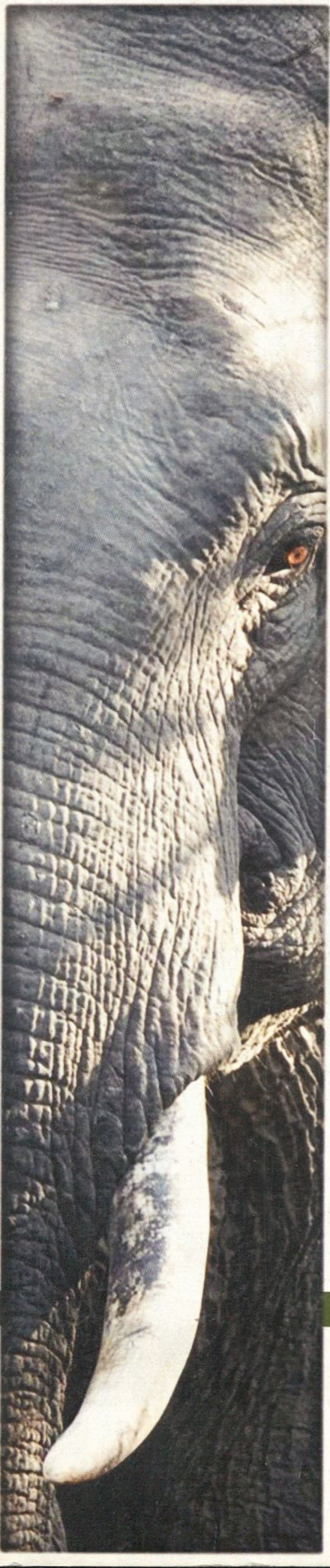
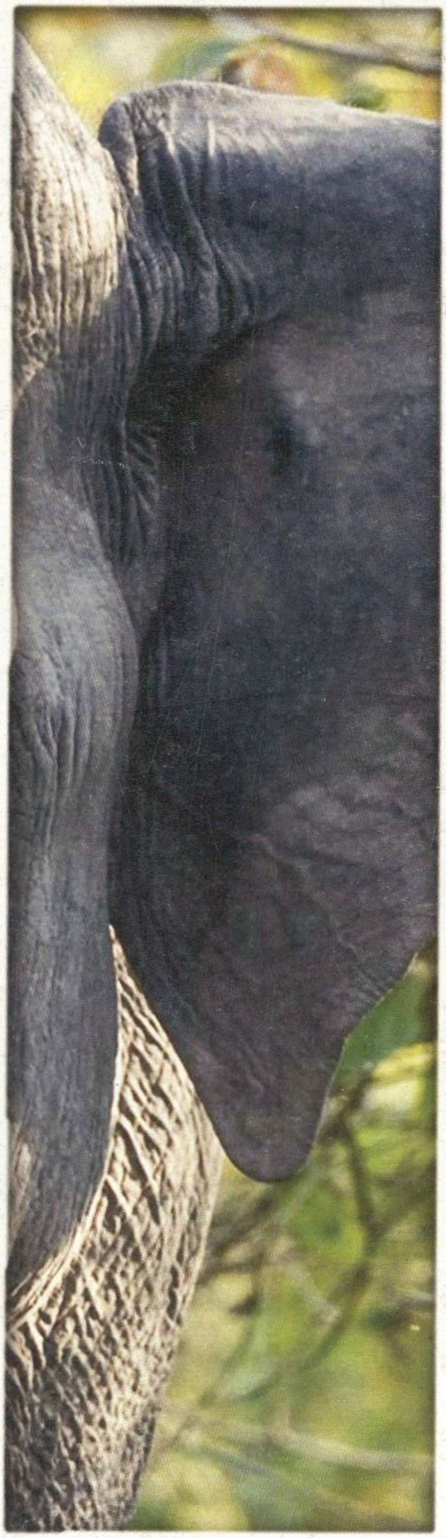
CONSERVATION & MANAGEMENT OF ELEPHANTS IN CHHATTISGARH





भारतीय वन्यजीव संस्थान
Wildlife Institute of India

FINAL REPORT 2017-22

CAPACITY BUILDING INITIATIVE ON THE DISPERSAL AND RANGING PATTERNS OF ELEPHANTS FOR EFFECTIVE MANAGEMENT OF HUMAN- ELEPHANTS INTERACTIONS

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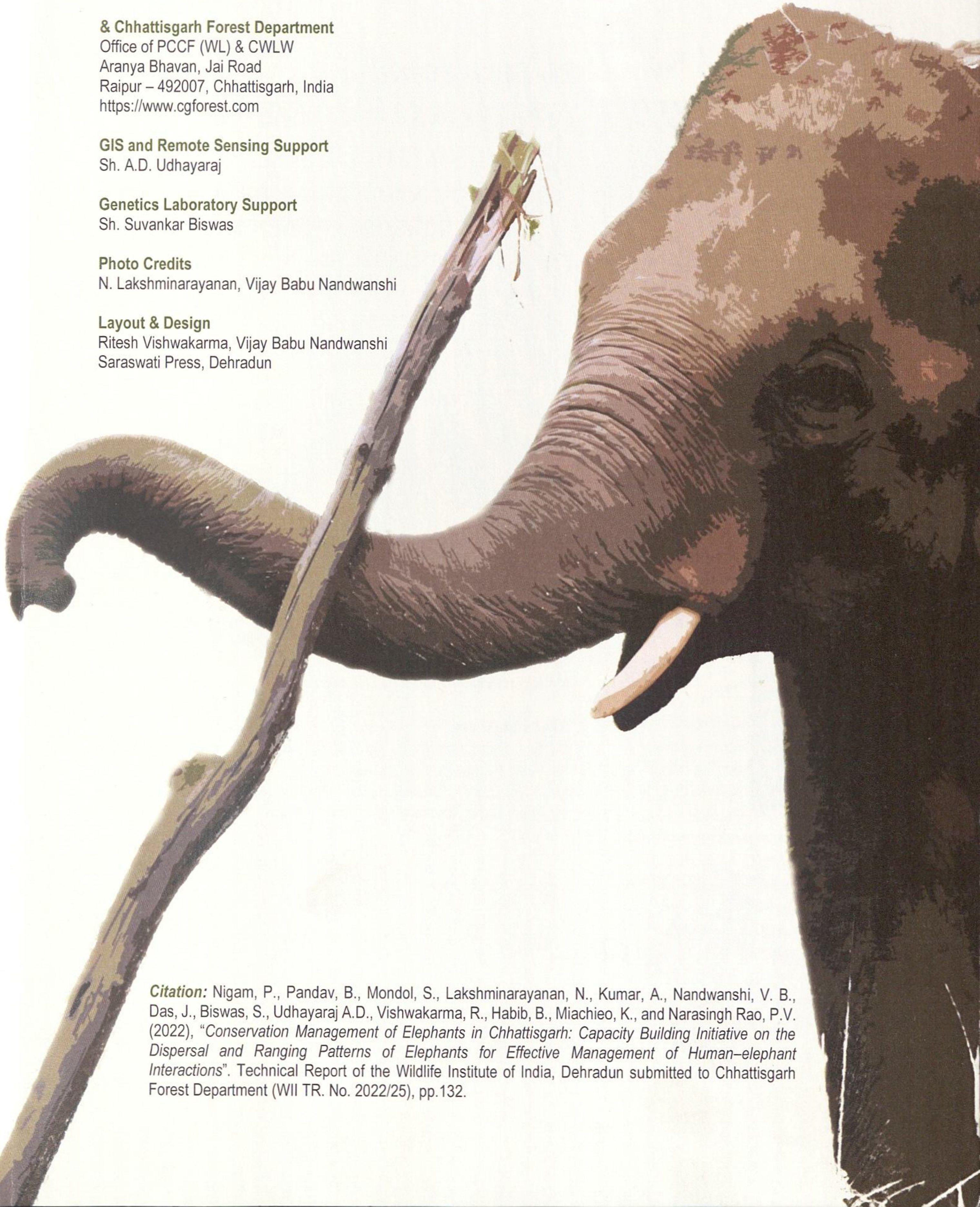

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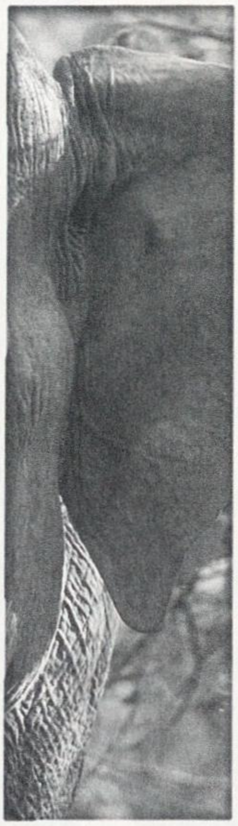

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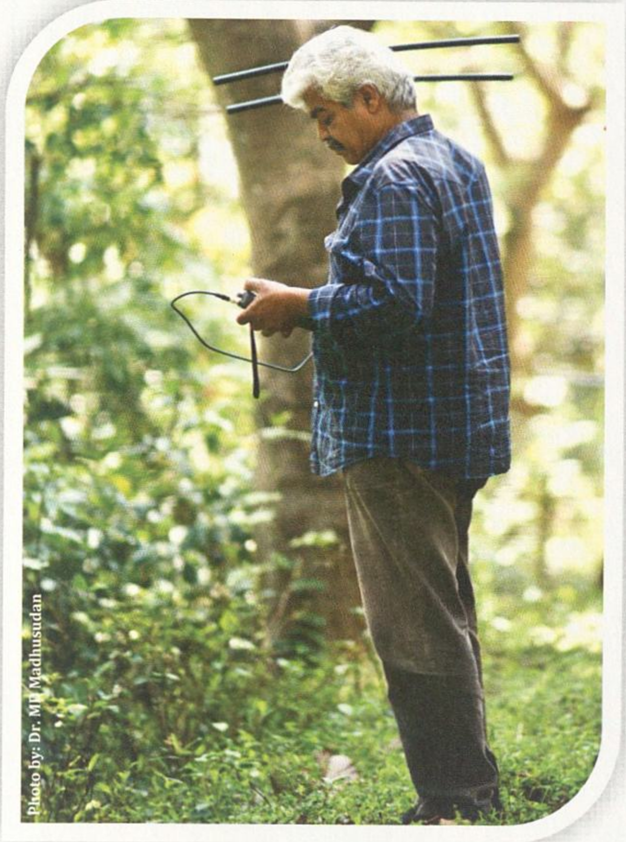
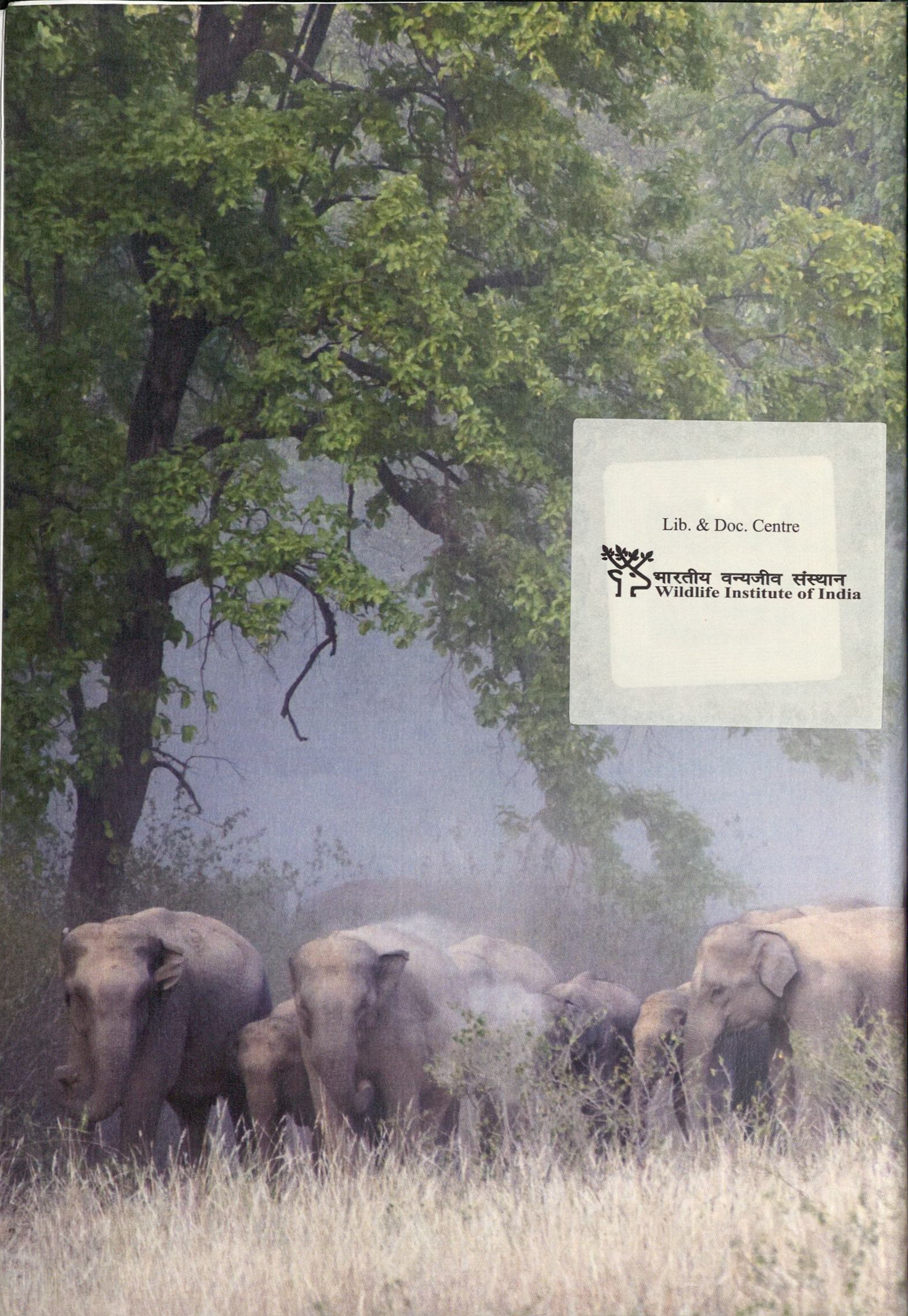


Dedicated to

Late Dr. Ajay Desai

(24th July 1957 – 20th November 2020)

"Dr. Ajay Desai was a distinguished field biologist who studied various wildlife species and was particularly reputed for his deep understanding of Asian elephants. He specialized and generated extensive first-hand knowledge on the social behaviour and ranging patterns of Asian elephants. Dr. Desai assessed human-elephant conflict across Asian elephant range countries and provided mitigatory measures to minimize conflict through his pragmatic and practical approach to the problem. He was as considerate towards the welfare of local communities as he was towards elephant conservation. He meticulously trained several forest officials, biologists and research personnel nationally and internationally during his long and distinguished career. His contributions to State Forest Departments, Project Elephant Division of the Ministry of Environment, Forest & Climate Change, Govt. of India and numerous other Government and non-Governmental organizations are immense. He was a co-chair of IUCN's Asian Elephant Specialist Group. He was very actively involved in WII's research project in Chhattisgarh and fine-tuned the project objectives and scope from its inception till his sad demise in November 2020. His premature demise has left a void in the conservation community of the nation particularly those working on issues related to elephants."



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EXECUTIVE SUMMARY

Wild Asian elephant (*Elephas maximus*) populations are distributed in four major regions namely North-West, North-East, East-Central and Southern regional meta-populations across India. Amongst them, the East-central regional population spread across the States of Odisha, Jharkhand, southern West Bengal, Chhattisgarh, and lately in Madhya Pradesh suffers disproportionately high levels of human–elephant conflict. Among the myriad challenges facing management of human–elephant conflict in the region, elephant range expansion into new areas is overriding. One such range expansion that resulted in acute human–elephant conflict is being witnessed in the State of Chhattisgarh. Although northern Chhattisgarh was historically an elephant range, elephants reportedly disappeared during the period 1920 to late 1980s. While episodes of sporadic elephant occurrence in Chhattisgarh was reported during the period 1988–1993, contemporary range expansion and concomitant human–elephant conflict began from the year 2000, and has accelerated during the last one decade.

Faced with an enormous challenge of managing human–elephant conflict that is spatiotemporally dynamic unlike that of other elephant range States, constrained by limited Institutional capacities to assess and deal with the issue. Chhattisgarh Forest Department has been trying diversity its conflict mitigation strategies. Recognizing the need to objectively evaluate human–elephant conflict situation in the State, during the year 2017 Chhattisgarh Forest Department invited Wildlife Institute of India to conduct ecological research on elephants in Chhattisgarh with a three-year budget outlay.

The project was a collaborative effort between Chhattisgarh Forest Department and WII. Considering the scope of the project, the project duration was further extended and eventually, the project lasted for the period July 2017 to March 2022. Being the final project report, the activities carried out as part of the project is summarized as under.

Distribution and Demography

In Chhattisgarh, the elephant distribution during the period 2012 to 2017 was reported from 16 Forest Divisions and four Protected Areas in the north and north-central regions of the state. The elephant population, as enumerated by Chhattisgarh Forest Department during 2021, ranged from 250 to 300. The adult sex ratio recorded during the study was 1: 4.5. About 44% of the female segment of the population comprised of adults. Chhattisgarh elephant population is presently contiguous with other elephant populations in the neighboring states i.e., Madhya Pradesh, Jharkhand and in Odisha occurring as a meta-population[1] and thus cannot be considered as an isolated population. However, within Chhattisgarh, the population is relatively small and it occurs scattered over a large area as small and disjunctive groups facing a perpetual risk of getting isolated by ongoing linear infrastructure and other associated developmental activities in the State. If such groups get isolated, then they will not be viable in the long run.

---

[1] Meta-population: Population of small populations that are connected through dispersals

Home Range, Movement Patterns & Dispersal, and Habitat Selection by Elephants

During the period 2018-2022, WII-CGFD collaborative effort resulted in 10 elephant radio collaring in Chhattisgarh. The resultant effort provided 3106 elephant days of tracking information. Each of the radio-collared elephants provided an average of 310.6 (± 273) days of tracking data. As on 31st March 2022 when WII-CGFD collaborative project ended, two of the collared elephants (BD - Behradev and MT - Maitri) were having functional collars. The estimated average home range (95% minimum convex polygon) of elephants in Chhattisgarh was 3172.8 km^2 (± 2002.2 km^2, Range: 462.3 – 6969.7 km^2). The 95% kernel density home ranges of elephants were much lower averaging 512.3 km^2 (± 235.3 km^2, Range: 126.5 – 748.9 km^2). The elephant home ranges were not wholly well defined, and marked by inter-annual shifts caused by exploratory behaviour. The elephant home ranges were relatively large. The dry season home ranges were significantly lower than monsoon and winter ranges. However, dry season home ranges of elephants are larger. The present study indicates that habitat quality in some of the forest patches – particularly those that are large and contiguous with minimal of human interference can potentially support elephants in the landscape. Thus, dry season ranges of elephants could serve as a surrogate for habitat quality. Monthly variations in home ranges were significant, and best explained by idiosyncrasies of individual elephants. Among the forest types open, moderately dense and very dense forests classified by Forest Survey of India based on crown densities, elephants selected open forests, that were predominantly juxtaposed with human–use areas. Although the crown density was low, the patches of open forests support dense stands of Sal (*Shorea robusta*) coppice with rank undergrowth offering adequate cover for elephants. Elephant habitat selection of these open forest patches appears to be influenced by potential foraging opportunities in human–use areas, and further facilitated by low inter-patch distance.

Genetic Structure of Elephants

Using 258 genetic samples collected from 9 Forest Divisions, elephant genetic structure in northern Chhattisgarh was evaluated. Analysis indicates that at least two different elephant lineages occur in Chhattisgarh. This implies that elephants occurring in Chhattisgarh have possibly come from different areas. Within the two different lineages, high relatedness amongst the individuals was observed corroborating with the general social structure of Asian elephant clans where individuals are mostly related.

Crop Losses and Human Fatalities due to Elephants

Crop losses caused by elephants were acute and widespread in Chhattisgarh. To draw an analogy, Karnataka's *ex gratia* payment towards crop losses by elephants during the period 2015-2020 was comparable with Chhattisgarh, although the former's elephant population is 93% more than the latter. The landscape-level assessment covering the whole of northern Chhattisgarh, and fine-scale assessment covering select areas in Surguja circle identified correlates of crop losses at both spatial scales. Elephant-related human deaths were widespread in the state. However, nearly 70% of incidences occurred in areas of high intensity of habitat-use by elephants. The human fatalities due to elephants were both temporally and spatially auto-correlated.

Capacity Building Initiatives

During the period July 2017 to March 2022, a total of 17 training programs were conducted in which **569** forest staff, mahouts and other officials participated. During the same period, two senior veterinarians were intensively trained in nuances of managing human–elephant conflict aspects for over 32 days. The training for veterinarians was provided both in the country and outside, in South Africa. Furthermore, a total of 15 training programs were conducted to sensitize village stakeholders and other civil society members with over **220** participants. While these capacity building programs were directly carried out under the project, WII had also been providing training to forest officials on various aspects of wildlife and human–elephant conflict management across India in which many officials from Chhattisgarh Forest Department were particularly invited and trained.

Conclusion

In a nutshell, "Chhattisgarh elephant problem" is typified by distribution of only a few hundred elephants over a very large mosaic landscape characterized by high interspersion of forests and human–use areas of agricultural fields and rural settlements. The challenges facing management of human-elephant conflict in Chhattisgarh are further compounded by undefined elephant home ranges caused by exploratory behaviour of elephants resulting in spread of human–elephant interactions that result in conflict. The conflict-related losses are increasing for both elephants and people with potentially negative long-term consequences for elephant conservation. While local conflict mitigation options to address the proximate causes of human–elephant conflict are manifold, and includes judicious land-use planning and identification of elephant conservation zones; Chhattisgarh human–elephant conflict situation is a wake-up call to devise and zealously implement landscape-level policies. These need to be intended towards stemming habitat losses in the remnant intact elephant ranges in the whole of East-central region with an overarching aim of minimizing environmental dispersals of elephants. Specific management recommendations to mitigate conflict have been provided in each of the technical Chapters and condensed in the final Chapter. The primary task vested with Chhattisgarh Forest Department in managing human–elephant conflict in Chhattisgarh is to contain elephant range expansion into new areas. Efforts should be targeted towards restricting the elephant population to the current distributional range and limit or minimize further expansion

CHAPTER-1
INTRODUCTION

Asian elephants are endangered species, occurring only in a small fraction of their vast historic ranges. Wild elephants occur in 13 range countries across Asia, with India holding more than 60% of the total population. Across India, elephants occur in four distinct regions namely North-West, North-East, East-Central and Southern regional meta-populations. Among the four populations, the East-Central region supports the smallest elephant population, which is enumerated to be around 3000 (Project Elephant, Government of India, 2017). However, the region suffers highest per-capita human–elephant conflict compared to other elephant bearing regions. Notably, since late 1980s, the elephants' distributional range in East-Central region has been witnessing redistribution, marked by expansion of elephant ranges into new areas where they did not occur for many decades. Such range expansions have been reported from many different areas throughout East-Central region. One such major range expansion of elephants has been occurring in the state of Chhattisgarh, where elephants immigrate from the neighboring Jharkhand and Odisha. The phenomenon of elephant immigration in northern Chhattisgarh began during 1988 after being reportedly absent in the state for over seven decades. Historically, northern Chhattisgarh was part of elephant range with numerous authentic records reporting elephant occurrence till 1920s. However, during the period from 1920 to 1988, elephants were reportedly absent in the landscape. Contemporary elephant immigration in northern Chhattisgarh intensified after the year 2000, when the State was carved out of Madhya Pradesh.

The elephant immigration and corresponding range expansion observed since the year 2000, has been resulting in intensive human–elephant conflict in the state. The intensity of conflict has been steadily on the rise during the last two decades, and has risen particularly steep during the last 10 years. Presently, over 60 human lives are being lost annually. The human–elephant conflict situation in Chhattisgarh calls for an urgent and holistic assessment of the patterns and underlying associated factors to develop site-specific management prescriptions, as appropriate. In response to the situation, Chhattisgarh Forest Department (CGFD) and Wildlife Institute of India (WII) embarked a long-term study of elephant population in Chhattisgarh during the year 2017. Initially, the project was envisaged for a three-year period. However, the duration was extended as per the joint need of CGFD and WII, and the project continued from July 2017 to March 2022. The objectives envisaged in the project as spelt-out in the proposal include:

(1) Assessment of elephant home ranges, dispersal and movement patterns
(2) Assessment of elephant habitat selection
(3) Assessment of patterns of human–elephant conflict
(4) Development of early-warning systems
(5) Assessing the efficacy of conflict mitigation methods of CGFD, and
(6) Capacity enhancement of staff and stakeholders.

During the period July 2017 to March 2022, the aforementioned project objectives were fulfilled and additionally, other objectives deemed important were included during the course of the project and completed. During the project period, a total of 20 interim and periodic reports were submitted by WII to CGFD including the two annual reports for 2017-2018 and 2018-2019, and one combined annual report for 2019-2021 (Annexure-1). The present one is the final project report, which condenses findings/results of all the objectives of the study and organized as 12 different Chapters. Chapters-1 & 2 elaborate on the context of the study and provide the detailed description of the study area in northern Chhattisgarh. Chapter-3 elaborates on the distribution and demographic parameters of elephants in northern Chhattisgarh. In Chapter-4, the home range, elephant movement patterns and dispersal as estimated and recorded during the study were elaborated. In Chapter-5, the habitat selection patterns by elephants along with seasonal habitat-use of different landscape elements were elaborated. In Chapter-6, population structure of elephant groups occurring in Chhattisgarh was elaborated. Chapters-7 & 8 detail the patterns and correlates of human–elephant conflict in the form of crop losses caused by elephants and human fatalities resulting from conflict. In Chapter-9, various conflict mitigation initiatives of CGFD were evaluated and recommendations as appropriate were provided. In Chapter-10, various capacity building initiatives of WII in Chhattisgarh were summarized. Chapter-11 provides a comprehensive synthesis of the technical Chapters and also enlists site-specific challenges facing management of elephant populations and human–elephant conflict in Chhattisgarh. Based on the overall findings of the study, recommendations on managing elephant populations and pragmatic approaches to manage human–elephant conflict in Chhattisgarh have been provided in Chapter-12.

CHAPTER-2
LANDSCAPE & THE STUDY AREA

2.1 The Location

The study was carried out in the north and north-central Chhattisgarh covering the districts of Raigarh, Korba, Jashpur, Balrampur, Koriya, Surajpur and Surguja administered under nine forest divisions in two forest circles of Surguja and Bilaspur (Figure 2.1). The focus of intensive study was Surajpur, Balrampur and Surguja Forest Divisions while the Forest Divisions in Bilaspur Forest circle acted as a peripheral study area. Forest cover with seasonal and sporadic elephant occupancy in north and north-central Chhattisgarh was around 17,500 km^2. The forest cover is patchy, and interspersed with agricultural and human settlements. The landscape is part of Indian Peninsula comprising of rugged hills, flat hilltops and forested plains collectively known as the "Central Highlands" (Forsyth, 1871, Rodgers & Panwar, 1988; Jayapal *et al.,* 2009). There are many eco-climatic sub-regions within the Central Highlands in which our study area mostly fell under the Satpura–Maikal–Maikal extension sub-region and southern extension of the Chota-Nagpur plateau. Over 50% of the north and north-central Chhattisgarh is forested. The altitude in the study area ranges from 400 to 1100 m a.s.l. Characteristic of the region is the flat hilltops locally known as "pats" (Mani, 1974).

2.2 Geological Formation

The geology of the northern Chhattisgarh is primarily Archean, and comprises of elements of middle Gondwana (Mani, 1974; Champion and Seth, 1968). The foundational rocks in northern Chhattisgarh is prominently of Gondwana, which Champion & Seth, 1968 defined as freshwater sediments of plant fossils with coal deposits that are over 100 to 200 million years old. In the north-central Chhattisgarh (Bilaspur area), the foundational rocks are even older – that of Pre-cambrian with ancient crystalline rocks that are over 500 million years old (Champion & Seth, 1968). The dominant soil type is the 'red and yellow' from the main Gondwana rock system, covering over 60 to 65% of northern and central zones of the state. The red soil is typically coarse, relatively poor in organic matter and nutrients, but rich in ferric concentrations. The red soil tends to favors moist and dry deciduous forests dominated by Sal (*Shorea robusta*) (Champion & Seth, 1968). The red-yellow soils, alluvial soils occur along the riverine tracts, and laterite soil exists in the hilltops. Further to this, the red and yellow soil favors paddy cultivation (*Oryza sativa*).

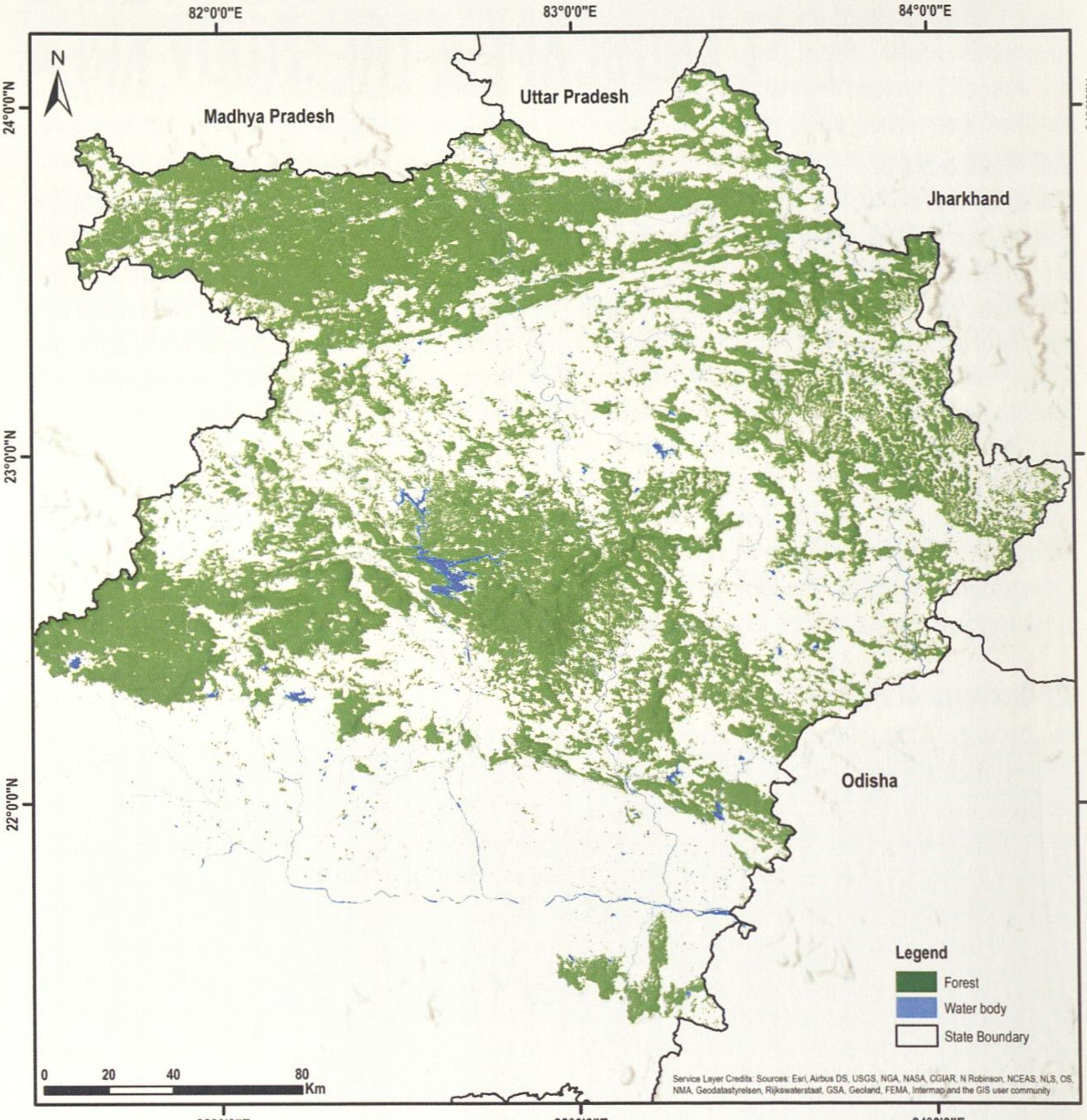


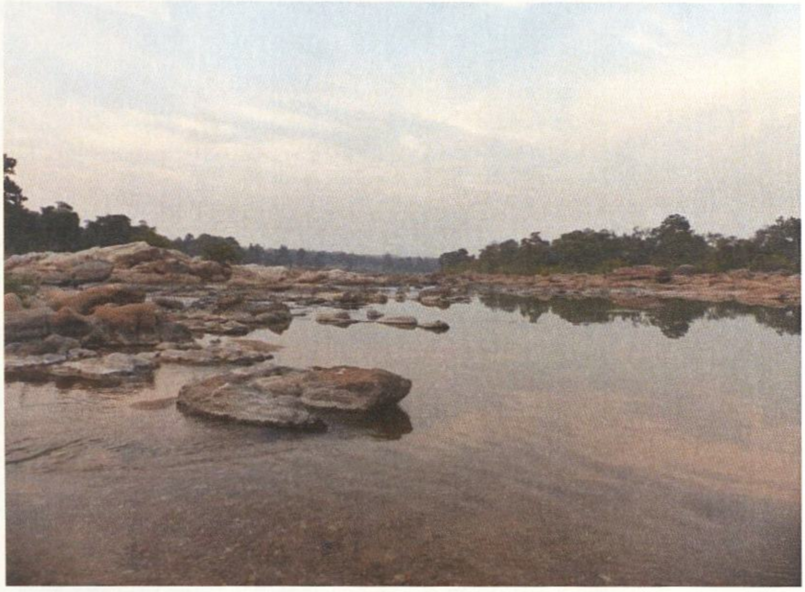
Figure 2.1: Forest cover map of Northern Chhattisgarh. (Based on FSI, 2019)

2.3 Climate, Temperature and Precipitation

The climate in northern Chhattisgarh is sub-tropical with three well-defined seasons namely dry (March to June), monsoon (July to September) and winter (October to February). The annual temperatures range from 1° C (minimum) to 45° C (maximum). Southwest monsoon accounts for more than 90% of the region's annual rainfall. The average annual rainfall is around 1200 to 1600 mm, which is usually spread-out for well over 100 days (Indian Meteorological Department, 2020).

2.4 Hydrology and Watershed

The study area is the watershed for two major river systems namely the Sone (part of Gangetic river system) and the Mahanadi (Figure 2.2). River Sone originates in the Maikal ranges near Amarkantak at 1000-m altitude overlooking the Chhattisgarh plains (including the Achanakmar Tiger Reserve in Mungeli District) towards the east. The origin of River Sone is less than a kilometer away from the source of another major peninsular Indian River, the Narmada that flows in the westward direction to meet the Arabian Sea. River Sone generally flows in the northward direction emptying into River Ganga near Patna in Bihar. Some of the major tributaries of River Sone that originate from elephant-range areas in Surguja include Mahaan, Rihand, and Kanhar. The second major river catchment in north and north-central India is that of River Mahanadi. Its upper course is in the Damtari district of south Chhattisgarh. However, tributaries originating from elephant range areas of northern Chhattisgarh feed the middle course of the river. The major tributaries include Hasdeo, Maand, and Eib that have their major catchments in both Surguja and Bilaspur circles. In addition to these rivers, there are many other relatively smaller rivers – many of them perennial with at least trickle of flow even during peak dry months eventually feeding into Sone, Mahanadi or their major tributaries. Most of the rivers in northern Chhattisgarh are shallow, and unbraided. In addition to river systems, there are numerous ponds and lakes in the villages, which are extensively used by villagers for irrigation, water-requirements of livestock and other domestic purposes. These ponds are usually created by impounding seasonal streams flowing from forest patches. Due to their multipurpose utility, villagers maintain the village ponds well. Elephants occurring in human-use areas also occasionally use these village ponds.



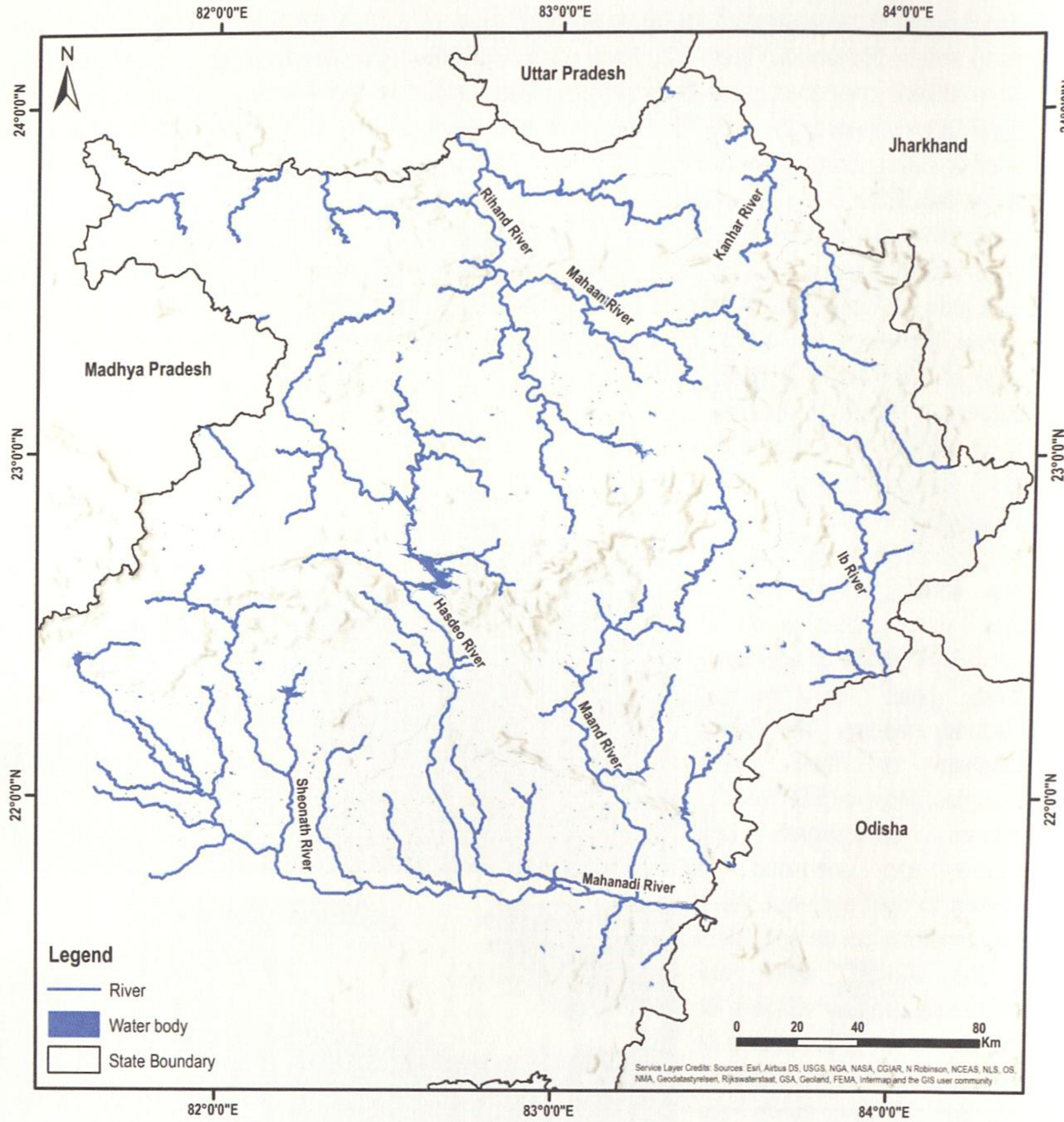


Figure 2.2: Watershed map of Northern Chhattisgarh showing major rivers

2.5 Forest Classification

The forests in Chhattisgarh can be classified in to two broad types namely tropical moist deciduous (in the relatively rainier tracts) and tropical dry deciduous (Krishen, 2013). These have been further divided into 12 Forest types (FSI, 2017) (Figure 2.3). The forest types and corresponding floristics as described by Champion & Seth (1968) is reproduced below*.

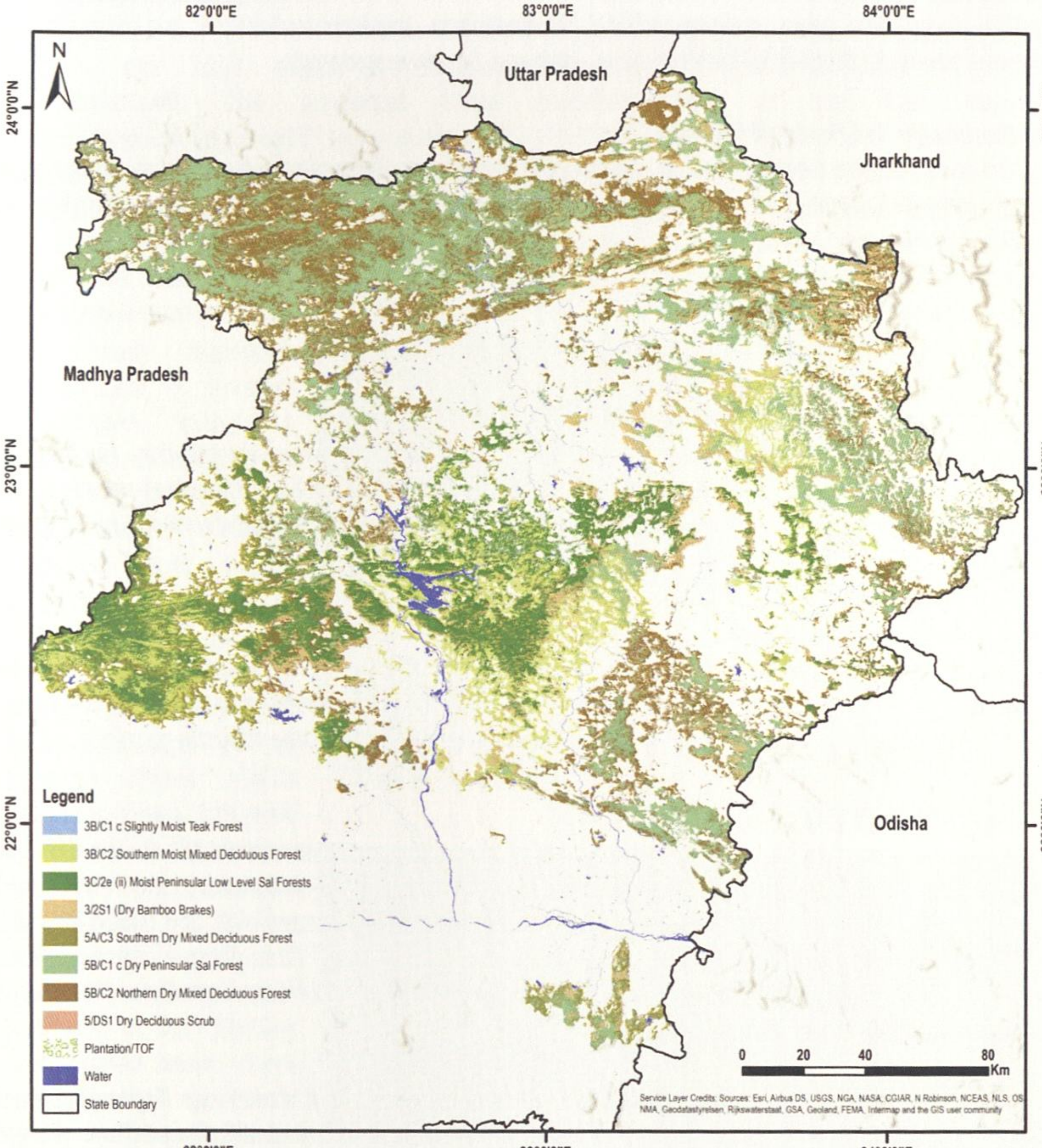


Figure 2.3: Forest types in Northern Chhattisgarh classified based on Champion and Seth, 1968

Moist Peninsular Low-Level Sal Forest [3C/2E (II)]

The floristic composition include *Shorea robusta, Terminalia tomentosa, Anogeissus latifolia, Syzygium cumini, Bauhinia spp., Pterocarpus marsupium, Madhuca latifolia, Largerstroemia parviflora, Phyllanthus emblica, Bridelia retusa, Terminalia chebula, Diospyros tomentosa, Buchanania lanzan, Casearia graveolens, Wendlandia exserta, Zyzyphus zyloprus, Butea monosperma, Randia spp,* and *Aegle marmelos in the* I[st] & II[nd] Storey.

The *Phoenix spp.*, *Grewia hirsuta, Helicteres isora, Desmodium pulchellum*, and *Woodfordia floribunda* the III[rd] storey. The grass species include *Themada spp, Imperata cylindrical, and Heteropogon contortus* whereas climbers include *Bauhinia vahlii* and *Smilax macrophylla*.

Dry Peninsular Sal Forest [5B/C1c]

The floristics include *Shorea robusta, Terminalia tomentosa, Pterocarpus marsupium, Anogeissus latifolia, Boswellia serrata, Buchanania lanzan, Diospyros melanoxylon, Terminalia chebula, Phyllanthus emblica, Bauhinia spp, Cleistanthus collinus,* and *Bridelia retusa* in the first and second storeys.

In the third storey, plants include *Woodfordia fruticosa, Indogofera spp, Ixora arborea*, and *Pheonix acaulis*. Grasses include *Themeda spp*, and *Cynadon dactylon*. Climbers of *Bauhinia vahlii* and *Smilax spp* are fairly common in areas with minimal human disturbance.

Northern Dry Mixed Deciduous Forests [5B/C2]

Floristics includes *Terminalia tomentosa, Anogeissus latifolia, Diospyros melanoxylon, Buchanania lanzan, Terminalia chebula, Cleistanthus collinus, Madhuca latifolia, Boswellia serrata,* and *Largerstroemia parviflora* in the top storey. The II and IIIrd storey includes *Phyllanthus emblica, Zizyphus xylopyrus, Phoenix acaulis* and *Woodfordia fruticose*.

Sal-coppice dominated forests

In addition to aforementioned natural forests, there are numerous forest patches that have been extensively modified by people through biomass extraction, livestock grazing and recurrent forest fires. These forest patches are dominated by dense strands of young Sal (*Shorea robusta*) coppices.

2.6 Faunal Diversity

North and north-central Chhattisgarh harbors most of the peninsular Indian mammals, albeit in very low densities. In addition to elephants, the large mammals that occur in the study area include the leopard (*Panthera pardus*), Indian wolf (*Canis lupus*), golden jackal (*Canis aureus*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus muntjac*), four-horned antelope (*Tetracerus quadricornis*) and wild pig (*Sus scrofa*).

