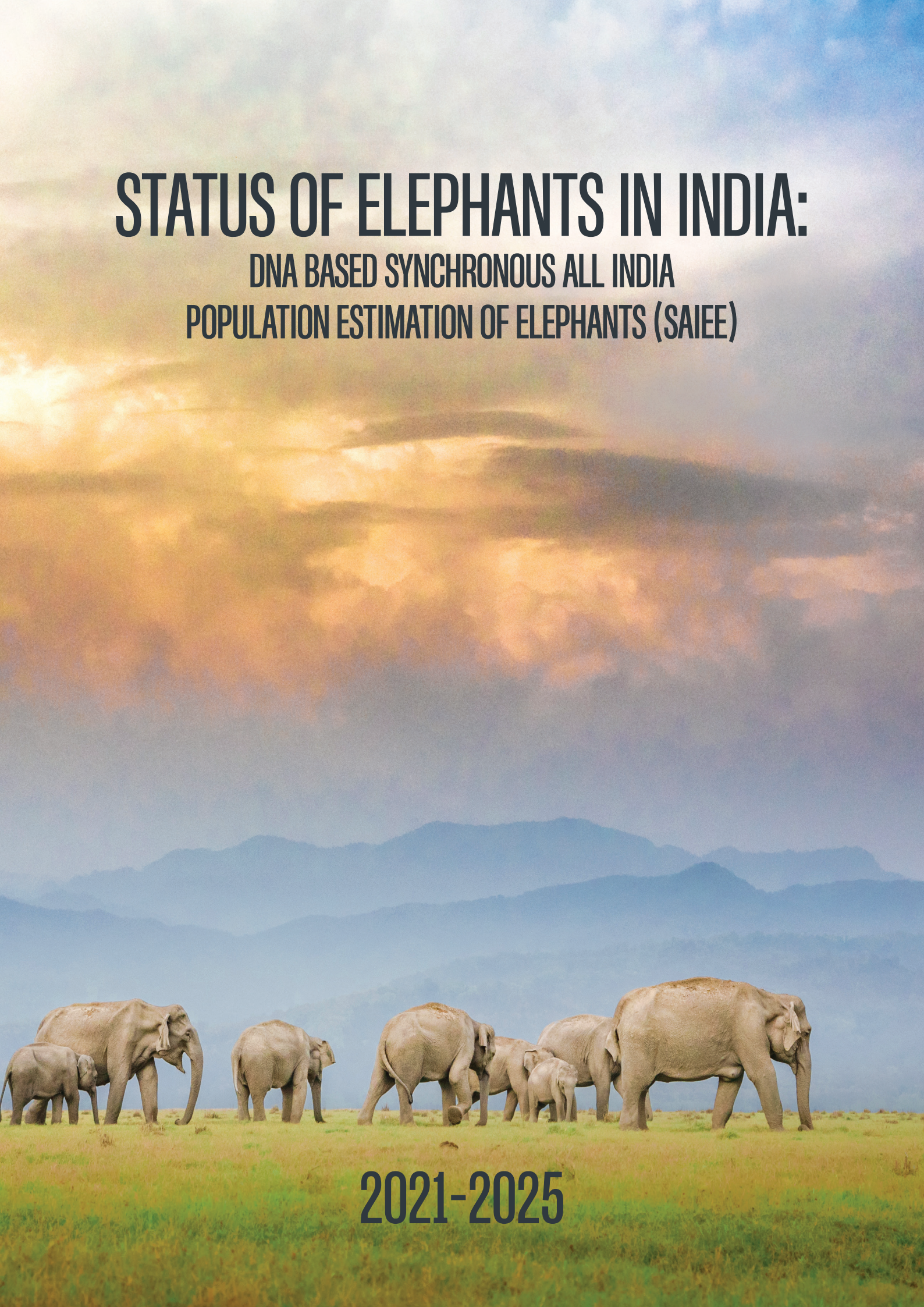
STATUS OF ELEPHANTS IN INDIA:

DNA BASED SYNCHRONOUS ALL INDIA POPULATION ESTIMATION OF ELEPHANTS (SAIEE)



2021-2025

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This nationwide estimate uses DNA-based mark–recapture for the first time in India; given the methodological changes, it is not comparable to past figures and may be treated as a new monitoring baseline for further research, monitoring and estimation.

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Executive Summary

EXECUTIVE SUMMARY

Elephants are easily relatable, carry layers of enigma and paradoxes. Revered in Indian culture with connections to deities like Indra, Lakshmi, Ganesha, and Buddha, they also symbolize material possession and vices, requiring control as depicted by figures such as Shiva, Krishna, and Buddha (Devidutt, P, 2018, Economic Times). Despite this cultural prominence, elephants have faced persecution for centuries, driven partly by their utility and conflict with humans.

India, home to the largest population of wild Asian elephants, faces several challenges in conserving the species, despite the cultural significance held by elephants. The historical human-elephant relationship dates back to the Harappan civilization, with elephants playing crucial roles in the economy and military. However, despite this historical care, elephants face challenges such as ivory trade demand, habitat loss, and hunting during various historical periods, including the British introduction of recreational killing. Current threats include habitat shrinkage, fragmentation, and increasing human-elephant conflicts, emphasizing the urgent need for comprehensive conservation policies in India. To inform any conservation policy, it is important to have a pulse on the current status, distribution, trends and threats.

Method: The present distribution of elephants in India represents a mere fraction of their historical range, which spanned the subcontinent around six thousand years ago. Attempts to evaluate the elephant population and trends requires a synchronous sampling framework. The contemporary elephant population, primarily found in forested tracts, remains relatively stable since 1984. The Synchronous All India Elephant Estimation program 2021-25 (SAIEE 2021- 25), was undertaken to estimate the population of Elephants in India, in a framework similar to that used for the monitoring of Tigers, Co-predators and prey (Qureshi *et al*., 2023). For SAIEE-2021- 25, India was divided into 100 sq km cells, which were further divided into 25 sq km, and 4 sq km cells. This design has been adopted for tiger estimation since 2006, where data about tiger, and other species like elephants has been collected since 2006, largely for distribution and relative abundance index (Jhala *et al*, 2008). Each grid is uniquely coded so that subsequent inferences could be compared on the same spatial scale and extent.

The first step in the assessment is Phase I, which involves undertaking ground surveys in forested habitats across all tiger bearing states to determine which grids have elephant presence and associated information, in a digital format on M-STrIPES mobile application, through forms which record carnivore and mega-herbivore sign encounters, ungulate abundance, dung count of ungulates, vegetation status through habitat plots, and human disturbance. This information helps in modelling elephant occupancy. The distribution and abundance of wildlife are likely to be determined by habitat characteristics and anthropogenic impacts. These covariates, like forest area, vegetation cover (Normalized Difference Vegetation Index (NDVI)), forest patch size, human footprint, distance to night lights, night light intensity, etc., were used to model elephant occupancy and abundance in combination with Phase I data. After Phases I and II, each landscape was adequately sampled using the area search method (Polygon survey) and camera traps. In this study, it is ensured that population in each landscape is sampled from low to high gradient as well as cover different broad vegetation type. Thus, ensuring that the modelled population is adequately sampled. In Phase I, the forested habitat of all landscapes except northeast is completely sampled, this ensures that the interpolation space is adequate. As Phase I sampling with All India Tiger Estimation excercise was not adequate, a renewed effort was made in 2024, to ensure sampling coverage across elephant occupied areas in the North Eastern Hills.

The area search method (Efford, 2011) for elephant bearing states of India, except North East, involved systematically sampling a 200 sq.km area divided into 4 sq.km cells and each cell was surveyed by walking a transect of at least 4 km length. Additionally, one camera was placed at the centre of each 4 sq.km cell. This method employed for population estimate indices or raw counts of abundance obtained from the entire sample space is calibrated against absolute density obtained from limited samples. In the Northeast, each 100 km² cell was subdivided into 25 km² grids, which were further divided into four quadrants. A 6.5 km transect was walked in each quadrant, resulting in a total of 25 km of survey effort per 25 km² grid. In each of these walks across India, elephant dung was collected for subsequent analysis in the lab for individual identification using genetic mark-recapture. Eleven microsatellite loci were used to differentiate individuals, which were sequenced on next-generation system, through the SSR-Seq method. We used the likelihood-based SECR method (Efford *et al*., 2011, Borchers and Efford 2008). This approach directly estimates elephants within mark-recapture areas and extrapolates it to areas with elephant presence that were not sampled for population size, utilizing a spatially explicit capture-recapture model.

Status of Elephant in India

Western Ghats
11,934
[9,897- 14,012]

Karnataka
6,013
[4,702- 7,236]

Kerala
2,785
[2,378- 3,168]

Tamil Nadu
3,136
[2,688- 3,585]

Central India & Eastern Ghats
1,881
[1,354- 2,523]

Andhra Pradesh
120
[103- 136]

Chhattisgarh
451
[297- 606]

Jharkhand
217
[149- 285]

Odisha
912
[578- 1,245]

Madhya Pradesh
97
[60- 135]

Maharashtra
63
[48- 79]

West Bengal (South)
31
[22- 41]

Shivalik Hills & Gangetic Plains
2,062
[1,709- 2,415]

Uttarakhand
1,792
[1,502- 2,083]

Uttar Pradesh
257
[183- 333]

Bihar
13
NA

North Eastern Hills & Brahmaputra Flood Plains
8,559
[5,444- 7,680]

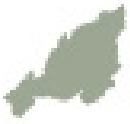
Arunachal Pradesh
617
[555- 680]

Assam
4,159
[3,885- 4,434]

Manipur
9
[8- 11]

Meghalaya
677
[585- 770]

Mizoram
18
[18- 18]



Nagaland
252
[207- 298]

Tripura
153
[140- 167]

West Bengal (North)
670
[541- 812]

This nationwide estimate uses DNA-based mark–recapture for the first time in India; given the methodological changes, it is not comparable to past figures and may be treated as a new monitoring baseline for further research, monitoring and estimation.

After evaluating multiple covariates associated with elephant density—including distance to water, terrain ruggedness, NDVI (April and November), proximity to nightlight sources, and human footprint metrics from ground surveys—the elephant encounter rate derived from Phase I & III data emerged as the most robust predictor for modelling elephant densities in the Western Ghats and the Shivalik Hills–Gangetic Plains landscape. In Central India and the Eastern Ghats, both encounter rate and distance to water were the most informative covariates. In the North East, elephant encounter rate (encompassing signs, sightings, and dung) from Phase I data demonstrated strong predictive power for estimating elephant densities.

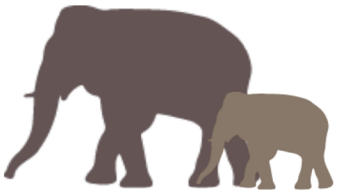
It is imperative to note that during the first period of sampling (during 2023), the Phase I data from North-east was extremely limited, compared to the known distribution of elephants. Therefore, initially it was not possible to model the density across the landscape. During this time, genetic mark-recatprue was under-taken in Buxa and Manas Tiger Reserves, estimating a population of 423 and 1,031 elephants respectively.

