retaliatory killing	1 ADM
	January	Bankura North	Bankura North	Retaliatory killing	1 ADM
	February	Beliatore	Bankura North	Retaliatory killing	1 ADM

ADM: Adult male; ADF: Adult female; SADM: Subadult male; SADF: Subadult female: CF: Calf

Crop depredation by elephants:

During August 2017 - December 2018,in Medinipur, Rupnarayan, and Kharagpur forest divisions with the total depredated area being 2370 hectares, a total of 683 crop depredation cases were reported. A total of Rs. 355.50 lakhs was incurred by the forest department during this period in form of ex gratia. Paddy was the most depredated crop (n=394), 113 cases of

Potato, 120 cases of vegetables, and 56 cases of sugarcane. Paddy turned out to be the most depredated crop leading to a loss of Rs. 222.75 lakhs, followed by potato with a total loss of Rs. 43.50 lakhs.

Table 7.10 Seasonal crop depredation by elephants in Medinipur, Rupnarayan, and Kharagpur Forest Divisions

Division	Crop	Season	Total no. of incidents	Area depredated (in ha)	Total loss (in Rs)
Medinipur	Paddy	Pre-monsoon	50	180	2700000
		Monsoon	40	140	2100000
		Post-monsoon	84	210	3150000
	Potato	Pre-monsoon	0	0	0
		Monsoon	0	0	0
		Post-monsoon	68	120	1800000
	Vegetables	Pre-monsoon	30	110	1650000
		Monsoon	0	0	0
		Post- monsoon	67	125	1875000
				Total	**12175000**
Rupnarayan	Paddy	Pre- monsoon	42	140	2100000
		Monsoon	29	155	2325000
		Post- monsoon	60	190	2850000
	Potato	Pre- monsoon	0	0	0
		Monsoon	0	0	0
		Post- monsoon	45	170	2550000
	Vegetables	Pre- monsoon	0	0	0
		Monsoon	0	0	0
		Post- monsoon	23	150	2250000
				Total	**12075000**
Kharagpur	Paddy	Pre- monsoon	41	240	3600000
		Monsoon	10	50	750000
		Post- monsoon	38	180	2700000
	Sugarcane	Pre-monsoon	56	170	2550000
		Monsoon	0	0	0
		Post- monsoon	0	0	0
				Total	**9600000**

7.4. Discussion

The sal-dominated forest with low availability of food resources (food species and their abundance) forcesthe elephants to move out of the forest to feed on agricultural crops that make them susceptible to conflict with humans. The *hula*drive increases the deprivation for a shorter period that can make the animals agitated and hungry, which in turn forces the elephants to be stubborn to driving them off, and their attempt to go for crop-raiding increases the chance of encountering the people leading to high human deaths and injuries. Thus, the high number of human deaths due to elephants was in non-forest areas than in the forest areas. Elephants are known to come out in search of food to agricultural land and sometimes human habitations when there is a shortage of food resources inside the forest (Sukumar 2003).

There is a discrete outbreak in human deaths probably due to the incessant*hula* driving and involvement of local people in driving after experiencing massive life loss as well as crop depredation by the elephants. Regular steps and measures are taken by the forest department to help in reducing the concentration of depredation or conflict by not allowing the elephants to stay in a place for a longer time. After experiencing a human loss or crop depredation, people have become less tolerant towards elephants and the relationship with the forest departmentbecame sour. To curtail the conflict, the forest department created a barrier (man monitoring or a physical barrier like electric fences or trenches) to restrict elephant movement away from high conflict areas. The intensity of conflict in 2013-2015 was most severe and spatially larger and was confined to the North Bankura Forest Division because while the elephant movement started expanding towards Bankura North and they tried to reach the Bardhman region, they were stopped and forcefully restrictedto Bankura North. That agitated elephants leading to higher human deaths. The high intensity of conflict in Purulia Forest Divisions in 2016-2018 occurred probably due to habitat degradation due to the nearby dam projects.

For the 23 elephant deaths recorded during the study, retaliatory killing and electrocution were the major reasons. The retaliatory killing of elephants due to anger for crop depredation or loss of human life is a major issue in all parts of the elephant range (Sukumar 1989). A large number of elephant deaths occurred due to electrocution (N=8) and that indicates intentional use of high voltage transmission lines to tapelectricity directly to the electric fences (Gubbi et al. 2014). Electrocution is widely known as an effective means to kill elephants and is a common practice reported from all parts of the elephant range in India (Sukumar 1989; Gubbi 2009).

PLATE 4

a)

b)

a) and b) Hula Driving conducted under Forest department

CHAPTER- VIII

What do the people think about elephants?

8.1. Introduction

The attitude of local people towards wildlife is the key for cohabitation between the two, and thus the assessment of peoples' attitudes towards wildlife is vital (Newmark et al. 1993). In wildlife conservation, several studies suggest that the appeal and aesthetics of a species affect the support for conservation in the society (Belaire et al. 2015; Knight 2008). However, negative interactions and the possibility of any risk from a wild species may substantially change people's view on the species and their support for its conservation (Verbruegge et al. 2013). Encroachment of wildlife habitats often leads to an increase in human-wildlife encounters (Barua et al. 2012) and thereby conflicts (Robertson and Hutto 2006). Potentially large-bodied animals may cause complications such as destruction of crops or property, depredation of livestock, competition for resources, pathogen transmission, and injury or loss of human life (Rust and Marker 2014; Dickman 2010; Ogra 2008; Madden 2004). These negative interactions often bring about hostility towards wildlife that sometimes could even cause the extermination of the problematic animals (Riley and Decker 2000). Any harm caused by wildlife also affects the financial security of the people (Bagchi and Mishra 2006) and whichmay propagate hostility towards wildlife (Ogra 2008). Also, humans may fear certain species due to the belief that it compromises their well-being or personal safety (Thirgood et al. 2005) that may instigate people to take extreme measures like illegally killing an animal rather than using preventative measures (Carter et al. 2012; Jenks et al. 2014; Lüchtrath and Schraml 2015; Treves et al. 2002). However, when wildlife becomes a source of income for people in the tourism industry, they have positive perceptions of wildlife (Kinnaird and O'Brien 2012). Certain religious beliefs of people in which wild animals sometimes are considered divine or deities and are worshiped (Ramakrishnan 1998) may also lead to a positive perception of wildlife. Therefore, understanding the factors that mouldthe attitude of people is vital to enable wildlife managers to implement approaches that drawthe support of stakeholders and the public (Ebua et al. 2011). To assess how economic, social, and psychological factors affect human perception of wildlife species, we interviewed residents of south Bengal as well as separately for Mayurjharna ER, as elephants are the recent migrants to the landscape.

8.2. Methods

The data were collected through structured interviews using a custom-made questionnaire (open and closed-ended) from the residents in the South Bengal and Mayurjharna ER. Face-to-face interviews were conducted with people of age group 50 and above while working in the study area from January 2018 to February 2019. Each respondent was asked a set of questions related to their ethnicity, socio-economic background, agricultural practices, attitude towards elephants, attitude towards the forest personnel etc. The closed-ended questions were to be answered in binary form (yes or no) following the method of Sodhi et al. (2010). Also, to minimize the bias from the tendency of people telling us what they thought we wanted to hear (Sodhi et al. 2010), we asked questions about their daily routines, their dependency on the surrounding landscape and natural resource use, etc. The interviews were conducted in the local language to avoid any misinformation or biases.

8.3. Results

Of the 498 people interviewed in South Bengal, 58.8% (N=293) belonged to scheduled tribe, and 41% (N=205) non-tribal residents, while of the 47 people interviewed in Mayurjharna ER, 78.73% (N=37) belonged to scheduled tribe, and 21.28% (N=10) non-tribal residents (Table 8.1).The respondents' family size varied between 4 to 12 members/family in the entire landscape;57.83% (N=288) and 61.70% (N=29) of the families have 5 to 7 members /family in South Bengal and Mayurjharna ER respectively. While 55.80% (N=278) respondents from South Bengal lack primary education, of those from Mayurjharna ER the percentage with no primary education was 95.74% (N=45). In the case of South Bengal, 48.69% (N= 242) of respondents were farmers with small landholding and 17.27% (N= 86) of respondents were landless and dependent upon NTFPs. However, in the case of Mayurjharna ER, 95.74% (N= 45) of respondents had small landholdings with two respondents having no land at all. In South Bengal, 41.96% (N=209) of the farmers cultivate paddy (only one crop in a year during Kharif season) while the rest grow vegetables (29.12%, N=145) and oilseeds (22.48%, N=112) along with paddy.

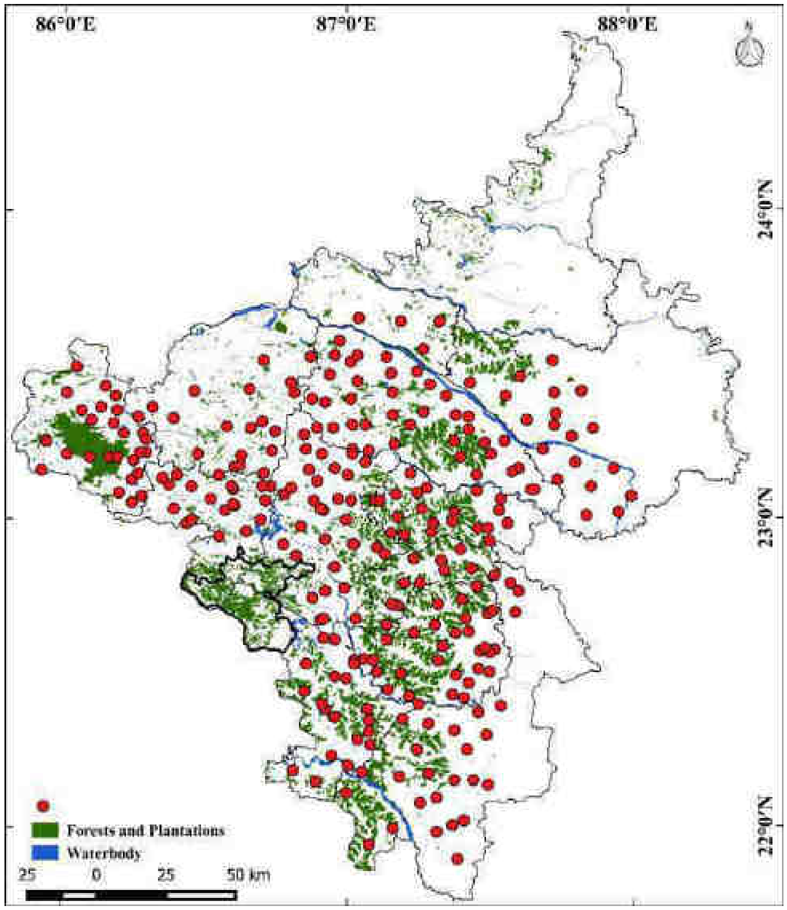

Figure 8.1 Locations of the interviews(red dot on the map) in South Bengal

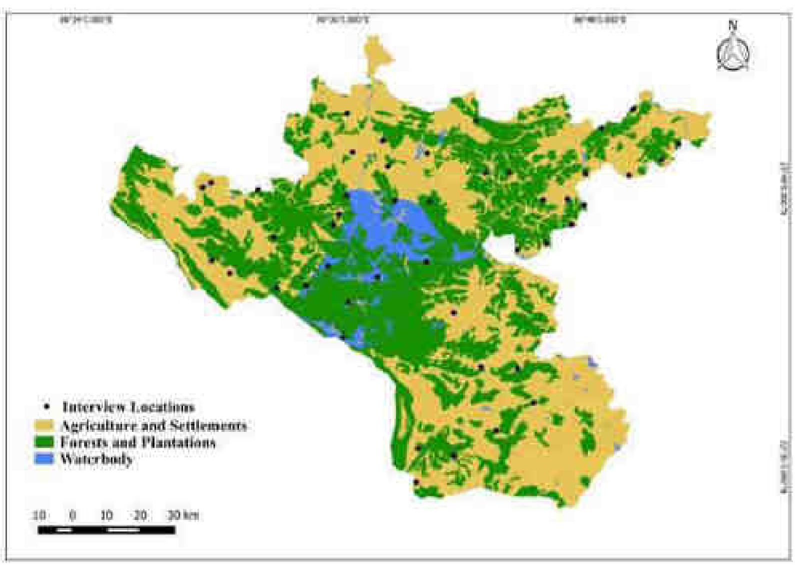

Figure 8.2 Locations of the interviews(black dot on the map) in Mayurjharna ER

In Mayurjharna ER 72.09% (N=31) of the respondents cultivate one crop of paddy in a year. Only a single respondent (2.32%) cultivated oilseeds and 11 were cultivating vegetables (25.58%). The major source of income for respondents from both South Bengal and Mayurjharna ER is agriculture, 48.59% (N=242) and 51.06 % (N=24) respectively.