During the course of fieldwork, we have seen all these animals except that of wild dogs. Tigers (*Panthera tigris*) sporadically occur in the two protected areas of Guru Ghasidas National Park and Tamor-Pingla Wildlife Sanctuary and rarely from other areas as well.

In addition to large mammals, many species of lesser mammals like small Indian civet (*Viverricula indica*), Asian palm civet (*Paradoxurus hermaphrodites*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), oriental honey badger (*Mellivora capensis*), smooth-coated otter (*Lutrogale perspicillata*), black-naped hare (*Lepus nigricollis*), Indian crested porcupine (*Hystrix indica*) and giant squirrel (*Ratufa indica*) occur in northern Chhattisgarh. Although occurrence of Chinkara or the Indian gazelle (*Gazella bennettii*) and leopard cat (*Prionailurus bengalensis*) was reported in Surguja.

2.7 Village Communities

In Surguja and Surajpur districts, the population density is 150 persons per km2 with a sex ratio of 978 females per 1000 males (https://censusindia.gov.in/2011census/dchb/2202_PART_B_DCHB _SURGUJA.pdf). The scheduled tribes constitute 55% of the total population (https://censusindia.gov.in/2011census/dchb/2202_PART_B_DCHB_SURGUJA.pdf). The main tribes include Kunwar, Baiga, Gond, Agaria, Binjwar, Manjwar, Rajwar, Teli, Nai, Panika, Dand-Korwa, Pando, Kudako, Pahari Korwa, Oraon, and others (Areendran *et al.,* 2011 & Present Study). Literacy rates in the district are around 60% (Directorate of Census Operations 2011). Tribal and forest dependent communities in northern Chhattisgarh collect a variety of non-timber forest products including timber, food plants, fodder, medicinal plants, honey, and others. The population density in the districts of northern Chhattisgarh is about 150 persons per sq.km (average of all districts). Paddy (*Oryza sativa*) is widely cultivated (<70% of all the cereals cultivated in northern Chhattisgarh) during monsoon while sugarcane (*Saccharum officinarum*) is cultivated in the relatively well-irrigated tracts. There are many local varieties of paddy that are relished for their aroma including the famous varieties of *Jeera phool* and *Vishnubhog*. In addition to paddy, wheat (*Triticum aestivum*) and local varieties of maize, millets, pulses, and vegetables are widely cultivated.

2.8 Forest Administration

The districts with elephant occupancy in northern Chhattisgarh are managed under two forest circles namely Surguja and Bilaspur (Figure 2.4). Although elephants do occur outside of these two circles too, our study was carried out only in the two aforementioned forest circles.

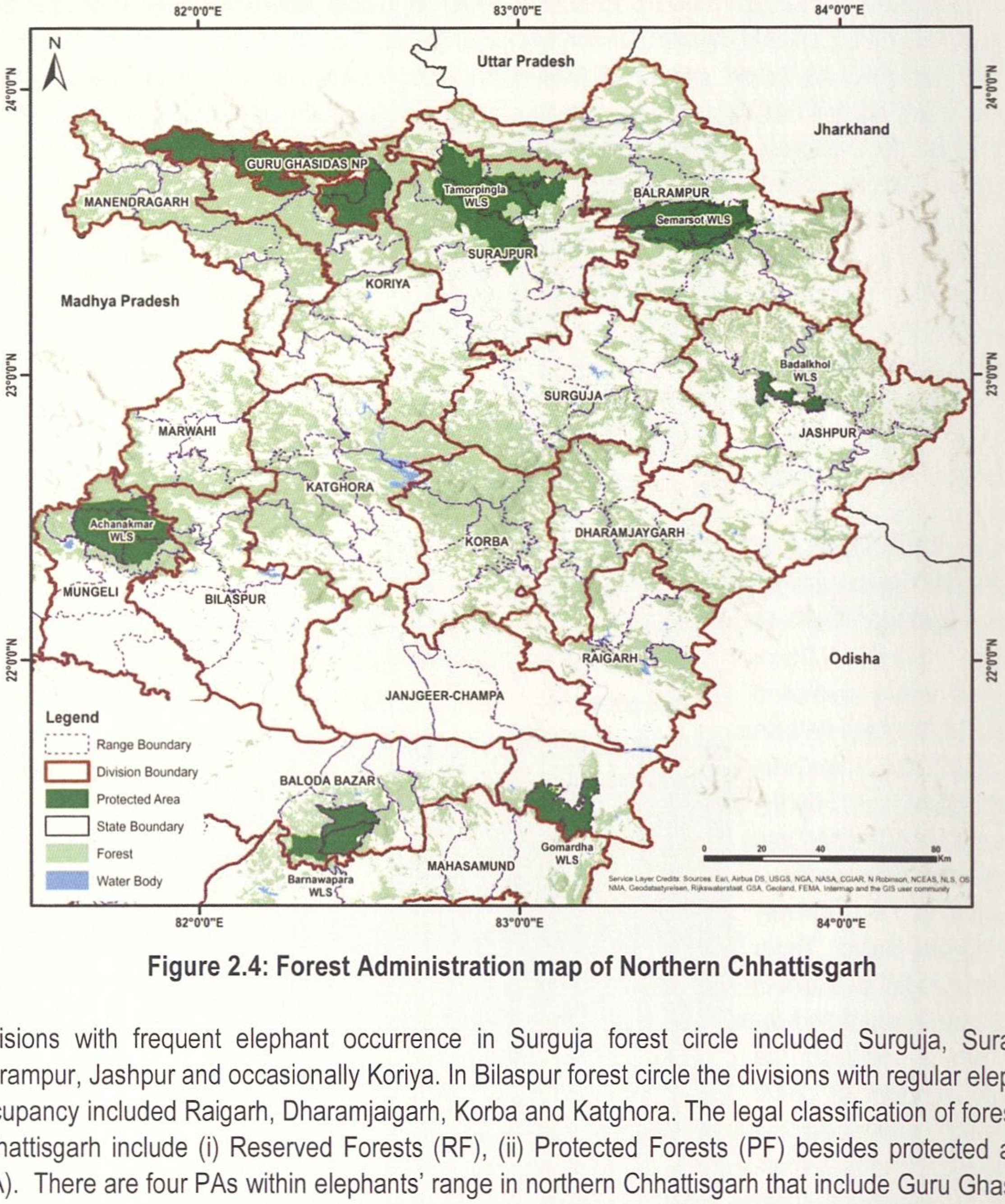


Figure 2.4: Forest Administration map of Northern Chhattisgarh

Divisions with frequent elephant occurrence in Surguja forest circle included Surguja, Surajpur, Balrampur, Jashpur and occasionally Koriya. In Bilaspur forest circle the divisions with regular elephant occupancy included Raigarh, Dharamjaigarh, Korba and Katghora. The legal classification of forests in Chhattisgarh include (i) Reserved Forests (RF), (ii) Protected Forests (PF) besides protected areas (PA). There are four PAs within elephants' range in northern Chhattisgarh that include Guru Ghasidas NP in Koriya district, Tamor-Pingla Wildlife Sanctuary in Surajpur distict, Semarsot Wildlife Sanctuary in Balrampur district and Badalkhol Wildlife Sanctuary in the Jashpur Forest Division. There is one notified elephant reserve namely the Tamor-Pingla – Badhalkhol Elephant Reserve in Surguja and another, Lemru Elephant Reserve is in the process of getting notified in the Korba district of Chhattisgarh.

CHAPTER-3
DISTRIBUTION AND BASIC DEMOGRAPHY OF ELEPHANTS

3.1 Introduction

Elephants are long-lived vertebrates with life-history traits such as late sexual and delayed social maturation, and slow rate of reproduction (Arivazhagan 2005; Moss 2012). Therefore, assessing their demographic parameters reliably would require longitudinal studies spanning many years and involve following cohorts of individually recognized elephants (Moss 2012; De Silva et al. 2013; Wittemyer et al. 2013). Although number in the population (or size) is an important metric that determines viability of animal populations (Williams et al. 2002), knowledge about population vital rates like fecundity, mortality, and dispersal would be crucial to forecast the future trajectories of elephant populations (Leimgruber et al. 2008). From conservation standpoint, for relatively small elephant populations, assessing demographic parameters is critical to understanding population viability as ecological theory suggests that small populations are susceptible for local extinction (Hanski 2013). Further, from the perspective of managing human–elephant conflict, knowing the trajectory of the population would be central to devising long-term conflict resolution strategies.

While assessing elephant demography is a challenge in itself, doing so in areas where elephants have relatively large and fluid home ranges is even more challenging. Yet, considering the importance of understanding elephant demography, we attempt to provide baseline data on population trends and demographic vital rates using both secondary data obtained from Chhattisgarh Forest department and field observations predominantly from Surguja forest circle an area of about 18,000-km2. In addition to demographic parameters, elephant body condition scores, which can be indicative of its nutritional status, have been estimated for animals observed during the study (Pokharel et al. 2021). As demographic parameters estimated were from population sampled opportunistically, computationally intensive population modeling approaches for making predictions on population vital rates with statistical credence were not used. Rather, this study attempts to provide baseline estimates of basic population parameters for future comparisons given that our study is the first systematic assessment of elephant ecology and human–elephant conflict in the state.

3.2 Methods

3.2.1 Secondary data

The Chhattisgarh Forest Department estimated elephant population during the year 2017 following a block-count method prescribed by the Project Elephant, MoEF&CC, Government of India. Block-count method is a total count approach prone to statistical problems of imperfect detection and spatial sampling. Therefore, the population trends presented are indicative especially in light of the fact that there is significant immigration and emigration of elephants from the neighboring states. Nevertheless, wide discrepancies may not exist as Chhattisgarh Forest Department has a statewide daily monitoring system, wherein range-level elephant distribution along with rough estimates of elephant numbers were collated and centrally pooled by the office of Director, Elephant Reserve, Surguja and transmitted to divisional forest department heads electronically.

3.2.2 Field Surveys

Field surveys to assess elephant demographic parameters were carried out during the period July 2017 to January 2020. The surveys involved opportunistically following and registering elephants with photos and videos recorded in the field. Systematic sampling approach was not followed to register elephants for demographic classification and rather, that objective was to provide crude estimates that can be useful for making future comparisons. Although direct elephant sightings were numerous, only on 158 occasions we could reliably record, photograph and video-record elephants during day-light conditions, which were eventually used for estimating demographic parameters.

3.2.3 Age classification

The elephants were classified into five age categories that included calf (< 2 years), juveniles (2 – 5 years), sub-adult-1 (5 – 10 years), sub-adult-2 (10 – 15 years), and adults (>15 years). Age-classification of elephants was done based on (i) Ear characteristics recorded: Assessment of lateral folds along with the degree of folds indicates relative ages. With age the pinnae get, thicker, develop depigmentation and get ragged along the margin.

(ii) Temporal depression: A qualitative assessment of temporal gland depression was carried out, as with age, the temporal depression (the concaveness) gets pronounced in elephants.

(iii) Relative heights and body length: A qualitative assessment of relative shoulder heights and body lengths were recorded as elephants grow almost throughout their life. While shoulder heights stop, the body lengths continue to increase and serve as a good indicator of relative ages.

(iv) For tuskers, tusk characteristics like thickness, appearance and length were recorded as they can indicate age-class of bulls.

(v) For adult cow elephants, extent of sagging of mammae was noted. Additionally, for bulls and cows, buccal cavity depression (brought about by molar progression), forehead hump (above the nasal cavity), development of head domes, relative skull size etc. was qualitatively recorded to classify the elephants into different age classes.

3.2.4 Individual identification of elephants

Identification of individual elephants was carried out using a combination of variety of body characteristics such as shape and size of tusks, characteristics of ear pinnae and others. This technique has been used in both Africa and Asia for many decades (Moss 2001; Vidya et al. 2014). The following body characteristics were used for individual identification:

i. Ear characteristics: Nicks, holes, notches, cuts and serrations in the ear margin that elephants develop with age along with ear folds (ranging from no folds to rolling folds) were noted. Further, the variations in the size, level of depigmentation (that usually increases with age), and shape of the lobe (lower part of the ear) were recorded.
ii. Tusk and *tush* characteristics: Tusks are modified upper incisors that grow almost throughout an elephant's lifespan. The characteristics related to tusks recorded include intact tusks, broken tusks, and single-tusked along with a written description. In addition to the above, the tusk

arrangement, thickness, length and angle with respect to the ground (during stable head position) were recorded (Goswami et al 2007). The tusk characteristics were recorded for both the left and the right tusk individually. Tuskless bulls were recorded as *makhnas*.

iii. Tail characteristics: Variation in tail length, presence of prominent kinks (abrupt twists in the caudal bone), and patterns of tail brush (tassels in the tail) were recorded.

iv. Prominent wounds and other body features like warts, scar tissues, deformities and other injuries were also recorded.

3.2.5 Assessment of body-condition scores (BCS)

While palpation techniques are readily available for assessing body condition of captive and immobilized elephants, for free-ranging elephants only visual-based assessments can be done. The downside of using visual-based assessment is the wide margin of possible errors in assigning scores. Therefore, the methods need to be simple to follow in the field. We followed Fernando et al. (2009), which was based on relative scoring of the body characters. The scoring ranged from 1 (poor) to 9 (healthy condition). We assigned BCS to individual elephants using photos and videos.

3.2.6 Data analysis

The age-structure, group size and sex ratios reported in the study were presented either in proportions or in relative percentages. Wherever appropriate, descriptive statistics were used to present the data. For comparing variations in the group size across seasons, and body condition scores between bulls and cows belonging different age groups and across seasons, we used the non-parametric Kruskal-Wallis analysis of variance (Sokal and Rohlf, 2012).

Table 3.1 Reported elephant occurrence in Northern Chhattisgarh (2012 to 2017)

S. No	Forest Division	Remarks
	Raipur circle	
1	Mahasamund	Regular. Elephants occur almost throughout the year
2	Balado Bazar	Elephants occur sporadically
3	Dhamtari	Range expansion during 2020. Elephants occur sporadically.
4	Ghariyaband	Range expansion during 2020. Elephants occur sporadically.
5	Raipur	Elephant movement into Naya Raipur was observed since the year 2018. Movement is sporadic
	Bilaspur circle	
6	Korba	Regular. Elephants occur almost throughout the year
7	Raigarh	Regular. Elephants occur almost throughout the year
8	Dharamjaigarh	Regular. Elephants occur almost throughout the year
9	Katghora	Movement was sporadic till 2018. But has become regular since then.
	Surguja circle	
10	Surguja	Regular. Elephants occur almost throughout the year
11	Surajpur	Regular. Elephants occur almost throughout the year

12	Balrampur	Regular. Elephants occur almost throughout the year
13	Jashpur	Regular. Elephants occur almost throughout the year
14	Koriya	Sporadic occurrence for a few days in a year
15	Manendragarh	Sporadic occurrence for a few days in a year
16	Tamor Pinlga WS	Regular. Elephants occur almost throughout the year
17	GuruGhasidas NP	Regular. Elephants occur almost throughout the year
18	Badalkhol WS	Regular. Elephants occur almost throughout the year
19	Semarsot WS	Sporadic occurrence for a few days in a year

NP = National Park, WS = Wildlife Sanctuary

3.3 Results

3.3.1 Distribution and population size

As part of the synchronized elephant census of the year 2017, Chhattisgarh Forest Department enumerated 247 elephants, which were distributed in seven forest divisions (Surajpur, Surguja, Jashpur, Dharamjaigarh, Korba, Raigarh and Mahasamund) and two protected areas (Tamor-Pingla WLS and Guru Ghasidas National Park). Based on the daily elephant monitoring effort of Chhattisgarh Forest Department, we noted that the elephant numbers had ranged from 240 to 280 during period 2017–2020. The reported elephant occurrence across forest divisions in Chhattisgarh during the period 2012 to 2017 is provided in Table 3.1.

3.3.2 Population Trends

As per the existing records, range expansion of elephants possibly from the neighboring states of Odisha and Jharkhand into northern Chhattisgarh began from 1988 onwards. During 1988, 18 elephants were reported from the then undivided Surguja district of eastern Madhya Pradesh (presently in Chhattisgarh). Following intensive human–elephant conflict, all these elephants were captured and held in captivity. As a sequel, from the year 2000 onwards, elephants dispersed into Chhattisgarh, where their ranges expanded with concomitant increase in population (Table 3.2).

Table 3.2: Elephant population trend collated from Chhattisgarh Forest Department for the period from 1988 to 2021. (The 1988 data was recorded by Madhya Pradesh Forest Department)

S. No	Year	Elephant population	Rate of change (times)
1	1988	18	NA
2	2001	24	+ 1.3
3	2005	123	+ 5.1
4	2007	122	- 0.81
5	2015	247	+ 2.02
6	2017	247	No change
7	2021 (as on September 2021)	279	+ 1.12

3.3.3 Group Size Dynamics

We used 156 direct elephant sightings to assess group size dynamics. Among the direct sightings, 33% (n = 52) were solitary males, 56.4% (n = 88) were groups, and 10% (n = 16) were all-male groups. Of the 52 solitary male sightings, 48 sightings pertain to 3 collared bulls that were regularly tracked. The frequency distribution of group size of female groups in the study area is provided in Figure 3.1. The mean group size of female groups observed in northern Chhattisgarh across all the seasons was 10.9 (± 6.9, median = 9, range = 2 – 41). Seasonal variations observed in the group-size of the female groups have been provided in Table 3.3. Inter-seasonal variations in female group sizes were not significant (Kruskal-Wallis $\chi^2 = 27.8$, df = 24, $P = 0.26$). However, there were significant monthly variations in the group sizes
(Figure 3.2)

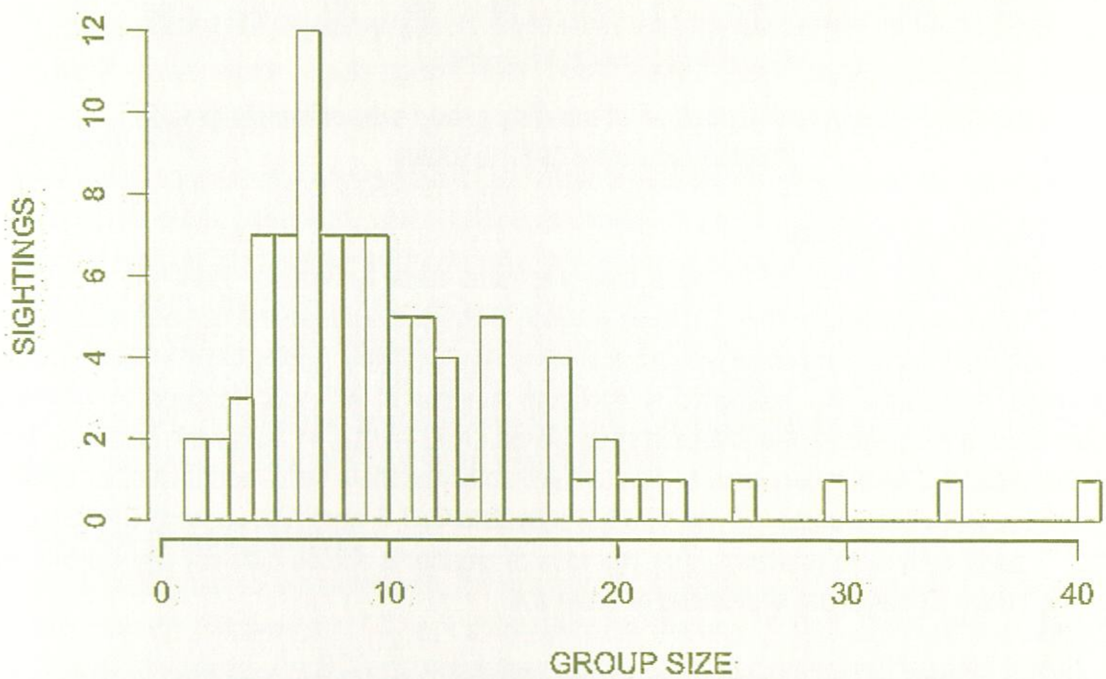


Figure 3.1 Frequency distribution of group size of female elephant groups recorded in Northern Chhattisgarh (n = 88). (Pooled data 2017 – 2020)

Table 3.3: Seasonal variations in the elephant group-size

Season	Group size
Dry season	μ: 10.4, (σ: ± 6.1), Median: 9, Range: 3 – 30
Monsoon	μ: 8.1, (σ: ± 8.6), Median: 5, Range: 3 – 35
Winter	μ: 12.1, (σ: ± 6.8), Median: 10.5, Range: 2 – 41

In the all-male groups, the mean group size observed was 2.6 (± 0.7). The maximum number of bulls seen in the all-male groups was 4. The number of sightings of all-male groups was few to make season-wise comparisons.

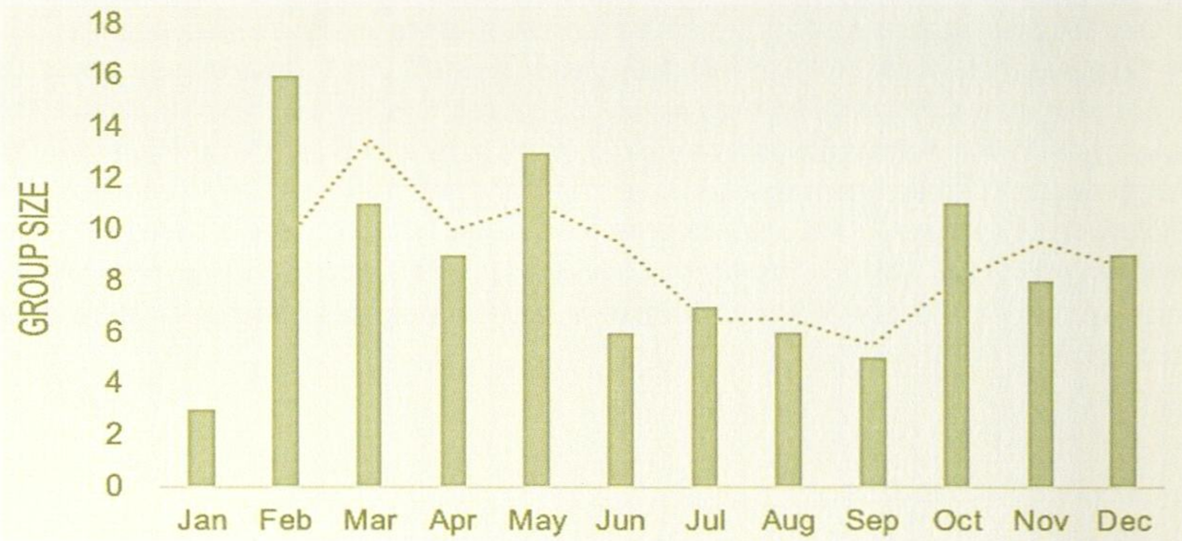


Figure 3.2: Frequency distribution of monthly group size of female groups. (Pooled data from 2017 to 2020)

3.3.4 Age-structure and Sex Ratio

In northern Chhattisgarh, a total of 34 adult cow elephants were individually identified based on morphological features (Natarajan *et al.* 2019). In addition to these individually recognized adult cows, 13 different female elephants were observed, but not individually identified. Adding the identified females and unidentified individuals, we estimated a minimum number of 47 adult females in northern Chhattisgarh. Furthermore, during the intensive study period (2017–2020), 11 bulls were recorded. The number of bulls reported here is best considered minimal number as there were reports of other bulls in the area, which could not be located. Of the 11 adult bulls observed, 5 were followed with GPS collars. Two of the 11 adult bulls were *makhnas*. The sex ratio of elephants across different age-classes as estimated in northern Chhattisgarh is provided in Table 3.4.

Table 3.4 Ratio of male to female elephants across different age classes recorded in Northern Chhattisgarh during the period 2017 – 2020

S. No	Parameter	Estimates	Remarks
1	Ratio of adult bull: adult cow	1: 4.5	Estimation largely based on identified bull and cow elephants, and a small fraction of unidentified elephants
2	Ratio of sub-adult bull: sub-adult cow	1: 0.6	Estimation based on the elephants age-classified in the field and from the photo/video repository
3	Ratio of juvenile male: juvenile female	1: 1.8	- do -
4	Ratio of adult *makhna* to tusker	1: 4.5	Estimation based on the repository of identified bull elephants

The age-structure of the female herds expressed as proportion of individuals classified across different age groups is presented in Figure 3.3.

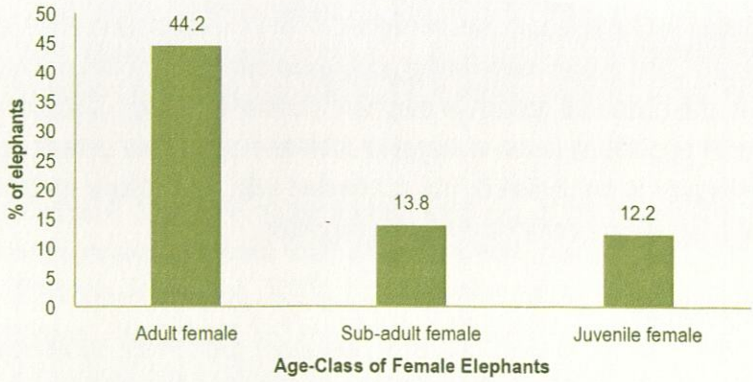


Figure 3.3: Age-structure of female elephants classified based on photographic records in Northern Chhattisgarh.

3.3.5 Birth Rate

The ratio of number offspring produced per adult female in the population can be used to calculate reproductive rates, particularly when reliable observations are made over time (Williams et al. 2002). The ratio method has been widely been used for assessing fertility and birth-rate of elephants and other large herbivores (Sukumar 1985; Tiwari 2002; Bonenfant et al. 2005). In this study, all the 47 adult females (>15 years of age) were considered as putative mothers. Further to this, a total of 14 calves (< 2 years) were recorded. Thus, the mother to calf ratio was estimated at 3.35:1. Using this ratio, the fertility rate of 0.29 births per adult cow elephant was estimated. Based on the observed female to calf ratio, mean inter-calf interval of 3.4 years was estimated.

3.3.6 Body Condition Scores

In the adult segment of the population, the recorded BCS of bulls [$\mu = 8.08$ ($\sigma = \pm 0.7$)] were significantly higher than the females [$\mu = 7.8$ ($\sigma = \pm 0.9$)] (Kruskal-Wallis $\chi^2 = 18.7$, df = 3, $P = 0.0003$). However, across all age groups, the BCS did not appear different between males and females (Fig-4). Further to this, we observed no significant seasonal variations in the BCS for both males and females (Figure-3.4).

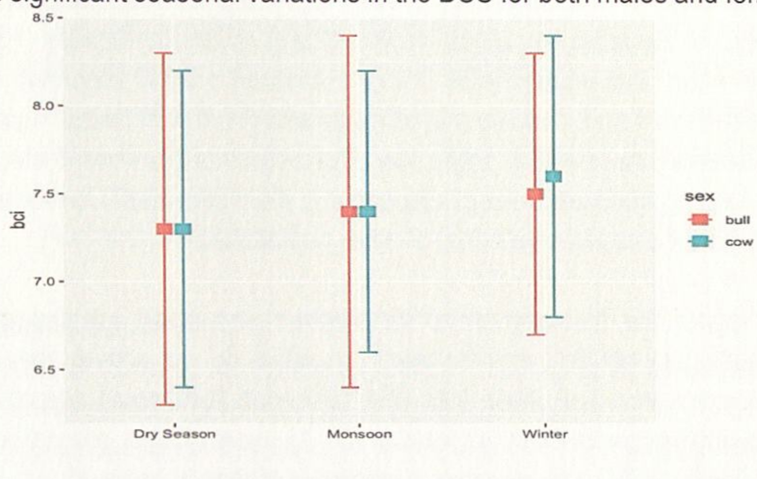


Figure 3.4: Seasonal comparison of body condition scores between cow (n = 536) and bull (n = 351) elephants

3.4 Discussion

3.4.1 Population

The elephant population in Chhattisgarh has increased from 24 elephants in 2001 to over 270 elephants in 2021 based on broad comparison made using population estimates of two discrete years of 2001 and 2021. Further to this, the observed growth in elephant population needs cautious interpretation in light of: (i) a relatively small population (even a marginal increase can inflate growth rates) (ii) the elephant population in Chhattisgarh is not isolated, but connected with populations in Odisha, Jharkhand and Madhya Pradesh with significant immigration and emigration.

3.4.2 Group Size Dynamics

In natural habitats with minimal human influence, elephant group-size dynamics would be primarily determined by their underlying social organization and resource availability (Moss, 2012). During resource limiting seasons, elephants may form smaller groups to avoid conspecific competition. On the contrary, when primary productivity is high, they may form larger groups of genetically related individuals to maximize social interactions. Migratory elephants (long-distance movement of elephants) and elephants that disperse out of natal areas due to saturated habitat conditions too may form large groups (even of un-related individuals) (Daniel *et al.,* 2008). Such large groups could be temporary in nature. In northern Chhattisgarh, seasonal variations in elephant group sizes were not significant. However, monthly variations were significant indicating high variability, probably owing to high frequency of fission and fusion of groups. The average group size recorded in the study is comparable to the group size of Asian elephants reported from different landscapes (Sukumar, 1985; Tiwari, 2002; De Silva *et al.,* 2013).

3.4.3 Age Structure and Sex Ratio

The estimated adult sex ratio of 1:4.6 in the study area is comparable with the sex ratio of 1:5.1 estimated by Sukumar (1985) in the Biligiri Rangan hills, Southern India and this landscape was vulnerable to poaching of tuskers. Williams, (2005) reported a sex ratio of 1:1.87 in Rajaji National Park, Uttarakhand wherein poaching was not reported indicating higher proportion of males in the population. In Chandaka wildlife sanctuary of Odisha, which occurs in the East Central landscape and thus, ecologically similar to Chhattisgarh, Tiwari (2002) reported a sex ratio of 1:2.1. Tiwari (2002) urged caution that since the elephant population size in Chandaka was small (< 60), the remnant bulls in the population were important regardless of the adult sex ratios. While socially mature adult bulls (>30 years) recorded in Chhattisgarh were few, sub-adult males were numerous. Since elephant range expansion in Chhattisgarh is quite recent and involves a small population size with limited number of reproductively receptive cows, it seems plausible that only a few adult bulls associate with these female groups in the present. Thus, assessing adult sex ratio of elephants in the entire East Central region would be more pertinent to gauge how it compares with that of other populations.

In northern Chhattisgarh, the male segment of the elephant population is represented in all age-classes (juveniles, sub-adults, and adults), and the adult sex ratios do not appear skewed. However, as the population size is relatively small, even loss of a few adult bulls could potentially affect population viability. In the sub-adult segment of the population (5 – 15 years of age), proportion of males was higher than females. Williams (2005) too reported a relatively higher number of sub-adult males in Rajaji National Park, Uttarakhand. From our observations, it is plausible that some of the sub-adult males observed with female herds may be a result of 'loose associations' of individuals that are in the dispersal phase. In the juvenile segment (2 – 5 years of age), the females were numerically higher than males. Arivazhagan (2005) observed a similar pattern in the Nilgiris, southern India. In general, juvenile elephants are difficult to sex-classify, and there is a possibility of misclassification. Therefore, the inherent difference between males and females in the juvenile segment could have resulted from a sampling artifact.

The adult females constituted over 44% of the female segment of the population, which corroborates with the age-structure estimates obtained from other elephant landscapes (Sukumar, 1985; Tiwari, 2002; Arivazhagan, 2005; De Silva *et al.,* 2013). For example, age-structure of female herds in the BR Hills and Sathyamangalam (Karnataka & Tamil Nadu), Chandaka WS (Odisha), Mudumalai (Tamil Nadu), Nagarahole (Karnataka) and Uda Walave (Sri Lanka) indicated that adult females constituted 40 – 45% of the whole female segment of the population. Our estimates from northern Chhattisgarh (44.2%) fell within this range.

3.4.4 Birth Rate and Inter-Calf Interval

The inter-calf interval reported in the study is lower than the estimates reported from other elephant landscapes (Table 3.5). This may be because of excellent nutrition available in the crops that were foraged by the Chhattisgarh elephants. It is also pertinent to note that although ratio method is widely used, it is prone to errors and thus, less reliable than the estimates obtained from monitoring individually identified animals (Bonenfant *et al.* 2005) highlighting the need to have longitudinal demographic assessment for at-risk elephant populations.

Table 3.5 Comparison of elephant inter-calf interval across different elephant landscapes

S. No	Inter-calf interval	Landscape	Reference
1	4.8	Biligiri Rangan Hills, South India	Sukumar (1985)
2	4.5	Rajaji National Park, Uttarakhand	Williams (2005)
3	4.7 – 4.9	Chandaka Wildlife Sanctuary, Odisha	Tiwari (2002)
4	5.1	Nagarahole National Park, Karnataka	Arivazhagan (2005)
5	5.3	Mudumalai Wildlife Sanctuary, Karnataka	Arivazhagan (2005)
6	6.9	Periyar Wildlife Sanctuary, Kerala	Arivazhagan (2005)
7	4.5	Amboseli National Park, Kenya (African elephant, *Loxodonta africana*)	Moss (2001)
8	3.4	Northern Chhattisgarh	Present study

3.4.5 Body Condition Scores

As Asian elephants occur in seasonal environments with pronounced fluxes in resource availability, their body condition scores are expected to exhibit significant seasonal differences (Pokharel *et al.,* 2017). However, in Chhattisgarh, the seasonal differences in the body condition scores were not significant for both males and females. This was likely a result of elephants (both bulls and female herds) foraging intensively on cultivated crops. Crop foraging by elephants is widespread in Chhattisgarh.

The average body condition scores of elephants recorded in Chhattisgarh were higher in comparison to elephants that predominantly occur within protected areas as observed in Rajaji National Park in Uttarakhand and Bandipur National Park in Karnataka (L. Natarajan, Wildlife Institute of India, personal observation). While crop foraging may result in higher body condition scores in elephants, the downside of long-term demographic impacts of crop foraging by elephants is poorly understood. For example, crop foraging can result in conflict-induced elephant injuries and mortalities. Injuries can affect the health condition of an animal (Goswami *et al.,* 2014). Further, there is considerable potential for crop foraging elephants to get exposed to agricultural pesticides and other intoxicants that are being increasingly used in India. The effect of such exposure on elephant survival and other aspects of fitness is a research question that begs urgent investigation.

3.5 Conclusion

During the period 2009 to 2019, 34 elephant deaths were reported due to conflict-related reasons (Project Elephant, Government of India). The age sex structure of the deceased elephants was not readily available. Additionally, episodes of local outbreaks of infectious diseases like "Elephant Endotheliotropic Herpesvirus" (EEHV) and "Hemorrhagic Septicemia" (HS) resulting in major deaths were reported from both Chhattisgarh and neighboring Odisha during 2019 - 2021. Thus, including age-specific mortality data would be crucial in understanding the elephant population trajectory in Chhattisgarh. In Chhattisgarh the population of about 200 to 300 elephants are spatially scattered occurring in numerous discrete forest patches. Accelerated habitat fragmentation can potentially result in isolation of spatially scattered elephant groups rendering them vulnerable to extinction. Therefore, advancing landscape-level policies with functional corridors aimed at maintaining elephant meta-populations in relatively large forested habitats both in Chhattisgarh and in the entire East Central region would be paramount.

CHAPTER-4
HOME RANGE, DISPERSAL AND MOVEMENT PATTERNS OF ELEPHANTS

4.1 Introduction

In wildlife–habitat assessments, evaluation of animal "home ranges" is important, as animals tend to use sites repeatedly over time (Powell, 2008). Thus, based on their repeated use of areas, it is possible to objectively delineate geographic space of animals in the landscape (Nielson, 2008). Burt (1943) defined animal home range as an area traversed by individual or group of animals during activities associated with feeding, resting, reproduction, and shelter. This definition is widely used in literature with suitable modifications and extensions, as appropriate. Regardless of the strict definition, home ranges can be summarized as geographic space within which animals use different habitats as facilitated by their ability to move (Ranc *et al.,* 2020). Thus, assessment of animal home ranges along with corresponding movement patterns can provide spatial information that can elucidate aspects of ecology and behavior of the species (Powell & Mitchell, 2012).

From the conservation standpoint, understanding animal home ranges is crucial for addressing contemporary conservation challenges like predicting extinction risks (Woodroffe & Ginsberg, 2008; Collen *et al.,* 2011) and human–wildlife conflicts. In particular, for large mammals like elephants, understanding home range distribution along with within home range habitat selection can be useful in managing human–elephant conflict. As elephants are generalist herbivores with respect their foraging behavior and exhibit remarkable behavioral plasticity, they occur in a variety of habitats ranging from wet evergreen forests to semi-arid tropical regions (Natarajan *et al.,* 2016). Elephant home ranges measured across Asia suggest high variability in the estimates that varies from 50-km2 to 3000-km2 (Sukumar, 1995; Desai, 1991; Sukumar, 2003; Baskaran & Desai, 1996; Fernando *et al.,* 2008; Joshua & Johnsingh, 1996; Williams *et al.,* 2010). With such high levels of variability in elephant home ranges across landscapes, generalizing or predicting patterns of home ranges is seldom easy for elephants.

4.1.1 Estimation of Home Ranges

Wildlife home ranges can be assessed using various field techniques. Using well-maintained re-sighting records of identified individuals, animal home ranges have been estimated (Sukumar, 1985; & this study). The aforementioned non-invasive methods have proved invaluable in getting crude outlines of animal home ranges. The advent of radio-telemetry during 1960s had revolutionized the field of spatial ecology enabling investigators to obtain high-resolution real-time information on animal movement, behavior and subsequent home range patterns (Sukumar, 2003). Radio telemetry studies involve capture, collaring and radio-tracking wildlife using very high frequency (VHF) transmitters. Telemetry unit comprises of VHF transmitter (encased in a belt that will wound on elephants) that emit radio signals (electromagnetic waves) and a receiver unit (along with antenna) that receive the signals (Rabinowitz, 1997). Triangulation and homing in techniques are used to obtain location fixes of animals and manually track them down respectively (Rabinowitz, 1997). Lately, the development of satellite tracking technology has further updated the fields of spatial ecology and animal behavior by enabling fine-scale data collection (Wittemyer *et al.,* 2019). Modern satellite collars can provide real-time high-resolution data on animal location fixes along with host of other add-ons like activity sensors that record behavioral states of animals in relation to environmental variables (Wittemyer *et al.,* 2019). In satellite tracking, the location fixes are uploaded to satellite and users download data from the servers (Powell *et al.,* 2004).

The GPS fixes obtained from telemetry collars are analyzed to compute home ranges and host of other details pertaining to animal ecology and behavior (Laver & Kelly, 2005). There are many home range estimators that are currently available. Amongst them, the minimum convex polygon (MCP) approach has been conventionally used to depict animal home ranges (Downs & Horner, 2008; Fleming *et al.,* 2015). The MCP polygon drawn by delimiting smallest polygon connecting peripheral location points with anterior angles less than 180 degrees. The downside of MCP approach includes the influence of outliers on the polygon and that the polygon includes large areas that animal may not use at all. Unlike the MCP, the Kernel Density Estimation (KDE) produces utilization distribution based on location points (Downs & Horner, 2008; Fleming *et al.,* 2015). The KDE estimates probability that an animal be present in any part of its home range using location fixes (Laver & Kelly, 2005). Thus, KDE estimates provide both the size of home range along with the intensity of use (Powell *et al.,* 2004).

The choice of estimator depends on its ability to provide biological insights useful for understanding the biology of the animal and in its the management. The absolute home range size may not be useful for wildlife manager. Rather the variations in home ranges across landscape and the relative effect of both ecological and human–induced variables explaining such variations would be more relevant for management. MCP provides a crude estimate of area that animals operate, which can be highly relevant for managing species involved in human–wildlife conflicts.

In Chhattisgarh, elephants occur over a large area in northern Chhattisgarh with concomitant high levels of human–elephant conflict. Unraveling elephant ranging behavior elucidating patterns on their home range distribution, use of habitats within their home ranges, and movement trajectories in the mosaic landscape would be essential in developing conflict mitigation strategies and conservation plans aimed at effectively managing habitats. As discussed earlier, telemetry collars provide fine-scale details on elephant home ranges and associated behaviors. However, collaring elephants is logistically challenging requiring highly skilled personnel, resources and admittedly, carries high amounts of risk to both people involved in the operations and to elephants as well.

In particular, in Chhattisgarh, the Institutional capacities and the infrastructure required for capturing elephants is limited. The elephant capture operations had to be carried out on foot as trained *kumkis* were not available. Due to these considerations, only a limited number of individual elephants can be collared. Alternatively, registration of individual elephants using morphological features and opportunistically monitoring can yield “re-sighting” records that can be used for estimating home ranges (eg. Sukumar, 1985). Such home ranges are crude estimates often constrained by sample size across seasons, but are nevertheless useful.

The objectives entailed in the chapter include the following:
(i) estimation of elephant home ranges using different methods along with description of home ranges
(ii) assessment of seasonal and monthly home ranges
(iii) assessment of home range stabilization
(iv) assessment of inter-annual fluctuations in home ranges (v) to describe movement patterns and use of corridors
(vi) to compare elephant home ranges with that of other landscapes, and discuss the relevance of understanding elephant ranging behavior for management of elephants in Chhattisgarh.

4.2 Methods

4.2.1. Individual Identification of Elephants

The individual elephants were identified using standard methods based on the morphological features of the elephants (Natarajan *et al.,* 2019). The parameters used for individual identification of elephants and the process therein have been elaborated in Chapter-4.

4.2.2 Chemical Immobilization of Elephants

Among the elephants individually identified, a few were selected for collaring based on many considerations. Such considerations included the (i) objectives of the study, (ii) age (iii) reproductive status (so as to avoid capturing cows that are aged, with tiny calves and are in advanced stage of pregnancy) and, (iv) patterns of elephant associations. Radio collaring operations were carried out in different phases. For each phase of the collaring operation, the preparatory activities for collaring were initiated many months in advance.

During the project period, realizing that the local capacities to track and follow elephants on foot were low, experienced elephant trackers from Tamil Nadu state in southern India and two experienced trackers from Rajaji tiger reserve, Uttarakhand were brought in to assist in the project. During the course of monitoring elephants on foot prior to collaring, the research team including the trackers became familiar with the terrain condition, which is a prerequisite for executing a safe elephant capture operation. In addition to trackers hired from Tamil Nadu, the local mahouts and trackers were included in the team so as to gain local terrain knowledge and simultaneously train the local trackers.

Elephants were immobilized with the assistance from research team, trackers, and the veterinarians. The immobilization drugs were remotely delivered using Dan-Inject IM and JM model immobilization equipment. The collars with built-in VHF and satellite transmitters that work on iridium technology were procured form M/s. Savannah Tracking, Kenya. The collars were programmed to provide a GPS fix at every one-hour interval. The entire collar unit weighs about 15 Kgs, which is approximately 0.3 to 0.5% of the average body weight of an adult bull and adult cow elephants respectively.

Drugs used for immobilizing elephants were combination of Xylazine HCl & ketamine HCl for sedation in two animals with Yohimbine HCl for reversal and Etrophine HCl in eight individuals with Diprenorphine HCl and Naltrexone used for reversal. The details of drugs used for collaring elephants are provided below (Table 4.1).

Table 4.1: Drugs used for immobilizing elephants in Chhattisgarh for collaring purposes during the period May 2018 to March 2022

S. No	Elephant ID	Gender & age class	Date of collaring	Drugs used for elephant capture
1	BD1	Adult Male (Makhna), > 40 years	12/05/2018	Xylazine HCl and ketamine HCl for sedation and Yohimbine HCl for reversal
2	GI	Adult Female, > 20 years	15/06/2018	Etrophine HCl for immobilization and Diprenorphine HCl and Naltrexone for reversal
3	PY	Adult Male (tusker), > 25 years	28/11/2018	Etrophine HCl for immobilization and Diprenorphine HCl and Naltrexone for reversal
4	MH	Adult male (Tusker), > 20 years	03/05/2019	Etrophine HCl for immobilization and Diprenorphine hydrochloride for reversal
5	KM	Sub-adult female, around 15 years	04/05/2019	Etrophine HCl for immobilization and Diprenorphine hydrochloride for reversal
6	GN	Adult Male (Tusker), > 25 years	23/07/2019	Xylazine HCl and ketamine HCl for sedation and Yohimbine HCl for reversal
7	BD2	Adult Male (Makhna), > 40 years	29/12/2019	Etrophine HCl for immobilization and Diprenorphine hydrochloride for reversal
8	PT	Adult Male (Tusker), > 40 years	27/05/2020	Etrophine HCl for immobilization and Diprenorphine HCl and Naltrexone for reversal
9	MT	Adult Female, > 20 years	24/10/2021	Etrophine HCl for immobilization and Diprenorphine HCl and Naltrexone for reversal
10	MI	Adult Female, > 30 years	27/10/2021	Etrophine HCl for immobilization and Diprenorphine HCl and Naltrexone for reversal

4.2.3 Analytical Methods

To visualize home ranges MCP was used. To assess home range and concomitant within home range habitat-use, KDE-based Utilization Distribution (UD) was used. The KDE UD contours (isopleths) were defined at kernel 50% (core use), 75% (moderate use), and 95% (intensive use). For smoothing parameter "h" used in estimating KDE, least squares validation cross-validation method (LSCV) method was used across all isopleth levels.

Monthly home ranges were calculated (95% UD) and month-wise difference in range estimation was evaluated using linear regression models with maximum likelihood estimators. The response variable in the models was monthly home ranges (95% UD) measured in km2, which was assumed to follow a normal distribution. The explanatory variables included individual elephant ID (BD1, BD2, PY, GN, GI), gender (bull/cow), *musth* status (presence/absence) and season (dry/monsoon/winter). Model comparisons were made using information-theoretic approaches by comparing plausible models with intercept-only model (Burnham & Anderson, 2002). The models were compared using Akaike Information Criterion (AIC) values and corresponding AIC weights (Burnham & Anderson, 2002). To compare seasonal difference in range areas, non-parametric Kruskal Wallis tests were used (Sokal and Rolhf, 1995). Descriptive statistics including basic graphs were carried out in excel spreadsheets. The home range estimations were carried out in program R using the package "adehabitatHR" (Calenge, 2006). The visualization and extraction of home range values were carried out in ArcGIS V. 10.6.1. The regression analysis was carried out in program R (R Core Development Team, 2019).