E.1: Estimated elephant numbers in each landscape

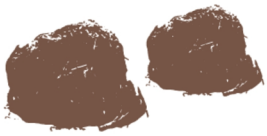
State/Landscape	Population	SE	Lower 95% CI	Upper 95% CI
Karnataka	6,013	623	4,792	7,235
Tamil Nadu	3,136	229	2,688	3,585
Kerala	2,785	208	2,378	3,193
Western Ghats	**11934**	**1060**	**9857**	**14012**
Jharkhand	217	35	149	286
Odisha	912	170	579	1,246
Madhya Pradesh	97	19	60	135
Chhattisgarh	451	79	297	606
Maharashtra (Western Ghats & Gadchiroli)	63	8	48	79
West Bengal (South)	31	5	22	41
Andhra Pradesh	120	9	103	138
Central India & Eastern Ghats	**1,891**	**325**	**1,254**	**2,528**
Uttarakhand	1,792	148	1,502	2,083
Uttar Pradesh	257	37	103	330
Bihar	13	NA	NA	NA
Shivalik Hills & Gangetic Plains	**2,062**	**185**	**1,700**	**2,425**
Arunachal Pradesh	617	32	555	680
Assam	4,159	390	3,395	4,924
Manipur	9	1	8	11
Meghalaya	677	47	585	770
Mizoram	16	1	13	18
Nagaland	252	23	207	298
Tripura	153	7	140	167
West Bengal (North)	676	69	541	812
North Eastern Hills & Brahmaputra Flood Plains	**6,559**	**570**	**5,444**	**7,680**
Total	**22,446**	**2,140**	**18,255**	**26,645**

INDIA

Dung Samples Collected
21,056

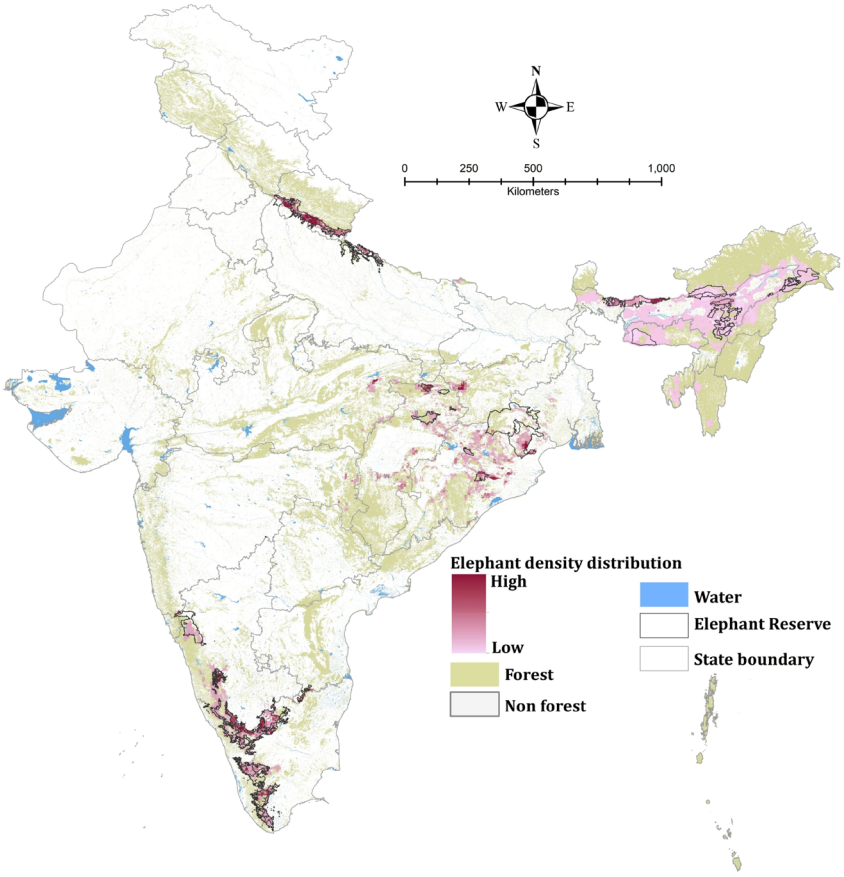


Dung Plots
3,19,460



Unique Individuals
4,065

Total Population Estimate
22,514
18,255-26,645



No. of Trails & Transects
1,88,030

Total Foot survey
6,66,977 KM

In the remaining elephant presence area of 32, 355 sq. km, the previously estimated elephant density of 0.26 elephants per sq.km (MoEFCC, 2017) was used to extrapolate the density in elephant presence area, to yield a total of 8,412 elephants, bringing the total elephant population approximation in the North Eastern Hills and Brahmaputra landscape to 9,866 elephants. However, since this is not a modelled estimate, but simply an extrapolation, renewed effort was made in 2024, to execute Phase I in the North Eastern Hills. With renewed effort, a total of 13 sites were additionally sampled for genetic mark-recapture additionally in the North Eastern Hills, and total number of dung samples analysed was 12,022. The genetic mark-recapture yielded an estimate of 6,559 elephants for this landscape.

Thirty seven sites were sampled using area search method, and 21,056 samples were collected for genetic mark-recapture, out of which, a proportion of them, based on quality of DNA, amplification and sequencing success, were processed for genetic mark recapture, across all landscapes, yielding 4,065 unique individuals. The elephant population estimated in Western Ghats was 11,934 (CI 9,857-14,012) with Karnataka harbouring the majority of the population, i.e., 6,013 (CI 4,792-7,235), followed by Assam (4,159 ; CI 3,395-4,924), Tamil Nadu (3,136; CI 2,688-3,585), Kerala (2,785; CI 2,378-3,193) and Uttarakhand (1,792; CI 1,052-2,083). In Central India and Eastern Ghats, the overall population is estimated to be 1891 (CI 1,254-2,528), which includes the small population in the states of Andhra Pradesh, Madhya Pradesh, Maharashtra and the southern part of West Bengal. While the majority of the population in this landscape is in the states of Odisha (912, CI 579-1,246), Chhattisgarh (451, CI 297-606) and Jharkhand (217, CI 149-286). Uttarakhand seems to be the stronghold of elephants in the Shivalik Hills and Gangetic plains, harbouring 1,792 (CI 1,052-2,083) elephants out of the 2,062 (CI 1,700-2,425) estimated for the landscape (Table E.1). In the North Eastern Hills and Brahmaputra flood plains, a total of 6,559 (CI 5,444-7,680) elephants were estimated, where Assam harboured the major population (4,159 ; CI 3,395-4,924), followed by Meghalaya (677; CI 585-770), North Bengal (676; CI 541-812), and Arunachal Pradesh (617; CI 555-680). The total estimated population of Asian elephants India is estimated as 22,446 (CI 18,255 – 26,645).

Conclusion: The synchronized 2023 estimation by the Karnataka, Tamil Nadu, and Kerala Forest Departments employed a protocol combining direct (sample block count) and indirect (line-transect dung count) methods—aligned with the All-India Tiger ungulate protocol and guided by elephant experts—and its outcomes find corroboration in the DNA-based mark–recapture results from SAIEE-2021- 25, indicating promise for large-scale deployment when calibrated by genetic mark–recapture at selected sites in each landscape. This national assessment, however, estimates abundance via DNA-based genetic mark–recapture, one of several accepted approaches, and owing to this methodological shift the figures are not directly comparable with earlier estimates and should be treated as a new baseline for future monitoring, research and estimation. Concurrently, further research on the efficacy, scalability, and robustness of alternative methodologies—being undertaken by the Institute with Project Elephant (Habib *et al*., 2025)—will refine quantitative criteria (e.g., low CV, high precision, cost-efficiency) to establish an improved, standardized, and scalable national protocol;results from this this effort will help in taking up calibrated method(s) to be used in future.

The once-contiguous elephant population in the Western Ghats is rapidly disconnecting due to changing land use, including expanding commercial plantations (coffee and tea), invasive plants, farmland fencing, human encroachment and mushrooming developmental projects. This fragmentation jeopardizes habitat contiguity, emphasizing the importance of safe guarding the connectivity in the landscape to enable free movement between the populations without escalating conflicts. Elephant habitats in the East Central landscape face fragmentation and deterioration from unmitigated mining and linear infrastructure construction, habitat degradation due to invasive plant species and human use. This has prompted long-ranging elephants to venture into historical range, but currently unoccupied areas, resulting in escalating conflicts with humans lacking cultural coexistence experience and posing a threat to elephant populations. Northeast landscape holds the second largest elephant population of India. However, historical exploitation of natural resources since the colonial era, driven by the productive nature of the floodplains and geopolitical considerations, has led to habitat fragmentation and increased conflicts. Currently, elephants are distributed in pockets amid various human land use patterns, including habitation, tea plantations, and mines. It is crucial to ensure corridor connectivity across habitat patches, and better strategies for law enforcement monitoring, for the long-term survival of this species in the landscape. Electrocution and railway collisions cause a significant number of elephant fatalities, while mining and highway construction disrupt habitats, intensifying man-wildlife conflicts. A sustainable resolution involves strengthening wildlife corridors, addressing mining and infrastructure-induced habitat fragmentation, implementing mitigation measures for linear infrastructure as well as power lines and enhancing law enforcement against poaching. It is essential to engage with community, for sensitization campaigns in elephant occupied areas and newly colonized places.

The critical aspect to ensure conservation of Asiatic elephants in the country needs the support of local communities. There is an urgent need to devise policy mechanisms for uniform compensation across areas with elephant presence, prioritizing the well-being of these communities. With increasing human elephant interface, reducing habitat and connectivity, it is important to critically analyse and arrive at future strategies that will not exacerbate existing threats. Strengthening corridors and connectivity, restoration of habitat, improving protection strategies and mitigation of developmental projects are the need of the hour to ensure the well-being of these gentle giants.

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Status of Elephants in India

Vishnupriya Kolipakam, Ujjwal Kumar, Yadvendradev V. Jhala, Ramesh K. Pandey & Qamar Qureshi

1

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1. Status of Elephants in India

1.1 Introduction

Elephants are widely familiar yet remain biologically and culturally paradoxical. In Indian culture they are revered—linked to deities such as Indra, Lakshmi, Ganesha, and Buddha—while simultaneously symbolizing material possession and vices necessitating restraint, as reflected in narratives involving Shiva, Krishna, and Buddha (Devidutt, P 2018- Economic Times). Despite their popularity, elephants have been persecuted for centuries, driven by conflict arising from their destructive potential and by the long-standing demand for ivory—an obsession that has proven difficult to comprehend and continues today (Fuller, E, 2019).

The subspecific taxonomy of the Asian elephant *Elephas maximus* has evolved. Shoshani and Eisenberg (1982) recognized three subspecies: *E. m. indicus* (Asian mainland), *E. m. maximus* (Sri Lanka), and *E. m. sumatranus* (Sumatra). Bornean elephants have been variously assigned to *E. m. indicus* (Shoshani and Eisenberg 1982) or *E. m. sumatranus* (Medway 1977), while Fernando *et al*., (2003) and Cranbrook *et al*. (2008) questioned their native status. These subspecies distinctions were based chiefly on body size, subtle coloration, relatively larger ears, and an additional rib pair in *E. m. sumatranus* (Shoshani and Eisenberg 1982).

Historically, Asian elephants ranged from the Euphrates in the west to Indonesia in the east, China in the north, and Sri Lanka in the south (Sukumar 2011). In India, their distribution spans from Haryana–Uttarakhand in the west to Arunachal Pradesh in the east and Tamil Nadu–Kerala in the south. India harbors the largest wild population—~60% of the global total—estimated at 26,000–29,000 elephants (Bist 2002, MoEFCC, 2017). The Indian Wildlife Protection Act (1972) affords the species the highest legal protection (Schedule I). Elephants' cultural and mythological salience, together with historic economic and military roles, has underpinned enduring support for conservation (Sukumar 2011). Human–elephant relations in India date to the Harappan period (~2000 B.C.), with evidence of domestication and, later, repurposing for warfare and labor (~1000 B.C.) (Sukumar, R., 2003). Conservation attention increased during the Mauryan era; by 6 B.C., Ganesha was established in Indian mythology, reflecting shifting perceptions (Sukumar, 2003). Management of elephants in captivity is well documented in classical treatises such as *Gajashastra* (Palkapya Muni), *Hastiayurveda* (Palkapya Muni), and *Matanglila* (Neelkantha), while *Arthsashtra* (Vishnugupta) described *Hastivana* (elephant forests) and their administration.