Although there is a positive attitude among all the respondents in Mayurjharna ER (100%, N=47) and South Bengal (95.98% N= 478) towards the presence of the animals, only 5.02 % (N=25) in South Bengal and 8.51% (N=4) of people in Mayurjharna ER agreed to tolerate their presence in the neighborhood or the crop field (Table 8.2). On a similar note, although people revere elephants as *Ganesha* (92.97%, N= 463) in South Bengal and (93.62%, N= 44) in Mayurjharna ER, still they do not prefer their presence (7.03%, N= 35) and (8.51%, N= 4) respectively near their cropland or houses. Nevertheless, they do not see any problem if the elephants are restricted to the forests (90.96%, N= 453) and (95.74%, N= 45) in South Bengal and Mayurjharna ER respectively. Interestingly, in South Bengal 29.52% (N=147) people and in Mayurjharna ER 72.34% (N= 34) said that elephants only use their cropland to pass through and do not to feed on the crop.

The respondents, about 91.77% (N= 457) in South Bengal and 95.74% (N= 45) in Mayurjharna ER said that fragmentation of forests is the major reason that although there is an increase in the number of elephants coming from the Dalma Wildlife Sanctuary they do not stay in Mayurjharna ER (Table 8.3). However, (89.36%, N= 42) of people in Mayurjharna ER agree that Babui grass and silkworm cultivation in Mayurjharna are the major reasons for the increased influx of elephants in Mayurjharna ER. From South Bengal 23.09% (N=115) and from Mayurjharna ER 23.40% (N=11) agreed to the fact that their activities have made the elephants move towards other areas outside the reserve and into the vast croplands. Further, none of the respondents told about the use of any harmful preventive measures against the elephants in Mayurjharna ER. However, in South Bengal, 69.88% (N= 348) of respondents said about the use of fire or crackers to drive away elephants

When asked about whether or not they inform the forest department, all the respondents (100 %) accepted informing the department about the presence of elephants both in south Bengal and Mayurjharna ER. They also said that the department helps in driving the elephants away. A big

Table 8.1 Socio-economic characteristics of the respondents

Parameters	% of respondents in South Bengal	% of respondents in Mayurjharna ER
Ethnicity		
Kurmi	9.03	21.28
Santhal	21.69	8.51
Other-tribe	28.11	48.94
Nontribal	41.00	21.28
Family size		
2 to 4	12.65	10.63
5 to 7	57.83	61.70
8 to 10	24.49	21.28
11 to 13	5.02	6.38
Education		
No education	55.82	95.47
Primary	22.49	
High school	21.68	4.26
Crop		
Paddy	41.96	72.09
Paddy+ mustard oil	22.48	2.33
Paddy+ vegetables	29.12	25.58
Sugarcane	6.43	
Landholding (in acres)		
0	14.66	8.51
0.1- 0.9	25.10	25.53
1 – 1.9	30.19	29.79
2 – 2.9	9.83	12.77
3- 3.9	10.24	8.51
4 – 4.9	10.04	10.64
5-5.9		2.13
6-6.9		2.13
No. of crops raised in a year		
Once	56.82	69.77
Twice	43.17	30.23
Source of income		
Agriculture	48.59	51.06
Agriculture and NTFP collection and selling	21.69	6.38
Agriculture and Small shop	12.45	38.29
Only NTFP	17.27	4.25

majority (92.57 %, N= 451) of people in South Bengal admitted having *hula*parties, executed by the forest department, in their villages. In Mayurjharna ER89.36 % (N= 42) people accepted the same. When asked about what can be done to solve the elephant issue, all the respondents (100%) expressed that the elephants belong to the forest department and they should take charge and try to remove them from the landscape to avoid crop fields.

Table 8.2 Views of respondents on elephants

Statements	In South Bengal	In Mayurjharna ER
	% respondents giving a positive response	
Should the animals be present in the landscape?	95.98	100.00
Do they tolerate the presence of animals in their crop field?	5.02	8.51
Do they respect elephants as it is considered as Ganesha?	92.97	93.62
Should elephants be present in the landscape?	18.27	65.96
Do they tolerate the presence of elephants in their crop field?	7.03	8.51
If elephants only use the forest and not their cropland then will they want the elephant to be present in the landscape?	90.96	95.74
Do elephants cause problems for them?	86.95	34.04
Doeselephant enter their crop field only to pass through?	29.52	72.34

Table 8.3 Respondents' views on the reasons and the response of the forest department towards elephants

Statements	In South Bengal	In Mayurjharna ER
	% respondents agreeing to the statement	
Forest fragmentation is a reason for elephants to move in this area	91.77	95.74
Do they think they disturb the forest forcing elephants to come to their land?	23.09	23.40
Do they Inform the forest Department when they see an elephant?	100	100
Does the Forest Department help in driving the elephant?	90.56	93.62
Is *hula*party employed by the Forest Department active in their village?	92.57	89.36
Do they use any method to protect themselves from the elephant?	69.88	0
Should the department keep the elephants away from their landscape?	100	100
Cultivation of silk / babui grass has caused mass scale degradation of forests		89.36

8.4. Discussion

Most of the respondents in South Bengal, as well as Mayurjharna ER, were farmers, with small landholdings. Reaping one crop of paddy per year, they do not mind the presence of elephants in the landscape or forest except close to human habitation or agriculture field. Existing beliefs and customs make them respect the elephants;however, the depredation by elephants has compelled them to turn intolerant towards the animal.

Agricultural practices in some areas often result in increased conflicts (Wolman and Fournier 1987). Some studies suggest that tolerance of farmers to damage of high-value cash crops is least (Blair 1979), while others suggest damage to crops such as cassava (a famine tuber crop in many areas) cause more dislike towards the animals (Mascarenhas 1971). Farmers feel especially vulnerable to large, highly symbolic animals that are perceived to belong to the government (Woodroffe et al. 2005). For instance, elephants are highly prized by tourists and wildlife agencies, but they cause catastrophic damage to both the livelihood and human lives (Woodroffe et al. 2005) which is why many respondents in the study area do not want elephants around the area. For most of the people in this area, their livelihood is dependent on the single crop that they grow in a year, which makes their survival difficult if the elephants depredate on their cropland. However, the difference in the opinions of people from south Bengal and Mayurjharna ER on whether the elephants should be present in the landscape is because, for Mayurjharna ER, the elephants only use this area to pass through while coming from Dalma Wildlife Sanctuary. The major time, almost nine months in a year, spent by elephants was in the other parts of south Bengal. The burden of losses on people outside the Mayurjharna ER change their opinion about elephants and their first instinct is always towards the removal of elephants from their area. Such behavior is in concordance with many other studies where people bear the costs of living with wildlife prone areas (Kiss 1990) and hence, the communities develop a negative attitude towards conservation (Omondi 1995; Hill 1998). However, when respondents were asked regarding their respect given to elephants as they symbolize Ganesha, their positive response was indicative of the fact that elephants are an icon of Indian culture, history, and religion. Such views are in accordance with several authors (Kellert 1983; Serpell 1995; Noske 1997; Morris 2000), who have confirmed that religious and cultural beliefs of a society provoke recognition of the value of animals. Noske (1997) suggests that the religious and cultural beliefs of people create a specific or general attitude toward a particular species of animal. Besides, some people always retain a positive attitude towards these animals despite all the costs (Newmark et al. 1993; DeBoer and Baquete 1998). Despite the positive attitude of the respondents towards their respect and beliefs towards the elephants, the threats elephants accidentally pose towards the local people there invoke a feeling of loathing towards these animals. The losses suffered by the respondents in one form or the other over many years make them non-tolerant of even small losses accidentally incurred due to elephants, and therefore they try hard not to let them enter their field or their backyard.

Elephant idol being worshipped

CHAPTER- IX

How many elephants can Mayurjharna carry?

9.1 Introduction

The carrying capacity of an ecosystem in short is the ratio of productivity of feeding resources to the average requirement of an individual (Wallmo et al. 1997). It broadly refers to the equilibrium between the population of a species and its resources in an area (Eltringham 1990). The concept of carrying capacity has been useful, but difficult to measure in practice, due to the tendency of animals to exist at unstable densities. To maintain the sustainability of a population, the rate of consumption has to be within the intrinsic rate of productivity so that the depleted patches could recover. Hence, carrying capacity is used as an indicator of ecosystem health and stability.

Elephants are generalist feeders requiring about 108 kg fresh (27 kg dry) plant fodder per day owing to its enormous size (Sukumar, 1986). Due to such huge daily requirement, elephants deplete small forest patches very fast and need to move to the next patch. Thus, they can alter the plant community of a landscape at a high rate. Elephants have been observed to venture into agricultural areas for high energy and adequately available food resources. Assessing ecosystem carrying capacity, hence, is an essential and great tool for drawing a management plan for such an animal.

9.2 Methods

In Mayurjharna Elephant Reserve, 119 quadrates of 10 x 10 m were randomly laid and woody plants were counted. In each quadrate, all the stems of >10 cm of GBH (Girth at Breast Height) were considered as woody species (Hall and Okali, 1979) and assessed. Each stem was recorded with the name of the species and their girth (GBH) measured at 1.3 m height from ground level. *Density* (i.e., the number of plants of a certain species per unit area) was expressed by converting individual numbers per plot to per hectare basis (Goldsmith et al. 1986).

Elephants feeding pattern was studied in 360 plots of 10 x 10 m area in Rupnarayan, Medinipur, and Kharagpur Forest Divisions. Tree species with clear signs of feeding such as chewed vegetation, debarked and broken twigs and branches, scratched posts, foot and body marks on the ground/soil were identified and recorded (White 1994; Demeke and Bekele 2000; Shoshani et al. 2004; Chen et al. 2006). For each plot, the number of food plants and parts eaten was documented. The analysis was done by computing the relative frequency of different plant species observed in the diet.