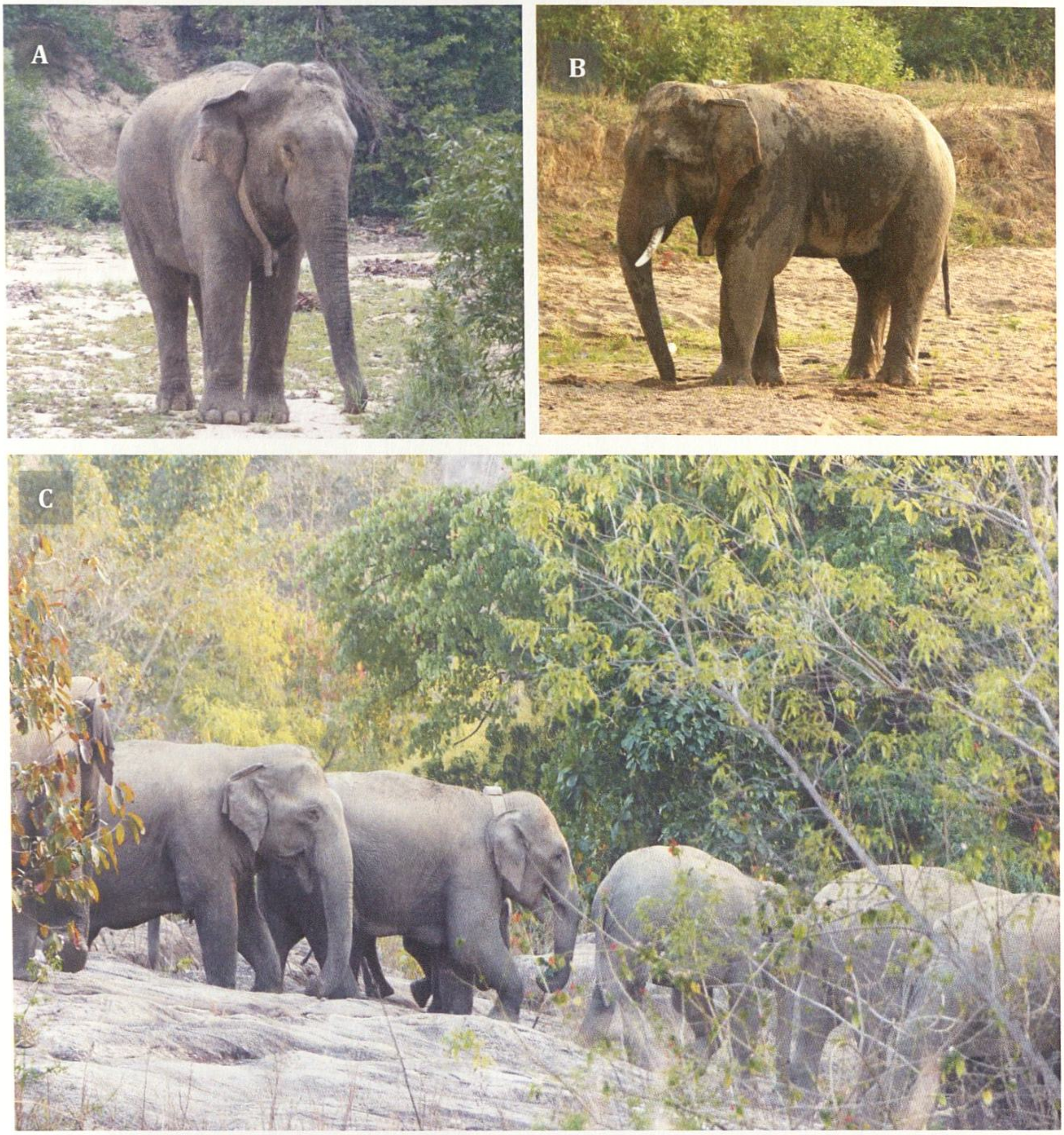


Plate 1. (A) BD1 (Behradev, adult *makhna*); (B) PY (Pyare, adult tusker); (C) GI (Gautami, adult cow) in herd

Plate 2. (A) GN (Ganesh, adult tusker), (B) PT (Pratam, adult tusker)

Plate 3. (A) WE (WaveEar), (B) TE (TornEar), (C) MT(Maitri)

4.3 Results

4.3.1 Details of Elephants Collared in Chhattisgarh

A total of 10 elephants were collared during the period 2018–2022 (Table 4.2). In addition to these 10 elephants, WII had provided field and technical support to Wildlife-SOS and Chhattisgarh Forest Department in collaring a female elephant in Mahasamund Forest Division. Thus, WII was involved in radio-collaring 11 elephants in Chhattisgarh during the period 2018 to 2022. The elephants collared in Chhattisgarh provided a total of 3106 elephant days of tracking information. The average number of days of data provided by each collared elephant was 310.6 (± 273). Only three elephants provided data for less than 20 days. Among them, a sub-adult cow collared in Tamor-Pingla Wildlife Sanctuary during May 2019 provided data only for 3 days. The young bull collared in Bagda of Surajpur Forest Division during May 2019 provided data only for 13 days. An adult cow collared in Sarhari of Surajpur Forest Division during October 2021 provided data only for 17 days. All other elephants provided data for a minimum of 200 days and maximum of over 820 days. Overall, during the period 2018 to 2022, due to combined efforts of WII and Chhattisgarh FD, elephants were radio-collared in Balrampur (1), Surajpur (5), Tamor-Pingla (1), Surguja (1), Korba (1) and Dharamjaigarh (1) Forest Divisions. Technical help was provided to collar a female elephant in Mahasamund FD.

Table 4.2: Elephants fitted with radio-cum satellite collars during the study period 2018–2022

S. No	Elephant ID	Gender and age-class	Location of collaring	Date of collaring	Period of monitoring	Present status (as on 31/03/2022)
1	BD1	Adult Male	Rewatpur, Balrampur FD	12/05/2018	404	Collar fell-off on 20/06/2019
2	GI	Adult Female	Mainpat, Surguja FD	15/06/2018	623	Collar fell-off on 28/02/2020
3	PY	Adult Male	Bansipur, Surajpur FD	28/11/2018	396	Collar fell-off on 29/12/2019
4	MH	Adult Male	Bagda, Surajpur FD	03/05/2019	13	Collar fell-off on 26/5/2019
5	KM	Sub-adult female	Khond, Tamor-Pingla WLS	04/05/2019	3	Collar fell-off on 7/05/2019
6	GN	Adult Male	Chaal, Dharamjaigarh FD	23/07/2019	292	Collar fell-off on 10/05/2020
7	BD2	Adult Male	Duppi, Surajpur FD	29/12/2019	823*	VHF unit still working. Satellite signals stopped
8	PT	Adult Male	Kudmura, Korba FD	27/05/2020	377	Collar fell-off on 08/06/2021
9	MT	Adult female	Mohanpur, Surajpur FD	24/10/2021	158*	Collar functional
10	MI	Adult Female	Sarhari, Surajpur FD	27/10/2021	17	Collar fell-off on 13/11/2021

* Collars are still providing data as on 31/03/2022

4.3.2 Elephants Monitored using Sighting-Resighting Approach

Further to satellite-collared elephants, a total of 93 elephants were individually identified and monitored during the study period (Natarajan *et al.*, 2021). Among them, two groups of elephants namely WE group (Wave Ear as named for matriarch) and TE group (Torn Ear as named for an adult female), were opportunistically, but regularly monitored. The monitoring yielded re-sighting GPS fixes with which home ranges (only MCP estimates) were calculated.

4.3.3 Elephant Home Ranges

The estimated home ranges of elephants (both satellite collared elephants and individually monitored) in northern Chhattisgarh during the period June 2018 to March 2022 using MCP and KDE approaches are provided in Table 4.3.

Table 4.3: The estimated home ranges of elephants in Northern Chhattisgarh during the period May 2018 to March 2022

S. No	Ele ID	Approach	MCP (in Km2)		UD (in Km2)	
			95%	100%	50%	95%
1	BD1	Satellite collared	1171.1	1416.6	26.5	281.7
2	GI		3327.5	4271.9	63.9	605.3
3	PY		3862.7	5540.2	85.2	662.9
4	MH#		256.2	290.0	NM	NM
5	KM#		NM	NM	NM	NM
6	GN		3582.7	8229.3	72.6	748.9
7	BD2		2118.4	3059.4	41.7	446.7
8	PT		3888.63	4107.12	82.8	714.4
9	MT		NM	696.3	16.2	126.5
10	MI#		70.4	95.4	NM	NM
11	WE	Re-sighting	NM	462.3	NM	NM
12	TE		NM	6969.7	NM	NM

** NM = Home ranges not measured. [$]The home ranges of TE and WE were estimated based on re-sighting records. # Collar did not last long*

4.3.3.1 MCP Home Ranges

The average home ranges were estimated for elephants that yielded data for over 200 days. Thus, while estimating home ranges, the elephants MI, KM, and MH were excluded. The average home range of elephants recorded during the study using 95% MCP approach was 3172.8 Km^2 (SD ± 2002.2 Km^2, Range: 462.3– 6969.7 Km^2). Home ranges spatially depicted as maps (Figure 4.1 – 4.12)

4.3.3.2 KDE Home Ranges

The KDE home ranges were estimated only for elephants that yielded data for over 200 days. KDE was not estimated for the elephants monitored without collars, as the data was coarse in nature. The average 50% UD elephant home ranges were 55.5 Km^2 (SD ± 59.7 Km^2, Range = 16.2 – 85.2 Km^2). The average 95% UD elephant home ranges were 512.3 Km^2 (SD ± 236.1 Km2, Range = 126.5 – 748.9 Km^2).

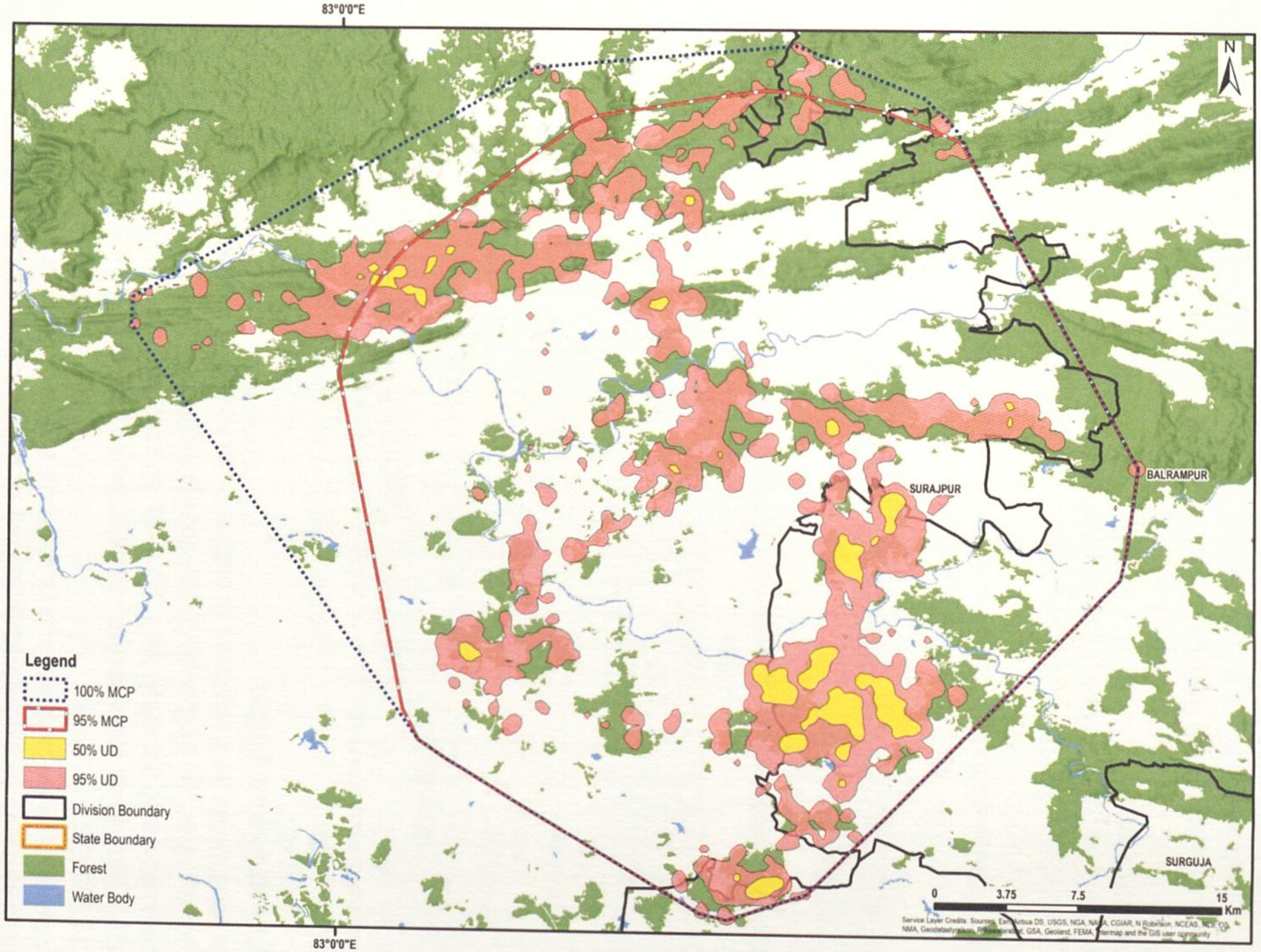


Figure 4.1: Home range distribution of elephant BD1 (Behradev, adult *makhna*)

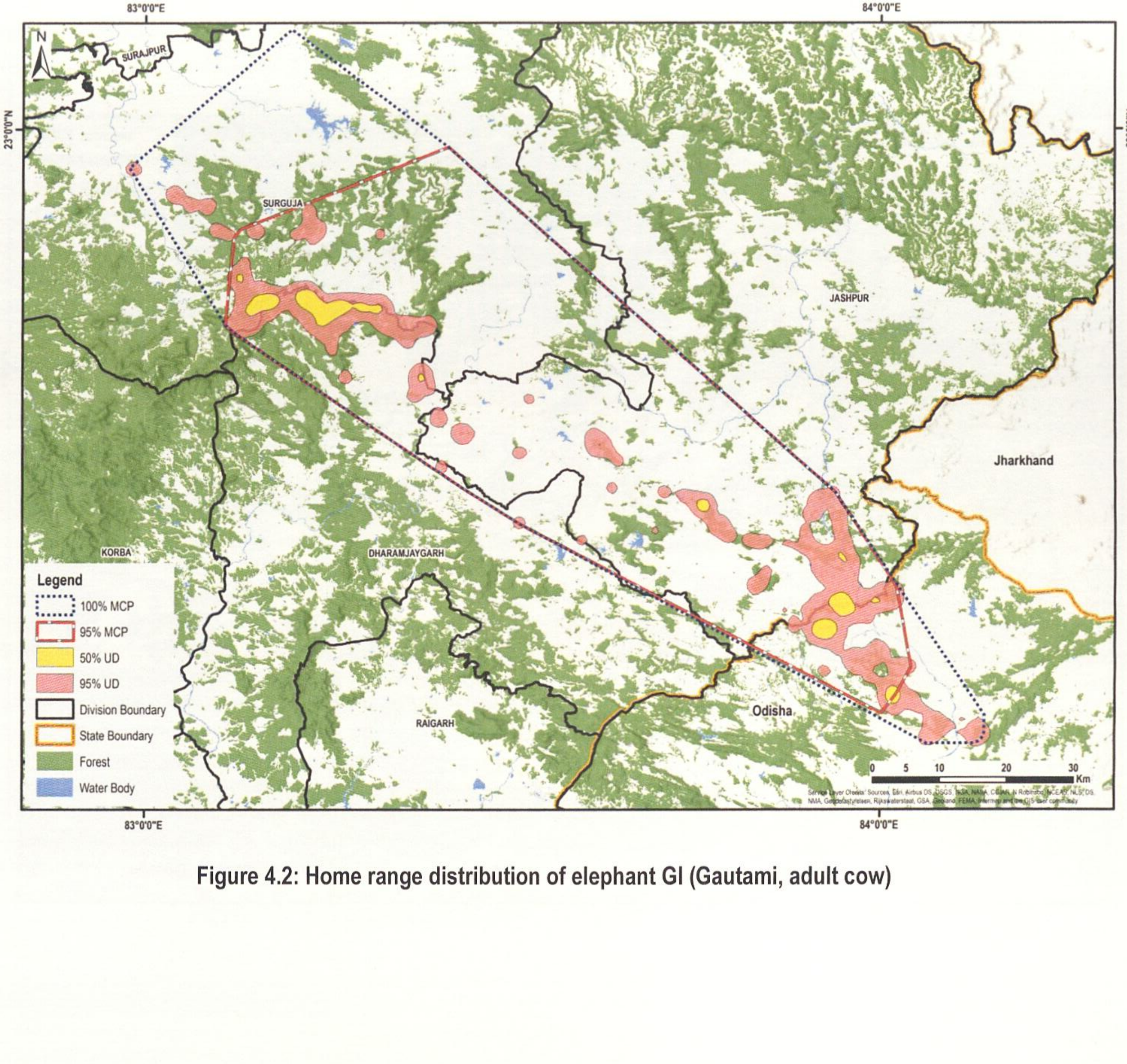


Figure 4.2: Home range distribution of elephant GI (Gautami, adult cow)

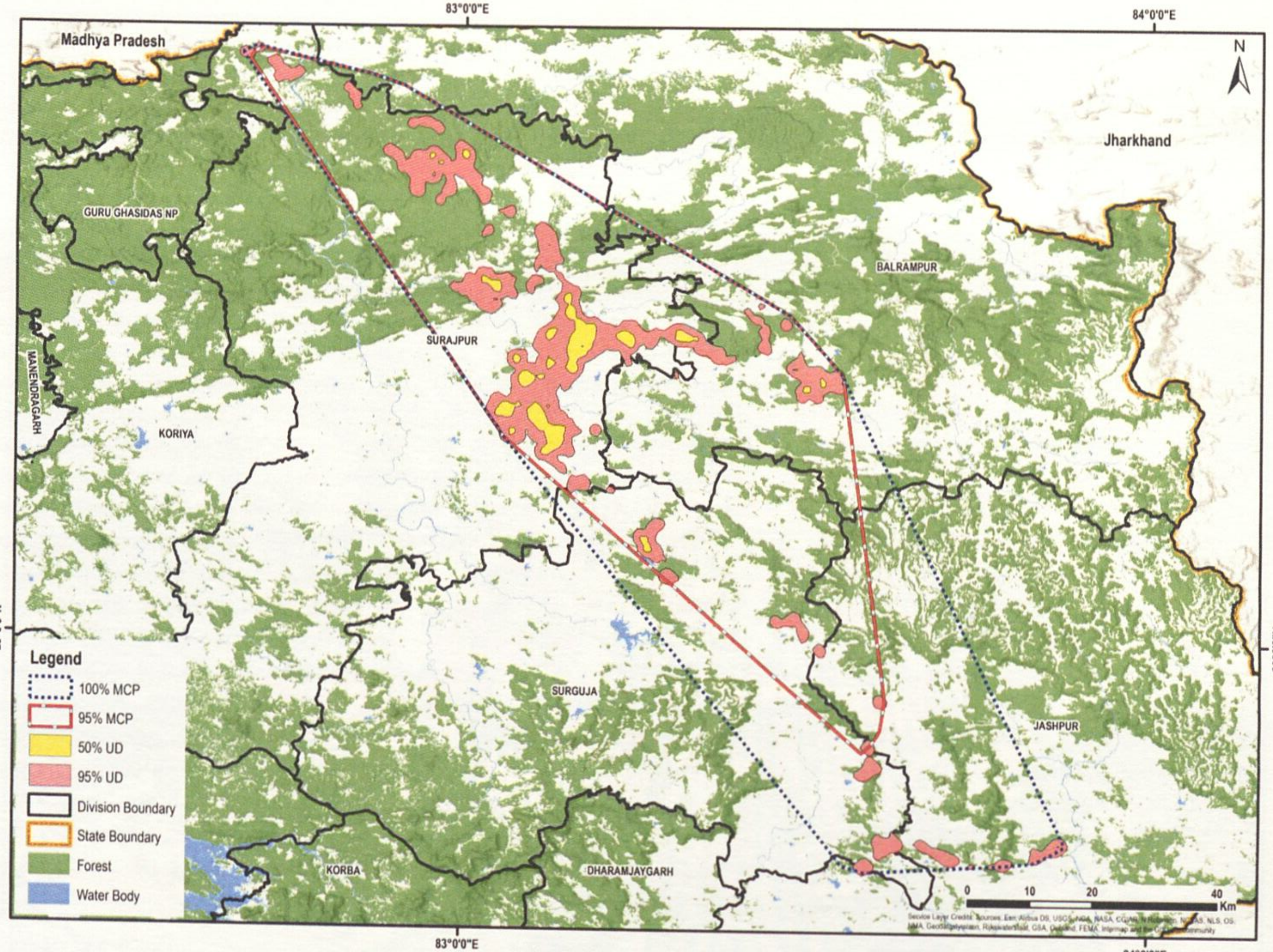


Figure 4.3: Home range distribution of elephant PY (Pyare, adult tusker)

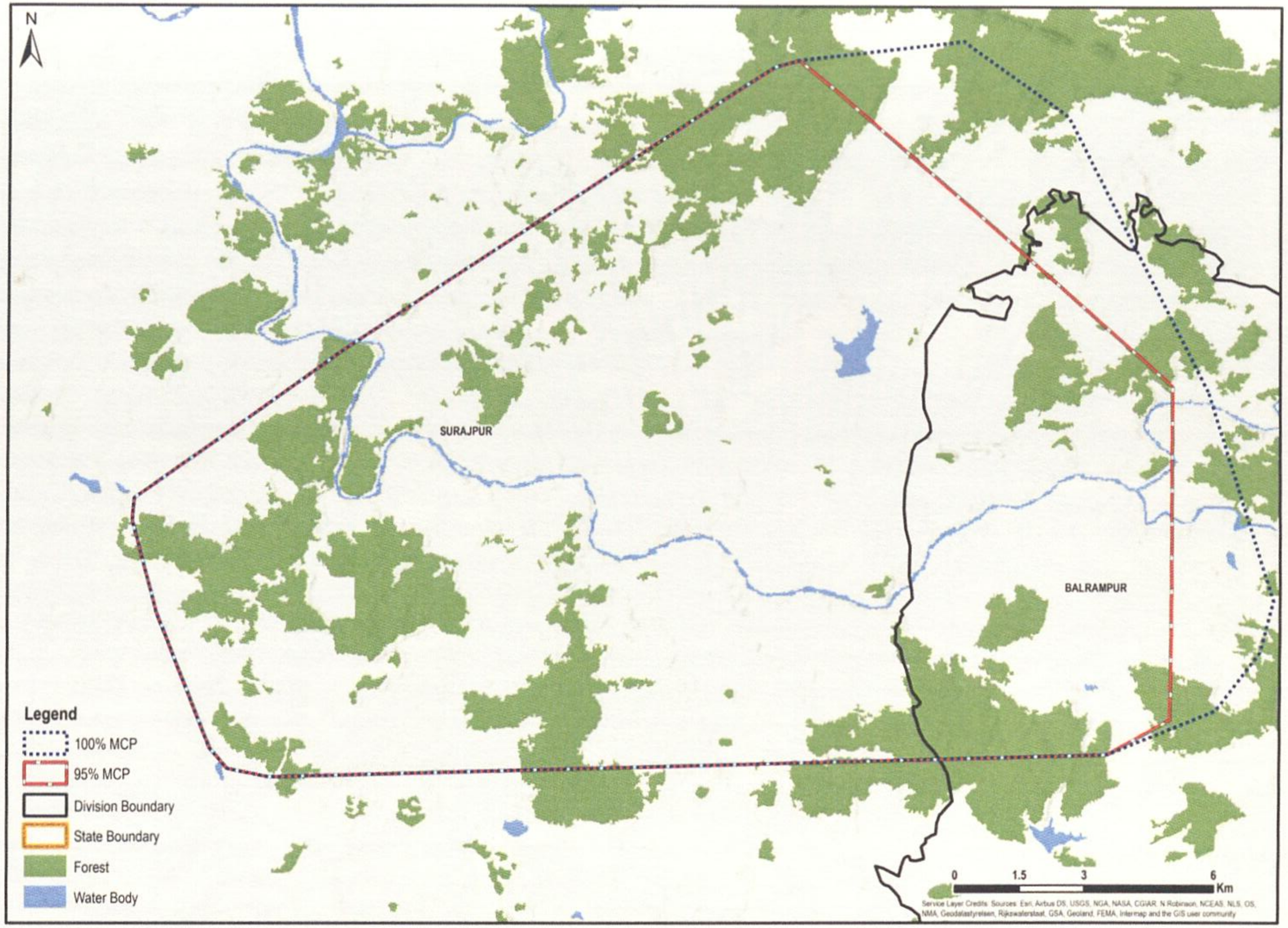


Figure 4.4: Home range distribution of elephant MH (Mahaan, adult tusker)

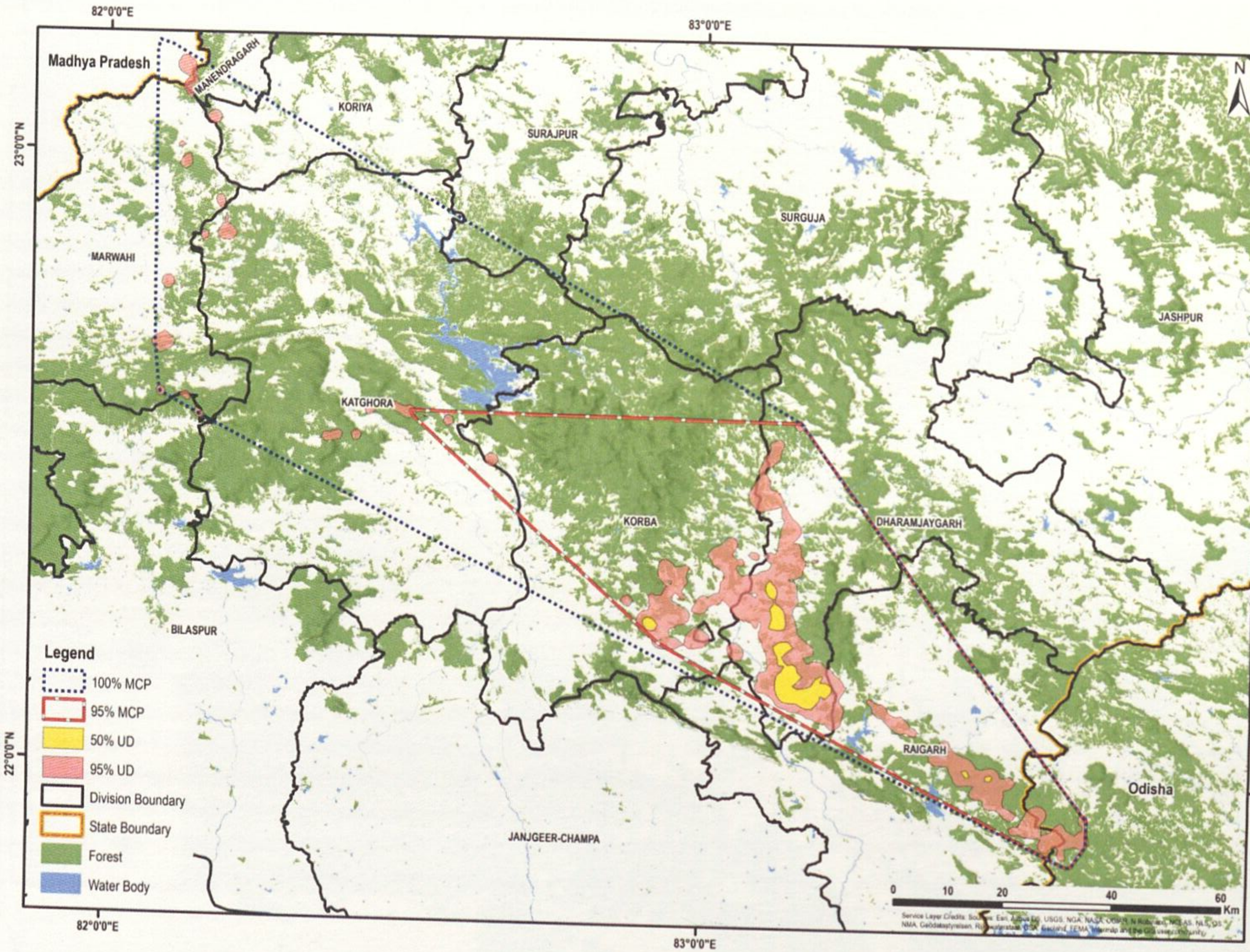


Figure 4.5: Home range distribution of elephant GN (Ganesh, adult tusker)

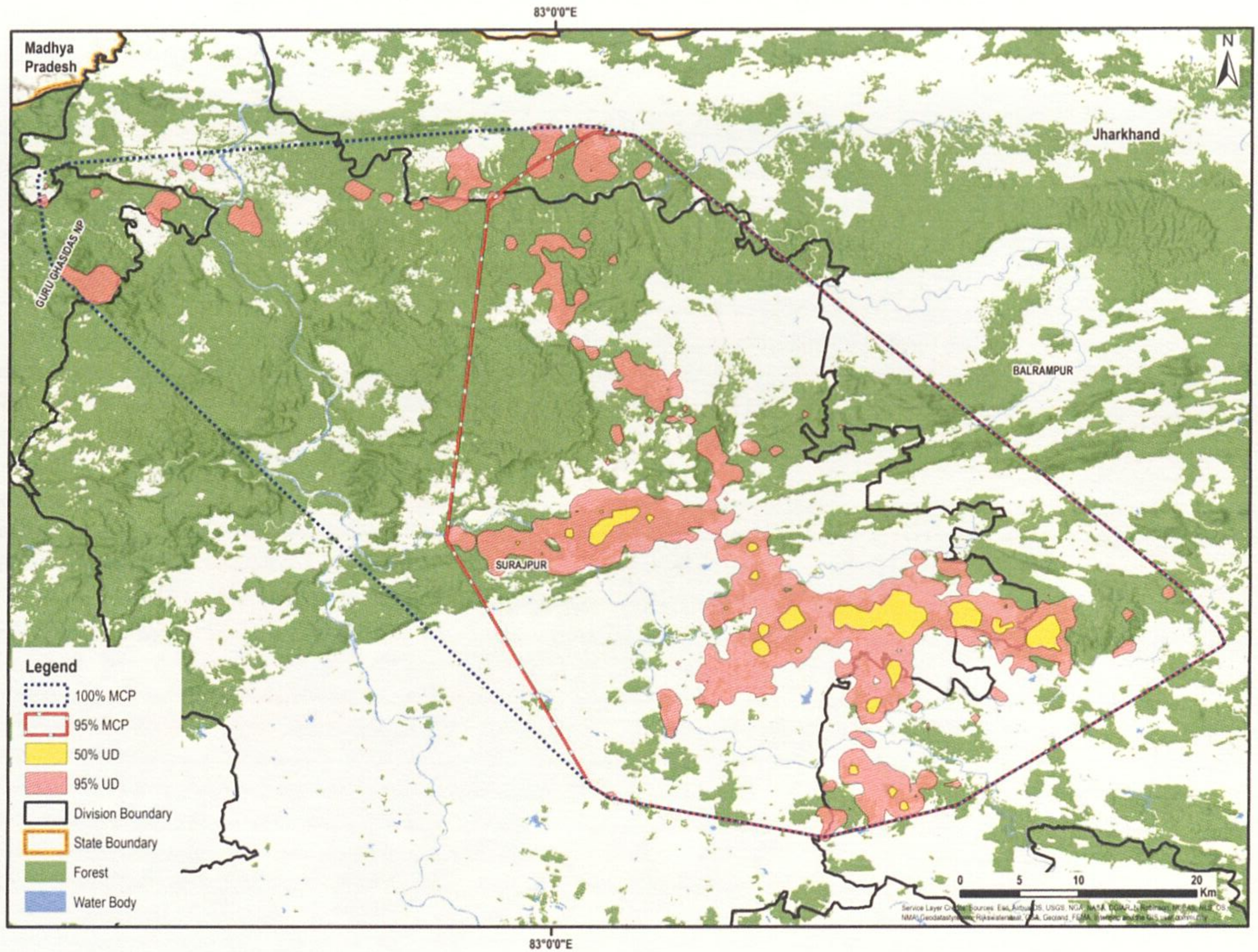


Figure 4.6: Home range distribution of elephant BD2 (Behradev, adult *makhna*)

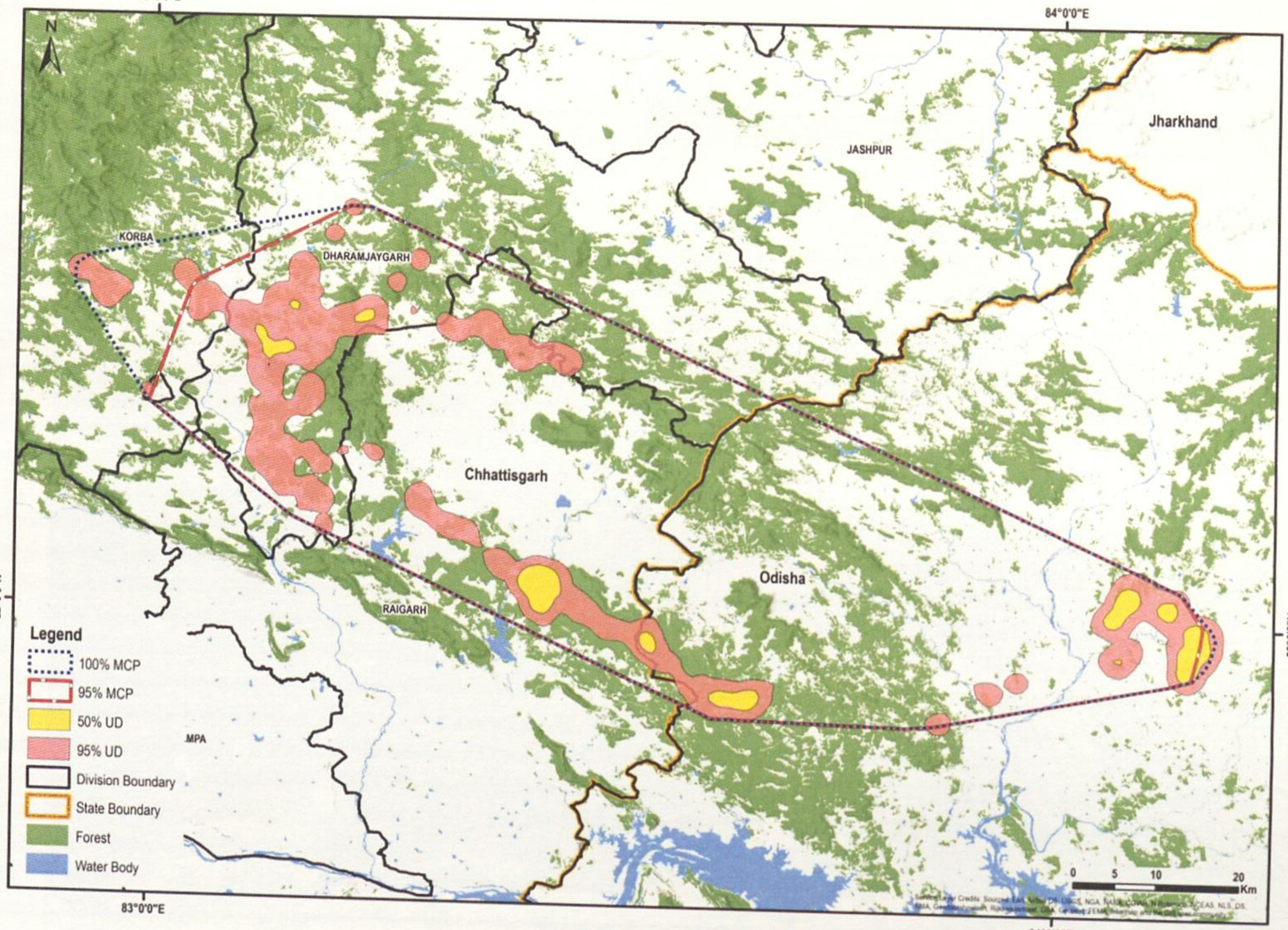


Figure 4.7: Home range distribution of elephant PT (Pratam, adult tusker)

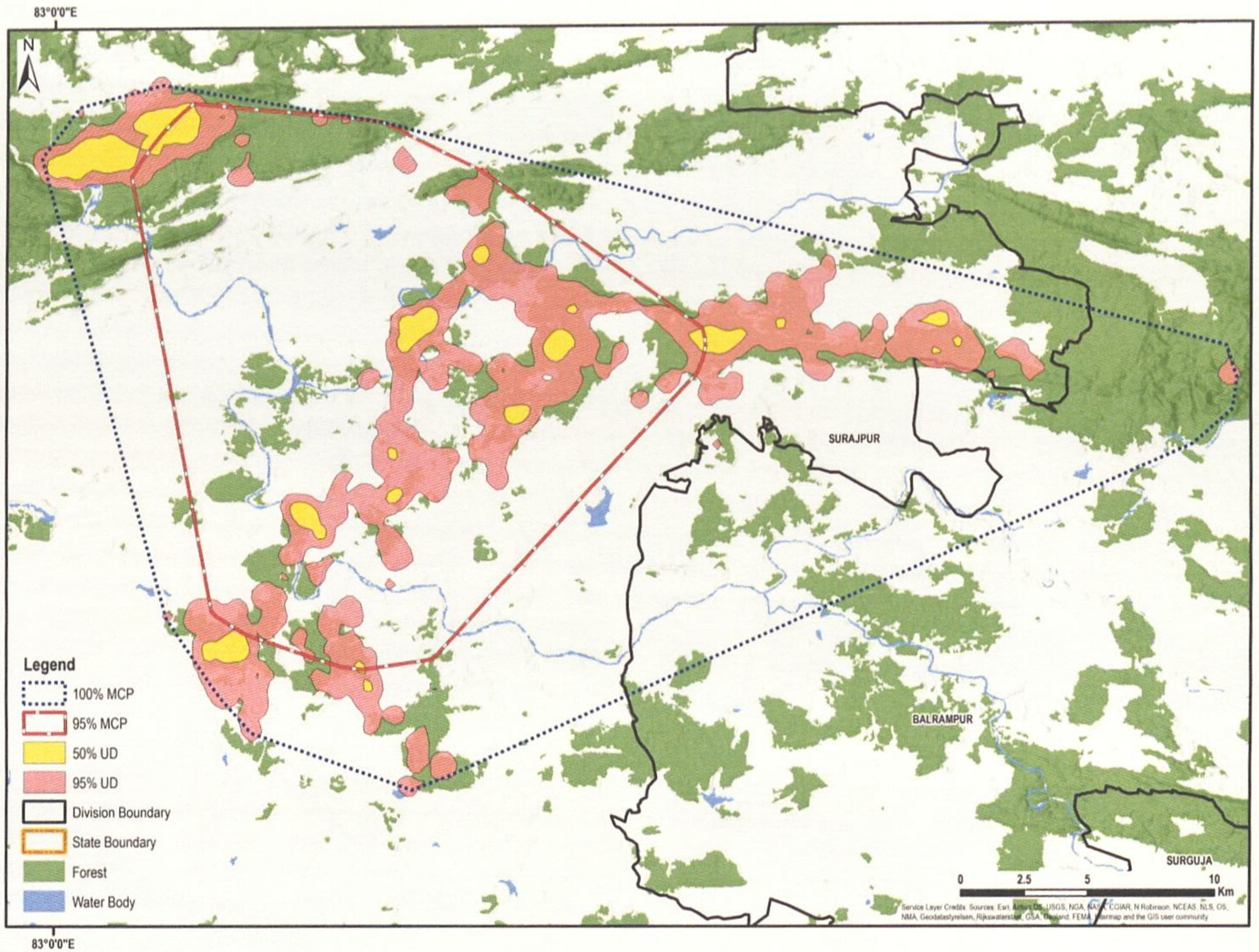


Figure 4.8: Home range distribution of elephant MT (Maitri, adult cow)

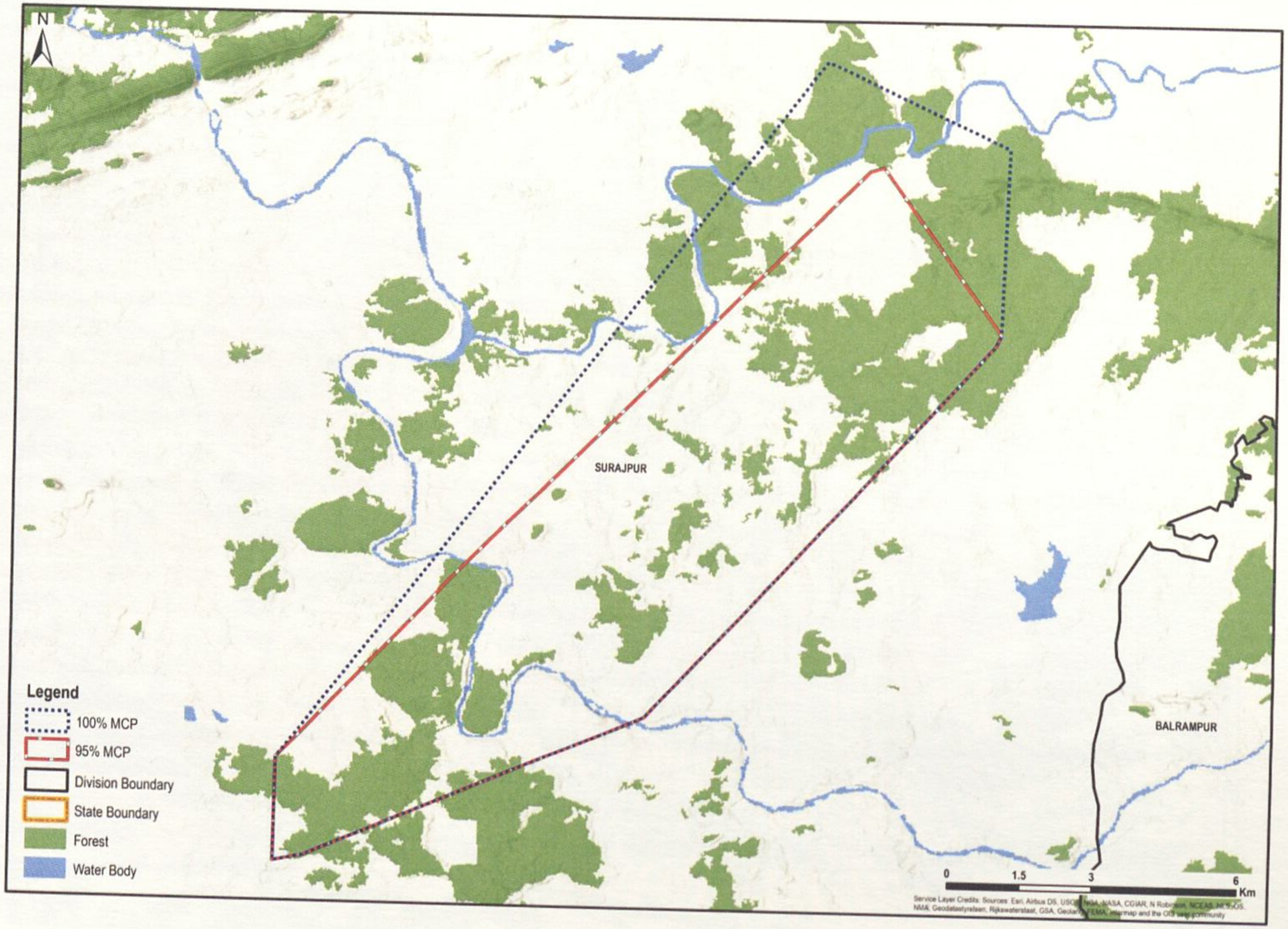


Figure 4.9: Home range distribution of elephant MI (Mohini, adult cow)

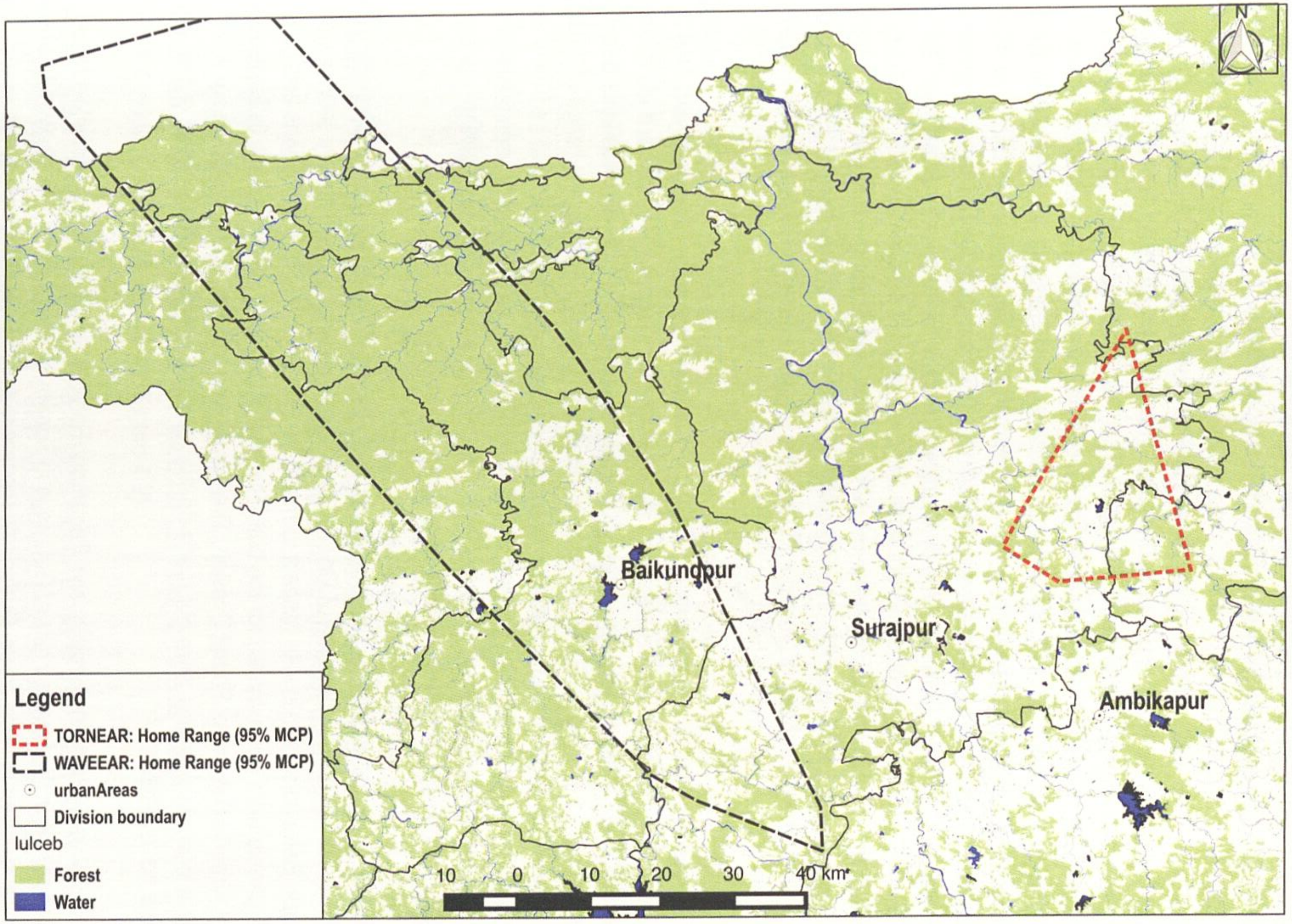


Figure 4.10: Home range distribution of elephant WE (WaveEar) & TE (Torn Ear)

4.3.4 Spatial Description of Elephant Home Ranges

The older adult bull *makhna* BD's home range (95% MCP) included 3 forest divisions namely Surajpur, Balrampur, and Surguja and also two protected areas namely Tamor-Pingla and Semarsot wildlife sanctuaries. For the latter, only the fringe of the sanctuary was used and the bull did not go into Semarsot. The intensive use area (50% UD isopleth) of the bull was limited to Rajpur range (of Balrampur FD), and parts of Surajpur, Pratappur and Gui forest ranges of Surajpur FD.