Despite long-standing cultural support, the Asian elephant (*Elephas maximus*) has faced persistent anthropogenic pressures. Ivory from Odisha was historically prized, fueling extraction, and elephant-bearing forests supplied war animals while sustaining an active ivory trade (Chakravarti, 2010). Much of the species' western Indian range had already contracted by the decline of the Harappan civilization due to increasing aridity and deforestation; in the early Mauryan period, killing an elephant was punishable by death (Chakravarti, 2010). Elephants remained common in Central India through Mughal times but declined under British rule. During the Mughal era, ~500–600 elephants were captured annually from largely forested Assam (agriculture concentrated along the Brahmaputra), with captures also reported from forests between the Ghaghara and Mahanadi and hunts from Dohad and Rajpipla (Gujarat). Abul Fath Gilani recorded ~2,500 elephants in captivity during Akbar's reign, replenished at ~13% annually from the wild; Abul Fazl listed sources including Agra, Allahabad, Bihar, Bengal, Odisha, and Malwa—regions from which elephants and habitat have since largely disappeared, except in Bengal and Odisha (Moosvi, 2010).

The British introduced recreational elephant hunting in the early 19th century—a sharp departure from taboos observed by earlier dynasties (Mauryas, Pandyas, Cholas, Rajputs, Mughals, Afghans, Marathas)—although elephants had long been killed elsewhere for ivory and meat (Sukumar, 2011). Distribution in India has shifted over historical time with climate variability and pervasive land-use change. Rapid 20th-century

population growth and economic expansion intensified resource demand, while habitat shrinkage and fragmentation promoted range shifts and dispersal, increasing human–elephant interfaces and conflict. Today, India's elephant distribution represents ~3.5% of its historical extent, which ~6,000 years ago spanned the subcontinent except the most arid tracts (Nair *et al*., 1980; Sukumar & Santipillai, 1996; Sukumar, 2011; Baskaran *et al*., 2011). Historical sources—from *Arthasastra* (300 BCE–300 CE) to Tamil Sangam literature (300 BCE–300 CE)—document former occurrence in regions where elephants have since vanished (Trautmann, 1982; Sukumar, 2011). By the late 19th century, agricultural expansion and settlement had confined elephants to the Himalayan foothills, East-central India, the Brahmaputra system and northeastern hills, and the Western Ghats; Tavernier noted captures north of Tirupati, and the terai forests of Awadh (Purnea–Bahraich) were reported to harbor elephants (Sukumar, 2011). Although precise historical numbers are unknown, early 17th-century records suggest ~40,000 elephants within Mughal and Bengal territories (Sukumar, 2011). Currently, wild elephants persist mainly in four forested hill regions—the Himalayan foothills, the Northeastern states, East-central India, and the Western/Eastern Ghats—with a small feral population in the Andaman Islands; overall numbers have been broadly stable since 1984 (MoEFCC, 2017).

Table 1.1: Population estimates of elephants from different landscapes of India from National level surveys, from 1978 – 2017 (MoEFCC 2017, Baskaran 2011). Details of surveys limited to States are explained in the landacape specific chapters

Region	1978-83	1993	1997	2002	2007	2012	2017	2021-25
Method used	**Total Count**	**Total Count**	**Total Count**	**Total Count**	**Total Count**	**Total Count & *Sample Block Count**	**Total Count, +Dung Count & *Sample Block Count**	**DNA Based SECR**
North Eastern Hills and Brhamaputra floodplains	10,273	11,027	9482	9243	9330	9239	10,139+	6,559
Shivalik and Gangetic Plains	525	875	1200	1667	1726	2865	2085	2,062
Central Indian Highlands and Eastern Ghats	2310	2314	2444	2649	2633	1637	3128	1,891
Western Ghats	6450	11,353	12,716	12,814	14,005	16,310*	14,587*+	11,934
Andaman		35	35	40			25+	
Total	**19,558**	**25,569**	**25,842**	**26,373**	**27,694**	**30,051**	**29,964**	**22,446**

**Some States in the landscape have adopted Sample Block Count for estimation*

+ Some States in the landscape have arrived at the estimate using Dung Counts

1.2 Methodology

The initial attempt in India to estimate the elephant population dates back to 1929 when F.W. Champion conducted the first-ever count in the forests of the United Province (Uttar Pradesh & Uttarakhand). Subsequent to this, in the years 1966-67, the Uttar Pradesh Forest Department engaged in further population assessments, repeating the process in 1976 and 1978 (Singh, V., 1978; Singh, K., 1995). These early estimations relied on the 'Direct Total Count' method, involving the averaging of figures obtained from three direct visual counts conducted at ten-day intervals at the forest beat level. The method changed with the inception of Project Elephant in 1992, leading to a shift in population estimation practices. Under this ini- tiative, population assessments occurred at five-year intervals, employing diverse methods including total count, tracking-based total count, registration count, water hole count, sample count, transect count, and dung count (Varman *et al*., 1995). The choice of method varied across sites for elephant population moni- toring thus making comparison difficult. The Synchronised Elephant Census (SEC) was conducted across various states in India in 2005, 2010 and 2017 (Sukumar, 2006 - Table 1.1). The SEC uses four main methods to obtain population sizes and related information: Total Count, Sample Block Count, Line Transect Dung Count, and Waterhole Count. The total count is also referred to as 'direct count' and the dung count as 'indirect count'. The waterhole count is primarily used to generate population structure to scan and categorize individuals in various sex and size classes.

The current monitoring exercise; Synchronised All India Elephant Estimation – 2021-2025 (SAIEE – 2021- 25) for elephants and their habitats were implemented across an extensive 400,000 sq km of India's forested areas. Conducting such extensive data collection requires a sizable workforce, strict discipline, smooth data flow, and technology for data collection. Considering the diverse habitats where elephants reside across India's vast geographical expanse, we have classified the elephant-bearing habitats into four major landscapes based on biogeography and habitat interconnectivity. These landscapes include 1) Shivalik-Gangetic plains; 2) Central India and Eastern Ghats; 3) Western Ghats; 4) North Eastern Hills and Brahmaputra Flood Plains. Each landscape is analyzed independently due to variations in the relationship between environmental and habitat covariates and elephant abundance. Furthermore, these landscapes serve as logical and biological units, facilitating the sharing of common individuals and a gene pool among elephant populations, allowing potential dispersal between them. This division aligns with the current landscape-scale management approach, providing ecological and practical benefits for management inferences and implementation. However, it's worth noting that elephant movement between landscapes is a rare occurrence in modern times and is happening between Western Ghats, Eastern Ghats and Central India. In this study, it is ensured that population in each landscape is sampled from low to high gradient as well as it covers different broad vegetation types. Thus, ensuring that the modelled population is adequately sampled. In Phase I of the All India Tiger Monitoring Excercise, forested habitats across all landscapes were sampled to ensure adequate interpolation space. In the North-East, areas known to be occupied by elephants, along with their immediate surroundings, were surveyed during December, 2024 - January, 2025. This landscape had been partially sampled earlier in 2021–2022 as part of the All India Tiger Monitoring exercise (Qureshi *et al*. 2023) and was re-surveyed to ensure comprehensive coverage of elephant-occupied habitats.

For SAIEE-2021- 25, India was divided into 100 sq km cells, which were further divided into 25 sq km, and 4 sq km cells in all of India. This design has been adopted for tiger estimation since 2006, where data about other species like elephants has also been collected since then, largely for distribution and relative abundance index (Jhala *et al*., 2008). Each grid is uniquely coded so that subsequent inferences could be compared on the same spatial scale and extent. For sampling in North-East (Fig. 1.3) the historical (MoEF-CC, 2017, Qureshi *et al* 2023) information was considered; area having elephant presence in 100 sq.km cells were considered for sampling. These grids were further divided into 25 sq.km which is further divided into 4 quadrants. In each quadrant minimum of 6.5 km walk was to be done which amounts to total of 25 km walk. In total 11,882 of 100 sq.km grids were sampled (Table 1.4, Fig. 1.3).

Phase I, Countrywide field data collection: Frontline staff of State Forest Departments in 20 potential tiger & elephant bearing States were trained to collect the Phase I data (Figure 1-2 & Table 1-2) in a digital format on the M-STrIPES mobile application. Field guides (Jhala *et al*,. 2017) in nine regional languages

were published and provided to forest staff.

Data collection on each of the following components was implemented in 2022 & 2024:

a. Carnivore and mega-herbivore sign encounters (Form 1: multiple occupancy surveys in a beat)
b. Ungulate abundance (Form 2: Distance sampling on line transect(s) in a beat)
c. Vegetation (Forms 3A and 3C: Canopy cover, tree, shrub, and herb composition, weed infestation on plots on a transect in a beat)
d. Human disturbance (Form 3B: Multiple plots of 30m diameter on line transects in a beat) and
e. Dung counts (Form 4: count of all dung identified by species in multiple 40 m2 plots on transects)

Phase I data was received from different States of India, and these were processed using MSTrIPES desktop software (Figure 1.1). Data entry errors, if any, were communicated back to the respective forest divisions for rectification. The MSTrIPES desktop software is capable of exporting the collected data into a data format that can be readily analyzed by existing quantitative analysis software. Data from the carni- vore-mega-herbivore sign survey (Form 1) was used to model the occupancy of elephants (single season, single species format). The data from habitat assessment, which includes information on different plant species (Forms 3 and 4), including invasive plants and ungulate dung, is extracted for mapping.

Phase II, Remotely sensed spatial and attribute covariates: The distribution and abundance of wildlife are likely to be determined by habitat characteristics and anthropogenic impacts. These covariates were obtained from remotely sensed data and used to model elephant occupancy and abundance in combination with Phase I data. Habitat characteristics were surrogated by forest area, vegetation cover (Normalized Difference Vegetation Index (NDVI)), forest patch size, forest core areas, elevation, distance from protected areas, and drainage density. Human impacts were surrogated by human footprint, distance to night lights, night light intensity, distance to roads, distance to Protected Area and density of the road network (Table 1-3). Remotely sensed spatial and attribute covariates: Remotely sensed data was extracted grid-wise and used as a covariate in occupancy and abundance models.

Phase III, Spatially Explicit Abundance Estimation: The spatial covariates of relative abundance of elephants, human impact indices, and habitat characteristics across all potential elephant habitats in India are collected on-ground surveys at a spatial resolution of a forest beat (average about 15 sq.km and via remote sensing data (Table 1.3)).

Subsequent to Phases I and II, an adequate area within each landscape was sampled using area search method (Polygon survey) and camera traps. The area search method (Efford, 2011) involved a systematic approach of sampling area of 200 sq.km, which is divided into 4 sq.km cells. Each cell was surveyed by walking at least 4 km length transect using MSTrIPES Polygon App (Qureshi *et al*., 2023). One single camera was placed in the center of 4 sq.km cell which was also sampled for elephant dung (Phase III) (Figure 1.2). In the Northeast, each 100 km² cell was subdivided into 25 km² grids, which were further divided into four quadrants. A 6.5 km transect was walked in each quadrant, resulting in a total of 25 km of survey effort per 25 km² grid. In each of these walks across India, dung of elephant was collected on these walks and stored in vials and was subsequently analyzed in lab for individual identification (See section on genetic characterization). The methodology followed for the population estimate indices or raw counts of abundance obtained from the entire sample space are calibrated against absolute density obtained from limited samples. This approach estimates elephants abundance within mark-recapture areas and extrapolates it to areas with elephant presence but not sampled for population size based on spatially explicit capture recapture model. Along with this, visual sampling of herds and elephant encounters were noted, to obtain demographic information as per Varma *et al*., (2012).