To calculate the biomass of these major food sources, we conducted a literature review to find out dry above-ground biomass and fruit yield of the food tree species (Behera and Mishra 2006; Kumar et al. 1998). Food tree density was used to extrapolate the number of trees in Mayurjharna ER. Using Dry above ground biomass values, we calculated the availability of total above-ground biomass in the Mayurjharna ER. Species wise details of above-ground biomass estimation are given in Table 9.1. The spatial distribution of above-ground biomass was assessed using LANDSAT 8 imagery. We performed Normalized Difference Vegetation Index (NDVI). Madugundu et al. (2008) have shown positive relation with leaf area index (LAI) and above-ground biomass for deciduous forests with similar composition. Leaf area index (LAI) and overall above-ground biomass for Mayurjharna ER were predicted using the linear regression model provided by Madugundu et al (2008), given below.

- NDVI to LAI
-

LAI = 7.3986 (NDVI) + 1.3402

- LAI to Above ground biomass (AGB)

AGB = 55.997 (LAI) - 8.2685

To estimate the elephant carrying capacity of Mayurjharna ER, we assumed 10% of total above-ground biomass as biomass available for utilization for elephants. This assumption was based on the regeneration capacity of deciduous forests which were (Madugundu et al. 2008) under constant pressure from elephants. To calculate annual biomass utilization by an individual elephant, we used relative utilization of natural feeding resources and average per tree biomass as provided in Table 9.1. The ratio of availability of biomass and its consumption was taken as the maximum number of elephants that could be sustainably supported by Mayurjharna ER.

Total number of elephants= Sustainable edible Biomass Available/ Annual biomass requirement by elephants

9.3 Results

Total above-ground biomass was estimated to be 13773.1 Megagram (Mg) (Table 9.1, Fig 9.1) for 10 food species in the forest area of Mayurjharna ER. Of this, 10% biomass was taken as sustainable biomass available for consumption by elephants. Based on the utilization frequency of different species, the annual biomass requirement for an adult individual elephant was found to be 9.58 Mg. However, only 5.39 Mg biomass could be obtained from the plant species present in Mayurjharna ER. *Madhuca longifolia*, *Diospyros melanoxylon*, and *Terminalia bellirica* were found to be the most important plant in terms of available biomass.

Based on biomass requirement and sustainable biomass available, the carrying capacity of Mayurjharna ER was estimated to be 143 elephants (**1377.30 / 9.58)**

Table 9.1.Biomass availability of food species and their estimated consumption by Elephants in Mayurjharna ER

Species	Part	Density / hectare	Total Above Ground Biomass (Mg)	Sustainable Biomass Available (Mg)	Percent Utilization	Annual biomass requirement (Mg)
Buchanania cochinchinensis	Foliage	136.97	1351.6	135.16	6.18	0.61
Diospyros melanoxylon	Foliage	131.09	2956.8	295.67	5.01	0.49
	Fruit		7460.1	746.01		1.97
Gardenia gummifera	Foliage	34.45	291.4	29.13	5.12	0.51
Gymnema sylvestre	Foliage	3.36	14.2	1.42	2.67	0.26
Lannea coromandelica	Foliage	31.93	243.1	24.30	2.67	0.26
Madhuca longifolia	Flowers	178.99	908.5	90.84	10.23	2.88
Mallotus nudiflorus	Foliage	3.36	14.2	1.42	2.67	0.26
Pterocarpus marsupium Roxb	Foliage	3.36	129.8	12.97	5.33	0.53
Syzygium cumini	Fruit	6.72	360.9	36.08	2.67	1.05
Terminalia bellirica	Foliage	10.08	42.6	4.26	7.68	0.76
Total			13773.1	1377.3		9.58

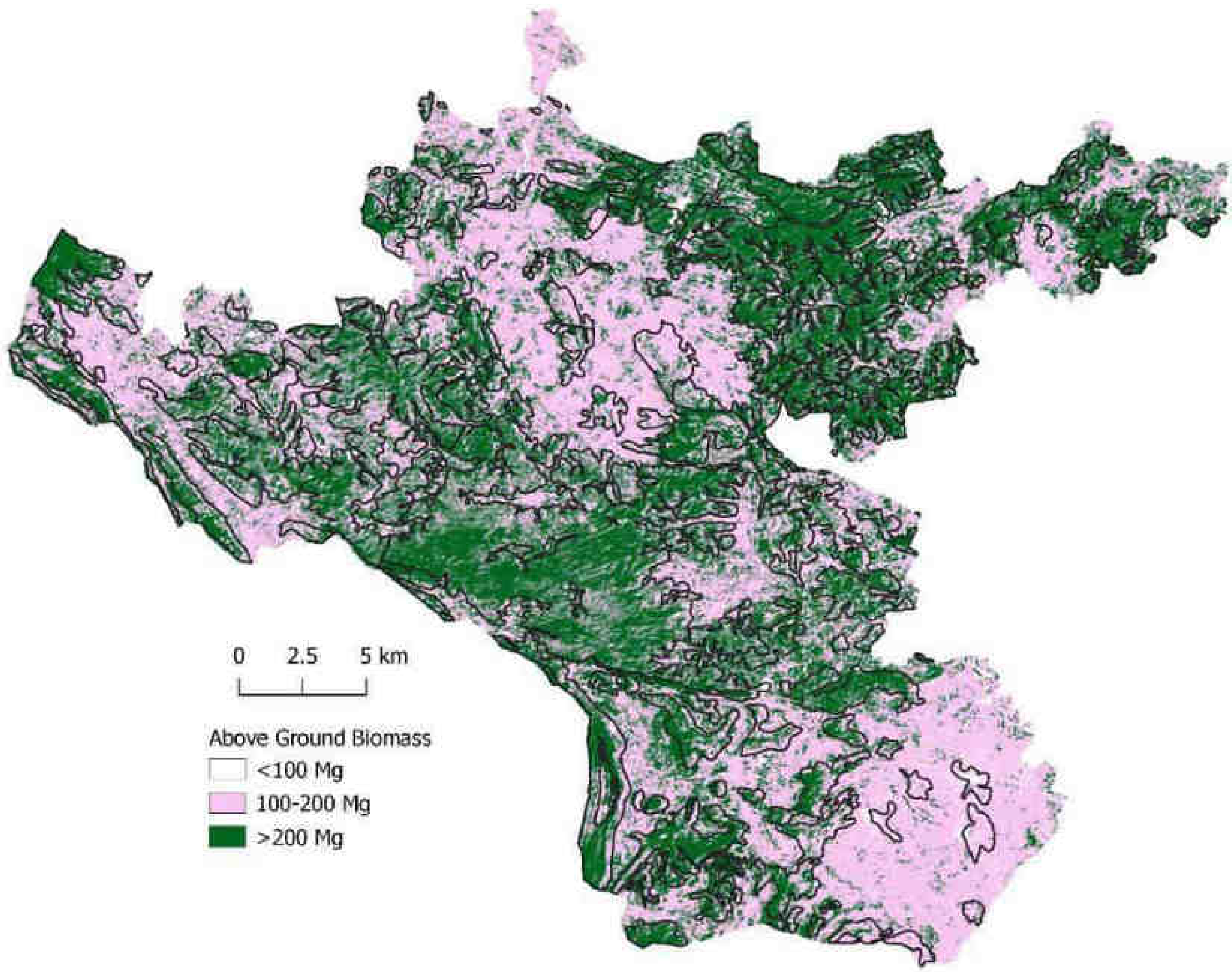

Figure 9.1. Map showing the distribution of above-ground biomass in Mayurjharna ER

9.4 Discussion

Mayurjharna ER has a total area of 414 km^2 with biomass that can support 143 elephants or in other words, the ER can support an elephant density of up to 0.36/ km^2. However, this estimation is based on the available biomass. It does not take the nutrient requirements of elephants into account. Mayurjharna ER has only 1377.3 Mg of sustainably utilizable biomass of 10 food species, which form only a fraction of biomass consumed by elephants. Some of the highly preferred species such as *Lannea grandis* (Preference Index - PI = 2.93) are not available at all in the area and species such as *Pterocarpus marsupium* (PI= 2.67) and *Gardenia gummifera* (PI= 2.56) have very little utilizable biomass, 12.97 Mg and 29.13 Mg respectively. Further, the seasonality of availability of each resource also plays a crucial role in estimating the biomass availability; however, that has been ignored in the current estimates. Therefore, the biomass availability for elephant's use may be much lesser than the estimated value. The estimated elephant number based on food resource availability, thus, maybe on the higher side. This indicates that the habitat quality of Mayurjharna ER needs to be improved by enriching it with more preferred food species. Assessment of carrying capacity done here is based on productivity values available in the literature. Those productivity values might not be very fitting for this area and hence, a more detailed study on forest productivity in this area along with the possible human disturbances is necessary. In addition, accurate estimation of carrying capacity depends upon nutrient uptake by elephants from the fodder that needs to be studied in a controlled environment.

PLATE 6

a)

b)

Interviews of a) Local people b) Forest staff

CHAPTER- X

Conclusion

The range expansion of Asian elephant in South West Bengal from the Dalma Wildlife Sanctuary perhaps led to the human-elephant conflict in the landscape. Elephants, which were earlier confined to certain pockets of Mayurjharna ER, have now expanded into the other parts of South Bengal i.e. Medinipur, Kharagpur, Jhargram, Rupnarayan, Panchet, Bankura North, and Bankura South forest divisions. Despite the absence of continuous forestsand sal dominated vegetation, the expanse of the area utilized by the elephant has increased. The presence of ample land under agriculture to feed on has lured the elephants in this region. Although elephants spendthe daytime in the forest that is usually close to the agricultural fields, they stray out in the night to agriculture fields for crop raids. The high presence of crop species in their diet revealed their dependency on agriculture as they are rich in nutrients, are preferred by the elephants despite the high risk of human interactions. The natural movement of elephants is highly influenced by the *hula* drives and the local drives to reduce the crop depredation by elephants, thereby completely altering their natural movement pattern and the increased conflict with the human population, which has led to a high number of human deaths and injuries occurring in non-forested areas. A huge number of human deaths (268) have occurred in the last nine years and the major situations in which these deaths have occurred are while defecation and while traveling through the forest roads. The retaliatory killing of elephants either by poisoning or electrocuting is common in the area for the excessive human life and the economic losses incurred due to elephants. The loss incurred due to the severe conflict overrides the sympathy of people over the respect of the animal as a deity.Various recommendations have been made by the team to attempt minimizing the conflict, the major being encouraging people participation and public awareness programmes dealing with specific goals. Also, providing the locals with basic facilities of toilets and well-lit roads where there is more probability of elephants residing in the nearby forests, proper management of the existing trenches and energized fencing and constructing new ones wherever needed. Developing plantations of elephant fodder species in areas with huge crop depredation is also suggested to ease out the huge depredation load on farmers in thearea.

ANNEXURE

A MANAGEMENT PLAN FOR ELEPHANTS IN SOUTH BENGAL

CHAPTER I. BACKGROUND TO THE MANAGEMENT PLAN

Wildlife management is indeedcrucial in today's world in view of the continuous rise in thehuman demands (Maurer 1996) for natural resources and since the ceaselesschange in thelandscape has caused the decline or even extinction of numerous species. Expanding human demands in addition to the effects of climate change have made conservation and management of wild areas and wild animals a top priority requirement.

The elephants in South Bengal are recent colonizers after a long gap of about five to six decades. Thus, the elephants have become a guest-pest for the current generation of humans in the landscape as they had less experience with them. Now, the guest elephants have become almost residents resulting in lots of chaos in the life of local people in terms of various depredation issues, and a major issue for the forest department to manage. We conducted a three-year study on elephants in South Bengal focusing on population, age-sex of the individuals, habitat use, movement pattern, feeding ecology, and pattern of conflict with people. Taking into account the above information and insights drawn from the same, we formulated the management plan presented here.