The younger adult bull GN's home range (95% MCP) included 4 forest divisions namely Raigarh, Dharamjaigarh, Korba, and Katghora Forest Divisions. The bull also exhibited "streaking behavior[2]" and traversed to Madhya Pradesh via Marwahi Forest Division (near Achanakmar Tiger Reserve). The latter division was not part of its usual range though. The bull did not use any of the protected areas. Its range also included a part of Sundargarh FD in the state of Odisha. The intensive use area (50% UD isopleth) of the bull was limited to Dharamjaigarh and Chaal forest ranges in Dharamjaigarh FD, Raigarh range of Raigarh FD; Kudumura and Kartala forest ranges in Korba FD. The younger adult bull PY's home range (95% MCP) included 4 Forest Divisions namely Surajpur, Surguja, Balrampur and Jashpur. The bull had also used Tamor-Pingla wildlife sanctuary frequently and the fringes of Semarsot wildlife sanctuary. Similar to GN, this bull too exhibited streaking behavior during *musth* and traversed into Jashpur FD for a few days and returned back to Surajpur FD. The intensive use area (50% UD isopleth) of the bull was limited to Surajpur and Pratappur ranges of Surajpur FD, Lundra range of Surguja FD and Tamor-Pingla wildlife sanctuary.

The younger cow elephant GI's home range (95% MCP) included Surguja, Dharamjaigarh, and Jashpur forest divisions in Chhattisgarh, and Sundargarh forest division in Odisha. The cowherd did not use any of the protected areas. The intensive use area (50% UD isopleth) of the cowherd was limited to Mainpat and Lakhanpur ranges in Surguja FD, Boro range of Dharamjaigarh FD, Pathalgaon range of Jashpur FD and Sundargarh FD in Odisha. The number of elephants in the group was observed to be highly variable. During dry season, when the herd is confined to forested slopes of Surguja and Dharamjaigarh FDs, the number of individuals was observed to range from 9 to 14 individuals. However, during monsoon and winter ranges, the number of individuals in the herd went up to 40.

The adult bull PT ranged in Korba, Dharamjaigarh and Raigarh Forest Divisions in Chhattisgarh and Sundargarh Forest Division in the state of Odisha. The home range of the bull clearly overlaps between the two states. Behavioral details with respect to musth period, intraspecific associations and patterns of conflict with people were not recorded for the bull. The adult female MT ranged mostly in Surajpur Forest Division and rarely in Balrampur Forest Division. The female was collared only during October 2021. Since detailed behavioral observations were not made on the herd, the details on the number of individuals in the herd were not available.

The herd WE ranged mostly in Surajpur and Balrampur Forest Divisions. During monsoon months, the herd occurred mostly in the forested hills of Gui range in Surajpur FD and Tamor-Pingla wildlife sanctuary, seldom occurring in human–use areas. During late monsoon months and the whole of winter extending to dry season, the herd occurs in Surajpur and Pratappur forest ranges in Surajpur Forest Division and Rajpur range in Balrampur Forest Division. As was the case with GI, the number of individual elephants in WE

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[2] Renowned elephant biologist Iain-Douglas Hamilton described streaking behavior in African elephants wherein elephants move greater linear distances often in rapid pace

herd was highly variable (observed range: 6 – 72) indicating significant fission and fusion in the herd. Numerous sub-adult males were observed associating with the herd particularly when the overall number of elephants increased owing to fusion of herds. The herd TE (described later) was observed to intermingle with the WE herd during the winter months. The herd TE had the largest home range in Chhattisgarh. The herd ranged in Sanjay Tiger Reserve in Madhya Pradesh and Guru Ghasidas National Park in Chhattisgarh. The herd also ranged in Koriya, Surguja, Surajpur, and Balrampur Forest Divisions in Chhattisgarh. During winter, the herd intermingled with WE herd and ranged in Surajpur and Balrampur Forest Divisions. The observed number of individuals in the herd varied significantly. Before its fusion with WE herd, the number of individuals in the TE herd ranged from 7 – 14.

4.3.5 Home Range Stabilization

The cumulative home ranges have been estimated across months 100% MCP and plotted sequentially against tracking duration (Fig-14.11). In general, the time-area curve as depicted in Figure 4.13 indicates that other than BD1 and BD2 (both pertain to the same bull tracked during different periods) and MT, the home ranges of other elephants were not well defined. Even after five to six months of satellite tracking data, the monthly home ranges did not asymptote.

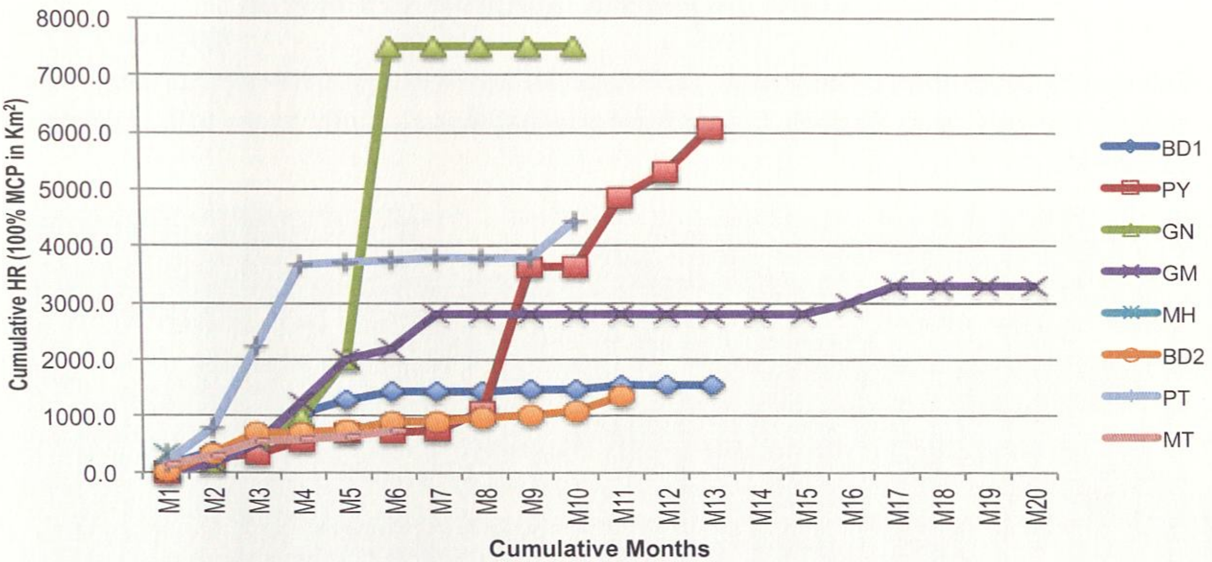


Figure 4.11: Time-area curve indicating cumulative increase in home ranges (100% MCP) of elephants' satellite collared in Northern Chhattisgarh

4.3.6 Monthly and Seasonal Range Areas

4.3.6.1 Mean Monthly Range Areas

The monthly range areas of elephants in collared in Chhattisgarh are as follows (shown only for elephants that were followed for longer duration) (Figure 4.2).

The average monthly range areas of the collared elephants were 57.9 (SD ± 48.1), 129.9 (SD ± 101.4), 138.4 (SD ± 248.5), 37.5 (± 46.0), 48.4 (±17.0), and 96.8 (±91.8) for BD (older bull), PY (young bull), GN (young bull), GI (young cow in a herd), MT (young cow in the herd), and PT (older bull) respectively. From Figure 4.14, it is evident that the average monthly range areas of the larger bull BD are lesser than that of the two of the younger bulls PY and GN.

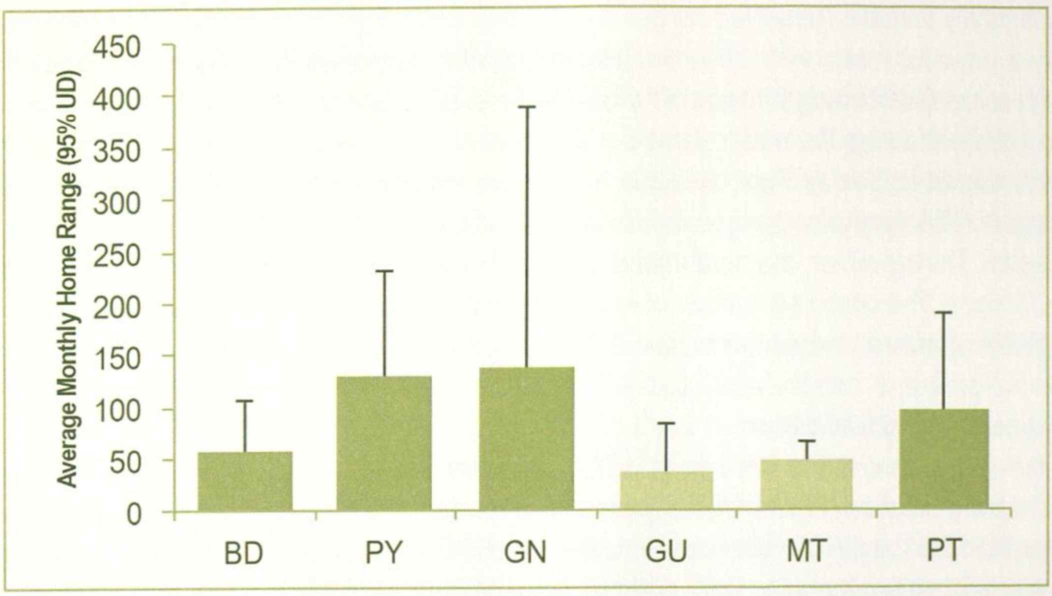


Figure 4.12: Average monthly home ranges (95% UD) of elephants collared in Chhattisgarh. Blue bars: Bull elephant, Orange bar: Cow elephant

The monthly range areas of the young bulls PY and GN were strikingly similar although they occurred in spatially separate areas. Similarly, the monthly home ranges were similar for the both the female herds GU and MT.

4.3.7 Seasonal Home Ranges

The year was divided into three seasons namely '*Dry*' (March – June), '*Monsoon*' (July – September) and '*Winter*' (October – February) and range areas (measured as 95% UD) were calculated for all the three seasons for the satellite-collared elephants (Table 4.4). The dry season ranges of elephants were significantly lower than ranges during the monsoon and winter seasons (KW chi-squared = 6.02, df = 2, P = 0.04). The dry season range is only about 28.8% (SD±22.05%) of the annual ranges for all the elephants collared and monitored. For the cow elephant GI, the dry season range of 25.5 km2 is just 5% of its annual range. The monsoon and winter ranges of elephants are comparatively much higher (Table 4.4).

Table 4.4: Seasonal range size estimates (95% UD) for satellite collared elephants having longer tracking duration (Data of elephants MH, MI and KM excluded from analysis)

S. No	Elephant ID	Home Range (95% UD) in km2	Range size (95% UD) in km2		
			Dry	Monsoon	Winter
1	BD1	281.7	95.5	135.4	215.1
2	BD2	246.3	156.4	275.2	159.6
3	GN	748.9	151.4	132.3	931.0
4	GI	605.3	25.5	291.1	275.0
5	PY	662.9	149.6	626.8	377.0
6	PT	714.4	Data available for short duration		
7	MT	126.5	Data available for short duration		

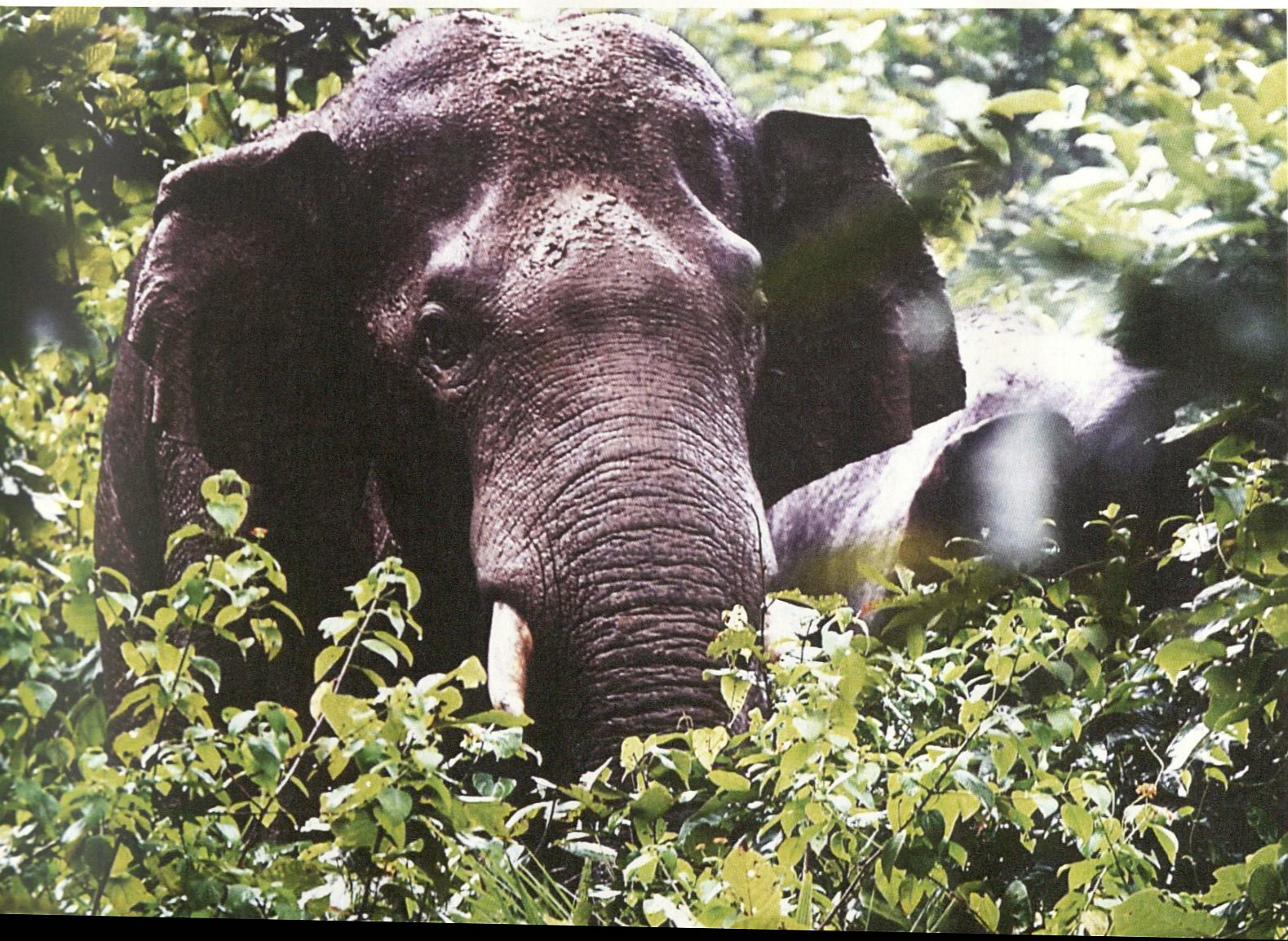
4.3.7 Seasonal Range Overlap

The seasonal extent of overlap of range areas is provided in Table 4.5. For the older big bull (BD), the seasonal range overlap was over 50% for all the seasons. For the younger adult bulls GN and PY, the average overlap was less than 18% for all seasons. For the adult cow GI from the herd, the overlap was 17.9% for monsoon and winter ranges and 6.4% for monsoon and dry season ranges. The range areas of the cow GI were completely different for dry and winter seasons.

Table 4.5: Seasonal range overlap (estimated based on 95% MCP) of satellite collared elephants in Northern Chhattisgarh

S. No	Elephant ID	MW	MD	DW
1	BD1	44.9%	38.3%	46.9%
2	BD2	56.8%	69.0%	68.6%
3	GN	9.9%	25.2%	9.4%
4	GI	17.9%	6.4%	0%
5	PY	20.7%	8.1%	26.5%
6	PT			
	Average	**30.04%**	**29.4%**	**30.2%**

MW: Monsoon/Winter, MD: Monsoon/Dry, DW: Dry/Winter. Only for the above 6 elephants were three season ranges obtained.



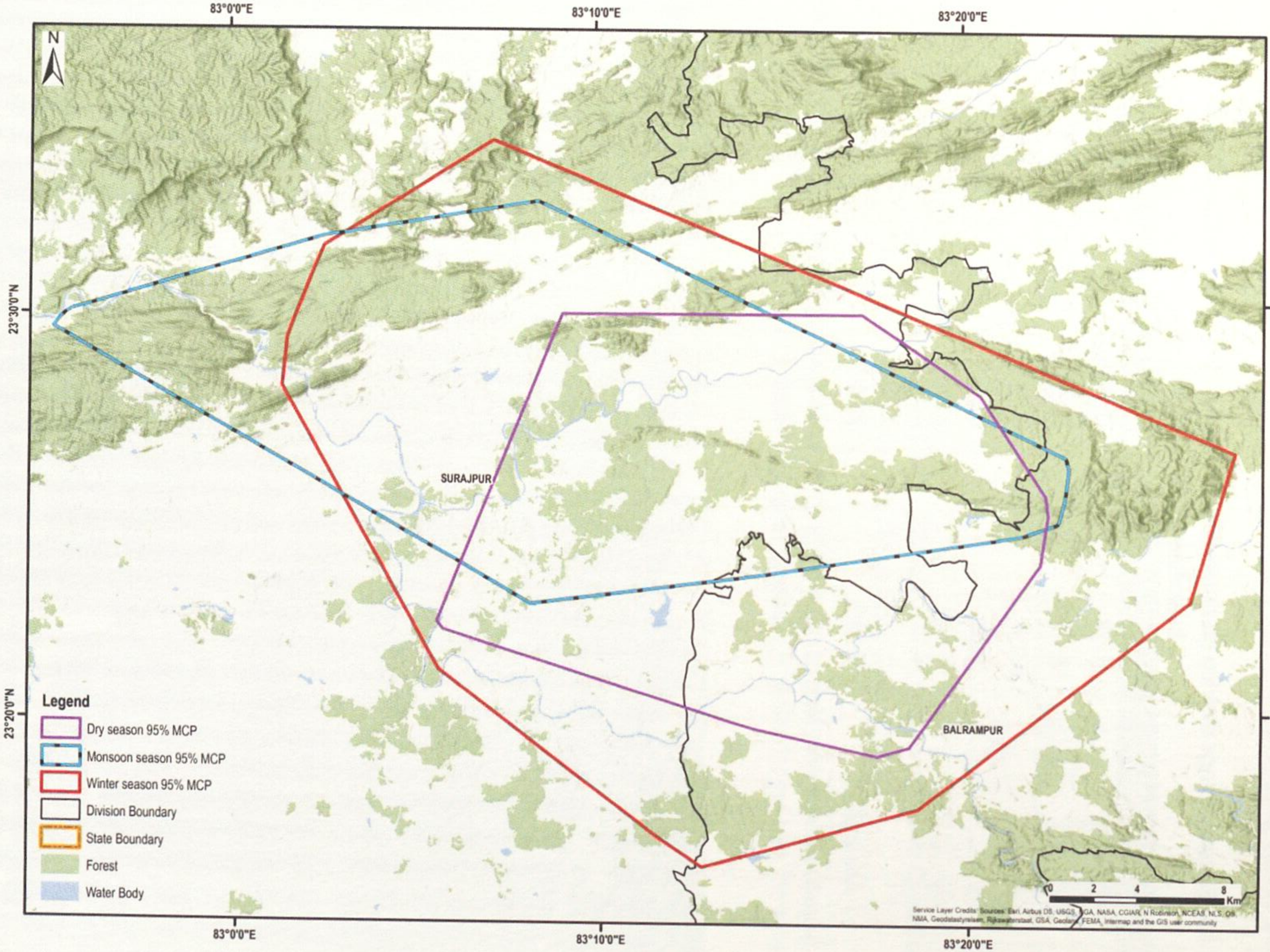


Figure 4.13: Seasonal home ranges for BD1

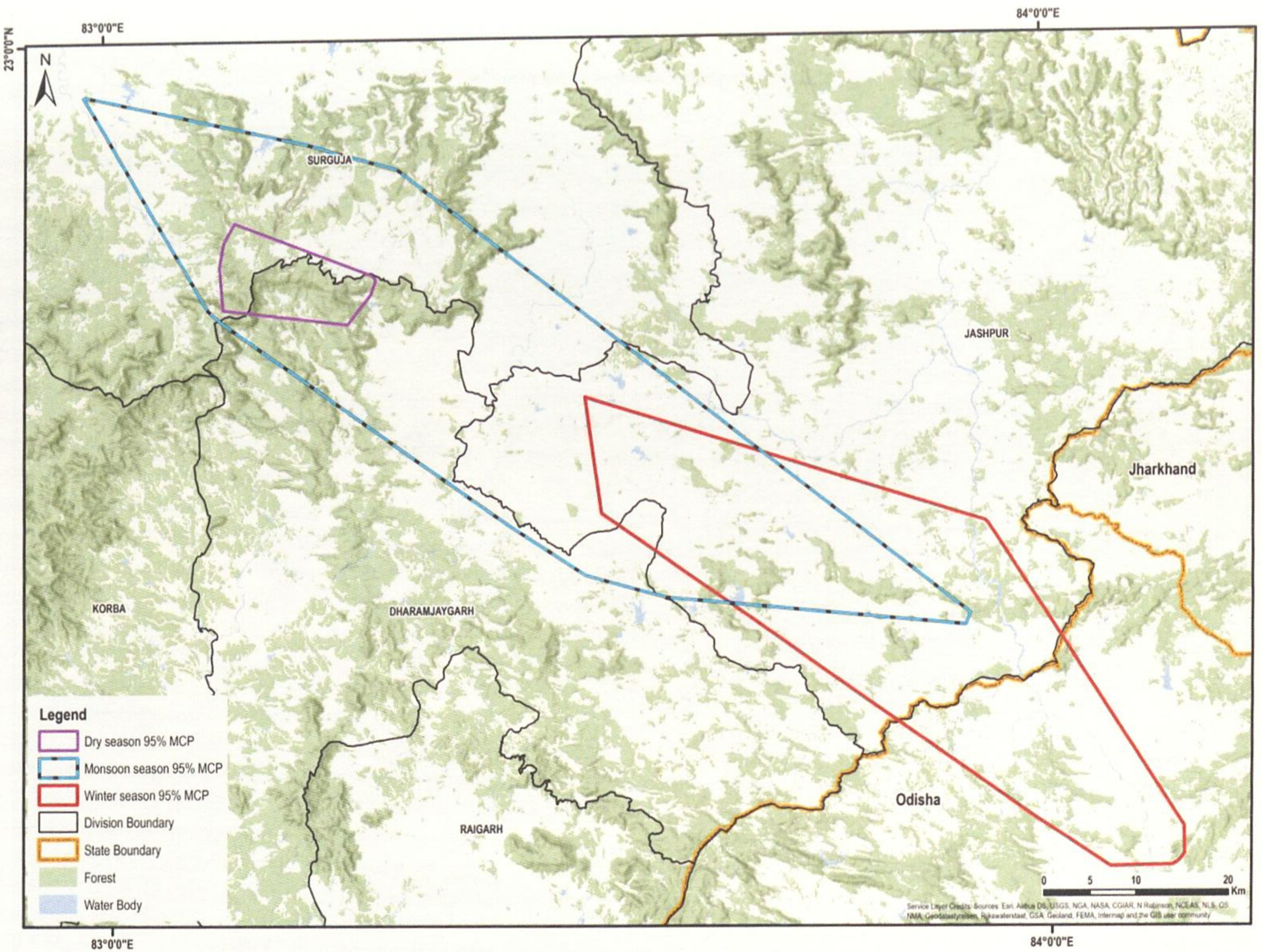


Figure 4.14: Seasonal home ranges for GI

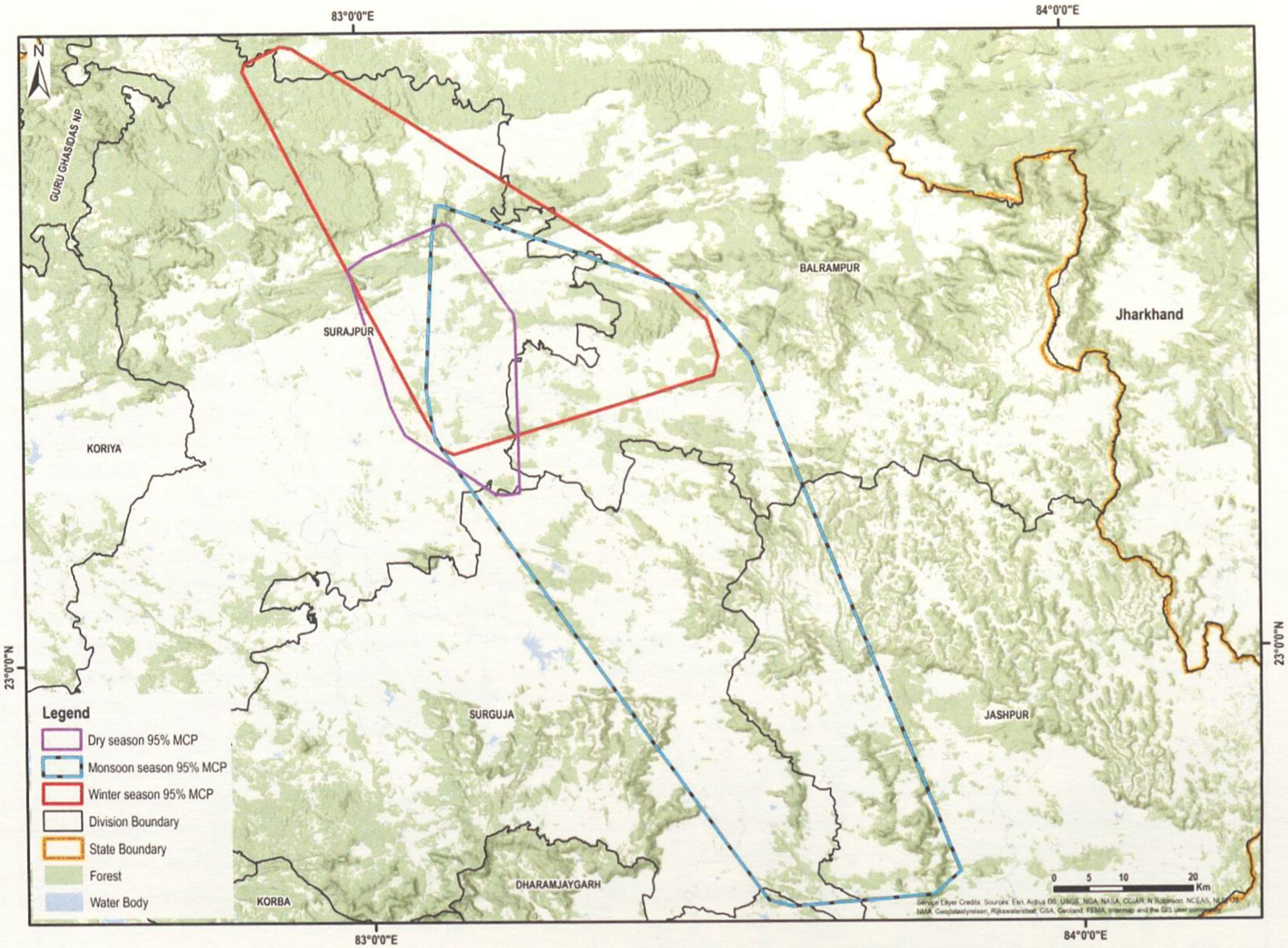


Figure 4.15: Seasonal home ranges for PY

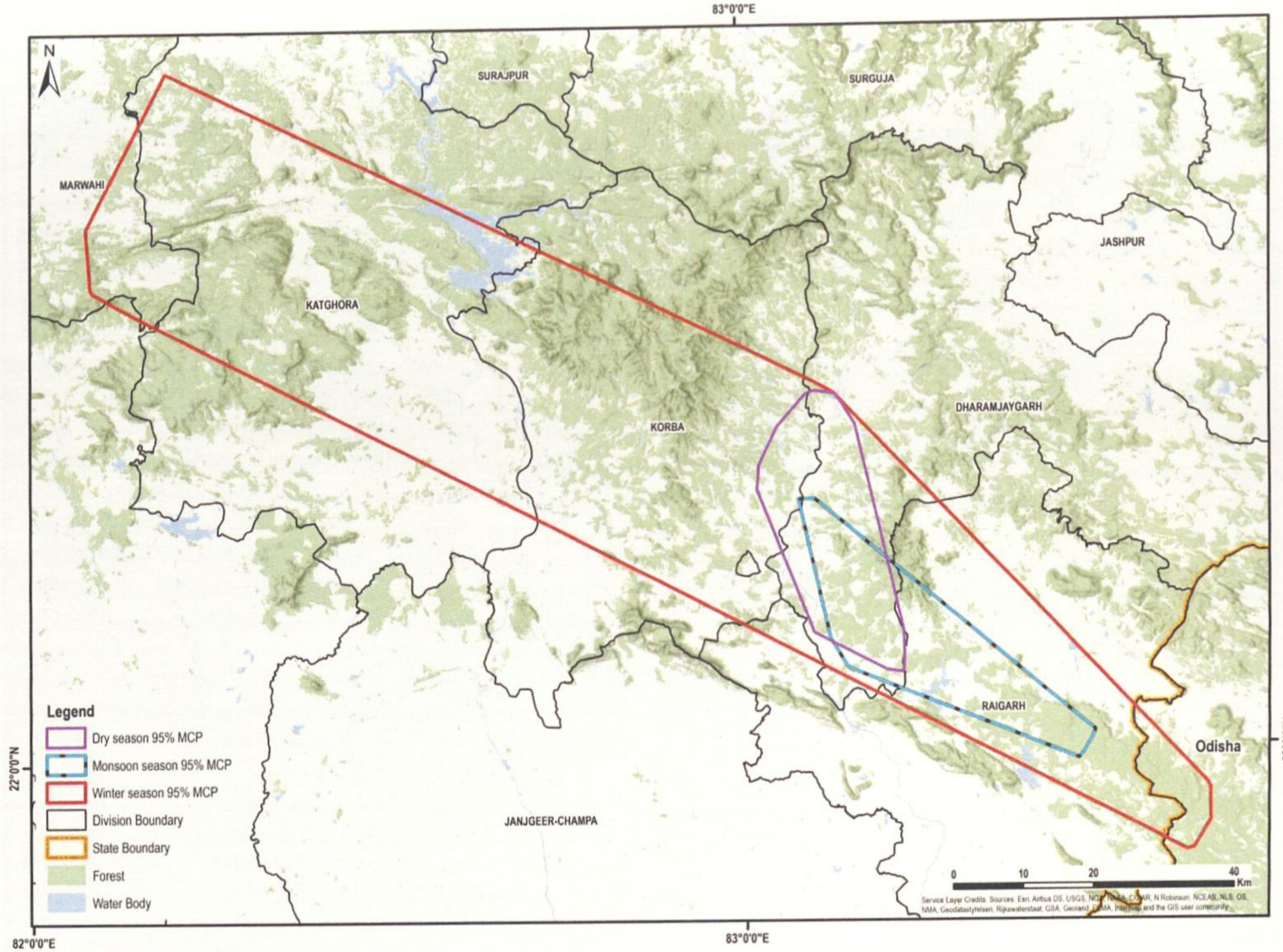


Figure 4.16: Seasonal home ranges for GN

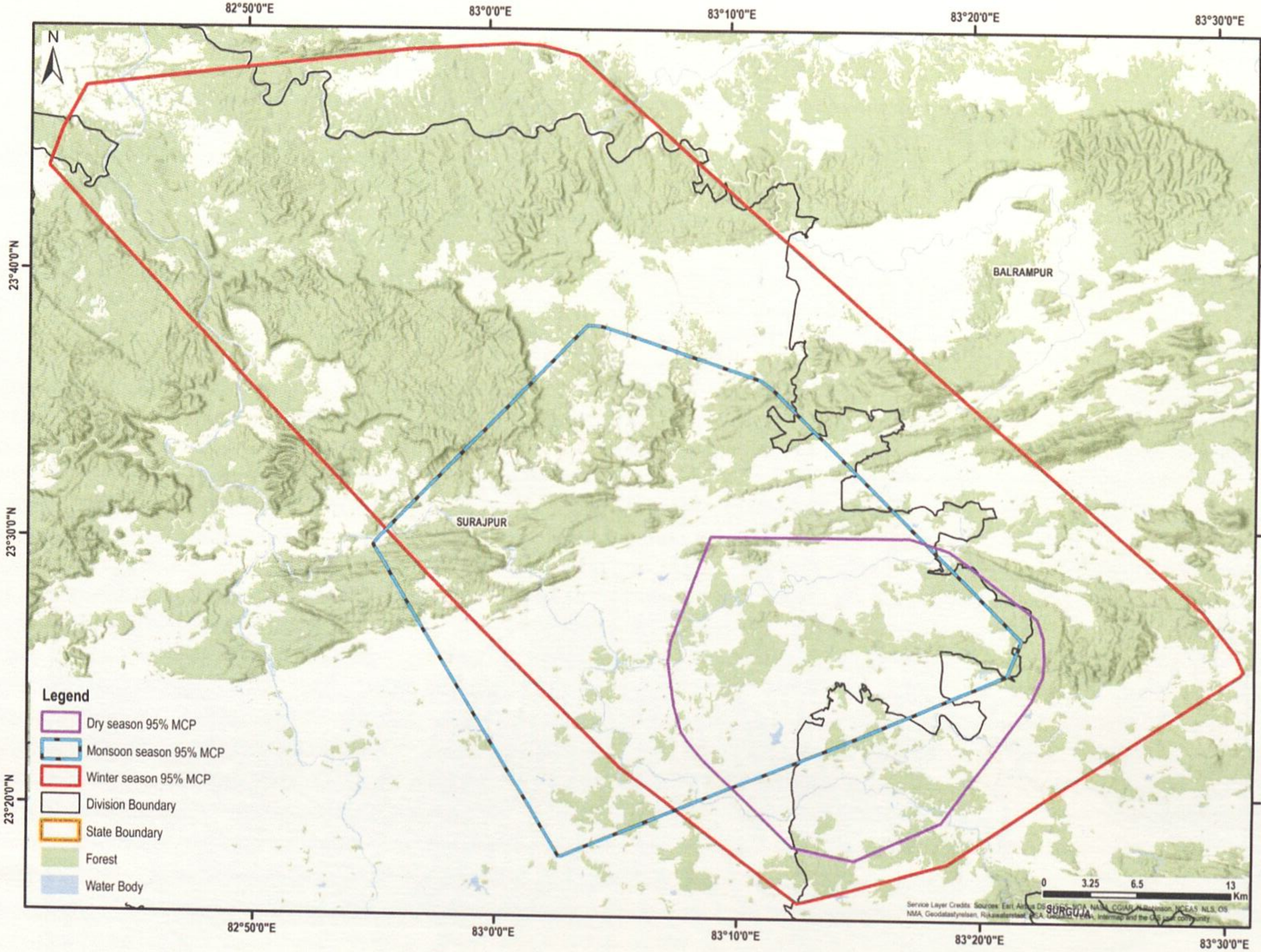


Figure 4.17: Seasonal home ranges for BD2

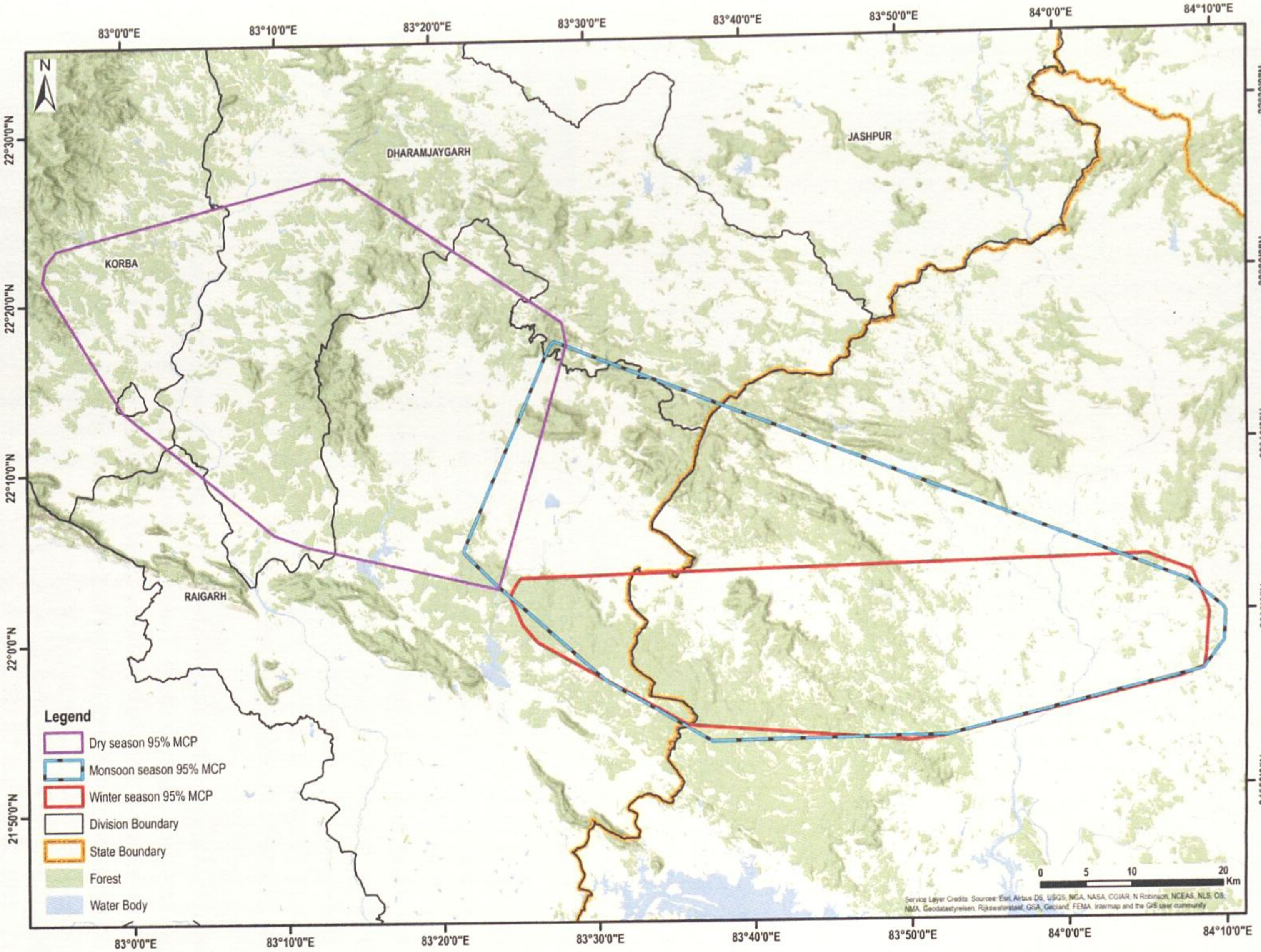


Figure 4.18: Seasonal home ranges for PT

4.3.8 Inter-Annual Variations in Home Ranges

The inter-annual comparison in home ranges was made for two of the collared elephants for which data was available for two different years. For the elephant BD (Behradev, adult bull *makhna*, > 40 years), the overlap in ranges for the period 2018-2019 and 2019-2020 was 73.5%. For the female herd GI, the overlap in ranges for the period 2018-2019 and 2019-2020 was 56.5%.

Box 1: The issue of collars falling-off elephants

The 10 elephants' radio-collared in Chhattisgarh provided data for an average of 310.6 (±284) days. Only three elephants (two cow elephants and a bull) provided data for less than a month. All the other elephants provided data for over 200 days. Weak belting was initially identified as an issue with collars received during the first consignment and the manufacturer reinforced the belt in subsequent consignment. The collars received during first consignment were also reinforced with new belts. For some of the elephants, the collars were kept deliberately loose considering the elephants' relatively young ages. Contrary to commonly held misbelief, elephant collars have limited life with either battery draining soon or belt wearing out.

4.4 Discussion

Using both telemetry and re-sighting-based approaches, elephant home ranges were estimated for six bulls (one was a re-collar) and six female herds in Chhattisgarh during the period May 2018– March 2022.

4.4.1 Elephant Home Ranges in Chhattisgarh

The home ranges sizes estimated in the study using MCP approach was higher than Kernel UD estimates. On an average, the (95%) Kernel UD estimates were less than 22% of the (95%) MCP estimates. This indicates that a large fraction of areas within MCP home ranges remain unused by elephants. In fragmented landscapes, animal home ranges would encompass patches embedded in unused areas resulting in inflated MCP home ranges (Mitchell & Powell, 2008). While 95% Kernel UD estimates may reflect the actual range area of elephants, the areas outside of intensive habitat use that elephant use for crop foraging and movement between patches may not reflect in the UD ranges. Therefore, from management point of view, understanding both MCP and UD ranges would be useful, as MCP can be viewed as the geographic space in which animals occur, and the UD ranges represent use of habitats within the geographic space (Moorter *et al.,* 2016).

The elephant ranges in Chhattisgarh often encompass multiple forest divisions and protected areas and also span across neighboring states. The home range estimates (95% MCP) of elephants in Chhattisgarh were in general higher than elephant home ranges reported from other landscapes (Table 4.6). The home range comparisons often do not account for terrain complexities. A relatively small 2-dimensional elephant home range in the hilly region may actually be comparable with a larger home range in the flatter region. Therefore, spatial distribution of home ranges that includes the underlying terrain factors, habitat quality including productivity, and competition (both intra-specific and inter-specific) may determine elephant home ranges (Sukumar, 2003). As elephant home ranges in Chhattisgarh are distributed in the mosaic of forest patches embedded in agricultural areas, they are predictably large and adding to the effect is that the home ranges appear poorly defined marked by shifts.

Table 4.6: Estimated elephant home ranges (using either 95% or 100% MCP) from different landscapes across India

S. No	Landscape	Sex	Home Range (in Km2)	Method	Fragmentation	Source
1	Buxa, North Bengal	Female	696	Telemetry	High	Sukumar *et al.*, 2003
2		Female	293			
3		Female	701			
4		Female	695			
5		Bull	180			
6		Bull	179			
7		Bull	444			
8	Rajaji, Uttarakhand	Bull	407	Telemetry	Low	Williams, 2005
9		Bull	188			
10		Bull	254			
11		Female	183			
12		Female	326			
13		Female	306			
14		Female	251			
15	BR Hills / Sathyamangalam	Female	240	Re-sighting	Low	Sukumar, 1985
16		Female	250			
17		Bull	320			
18		Bull	170			
19		Bull	215			
20	Mudumalai, Western Ghats, TN	Female	232	Telemetry	Low	Desai, 1991
21		Female	111			
22		Female	265			
23		Bull	199			
24		Bull	243			
25		Bull	168			
26	South Bengal	Female	3368	Re-sighting	High	Singh (2006)
27	Mudumalai, Western Ghats, TN	Female	464	Telemetry	Low	Baskaran & Desai
28		Female	382			
29		Female	288			
30	Hosur, Eastern Ghats, TN	Female	302	Re-sighting	Low	Kumar, 1994
31		Female	224			
32		Bull	876			

4.4.2 Shift in Home Range Across Years

Repeated use of the same areas is known to confer fitness benefits to animals owing to familiarity of areas, knowledge about microhabitats, and threats. Such recurrent use of areas will eventually result in consistent home ranges as animals begin to obtain and store cognitive maps of the landscape. Thus, animals tend to exhibit fidelity to home ranges (Powell, 2008). Conversely, fidelity to areas can be used to infer animal home ranges. The function of spatial memory helps in keeping home ranges intact (Moorter *et al.*, 2009; Moorter *et al.*, 2016; Fagan *et al.*, 2013; Ranc *et al.*, 2020). Elephants – both African and Asian exhibit considerable fidelity to their home ranges (Baskaran, 1998, Kumar, 1995; Goldenberg *et al.,* 2018). However, elephants may alter movement and shift ranges in response to novel pressures. For example, in Samburu, East Africa, loss of adult females in the clans led to major range shifts (Goldenberg *et al.,* 2018). Range shifts or unstable home ranges often manifest through drifts away from previously used areas (Moorter *et al.,* 2009). In Chhattisgarh, time-area curve of home ranges plotted against months indicates that other than the older bull BD, the home ranges of other individuals remain relatively less defined. The observed inter-annual shift in home ranges was minimal for the older bull BD, but high for the herd GI. Thus, longer duration of monitoring elephants would be required to confirm if the observed range areas are indeed set elephant home ranges.

4.4.3 Monthly and Seasonal Home Ranges

The monthly ranges (as measured in 95% UD) were relatively smaller for the older adult bull BD and the female herd GI, but considerably larger for the young bulls GN and PY. With respect to seasonal range areas, the dry season ranges of elephants were significantly lower than the monsoon and winter ranges. For the female herd GI, the dry season range was just 5% of its overall home range. During dry season, the herd comprising about 9 – 14 elephants remained in 25-km2 of forested habitat along the slopes of Mainpat in Surguja and Dharamjaigarh forest divisions. These slopes drop down from the Mainpat plateau and support luxuriant vegetation including several species of browse plants and perennial springs flowing down from the plateau even during dry season. This indicates that habitat quality in some of the forest patches – particularly those that are large and contiguous with minimal of human interference can potentially support elephants in the landscape. Thus, dry season ranges of elephants could serve as a surrogate for habitat quality (Sukumar, 1989; Sukumar, 2003). Habitat management efforts in Chhattisgarh can benefit from understanding habitat quality – in terms of fodder and water resources in GI's dry season range. The advent of monsoon and subsequent winter seasons mark the availability of standing crops in the landscape. During monsoon and winter months, elephants range areas measure over 50% of their annual range as crop foraging in Chhattisgarh is widely scattered and not concentrated to few sites.