Table 1.2: Country wide sampling effort for ground surveys during Phase I of each state (including non-elephant states, as it is done for tigers, co-predators and mega herbivores)

State / Landscape	No. of Trails	Trail Length (km)	No. of Transects	Transect Length (km)	No. of Plots
Karnataka	8,874	45,323	10,002	18,297	31,742
Kerala	1,522	7,463	1,201	2,361	4,156
Tamil Nadu	1,892	11,019	1,845	3,681	5,376
Western Ghats	12,288	63,805	13,048	24,339	41,274
Madhya Pradesh	26,757	1,39,651	26,341	54,256	96,924
Maharashtra	16,331	78,016	16,124	31,210	56,512
Odisha	9,623	52,633	9,531	19,522	33,544
Telangana	6,633	29,188	5,599	10,502	18,264
Andhra Pradesh	3,456	16,597	3,430	6,637	11,090
Chhattisgarh	9,855	46,176	8,422	16,185	31,664
Jharkhand	976	4,600	732	1,457	4,570
Central India & Eastern Ghats	73,631	3,66,861	70,179	1,39,769	2,52,568
Bihar	232	1,775	499	981	1,372
Uttar Pradesh	1,270	6,412	1,237	2,408	4,396
Uttarakhand	2,735	12,389	2,522	4,299	8,256
Shivalik Hills & Gangetic Plains	4,237	20,576	4,258	7,688	14,024
Arunachal Pradesh	940	4,141.72	NA	NA	8,064
Assam	3789	22,993	483	856	1,356
Manipur	NA	NA	NA	NA	NA
Meghalaya	991	6,173.37	NA	NA	NA
Mizoram	149	545.72	NA	NA	NA
Nagaland	711	2,972.60	NA	NA	NA
Tripura	205	1,042.80	NA	NA	NA
West Bengal	786	4,011	586	1,203	2,174
North Eastern Hills & Brahmaputra Flood Plains	9,320	41,880	1,069	2,059	11,594
India Total	**99,476**	**4,93,122**	**88,554**	**1,73,855**	**3,19,460**

Table 1.3: Remotely sensed data, spatial data based on field sampling and secondary data used for modelling occupancy and abundance of elephants.

S. NO.	DATASET	SOURCE	SPATIAL RESOLUTION
1	Elephant encounter rate	Phase-1 Survey, AITE 2022 & NE-EE-2024	4 & 25 km^2 *
2	Elephant dung encounter rate	Phase-1 Survey, AITE 2022 & NE-EE-2024	4 & 25 km^2 *
REMOTELY SENSED DATA			
4	Night time lights Intensity (2021)	C. D. Elvidge, K. Baugh, M. Zhizhin, F. C. Hsu, and T. Ghosh, "VIIRS night-time lights," International Journal of Remote Sensing, vol. 38, pp. 5860–5879, 2017.	500 m
5	Normalised Difference Vegetation Index-Pre and post monsoon	Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.	30 m
6	Digital Elevation Model	NASA Shuttle Radar Topography Mission (SRTM) (2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography. https://doi.org/10.5069/G9445JDF.	30m
7	Global Human Modification Index (2016)	Kennedy, C. M., J. R. Oakleaf, D. M. Theobald, S. Baruch-Mordo, and J. Kiesecker. 2020. Global Human Modification of Terrestrial Systems. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/edbc-3z60.)	1000 m
8	Forest Cover (2021)	India state of Forest Report (2021).Forest Survey of India, Ministry of Environment, Forest and Climate Change , Government of India	23.5 m
9	Ruggedness Index	Derived from Digital Elevation Model	1000 m
10	Distance to Nightlights	Euclidean distance from Night time light data	1000 m
11	Distance to water sources	Euclidean distance dervied from global surface water dataset (Pekel *et al.,* 2016)	1000 m
12	Distance to Protected Areas	Data archived from Wildlife Database Cell, WII and Project Tiger database	1000 m

Table 1.4: Sampling for Phase 3, based on area search method, and camera trapping for elephant

Landscape	No of State Sampled	No. of Localities	Total No of Trails Walked	Total Effort (km)	Camera locations	Elephant Images
Central India & Eastern Ghats	4	10	469	1,957.97	181	1,188
North East Hills and Brahmaputra Floodplains	6	15	9,320*	41,880*	114	2,731
Shivalik hills and Gangetic Plains	2	4	212	824.39	187	1,758
Western Ghats	3	9	571	2,160.68	341	37,941
Total	**15**	**38**	**10,599**	**46,823.04**	**823**	**43,618**

**Phase I & Phase III combined trail effort*

Figure 1.1: Phase 1 sampling of forest beats in all four landscapes with elephant presence.

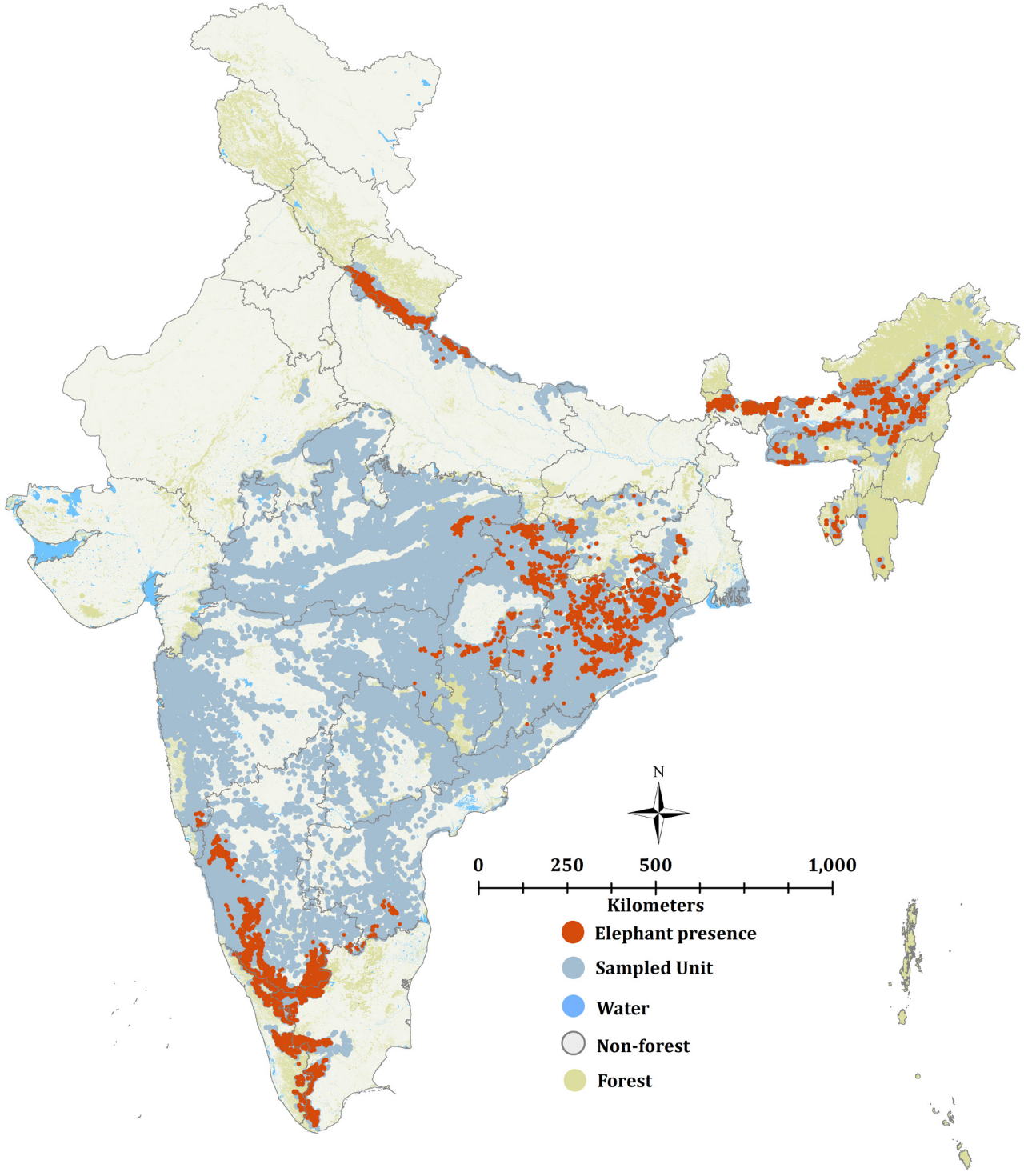
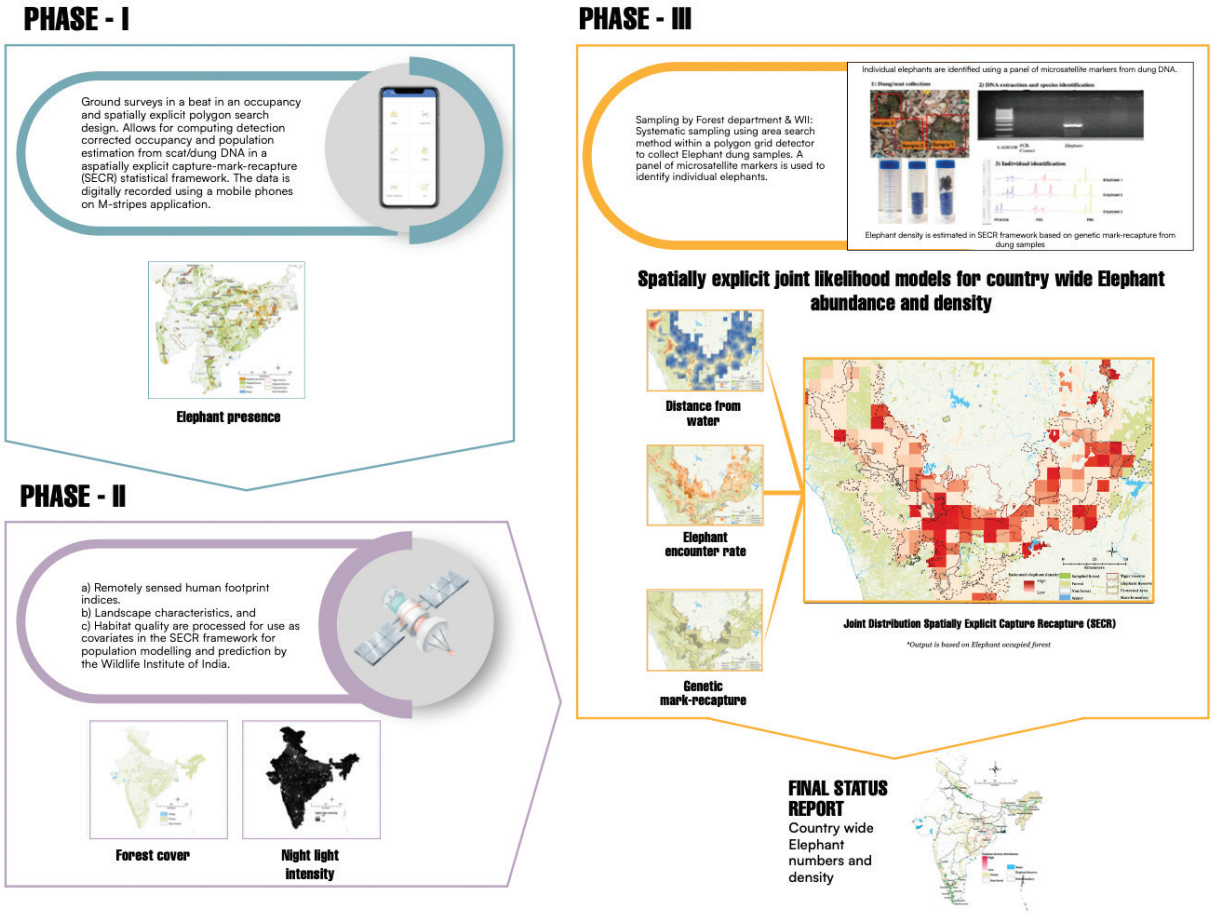


Figure 1.2: Workflow of data collection and analysis for All India Elephant Estimation (SAIEE – 2021- 25)



1.2.1 Genetic based mark-recapture

For efficient wildlife management and conservation actions, accurate population estimates are critical. Through their insights into the state of species, assistance in identifying risks, and facilitation of the development of focused conservation measures, they support informed decision-making. For marked individuals, mark-recapture techniques provide robust population estimates that support demographic studies and conservation strategy development.