CHAPTER II. POPULATION MONITORING

Determining the population of any species and its periodical monitoring is important while designing the management plan. Various methodologies are employed to estimate animal populations, which include recording direct and indirect evidences such as count of dung, nests, trails, calls, and direct counts along transects and photo capturing. For elephants, line transect surveys using direct detections, dung count techniques, mark-recapture method, waterhole count, and use of acoustic sensors have been widely employed with robust results in many parts of the world. Yet, it is usual that an appropriate technique for the local conditions is adopted for monitoring. Thus, we adopted a dung count technique and direct counts using the line-transect technique to estimate the elephant density in South Bengal.

The dung count technique has provided the estimate, but due to the lack of detection of elephants on the line transect could not provide us an estimate of their number. In Rupnarayan - Medinipur forest divisions and Mayurjharna Elephant Reserve, the estimated density was 0.51 elephants/ km^2 and 0.003 elephants/ km^2 respectively. If the area of the two divisions taken together is 2697 km^2, then the minimum population size of elephants is 1348 elephants. Considering that the area of the reserve is 414 km^2, and then the minimum population of elephants in Mayurjharna ER is only 1.2 elephants. However, in the case of the all India elephant census conducted by the forest division (2017), the total number of elephants reported was 194 using the dung count method. These numbers seem to be highly unreliable and the difference between the two estimations possibly is a result of the highly mobile population of elephants in the area; the incessant movement of elephants from one part of the study area to another in a short time due to hula drives resulting in the biased estimate.

In addition to such counts and estimates, the forest department is monitoring the elephants using their well-established network, which provides them the total count of the elephants for the entire landscape. Therefore, we suggest that both the total count method and dung count method may be adopted for estimating the elephants in South Bengal to estimate the total number of elephants.

1. Dung Count Method

The dung count technique involves the estimation of three factors; i) estimation of the dung decay rate, ii) dung density, and iii) defecation rate.

Dung Decay Rate: To determine the dung density, the dung decay rate (r) has to be determined in the landscape. The dung decay rate is the rate at which the dung disappears in natural conditions which can highly vary between different sites due to differences in climatic conditions, especially rainfall. Inter-site differences in rainfall regime, weather conditions, elephant diet, and vegetation type have major implications for dung-based surveys. Therefore, the decay rate from other sites may not be used and it is preferred to estimate the decay rate for each site. Categorization of the decay stages (Plate 1) has been done according to Dawson (1990)'s categorization since termites attack the boli from within, making the breakdown of the boli not readily evident. These decay stages are defined as given below:

A: Boli intact, very fresh (<1 day old), moist with odour.

B: Termite activity commenced from beneath (detected by the fact that dung was cemented to the substrate), but all boli still intact.

Cl: Less than 50% of the boli consumed by the termites.

C2: More than 50% of the boli consumed by the termites

D: All boli disintegrated as a result of termite activity but not necessarily a flat amorphous mass.

E: Only mud left (in the shape of boli); no dung left except for a few fibers

To determine the dung decay rate, fresh dung piles have to be selected and GPS coordinates for each location taken. Visits have to be made once every seven days to check the piles for decomposition and the decay stages have to be recorded and have to continue until the dung piles are fully decomposed. To calculate the decay rate, the survival method has to be adopted (Dawson 1990). It derives the "life expectancy" of a dung pile from a life table of dung surviving at the end of each week (Armitage and Berry 1987). In this method, dung is monitored until the last dung pile disappears and the mean expected survival time is calculated. The reciprocal of this survival time gives the decay rate (r). r = 1 / T, where T is the mean survival time (in days) per dung pile.

Since the decay rate varies from one region to another depending on the termite activity and the weather conditions, it is suggested to estimate the dung decay rate at two to three locations, where one location can be in Mayurjharna ER and the other in Medinipur-Rupnarayan.

STAGE A

STAGE B

STAGE C2

STAGE C1

Plate 1 Different dung Stages

Defecation rate: To determine the defecation rate **(D),** the elephants have to be followed for 24 hours to record the number of times the animals are defecating. This has to be done meticulously for a few days for both herds as well as loners to minimize error, and the average number of times of defecation calculated.

Dung density: The habitat of the elephants in the entire landscape has to be mapped. Consider the forest beat of the elephant habitat as the smallest unit of area for sampling. One two-kilometer belt transect has to be laid in each selected forest beat. The width of transects has to be 4 m (2 m on each side). All the belt transects have to be walked in total and all dung piles have to be recorded within 2 m on both sides of the transect (Fig.3.1). On sighting dung piles, the GPS readings and dung stages have to be recorded. Since elephant dung piles consist of several boli ('balls' of dung), which can often be scattered over considerable distances and intermingled with boli from other dung piles in the same general locality, great care has to be taken when deciding which boli belong to which dung piles while counting the dung count. Further, we suggest not conducting any elephant drive at least for a month before the day of dung count.

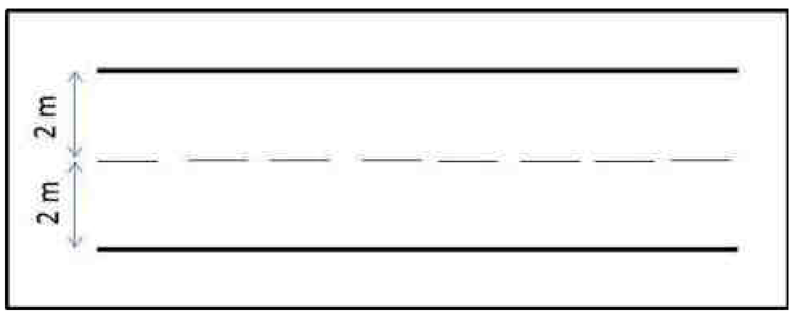

Figure 2.1 Belt transect for dung count

Dung density (Y) = total number of dungs found / total area covered

Where the total area covered is- length of transect ***X*** width of the transect.

Elephant density estimation: It requires estimates of three variables, i.e., dung-pile abundance on the ground, defecation rate, and dung decay rate that gives the dung density which is then converted into elephant density using the formula (Baskaran et al., 2013; Varman et al., 1995) given below.

$$E = Y \times r / D$$

Where E is the density of elephants, Y is dung density, r is the decay rate, and D is the number of dung piles deposited (defecation rate) per elephant per day.

Table 2.1 Datasheet used for Dung count method

Belt transect number	Place	Range	Division	Latitude	Longitude	Stage of dung

This has to be done as a one-time survey using the above-shown format (Table 2.1); all the divisions must be covered simultaneously on one single day preferably during the same time of the day.

2. **Total Count Method**

The total count method (Douglas-Hamilton, 1996) can be an effective way to estimate the total population of elephants in the landscape. The elephant herds have to be monitored and followed regularly in each division using a network of people who would report any sighting that happens. The total number of elephants has to be counted and a database of the daily records of elephants in each division has to be prepared. For each sighting, the total number of males, females, sub-adults, and calves has to be counted and recorded for the demography study. The herds have to be identified based upon the group composition and specific individuals identified within a herd.

Elephant demography

Documenting the age-sex of the individuals may be difficult in the South Bengal landscape. During a suitable time, when elephants are in the pen area or while crossing the river or open areas, the animals can be photographed. An attempt has to be made to document all the individuals in the herd. The age-sex of the individuals has to be categorized following the features mentioned in Table 2.2.

Table 2.2 Classification of elephants based on their shoulder heights

	Male shoulder height	**Female shoulder height**
Age-classes	**Feet**	**Feet**
Calf (<1 year)	up to 4	up to 4
Juvenile (1 to 5 years)	4 to 6	4 to 6
Sub-adult (5 to 15 years)	6 to 8	6 to 7
Adult (15 years and above)	above 8	above 7

Further**,** it has to be noted that-Bulls include both Tuskers and *Makhanas* (Tusk-less Bulls). Care has to be taken to differentiate *Makhanas* from females using body characteristics and shape of genitalia. From the age and sex classification data, the sex ratio can be calculated for adults in each division.

It is suggested that the following types of photographs have to be taken of elephants; (1) frontal pictures with the head down, showing tusk and ear morphology; (2) profile pictures for both flanks to ascertain tusk angle (with respect to the ground) and tail length, and to identify scars, warts and other marks on the body; (3) clear side or frontal pictures of both ears; and (4) a close-up picture of the tail to identify the brush type. These pictures can help to identify individuals and also the herd.

CHAPTER III. RESOURCE MANAGEMENT

In South Bengal, due to the expansion of the Bengal - Nagpur railway line in 1889 and construction of railway tracks through Medinipur district in 1903 (Palit 1991; Malhotra 1995), uncontrolled forest destruction occurred. To combat this loss, the government promulgated the Bengal Private Forest Act of 1945, mandating the landowners to plant and restores forests. Then in 1981, the Social Forestry Project was launched with the objective of planting fast-growing plant species on public and private lands to meet the fuel demands of the local people (Malhotra and Poffenberger 1989). The trees planted for this purpose included Sal (*Shorea robusta*), *Eucalyptus* sp., akashmoni (*Acacia auriculiformis*), and mahua (*Madhuca longifolia*), which in effect replaced the indigenous plant species of these lateritic tracts. Hence, within the last one and a half-century, the forests were modified due to the replacement of the indigenous species. Therefore, the present study explored the present species composition and vegetation of South Bengal in order to appreciate the resource availability for elephants and to understand their dietary use and preferences.

The findings show that *Shorea robusta* (14.68 individuals per hectare, Table 3.1) is the most dominant species followed by *Madhuca longifolia* (0.88 individuals per hectare) in South Bengal. Similarly, in Mayurjharna ER, *S. robusta* (11.7 individuals per hectare) was the most dominant species followed by *M. longifolia* (1.79 individuals per hectare). *Lannea grandis, Pterocarpus marsupium Roxb,*and *Gardenia gummifera* are the most preferred species (Table 3.2 and 3.3) by the elephants; but these species are the lowest in availability in the area. Although the percent availability of *S. robusta* is very high, its utilization is low.

As the average requirement of food for an elephant is about 108 kg fresh and 27 kg dry plant fodder per day (Sukumar, 1986), it is clear that the total fodder requirement is not fulfilled by the natural food plants available in the forests, and as a result the dependency of the animals on crops increases.