4.4.4 Use of Corridors by Elephants

Identifying and restoring corridors is often a cornerstone in conservation of wildlife populations in highly fragmented habitats. Corridors may facilitate daily and seasonal migrations and also periodic dispersal of animals to maintain population and genetic connectivity. Corridors are easy to identify within landscapes where the difference between habitat and non-habitat is clear (Sukumar *et al.,* 1998; Johnsingh *et al.,* 2006; Menon *et al.,* 2017). However, in areas where the difference between habitat and non-habitat is diffuse, as is the case in northern Chhattisgarh, identifying corridors can be challenging. Here, the elephant landscape is a hinterland of forest patches interspersed with settlements and agriculture. Stark differences in the overall structure as well as levels of human occurrence between forests and non-forests do not exist in the rural areas, as agriculture is still highly marginal and seasonal in most areas. Thus, the landscape appears to offer minimal resistance for elephants to move, especially in the cover of the night. There are numerous forest patches, scrubland, forest plantations and uncultivated fallow lands that could serve as daytime habitats for elephants. Night-light in the landscape continues to be minimal compared to many other states in the country, which are more economically developed. These conditions may facilitate free movement of elephants in Chhattisgarh. To illustrate, the GI herd's movement trajectory (both onward and return) from Dharamjagarh FD to Sundargarh FD in Odisha did not follow the identified structural corridor (Menon *et al.,* 2017), but followed a different route outside of forests through crop fields. Thus, defining and maintaining elephant corridors in Chhattisgarh would require a data-driven approach

(Vasudev *et al.,* 2021) but also be extremely challenging in terms of management. It must be remembered that "corridors" should not serve to perpetuate elephant-human conflicts.

4.4.5 Elephant Dispersal Patterns

In most large mammals, females are philopatric, and are concerned with securing resources and ensuring offspring safety, while males disperse to maximize their reproductive fitness (Greenwood, 1980; Sinclair *et al.,* 2006; Ahlering *et al.,* 2012). Contrarily, 'environmental dispersals can occur due to resource saturation and mediated by density dependent mechanisms (Howard, 1960; Sinclair *et al.,* 2006). For the past few decades, elephants in the East Central region have been faced with deteriorating habitat conditions (Singh *et al.,* 2002; Singh and Chowdhury, 2006). This apparently had triggered major redistribution of elephants across the entire east-central region marked by frequent immigrations or dispersals. In general, the dispersal distance of mammals is related to its home range size (Bowman *et al.,* 2002). The larger the home range, the greater the distance dispersed (Bowman *et al.,* 2002). Thus, the observed large home ranges are one of the major reasons for long-distance dispersal of elephants in Chhattisgarh. During the period of study, a few such long-distance dispersals were anecdotally recorded. Some of them include:

i. During September 2018, a herd of elephants dispersed into Bandhavgarh tiger reserve (BTR) in Madhya Pradesh from Chhattisgarh. Among the elephants that dispersed, 8 individuals were photo-captured earlier in Korba, Koriya, Katghora and Dharamjaigarh forest divisions in Chhattisgarh. As on April 2022, the herd still occurs in and around BTR.
ii. During August 2018, a herd of five elephants that were earlier identified from Surguja FD dispersed into buffer zone of Sanjay tiger reserve in Madhya Pradesh. This herd comprised of an adult cow, sub-adult cow, two sub-adult bulls and a juvenile bull. Owing to conflict reasons, the Madhya Pradesh forest department captured all the five individuals.
iii. During the year 2020, two young bulls reportedly from Odisha dispersed into Mahasamund in Chhattisgarh and then onwards traversed widely covering the forest divisions of Rajnandgaon, Dhamtari, and Gariyaband in Chhattisgarh, Gondia district in Maharashtra and reached Kanha tiger reserve, Madhya Pradesh. One of the two bulls got electrocuted in Balaghat district of Madhya Pradesh and the other bull was captured and moved to captivity by Madhya Pradesh forest department.
iv. During August 2018, an adult cow and a sub-adult bull photo-captured in Surguja Forest Division dispersed into Korba Forest Division. The sub-adult bull was electrocuted.
v. Wildlife-SOS had collared a female elephant from a herd of 22 elephants during September 2018 in Mahasamund forest division, Chhattisgarh. This herd dispersed into Gadchiroli forest division in Maharashtra (Wildlife-SOS, 2021).

Other similar unrecorded elephant dispersal events in the landscape were plausible. From the above, it is evident that many elephant immigration events ended-up as failed dispersals if the small-population paradigm (Channell & Lomolino, 2000) is invoked. Further to this, such dispersals also result in heightened human–elephant conflict. Therefore, monitoring elephant dispersals would be critical in the landscape.

CHAPTER-5
HABITAT SELECTION PATTERNS BY ELEPHANTS

5.1 Introduction

The tropical forested habitats of Asian elephants undergo seasonal fluxes in the resource distribution (Natarajan *et al.,* 2015). In the relatively drier tracts, surface water and pre-formed water sharply decline during dry season (Natarajan *et al.,* 2015). These natural seasonal rhythms in resource availability drive differential use of habitats by elephants (Sukumar, 1989, Baskaran, 1998, Natarajan *et al.,* 2015). In addition to environmental, biotic influences like inter-clan dominance hierarchies and resultant competition can result in differential habitat selection by elephants (Desai, 1991). Furthermore, in addition to natural factors, human impacts on the habitat can exert an overriding influence in determining spatial distribution of elephants (Desai & Baskaran, 1996). Elephant–habitat interactions have been extensively researched in Asia as the topic is of immediate relevance for the management (Sukumar, 1989; Desai & Baskaran, 1996; Jathanna *et al.,* 2015; Natarajan *et al.,* 2016). From these studies, general patterns and major determinants of elephant habitat selection can be inferred. However, site-specific information is crucial to better understand and manage elephant habitats.

Wildlife–habitat relationships can be examined at different spatial and temporal scales (Morrison *et al.,* 2003). Among the host of metrics used in assessing wildlife–habitat relationships, habitat selection by animals is a hierarchical process that involves behavioral decision-making aimed at increasing fitness benefits (Krausman, undated manuscript). Habitat selection can be assessed using several approaches that collectively compare habitat-use by animals with resources available for them (Manly *et al.,* 2002). Johnson (1980) provided a framework elucidating "four orders of selection" based on hierarchical classification to study habitat selection. The four orders include the first-order selection defined as selection of geographic range among the available options, the second order is defined as selection of home ranges within the geographic range, the third order is defined as habitat-use within home ranges, and the fourth order pertains to selection of micro-habitats at finer spatial scales (Johnson, 1980). Akin to the clarity provided by Johnson (1980) on the orders of habitat selection, Thomas & Taylor (2002) suggested three sampling designs relevant for assessing wildlife–habitat relationships. Among the three sampling designs, under design III, use of habitat within home ranges is compared with the availability of resource units within habitats (Manly *et al.,* 2002). Using this framework, the aim of this chapter is to assess patterns of habitat selection by elephants in northern Chhattisgarh. Additionally, habitat-use by elephants across different seasons has been assessed and implications for management were discussed.

5.2 Methods

Ten elephants were immobilized and fitted with GPS satellite collars programmed to provide location fixes at one-hour interval. The collared elephants were monitored during the period May 2018 to March 2022, for different durations. Among the 10 collared elephants, seasonal use of different habitats was assessed for 7 elephants that provided data for longer duration. Habitat selection was assessed only for five elephants that provided data for longer duration (>250 days).

The elephant MT was not included considering shorter duration of the data (the collar is still active though). Similarly, the elephant PT was never followed as the bull spent considerable time in Odisha forests and therefore not included in the analysis. The five elephants included GI (adult cow of the herd) and the others were bulls (BD1, BD2, PY and GN).

Home ranges were estimated using both MCP and Kernel UD approaches. By combining the 100% MCP areas of five satellite collared elephants BD1, BD2, GN, GI and PY, the sampling measuring 20,990-km2 frame was created in GIS. Within the sampling frame, 1-km2 grids that serve as spatial sampling units, were overlaid. The grid size selection was based on the combined potential impact of the environmental variables, which were readily available at 1-km2 resolutions. Habitat selection by elephants was assessed following "use" vs "availability" approach. The collar GPS fixes falling within the grid indicate "use". The extent of environmental variables used in the models indicates "availability". The environmental variables used in the models included (1) extent of open forest in the grid (2) extent of moderately dense forest in the grid (3) extent of very dense forest in the grid and, (4) extent of rivers in the grid. The variables open forest; moderately dense forest and very dense forest were extracted from the forest cover layer of the Forest Survey of India available at 30-m resolution (FSI, 2009).

In addition to habitat selection by elephants, the proportional use of forest, crop fields and other habitats was descriptively evaluated across three different seasons. The seasons included dry (March to June), monsoon (July to September) and winter (October to February). The variables of forest cover, agriculture, still water, rivers, urban and rural built-up were extracted from 10-m resolution land-use land-cover layer developed by NRSC–IIRS, Nagpur for northern Chhattisgarh.

Habitat selection by elephants was assessed using generalized linear models (GLM) by quantifying the influence of potential explanatory variables on the response variable. However, because elephant MCP home ranges encompassed areas that elephants did not use, there were many zero entries that caused over-dispersion of the counts in the response variable. Over-dispersion in the response variable is a violation of assumptions of Poisson distribution that assumes population mean equivalent to its variance. Negative binomial regression that accounts for over-dispersion of counts during the modeling process itself was used for analysis. Model selection was done based on information-theoretic approaches by comparing plausible models with intercept-only models (Burnham & Anderson, 2002). The variable significance and ranking were done using P-values (indicating significance) and Z scores of each variable, wherein higher relative scores indicate better explanatory power of the variable. The regression analysis was carried out in program R (R Core Development Team, 2019) using the package MASS.

5.3 Results

5.3.1. Seasonal Habitat-use Patterns

During dry season (March to June), elephants have spent an average of 80.8 % (± 8.6) of their time in the forests, while 14.0% (± 7.0) of time was spent in the crop fields and about 5.2% (± 3.0) of time was spent in other areas. The other areas indicate rivers and streams, water holes and vicinity of settlements. Unlike the bulls, the female herd of GI spent the dry season completely within forests, seldom venturing into human–use areas (Table 5.1). This pattern was observed for the family herd of GI for two years of 2019 and 2020. The family herd of MT did spend considerable time in the crop fields during dry season too. However, the data on MT is still coming on and the tracking has been done only for a shorter duration of time. Thus, accumulating data for longer duration would be essential for comparing the patterns for both the family herds of MT and GI.

During monsoon (July to September), elephants have spent an average of 79.9% (± 3.2) of time in the forests and about 15.4 % (± 3.6) of time in the crop fields. Even the female herds of GI spent about 13.6% of time in the crop fields unlike that of the dry season when they were confined to the forests (Table 5.1). The seasonal use of habitats during the winter months (October to February) was comparable with that of monsoon months. During winter, elephants have spent an average of 79.8 % (± 7.8) of time in forests, 15.3% (± 8.3) of time in the crop fields, and 5.0 % (± 1.3) of time in other areas (Table 5.1).

Table 5.1: Seasonal use of forests, crop fields and other habitats by satellite collared elephants in Chhattisgarh during May 2018 to March 2022

Ele ID	Forest (in %)			Agriculture (in %)			Others (in %)		
	Dry	Mon	Win	Dry	Mon	Win	Dry	Mon	Win
BD1	74.8	79.2	69.6	20.7	18.0	26.2	4.5	2.8	4.2
BD2	77.0	80.3	80.0	19.1	15.0	15.6	3.8	4.6	4.0
PY	73.2	78.2	71.2	18.6	17.7	22.9	8.2	4.1	5.9
GN	81.7	75.0	79.6	11.2	19.0	13.7	7.1	6.0	6.7
PT	79.5	83.5	93.1	11.7	9.2	0.1	8.7	7.2	6.7
MT	80.8	NA	83.4	16.1	NA	14.7	3.7	NA	3.7
GI (cow)	99.2	83.2	81.9	0.5	13.6	13.8	0.3	3.2	4.3
Average (± SD)	**80.8 (8.6)**	**79.9 (3.2)**	**79.8 (7.8)**	**14.0 (7.0)**	**15.4 (3.6)**	**15.3 (8.3)**	**5.2 (3.0)**	**4.6 (1.7)**	**5.0 (1.3)**

Dry: Dry season (March – June) Mon: Monsoon (July – September), Win: Winter (October – February)

5.3.2. Habitat Selection Patterns

Within their home ranges, elephants predominantly selected forested habitats over other major land-use forms like agricultural crop fields. The variable Rivers did not emerge significant in explaining the observed variations in elephant habitat selection (Table 5.2). Among the three categories of forests classified by Forest Survey of India (FSI, 2009), elephants selected open forests over moderately dense and very dense forests (Table 5.3).

Table 5.2: Summary of model selection results to explain habitat selection by elephants in Chhattisgarh using negative binomial regression

Model*	AIC	DAIC
HabSel~MDF+OF+VDF+Riv	27611	0
HabSel~OF	27735	124
HabSel~VDF	27741	130
HabSel~MDF	27752	141
HabSel~1 (Intercept only)	27762	151
HabSel~Riv	27763	152

*HabSel: Habitat selection by elephants. MDF: Moderately dense forests, OF: open forests, VDF: very dense forests, Riv: Rivers and streams

Table 5.3: Parameter estimates including those of forest types and rivers included in the negative binomial regression models to explain elephant habitat selection patterns

Variable	Estimate (±SE)	95% CI (lower & upper)	Z	P
Intercept	-0.08 (0.09)	-2.7 – 0.10	-0.92	0.35
Moderately dense forest	1.17 (0.13)	0.91 – 1.44	8.96	<0.001*
Open forest	2.29 (0.21)	1.85 – 2.73	10.60	<0.001*
Very dense forest	2.25 (0.27)	1.73 – 2.81	8.25	<0.001*
Rivers and streams	7.15 (1.98)	2.91 – 12.0	3.60	0.0003*

5.4 Discussion

5.4.1. Seasonal Habitat-use Patterns

During all the three seasons of dry, monsoon, and winter, elephants have spent over 75% of time in the forests and about 14 – 19% of time in the crop fields. Exception to this was by GI herd, which spent the dry season almost entirely in the forests. In the tropical deciduous forests, dry season is characterized by low primary productivity and dried up surface water sources (Natarajan *et al.,* 2016). Thus, the ability of the habitat to support elephants in such dry conditions should be an essential metric of assessing habitat quality. Sukumar (1985) opined that dry season habitat represents the 'best available habitat' for elephants. Therefore, the dry season range of GI herd may represent the best of habitats available for elephants in northern Chhattisgarh. Not only did elephants spent the entire dry season of about 4 months within forest without venturing into human-use areas, their body condition also did not show any drastic decline (Chapter-3). GI's dry season range was spread about 25.5 km2 of mixed deciduous forests located along the Mainpat slopes in Surguja and Dharamjaigarh forest divisions (Chapter-4). Identifying habitats similar to that of GI's dry season range and improving habitat conditions in such habitats seems to be an important strategy in northern Chhattisgarh. Unlike the GI herd, the bulls (BD1, BD2, PY and GN) spent considerable time in the crop fields even during dry season when standing crops were sparse in the landscape. This indicates that even if the crops remain unavailable at the landscape-scale, bulls could still sneak in and forage on vegetables (like cucumber and water melon), pulses and grains grown in a small scale near the settlements.

In northern Chhattisgarh, the paddy (*Oryza sativa*) is sown after the onset of seasonal monsoon during June and July months. Paddy harvest is done during October – November. In Surguja, after paddy harvest is completed, the annual crop of sugarcane (*Saccharum officinarum*) attracts elephants (Chapter-7). Sugarcane harvest is usually completed by March after which the fields remain fallow till monsoon sets in. Thus, during monsoon and winter months, elephants start spending considerable time in the crop fields. Even the female herds of GI and MT spent considerable time in the crop fields during winter and monsoon (data not available for MT for monsoon though) indicating that standing crops attract elephants regardless of inherent habitat quality of forest patches.

5.4.2 Landscape-level Habitat Selection

Overall, within their home ranges, elephants have predominantly selected forests over other land-use categories. This is intuitive as forests are the primary habitats of Asian elephants and use of other forms of land-uses in the environment would be conditional on availability of forest cover (Ram *et al.,* 2021).

The reports of elephants occurring in plantations, groves, and thickets of weeds in wetlands without any forest cover (Srinivasaiah *et al.,* 2019) should thus represent exceptionally erratic and ephemeral scenarios. In the study area, elephants did not use urban areas and the industrial mining areas, as these are clearly non-habitats for elephants. Thus, elephants occasionally entering urban areas as had happened on few occasions in Surguja are clearly anomalous, and possibly a result of haphazard and unplanned elephant drive operations. While elephants avoided urban areas, they did occasionally use rural settlements sometimes damaging houses to raid stored grains resulting in acute human–elephant conflict.

In the combined MCP home ranges of the five collared elephants, the total extent of moderately dense, very dense and open forest was around 4783 km2, 587 km2 and 3153 km2 respectively. Among these three broad forest types, elephants selected open forests more than the moderately dense and very dense forests. The 'open forests' as classified by the Forest Survey of India (FSI, 2009) are those with crown density of less than 40%. Particularly in Surguja, forest patches categorized as open forests are typically small, embedded in human-use areas, and are under continuous resource use by local communities in the form of fodder for livestock, fuel wood, and variety of non-timber forest products. Fragmentation and degradation of these forest patches occurred long since before even contemporary elephant use began.

Unlike other landscapes where intact elephant habitats suffered fragmentation and degradation jeopardizing elephant populations (Singh & Chowdhury, 1999; Puyravaud *et al.,* 2019), elephant range expansion in northern Chhattisgarh has been occurring in the mosaic of fragmented 'open forests' interspersed in human–use areas. Elephant selection of the relatively patchy open forests in human–dominated areas present a conundrum that is critical to elucidate in light of human–elephant conflict. The 'open forests', as classified by FSI, although poor in the crown density, constitutes predominantly of strands of Sal (*Shorea robusta*) coppice interspersed with secondary vegetation comprising a few browse species for elephants. This is particularly the case in Surguja region. Thus, the term 'open forests' may be a misnomer in the context of elephant management as they provide dense cover throughout the year.

Given that the elephants extensively forage on cultivated crops in the vicinity of forest patches using latter as daytime refuges (Chapter-7), it is plausible that elephants select forest patches not only based on inherent patch characteristics, but also by the potential foraging opportunities in the human–use areas surrounding the forest patches. In addition to fodder and shade provided by open forests, the majority of them is Sal-dominated patches have surface water throughout the year. The ongoing management interventions like water conservation and augmentation, and achieved by constructing water holes and check-dams had also increased the surface water availability in these forest patches.

Another important feature of the patchy forests in northern Chhattisgarh is the low inter-patch distance. The average inter-patch distance recorded in Surguja, Surajpur and Jashpur forest divisions in the landscape was < 1 km. In landscapes where inter-patch distances and the resistance for movement are high, elephants may remain in patches for longer period of time (personal observation from Eastern Ghats). However, when inter-patch distance is low, elephants' residence time in the patch can be low as they can easily switch between patches. These are possible reasons explaining elephant use of open forests significantly more than moderately dense and very dense forests.

5.4.4 Elephant Habitat Selection: Management Perspectives

The small and isolated patches of open forests are important source of livelihood for local communities that are predominantly forest-dependent tribes (Chapter-9). Thus, the local communities would certainly continue to use these forests. Curtailing their use can only further strain the possibilities of co-existence between elephants and people, and such restrictions wouldn't augur good for elephants too as small and isolated patches of forests cannot qualify as viable elephant habitat. Even the moderately dense and very dense forests that occur patchily without connectivity wouldn't be viable elephant habitats. Therefore, management should aim to reduce elephant use of patchy forests in human-use areas and simultaneously increase elephant use forests that are interconnected with relatively minimal human interface. The interconnected forests of Tamor-Pingla Wildlife Sanctuary along with forests of Surajpur and Balrampur forest divisions in Surguja region are an example. Improving habitat conditions by carrying out activities like water provisioning, raising fodder plantations (of bamboo *Dendrocalamus strictus* and other edible grasses) and others in the patchy open forests is counter-productive and would result in perpetuating human–elephant conflict. Instead, habitat-improvement activities should be concentrated in the moderately dense and very dense forests with a clear aim of attracting and retaining elephants in such areas. Given that elephants exhibit selection for foraging opportunities in human–use areas, reducing their use in patchy open forests is going to be challenging. Nevertheless, since the year 2019 elephants have started using Tamor-Pingla Wildlife Sanctuary with increased frequency following improvement in habitat conditions (this included water augmentation and grassland creation). Thus, the long-term strategy of harboring elephants in the identified relatively intact habitats should be pursued.

CHAPTER-6
GENETIC STRUCTURE AND RELATEDNESS OF ELEPHANTS

6.1 Introduction

The entire East-central Indian elephant population consists of approximately 2400–2700 individuals distributed along the Eastern Ghats in several fragmented dry deciduous, moist deciduous and semi-evergreen forest areas (Datye & Bhagwat, 1995). However, significant movement of elephants across these fragmented forests is known (Datye and Bhagwat, 1995), and therefore, the elephants distributed across entire East-central region can be considered as a single population (Vidya *et al.*, 2005). Currently about 200–300 elephants reportedly occur in Chhattisgarh and HEC has been increasing (Chapter-3). Since these elephants have dispersed into Chhattisgarh only during the last two decades, the fundamental question of where these herds have come from would be important to understand. This, however, would require landscape-level assessment of genetic structure of elephants covering the whole of East-central region.

Elephants have fission-fusion social organization marked by break-up and re-grouping of herds in response to environmental and behavioural factors (Chapter-3). Therefore, the elephant group sizes (number of individuals in the group) are neither constant nor rigid (Chapter-3). Based on the spatial sorting of elephant occurrence in Chhattisgarh, there could be a temptation to consider different elephant groups as discrete. However, to understand if these groups are inter-related or not, it is important to assess the population structure through genetic relatedness. Such an assessment can throw light on how many genetically distinct clans occur in Chhattisgarh.

Genetic diversity is an important metric for wildlife populations with relevance for long-term conservation (Kaljund & Jaaska, 2010; Gordon *et al.*, 2012). It is well established that preserving the genetic diversity of endangered species can substantially affect their long-term survival and evolution in changing environments (Frankham *et al.*, 2002). This chapter is aimed at understanding the genetic status and relatedness within a small population of elephants occurring in Chhattisgarh.

6.2 Methods

6.2.1 Sample collection and DNA extraction

A total of 258 geo-referenced elephant dung samples were collected from Korba, Jashpur, Dharamjaigarh, Surajpur, Mahasamund, Surguja, Tamor-Pingla, Katghora and Balrampur forest divisions of Chhattisgarh (Figure 6.1) during 2017-19. In addition, 10 tissue samples and four blood samples were also collected opportunistically from Tamor-Pingla Rescue Centre. During sampling, the bolus of fresh samples was swabbed with sterile cotton swabs and stored in Eppendorf tubes. The tubes were stored in cold, dark place and later sent to WII laboratory where they were stored in -20°C freezer. In the laboratory, DNA extraction was carried out from all the samples using standardized protocol described in Biswas *et al.*, (2019).

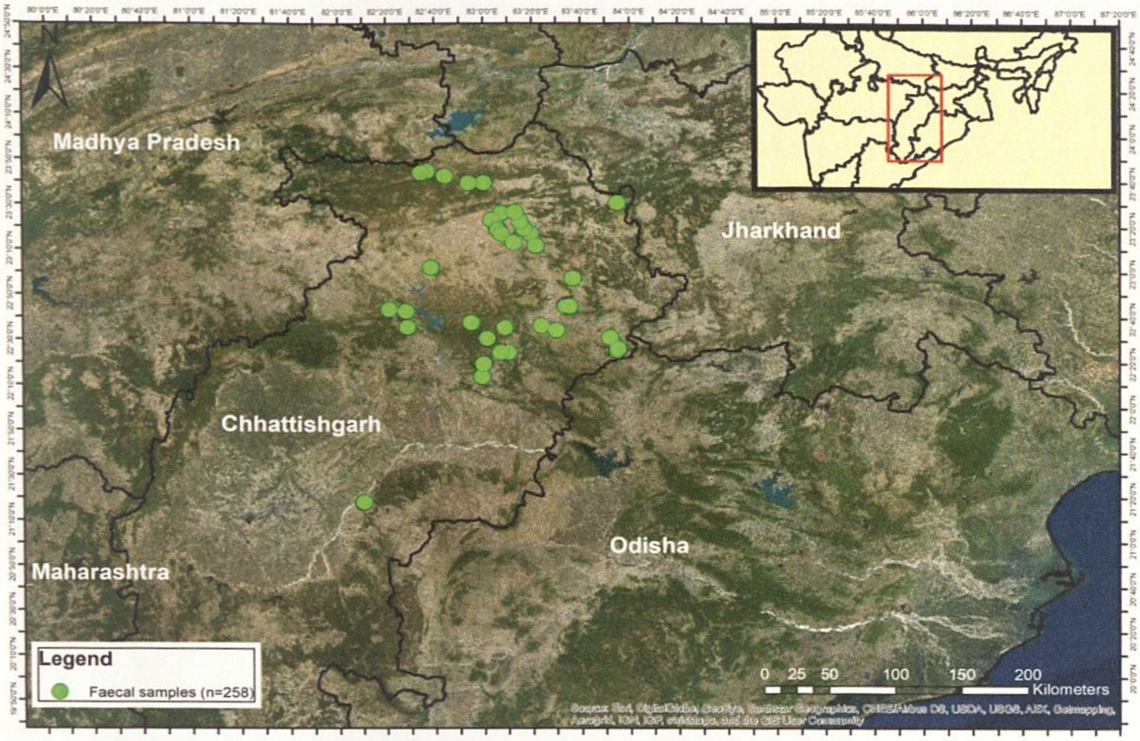


Figure 6.1: Study area and sampling locations

6.2.2 Microsatellite marker selection and standardization

Previously published research articles on elephant genetics were studied to select appropriate Asian and African elephant markers (STRs) for population genetic analysis. A total of 30 primers were shortlisted initially based on various characteristics (for e.g. polymorphism, amplification success rates etc. The tissue DNA samples extracted were used to standardize the markers. On the basis of their amplification success, 20 primers were finally selected for further testing. Primers with common annealing temperatures were grouped together and multiplex reactions were prepared. PCR reactions were carried out for each multiplex set using the same tissue samples.

6.2.3 Individual identification of elephants

Following initial standardization of the markers with reference samples, data from 243 faecal DNA samples was generated using the same protocols described earlier. Allele scoring was done using the program GeneMarker 2.6.7. (SoftGenetics Inc., USA). For every sample the amplification success rates for each *loci* were checked and any sample with less than 50% data from the loci were dropped from further analyses. The samples with good quality data were used to identify genetic recaptures using program CERVUS (Marshall *et al.*, 1998). Further GIMLET program (Valière *et al.*, 2002) was used to calculate the cumulative P_{IDsibs} value for the loci used. P_{IDsibs} refers to the probability that two siblings drawn at random from a population will have the same genotype at multiple loci.

6.2.4 Population genetic analysis

The discriminant analysis of principle component (DAPC) (Jombart *et al.*, 2010) was used for cluster analysis. The method converts the genotype data into principal components and defines groups of individuals with the best-supported number of clusters identified by the Bayesian Information Criteria (BIC) (Basto *et al.*, 2015). Once DAPC results were obtained program TESS 2.3.1 (Chen *et al.*, 2007) were used to identify any possible population structure. This approach implements a Bayesian clustering algorithm for spatial population genetics to detect genetic barriers or genetic discontinuities in continuous populations. TESS runs were performed under the admixture model for 60,000 sweeps, with a burn-in period of 10,000 sweeps, interaction parameter set to 0.6, 10 independent runs per analysis and the maximum number of clusters fixed to K_{max} = 10. The results from DAPC and TESS were plotted on the study area. The population pairwise F_{st} value was also calculated in ARLEQUIN 3.1 (Excoffier *et al.*, 2005). F_{st} depicts the variance in allele frequency among populations and is conversely related to the degree of resemblance among individuals within populations (Holsinger & Weir, 2009). ARLEQUIN 3.1 (Excoffier *et al.*, 2005) was also used to determine the number of gene copies, number of alleles (N_a), allelic range, observed heterozygosity (H_o) and expected heterozygosity (H_e).

6.2.5 Relatedness and demography analyses

The program ML-Relate (Kalinowski *et al.*, 2006) was used to calculate maximum likelihood estimates of pair-wise relatedness and relationship categories between individuals from the genotypic data. It was used to determine the number of half-sibling (HS), full-sibling (FS), and parent-offspring (PO) relationships, and the number of unrelated individuals (U). We used BOTTLENECK (Cornuet *et al.*, 1996) and Garza and Williamson's M-ratio (Garza *et al.*, 2001) approaches to ascertain population demography.

6.3 Results and Discussion

DNA was extracted from all 243 field-collected samples. Out of these, 209 samples (84%) provided data for genotyping.

6.3.1 Individual Identification

A total of 55 unique individual elephants were identified from this data. About 21 samples were genetic recaptures of same identified individuals, revealing that same individuals are using different areas over the sampling period in this landscape (Figure 6.2 to 6.5).

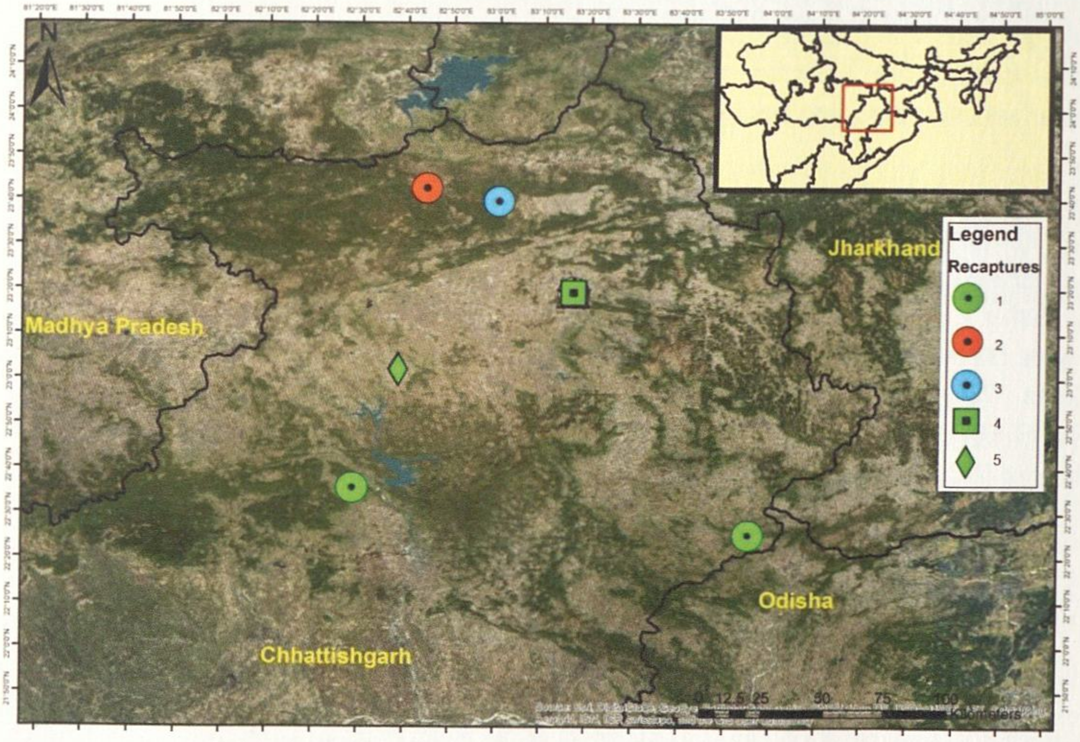


Figure 6.2: All nine recaptures in the study area

Figure 6.3: Recapture locations of individual no. 2 in the study area

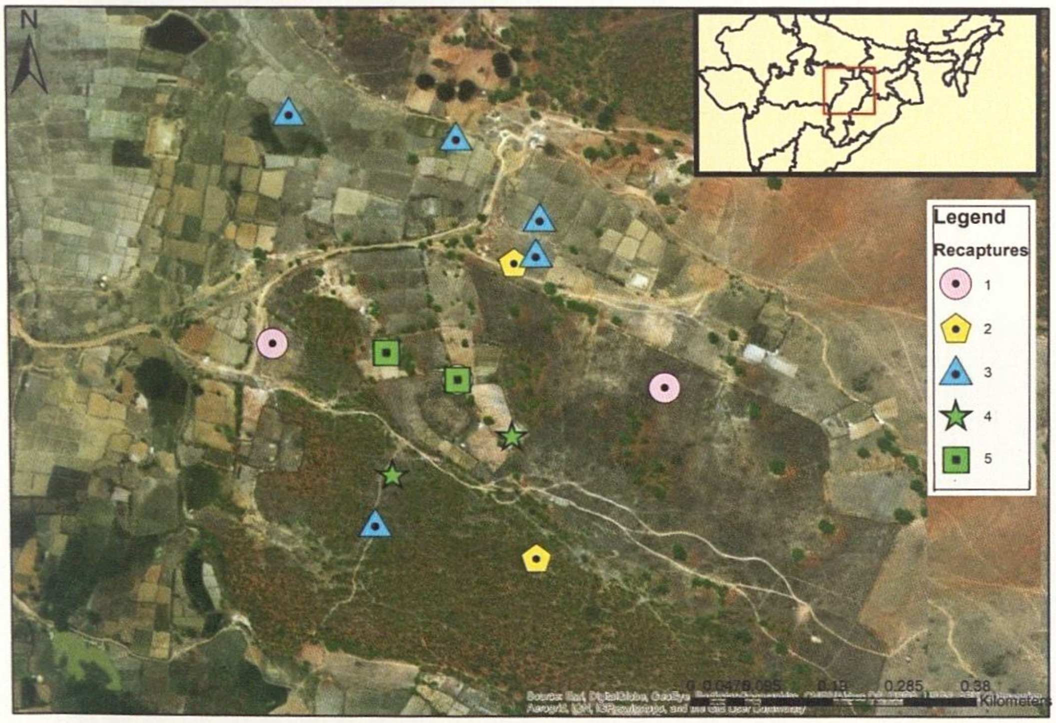


Figure 6.4: Recapture locations of individuals 4, 5, 6, 7 and 8 in the study area

Figure 6.5: Recapture locations of recaptures of individual no. 9 in the study area

6.3.3 Population Genetics Analysis

Through genetic assessment we could identify two different clusters of elephants. This hint at possibility of a minimum of two different lineages of elephants occurring in the sampled area. Possibly, as there was a minimum of two different genetic lineages of elephants in Chhattisgarh, elephants occurring in Chhattisgarh could have come from different locations and not necessarily from the same area. Cluster 1 comprised of 26 individuals and Cluster 2 comprised of 29 individuals. This has been presented in Figure-6.6 & 6.7

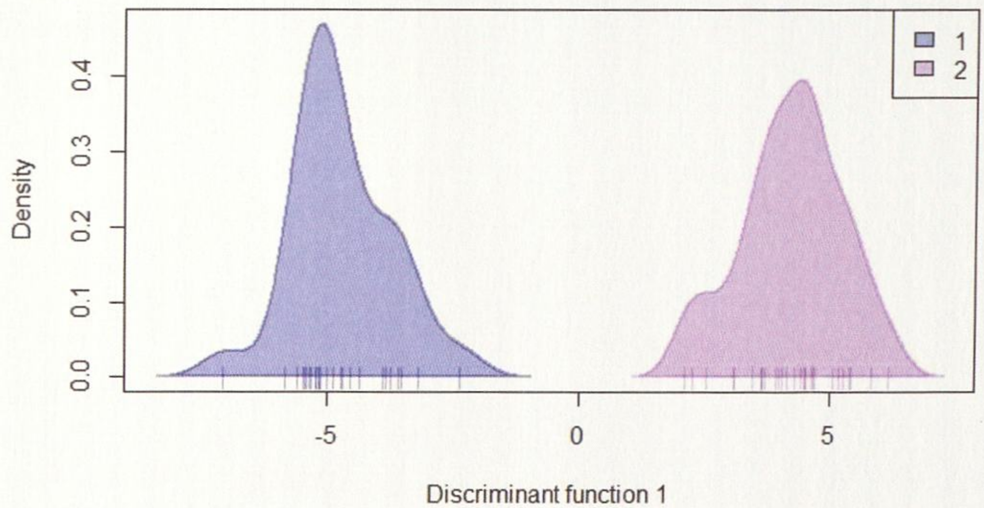


Figure 6.6: Identification of two clusters of elephant genetic lineage

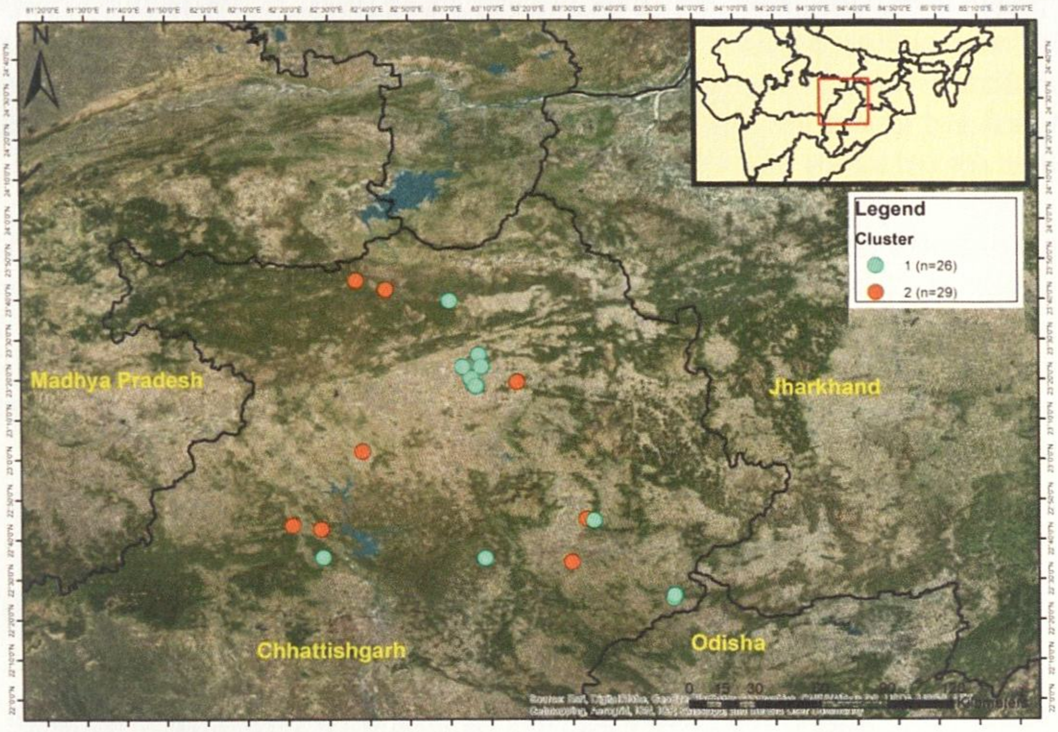


Figure 6.7: Elephant genetic cluster and their locations

The results of TESS analysis indicate that cluster 1 had 18 individuals whereas cluster 2 had 35 individuals. This has been presented in Figure 6.8.

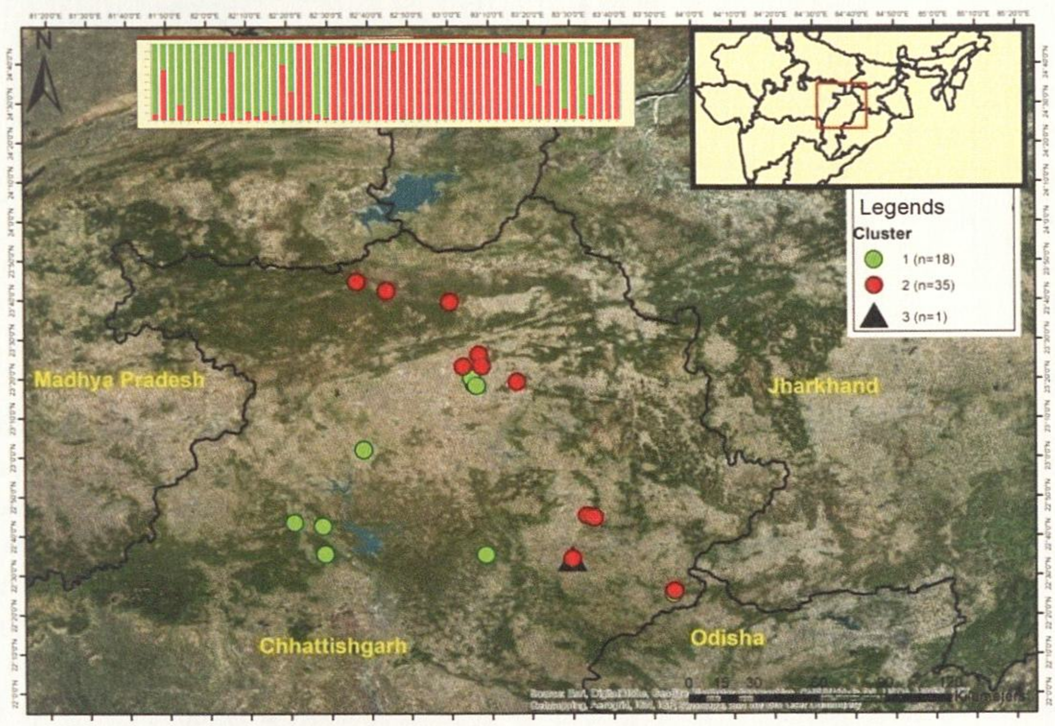


Figure 6.8: TESS analysis identified two major population clusters

This pattern of multiple genetic lineages is probably not surprising for elephants in Chhattisgarh. The central Indian elephant population across Jharkhand, Odisha, West Bengal have suffered considerable disturbances, resulting in range expansion into neighbouring states. The movement of elephants from Jharkhand and Odisha into Chhattisgarh could be possible reason behind such multiple lineages. However, detailed work is required to confirm this hypothesis.

In terms of genetic variation in the identified individuals (n=55), the number of alleles ranged from 4 to 13 with a mean of 7.5 alleles per locus. The overall P_{IDsibs} value was 4.68*10^{-6} indicating the probability of misidentification of two elephant siblings as one is very low. Mean observed heterozygosity over all loci (H_o = 0.34947) was lower than expected heterozygosity (H_e = 0.72885) (Table 6). The pairwise F_{st} between the two genetic lineages was found to be 0.058, showing low but significant genetic differentiation between the two groups.

Table 6.1: Summary statistics for the 55 identified individuals

S. No	Locus	No. of gene copies	N_a	Allelic range (bp)	H_o	H_e	P_{IDsibs}
1	EMX-2	102	4	9	0.58824	0.60513	5.10E-01
2	LafMS03	106	7	14	0.56604	0.73872	2.10E-01
3	EMU03	108	8	18	0.33333	0.78228	8.06E-02
4	LafMS05	96	12	28	0.41667	0.82171	2.88E-02
5	Lat24	66	8	52	0.06061	0.82984	1.03E-02
6	Lat25	108	6	12	0.53704	0.49896	5.97E-03
7	EMU04	102	7	12	0.39216	0.75189	2.42E-03
8	FH103	84	9	24	0.28571	0.74182	9.85E-04
9	FH94	88	8	22	0.22727	0.75131	3.99E-04
10	LafMS02	96	10	18	0.35417	0.7568	1.59E-04
11	LA6	104	5	20	0.23077	0.5435	8.73E-05
12	EMU17	74	8	34	0.10811	0.80415	3.25E-05
13	EMU15	96	7	18	0.3125	0.79276	1.22E-05
14	FH60	100	6	12	0.48	0.78505	4.68E-06
Mean		95	7.5	20.929	0.34947	0.72885	
S.D.		12.3	1.955	10.866	0.15559	0.09971	

6.3.4 Relatedness within the Elephant Population

The relatedness analyses revealed a number of different first-degree relationships, including parent-offspring (PO), half-sibs (HS) and half-sibs (HS) levels. Majority of these relationships (74%) are at half-sibs level, followed by full-sibs (24%) and parent-offspring (Figure 6.9). The results corroborate with the prevailing general understanding on elephant social-behavior where related individuals form clans and unrelated individuals usually do not intermingle. Elephants live in a matriarchal family group, often led by the oldest female (Sukumar, 2006). Males disperse from their natal herds, thus reducing the effects of inbreeding (Sukumar, 1989). Adult bulls live alone or in small, temporary groups ('bull herds') with weak social bonds. When males move from one location to another, they mate with females from other populations. Therefore, half-sibs, full –sibs relationships within close by areas are very much possible. However, more intensive sampling is required to provide better understanding of the social structure in this population.

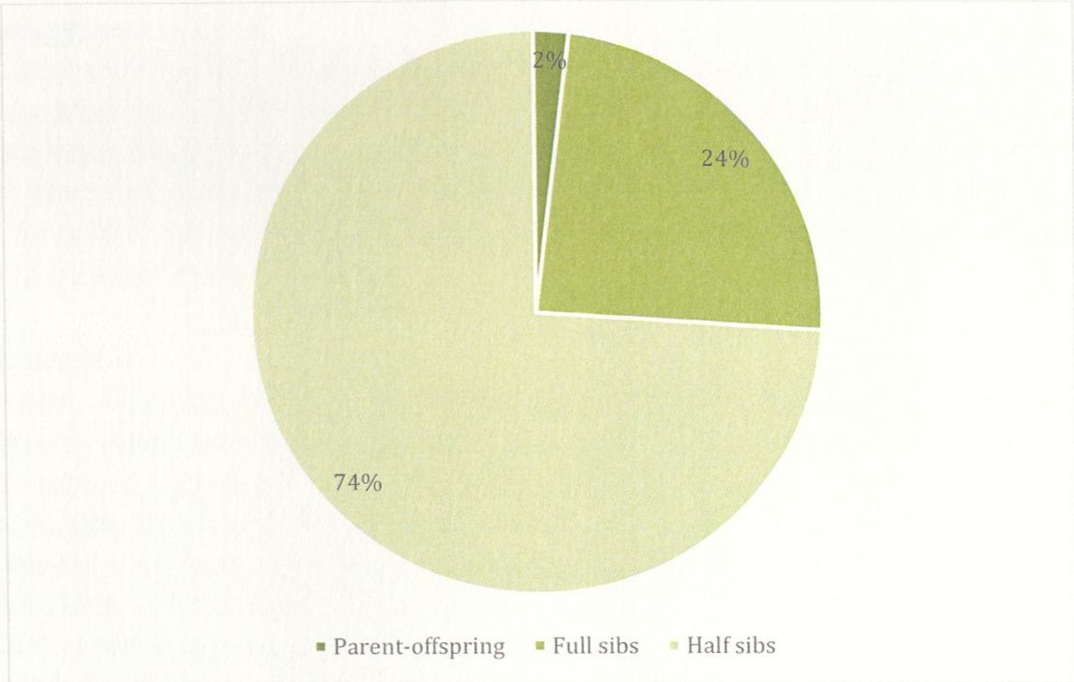


Figure 6.9: Relatedness patterns in the sampled Chhattisgarh elephant population

Relatedness analysis with two different genetic lineage data showed slightly different relationship patterns. Lineage 1 showed 3.57% PO, 39.2% FS and 57.14% HS relationships, whereas lineage 2 showed 4% PO, 24% FS and 72% HS relationships (Figure-6.10 - 6.12).