For individually unidentifiable and elusive animals, genetic mark-recapture offers a non-invasive method of data collecting that gets beyond the difficulties of direct observation. This technique provides individual identification, which is helpful in estimating populations accurately and comprehending ecological dynamics—especially for species that are challenging to monitor. In the genetic mark capture recapture method, non-invasive sampling is used to capture the genetic signature of an individual through its unique genetic signature based on several genes. Several studies have employed genetic-capture-mark-recapture methods, using microsatellites for elusive and endangered species population assessment. Studies on African elephants in Ghana (Eggert *et al*., 2003) and Scandinavian brown bears in Sweden (Bellemain *et al*., 2005) used non-invasive mark recapture to estimate the population size. Genetic based population estimation has been successfully demonstrated in Africa to estimate the population status and demographic pattern of forest and savannah Elephants (Santos *et al*., 2019; Okello *et al*., 2008; Laguardia *et al*., 2021).

One aspect of using non-invasive samples for identifying individuals and recaptures is the presence of null alleles, and allelic drop outs. To understand the power of discrimination between individuals and rate of allelic dropout, a preliminary study was undertaken with camp elephants near Mathigodu, Karnataka, where blood and dung samples were collected from the same individuals. A set of eleven polymorphic unla- beled microsatellites was selected for individual identification EMX1, EMX2, EMX3 and EMX5 (Fernan- do &

Melnick 2001); EMU02, EMU03, EMU11, EMU12 (Kongrit *et al*., 2008) and LAT6, LAT8, LAT13 (Archie *et al*., 2003). Primer standardization of the microsatellite markers was done using gradient PCR with elephant blood and dung samples. The combined probability of identity (PID) indicates the probabil- ity that two individuals chosen at random from a population will have the same DNA profile at a specific set of genetic markers, and PID-sib value indicates the same, assuming they are full siblings. A lower PID value suggests a higher level of genetic differentiation, meaning it is less likely for two unrelated individu- als to have the same DNA profile. In this case, the value was determined to be $3.6x10^{-11}$ and the combined probability of identity for siblings (PID-sib) was determined to be $2.1x10^{-7}$, is very low, indicating a high discriminatory power in distinguishing between individuals based on the analyzed genetic markers.

Here, we directly tested the reliability of population estimation methods by comparing conventional line-transect dung counts with non-invasive genetic spatially explicit capture–recapture (SECR) using SSR-Seq microsatellites, against a known reference population of 34 elephants. Dung counts overestimated density nearly six-fold, while genetic SECR produced estimates closely matching the true population and simultaneously revealed allelic richness and population substructure. These results demonstrate that genetic SECR is a robust and unbiased approach for elephant monitoring, providing both demographic accuracy and evolutionary insights, and can serve as a calibration tool for more cost-efficient methods within large-scale monitoring frameworks (Kolipakam et al., 2025)

For each identified sampling unit of 200 sq.km was divided into 50 sampling grids of 4 sq.km . From each grid, elephant dung samples were collected using Polygon Search Method (Efford, 2011). Upon encountering a dung pile, approximately 10gm of bolus was collected from the outer layer and stored in silica gel containing plastic zip locks. GPS locations of each sample were recorded using Polygon search app and the collected samples were sent to WII genetics lab where they were stored at -20° C. A total of 21,056 dung samples across the country were collected (Table 1.5), out of which, a proportion of them, based on quality of DNA, amplification and sequencing success, were processed for genetic mark recapture, across all landscapes.

DNA from dung samples was extracted Using QIAamp Fast DNA Stool Mini kit (Qiagen Inc). For this, the outer layer of the sample was swabbed using cotton swabs dipped in Inhibit X lysis buffer and PBS solution. A negative control was also taken to check the contamination of the extraction buffers. Further extraction process was carried out as instructed in the kit protocol. Extracted products were visualized un- der UV light on 0.8% agarose gel to check DNA quality.

PCR amplification of DNA was carried out in 10µl reaction mixture containing 5 µl of Qiagen PCR Buffer (Qiagen Inc.), 1 µl of 20 µg /µl BSA, 0.3 µl of each 20 µM unlabeled primers, 2.0 µl DNA and 3 µl water to make up the volume. The thermo-cycling conditions include – initial denaturation at 95° C for 15 minutes followed by 40 cycles of denaturation at 95 ° C for 4s seconds, annealing was done at 60° C for all prim- ers, except LAT13 (64° C), EMX2 (56° C) and EMX1 (58° C) for 1 min, extension at 72° C for 1:30 min and final extension at 60° C for 30 min. In addition, negative and positive controls were taken to check the contamination of the PCR buffers. The PCR products were visualized under UV light on 2% agarose gel to confirm amplification. All amplified product of samples was pooled together for library preparation.

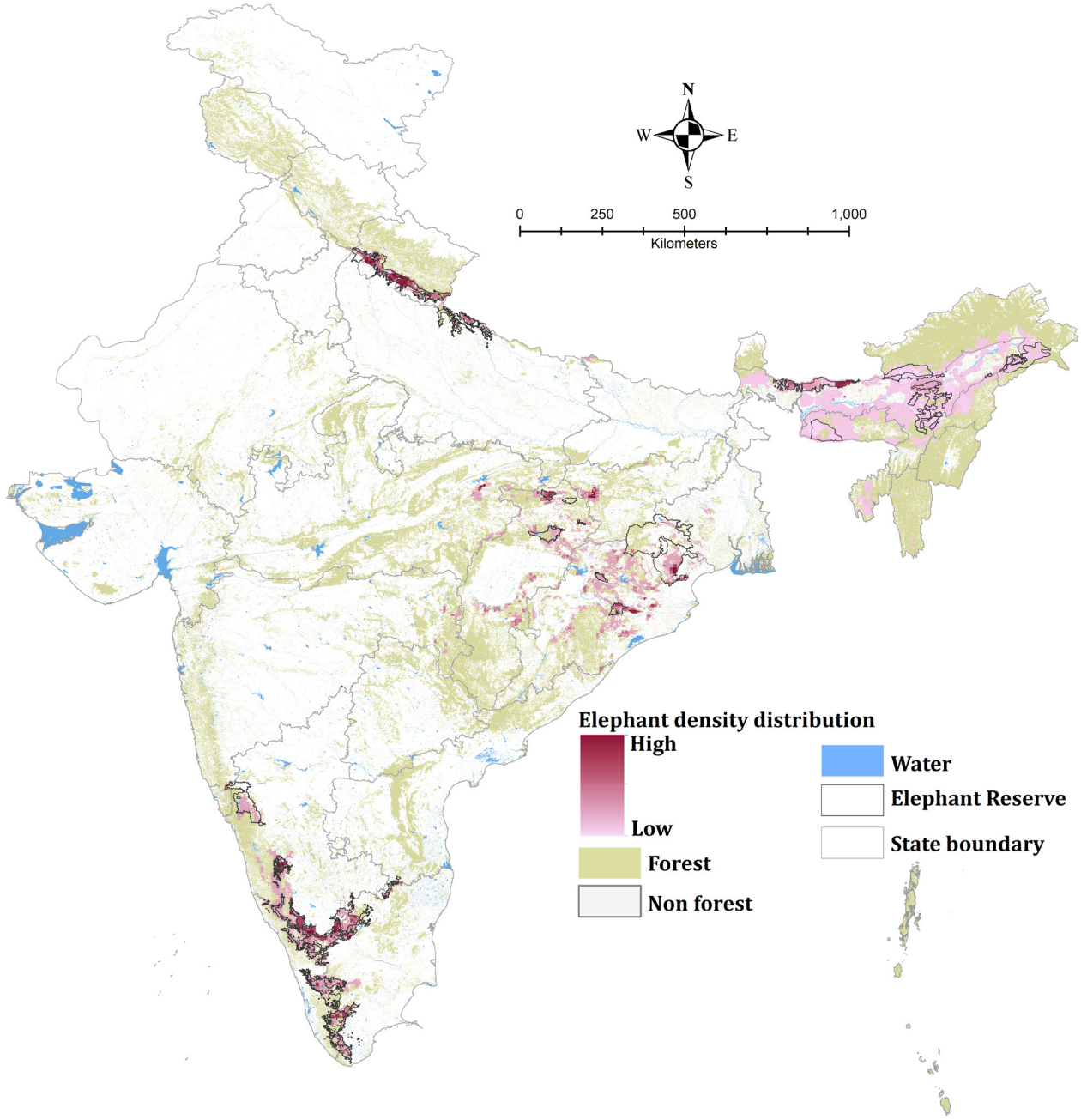
Prepared libraries were run on Next Generation Sequencing platforms for generating data. Resultant reads were demultiplexed using *bcl2fastq* with default parameters and merged using *Pear*. The merged reads were further demultiplexed at the amplicon level based on the forward and reverse primer sequences using *seqkit*. For each amplicon, minimum and maximum length thresholds were determined based on published studies, and reads were filtered accordingly using *seqkit* to retain only those within the specified length ranges. The filtered reads were then analyzed using custom shell scripts to count read lengths and zygosity of the genotypes. The raw allele sizes were binned using *TANDEM* (Matschiner & Sal- zburger, 2009) based on the repeat motif of the microsatellite. The data was then analysed for identifying individuals and recaptures through *allelematch* package in R (Galpern *et al*., 2012), which is ideal for samples with null alleles, and missing data, which is the case with non-invasive samples. The algorithm also has provisions to incorporate allelic dropout error rates, which was calculated using the comparison between blood and dung samples from the captive elephant population. Based on missing data, allelic dropout rate and PID values, threshold for mismatch of alleles is estimated which is then used to identify unique individuals, and recaptures. The details of unique number of individuals from the dung samples collected is given in Table 1.5. This information is then analysed under the spatially explicit mark-recapture framework to determine the population estimation of elephants in the population and landscape.

Table 1.5: Details of sites sampled in each landscape, number of dung samples collected for genetic analysis, unique number of individuals from the samples collected, identified through genetic analysis. Recapture Index (Total detctions/unique individuals) and Recapture Rate for each landscape.