Table 3.1 Density and Importance Value Index of fodder tree species in South Bengal

Tree species	Family	TI	D	BA	Rel. BA	IVI
South Bengal						
Aegle marmelos	Rutaceae	58	0.01	0.07	0.2	0.91
Annona squamosa	Annonaceae	68	0.04	0.11	0.31	2.45
Artocarpus heterophyllus	Moraceae	98	0.04	0.05	0.15	1.65
Buchanania cochinchinensis	Anacardiaceae	68	0.07	0.09	0.26	1.34
Diospyros melanoxylon	Ebenaceae	47	0.09	0.44	1.28	4.36
Gardenia gummifera	Rubiaceae	85	0.01	0.01	0.03	0.74
Lannea grandis	Anacardiaceae	108	0.1	0.13	0.39	4.82
Madhuca longifolia	Sapotaceae	308	0.88	1.66	4.88	23.62
Pterocarpus marsupium	Fabaceae	68	0.01	0.02	0.05	0.76
Shorea robusta	Dipterocarpaceae	7804	14.68	29.82	87.8	227.26
Syzygium cumini	Myrtaceae	98	0.05	0.06	0.17	3.03
Terminalia bellirica	Combretaceae	38	0.04	0.11	0.33	2.47
Terminalia elliptica	Combretaceae	108	0.21	0.29	0.86	8.51
Mayurjharna ER						
Annona squamosa	Annonaceae	4	0.03	0.213	0.12	0.86
Buchanania cochinchinensis	Anacardiaceae	163	1.37	1.513	6.25	22.00
Diospyros melanoxylon	Ebenaceae	156	1.31	1.705	5.86	21.63
Gardenia gummifera	Rubiaceae	41	0.34	0.087	0.86	5.93
Gymnema sylvestre	Asclepiadaceae	4	0.03	0.033	0.15	0.89
Lannea coromandelica	Anacardiaceae	38	0.32	0.863	2.34	7.73
Madhuca longifolia	Sapotaceae	213	1.79	1.965	8.05	25.31
Mallotus nudiflorus	Euphorbiaceae	4	0.03	0.007	0.07	0.52
Pterocarpus marsupium	Fabaceae	4	0.03	0.011	0.10	0.83
Shorea robusta	Dipterocarpaceae	1402	11.7	14.025	56.18	127.46
Syzygium cumini	Myrtaceae	8	0.07	0.082	0.33	1.80
Terminalia bellirica	Combretaceae	12	0.10	0.082	0.41	2.47

TI- Total individuals, D- Density, BA- Basal area, Rel. BA- Relative basal area, IVI- Importance value index

Table 3.2 Preference index (PI) for the most important species in the diet of elephants

Species	Plant Part Consumed	Relative Frequency (% Utilization)	Relative Abundance (% Availability)	PI
Aegle marmelos	Fruit	2.56	2	1.28
Artocarpus heterophyllus	Fruit	2.24	3	0.75
Buchanania cochinchinensis	Foliage	6.18	10	0.62
Diospyros melanoxylon	Foliage and fruit	5.01	3	1.67
Gardenia gummifera	Foliage	5.12	2	2.56
Lannea grandis	Foliage	5.86	2	2.93
Madhuca longifolia	Flowers	10.23	6	1.71
Pterocarpus marsupium Roxb	Foliage	5.33	2	2.67
Phoenix sylvestris	Pith and fruits	2.13	1	0.21
Shorea robusta	Foliage and bark	39.34	25	1.57
Syzygium cumini	Fruit	2.67	2	1.33
Terminalia bellirica	Foliage and fruit	7.68	17	0.45
Terminalia elliptica	Foliage	5.65	3	1.88

Table 3.3 Preference index (PI) for the most important species in the diet of elephants according to different seasons

Tree species	Relative Frequency (% Utilization)			Relative Abundance (% Availability)	PI		
	Pre Monsoon	Monsoon	Post Monsoon		Pre Monsoon	Monsoon	Post Monsoon
Aegle marmelos	0.02	-	0.03	0.02	1.57	-	0.78
Artocarpus heterophyllus	0.03	0.01	0.00	0.03	1.05	0.40	-
Buchanania cochinchinensis	0.06	0.04	0.07	0.1	0.63	0.44	0.74
Diospyros melanoxylon	0.03	0.05	0.06	0.03	1.04	1.57	1.85
Gardenia Gummifera	0.06	0.06	0.04	0.02	3.13	3.01	2.21
Lannea grandis	0.05	0.06	0.06	0.02	2.34	3.14	2.95
Madhuca longifolia	0.11	0.10	0.11	0.06	1.82	1.61	1.75
Phoenix sylvestris	0.02	0.02	0.02	-	-	-	-
Pterocarpus marsupium Roxb.	0.06	0.05	0.05	0.02	3.13	2.56	2.68
Shorea robusta	0.36	0.47	0.37	0.25	1.44	1.86	1.46
Syzygium cumini	0.03	-	-	0.02	1.56	-	-
Terminalia bellirica	0.11	0.07	0.08	0.17	0.64	0.41	0.47
Terminalia elliptica	0.09	0.06	0.05	0.03	3.13	2.01	1.66

Highly preferred food species found in the forests during our study were *L. grandis, Gardenia Gummifera,Pterocarpus marsupium Roxb,* and*T. elliptica.* The foliage of *L. grandis* is highly preferred by elephants throughout the year; however, its consumption was further high in the monsoon. Similarly, the foliage of *G. gummifera* is alsohighly preferred by elephants throughout the year. The fruits of *Artocarpus heterophyllus, A. marmelos,*and *Syzygium cumini* are eaten by elephants during the summer. Similarly, consumption of *S. robusta* was also observed throughout the year.

Management steps to be taken-

- The degree of fragmentation of forests needs to be reduced, as it is a significant factor in the economic loss from a conflict (WWF 2008). In one of the studies in Malaysia, it was reported that the bigger the size of the forest, the fewer the raids (Chong and Dayang Norwana 2005). Thus, by increasing the size of the forests (in the area) the crop-raiding could be controlled to a great extent. In addition, changes in the forest structure like the replacement of the species like *Shorea robusta* and *Eucalyptus tereticornis* with preferred fodder species like *Lannea grandis, Gardenia Gummifera, Pterocarpus marsupium, Aegle marmelos, Annona squamosa, Artocarpus heterophyllus, Buchanania cochinchinensis, Diospyros melanoxylon, Madhuca longifolia, Syzygium cumini,* *Terminalia bellirica, Terminalia elliptica,* and Bamboo species would provide more food resources for elephants. These species are already a part of the native vegetation in this area and can be propagated easily. Such replacement by fodder species might eventually help in retaining the elephants inside the forest.

- Planting bamboo in Patrasayer Range has already been started in Bankura North Division, which is still in a preliminary stage. Similar efforts in other forest divisions too would help in improving the habitat.
- Planting fruiting trees in the forests where elephants spend most of their time such as Chandra range (Gurguripal and Sukhnakhali forests), Pirakata range (Ranja and Kalibhasa forests), Bhadutala range(Khas jungle 277), Kamrangi forest, Salboni forest, and around Ajodhya Hill, etc. will eventually make the elephants stay inside the forests.
- Cattle grazing in crucial habitats of elephant are suggested to be controlled to avoid resource competition, especially at Lalgarh, Sukhnakhali, and Gurguripal in Medinipur and Jotiya jungle.
- Making Buffer Zones with inedible crops: Farmlands that are in close proximity to forests are the most affected by the conflict. Therefore, the best defense against crop loss is having another farm along the forest boundary as a buffer (Naughton et al. 1999). Growing unpalatable crops for a 1 km width (Kulkarni et al. 2007) adjoining the forest areas can reduce crop raiding (Chiyo et al. 2005, Sitati and Walpole 2006). In one of the cases in Bardia National Park (Nepal), menthe was promoted as a replacement for maize and reportedly, farmers earned good income for 750 kg of menthe oil (WWF 2008) due to no economic loss to them when they grew menthe. In the case of South Bengal too, with the help of the Department of Agriculture, strategic replacement of the crops with inedible crops can be done on the peripherals villages of forests. Farmers have to be provided with assistance on farming unfamiliar crops, to give them the confidence of switching over and the market for their produce.
- As we have witnessed very few trees with a girth size of more than 70 cm, the canopy cover is very thin. Maintaining a thick canopy cover is essential for elephants to stay inside the forests for shelter. Coppicing and extraction of timber by both departments as well as the local villagers may be controlled in areas like Mayurjharna ER, Belpahari, Banspahari, Lalgarh, Sukhnakhali, and Gurguripal.

CHAPTER IV. CONFLICT MANAGEMENT

Human-wildlife conflict occurs when the needs and behavior of wildlife leaves a negative impact on the goals of humans or when the goals of humans negatively impact the needs of wildlife (Madden 2004). These conflicts can be in any form - crop damage, injuries or deaths of domestic animals, or deaths of people. Human-wildlife conflict (HWC) is increasing in both frequency and severity worldwide and likely to continue escalating (Madden 2004). Forests are increasingly surrounded by cultivation and development. Wildlife and humans increasingly compete for space, resources, and home. Although ecosystem-based approaches (including the development of corridors between protected areas) offer improved long-term protection for many species from a biological perspective, they also involve extensive regional opportunities for interaction and conflict between local people and wildlife. Without properly addressing HWC in the effort to conserve wildlife and their habitat, conservation efforts will lose stability and progress, as well as support from local communities.

Human deaths and injuries:

A total of 268 human deaths and 372 human injuries were recorded between 2010 and 2018 in South Bengal. Based upon the circumstantial evidence collected from these cases, travel through the forest (21.64 % deaths; Fig. 4.1and 23.39 % injuries) and open defecation (17.91% deaths and 11.02% injuries) were found to be the most frequent causes. Figure 4.1 shows the distribution of these cases across the landscape. Apart from these, hula driving, NTFP collection, herding, and farming activities have also caused human casualties. Negligent behaviors such as trying to take selfies, approaching elephants in vehicles, etc. have also been reported in 17 instances of human casualty. Considering all such instances, we listed highly affected beats in each forest division in South Bengal that requires immediate concern (Table 4.1).

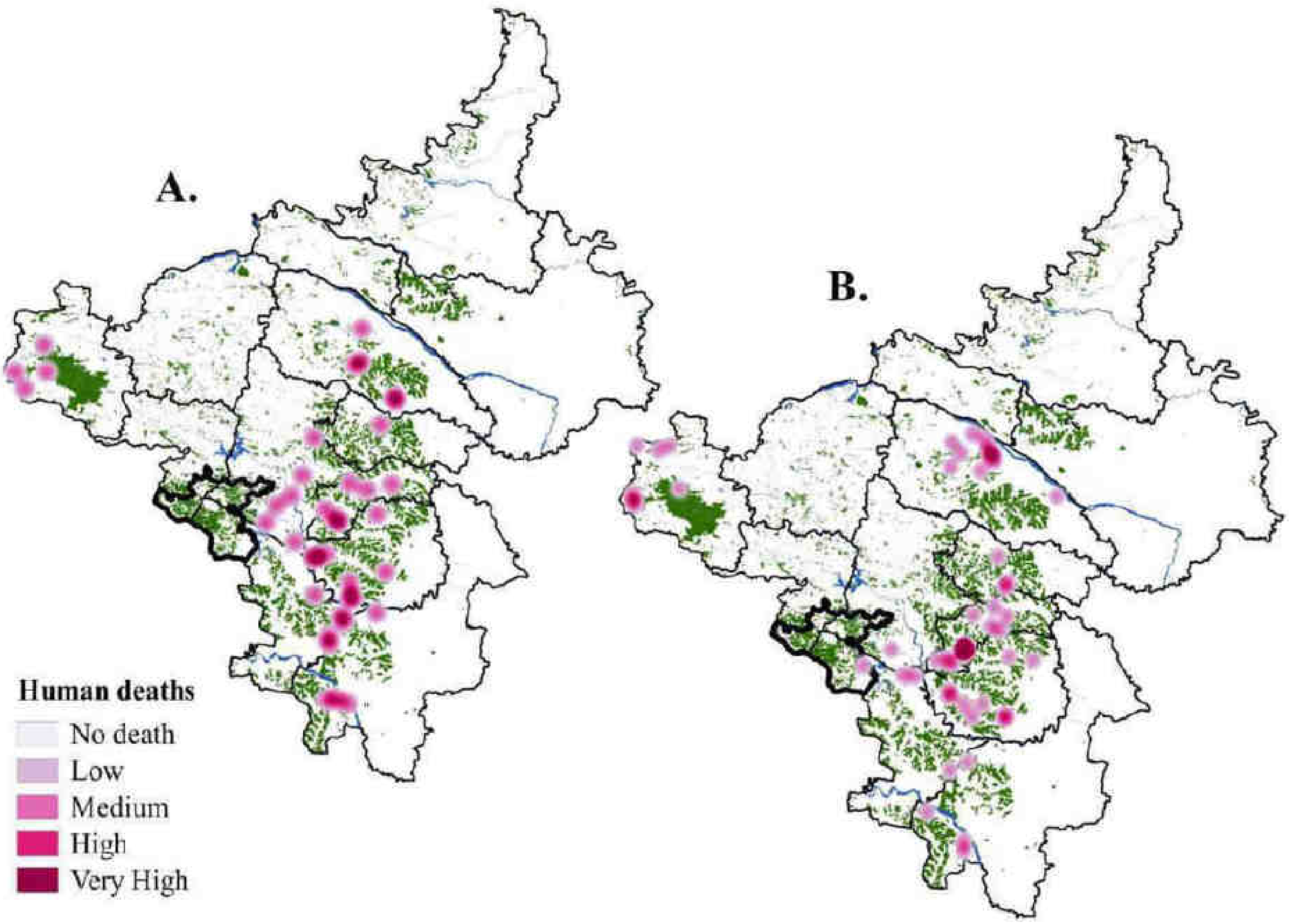

Figure 4.1 Hotspot analysis of human deaths due to elephants in South Bengal: A. While traveling to or from the village, B. while had gone out for open defecation