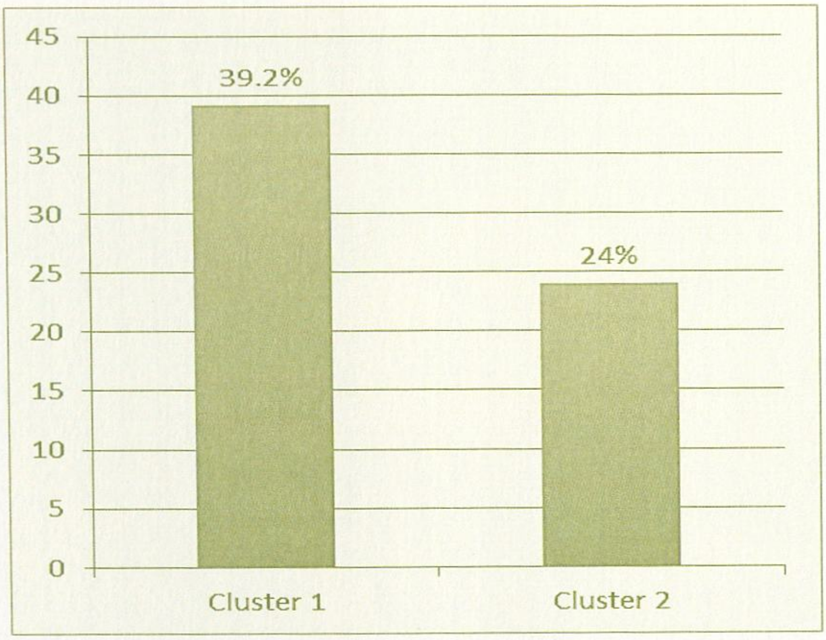


Figure 6.10: Comparison of Full-sibs (FS) relationships in cluster 1 and cluster 2

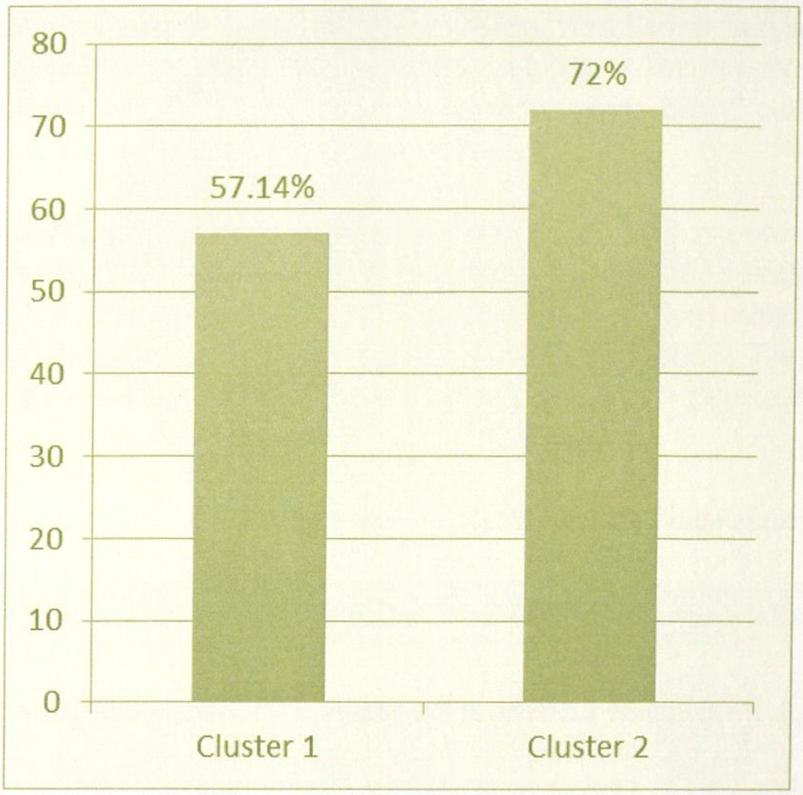


Figure 6.11: Comparison of Hull-sibs (HS) relationships in cluster 1 and cluster 2

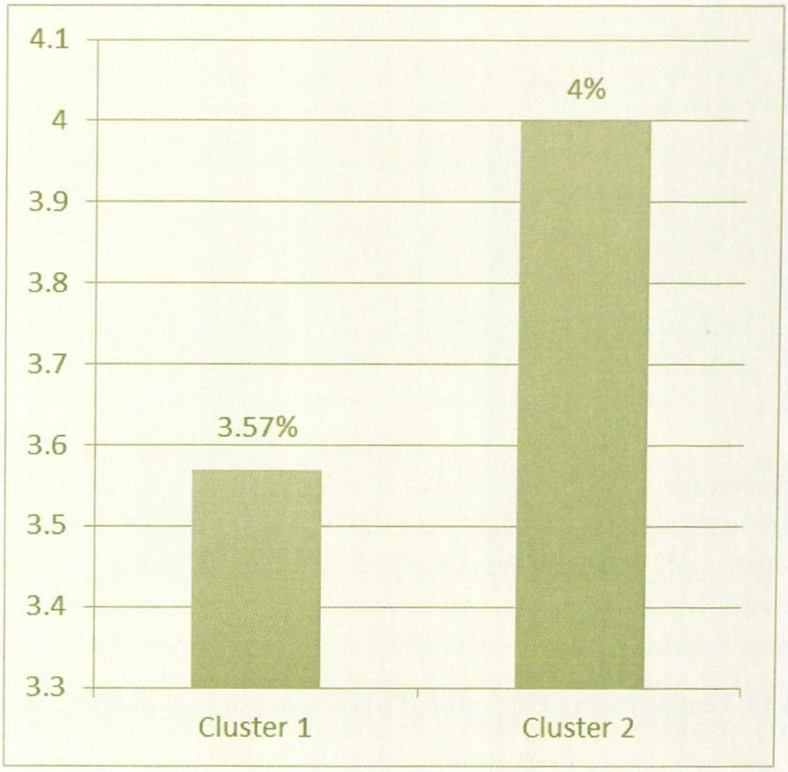


Figure 6.12: Comparison of Parent-offspring (PO) relationships in cluster 1 and cluster 2

6.3.5 Demographic Analyses

Both qualitative demographic analyses (Bottleneck and M-Ratio approaches) indicated signatures of recent population decline. The Bottleneck analyses revealed heterozygosity excess in 11-13 loci, suggesting recent population decline. Analyses with the different genetic lineages showed similar pattern. Similarly, the M-Ratio value for the entire population was found to be 0.38, again indicating population decline. Such result for this Chhattisgarh population is not surprising given the known history of the elephant population in this region.

6.4 Conclusion

In conclusion, the results demonstrated that the standardized panel of 14 microsatellite loci could unambiguously identify individual elephants from poor quality, non-invasive biological samples and aid in exploring various population parameters. Our sampled elephant population showed two different genetic lineages, possibly explained by the movement of elephants from adjoining areas into the state over the years. The high proportion of half-sibling relationships found in the population could be explained by elephants' inherent characteristic of moving in matriarchal herds, with males moving long distances and mating with females in other populations. The two clusters have also been found to go through a population decline in the past. Different recapture locations of the same individuals indicated the habitat use pattern of elephants in a matrix of forested patches and human settlements, where they could come in contact with humans. Existing information, when combined with future sampling from neighbouring regions, and analysis of the movement of these elephants, could potentially help in identifying conflict individuals, and help in their management.

CHAPTER-7
PATTERNS OF CROP LOSSES DUE TO ELEPHANTS

7.1 Introduction

Loss of cultivated crops caused by elephants are major source of human-elephant conflict with local marginal communities (Sukumar 2003, Rangarajan *et al.* 2010). Crop losses caused by elephants directly affect livelihood and could increase the local antagonism towards conservation. There are numerous proximate (immediate) and ultimate (long-term) causes that could explain elephant crop raiding behavior. The ultimate reasons that explain elephant crop raiding behavior include (i) use of cultivated crops as fallback food to offset forage scarcity resulting from habitat loss (Balasubramaniam *et al.,* 1995; Desai and Baskaran, 1996) (ii) as part of optimal foraging strategy (Pyke, 1984) since crops may be a concentrated source of food, which elephants can exploit to maximize time (Chiyo *et al.,* 2011; Sukumar, 1991), (iii) to overcome nutrient deficiencies in diet (Osborn, 2004; Sukumar, 1990; Williams *et al.,* 2001), and (iv) as a male strategy to gain reproductive advantage through better expression of *musth* (Chiyo *et al.,* 2011; Hollister-smith *et al.,* 2007; Hollister-Smith *et al.,* 2008; Sukumar, 1991). Elephants feed on cultivated crops almost exclusively during night, likely due to perceived 'landscape of fear' (Troup *et al.,* 2020) as crop foraging entails considerable risks (Goswami *et al.,* 2014; LaDue *et al.,* 2021). However, in human–dominated landscapes characterized by high interspersion of natural forests and agriculture, observations show that both males and females forage crops (Datye and Bhgawat, 1995; Singh *et al.,* 2002). The phenomenon of both males and female elephants foraging crops seems particularly acute in landscapes witnessing large-scale immigration of elephants into human–dominated areas, out of their home ranges (Daniel *et al.,* 2008; Datye and Bhgawat, 1995; Singh *et al.,* 2002).

Conflict resolution with elephants aimed at reducing crop losses would benefit from understanding the spatio-temporal patterns of crop losses, relative losses of different crops and underlying processes that could predict crop losses due to elephants. As part of the project, a fine-scale assessment of crop losses aimed at understanding seasonality of losses, crop selection, and elephants' response to local mitigation strategies was carried out in a 1000-km² covering Surajpur, Pratappur range of Surajpur FD and Rajpur range of Balrampur FD. Furthermore, landscape-scale assessment, which covers most of the elephants' range in Chhattisgarh, was carried out to understand variations in crop losses caused by elephants.

7.2 Materials and Methods

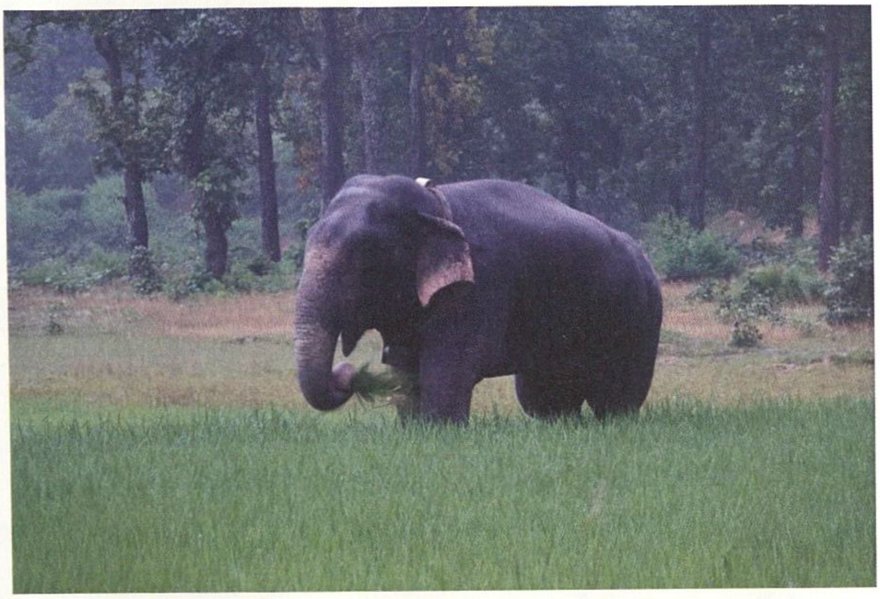
7.2.1 Landscape-level Assessment

The landscape-level assessment of crop losses by elephants was carried out in 10 forest divisions namely Surguja, Surajpur, Balrampur, Jashpur, Manendragarh, Koriya, Katghora, Korba, Raigarh and Dharamjaigarh in two forest circles of Surguja and Bilaspur (Fig-1). The landscape also includes four protected areas namely Guru Ghasidas national park (1411 km2), Tamor-Pingla (543 km2), Semarsot (430 km2) and Badhalkol wildlife sanctuaries (104 km2) where elephant occurrence is reported.

For landscape-level assessment of crop loss intensity, we collated crop loss records from 10 forest divisions and four protected areas in Surguja and Bilaspur circles for the period 2015 to 2020. We mapped those records in GIS at the village level and calculated average number of crop loss days for each village. We preferred the metric mean crop loss days to mean crop incidences, as the former is sensitive in capturing "intensity of crop loss" and less vulnerable to statistical non-independence unlike crop loss incidences, which could be correlated.

7.2.2 Fine-scale Assessment

Fine-scale assessment of crop losses by elephants was conducted in a subset of larger landscape (henceforth 'intensive study area') with reported high levels of human–elephant conflict, located in the inter-junction of three forest divisions in Surguja circle namely Surguja, Surajpur and Balrampur. The demarcation was based on logistical familiarity and local information network. In the demarcated area, crop loss incidences recorded during field surveys were mapped in GIS to create a polygon (following minimum convex polygon approach). The intensive study area measures 1200 km2, which constitutes 450 km2 of forests (Figure 7.1). The fine-scale assessment of crop losses was carried out in the intensive study area during February 2019 to February 2020. Two of the project field assistants from local villages (enumerators henceforth) and a researcher were trained in identifying elephant signs and recording crop loss information in the field. The enumerators coordinated with the forest guards, local villagers and carried out site visits (usually on the next day of the damage) to record crop type, GPS location, stage of damage, number of elephants involved and their gender, wherever appropriate. The villagers were forthcoming in assisting our enumerators in recording reliable data. A measuring tape was used to record the length and width of the crop loss area in meters' unit.



7.2.3 Data Analysis

For the landscape-level assessment of crop loss intensity by elephants, we overlaid 4 km2 grids across the entire elephant range in northern Chhattisgarh. At 4 km2, the grids were large enough to accommodate an independent crop loss incident and also amenable for evaluation of potential covariates. The grids with no reported crop losses were excluded from analysis resulting in a total of 1126 grids in the sampling frame. For each grid, we calculated the mean number of crop loss days. If there were multiple villages within the grid, we calculated the overall mean number of crop loss days pooled across villages. We used linear regression models to evaluate the effect of explanatory variables on intensity of crop losses by elephants. For fine-scale assessment of probability of crop loss by elephants we overlaid 1-km2 grids in the intensive study area. The response variable was presence (1) or absence (0) of crop loss incidences within the grid, which was analyzed using logistic regression.

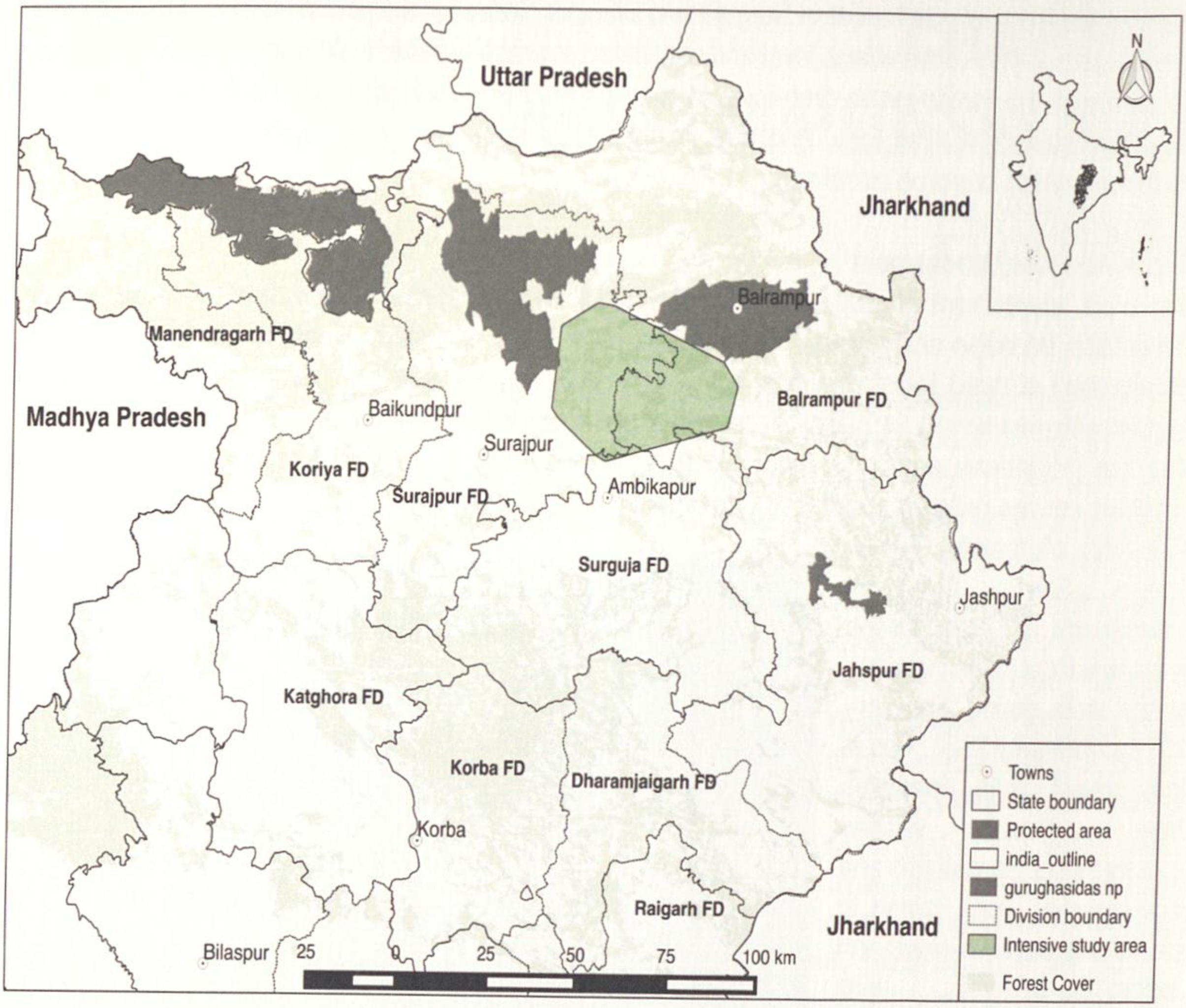


Figure 7.1: Study area map showing the fine-scale study area and the overall landscape

7.3 Results and Discussion

7.3.1 Landscape-level Intensity of Crop Loss

During the period 2015–2020, 1426 villages from 10 Forest Divisions and four Protected Areas in northern Chhattisgarh reported crop losses by elephants. Based on the reported intensity of conflict, four major conflict hotspots were identified (Figure 7.2). Regression analysis indicated that variations in crop loss intensity were best explained by intensity of habitat use by elephants, whereby; crop loss intensity was high in areas that were intensively used by elephants in comparison to areas with low, medium and sporadic use by elephants (**Annexure-6**).

7.3.2 Fine-scale Patterns of Crop Losses

We recorded 363 incidences of crop foraging by elephants from 60 villages (that include small settlements as well) in the intensive study area for the 13-month period (February 2019 – February 2020). The measured extent of crop loss by elephants was 12.4 hectares comprising of 10 different cultivars (Figure 7.3).

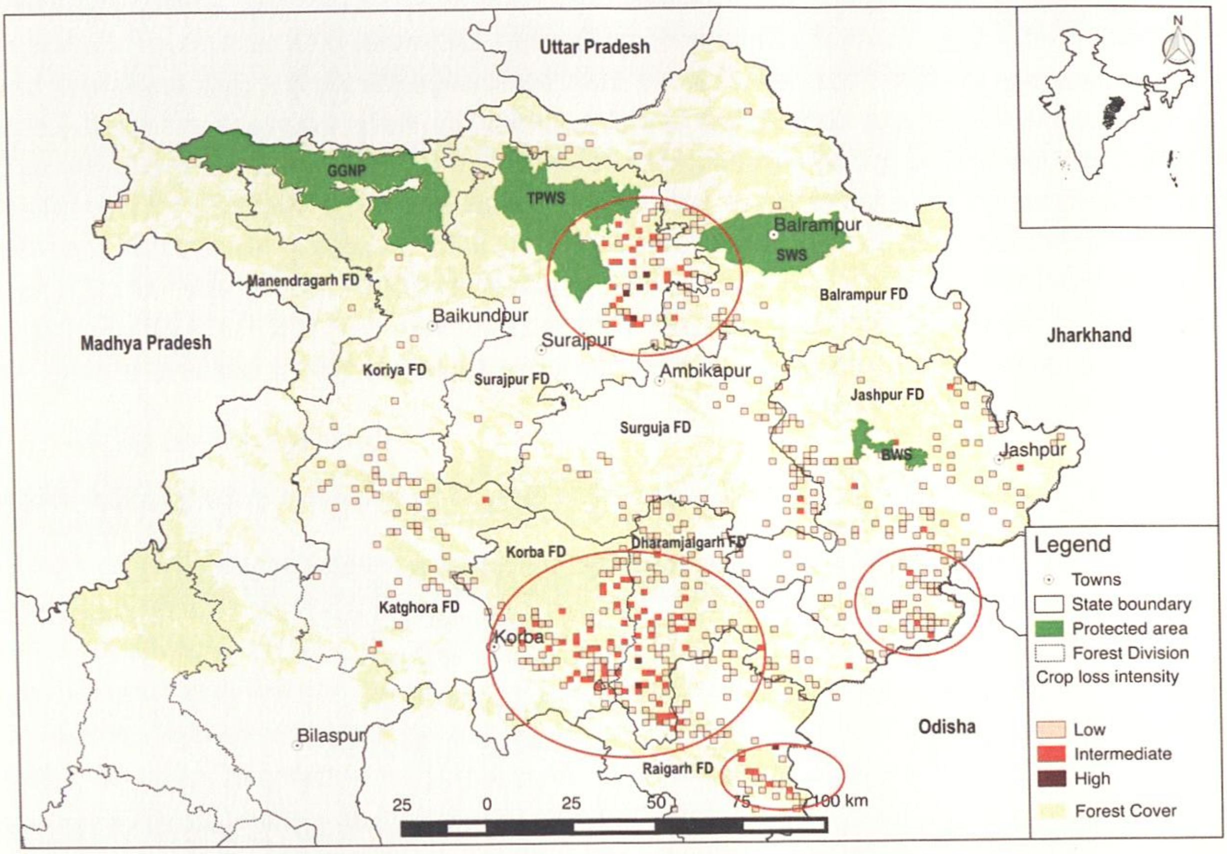


Figure 7.2: Intensity of crop loss by elephants at the landscape-scale in Northern Chhattisgarh

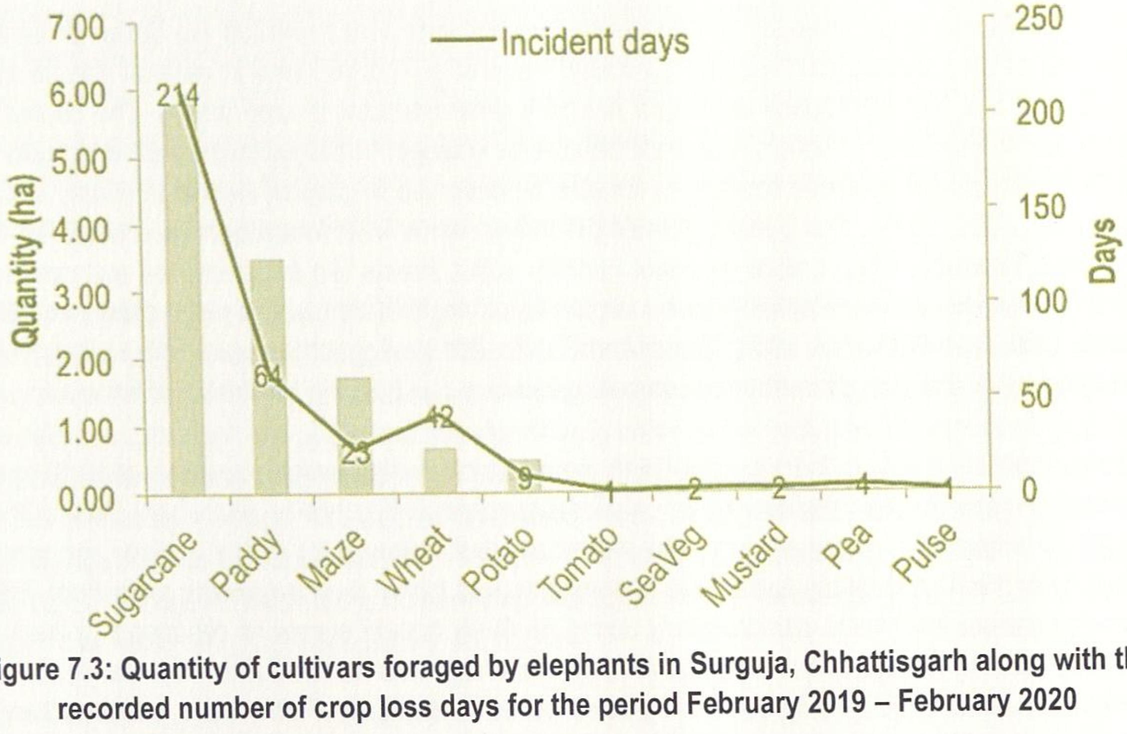


Figure 7.3: Quantity of cultivars foraged by elephants in Surguja, Chhattisgarh along with the recorded number of crop loss days for the period February 2019 – February 2020

Amongst them, loss of sugarcane was highest (5.81 hectares, n = 214 days), followed by paddy (3.5 hectares, n = 64 days), maize (1.73 hectares, n = 23 days), and wheat (0.68 hectares, n = 42 days). The losses pertaining to other crops were relatively minimal. Amongst the top four cultivars, severity of crop losses due to elephants was relatively high for maize; followed by paddy, sugarcane, and wheat. Elephant-related crop losses were spread out throughout the year due to availability of sugarcane, an annual crop in the landscape. The period of losses pertaining to cereals and maize mirrored local crop cultivation cycles. They were foraged predominantly damaged during mature stages, whereas sugarcane suffered elephant-related crop losses during mature and vegetative stages (Table 4). The extent of crop loss was positively correlated with number of elephants (Pearson's $r = 0.51$, $t = 11.25$, $P < 0.001$). Further, crop losses caused by elephant groups were higher than losses caused by solitary elephants (Kruskal Wallis $\chi^2 = 305.78$, df = 237, $P = 0.001$).

Table 7.1: Phenophase of top four cultivated crops foraged by elephants in Surguja, Chhattisgarh

Crop	Incidences	Phenophase of crops
Sugarcane	214	57% mature, 43% others
Paddy	64	94% mature, 6% others
Maize	33	91% mature, 9% others
Wheat	42	83% mature, 17% others

Among the spatial determinants of crop losses caused by elephants, we found that probability of elephants causing crop losses was high crop fields closer to forest patches, and are away from the main roads (**Annexure-6**).

7.4 Discussion

At the landscape-scale, intensity of habitat-use by elephants best explained the observed variations in intensity of crop losses. Our findings contradict Pozo *et al.,* (2018), who in case of African elephants suggested that elephant space-use might not be a good predictor of crop losses. The contradiction is important to elucidate in light of elephant behavioral ecology. In polygynous social mammals, natural selection favors risk-aversive strategy in females as observed in case of elephants (Chiyo *et al.,* 2011; Sukumar, 2003, 1991). This generally preempts female herds from foraging crops considering the risks involved. However, when natural elephant habitats suffer threats like fragmentation and corresponding loss in area available for elephants, even female herds might start foraging crops (Datye and Bhagwat, 1995; Desai and Baskaran, 1996). Desai and Riddle (2015) suggest that such initial exposure to crop foraging either due to opportunistic or compelling reasons can become habitual over time.

At finer-spatial scales, in the intensive study area, although elephants foraged on over 10 species of cultivated crops, losses were substantial only for sugarcane, paddy, maize, and wheat. Among these four crops, quantitatively, sugarcane was the most damaged; followed by paddy, maize, and wheat. The severity of maize and paddy losses due to elephants was higher than sugarcane and wheat. Elephants foraged cereals and maize predominantly during relatively mature stages as reported by others (Gubbi, 2012; Sukumar, 2003). As the temporal window of damage was narrow for the cereals, concerted crop protection efforts for few weeks could bring down losses substantially. Furthermore, seasonal barriers like mobile fences (that can be dismantled after use) with active community participation can be experimented in select hotspots.

The option of seasonal barriers is particularly relevant to Chhattisgarh as high fragmentation preclude use of permanent barriers like trenches. Sugarcane suffered elephant-related losses throughout the year, and it has seemingly increased the duration of cropland–elephant conflict in Surguja.

When elephants occur in human–dominated areas, they may use natural forest patches as daytime refuges (Graham *et al.*, 2010). We found higher probability of crop loss by elephants in the proximity to forest patches. We would urge caution in carrying out habitat improvement activities like water augmentation in small forest patches as they could become day-time elephant refuges. Instead, efforts to improve habitat conditions should target larger forest patches that exist the landscape where it is desirable to sustain elephants.

7.4.1 Management Implications

The contemporary range expansion of elephants in the forest-agriculture interface in Chhattisgarh and concurrent crop losses and other forms of conflict necessitate landscape zonation for better management. The envisaged plan should identify elephant conservation and conflict management zones using existing information on human–elephant conflict, elephant occurrence, and also predict possible range expansion using robust niche-modeling approaches. Elephant range expansion outside of these zones, in predominantly human-dominated areas need to be limited by demarcating and gradually enforcing boundaries using natural geographic features (like major rivers) and man-made barriers like road and railway network. The zonation of landscape would be conditional on prioritizing elephant conservation zones and keeping them safe from threats of mineral mining and infrastructure development so that elephant conservation prerogatives are not compromised. In particular, the mineral mining in East Central region has been identified as inimical to elephant conservation as it trigger human–elephant conflicts by saturating natural elephant habitats (Singh and Chowdhury, 1999).

At finer spatial scales, management priority would be to prevent spread of conflict outside of the current high-conflict zone (Fig.5) and aim to gradually increase duration of elephant occurrence within large forested complex comprising of Tamor-Pingla wildlife sanctuary, Guru Ghasidas national park and connected forests in Surajpur and Balrampur forest divisions. As the area to perimeter ratio of forest patches is high, utility of permanent barriers would be minimal. Therefore, portable barriers can be tactfully experimented to limit elephant distribution within the current conflict zone.

Building on simple methods that field staff and local villager can understand seems to be a better strategy rather than seeking a proverbial 'silver bullet' for conflict mitigation. As even moderately effective interventions like daily conflict monitoring, developing early-warning mechanism, timely payment of *ex gratia* relief, and strategic use of barriers can significantly contribute in reducing the impact, strengthening them and the expertise thereof assumes a greater priority. Amongst these measures, institutionalizing elephant monitoring through well-trained field teams with enhanced technical capacity to deal with exigency would be an important long-term investment towards conflict resolution efforts. From elephant conservation standpoint, addressing human–elephant conflict is crucial as high levels of conflict-induced mortality can render elephant populations stochastic.

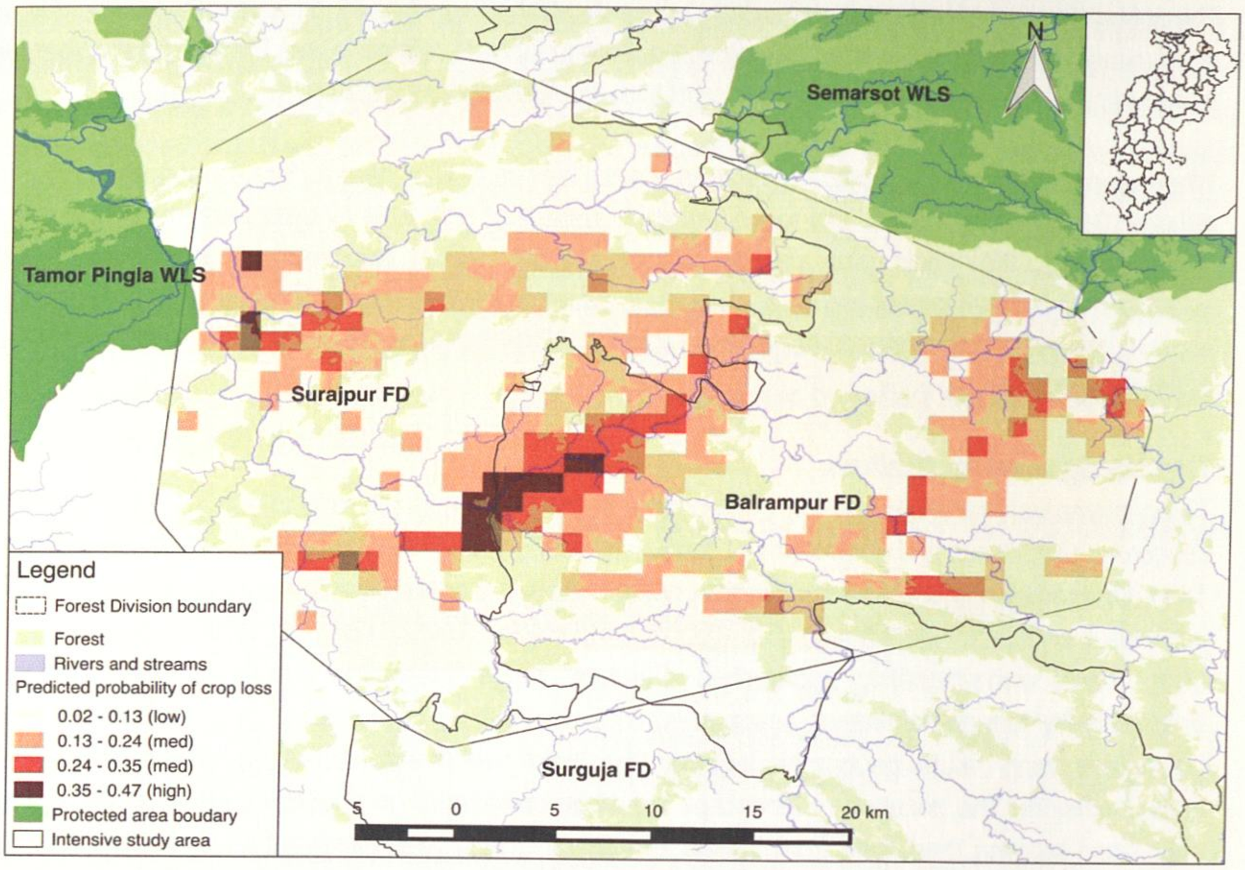


Figure 7.4: Predicted probability crop loss in Surajpur and Balrampur forest divisions of Surguja and Bilaspur circles

7.4.2 Summary

1. A total of 1426 villages from 10 Forest Divisions in Surguja and Bilaspur circles reported crop losses due to elephants during the period 2015 – 2020. The crop losses reported in Raipur circle was not covered in this study.
2. At the landscape-scale, variations in intensity of crop losses were determined by habitat-use patterns by elephants. Elephant-related crop losses were higher in areas of high intensity of use by elephants.
3. With respect to quantity, sugarcane losses were higher. In terms of severity, paddy suffered relatively higher losses.
4. Crop losses caused by elephants in Chhattisgarh were seasonal reflecting local crop cultivation cycles. Nevertheless, area under sugarcane cultivation (an annual crop) is increasing and this is making crop losses year-round problem in certain areas. Currently, most of the recorded crop losses were during the early winter and subsequent winter months.
5. Most of the crops including cereals were damaged by the elephants during harvest stages. Losing crops during harvest stages can shoot-up the economic losses to aggrieved farmers
6. Although the losses at the village-level are low, individual farmers have lost substantial yield of their crops to elephants.

CHAPTER-8
ASSESSMENT OF PATTERNS & CIRCUMSTANCES OF HUMAN FATALITIES DUE TO ELEPHANTS

8.1 Introduction

Human deaths due to elephants is often considered as the most acute form of human–elephant conflict. More often, human deaths lead to local antagonism towards conservation as a whole and turn into political flashpoint. There are also ethical and moral compulsions to reduce human deaths due to conflict situations. Nevertheless, in places like northern Chhattisgarh where elephants range extensively in a landscape mosaic with highly overlapping human use areas and natural forests, containing human deaths due to conflict is far from easy. In order to advance mitigation strategies that could help in reducing conflict-related human deaths, an understanding of circumstances leading to human fatality is helpful. Such an understanding shall help in identifying locations and activity patterns of villagers that predispose them to attacks. However, it is seldom easy to gather information regarding deaths as it often dies with the victim. Nonetheless, by visiting the sites of incidences immediately to record circumstantial evidences and also by interacting with eyewitnesses and field staff, it may be possible to weave pieces of information together coherently. With this aim, during the period between August 2017 to June 2019, we have collected fine-scale details on 46 cases of elephant-caused human deaths in northern Chhattisgarh by directly visiting the sites. Additionally, we have also collected secondary details from Forest Department records from Surguja circle. Pooling both the primary and secondary data together, we used basic descriptive statistics to understand the patterns and possible correlates of human deaths due to elephants and discuss management implications.

8.2 Methods

We have visited sites of human deaths caused by elephants and recorded basic details that include site characteristics (habitat, distance to forest, habitation, micro-habitat and others), details about the victim (age, gender, physical condition, activity the victim was engaged during the incident and others) and details about elephants (group size, gender etc). We have also interacted with eyewitnesses and collected other circumstantial direct evidences. Additionally, we have also recorded elaborate field notes based on our direct observations and discussions with staff and villagers.

8.3 Results

8.3.1 Age and Gender of Victims

Of the total number of victims, about 46% (n=37) were elderly, 28% (n=23) were middle aged and 19% (n=17) were youth. These three categories constitute the majority. In addition to this, there were infants (5%, n=4), children (1%, n=1) and teens (2%, n=2) (Figure 8.1).

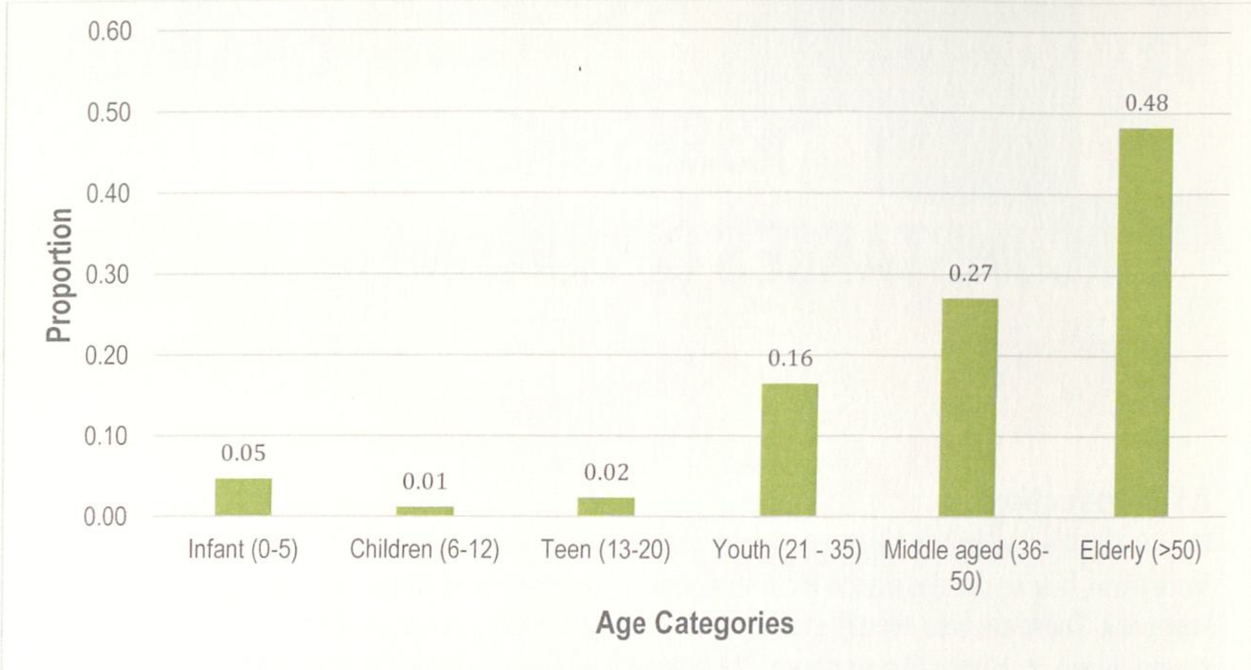


Figure 8.1: Age categories of victims, from the combined primary and secondary data

Overall, more men (64%, n=56) were killed by elephants in comparison to women (36%, n=31) (Figure 8.2). Comparison across three years for the period from 2017 to 2019 also shows that every year more men are killed than women (Figure 8.3).

Figure 8.2: Overall gender-wise proportion of death, from combined primary and secondary data

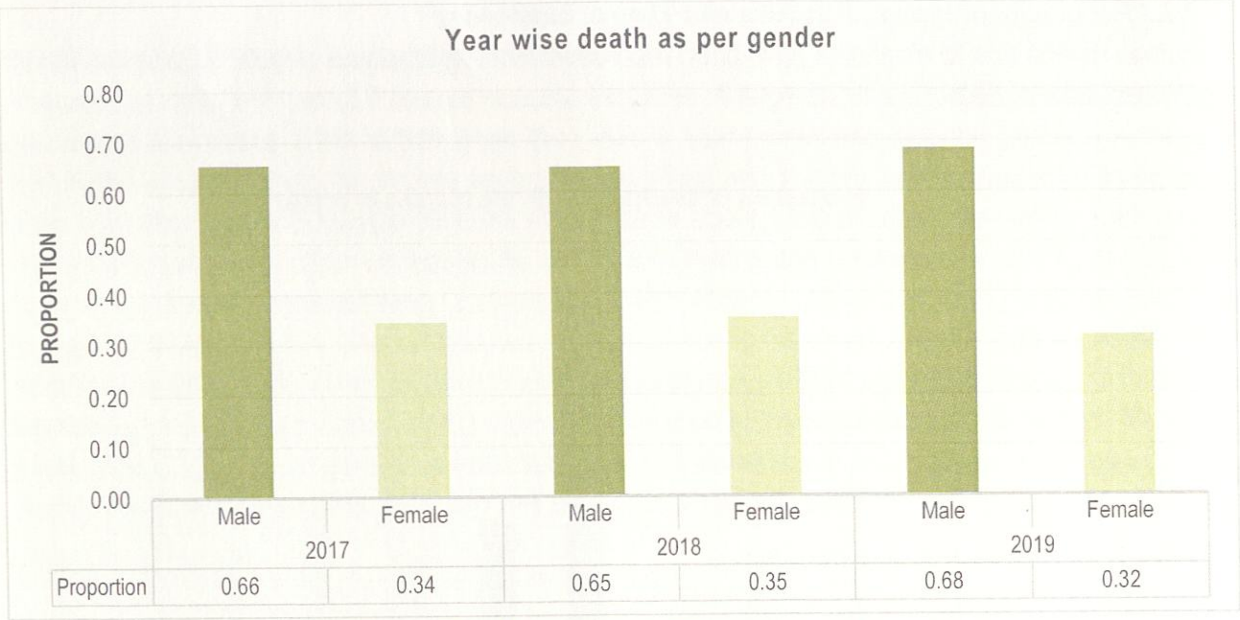


Figure 8.3: Year wise death as per gender

8.3.2 Sites of Incidents

Out of the recorded primary cases (n=46), a large fraction of deaths have occurred in and around the vicinity of the houses (30%, n=14) and in agricultural fields (30%, n=14). An almost equal number of deaths occurred in the forests (28%, n=13) (Figure 8.4). Five deaths (11%) occurred in the scrub lands. The category "inside/vicinity of the house" represents the sites where the incidents have occurred inside the or within the radius of 100 m from the house, for houses located both inside settlements as well as those close to forest.

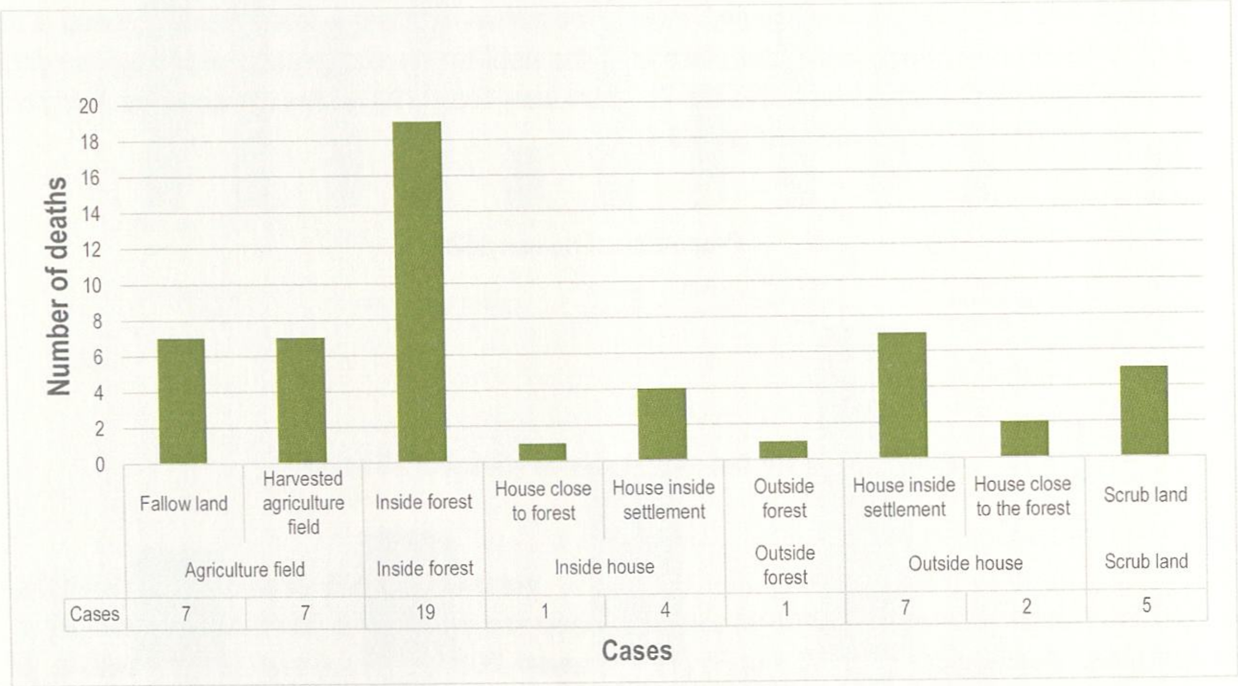


Figure 8.4: Number of deaths recorded with respect to site of incident. Agricultural fields been divided into fallow fields and harvested fields

8.3.3 Periodicity of Human Fatalities and Time of Incidences

Human deaths due to elephants have been recorded all through the year (Figure 8.5) and not limited to any particular period.