S no.	Landscape	No. of sites sampled	Sites Sampled	No.of dung samples collected	No. of unique individuals	Recapture Index	Recapture Rate
1	Western Ghats	9	• Bandipur • Nagarhole • Bhadra • Kali • Biligiri Ranganatha Swamy Temple • Mudumalai • Sathyamangalam • Kalakad Mundanthurai • Periyar	4597	1754	1.62	0.38
2	Shivalik Hills & Gangetic Plains	4	• Corbett • Landsdowne • Rajaji • Katerniaghat	2543	627	2.18	0.54
3	Central India & Eastern Ghats	9	• Bandhavgarh • Similipal • Satkosia • Atgarh • Dhekenal • Palamau • Dalma • Tamor Pingla • Guru Ghasidas	1894	380	1.60	0.37
4	North East Hills & Brahmaputra Floodplains	15	• Manas • Buxa • Raimona Cluster • East &West Garo Hills Cluster • Kamrup Cluster • Karbi Anglong Cluster • Golaghat Cluster • Kaziranga Cluster • Mokokchung • Mon • Nagaon Cluster • Pakke-Nameri Cluster • Shergaon • South Garo Cluster • Wokha Cluster	12,022	1304	1.63	0.39

Abundance estimation through Spatially Explicit Capture Recapture (SECR): We used the likelihood-based SECR method (Efford *et al*. 2011, Borchers and Efford 2008), implemented in R (R Development Core Team 2010), to estimate elephant abundance from dung data. A habitat mask with a sufficiently realistic buffer around the camera trap array that excludes non-habitat was used, and density was modelled as a function of covariates. Encounter rate of elephants and distance to water, were used as both these covariates were highly correlated and other variables NDVI of April and November and distance to nightlight (as surrogate of disturbance). Camera trap based elephant RAI and human footprint variables obtained from ground surveys and remotely sensed data are used within SECR as covariates in a likelihood framework to model elephant density (Figure 1.2 & 1.3).

Figure 1.3: Elephant density distribution across India, modelled through Phase I data



1.3 Comprehensive Abundance Assessment of Elephants in India

SAIEE-2021- 25 covered forested habitats in 20 states of India. A foot survey of 6,60,804 km was done for signs, direct sighting and abundance estimation (including dung collection), including non-elephant habitats (Table 1.2). In these forests, along 3,19,460 habitat plots were sampled for vegetation, human impacts and elephant dung (Table 1.2 & Table 1.4). The 37 sites sampled for dung collection for genetic mark-recapture, yielded 21,056 dung samples, of which a subset was processed, and yielded 4,065 unique individuals identified (Table 1.5).

We utilized a combination of various covariates (such as Elephant encounter rate from Phase survey, distance to water, NDVI, elevation, human-modified indices, and distance to protected areas as remotely sensed covariates) in a spatially explicit capture-recapture model to estimate Elephant density beyond the sampled area. To identify the most effective combination of factors for each landscape, we relied on the AICc value, selecting the model with the lowest value.

In the Western Ghats landscape, the selected model featured Elephant encounter rate (β= 0.34 ± 0.02, positively correlated) as the most influential predictive covariate. In the Central India and Eastern Ghats landscapes, the optimal model included Elephant encounter rate (β= 0.19± 0.02, positively correlated) along with distance from water in Elephant occupied habitat (β= 1.04 ± 0.02, negatively correlated). Similarly, for the Shivalik and Gangetic plain landscapes, the top model incorporated Elephant encounter rate (β= 0.59 ± 0.03, positively correlated).

In North eastern hills and Brahmaputra flood plains the best model incorporated elephant encounter rate (β= 1.024 ± 0.034, positively correlated). Phase I data from the North Eastern Hills was severely limited relative to the documented distributional range of elephants, thereby precluding robust density modelling at the landscape scale. In this context, genetic mark–recapture surveys were initially undertaken in Buxa and Manas Tiger Reserves, which yielded population estimates of 423 and 1,031 elephants, respectively.

For the remaining 32,355 km² of confirmed elephant presence, density was extrapolated using the previously reported estimate of 0.26 elephants/km² (MoEFCC, 2017). This extrapolation produced an estimate of 8,412 individuals, bringing the provisional elephant population for the North Eastern Hills and Brahmaputra landscape to 9,866 elephants. It is important to note that this figure was derived through extrapolation and did not represent a modelled estimate.

Recognising this limitation, a renewed Phase I survey effort was implemented in 2024 across the North Eastern Hills. A total of 13 additional sites were systematically sampled, and 12,022 dung samples were subjected to genetic analysis. The resulting genetic mark–recapture analysis yielded a refined estimate of 6,559 elephants for the landscape. Importantly, this estimate supersedes the earlier extrapolated figure and provides the first empirically modelled baseline against which future monitoring and population assessments in the region can be compared.

Table 1.6: Estimated elephant numbers in each landscape. Number in parenthesis are Standard Error (SE) & CI = Confidence Interval.

Landscape	Elephant Population	Lower 95% CI	Upper 95% CI
Western Ghats	11,934 (SE 1,060)	9,857	14,012
Central India & Eastern Ghats	1,891 (SE 325)	1,254	2,528
Shivalik Hills and Gangetic Plains	2,062 (SE 185)	1,699	2,425
North Eastern Hills and Brahmaputra Flood Plains	6,559 (SE 570)	5,444	7,680
Total	**22,446 (2,140)**	**18,255**	**26,645**

India is estimated to harbour a total of 22,446 Asian elephants (SE = 2,140). Among the states, Karnataka supports the highest population with 6,013 elephants (SE = 623), followed by Assam (4,159; SE = 390), Tamil Nadu (3,136; SE = 229), Kerala (2,785; SE = 208), Uttarakhand (1,792; SE = 148), Odisha (912; SE = 170) . Across landscapes, the Western Ghats host the largest regional population, estimated at 11,934

elephants (SE = 1,060), primarily distributed in Karnataka, Tamil Nadu, and Kerala. The Northeastern Hills and Brahmaputra Flood Plains support an estimated 6,559 elephants (SE = 570), with Assam contributing the majority. Other significant populations occur in Meghalaya (677; SE = 47), North Bengal (676; SE = 69), Arunachal Pradesh (617; SE = 32), and smaller numbers in Nagaland, Tripura, Mizoram, and Manipur. The Shivalik Hills and Gangetic Plains landscape has an estimated population of 2,062 elephants (SE = 185), with Uttarakhand being the key stronghold, along with smaller populations in Uttar Pradesh and Bihar. In Central India and the Eastern Ghats, the population is estimated at 1,891 elephants (SE = 325), with major concentrations in Odisha (912; SE = 170), Chhattisgarh (451; SE = 79), and Jharkhand (217; SE = 35). Smaller populations occur in Madhya Pradesh, Andhra Pradesh, Maharashtra (Western Ghats and Gadchiroli), and southern West Bengal.

1.4 Conservation implications

India's elephant population is estimated at 22,446 individuals. This estimate is not directly comparable to earlier figures due to methodological and protocol differences across previous estimation cycles. While various monitoring methods have been employed historically (e.g., Baskaran *et al*., 2011; Lahi- ri-Choudhury, 1991), concerns regarding observer bias and methodological consistency have persisted. The current approach, based on genetic mark-recapture, offers a statistically robust alternative albeit one that is resource-intensive and technically demanding. Concurrently, further research on the efficacy, scalability, and robustness of alternative methodologies—being undertaken by the Institute with Project Elephant (Habib *et al*., 2025)—will refine quantitative criteria (e.g., low CV, high precision, cost-efficiency) to establish an improved, standardized, and scalable national protocol; results from this effort will help in taking up calibrated method(s) to be used in future.

In April 2023, Karnataka, Tamil Nadu, and Kerala jointly estimated the Western Ghats population at 11,276 elephants using direct counts and indirect line-transect dung counts, following a protocol similar to the All India Tiger Estimation (Forest Departments of Karnataka, Tamil Nadu, and Kerala, 2023). Our independent estimate for the same region and period, based on genetic data, was 11,934 individuals—a difference not statistically significant ($p = 0.98$). Elephant conservation in India faces a suite of threats: habitat loss and fragmentation; disruption of traditional corridors by linear infrastructure, encroachments, and land-use change in the Western Ghats, Shivalik & Gangetic Plains, and North Eastern Hills–Brahmaputra Plains (Williams *et al*., 2001; Menon *et al*., 2005; Baskaran *et al*., 2011); and mining pressures in Central India that necessitate restricting operations to defined blocks while maintaining safe passages and corridor integrity. In the North East, fragmentation, corridor loss, and other developmental activities are acute. Plant invasions and human-induced disturbance occur across landscapes, while human–elephant conflict remains a major issue requiring cooperative engagement with communities. Priority actions include protecting riparian forests and corridors, participatory conflict mitigation with timely compensation, habitat restoration, stronger enforcement, and targeted awareness programs to secure a sustainable future for elephants in India (Sukumar, 1990; Madhusudan, 2003; Menon *et al*., 2005; Rangrajan *et al*., 2010; Baskaran *et al*., 2011; Kumara *et al*., 2019).

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Western Ghats

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2. Western Ghats

The Western Ghats, including its extension in Sri Lanka, stands as a globally recognized biodiversity hotspot (Myres *et al.,* 2000). Characterized by a significant altitudinal and precipitation gradient, this region boasts a remarkable diversity of vegetation and topography, fostering unique faunal assemblages with high endemism, including around 25% of the global Asian elephant population (Baskaran, 2013). The elephant population in the Western Ghats spans the states of Kerala, Karnataka, and Tamil Nadu, occupying diverse habitats like tropical evergreen and semi-evergreen forests, shola grasslands, monoculture plantations of tea and coffee, as well as tropical dry and moist deciduous forests (Ramkumar *et al.,* 2017). Asian elephants in this landscape cover a broad altitudinal range, from as low as 100 m msl to approximately 2000m msl (Ramkumar *et al.,* 2017; Baskaran, 2013). This region comprises 11 Elephant Reserves, encompassing a total area of about 28,000 sq. km.

2.1 Elephant occupancy and population estimate

The elephants in this landscape are reported from 567 cells of 100 sq km out of 1,558 cells, having naive occupancy of 36%. In the current exercise of SAIEE- 2021- 25, the population is estimated to be 11,934 (SE 1060). The elephants are largely distributed along Western and Eastern Ghats in the southern states. The state wise population estimate indicates highest population in Karnataka (6013) not only in this landscape but in entire country followed by Tamil Nadu (3,136) and Kerala (2,785) (Table 2.1, Figure 2.1). Mysuru, Nilgiri, Anamudi and Periyar Elephant Reserves have the larger population amongst the reserves of Western Ghats (Table 2.2)

According to the 2023 estimation carried out by the Forest Departments of Karnataka, Tamil Nadu and Kerala, the Western Ghats population was 11,276 individuals, the major distribution of elephants in this landscape is in Karnataka (6,395 elephants), followed by Tamil Nadu (2,961 elephants) and Kerala (1,920 elephants) (Karnataka Forest Department, 2023, Tamil Nadu Forest Department, 2023 & Kerala Forest Department, 2023).

It can be inferred from our direct sighting observations that the Mean group size of elephants in Western Ghats is 2.99 (SE = 0.22, min = 1, max = 15, n = 137) and the typical group size is 5.26. The adult female to young ratio is 2.4 : 1 and the adult female to adult male ratio is 2 : 1. In Karnataka Elephant Census 2010 (Baskaran & Sukumar, 2011), population structure of elephants in Bhadra TR adult female to young ratio was 1 : 1.5 whereas the adult female to adult male ratio was 2.3 : 1, Earlier studies (Arivazhagan, 2005; Karanth & Sunquist, 1992) conducted in Nagarhole TR found mean group size to be 3.5 where the adult female to young ratio was 1 : 0.2 and adult female to adult male ratio was 5.8 : 1. Studies in Periyar (Arivazhagan, 2005; Easa & Sabu-jahas, 2002) reported 0.16 young elephants per adult female and the sex ratio was 1.9 adult females per adult male.