Socio-economic status of affected people: The socio-economic survey using a customized open questionnaire was done for 214 people whose crop was damaged by elephants during the period of the study. Cases were taken from 17 beats in four forest divisions. We collected the data on their landholdings; types and number of times crop grown, alternate sources of income if any, and total crop damage by elephants. The data were pooled to assess the high crop damaged area and calculated the loss incurred by the affected people.

Table 4.1 Name of beats affected during different circumstances

	Beats	
Division	**Open defecation**	**Travel through forest roads**
Bankura North	Barjora	Gangajalghati
	Beliatore	Barjora
	Bhara	Shitla
	Patrasayer	Patrasayer
		Amarkanan
Bankura South	Harmasra	Motgoda- II
	Pirargar- I	Fulkusma
	Pirargar- II	
	Motgoda- I	
	Motgoda- II	
	Fulkusma	
Jhargram	Binpur	Belpahari
	Dhabani	Balibhasa
	Balibhasa	Binpur
Kharagpur	Kalaikunda	Patina
	Kalmapukuria	Kalaikunda
	Nayagram	Nayagram
	Panchkahania	
Medinipur	Nayabasat	Bhadutala
	Godapeasal	Moupal
	Chandra	Chandra
	Lalgarh	Bhimsol
	Bhaudi	Bhaudi
	Gurguripal	Arabari
	Bhadutala	Andhnarayan
Panchet	Bishnupur- I	Bankadaha
		Bishnupur- I
Purulia	Khamar	Kalma
	Kalimati	Simni
	Burda	Murguma
	Jhalda	Khamar
Rupnarayan	Amlasuli	Amlasuli
	Hoomgarh	Hoomgarh
	Pathrisol	Pathrisol
	Kadasol	Kadasol
	Mahalisai- I	Mahalisai- I
		Mahalisai- II
		Nohari
		Ramgarh

The most losses were incurred by people in Chandra, Dherua, Ramgarh, Baramesia, Bankadaha, and Goaltore beats. Goaltore and Bankadaha beats incurred a maximum loss of above 3 % from their annual income. On average, the loss incurred considering all the ranges was about 2.5 %. The losses incurred have a great impact on the already low average income of these people (Table 4.2). For farmers owning no land, the situation was much worse as they have to bear the crop losses along with the lease money.

Table 4.2 Socio-economic status of the affected people

Division	Beat	No. of households with land	No. of households with land on lease	Average Landholding (in acres)	Average Annual Income	Average annual loss	% loss
Medinipur	Chandra	23	10	2	180000	5000	2.77
	Gurguripal	15	5	1.5	150000	2500	1.77
	Bhimsol	10	4	2	200000	2500	1.25
	Moupal	4	3	1.3	200000	3000	1.50
	Dherua	11	3	2	200000	5500	2.75
	Bhaudi	10	2	1	150000	4000	2.66
Rupnarayan	Ramgarh	5	4	2	180000	5000	2.77
	Goaltore	10	6	1.5	160000	5000	3.13
	Mahalisai- 1	4	4	1	170000	3000	1.76
	Hoomgarh	4	5	1.2	150000	4000	2.66
	Baramesia	10	2	2	190000	5500	2.89
Kharagpur	Panchkahania	10	6	2	200000	4500	2.25
	Nayagram	5	8	2.2	200000	3500	1.75
	Kalmapukuria	6	4	1	190000	4000	2.10
	Baligeria	2	3	1.5	210000	5000	2.38
Panchet	Bishnupur- 1	5	4	1	200000	3500	1.75
	Bakadaha	4	3	1	150000	4500	3.00

The management recommendations:

State Administration Level: Some important ground-level interventions are beyond the scope of the forest department and need active participation and strategic partnerships of other line departments. We propose constituting a state-level committee (SLC) comprising representatives from Forest Department, Rural Development Department, State Transport Corporation, Public Works Department, and Elected representatives, to be considered with PCCF as a member too. The committee may make it possible to provide the necessary facilities or provisions such as listed below to the identified villages or areas.

- **Improving public transport facilities:** Rupnarayan, Bankura north and south, Medinipur and Kharagpur divisions suffered the highest casualties despite proper public transport facilities (Table 4.1). Although there are a good number of busses running between major villages and cities, the timings of the busses may be re-scheduled according to the needs of the local people. Strengthening mass public transport through more frequent buses and improvement in public transport infrastructure such as sufficient streetlights along the roads at locations frequented by elephants are required. This requires partnership with the State Transport Authority and the Public Works Department. Provisions may be made for frequent public transport to areas close to the forests. Early morning (5:00 AM to 10:00 AM) and evening (5:00 PM to 10:00 PM) is the most active time for elephant movements, and hence public transport during these timings will help the people residing in such areas to travel safely. However, the timings and the requirement of transportation and their frequency need to be sought from the villagers, to ensure them using such facility.
- **Curbing open defecation**: Despite the 'Swachh Bharat Mission' scheme, there is a severe dearth of toilet facilities in some of the highly elephant affected areas (Table 4.1) in Bankura North, Bankura South, and Medinipur Divisions. Although, toilets are constructed in some of the villages, their usage by the villagers is negligible due to lack of maintenance, availability of water, and awareness. Providing functional toilets with proper water facilities, followed by an awareness program to make them understand that its usage is critical for saving their life is also very important. This must be carried out on a priority basis especially in beats mentioned in Table 5.1. For that, joint efforts by

the forest department and departments of water supply and sanitation, and rural development in priority areas are necessary.

Special attention should be given to villages like Pushti, Chutamghutu, Suisa, Burda, and Dahi in Purulia; Sagar Bhanga, Kukrakhupi, Rangiam, Tapoban,Banspat, Damuria and Kiakati in Kharagpur; Bhora, Tentulara, Saharjora, Sarenga, Polsona, Roniara, and Hamirpur in Bankura North; Fulkusuma, Turuktoba, Sidi, Hod, and Nachna in Bankura South; Tentulia, Gopalpur, Darigeria, Bhangodli, Patharchati, Bhula, Golakchak, Saapkata and Baghmari in Medinipur; Nuagarh, Chhuchada, Chhotachuasuli and Dogoria in Jhargram; Ledagram and aKumari in Rupnarayan Forest Division.

Division level interventions: A special emphasis at the division level is required to improve communication between stakeholders and the forest department. For this, a stakeholder committee needs to be constituted at the division level. In this, the involvement of representatives from the District Administration, VLIs such as BMCs and JFMCs, and forest range offices would be beneficial. Mechanisms for sharing elephant conflict-related knowledge and information dissemination between the forest department and various other stakeholders also need to be established.

- The use of popular media such as newspapers, television channels, radio, etc. would help in disseminating the information of conflict dynamics to the masses along with division-specific do’s and don’ts formulated to reduce the conflict. Highlighting elephant attacks due to negligence such as taking selfies and approaching the animal is important.
- During socio-economic surveys, it was revealed that compensation received for crop damage and human casualty is inadequate to meet the loss incurred by the affected community. The Forest department may consider conducting capacity development programs to empower VLIs with additional livelihood options such as apiculture, eco-tourism, etc. to improve the livelihoods of the affected community.

Beat/ Village level interventions: Highly affected areas could be prioritized for developing infrastructure and logistics to minimize crop loss and human casualties. Suggested interventions in this line are as follows.

- Infrastructure development: Public and private toilets need to be constructed. Despite the presence of toilets, people still choose open defecation due to either scarcity of water or their personal preference to defecate in open. In parts of Purulia and Jhargram, there are drought spells during summer causing severe scarcity of water. In such cases, proper awareness programs focusing on health benefits as well as on the security from the elephants by using safe and closed toilet facilities should be organized.
- Awareness generation programs on the need of maintaining proper elephant barriers in the context of death incidences due to the non-maintenance of such structures have to be organized.
- People's participation in managing the problems related to elephants is very important and is necessary to gain their confidence. Village committees can be formed which can work along with the forest department for managing elephant-related issues.
- Awareness programs highlighting the need of avoiding getting close to elephants and maintaining a safe distance from them is very important. Local villagers can be given special training on the do’s and don’ts when encountering elephants through interactive programs like street plays and workshops organized preferably in villages rather than in forest offices to ensure more people participating in them.

CHAPTER V. MANAGEMENT OF CRUCIAL CROSSING POINTS AND CORRIDORS

Conservation corridors help in the safe dispersion and movement of individuals between habitats, thus increasing effective population sizes and in turn decreasing extinction probabilities (Johnsingh and Williams, 1999). They also provide animals with access to habitats that would otherwise be inaccessible to them. As far as elephants are concerned, the disadvantage of corridors is that they may increase the interface between elephants and humans, thus leading to elephant-human conflicts. Careful planning and serious efforts are needed to mitigate such conflicts around corridor areas. However, keeping in mind the long-term conservation benefits that would add to the species, the necessary efforts would be worthwhile.Because of increased awareness of the advantages of corridors and the need to ensure the survival of large-bodied mammals such as elephants, conservation of corridors are indispensable (Rodgers and Panwar 1988; Sukumar 1991) and that has resulted in identifying and declaring several elephant corridors.

Elephant movements were studied with select herds in the region from August 2017 to December 2018. During this period, elephant paths were followed and geo-coordinates for the same were recorded. Vegetation and land use parameters for these locations were also collected. The crucial crossing points were then identified based on the intensity of use and importance for the regular and safe movement of elephants from one patch to another.

The elephants usually enter Mayurjharna ER from Dalma Wildlife Sanctuary in Jharkhand (Fig. 5.1) and cross through the Kankrajhore forest region in Jhargram, go towards Amlasol and Jamaimari region (in Jhargram), then move towards Sutan (Bankura south) and Burdwan, Banspahari, Kuilapal and Jhilimili regions of Bankura south within the reserve. They then enter Silda, move towards Malabati forest, cross Kangsabati River at Sijuaghat, and enter the Lalgarh region in West Medinipur. In Medinipur, they move to Goaltore, Hoomgarh, Garhbeta, Dhadka, and finally Shayamnagar. From there they enter Bankura District via Bankadaha and move towards Patrasayar, Sonamukhi, Brindabanpur, and Barjora. Through Barjora, they move back towards Dalma Hills taking a little different route where they covered Sonamukhi, Radhanagar, Bishnupur, Nayabasat, Arabari, Mirga, Moupal, Chandra, and then again moving towards Lalgarh, finally crossing Sijuaghat, to reach Malabati forest. From Malabati the elephants move towards Silda and then cross Kankrajhore to reach Dalma hills of Jharkhand. A route taken by the animals while going towards Odishaisafter Chandra they move through Kalaikunda, Patina, Nayagram and then cross Keshorrekha and reach Odisha State.