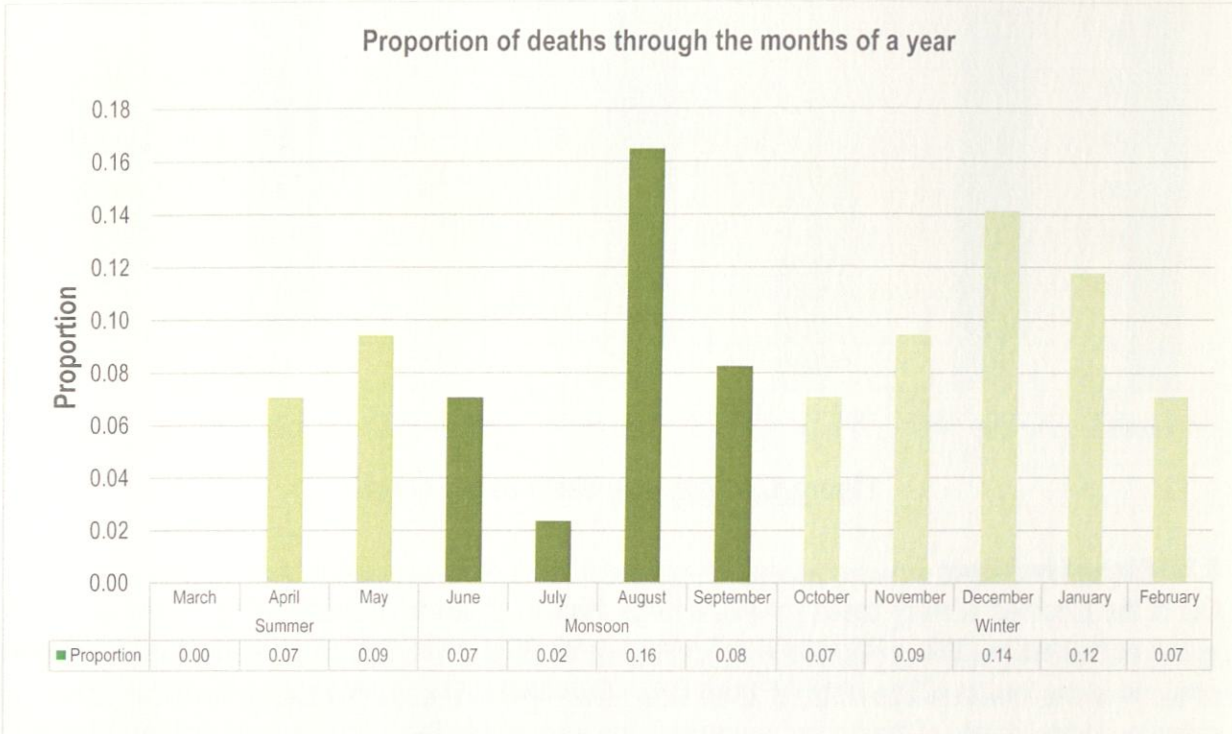


Figure 8.5: Proportion of deaths through the months of a year. Months have been grouped together into seasons summer, monsoon and winter

As far as time of incidences is concerned, most of the human deaths due to elephants occurred at night (50%, n=23). Further, many deaths took place when the visibility was relatively poor due to light conditions, i.e. dusk (24%, n = 11) and dawn (15%, n = 7). There were five (11%) deaths that occurred during broad day light between 0700 h to 1600 h (Figure 8.6)

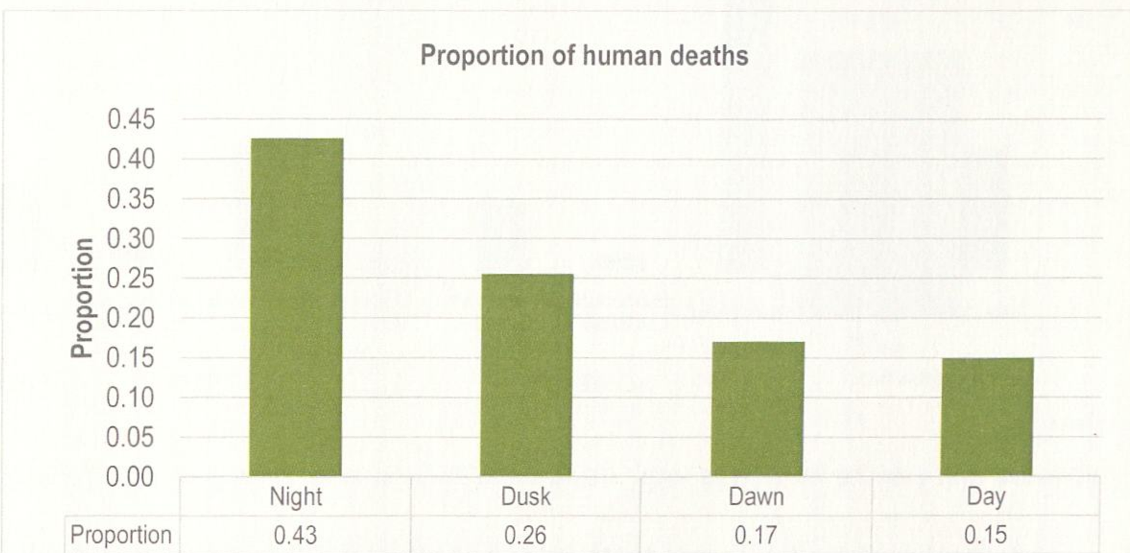


Figure 8.6: Proportion of human deaths as per the time of the day categorised as dawn, day, dusk and night

8.3.4 Activities of Victims during the Incidences

The activities listed in Figure 8.7 are not mutually exclusive. A large fraction (16/46) of deaths occurred in and around the houses of the victims when they were in their homes and probably taken by surprise. A few deaths occurred when the victims were sleeping/sitting and in a few cases, they were trying to run away from their homes to escape from the elephants. In about 17% of cases, the victims were moving inside the forest (n = 8) either on foot (4.3%, n = 2) or in their cycles / two-wheelers (11%, n = 5). About 15%(n = 7) of deaths occurred during collection of forest produces. About 15% (n=7) of deaths were due to elephant drives wherein; elephants turned aggressive during the drives and charged at people. There were three deaths (6.5%) during which the victims were working in their agricultural fields and there were two deaths (4.3%) where victims went to relieve themselves in the bush around their homes. There was a lone case (2%) of victim going to a waterbody next to their homes to fetch water and during two cases (4.3%), the victims approached the elephants either out of curiosity or to photograph them

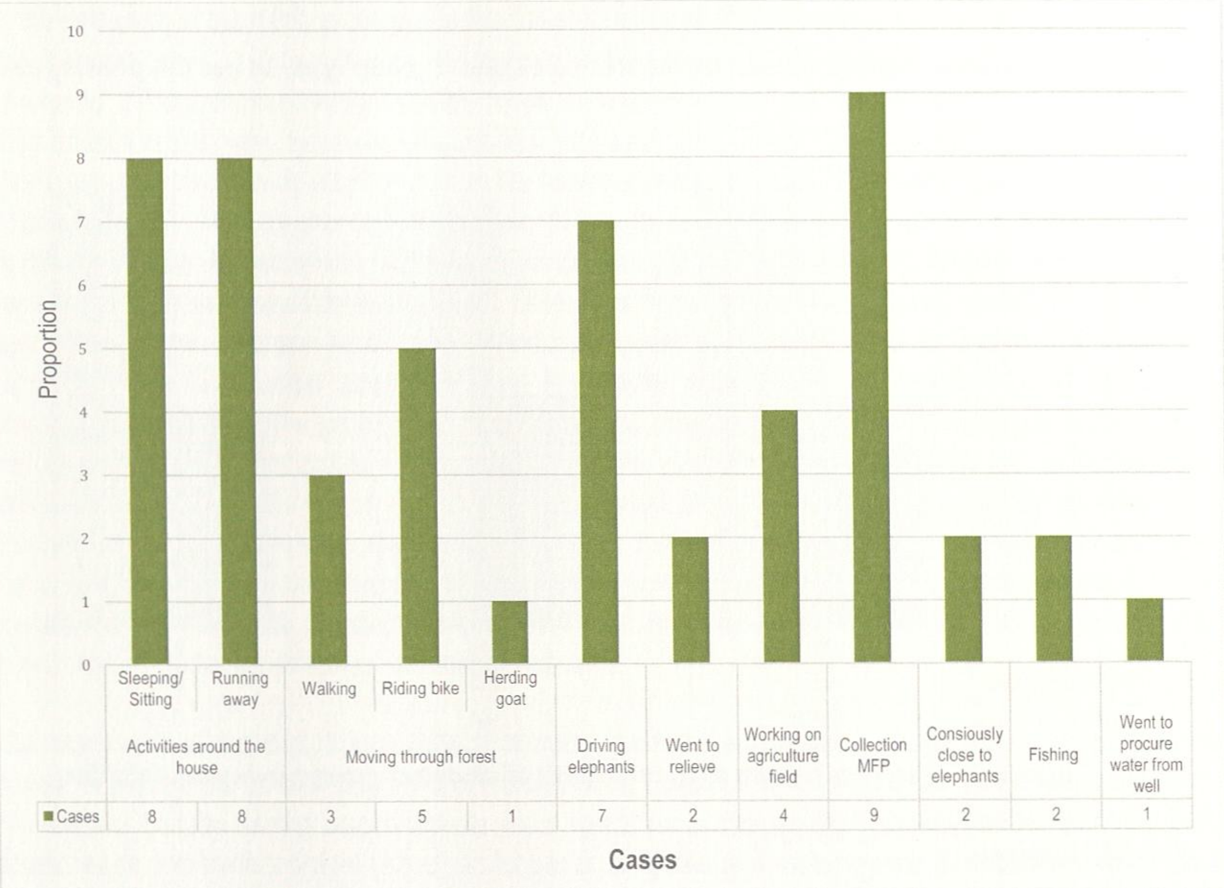


Figure 8.7: Activity of victims, as per the primary data

8.3.5 Fatality Caused by Elephant Groups

In the overall cases (n=45), female herd was responsible for over 40% cases (n = 18), while males (solitary or all-male groups) were involved in 60% cases (n = 27) (Figure 8.8 & 8.9). Statistically, the difference between these numbers were not significant (Chi-Square = 1.8, df = 1, *P* = 0.17).

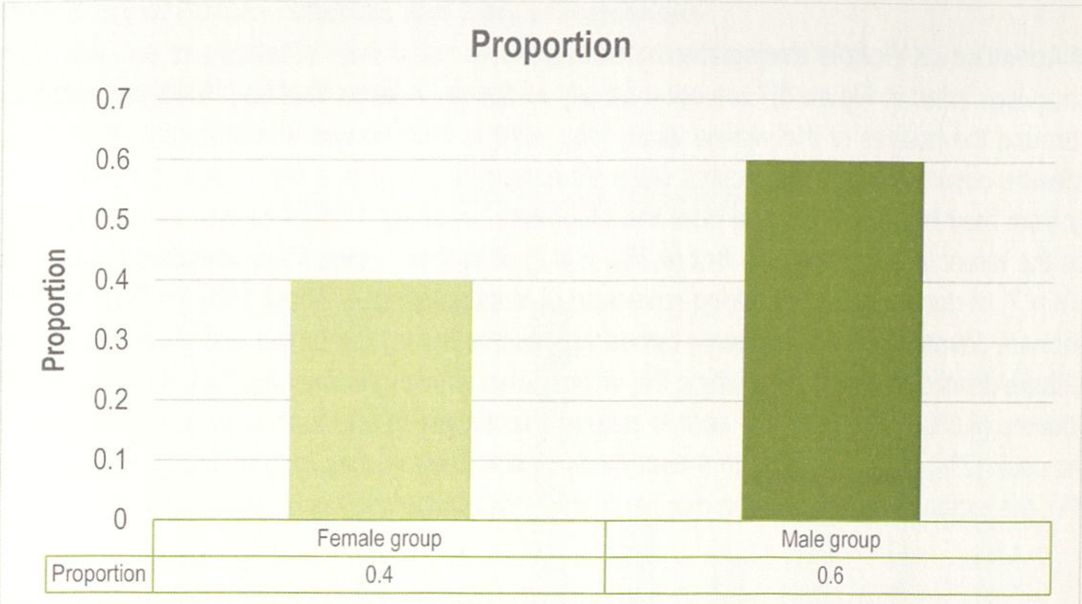


Figure 8.8: Overall deaths caused by respective elephant group type, as per the primary data

Figure 8.9: Year wise pattern of involvement of elephant groups in human fatalities

8.4 Discussion

Given that elephants are ranging extensively in northern Chhattisgarh landscape where forests and human use areas tightly overlap, containing human deaths is a huge challenge (Chapter-1). From our study, certain intuitive patterns emerge: More men die in comparison to women during human–elephant conflict situations. Further, more elders are killed during encounters with elephants. This is possibly due to the fact that village elders (both men and women) often go to forests to collect forest produces and also, their physical faculties that are needed to detect and evade elephants tend to be poor. In Surguja and Bilaspur circles, it is not uncommon to see frail elders taking their cattle inside the forests to graze. An equal fraction of youth & middle-aged men dies as well. In addition to grief, death of middle-aged earning member can economically cripple down families and jeopardize their social security in the long-run. This highlights the fact that human–elephant conflict is both an economic and a social problem.

With regards to periodicity, human deaths due to elephants are spread out throughout the year and not limited to any particular period. This pattern merits explanation: In northern Chhattisgarh, although intensive cultivation of crops is seasonal (except in some districts that have better irrigation facilities), standing crops that small groups of elephants can feed on such as vegetables, pulses and fruits are always there, albeit in small quantities. Some of the bulls and even small groups of elephants raid even the gardens in the backyard of dwelling places. Thus, the frequency of interactions elephants and people in and around human habitations is always high. Similarly, the local communities are also highly dependent on forests for their livelihood. They frequently venture to forests to collect a variety of forest produces across different seasons. Thus, the chances of encounters between people and elephants inside the forest is always high.

A large number of human deaths have occurred in the vicinity of houses and other dwelling places. Deaths have occurred around solitary houses in the jungle and in the settlements as well. Elephants do break houses to raid stored grains, salt and possibly liquor. Elephants breaking houses creates pandemonium in the darkness of the night as people in the house are usually taken by surprise by the elephants. There are reported cases of victims fleeing from their houses in the darkness of the night and bumping into the elephants. It is usually impossible to safely move out women, elders and children when elephants surround their houses in the night. Because villagers fear that elephants will raid their houses in the night, some of them resort to driving away elephants from the forests during daytime. There were quite a few deaths due to drives as well. Thus, elephants coming closer to houses and at times breaking them is a serious concern in this landscape. Nevertheless, addressing the problem of house breaking by elephants is not an easy task as the problem is spatially widespread; villagers continue to live in isolated houses within the forests; and some of the elephant herds and individuals appear to be habituated to breaking houses. The worrisome part is, younger elephants learn from older elephants – the process known as cultural transmission and thus, the problem of house breaking may persist if we do not develop solid plans to reduce it. In high-conflict areas, holding dialogues with villagers and consolidating the settlements and developing community-managed fences (with trip alarm) around the settlement may be experimented. Further, some of the individual elephants and groups that are more habituated to breaking houses may have to be deterred and negatively conditioned using powerful *kumki* elephants and other measures that invoke fear in elephants. These methods, of course need to be considered in lieu of existing legal requirements under the Wildlife (Protection) Act, 1972.

Our study also shows that around 20% of human deaths have happened on the roads and trials in the forest. In places like Dharamjaigarh and Korba Forest Divisions where there are village enclaves within the forests, despite having comparatively wider roads (or *kucha* roads) villagers use numerous narrow forest roads and trails to travel (either on foot or in bi-cycles and motorcycles) to cut down the distance meagrely. This is dangerous as wild animals including elephants have the habit of using these trials for directed movement and thus, chances of close encounters between people and elephants are usually high. Further, villagers moving in motorcycles are more vulnerable as engine noise of their motorcycles preclude detection of elephants nearby. Thus, it is imperative to engage with the local villagers and try and reduce use of narrow roads and instead use wider roads with good visibility.

It is noteworthy that over 30% of human deaths have occurred in the crop fields – possibly while guarding crops or driving away crop raiding elephants. In northern Chhattisgarh, the farmers are highly marginal and crop loss is perceived as a direct threat to livelihood. This seems to be the reason why villagers guard crops despite knowing the risks associated with it. Teaching them simple, but safe crop guarding techniques can be helpful. For example, we have observed many farmers guarding their crops from flimsy thatched huts erected in the fields. With numerous sturdy Mahua (*Maduca indica*), mango (*Mangifera indica*) and ficus trees around, it is prudent to guard crops from *machans* erected over a sturdy tree as is done by many forest dwelling communities in south India. Timely disbursement of ex-gratia to affected farmers is crucial as well. Our study shows that male elephants were responsible for more human deaths than the female herds. Even in cases of human deaths involving herds, it is ambiguous whether female elephants were responsible for human deaths or young males that operate along with the herds. During our study period, we have identified numerous young males that are in the dispersing age-class (around 10 to 15 years). These young males move out of their natal ranges, operate alone or sometimes associate with other males or family herds. In general, young males that move out of natal ranges tend to be more excitable when they operate alone as they lack social buffering that older and experienced elephants provide when they are in the herd. It is difficult to continuously monitor young males as they form loose associations and may move widely. Fitting collars on young males is difficult too as there are several in the landscape and males have rapid growth spurt and thus the collars would soon choke them. Human deaths due to family groups are comparatively less as family herds can be better detected and monitored.

CHAPTER-9
INITIATIVES TO ENHANCE INSTITUTIONAL CAPACITY TO DEAL WITH HUMAN–ELEPHANT CONFLICT IN CHHATTISGARH

9.1 Introduction

An important component of WII-CGFD collaborative project is the capacity enhancement of the frontline staff of forest department and other important stakeholders in aspects on human–elephant conflict management. Since the inception of the project during July 2017 till its completion during March 2022, WII had carried out numerous training programs to the frontline staff, officials, veterinarians, mahouts and elephant handlers, trackers and volunteers, and village stakeholders on range of topics relevant for managing human–elephant conflict. The WII initiative on capacity building programs had resulted in significant increase in the local capacities required for handling conflict situations. Besides completing the structured training programs envisaged in the project, the field activities of the project entailing daily monitoring of elephants and conflict, capture and collaring operations, *kumki* operations involving use of *kumki* elephants in the field conditions etc., provided on-the-field training.

Broadly, the capacity building initiatives carried out as part of the project have been categorized into four different types as elaborated in the subsequent sections. The structured training programs conducted by WII during the period July 2017 to March 2022 are as follows:

9.1.1 Training for Frontline Staff of Forest Department

The primary stakeholders intended in the workshops planned by WII were the Forest Department frontline staff that is engaged in day-to-day conflict management. The trainees in this category included Forest Guards, Deputy Range Forest Officers, Foresters, and Range Forest Officers. The trainees also included volunteers from the Hathi-Mitra-Dal units. Furthermore, trainings imparted to *mahouts*, *kavadis* and other elephant handlers too were included. Therefore, numerous field and off-field training programs were conducted to enhance the capacity of frontline staff of Chhattisgarh Forest Department. Training modules (power-points and videos) for the workshops were developed and shared with PCCF (Wildlife) and CCFs (Surguja and Bilaspur) during the year 2017-2018

(to then PCCF Dr. R.K. Singh and CCFs Shri. K.K. Bisen and Shri. Anand Babu). The modules straddled across themes such as natural history, basic ecology and behavior, drivers of conflict and solutions widely used. The trainings included ample photos, videos and also field sessions. The list of trainings along with the resource personnel has been provided in Table 10.1

Table 9.1 List of training/capacity building programs conducted for Frontline Staff of the Forest Department

S. No	Date / Period	Mode & Location	Training Details	Topics Covered	Resource Personnel	Trainees / Participants
1	5/11/17	**Direct**, Sitapur Range Office, Surguja Forest Division	Understanding elephants and managing human–elephant conflict in Chhattisgarh	Elephant behavior, ecology and natural history	WII internal = 2 External = 2	40 (Forest Staff comprising of ROs, DROs, FGs and Hathi-Mitra-dal)
2	7/11/17	**Direct**, Mahasamund DFO Office	Primer on Elephant Behavior and Ecology and aspects of human–elephant conflict management	Elephant behavior, ecology and natural history	WII Internal = 2 External = 1	30 (Forest Guards and Hathi-Mitra-dal volunteers)
3	01/05/19	**Direct**, Elephant Rescue and Rehabilitation Centre, Pingla, Surajpur	Field demonstration of health assessment for captive elephants	Captive elephant health, screening, disease monitoring and others	WII internal = 4 External = 2	Mahouts and kavadis of 9 elephants
4	18/05/19	**Direct**, Sanjay Tiger Reserve, Madhya Pradesh	On aspects of elephant dispersal into Madhya Pradesh	Dispersal of elephants from Chhattisgarh	WII Internal = 2 External = 1	30 Forest Department frontline staff
5	21/05/19	**Direct**, Bandavgarh Tiger Reserve, Madhya Pradesh	On aspects of elephant dispersal into Madhya Pradesh	Dispersal of elephants from Chhattisgarh	WII Internal = 2 External = 1	30 Forest Department frontline staff
6	August 2019	**Direct**, JFM training school, Ambikapur	On management of elephant populations	Tracking elephants in the field, taking notes and others	WII Internal = 1 External = 1	14 newly recruited game guards of Chhattisgarh FD
7	Septem ber 2019	**Direct**, JFM training school, Ambikapur	On management of elephant populations	Tracking elephants in the field, taking notes and others	WII Internal = 1 External = 1	14 newly recruited game guards of Chhattisgarh FD

8	13/01/21	**Virtual,** live-streamed from WII campus	Aspects of captive elephant management	On general aspects of elephant behavior, management with focus on captive elephant management including that of elephant-related diseases	External – 1 (Padmashri. Dr. K.K. Sarma) Internal – 2	50 Frontline Staff including the ACFs, RFOs, Deputy Rangers, Range Assistants, and Forest Guards
9	22/02/21	**Direct,** DFO office, Katghora	Aspects of human–elephant conflict in Chhattisgarh	Topics including that of the elephant behavior, ecology and aspects of human–elephant conflict	Internal – 1 External – 1	19 trainees (all frontline staff of FD) participated in the workshop
10	17/02/21	**Direct,** Sanctuary Superintendent Office, Badhalkhol Wildlife Sanctuary	Aspects of human–elephant conflict in Chhattisgarh	Topics including that of the elephant behavior, ecology and aspects of human–elephant conflict	Internal – 1 External – 1	27 frontline staff of FD participated in the workshop
11	18/02/21 to 19/02/21	**Direct,** Sanctuary Superintendent Office, Tamor-Pingla Wildlife Sanctuary	Aspects of human–elephant conflict in Chhattisgarh	Topics including that of the elephant behavior, ecology and aspects of human–elephant conflict	Internal – 1 External – 1	64 participants including that of the Assistant Conservator of Forests, Range Forest Officers, Deputy Range Officers, Beat Guards and others
12	05/04/21	**Direct,** DFO office, Katghora	Aspects of human–elephant conflict in Chhattisgarh	Topics including that of the elephant behavior, ecology and aspects of human–elephant conflict	Internal – 1 External – 1	52 Frontline Staff including that of ACF, Range Forest Officers, Deputy Range Forest Officers, and Forest Guards

13	06/04/21	**Direct,** DFO office, Korba	Aspects of human–elephant conflict in Chhattisgarh	Topics including that of the elephant behavior, ecology and aspects of human–elephant conflict	Internal – 1 External – 1	42 Frontline Staff including that of ACF, Range Forest Officers, Deputy Range Forest Officers, and Forest Guards
14	08/04/21	**Direct,** DFO office, Dharamjaigarh	Aspects of human–elephant conflict in Chhattisgarh	Topics including that of the elephant behavior, ecology and aspects of human–elephant conflict	Internal – 1 External – 1	42 Frontline Staff including that of ACF, Range Forest Officers, Deputy Range Forest Officers, and Forest Guards
15	09/04/21	**Direct,** DFO office, Jashpur	Aspects of human–elephant conflict in Chhattisgarh	Topics including that of the elephant behavior, ecology and aspects of human–elephant conflict	Internal – 1 External – 1	30 Frontline Staff including that of Range Forest Officers, Deputy Range Forest Officers, and Forest Guards
16	16/08/21	**Direct,** Office of the Sanctuary Superintendent , Tamor-Pingla WS, Surguja	Essentials for management of elephants in captivity (including field demonstration)	Captive elephant management, health care, use of kumki elephants for conflict mitigation, managing emergency situations	External = 3 (Dr. AB Srivastava, Dr. Ilayaraja and Sh. Prabhat Dubey) Internal = 2 (including Dr. Nigam)	38 officials including elephant handlers, mahouts and frontline staff
17	19/08/21	**Direct,** Office of the Chief Conservator of Forests, Surguja Forest Circle, Ambikapur			External = 3 (Dr. AB Srivastava, Dr. Illayaraja, Sh. Prabhat Dubey) Internal = 2 (including Dr. Nigam)	80 officials ACFs, Range Forest Officers, Deputy Rangers, Range Assistants, Foresters and Forest Guards

9.1.2 Capacity Enhancement of Professional Veterinarians

Veterinarians form the backbone of human–elephant conflict management. The role of veterinarians. Developing veterinary expertise is one of the important means towards improving captive elephant welfare conditions and also in effectively managing human–elephant conflict situations in the field. In fact, veterinarians form the backbone of human–elephant conflict management with very important roles. In Chhattisgarh, the veterinary capacity to handle emergency situations facing elephant management continues to be limited. Recognizing this lacuna, WII had provided intensive training by involving world-class institutions to select senior veterinarians in the state.

Additionally, since the inception of the project, WII had been working closely with the field veterinarians and all the elephant chemical captures were carried out in presence of forest department veterinarians and their teams. This direct field exposure had significantly increased the technical know-how of veterinarians in Chhattisgarh.

Table 9.2 List of training/capacity building programs conducted for Veterinary Professionals

S. No	Date / Period	Mode & Location	Training Details	Topics Covered	Resource Personnel	Trainees / Participants
1	27/01/2019 to 15/02/2019	Sariska Tiger Reserve	Interventions in wild animal health (IWAH)	Wildlife health management and wild animal immobilization	WII, University of Edinburg, UK and Zoological Survey of London, UK	Dr. C.K. Mishra, Veterinary Officer, Ambikapur
2	4/08/2019 to 17/08/2019	Mpumalanga, South Africa	International training on "Zoo, exotics and wildlife anaesthesiology" for veterinarians	Wild animal immobilization	WII and Wildlifevets.net, South Africa	Dr. J.K. Jadia

9.1.3 Exposure Workshop for Village Stake Holders

Effective management of human–elephant conflict rests with multi-stakeholder involvement. Village communities sharing landscape alongside elephants are the primary stakeholders in managing human–elephant conflict. Thus, providing exposure workshops to village stakeholders on ecological and behavioral aspects of human–elephant conflict would be helpful so as to get their support and involvement. In this regard, WII initially intensively trained Shri. Prabhat Dubey on elephant conflict management and later, Sh. Dubey, who is well-known among local communities due to his continuous involvement in conflict management eventually contributed in training village stakeholders.

Table 9.3 List of training/capacity building programs conducted for village stakeholders

S. No	Date / Period	Mode & Location	Training Details	Topics Covered	Resource Personnel	Trainees / Participants
1	21/08/17	**Direct,** Narbadapur Pachayat Union, Mainpat, Surguja	General presentation on HEC and discussion thereafter with Sub-Divisional Magistrate	HEC, dos and don'ts during HEC situations and people participation	WII Internal – 1 External - 1	100 villagers from Narbadapur Panchayat including villagers of Kandraja
2	25/08/17	**Direct,** Holy Cross Sr. Secondary School, Ambikapur	Elephant and wildlife conservation for school children	On wildlife conservation aspects	WII Internal – 2 External - 1	School children (+1 and +2)
3	24/01/20	**Direct,** Guru Ghasidas University, Bilaspur	On aspects of wildlife and elephant conservation	General aspects of wildlife and elephant conservation	WII Internal – 1 External – 1	32 trainees participated in the meeting. The team included frontline staff from Bilaspur circle and university students
4	10/07/21	**Direct,** Bagda village, Surajpur District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	42 villagers and frontline staff from Surajpur FD
5	11/7/21	**Direct,** Songara village, Surajpur District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	44 villagers and frontline staff from Surajpur FD
6	13/07/21	**Direct,** Patkura village, Surguja District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	45 villagers and frontline staff from Surguja FD

7	13/07/21	**Direct,** Ghaton village, Surguja District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	35 villagers and frontline staff from Surguja FD
8	14/07/21	**Direct,** Singhra village, Surajpur District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	41 villagers and frontline staff from Surajpur FD
9	15/07/21	**Direct,** Bharda village, Surajpur District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	50 villagers and frontline staff from Surajpur FD
10	15/07/21	**Direct,** Khandraja village, Surguja District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	70 villagers and frontline staff from Surguja FD
11	19/07/21	**Direct,** Bardand village, Surguja District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	60 villagers and frontline staff from Surguja FD
12	20/07/21	**Direct,** Chorkipani village, Surguja District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	60 villagers and frontline staff from Surguja FD

13	21/07/21	**Direct,** Mohanpur village, Surajpur District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	60 villagers and frontline staff from Surajpur FD
14	23/07/21	**Direct,** Duppi village, Surajpur District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	40 villagers and frontline staff from Surajpur FD
15	23/07/21	**Direct,** Rewatpur village, Balrampur District	Human–elephant conflict management, village-level involvement and collective efforts required to address conflict	HEC particular to Chhattisgarh, behavior, elephant movement and other aspects	WII Internal – 3 External – 1	35 villagers and frontline staff from Balrampur FD

9.2 Summary

During the period July 2017 to March 2022, WII had conducted 17 training programs over a period of 18 days in which 569 forest staff, mahouts and other officials participated and benefited. During the same period, two senior veterinarians were intensively trained in nuances of managing human–elephant conflict aspects for over 32 days. The training for veterinarians was provided both in the country and outside, in South Africa. Furthermore, a total of 15 training programs were conducted to village stakeholders and other civil society members in which over 220 participants attended. While these capacity building programs were directly carried out under the project, WII had also been providing training to forest officials on various aspects of wildlife and human–elephant conflict management across India in which many officials from Chhattisgarh Forest Department were particularly invited and trained.

CHAPTER-10
EVALUATION OF CURRENT CONFLICT MITIGATION INITIATIVES OF CHHATTISGARH FOREST DEPARTMENT

One of the objectives of the WII-Chhattisgarh FD collaborative project was to evaluate the current management strategies used in mitigating human–elephant conflict and provide recommendations as appropriate. Accordingly, some of the ongoing conflict mitigation strategies deployed by Chhattisgarh FD were evaluated. The conflict mitigation strategies deployed by Chhattisgarh Forest Department have been broadly classified into the following:

1. Use of various physical barriers and other deterrents
2. Use of early-warning systems
3. Use of *kumki* elephants in managing human–elephant conflict
4. Habitat management activities
5. Use of rapid-response teams
5. Community engagement

The current efficacy and recommendations to improve the same are as provided below:

10.1 Physical Barriers and Other Deterrents

A variety of physical barriers/deterrents are being widely used in both Africa and Asia for containing elephants in natural habitats. An essential consideration in designing and implementing these barriers is to have a background understanding of elephant behavioral and morphological peculiarities. Elephants possess extraordinary sensory perceptions that help them in recognizing and overcoming barriers. Anatomically speaking, the orientation of the limb bones in elephants is almost vertical without angles. Due to this, the elephants cannot jump or vault. Barriers that consider these limitations of elephants can work effectively.

The major challenges facing creation of physical barriers in Chhattisgarh include the following:

I. High level of forest fragmentation and corresponding interspersion of forests and agricultural crops.
II. High dependence on forests by villagers/local communities
III. Shifting elephant home ranges

Table 10.1: Appropriateness of some of the widely used barriers in Chhattisgarh context

S. No	Barrier	Design	Appropriateness
1	Elephant Proof Trench (EPT)	3m (top width) x 2m (height) x 1m (bottom width)	EPTs generally are **not appropriate for Chhattisgarh** due to highly fragmented habitats, high dependence of villagers that can undermine the trench and relatively high rainfall during monsoon May be considered for large population in large habitats
2	Power fence	Powered by energizer (solar-tapped) and designed to deliver 6–9 kilovolts of electric shock at 1/3000 seconds	I. **Permanent fences are not useful** in Chhattisgarh due to large and shifting elephant home ranges in fragmented mosaic. II. Instead, **temporary barriers that can be easily dismantled after use is appropriate.** III. The temporary barriers can be best used to **protect settlements rather than crop fields**.
3	Railway fences (High-spec barrier)	Discarded railway lines. (i) Foundation (vertical rails): 100-cm deep with 30-cm concreting (ii) Standing height of rails: 210 cm above the floor (iii) Span between vertical rails: 350cm (iv) Number of horizontal rails: 2 (v) Span between horizontal rails: 90cm	High perimeter to area ratio of forests and shifting elephant home ranges render **Railway-fences unsuitable for Chhattisgarh.** **These may be considered to prevent elephants from crossing over to identified no-go zones**
4	Honey-bee deterrents	Beehives are suspended on GI strings at regular intervals	The long-term efficacy of honeybee deterrents for Asian elephants is yet to be ascertained. There are only short-term experiments. **Considering this, honey-bee fences can only be experimented in few sites**. Honeybee barriers are not appropriate for large-scale implementation. **The potential risk of honeybee fences attracting sloth bears need to be considered.**
5	Chilli-smoking	Idea is to smoke potent chilli along the forest boundary	Chilli-smoke accompanied by active guarding is appropriate only for individual farms. **The claimed efficacy of chilli-smoke in deterring elephants is yet to be scientifically established.**
6	Solar *bijuka* (electrified human dummy)	Idea is that elephants will get shock upon touching the human dummy and develop healthy respect for humans	Elephants have multitude of sensory perceptions based on sound, smell and vision to recognize elephants. **It is too simplistic to assume that elephants would mistake electrified human dummy for a real human being.**

Recommendation

The high perimeter to area ratio and shifting home ranges of elephants preclude construction of permanent physical barriers in all locations. The Chhattisgarh Forest Department can develop temporary barriers and install them in select conflict hotspots using a participatory approach involving village communities for cost-effectiveness.

10.2 Early-Warning System

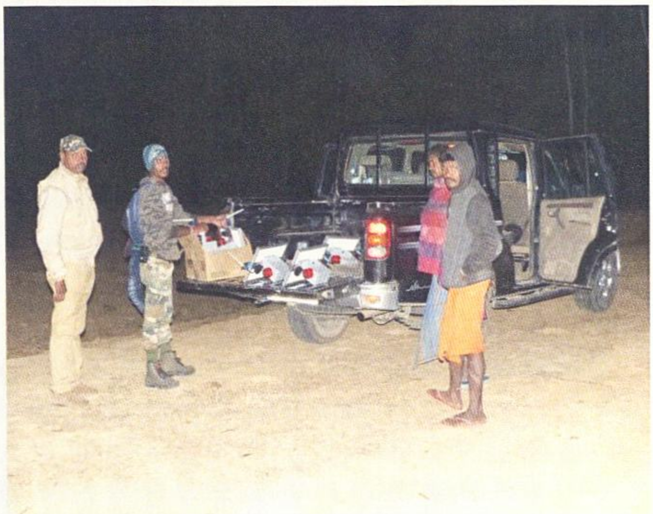
The early-warning systems aim to alert people to prevent/minimize human–elephant interactions through multitude of secondary responses like avoiding forest routes, putting up physical barriers, and in some cases even temporarily shifting people from sensitive areas. There are diverse types of early-warning approaches used for mitigating human–elephant conflict. These include:

(i) Mobile-phone based early warning system
(ii) Visual-based early warning system
(iii) Vehicle-based broadcast parties
(iv) Telemetry-based early warning system and
(v) Radio (all-India radio) alerts.

Chhattisgarh Forest Department has developed fairly robust mobile phone-based early warning system. While the staff members in a circle remained core members, there were beat-level sub-groups wherein; the messages of elephant locations were communicated to the villagers. Incidentally, large fraction of messages on elephant presence in a patch was obtained from village grazers and those collecting forest produces that come across fresh elephant signs in and around the forest patches.

Visual-based early warning system involving display boards, flash lights etc. illuminated in critical locations like bus stops, ration shops etc. Visual-based early warning system has been very effectively used in Valparai region of Anamalai Tiger Reserve in Tamil Nadu by the combined team of Nature Conservation Foundation (NCF), Tamil Nadu Forest Department and local tea plantations to minimize human–elephant interactions.

Vehicle-based early warning system involves broadcasting information on elephant occurrence to villagers using loud speakers mounted on vehicles.



Telemetry-based early-warning system involves broadcasting telemetry location fixes of the collared elephants (radio or satellite collars) through SMS, WhatsApp messages etc. to the respective beats/villages to alert people of elephant presence. It is also possible to create "virtual fences" wherein conflict locations can be mapped in GIS and when satellite collared elephants use such areas, automatic alert messages can pop-up.

Radio-based early warning involves broadcasting locations of elephant occurrence through All-India Radio (local station) during the specific time of the day.

Recommendations

1. **Mobile phone-based early warning system**: Chhattisgarh Forest Department has developed fairly robust mobile phone-based early warning system. While the staff members in a circle remained core members, there were beat-level sub-groups wherein; the messages of elephant locations were percolated to the villagers. Incidentally, large fraction of messages on elephant presence in a patch was obtained from village grazers and those collecting forest produces that come across fresh elephant signs in and around the forest patches. Considering its utility in mosaic landscapes with high interspersion of human-use areas and forests, Chhattisgarh Forest Department can institutionalize mobile-based early warning system in areas where mobile network is good. In high conflict areas, improving mobile network connectivity would be crucial.

2. **Visual-based early-warning system:** Though this has not been explored well in Chhattisgarh, the visual-based early warning system can be experimented in select high-conflict locations. In bus-stands, ration-shops, weekly markets and village centers, notice boards mentioning elephant locations in nearby areas can be useful. Considering this, Chhattisgarh FD can experiment visual-based early warning system in critical locations by roping in local naturalists and *Hathi-mitra-dal* volunteers in select conflict hotspots. In addition to visual-based early-warning system, vehicle-based early warning system for broadcasting information is essential, particularly in weekly markets.

3. **The telemetry-based early warning system:** This_may be one of the option for monitoring animal movement in human dominated landscape. It would involve deployment of collars on select individuals in the group or identified solitary bulls that frequent human habitation. The information of their movement can be used as early warning and necessary preparedness and planning can be done before the herd/ individuals reaches a location/ village or habitation to prevent possible interaction, loss or damage.

4. **Radio alerts that Chhattisgarh Forest Department is broadcasting every day at a stipulated time are of limited use** as the spatial-scale of information shared is at a coarse level (space, time and to & fro movement). It would be more appropriate to use a finer scale such as a division or range and link the broadcast time with popular programmes that have a wide audience base.

10.3 Kumki Elephants

Trained captive elephants can be invaluable for managing elephant habitats and in handling human–elephant conflict situations. Chhattisgarh forest department took a right decision in developing an in-house *kumki* unit in the state and during 2018, brought in 5 captive elephants from Karnataka. Prior to this, the state forest department already had 3 captive elephants. Since the year 2018, WII played an important role by providing technical inputs and field support during transportation of elephants from Karnataka and subsequent training of the captive elephants for use in field operations. With direct field involvement and guidance by WII, *kumki* elephants trained in Chhattisgarh were used during different wild elephant capture and collaring operations across Chhattisgarh (Table 10.2).

Table 10.2 Kumki elephants used in different elephant capture operations in Chhattisgarh

S. No	Division	Period	Operation	Details
1	Dharamjaigarh FD	July 2019	Operation Ganesh	This operation involved capture, transportation and collaring of wild elephant (adult bull tusker)
2	Surajpur FD	December 2019	Operation Behradev	This operation involved capture, treatment (of wounds) and collaring of wild elephant (adult *makhna*)
3	Korba FD	May 2020	Operation Pratam	This operation involved capture and collaring of wild elephants (adult bull tusker)
4	Surapur FD	November 2021	Operation Maitri and Mohini	This operation involved capture and collaring of two cow elephants from different herds

In addition to aforementioned elephant capture operations; these elephants were also used in patrolling activities, elephant conservation and conflict mitigation trainings and while carrying out rescue operations.

Table 10.3: Details of captive elephants maintained in Chhattisgarh

S. No	Elephant	Source
1	Civil Bahadur, bull tusker, > 60 years	Wild caught (Chhattisgarh)
2	Thirathram, bull tusker, ~40 years	Wild caught (Karnataka and transferred to Chhattisgarh during 2018)
3	Ganga, adult cow, ~28 years	Wild caught (Karnataka and transferred to Chhattisgarh during 2018)
4	Yoglakshmi, adult cow, ~18 years	Wild caught (Karnataka and transferred to Chhattisgarh during 2018)
5	Sonu, sub-adult male, ~ 15 years	Wild caught (Chhattisgarh)
6	Parasuram, sub-adult male, ~ 16 years	Captive born in Karnataka and transferred to Chhattisgarh during 2018
7	Duryodan, bull tusker, ~ 35 years	Wild caught (Karnataka and transferred to Chhattisgarh during 2018)
8	Laali, adult cow, ~ 25 years	Wild caught (Chhattisgarh)
9	Raju, bull tusker, ~35 years	Wild caught (Chhattisgarh)

10.3.1. Activities Expected from kumki Elephants

Role of *kumki* elephants in elephant conflict management can be diverse. Broadly, a well-trained *kumki* can act as a parent, friend and in situations that demand sternness, a boss. The activities expected of *kumki* elephants in forestry and wildlife operations in the State include:

i. Patrolling the forests, particularly the protected areas
ii. Commuting ration and other resources to remote forest camps and *chowkis* (patrolling camps)

iii. Wildlife rescue operations including that of wild elephants, sloth bears, large carnivores and other potentially dangerous animals

iv. Managing human–wildlife conflict. This includes monitoring elephant movement, dealing with individual elephants in human–use areas, elephant capture and translocation operations, and also in soft-drives aimed at moving wild elephants away from human-use areas.

Recommendations

i. Although Chhattisgarh Forest Department had made the right investment in developing a state-of-the-art *kumki* elephant camp, the actual use of *kumki* unit in the field conditions needs to be enhanced. The *kumki* elephants and the handlers have basic training, but substantial continuous training by regularly using the *Kumki* unit in different operations is essential for developing skills of both *kumkies* and handlers.

ii. The recommendations provided by WII with respect to elephant camp management vide reports "*Assessment of Husbandry and Healthcare Practices for Captive Elephants at Pingla Elephant Rehabilitation Centre, Tamor-Pingla WLS, Surajpur*"submitted during May 2019 and "*Upkeep and Utilization of Elephant "Sonu" Housed in Elephant Rescue and Rehabilitation Centre, Pingla, Surguja*" submitted during August 2021 can be used as a guiding document. In those reports critical considerations to enhance captive elephant welfare have been highlighted.

iii. Chhattisgarh Forest Department may fabricate high-quality elephant transportation trucks for internal rapid and safe transportation of *kumkis* to different sites for conflict management activities. The truck design may be obtained from Karnataka Forest department / WII.

iv. Presently there is no fixed work schedule for the mahouts and the *kumki* elephants. Thus, there is under-utilization of the force in spite of high recurrent expenditure. A work schedule to actively engage mahouts and *kumki* elephants on a variety of forestry and wildlife activities needs to be finalized and actively implemented.

v. Ramkola may be developed as nodal centre for elephant conservation, HEC management training & capacity building.

10.4 Habitat Management

Habitat improvement activities currently undertaken by Chhattisgarh Forest Department with an objective of increasing suitability of habitats for elephants include (i) plantation of fodder species (ii) weed removal (iii) grassland development (iv) water regime development (*narua* treatment, *talab* construction, stop dam creation).

Recommendations

i. Among the aforementioned initiatives, Chhattisgarh FD's grassland development with scientific guidance from restoration experts has proven valuable in increasing the fodder base for herbivores in Boramdeo and Barnawapara Wildlife Sanctuaries (where elephants are either absent or occur only sporadically). Based on the learning and experience obtained in these sanctuaries, Chhattisgarh FD can emulate the same in Protected Areas of Guru Ghasidas NP, Tamor-Pingla WLS, and other select areas in Bilaspur and Surguja forest circles.

ii. While habitat improvement activities listed above (particularly grassland development and water augmentation) are essential for restoring elephant habitats, caution should be exercised in developing only large, intact and contiguous habitats and not the small patches of forests. Improving habitat conditions in small and isolated patches of forests can be counterproductive as elephants would start using small patches as daytime refuges and venture out in the nights for crop raiding.

10.5 Rapid Response Teams

Chhattisgarh FD had developed good teams of elephant volunteers called "*Hathi-mitra-dal*". The teams work with the Forest Department and act as a bridge between Forest Department and local communities. Their involvement has proved crucial in human–elephant conflict mitigation. However, Chhattisgarh Forest Department is yet to institutionalize the functioning of *Hathi-mitra-dal* with better budgetary support and remuneration, well-defined work schedule that enables engagement throughout the year besides capacity building and improvement in human resource management.

10.6 "Gajraj" Vehicle

Chhattisgarh FD fabricated multi-purpose vehicles called Gajraj for use in elephant-conflict mitigation. The vehicles were designed to handle emergency situations that may involve elephant capture and are thus, adequately equipped. The vehicles were neither adequately large and strong for transporting elephants, nor small enough for use in daily monitoring. Therefore, instead of investing on Gajraj vehicles, Chhattisgarh FD can invest on two large specially designed trucks that can be used for carrying elephants during emergency situations.