2.2 Karnataka

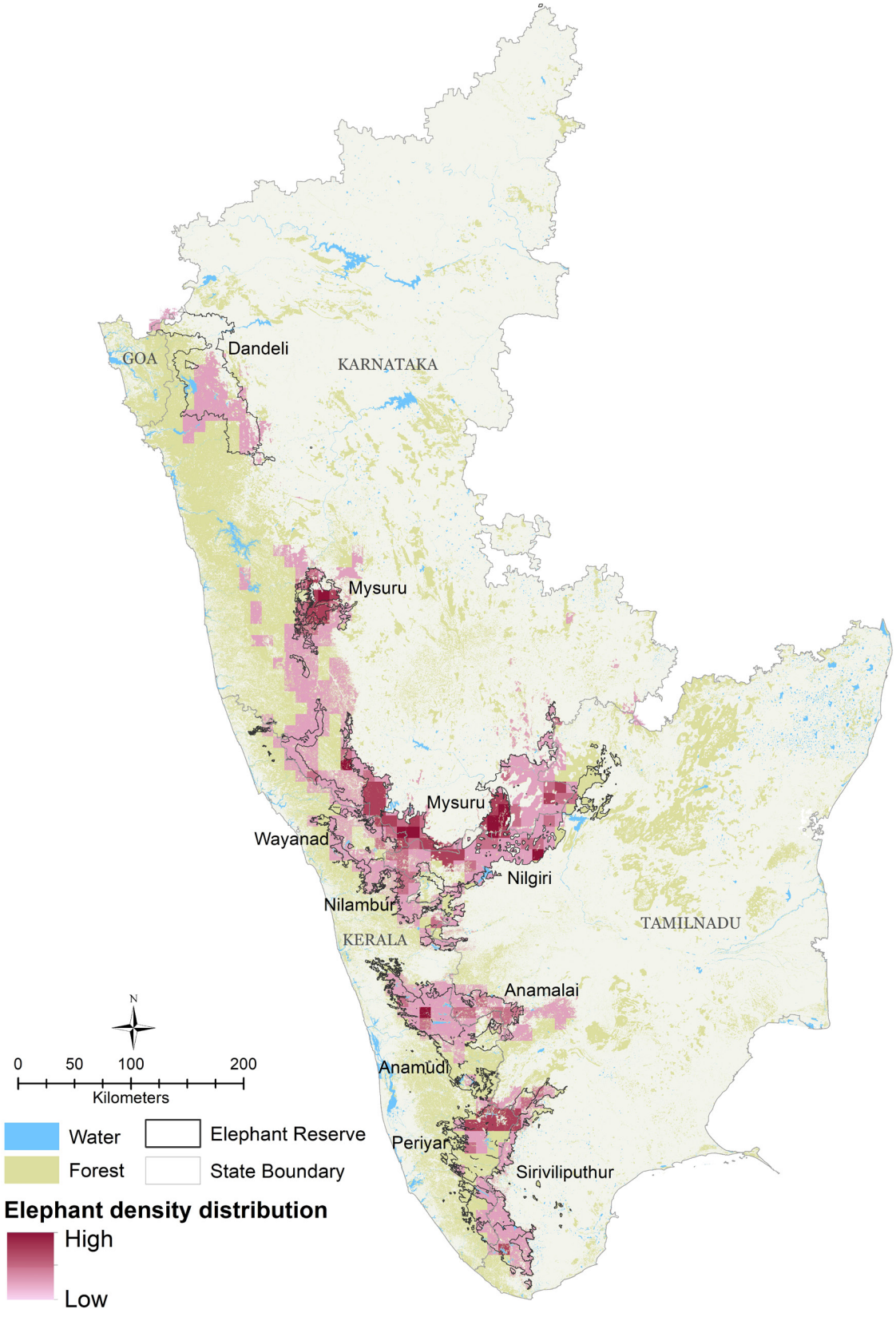
Karnataka harbours a diverse range of elephant habitats – range from the dense forests of the Ghats to the Deccan plateau landscape. The largest population of country is in this state with 6,013 (SE 623) elephants (Figure 2.1), Mysuru Elephant Reserve has highest population amongst Elephant Reserves in the Western Ghats. The habitats surrounding the Kali Tiger Reserve (Dandeli Elephant Reserve) in conjunction with adjacent Protected Areas in Karnataka and Goa forms an extensive conservation landscape. The tropical evergreen, semi-evergreen, and moist deciduous forests of Dandeli ER supports a low density elephant population. Bhadra Tiger Reserve along with Forest Divisions of Chikmagalur, Koppa, Bhadravathi and Shimoga consists of a low to medium density of elephant population which comes under the Mysore Elephant Reserve landscape. The primary forest type of Mysuru ER is dominated with tropical moist-deciduous and tropical dry deciduous forests; human-induced habitat modifications have resulted in a diverse vegetation matrix over the years. The surrounding land cover features extensive forested areas, coffee plan-

tations, and a mosaic of other crops in different parts of the landscape. The contiguous forest connectivity between different PAs act as a major factor for harbouring a healthy population of elephants.

Table 2.1: Elephant population estimate of the Western Ghats

State	Population (CI) as per SAIEE- 2021- 2025	Previous population estimate (Source - Year)
Method	**DNA based SECR**	**Sample Block Count & Dung Count (State Forest Department - 2023)**
Karnataka	6,013 [4,792- 7,235]	6,395
Tamil Nadu	3,136 [2,688- 3,585]	2,961
Kerala	2,785 [2,378- 3,193]	1,920
Western Ghats	**11,934 [9,857- 14,012]**	**11,276**

Figure 2.1: Elephant distribution in Western Ghats landscape (2023-24)



While Karnataka harbours the highest number of wild elephants in India, it is also one of the major hotspots for human-elephant conflict. Elephant-human interface is high as the vast expanse of crop fields and plantations, and numerous human settlements are present inside as well as outside the ecological range of elephant.

Apart from human-elephant conflicts, majority of the elephant habitats in the State are facing issues with increasing human populations and encroachment of wildlife habitats. Reserves like, Kali, Bhadra and the habitats in the Mysuru plateau experience forest fragmentation challenges posed by increasing human footprint. Large number of cattle population, which occupy majority prime locations increase the resource competition as well as increase the threat of spreading diseases. Developmental projects, especially the linear infrastructure projects possess another major challenge in the landscape and caused numerous elephant mortalities. The contiguous forests of the Nagarhole, Bandipur, BRT Hills face the threat of spreading of invasive species, frequent forest fires, and also face increasing pressure from upcoming developmental projects. Additionally, plantations of *Acacia auriculiformis* and *Eucalyptus citriodora,* and spread of invasive alien species like *Lantana camara, Senna spectabilis, Chromolaena odorata* have affected the vegetation of the area.

2.3 Kerala

The elephant population in Kerala is estimated to be 2,785 (SE 208) and is primarily found in the hilly region of the state, in the densely forested tropical evergreen, semi-evergreen patches (along with teak, eucalyptus and tea plantations) (Figure 2.1). In the northern part of the state, the elephant population found in the Wayanad landscape is a part of the Nilgiri cluster (sharing borders with Nagarhole, Bandipur, and Mudumalai). This part, especially the shared boundaries of Wayanad-Mudumalai-Nagarhole, harbours high density elephant population. The Parambikulam-Anamalai landscape complex is located in the south of the Palghat gap in the southern Western Ghats is one of the potential areas for long-term conservation of the Asian elephant. The Periyar-Srivilliputhur complex forms the largest contiguous patch of forest in the southern Western Ghats (beyond Palghat). Srivilliputhur-Meghamalai TR on the east and Ranni Forest Division in the South allow the elephants to disperse in the larger landscape. This landscape harbour medium density elephant population, and seasonal migration is common between the Protected Areas in this region.

Although the elephant populations in Kerala are situated in some of the best managed Protected Areas in India, rapid urbanization, mushrooming developmental projects, and encroachment of wildlife habitat by human increased the human-elephant interface in the state. Primarily, reactive measures and short-term fixes largely have been practiced to handle the situation, however, the state is grappling with the increasing number of human-elephant confrontations and needs long-term comprehensive solutions. The corridor connectivity is getting impacted by development and there is urgent need to do landscapes planning as well as improvising the development by using appropriate mitigation to allow unhindered movement of elephants. There is a need to reassess the land use pattern and practices, adopting sustainable strategies that focus on habitat conservation, and community engagement.

Apart from the omnipresent threat from habitat fragmentation and loss due to developmental activities, the elephant habitats of Kerala face threat from invasive species. For instance, spread of Lantana in the montane grasslands (sholas) of Periyar landscape pose a major threat to the native flora and fauna.

2.4 Tamil Nadu

Tamil Nadu hosts a sizable population of wild elephant spreads across diverse landscape of the state, from the semi-evergreen patches of Western Ghats to deciduous forests of Eastern Ghats. The state has the second largest population in Western Ghats, of 3,136 (SE 229). The protected forests of Mudumalai and Sathyamangalam landscape (part of Nilgiri Elephant Reserve) harbour moderate to high density elephant population, one of the highest densities of elephants in the country. The Anamalai-Kodaikanal-Parambikulam landscape also harbours a sizable elephant population, shared between states of Tamil Nadu and Kerala. The Srivilliputhur-Meghamalai landscape (within the Periyar landscape) harbours moderate den-

sity elephant population. The Kalakkad-Kanyakumari landscape (Agasthiyamalai ER) hosts a low-density elephant population.

Human-elephant conflicts in the Nilgiris region of Tamil Nadu have taken a toll on both human and elephant populations. The shrinking elephant forests in the state are increasingly surrounded by agriculture and human habitations. Elephants do migrate using certain migratory routes between seasons. Human encroachments in such areas are jeopardizing the local livelihood as well as elephants. The elephant attacks have claimed 150 human lives in the Coimbatore Forest Division over a decade, with 170 elephants losing their lives in the conflict. In response to the escalating crisis, the Tamil Nadu government has established an expert committee to study the human-elephant conflict in Nilgiris. The challenge lies in finding a balance between human development and elephant conservation. There is a need to develop sustainable conservation efforts carefully considering the intricate relationship between elephants and humans in the Nilgiris.

The contiguous habitats of Nilgiris is becoming increasingly fragmented by linear infrastructures, such as the planned railway line from Sathyamangalam town to Chamarajanagar which will bifurcate the habitat and would limit access of elephants to the Moyar valley. This is in addition to National Highway 209, state highways and other major roads already crisscrossing the elephant forests. Heavy traffic on the Mysuru-Gudalur NH766/NH 181 which links Theppakadu, Masinagudi and Udhagamandalam passing through the Tiger Reserve is major cause of disturbance and causes fragmentation of the forest which creates obstacles for the movement of animals. In addition to this, invasion of alien species like *Lantana, Eupatorium* and *Optunia* in the elephant habitats is a major concern.