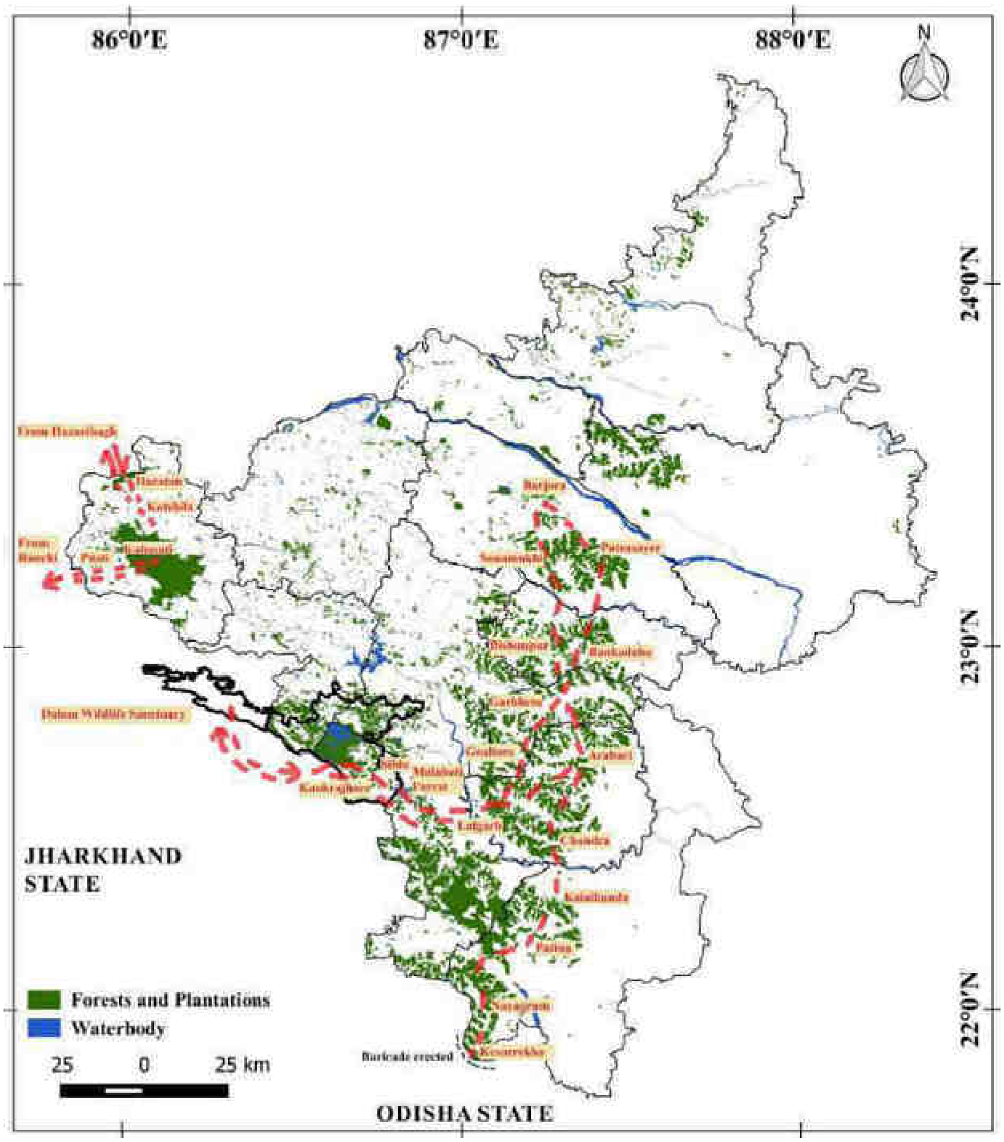

Figure 5.1 Route followed by elephants while traveling from Dalma Wildlife Sanctuary, Hazaribagh area, and Ranchi in Jharkhand state

Resulting from the study, the following two railway crossings, and five crucial crossing points and corridors have been demarcated in the study area (Figure 5.2).

Railway crossings

- Panchet division- Railway track near Basudebpur, Ghughumura, and Piardoba
- Jhargram division- Railway track near Manikpara

Elephants frequently cross two major railway tracks i.e. Bishnupur- Mynapur track and Bishnupur- Kharagpur track in the Panchet division. Five zones have been identified as vulnerable zones on the two railway tracks. On the railway track from Bishnupur to Mynapur, one zone has been identified around the Tribanka bridge in Basudebpur. Another four zones are identified on the Bishnupur- Kharagpur railway track, situated at Ghugumura railway crossing, Dhabani railway crossing (two zones), and Nachanjam railway crossing. Since 2013, three incidences of collision with train have happened which have caused the death of 5 elephants (Plate 2).

Crossovers and corridors

- Jhargram division- Silda area
  The area where the elephants cross Silda to enter Malabati Forest and move towards Lalgarh through Sijua Ghat is a mosaic of agricultural land and forest patches. The elephants when passing through this area are highly vulnerable, as they have to cross the huge patches of agricultural land.
- Mayurjharna ER - Ranibandh area near Sutan
  This is a major corridor for elephants when they move out from Mayurjharna ER. The region is a patch of forest under the forest department and is extensively used by the villagers to collect NTFP and as grazing ground for cattle.
- Kharagpur- Near Odissa- Bengal border in Keshorrekkha
  The area is a crossing point for elephants to enter Odisha state from West Bengal. The State Government of Odisha has laid down a concrete water canal on the main crossing point leaving behind only a small patch of degraded land surrounding few villages near the Jambani area. A narrow strip of land is left through which the elephants are forced to cross over through the states.
- Kharagpur Division- Near Jhargram and Kharagpur border in Chandabila

The area is the boundary of the Chandabila range of Kharagpur and Gopiballabhpur of the Jhargram forest range and is a mosaic of forest and agricultural land.

- Medinipur Division- Pirakata- Goaltore road near Ranja,
  This area is a major cross over and is continuously used by the elephants to cross over the two ranges of the Medinipur forest division. The major area near the road is forest surrounded by agricultural land. The forest is basically sal plantation land used by the department as coppice land.

Management requirements

Railway crossing points**:**

- Important ground-level interventions require synergetic partnership and active participation, especially with railways. Although we have identified a few crossing points and corridors, some of the crossing points or stretches of land that are very crucial have to be monitored for a longer time, and an early warning system needs to be developed to alert oncoming trains.
- Intersection points of elephant corridors and railway lines (especially in the Bishnupur-Kharagpur track and Jhargram-Purulia track) need to be regulated to ensure safe passage for elephants. Strict directives should be issued to ensure speed limits are adhered to by trains traversing these sections.
- Underpasses can be made at specific railway crossing points to ensure safe passage for elephants as well as other wildlife.
- Erect energized fences along the crossing points to restrict the movement of elephants from specific locations.

Crossovers and corridors

- Interstate interventions to ensure proper passing of elephants from the corridor near Odissa- Bengal border in Keshorrekkha to provide safe passage to elephants.
- Habitat conservation and restoration programs to be initiated in the Ranibandh area near Sutan to curtail over-grazing by cattle and excessive NTFP collection in the area by people.

- The crossover of Pirakata- Goaltore road near Ranja should be avoided for coppicing and should be encouraged by the department to grow naturally to provide better habitat for the elephants to stay and spend more time there. Besides, the movement of the elephants should be monitored to warn the locals of the same so that they could avoid passing through these roads during elephant movements.
- The corridor from Silda to Lalgarh is mostly of agricultural patches and a few mosaics of small forests. This whole stretch of land is regularly used by elephants. The forest department has to identify the shortest routes for elephants to reach Malabati forest from Silda and further from Malabati to Lalgarh forest to minimize damage to agriculture because of elephant movements. The department has to procure the land from the villagers where the elephant moves regularly and develop it as a safe corridor or they should put in place a firm compensation plan for the farmers suffering because of elephants to ensure safe passage for elephants without any disturbances (local or hula drives) by the farmers or the department. Similar steps have to be taken in the case of crossovers at Chandabila and Gopiballabhpur area.

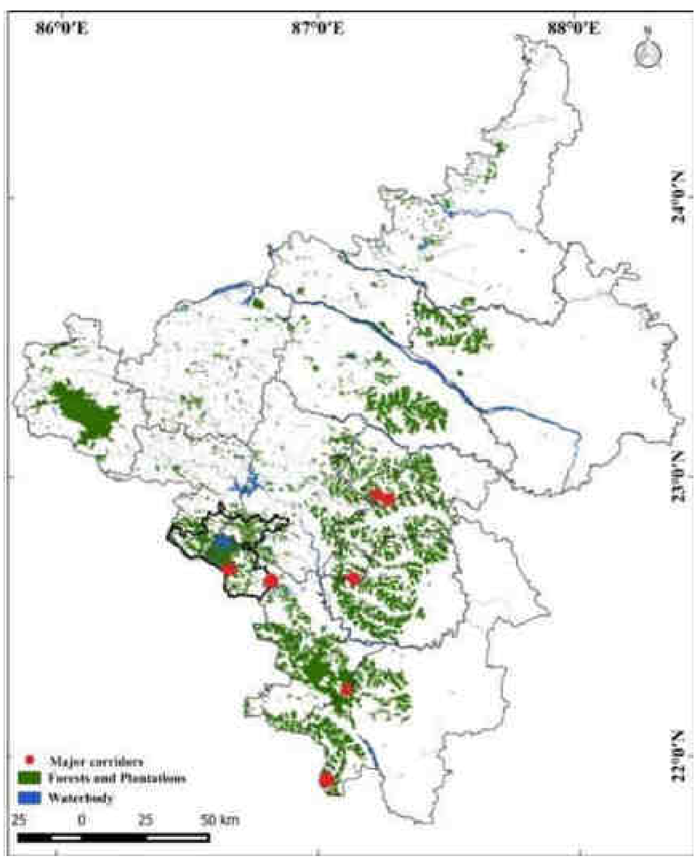

Figure 5.2 Crucial Elephant corridors and crossover in South Bengal

Plate 2 Elephant deaths on after collision with train

CHAPTER VI. OVERVIEW OF CURRENT MITIGATION MEASURES

Elephant proof trenches (EPT): EPTs have been dug in many areas (Table 6.1, Fig. 6.1) all around South Bengal as precautionary measures. However, not all trenches have been effective (Plate 4 and 5) or many have been total failures because of multiple reasons. Few among them are because of neglect in maintaining the trenches that gradually turned shallow enough for the elephants to cross over easily.

The EPTs will serve to keep elephants away from farmland (Fernando et al. 2008a). However, villages surrounding those protected by barriers often suffer an increase in conflict (Chong and Dayang Norwana 2005; Sitati and Walpole 2006; Fernando etal. 2008a) indicating that elephants were being displaced to neighboring areas. Barriers suffer a high rate of failure as people who need access to forests undermine them. When habitual elephant routes are blocked, they are also prone to failure (Sitati and Walpole 2006) as elephants as seen in Kankrajhore and Belpahari region in the Jhargram Forest division usually damage them. To be effective, all gaps including those accommodating streams and roads need to be secured (Fernando et al. 2008a). Barriers work when there is a sharp edge between forests and farmlands and are unlikely to work in a mosaic of forest fragments and fields as is seen in and around south Bengal.