CHAPTER-11
SYNTHESIS OF RESEARCH FINDINGS & SUMMARY OF CHALLENGES SPECIFIC TO CHHATTISGARH

11.1 Introduction

Although human–elephant conflict is widespread across the four regional elephant populations in India, in the East-central region comprising of Odisha, Jharkhand, Chhattisgarh and South West Bengal (and lately north Andhra Pradesh and Madhya Pradesh) the conflict is particularly acute. East-central region supports less than 10% (around 2500 elephants) of the wild elephant population in India, but accounts for over 50% (> 200 lives) of reported conflict-related human fatalities. Addressing human–elephant conflict in the East-central region is complex and challenging, particularly in light of elephant dispersals (this is not post-natal dispersal of male elephants, but involve 'environmental dispersal'[3]) into new areas spreading the zone of conflict. The human–elephant conflict that intensified in the East-central region after 1980s clearly corresponding with large-scale disturbances to elephant habitats due to mineral mining activities and associated developmental activities (Singh & Chowdhury, 1999; Singh *et al.,* 2002). Elephant management in Chhattisgarh represents issues facing environmental dispersal of elephants in human–dominated areas. In relative terms, human–elephant conflict in Chhattisgarh is recent (about two decades old). But, the extent and severity of human–elephant conflict in Chhattisgarh are high necessitating basic research on elephants. Managing human–elephant conflict without conducting basic ecological research focusing on demography, ranging behavior, habitat utilization and social aspects would be difficult and *ad hoc*. This lacuna is partly addressed through the multi-dimensional research carried out by Wildlife Institute of India.

11.2 Summary of Technical Chapters

Chapter-3 provided details on elephant distribution, abundance and other demographic variables. During the period 2000 to 2020, the elephant numbers in the Chhattisgarh had increased due to immigration and in-situ births. The current population estimate (2021) was around 250, which occurs in 15 forest divisions and four protected areas in the northern and central Chhattisgarh. It is noteworthy that since 2021, elephants have started ranging in southern districts of Chhattisgarh. The adult sex ratio recorded during the study was 1:4.5. Eleven adult bulls were recorded during the study. About 44.2% of the female segment of population comprised of adult cows. In the sub-adult segment of population, the males were numerically higher and this was likely due to high turnover of sub-adult males as a consequence of dispersals. Body condition scores of elephants were optimal. Inter-calf interval was estimated to be about 3.4 years, which is relatively low. Although the number of elephants in Chhattisgarh oscillates around 200 to 250, the groups are spatially scattered and continue to move apart farther.

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[3] Environmental dispersal refers to dispersal of animals triggered by resource saturation in their home ranges caused either by habitat loss or increased population (Sinclair et al, 2006)

Chapter-4 provided an assessment of elephant home ranges in Chhattisgarh. Elephant home ranges in Chhattisgarh were studied using two different field techniques namely (i) individual recognition and re-sighting (ii) satellite cum radio telemetry. Home ranges were estimated using minimum convex polygon (MCP) approach that provides a geometric representation of elephant home ranges and the kernel density estimates (KDE) that produces utility distribution based on location fixes.

i. During the period 2018 – 2021, a total of 6 bulls (including one bull collared twice) and 4 females from the herds were collared. Additionally, two of the female herds were monitoring using sighting-resighting approach without collars. Furthermore, WII provided technical and field support to Wildlife-SOS and Chhattisgarh Forest Department in collaring a female elephant in Mahasamund Forest Division. Satellite collaring of elephants generated 3106 elephant days of tracking data with an average of 310.6 (± 273) days of data per elephant (Range = 3 to 823 days).
ii. The average home range of elephants recorded during the study using 95% MCP approach was 3172.8 Km2 (SD ± 2002.2 Km2, Range: 462.3 – 6969.7 Km2). The average home range of elephants recorded during the study using 95% KDE approach was 512.3 Km2 (SD ± 236.1 Km2, Range: 126.5 – 748.9 Km2). This indicates that home ranges estimated using MCP approach comprises of a large fraction on unused areas.
iii. Elephant home ranges recorded in Chhattisgarh were much larger than home ranges reported from other parts of India
iv. The time-area curve of monthly home ranges indicated that elephant home ranges were not well defined. Significant shifts in home ranges across years were observed. The shifts were caused by elephant exploratory behavior.
v. In general, dry season ranges of elephants were smaller than monsoon and winter season home ranges.
vi. Documented examples of elephant dispersal events that occurred during the study period were reported.

In **Chapter-5**, habitat selection patterns by elephants were elaborated. Across the year, during all three classified seasons of dry (March to June), monsoon (July to September) and winter (October to February), elephants have spent over 75% of time in forests and 14 – 19% of time in the crop fields. During dry season, the collared cow elephant GI and herd remained almost entirely within the forests in an area measuring 25.5km2. For this herd, monsoon and winter months triggered movement into human–dominated areas. Among the three broad categories of forests namely open, moderately dense and very dense forests, elephants selected open forests over the other two types at the landscape-scale. Open forests predominantly occur in human–dominated areas. From results it appears that elephant select forest patches not only based on inherent patch characteristics, but also by the potential foraging opportunities in the human–use areas surrounding the forest patches.

In **Chapter-6,** genetic relatedness of elephants in Chhattisgarh was evaluated using 258 non-invasive elephant dung samples collected from 9 Forest Divisions. The analysis revealed that there is a minimum of two different elephant lineages operating in Chhattisgarh. This is likely an indicator that elephants occurring in Chhattisgarh have possibly come from different locations. Within the groups, there was an observed high level of relatedness, which corroborates with the general social structure of elephant societies. A landscape-level genetic assessment covering the whole of East-central region would be important to find out areas from where environmental dispersals of elephants are common.

In **Chapter-7**, the spatial patterns and possible determinants of crop losses by elephants were investigated at two different spatial scales. At the landscape-scale covering elephants' distributional range in northern Chhattisgarh, variations in crop loss intensity were assessed. In the intensive study area centered around 1200 km2 of forest-agriculture crop losses were quantified and also broad correlates were identified. About 1426 villages from 10 forest divisions and 4 protected areas in northern Chhattisgarh reported crop losses during the period 2015-2020 indicating the enormous spatial scale of the problem. At landscape-scale, the explanatory variables of elephant habitat-use intensity, extent of forest cover, number of forest patches, and extent of agriculture explained variations in crop loss intensity.

Chapter-8 focused on the issue of human fatalities due to human–elephant conflict. In Chhattisgarh an average of 60 human lives are lost every year due to human–elephant conflict. As part of the project activities, circumstances surrounding human death incidences due to elephants were recorded in detail. About 70% of human fatalities due to elephants occurred in areas of high-intensity habitat use by elephants. The remaining 30% of incidences occurred in areas of intermediate and sporadic elephant habitat use. Among the human victims, there were more men. Human deaths have occurred both inside and outside the forests. However, frequency of incidences was significantly higher outside. Most of the human deaths occurred during the night and low-light hours of evening/early morning. While crop foraging by elephants were clearly seasonal mirroring crop cultivation cycles, human deaths due to elephants occurred throughout the year. Incidences of human deaths were particularly high near houses, associated with house break-in behavior of elephants, and along the roads during low-light hours. Elephant bulls caused significantly high number of human deaths when compared to female herds. Minimizing human deaths due to elephants would be contingent on: (1) intensifying and institutionalizing elephant monitoring in areas that are regularly used by elephants (2) minimizing house break-ins by elephants by experimenting portable fences around settlements in areas where elephants regularly damage houses (3) advancing early-warning system providing early information to villagers while using roads around their villages during low-light hours (4) Experimenting "elephant friendly buses" in stipulated time in select villages that are vulnerable for human–elephant encounters (5) educating villagers on safe crop guarding measures (6) closely monitor and collect data on individual elephants that have proven dangerous to human lives, as such elephants may have to be captured if all other mitigation measures fail.

11.3 Summary of Major Site-Specific Challenges

11.3.1 HEC is spatially widespread and HEC hotspots are few

Chhattisgarh elephant problem presents a paradox. Although there are just about 250 to 300 elephants, which is a relatively small population, they are distributed over a very large area in patchy habitat characterized by high interspersion of forests and human settlements. The elephants' distributional range and corresponding extent of HEC in the state is close to 47,000 km2 (based on 100% MCP of affected village). This is excluding the Mahasamund elephant population, which has been dispersing all through southern Chhattisgarh as well. While conflict hotspots (where conflict is recurring) are relatively few, cold-spots (where conflict is unpredictable and infrequent) are numerous. While it is relatively easier to manage conflict in hotspots (due to better predictability), managing the same in cold spots is challenging, as it is difficult to prioritize any locality for HEC resolution as conflict shifts over time.

11.3.2. Large and fluid elephant home ranges

It is comparatively easier to manage HEC in landscapes where elephants have well-set home ranges. In such areas, it is possible to make predictions about their habitat use patterns and plan for HEC resolution accordingly. Furthermore, in relatively intact habitats, elephant home ranges are small. Home range size and intensity of human–elephant conflict are positively correlated. For example, elephant home ranges in the Rajaji National Park of Uttarakhand are about 300 – 400 km2. However, in fragmented habitats like Chhattisgarh, elephant home ranges are large, as small patches cannot sustain elephants for a longer duration. The elephants radio collared and monitored by WII-CGFD in Chhattisgarh show that elephant home ranges are one of the largest recorded in India. Apart from being large, the elephant home ranges are fluid and not well-defined resulting in elephants dispersing into new habitats continuously. It is noteworthy that elephants from Chhattisgarh have dispersed into Bandhavgarh and Sanjay Tiger Reserves expanding their range into Madhya Pradesh as well. Such explorations of elephants going into new areas continue to be recorded in Chhattisgarh and Madhya Pradesh. These dispersing elephants have unpredictable movement patterns making conflict resolution challenging.

11.3.3. Diffuse boundaries between habitat and non-habitat preclude application of conventional fence- based conflict management

In northern Chhattisgarh, elephant landscape is characterized by forest patches interspersed with human settlements. Stark differences between forests and non-forests do not exist in rural areas, as agriculture is still highly marginal and seasonal in most areas. The elephants spend considerable time outside the forests in human-use agricultural areas and fallow lands. These landscapes with diffuse boundaries preclude direct application of conventional fence-based conflict management approach as:

(i) the patches are often too small to contain elephants within
(ii) perimeter to area ratio is high making it prohibitive to invest on fences and other physical barriers
(iii) local populace is dependent on forests and therefore maintenance of barriers would be a challenge
(iv) elephant movement is highly seasonal in many areas.

11.3.4. The difficulty in identifying elephant corridors

In fragmented habitats, identifying and restoring corridors is one of the major conservations and conflict mitigation strategies for large mammals considering their high mobility and large home ranges. Role of wildlife corridors as conduits between otherwise isolated forest patches is clearly demonstrated in areas where the difference between wildlife habitat and non-habitat is conspicuous. However, when difference between habitat and non-habitat is less conspicuous like in case of Chhattisgarh, delineating elephant corridors would be difficult. The landscape offers minimal resistance for elephant movement, particularly during low-light hours of the day. In addition to numerous forest patches, there are scrublands; forest plantations and uncultivated fallow lands that can provide adequate cover for elephants to pass through even if actual forest cover doesn't exist. Further, in rural northern Chhattisgarh, the settlements are meager and villagers retire early in the evening with minimal of human activities outside of the settlement. Night-light in the landscape is minimal as well when compared to many other developed states. These conditions facilitate free movement of elephants, and therefore, structural corridors mapped with GIS may not be appropriate.

11.3.5. Problem of house break-in by elephants

House break-in by elephants continues to be a major challenge in this landscape. Observations suggest that house breaking is seasonal and peaks during monsoon when there are no standing crops. House breaking by elephants can create abject terror as it invariably happens in the cover of night. The aberrant behavior of house breaking can spread to other elephants very quickly through social learning. Casual observers of the problem suggest building *pucca* houses to address the problem of house breaking by elephants. This suggestion is impractical because the spatial scale of the problem of house breaking is vast (spread across several districts). Over 558 villages have suffered the problem of house damage by elephants during the period from 2015-2020 (Figure 11.1). It is impractical at this scale to covert *kutcha* into *pucca* houses. Further, elephants range very widely and therefore, the problem can shift from one village to the other. It is clear that there are no easy solutions to the problem.

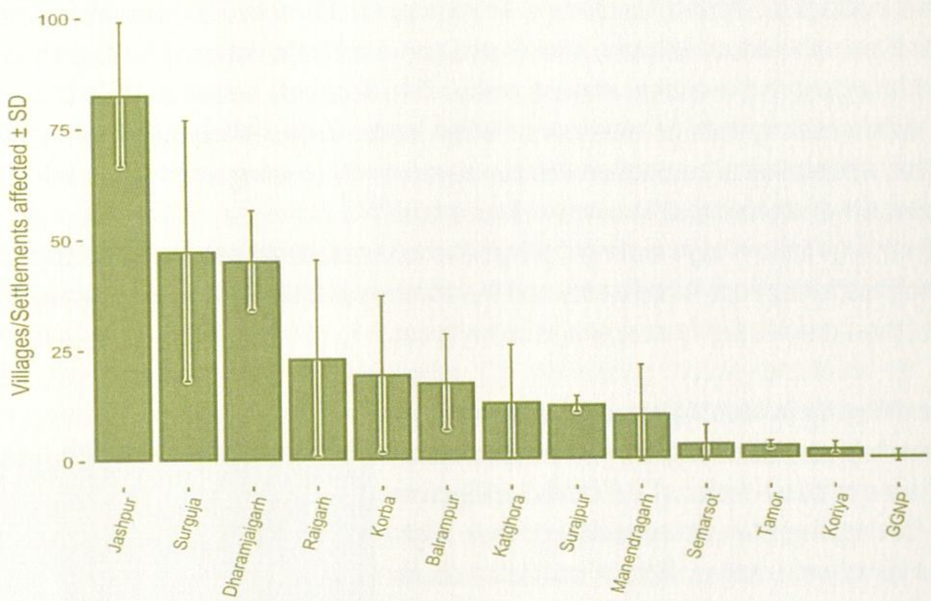

Figure 11.1: Division-wise villages reporting housebreak-ins by elephants during the period 2015 – 2020

11.3.6. Capacity-related challenges

It is observed that the human-resource capacity required for handling human–elephant conflict situations as well as other elephant management issues is relatively weak in Chhattisgarh due to lack of exposure and experience with respect to elephants.

CHAPTER-12
MANAGEMENT RECOMMENDATIONS

12.1 Defining Conflict Priorities

Although the varied forms of conflict may not be mutually exclusive, it is important to have clear management priorities. Due to social, ethical and moral compulsions, reducing human fatalities due to HEC is usually the topmost priority. Because elephants operate in areas that are interspersed with human use areas, reducing crop damage with an immediate effect is impossible. While we continue to work on long-term strategies to reduce crop depredation, one should not loose focus on the main priority of reducing human deaths. Sometimes, when crop depredation incidences escalate, out of pressure the management and the local villagers sometimes resort to haphazard unplanned drives. Such drives do more harm than good and may also lead to human fatalities. The management should make its priority explicit so that it percolates down the level to staff at different levels so that strategies towards achieving a reduction in human fatalities are never compromised.

12.2 Restricting Spread of Conflict to New Areas by Adopting a Zone-Based Management Approach

The first and foremost priority in Chhattisgarh is to clearly demarcate areas where elephants can be conserved. The current elephant range is very large and efforts should be made to not allow the range expand even further. If elephant range expansion in forest areas is deemed desirable, then the same should be well thought-out and executed. While there is certainly inherent elephant range expansion, some of the range expansion can be attributed to unplanned drives and lack of monitoring. There is also a wrong notion that wherever elephants go, those areas constitute elephant habitats. Since elephants are continuing to explore the landscape, possibly in search of suitable habitats, it is critical to delineate elephant "no-go" areas in the landscape. These no-go areas could be areas with minimal forest cover embedded in intensive human-use areas. HEC in such situations are inevitable. Therefore, before HEC situation turns acute due to elephants occurring in no-go areas, it is important to react early and remove elephants from such areas (through controlled drives or translocation). Dispersal of elephants into areas where substantial natural habitat remains is idyllic. However, if elephants disperse into areas where forests are patchy and are not viable to support elephants, then, the management has to swing into action to remove elephants from those areas.

i. In Chhattisgarh context, isolated forest patches that are less than 20 km2 in size; surrounded by human habitations and agriculture, and with inter-patch distance to other forest patches over 5-km are clearly unsuitable for harboring elephants even if elephants use these patches presently. Such small and isolated patches of habitats should not be further developed for elephants and instead, the objective should be discouraging elephant use of small patches and paralleled development of large and viable habitats.
ii. Forest patches that are large and interconnected need to be developed as elephant conservation zones and habitat improvement activities should be carried out only in such forest patches.

iii. Early detection of the problem of elephants dispersing into areas without adequate natural habitats is crucial.

iv. If large patches of natural habitats are close by, driving elephants back to such large patches could be an option. Firstly, doing a thorough investigation to find out from where elephants had come is important. Driving elephants should be done with adequate planning and precautions, and only specially trained teams of the Forest Department should be allowed to drive elephants with complete supervision of the concerned DFOs.

v. Mapping linear infrastructure vis-à-vis habitat connectivity of elephants would be important. While cautious approach towards infrastructure development taking due care of the ecological needs of elephants is absolutely critical from elephants' conservation standpoint, some of the existing linear infrastructure can be used as barriers to restrain elephant movement into human-use areas.

12.3 Habitat Protection from Mining and Infrastructure Threats

Mineral mining in elephant habitats is understood to be a major threat that can displace elephants from the home ranges. Impacts of mining and associated development will not be possible to mitigate. In fact, the impact of mining on elephant habitat and populations is known to be beyond the notional impact zone. Chronic habitat stress can lead to displacement of elephants. Such displacements are one of the major reasons for high-levels of conflict in East-central region. Therefore, the identified elephant conservation zones should be kept free from the threats of mineral mining and associated developmental pressures. Similarly, the mining sites that are juxtaposed to elephant conservation zones should be properly restored by adopting sound ecological restoration techniques.

12.4 Evaluating and Rationalizing Elephant Reserve and Protected Area Boundaries

i. Chhattisgarh Forest Department had recently declared Lemru Elephant Reserve spanning 1998 km2. Lemru ER encompasses Dharamjaigarh, Korba, Katghora and Surguja Forest Divisions. This ER was long over-due and would be helpful in developing comprehensive inter-division management plan. In Lemru ER, it would be appropriate to include Kendai range of Katghora Forest Division as elephants regularly occur in the range. Similarly, important habitats in Udaipur and Lakhanpur ranges of Surguja that currently fall outside Lemru ER need to be included in the Elephant Reserve.

ii. Although Semarsot Wildlife Sanctuary is about 430 km2, most of the important habitats for wildlife inside the sanctuary have already been lost. It seems difficult to recover them. Alternatively, the forests of Wadraf Nagar and Balrampur ranges of Balrampur Forest Division can be added with Semarsot Wildlife Sanctuary. In Balrampur range, about 180 km2 of reasonably intact forest with minimal of human disturbance occurs. Similarly, in Wadraf Nagar range, about 150 km2 of intact habitats remain. Both these ranges have perennial streams and thus ideal to be further improved with better protection and habitat management activities. Including Wadraf Nagar and Balrampur Ranges of Balrampur Forest Division with Semarsot Wildlife Sanctuary can create a large tract of connected protected area complex of Guru Ghasidas NP – Tamor-Pingla WLS and Semarsot WLS in northern Chhattisgarh.

iii. Using existing habitat use data of elephants, the reserve boundary of Badalkhol WS may be redrawn by including viable areas that are adjacent to the reserves. Badalkhol is a very small sanctuary that is linear in shape with significant edge effects. Eventually, the Tamor-Pingla – Badhalkhol Elephant Reserve needs to be redrawn based on elephant habitat-use data.

12.5 Identifying and Improving Habitat Conditions in Large and Intact Habitats

HEC resolution involves both short-term and long-term measures. In the long run, improving the resilience of large and reasonably intact habitats would be ideal. However, identifying such habitats in the first place is a priority. As indicated above, habitat improvement activities aimed at improving residence time of elephants need to be carried out in large and connected habitats and not in small and isolated forest patches. A potential habitat complex for elephants in northern Chhattisgarh is the connected forest complex of Guru Ghasidas NP, Tamor-Pingla WLS, Semarsot WLS and territorial forest divisions of Surajpur and Balrampur. The other forest complex in Surguja that regularly harbors elephants is the Udaipur and Lakhanpur forest ranges of Surgja and Boro and Kaapu ranges of Dharamjaigarh forest division.

Habitat management in these areas should try and minimize the threats of degradation and improve habitat through restoration. Habitat restoration should focus not only on trees, but also herbaceous plants and grasses that include bamboo. From the observations made by WII project team, even the Protected Areas in northern Chhattisgarh lack intact layers of vegetation. For elephants more than tree layer, the ground and shrub layers are important. Ideally, all layers of the forest should be restored.

Specific habitat management suggestions in relatively large and connected forest patches in Chhattisgarh include

(1) grassland restoration (described above) (2) planting of bamboo, which has virtually disappeared from the forests due to over-use. Thus, recovering bamboo in the forests would be critical (3) while surface water is generally not a concern for elephants in northern Chhattisgarh, soil and moisture conservation efforts in relatively drier protected areas like Tamor-Pingla and Guru Ghasidas NP could augur well for wildlife (4) Any forest plantation drive in forests should ideally comprise of elephant fodder trees.

12.6 Habitat Improvement

While habitat improvement is critical for HEC resolution, developing small, degraded and patchy habitats that occur within intensive human use areas can be counterproductive for HEC management. Elephants exhibit remarkable behavioral plasticity and therefore, they can adapt to use even small patches of forests in the midst of human use areas as daytime refugee and raid crops in the night. Improving habitat conditions in small patches that exist within human use areas might result in increased conflict as better water and forage conditions might increase the residence time of elephants in such patches. Therefore, adequate care is needed to select sites for habitat improvement. Ideally, such sites should be large, relatively intact, have elephant occupancy and connected to other patches.

12.7 Minimizing Human Fatalities due to Elephants

Some of the suggestions to minimize human fatalities due to elephants include the following:

i. Teaching better crop guarding techniques to communities as they continue to guard crops from thatched huts or from the ground
ii. Minimizing unorganized and haphazard elephant drives
iii. Minimizing use of forest trails during early morning, evening and night hours. Villagers use these trials instead of main roads to cut down travel time and distances. It is impossible to monitor all these trails and instead the main road to village can be maintained with good visibility

12.8 Active Interstate Cooperation in Conflict Management Critical

Elephant habitats in Chhattisgarh are contiguous to forests of Jharkhand, Odisha and Madhya Pradesh. Between the four states there is frequent movement of elephants. Two elephants satellite collared in Chhattisgarh by WII and CGFD frequently move into neighboring state of Odisha. Active interstate coordination will go a long-way in managing conflict in the state as well as the entire central region

i. It is pertinent to view HEC as a regional problem rather than the problem of a particular state.
ii. Interstate exchange of resources and resource personnel (*kumki*, trackers, veterinary personnel, mahouts and experienced staff) to effectively manage situation is quite important. To handle conflict situations, it would be effective to mobilize resources from the neighboring states as well and make constitute a team. By doing so, the personnel involved will gain enormous experience and will go a long way in managing conflict in the region.
iii. Madhya Pradesh has good mahouts and well-trained captive elephants that are currently used for perambulation purposes in the tiger reserves. Chhattisgarh has just started training *kumki* elephants for conflict management purposes. It shall be helpful for Chhattisgarh to send their mahouts and *kavadis* to camps in Madhya Pradesh and learn patrolling techniques. By doing this, mahouts may develop bonds to work together as a team in the future. Further, the elephants can get familiar with each other and if need be, the elephants can be paired up (for example, the bull tusker Thirtharama of Pingla Elephant Camp in Chhattisgarh can be paired with Shivaji of Bandhavgarh Tiger Reserve) for operations involving capture and collaring of wild elephants.

12.9 Use of Deterrents and Barriers

The barriers and deterrents applicable for Chhattisgarh are as under (Table 12.1)

Table 12.1: List of barriers and deterrents as appropriate in Chhattisgarh context

S. No	Deterrent	Remarks
1	Elephant proof trench	Appropriate only for large population in large habitats
2	Permanent solar fence	Appropriate only in areas where problem is regular and elephants have fixed ranges
3	Individual guarding	Appropriate for small farms. However, awareness on safe guarding practices is important
4	Community guarding	Appropriate for settlements. Awareness on safe guarding practices and consideration of elephant movement is important
5	Portable solar-powered fences (that can be immediately laid)	Appropriate for both settlements and small-scale crop fields.
6	Rapid response teams	Useful in monitoring elephants and alerting villages. Sometimes in driving elephants away from human habitations
7	Mobile phone-based early warning system	Useful in high conflict villages to minimize interactions between people and elephants

12.10 Developing Alternative Livelihood Strategies for Local Communities

Local tribal populace in northern Chhattisgarh where elephants occur shows high level of dependence on forests for their livelihood. Some of the forest produce collection processes involve setting fires to the forest floor. Recurrent fires and sustained resource extraction pressures can degrade forests and reduce their suitability to support elephants. Further, such degraded forests may not be able to support local communities as well in the long run as forest produce yields may drop drastically overtime. Therefore, it is pertinent to experiment alternative livelihood options that can reduce biomass extraction pressures on natural forests. Northern Chhattisgarh is still heavily forested with lot of rivers, mountains, wildlife and rich tribal culture. Well-planned ecotourism in select areas can be an attractive income-generating avenue for local communities. Further, setting up cottage industries that can process fruits and other local commodities for value addition and marketing can be explored as well. Extending schemes of rural LPG that Government of India is promoting to high conflict areas shall be useful to reduce frequent human–elephant interactions as well as help the forests recover.

12.11 Operating "Elephant Friendly Bus" During Critical Hours in Conflict Hotspots

As an empathetic gesture towards local communities and also in an attempt to minimize elephant-related human deaths along the roads, Chhattisgarh Forest Department with support from District Administration can experiment by operating elephant friendly buses during the evening hours in select conflict hotspot locations. Dr. Ananda Kumar of Nature Conservation Foundation provided this novel suggestion during a field visit to Surguja as part of WII project. Experiments in this regard can be carried out in Surajpur and Pratappur ranges of Surajpur Forest Division and select locations in Korba Forest Division. The main roads passing through forests in Forest Ranges with reportedly high number of human deaths can be identified. When elephant herds occur in the vicinity, a mini-bus can be operated at a stipulated timing so that villagers can safely reach their homes without having to risk walking/cycling back through forest roads. Children and women would be the primary beneficiaries of this effort.

12.12 Institutionalizing Rapid Response Teams and Other Volunteer Groups

The role of rapid-response teams and their equivalent like the Hathi-Mitra-dal (collectively RRT, henceforth) proved to be crucial in managing human–elephant conflict. The RRT units were crucial in bridging local communities with frontline staff of the forest department. The roles expected of RRT units include the following:

i. *Actively monitoring elephants occurring in human–dominated areas*. Although this is being actively done in a few forest divisions across the State, there is scope to improve it by making it more systematic. The State of Odisha has developed a user-friendly app that is quite useful to systematically record data for monitoring elephants. The app can be implemented in Chhattisgarh as well with suitable modifications

ii. *Broadcasting information on elephant occurrence to villagers*: Besides monitoring elephants, it is crucial to broadcast information on elephant locations to villagers in vulnerable locations. This is best done by RRTs as most of the RRT recruits are from local communities

iii. *Soft drives of elephants from human–use areas:* When elephants get stranded in human–use areas, soft drives to nearby forests could be important. However, drives are often risky and would require well-trained teams to do that. RRT would be ideal choice for carrying out such soft drives, if adequate training in this regard is imparted.

Currently, RRT is not well institutionalized and there are funding and work-plan concerns. Developing a proper work plan would be critical for RRTs. As the elephant conflict issues are seasonal in most forest divisions, RRTs are engaged only on a need basis. This poses challenges of attrition and lack of motivation. To circumvent these problems, RRTs can be trained on other wildlife management and forestry activities including fire management, patrolling, data collection, nursery and plantation activities so that there can be year-around engagement of RRT staff.

12.14 Dealing with the Problem of House Break-ins by Elephants

i. Focused research is essential to unravel aspects of house breaking such as seasonality, plausible reasons for house breaking, group-specific differences in the behaviour and individual recognition of elephants that are habituated to breaking houses
ii. Research is required to see if negative conditioning of elephants can help stop spread of house breaking. If elephants associate risks with breaking houses, then the behaviour could wane
iii. It may be important to engage with local communities in areas where the problem of house breaking by elephants is severe and try and develop portable fences (that can be quickly laid and removed later) to secure human settlements
iv. Better grain storage techniques can be experimented and the concept of community grain banks can be explored
v. Better illumination in the settlements: As a number of human injuries and deaths occur late evening or at night when people living in settlements near the forest areas venture outside, a simple measure such as increasing the overall illumination in the settlement (if necessary, through solar panels) could be helpful in detecting and avoid elephants. This is recommended in areas where house break-in by elephants is recurrent.

12.13 Elephant Translocation and Captures

Escalated conflict situations sometimes necessitate capture and removal of individual elephants and even groups from the site. From conservation standpoint and economic and logistic considerations, bringing a large number of elephants into captivity is neither practical nor desirable. Therefore, experimenting well-planned elephant translocation with telemetry is crucial. Identifying potential habitats to translocate elephants is crucial. Considering the vastness of the area and good connectivity to Sanjay TR in Madhya Pradesh, the Guru Ghasidas – Tamor-Pingla WLS complex may be considered for experimenting elephant translocations. This landscape complex already supports over 50 – 100 elephants. Nevertheless, prior work in assessing habitat quality, finding suitable release sites that are reasonably far from human settlements and mapping the roads to transport elephants are a prerequisite before experimenting translocation. Before experimenting translocation, it is prudent to identify and train teams to follow collared elephants at the release site. The state should also keep a few collars ready for contingencies. The state should start identifying suitable sites and train teams at the earnest before any emergency situations arise. The translocation can be executed as per the SOP (in preparation by WII) to maximize the chances of translocated elephants settling down in good habitats. Sites identified for translocation should have barriers to protect villages and crops. When translocations fail with respect to problem individuals, they may have to be brought into captivity permanently.

Furthermore, some of the individual elephants that show propensity to involve in heightened conflict including that of regularly breaking houses and aggression towards people, when reliably identified, need to be captured without delay. As the undesirable behavior (that of attacking people or breaking houses) can spread among elephants, it would be important to act upon the situation immediately. In this regard, the provisions of the Wildlife (Protection) Act, 1972 with respect to dealing with problem animals shall be complied with.

12.14 Long-term Monitoring of Elephant Populations

Research and monitoring of elephant populations in the landscape is absolutely critical. It is imperative to collect relevant data for managing HEC in the landscape in a systematic manner. Absence of such systematically collected information may impede development and implementation of effective HEC mitigation strategies.

Some of the research themes are:

i. Monitoring key population variables such as abundance and age-structure will be helpful to assess population stability and its growth rate over time

ii. By monitoring individuals that regularly occur in human use areas, it may be possible to pick early signals of conflict and devise resolution strategies accordingly. For example, dispersal of elephants into sub-optimal, non-viable habitats can be investigated during early stages itself before elephants colonizing such habitats increase in number. Individuals that disperse into non-viable habitats and get into conflict can be trans-located to potential viable habitats thereby addressing the problem before it amplifies

iii. For small populations, assessment of its viability using advanced analytical approaches such as Population Viability Analysis (PVA) shall be useful for adaptive management

iv. Habitat assessment (quantifying productivity, availability of surface and pre-formed water, threats to habitat and others) is required from time to time in potential habitats to suggest appropriate habitat improvement suggestions

v. Understanding Home Range, movement and dispersal patterns of elephants is useful to unravel crucial aspects of elephant behavior in the landscape. In this project, numerous elephants were collared and crucial data were collected. However, it is important to note that collaring elephants is not a one-off effort. There are still gaps that the present study did not address. Based on the need, the following may be considered:

   a. There is a need to collar more elephants in Bilaspur circle and also in Jashpur Forest Division where elephants enter from Jharkhand and Odisha.

   b. Monitoring elephants with high-definition satellite collar in Tapkara area of Jashpur Forest Division would be crucial.

   c. Similarly, collaring elephants in Raigarh Forest Division would provide important insights on how elephants use Odisha-Jharkhand-Chhattisgarh complex.

vi. In the study, vegetation assessment couldn't be carried out. In northern Chhattisgarh, within Protected Areas, it is crucial to assess the availability and quality of the three layers of vegetation – namely ground layer, shrub layer and the tree layer.

12.15 Capacity Enhancement of Forest Department Staff

Overall, the Institutional capacity required to deal with management of HEC is relatively poor (compared to other elephant-bearing regions in the country) and needs to be developed at the earnest. The lacuna is partly due to lack of experience in managing HEC as the problem is still emerging in new areas. It is noteworthy that Chhattisgarh Forest Department had taken proactive steps during the last few years to bridge the gap by initiating a long-term study on elephants by collaborating with WII, establishing a state-of-the art *Kumki* camp, and targeted capacity building initiatives. Based on the experience gained during the project, the target areas identified for capacity building include the following:

i. WII-CGFD collaborative project has imparted considerable field skills to mahouts and *kavadis* in conflict management. To further augment the skills learnt, the mahouts and *kavadis* can be exposed to field situations on managing elephant-related conflict. In this regard, field visits of elephant handlers to Assam/West Bengal and other states where elephants are actively used for conflict mitigation would be useful.

ii. WII-CGFD collaborative project has resulted in considerable development of capacity of veterinary professionals (Chapter-9). It would be appropriate to engage and seek the professional services of well-trained veterinary professionals that were already developed. These trained and well-experienced veterinary professionals can be trainers for the younger generation of veterinarians and would eventually help in developing the overall veterinary in the State, which is absolutely essential for managing human–elephant conflict

iii. Frontline Staff training on aspects on human–elephant conflict management are essential to continue. The themes shall essentially include the following aspects:

   a. Creation of database on elephant identification and movement
   b. Sample collection procedures including that of collecting tissue samples
   c. Patrolling techniques including the use of GPS and compass for marking trials and monitoring elephant movement within forests
   d. Field monitoring techniques involving VHF tracking of elephants. The staff should be able to triangulate and home-in VHF collared elephants
   e. Plotting GPS fixes from collars in GIS platform including that of GoogleEarth and QGIS, computation of animal Home Ranges and visualization in computer

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ANNEXURE-1

List of Technical Reports Submitted by WII to CGFD from the Project

SN	Report	Type	Period
1	Operation Mainpat: Elephant Chemical Immobilization and Collaring at Surguja	Field Technical Report	June 2018
2	Annual Report for the Period July 2017 – June 2018	Annual Report	July 2018
3	Assessment of husbandry and healthcare practices for captive elephants at Pingla elephant rehabilitation centre, Tamor Pinga Wildlife Sanctuary, Surajpur	Technical Report	May 2019
4	Training and welfare of captive elephants in Pingla elephant rescue centre	Training Workshop Report	May 2019
5	Capture and collaring of wild elephant in Korba and Dharamjaigarh Forest Divisions	Field Technical Report	August 2019
6	Annual Report for the Period July 2018 – June 2018	Annual Report	August 2019
7	Capture, treatment and satellite of a bull elephant	Field Technical Report	December 2019
8	Operation Dumadand: Elephant Chemical Immobilization and Collaring at Surajpur	Field Technical Report	December 2019
9	Workshop on management of HEC in the context of Chhattisgarh at Katghora Forest Division	Training Workshop Report	February 2020
10	One-day workshop on elephant behaviour, human–elephant conflict and aspects of captive elephant management	Training Workshop Report	January 2021
11	Workshop on management of HEC in the context of Chhattisgarh at Badhalkhol Wildlife Sanctuary	Training Workshop Report	February 2021
12	Workshop on managing HEC in and around Tamor-Pingla WLS, Surguja	Training Workshop Report	February 2021
13	One-Day Workshop on Elephant Behaviour, Ecology and Human- Elephant Conflict Management for the Frontline Staff and Hathi Mitra Dal of Katghora Forest Division	Training Workshop Report	April 2021
14	One-Day Workshop on Elephant Behaviour, Ecology and Human- Elephant Conflict Management for the Frontline Staff and Hathi Mitra Dal of Dharamjaygarh Forest Division	Training Workshop Report	April 2021
15	One-Day Workshop on Elephant Behaviour, Ecology and Human- Elephant Conflict Management for The Frontline Staff and Hathi Mitra Dal of Jashpur Forest Division	Training Workshop Report	April 2021
16	One-Day Workshop on Elephant Behaviour, Ecology and Human- Elephant Conflict	Training Workshop Report	April 2021

	Management for the Frontline Staff and Hathi Mitra Dal of Korba Forest Division		
17	Annual Report for the Period July 2019 – June 2021	Annual Report	July 2021
18	Capacity Building of Local Communities, in Surguja Forest Division	Training Workshop Report	July 2021
19	Upkeep and utilization of elephant "Sonu" housed in Elephant Rescue and Rehabilitation Centre, Pingla, Surguja	Technical Report (based on CGFD's committee formation)	August 2021
20	Capacity Building Workshop 'Essentials for Management Elephants in Captivity' for Mahouts and Frontline Staff	Training Workshop Report	August 2021

ANNEXURE-2

Datasheet-1: Monitoring of Collared Elephants

COLLARED ELEPHANT MONITORING FORM

Date		Personnel:
Division:	Range:	Beat:
GPS:		Village:

Elephant details

Collar id		Elephant id	
Directly seen	Heard	Saw signs	Not seen

In forest	In road	In crop field	In fallow land	In settlement
Description of location:				

Musth:	Pregnancy:	BCI:
Injuries & wounds:		

Associated elephants

S.no	Id	Sex	Age	T/M	Phy.stat	BCI	IID

Activity of collared elephant

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Conflict details

Crop raiding	Entered basti	House damage # Damaged:	Antagonism towards people

Crop damage details

Crop	Stage

Wildlife Institute of India

ANNEXURE-3

Datasheet-2: Recording Human Fatalities due to Elephants

CONFLICT REPORTING: HUMAN CASUALTY DUE TO ELEPHANTS

Today's date:	Form number:
Forest division:	Range:
Beat & Comp:	PA/RF/PF/others:

Incident particulars

Date and time of incident					
Incident site's GPS					
Nearest house (and description)					
Detailed description of the incident site					
Details of the first reporter					
Time of first detecting the incident					
Method of detection of the incident	*Directly seen*	*Heard*	*Seen elephant*	*Dogs barked*	*Others*
Notes					
Grains/others stored in the house					
Details of fruiting trees around incident site					
Crops cultivated and stage	*Crop*	*Stage*			

Victim particulars

Name, age, gender and ethnicity:					
Condition of the victim:	*Normal*	*Handicap*	*Unwell/Weak*	*Mentally unstable*	
What was the victim doing in the incident site?					
Condition of the corpse	*Severely mangled*	*Mangled*	*Severely injured*	*Mildly injured*	*No external injuries*
Notes					
Description of victim's garments					
Eyewitness and their statement					

Elephant details

Group type	*Family herd (with calf)*	*All-male group*	*Solitary elephants*	*Not clear*
Group size				
Elephant movement	*Came from…* *Headed towards…*			
Elephant identification				
Dung particulars	*Adults*	*Sub-adults*	*Juveniles*	*Infants*
Elephant signs near incident site	*Id*	*Diameter of forefoot*	*Diameter of dung*	*Remarks*

Were villagers aware that the elephants were around in the vicinity?.........................

Detailed field notes...........

ANNEXURE-4

Datasheet-3: Recording Crop Losses due to Elephants

CROP RAIDING DATA SHEET

DATE OF SURVEY:____________________ SURVEYER:_____________________________________

VILLAGE:__________________ DIVISION:_________________RANGE:____________BEAT/COMPT NO.: __________

START TIME: ____________________ END TIME:______________________

DATE OF CROP DAMAGE: ___________________________ TIME OF CROP DAMAGE :_______________________

FARMER NAME: ____

SOLITARY / GROUP: ______________ELEPHANT NO:_______ADULT:________SUBADULT:________________

ELEPHANT ID:____

CROP DETAILS

S.N.	GPS Lat	GPS Long	CROP	CROP STAGE	CROP HEIGHT	DAMAGE (L.x B.)	EATEN (L.x B.)	TRAMPLED (L.x B.)	BARRIER & RESPONSE

CROP SATGE: GERMINATION/ TILLERING/FLOWERING /FRUITING / MATURE

ANNEXURE-5

Datasheet-4: Individual Identification of Elephants

ELEPHANT IDENTIFICATION PROFILE: CHHATTISGARH

Date of the identity card	26-2-2018		
Profile created by			
Elephant id number			
Elephant name	-		
Sex	Female		
First photograph details	GPS	Location	Range, FD
	Date	Habitat	Photographer
Height	Front foot circumference: Not measured, Estimated shoulder height: Not measured		
Estimated age	>50 years (possibly a matriarch of a small family)		

Left profile picture
Photo details:
Right profile picture
Photo details:

Frontal picture	Rear picture
Photo details	

1) Tusk/ tush

	Right	Left
(i) Arrangement (parallel, divergent, convergent, crossed)		
(ii) Direction to ground (parallel, angled down 30°, angled down 60°, angled down straight)		
(iii) Length (long, medium, short)		
(iv) Thickness (thick, intermediate, slender)		

2) Ear pinnae

	Right	Left
(i) Size		
(ii) Fold orientation		
(iii) Fold type		
(iv) Fold extent		
(v) Ear lobe shape		
(vi) Tears, nicks, holes, and cuts		
(vii) Prominent depigmentation		

3) Tail

a. Length (long, medium, short, stump)	Long (on par with ankle)
b. Brush (absent, only anterior, only posterior)	Dense brush, long anterior and short posterior
c. Kink	-

4) Wounds and bodily injuries

Location of wounds (also mention if they are fresh, festering or old)	
Warts and lumps	
Any deformity	

5) Notes

6) Additional photos (of specific interest)

ANNEXURE-6

Model selection details to elucidate spatial landscape-level patterns on elephant-related crop losses in Chhattisgarh

Summary of model selection results explaining spatial variation in intensity of crop losses caused by elephants at the landscape-scale in Chhattisgarh, India

Model	AIC	ΔAIC	ω	Deviance	R^2
CLintensity~eleUse+extAgr+extFor+forPatch	3395.1	0	0.605	1323.2	0.12
CLintensity~eleUse+extAgr+extFor+distRiv +forPatch	3397.0	1.9	0.244	1323.0	0.12
CLintensity~eleUse+extAgr+extFor+distRiv +MSI+forPatch	3398.6	3.5	0.110	1322.5	0.12
CLintensity~ eleUse+extAgr+extFor	3400.9	5.8	0.033	1332.4	0.12
CLintensity ~ eleUse+extFor	3403.9	8.8	0.008	1338.3	0.11
CLintensity ~ eleUse	3441.9	46.8	0.000	1386.6	0.08
CLintensity ~ extFor	3487.4	92.3	0.000	1451.6	0.03
CLintensity ~ extAgri	3496.7	99.7	0.000	1463.6	0.03
CLintensity ~ forPatch	3515.8	120.7	0.000	1488.6	0.01
CLintensity ~ distRiv	3516.3	121.2	0.000	1489.3	0.01
CLintensity ~ MSI	3518.0	122.9	0.000	1491.5	0.00
CLintensity ~ builtArea	3522.7	127.6	0.000	1497.8	0.00
CLintensity ~ 1 (intercept only)	3523.4	128.3	0.000	1501.3	NA
CLintensity ~ nigLight	3525.2	130.2	0.000	1501.2	0.00
CLintensity ~ MPAR	3525.3	130.2	0.000	1501.2	0.00

Parameter estimates including those of elephant habitat use, extent of agriculture, extent of forest area, number of forest patches, and distance from the river as included in the top models that explain intensity of crop losses

Variable	Estimate	SE	95% CI (lower)	95% CI (upper)	Z	P
Intercept	0.36	0.06	0.240	0.485	5.79	< 2e-16***
eleUse-low	-0.68	0.09	-0.844	-0.507	7.86	< 2e-16***
eleUse-medium	-0.61	0.08	-0.771	-0.447	7.37	< 2e-16***
eleUse -no	0.01	0.78	-1.524	1.548	0.02	0.98
eleUse -sporadic	-0.74	0.12	-0.972	-0.501	6.13	< 2e-16***
extAgr	-0.10	0.05	-0.194	-0.003	2.03	0.042*
extFor	0.12	0.05	0.021	0.216	2.38	0.017*
forPatch	0.07	0.03	0.022	0.124	2.79	0.005**
distRiv	0.02	0.04	-0.058	0.090	0.43	0.666

Abbreviation (for both Annexure-6 & 7):

eleUse: Categorical variable (of categories high, medium, low and sporadic) depicting intensity of habitat use by elephants at the level of forest range
extFor: Extent of forest (all forest types) and other natural habitats measured in km2
extAgr: Extent of agricultural field measured in km2
forPatch: Count of discrete forest patches
distRiv: Euclidean distance from grid centroid to nearest river ($>4^{th}$ order)
MSI: Mean shape index depicting shape complexity of the forest patches. Relatively higher scores indicate higher complexity
builtArea: Extent of built-up area measured in km2
nigLight: Mean density of night illumination
MPAR: Mean perimeter to area ratio of forest patches
extSett: Extent of settlement measured in km2
forEdge: Measure of frontage (in kilometer) of the forest patches
distFor: Euclidean distance from the grid centroid to nearest forest patch
distRoad: Euclidean distance from the grid centroid to nearest main road

ANNEXURE-7

Model selection details to elucidate spatial fine-level patterns on elephant-related crop losses in Surguja area

Summary of model selection results explaining probability of crop loss by elephants in Surguja, Chhattisgarh

Model	AIC	ΔAIC	ω	Deviance	LogLik
CLprob ~ distRoad+distFor+MSI	725.7	0.0	0.439	717.7	-358.8507 (df=4)
CLprob ~ distRoad +MSI	726.1	0.4	0.350	720.1	-360.0735 (df=3)
CLprob ~ distRoad + distFor + MSI +forEdge	727.1	1.4	0.210	717.1	-358.5853 (df=5)
CLprob ~ distRoad	745.3	19.6	0.000	741.3	-370.6602 (df=2)
CLprob ~ MSI	757.7	32.0	0.000	753.6	-376.8308 (df=2)
CLprob ~ distFor	759.1	33.4	0.000	755.1	-377.5677 (df=2)
CLprob ~ forEdge	768.2	42.5	0.000	764.2	-382.1143 (df=2)
CLprob ~ 1 (intercept only)	779.1	53.4	0.000	777.1	-388.5518 (df=1)
CLprob ~ extSett	779.1	53.4	0.000	775.1	-387.5713 (df=2)
CLprob ~ extAgri	779.2	53.5	0.000	775.2	-387.6202 (df=2)

Parameter estimates including those of distance to road, distance to forest, mean shape index of the patch and total edge as included in the top models that explain probability of crop losses by elephants

Variable	Estimate	SE	95% CI (lower)	95% CI (upper)	Z	P
Intercept	-2.24	0.12	-2.47	-2.01	19.42	<2e-16 ***
[illegible]	[illegible]	[illegible]	[illegible]	0.71	5.71	<2e-16 ***
[illegible]	[illegible]	[illegible]	[illegible]	0.09	1.49	0.135
[illegible]	[illegible]	[illegible]	[illegible]	0.67	2.70	0.007 **
[illegible]	[illegible]	[illegible]	[illegible]	0.20	0.72	0.469