Table 6.1 Elephant Proof Trenches (EPT) examined during the study

Division	Village	Length in Km	Condition of EPT
Jhargram	Amjharna	5	Working
Jhargram	Thakurthan	4	Working
Jhargram	Radheshyampur	2	Working
Jhargram	Ghatidoba	3	Working
Kharagpur	Raibera	2	Working
Kharagpur	Kamlatola	1	Working
Medinipur	Arabari	Not measured	Working
Rupnarayan	Jangal khas	2	Working
Jhargram	Belpahari	Not measured	Leveled due to non-maintenance
Kharagpur	Keshorrekha	Not measured	Leveled due to non-maintenance
Purulia	Matha	Not measured	Leveled due to non-maintenance
Medinipur	Lalgarh	Not measured	Leveled due to non-maintenance
Medinipur	Arabari	Not measured	Elephants using different routes now

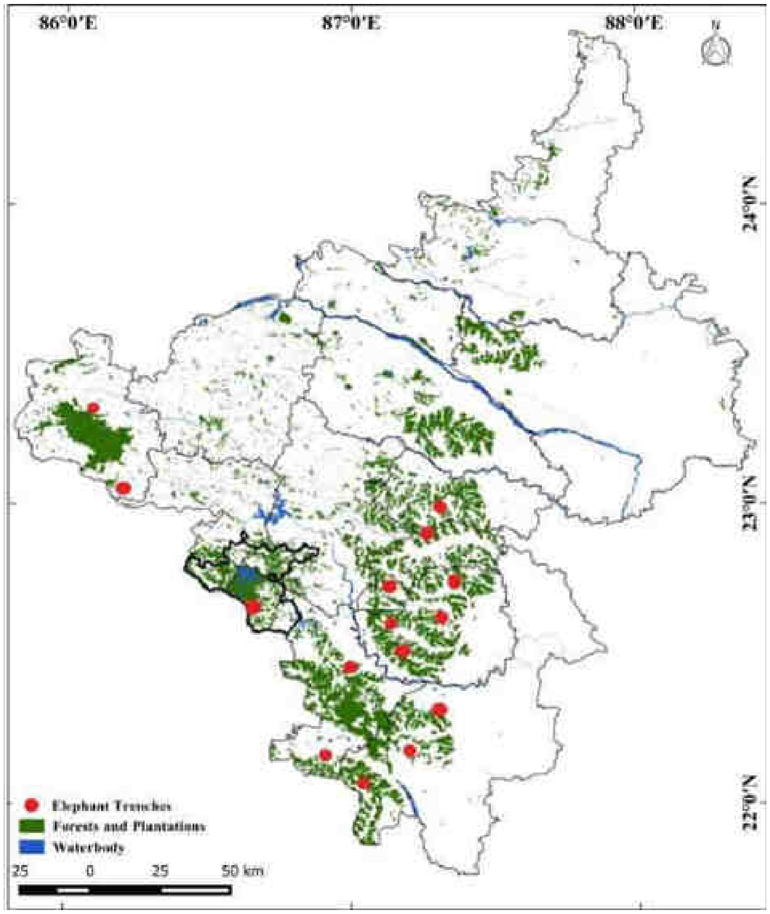

Figure 6.1 Non- maintained Elephant trenches and EPT in South Bengal

Energized fencing: Energized fences are said to be themost effective method for containing elephants within an area (Grant et al. 2008). Electric fences (Hoare 2001, Omondi et al. 2004) can protect corridors connecting elephant-use areas and specific buildings such as grain stores. In South Bengal also many energized fences (Table 6.2, Plate 3) have been erected throughout for keeping the elephants at bay. However, many instances of the locals taking away the batteries leaving the fence defunct have been reported. Further, elephants also at times breach the fences successfully by breaking the insulated poles.

Electric fences are considered as a lasting solution and hence, there is a temptation to install fences wherever there is conflict. However, the fences are expensive and require constant and high maintenance (Grant et al. 2008). There is also a high rate of failure of electric fences due to lack of maintenance. According to one of the studies conducted by Chowdhury et al. in 1998, out of 49 fences examined in West Bengal,only 12 were functional, whereas, in Karnataka and

Kerala, approximately 19 of 37 fences were functional (Nath and Sukumar 1998). Fences that were illegally tapped into mains AC power supply have killed elephants and have proved to be a major concern.

Considerations: Electric fencing is a good deterrent and has been used extensively in India as well as other countries to manage conflict. However, its effectiveness is largely dependent on the maintenance. To ensure proper functioning, the earthing of the fences should be regularly maintained using salts and all the live wires need to be cleared from vegetation and other obstructions. This requires continuous human efforts which increase the operational cost of energized fencing. The current condition of energized fencing in South Bengal needs to be improved to be more effective. It has been observed that the smaller fencing projects are both cost and functionally effective (Hoare 2001). Hence the emphasis can be given to decentralizing the management efforts.

Unless the value of the saved crops exceeds the cost of installation and maintenance of an electric fence over the years, it cannot be rated as cost-effective (Masunzu 1998). Since the majority population in the area comprises poor farmers, Sukumar 2003 has stated that the energized fencing is not a cost-effective measure. However, it can be made effective if the management cost can be dovetailed with State department schemes such as JFM, NREGS, etc. to ensure cost-effectiveness of existing energized fencing

Table 6.2 Energized fences examined in the study area

Division	**Village**	**Length in Km**	**Condition of the fences**
Medinipur	Lalgarh	-	Battery removed by villagers
Medinipur	Lalgarh	-	Fence broken by elephants
Kharagpur	Kalaikunda	-	Fence broken
Jhargram	Salboni	5.5	Working
Jhargram	Sirshi	2	Working
Jhargram	Amlachati	9	Working
Jhargram	Koima	3	Working
Jhargram	Louridam	5.5	Working
Kharagpur	Kalusar	3	Working
Medinipur	Arabari	-	Working

Hula drive:

During the crop-raiding season, every division of the Forest Departments has a squad (Plate 5 and 6) to respond to any elephant movement and help villagers in chasing away the animals from the crop fields. Such operations regularly take place at night (almost every night during peak raiding season), and are an instant response to complaints from the people. The members of the squad use powerful spotlights, sirens, crackers, *Hula* to chase the wild elephants from the area. The squads and the drive provide only temporary relief since elephants come back and therefore this cannot be considered part of any sound conflict mitigation policy (Nath and Sukumar 1998, Osborn and Parker 2002). While the short-distance displacement of elephants provides initial relief, if the same elephants are regularly chased and not prevented from returning, they become habituated to this practice (Hoare 2001, Nelson et al. 2003).

- In the case of hula driving in this area, the elephants are being driven regularly. Such intensive driving forces the elephants to move continuously without much rest and food. Consequently, they become tired and deprived of food. That increases their food intake when they get the opportunity to eat; prompting them to take more risk and becomes agitated while depredating upon the cropland. This risk-taking attitude leads to increased interactions with humans and might increase the conflict rate.

Use of automated trip bell method:

The use of automated tripping bell was started in the Patrasayer Range of Bankura to alarm the people about the whereabouts of the elephant near their village and houses. However, finding the method not effective in the area, it was not adopted as a permanent method to mitigate the issue.

- Setting up of the alarm wires should be around 100 m away from the villages so that when the alarm is triggered by the elephants it could be heard by maximum households and people would be aware of elephants nearby. Setting it up near the boundary of the house (as practiced in the range) will not give desired results as people would get information about elephants only after the animals have reached nearer their houses.

- People's participation is very necessary when it comes to introducing any new form of mitigation measure. The villagers need to feel the responsibility for the steps taken for their safety and wellbeing and such measures can only work with the acceptance and cooperation from the villagers.
- Proper routine maintenance of the bell system is very necessary as any fault in the wiring system could make the entire system fail.

a)

b)

Plate 3 a) Worki… eam inspecting a non-maintained elephant proof trench in Jhargram Division

a)

b)

Plate 4. a) Working energized fence in Medinipur forest division; b) A non-maintained energized fence in Medinipur forest division

a)

b)

Plate 5. a) Hula driving in Rupnarayan forest division; b) Hula driving in Panchet forest division

a)

b)

Plate 6 a) Local driving in Panchet forest division; b) Hula driving in Rupnarayan forest division

CHAPTER VII. MANAGEMENT OF MAYURJHARNA ELEPHANT RESERVE

Due to various reasons, elephants from Dalma Wildlife Sanctuary in Jharkhand started moving towards Mayurjharna Elephant Reserve (ER) in the 1950s. Currently, small herds or lone individuals spend some time in the Mayurjharna; but they use Mayurjharna as a corridor to pass through to reach West Medinipur. Thus, the estimate of elephant density was 0.0029 elephants/ km^2 only, very apparent since the elephants are not spending much time in the Mayurjharna and they use the area largely as a corridor.

In the ER, the mean tree density was 2163.03 trees $ha^{-1,}$ and the mean basal area 21.28 $m^2\ ha^{-1}$. The forest is dominated by a single tree species *Shorea robusta* (11.78 individuals ha^{-1}, 64% of the tree density) which is non-palatable for elephants. The fodder species like *Madhuca longifolia* (1.79 individuals ha^{-2}) *Buchananiacochinchinensis* (1.37 individuals ha^{-1}) and *Diospyros melanoxylon* (1.31 individuals ha^{-1}) are present but in low density. Most of the people in Mayurjharna ER are farmers, with small landholdings raising only one crop of paddy per year.

Management requirements:

- Habitat improvement: Bringing certain changes in the habitat of Mayurjharna ER might help to reduce the rate of elephant movement out of the reserve. Restoration of degraded habitat planting more fodder tree species might help in improving the habitat. Further, the replacement of species like *Shorea robusta* and *Eucalyptus tereticornis* with fodder species like *Lannea grandis, Aegle marmelos, Madhuca longifoila, Pterocarpus marsupium,* and *Buchanania cochinchinensis* will help in enriching the forests in terms of food availability for elephants. The presence of an adequate amount of palatable fodder in the forests might make the elephants spend longer within these forests. Thus, eventually, interactions and conflicts in the landscape could be reduced. Plantation of more fruiting trees along with other traditional food plants of elephants would also lure them and confine them in the reserve relatively longer.
- Estimation of elephants: Intensive belt-transect technique for dung count may provide relatively robust estimates than line transects walks for direct detection of elephants in the ER.

- Degradation of Mayurjharna ER due to silkworm or grass cultivation is important to be noted and curtailed.
- The existing agriculture fields along the path that has been used by elephants need to be protected to gain the confidence of the local people of Mayurjharna.
- Interstate collaboration should be made with Jharkhand State for enriching the forests of Dalma Wildlife Sanctuary so that the duration of the animals' stay in Jharkhand could increase, reducing the pressure on certain forest patches in West Bengal to an extent.
- Arrangement of alternative sources of income for the people inside the reserve has to be made so that the pressure from cultivating silkworm and babui grass could be reduced and habitat be restored.
- Apart from scientific components, many other chapters related to official land holdings, mapping of all aspects of the entire reserve, conventional management issues with the budget, etc. might be developed in close consultation and assistance of the concerned officers of the divisions and circle.

Plate 7.Women collecting Babui grass in Mayurjharna ER

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