The elephant population of the Western Ghats can be divided into four major subpopulation blocks:

1. Northern Karnataka: This block comprises isolated populations in Kali Tiger Reserve and adjoining areas (part of Dandeli Elephant Reserve). The elephant population ranges from the South of the Sharavathi valley in Shimoga to Bhadra Wildlife Sanctuary of Chikmagalur district and plantation regions of Hassan and Kodagu districts. The elephant population of Kali Tiger Reserve occasionally ventures into Sirsi, Belagavi, Haliyal, Yellapura and Dharwad Forest Divisions (Karnataka State Report 2023). This block has diverse vegetation ranging from evergreen to dry thorn types (Prasad *et al.,* 1974). Evergreen forests dominate the natural vegetation in the landscape, followed by an almost equal spread of tropical deciduous and dry-thorn forests. However, two-thirds of the land cover at the landscape level is occupied by human settlement/cultivation. The expanding human population has fragmented the natural habitats in this region. Heavy exploitation of forests for timber and softwood, mining (iron and manganese), hydroelectric projects, commercial plantations like coffee (*Coffea arabica*), tea (*Camellia sinensis*) and linear infrastructure projects have caused drastic land use changes in the landscape (Prasad *et al.,* 1974, Sukumar 1989).

2. Brahmagiri-Nilgiri-Eastern Ghats: This is the largest population block of Western Ghats comprising of Mysore Elephant Reserve, Nilgiri Elephant Reserve, Wayanad Elephant Reserve, Nilambur Elephant Reserve, Coimbatore Elephant Reserve. The elephant habitats above the Mysore plateau (Coorg and Malnad plateau) harbor a low to medium-density elephant population (~0.5 elephants/sq.km) in and around Bhadra Tiger Reserve. The areas south of Bhadra Tiger Reserve harbor a high-density elephant population (1.5-2.5 elephants/ sq.km) distributed across a chain of Protected Areas (e.g., Brahmagiri Wildlife Sanctuary, Nagarahole Tiger Reserve, Wayanad Wildlife Sanctuary, Bandipur Tiger Reserve, Mudumalai Tiger Reserve, Mukurthi National Park, Silent Valley National Park, etc. (Baskaran 2013). The western side of the Ghats receives more precipitation than the eastern side and has closer canopied tropical evergreen and moist forests. The habitats on the east side (slopes and the Malnad-Mysore and Nilgiri plateaus) have more open canopied tropical deciduous forests and dry thorn forests with a higher biomass of grass cover, therefore creating one of the most outstanding elephant habitats. The entire elephant habitat in this block is severely infested with exotic weeds such as *Lantana, Eupatorium* and *Mikania*. Apart from enclosures of human habitations found within and around the forests, linear infrastructure development, heavy tourist influx and increasing conversion of forest areas into monocultures of tea and coffee plantations have created many bottlenecks threatening the habitat contiguity. The elephant population of the Malnad region is almost isolated from the Coorg region due to widespread human settlements and coffee plantations. The Malnad region is tenuously connected to Mysore forests (through the Chikmagalur region) via ridge-top forests and water channels.

3. Anamalai-Anamudi: This block comprises Anamalai Elephant Reserve and Anamudi Elephant Reserve and harbors the second-largest elephant population in India. This includes Peechi & Chimmony (Thrissur Wildlife Division), Nemmara, Parambikulam Tiger Reserve, Chalakudy, Vazhachal, Thattekad, Malayatoor, Mankulam, Munnar, Eravikulam & Chinnar (Munnar Wildlife), Dindugul, Kodaikanal, Theni, Kothamangalam and Idukki. This region is known for its rich biodiversity (Gadgil & Meher-Homji 2003, CEPF 2007), and the elephant population in this block is reported to be more genetically diverse than the larger northern population of the Ghats (Vidya *et al.,* 2005). This landscape is characterized by diverse vegetation types, but the elephant habitats are mostly dominated by moist deciduous forests (Baskaran *et al.,* 2007; Baskaran *et al.,* 2013). On the upper elevation of the Ghats, tropical climax shola-grassland habitat is also found, which increases the diversity of the landscape. This population block is connected with contiguous stretches of forest but separated by the Brahmagiri-Nilgiri-Eastern Ghats population block by the Palghat gap. The elephant habitat is under threat due to fragmentation by a large number of hydroelectric projects (dams, open canals, penstock pipelines and powerhouses), commercial plantations (tea, coffee, and cardamom), and settlement/cultivation along with the development of major roads. Monoculture forest plantations (*Teak Tectona grandis, Acacia* sp. and *Eucalyptus* sp.) are also not preferred by the elephants.

4. Periyar-Agasthyamalai: This block comprises the southern part of the Periyar Plateau and its eastern spur, the Varushnad and Meghamalai hill ranges, the Achankoil valley, and the Agasthyamalai and Mahendragiri hill ranges on the southern side. Periyar Elephant Reserve is contiguous with Srivilliputhur Elephant Reserve and Agasthyamalai Elephant Reserve in Tamil Nadu. This intact population is considered on the northern side, which includes forested landscapes of Periyar, Srivilliputhur, Meghamalai and Thirunelveli. Out of these, elephants are isolated in southern Agasthyamalai and Mahendragiri hill ranges in the evergreen forests of Thiruvananthapuram Forest Division, Neyyar, Shendurney and Peppara Wildlife Sanctuaries, and Kalakkad-Mundanthurai Tiger Reserve. Human settlements and vehicular movement on the Senkotai-Pulalur highway are major threats to the population, which has restricted the contiguity between Agasthyamalai-Mahendragiri and the Periyar plateau. Due to this, the population has been isolated from the larger population from the northern side.

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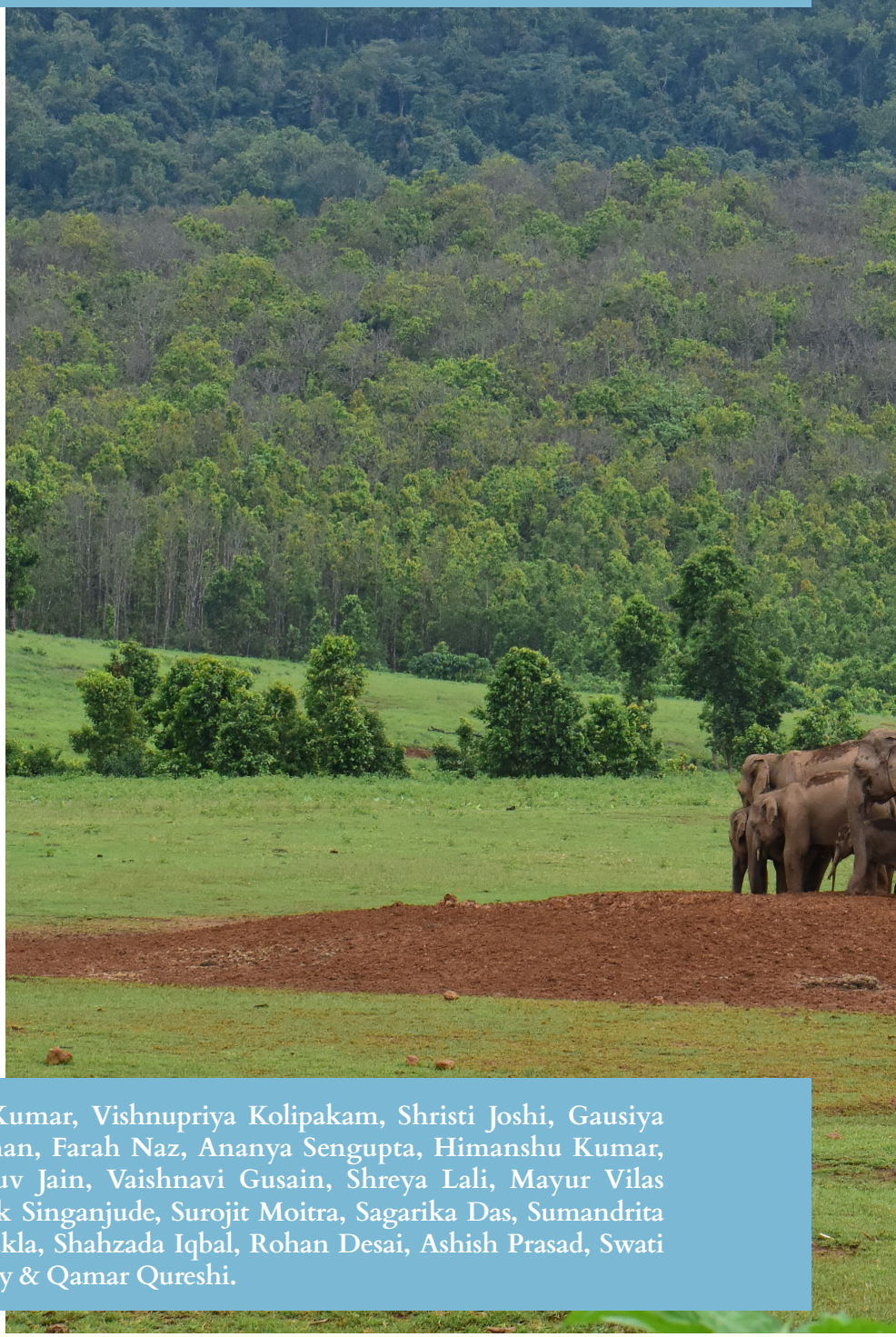
Central India & Eastern Ghats



Bhim Singh, Ujjwal Kumar, Vishnupriya Kolipakam, Shristi Joshi, Gausiya Kelawala, Vishnuvardhan, Farah Naz, Ananya Sengupta, Himanshu Kumar, Maneesha Bhatt, Dhruv Jain, Vaishnavi Gusain, Shreya Lali, Mayur Vilas Markad, Manish Ashok Singanjude, Surojit Moitra, Sagarika Das, Sumandrita Banerjee, Abhishek Shukla, Shahzada Iqbal, Rohan Desai, Ashish Prasad, Swati Saini, Ramesh K. Pandey & Qamar Qureshi.

3

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3. Central India and Eastern Ghats

The Central India and Eastern Ghats landscape is composed of the dry deciduous forests of Jharkhand, Odisha, Southern West Bengal and Andhra Pradesh. Biogeographically this area is located within the Chota Nagpur plateau, to the north of the Eastern Ghats (Rodgers and Panwar, 1988). The predominant vegetation in this region encompasses extensive deciduous forests, particularly in the states of Jharkhand, southern West Bengal, and the north-western reaches of Odisha.

A pivotal moment occurred in 1988 when elephants, driven by habitat loss, migrated from the primary elephant habitat in Jharkhand to Chhattisgarh, resulting in unprecedented damage to both life and property. In response to the escalating human-elephant conflict, the state government acted in 1993 by capturing 10 elephants to prevent further invasions into Chhattisgarh. However, contrary to expectations, within two years of this intervention, from 1995 onwards, elephants resumed regular incursions into Chhattisgarh, challenging the effectiveness of the previous capture strategy (Singh, 2002). Subsequently elephants have expanded their range in the forests of Chhattisgarh and more recently in the eastern Madhya Pradesh and Vidarbha region of Maharashtra adjoining Chhattisgarh. The elephant occurrence has been also reported in Northern Andhra Pradesh, these are elephants which usually migrate from Odisha to Vijayanagaram and Srikakulam districts of Andhra Pradesh. Elephants in southern Andhra Pradesh are those which have migrated from Nekal-Hosur in Tamil Nadu and Bannerghatta in Karnataka. In the southern Maharashtra in Sindhudurg region, elephants have been coming from the adjoining forests of Karnataka the Southern India (Western Ghat) population.

The Central Indian landscape is a vast network of Protected Areas, with around half of the total notified Tiger Reserves in India and numerous other Protected Areas, which has potential to harbor elephant population. The majority of fragmented elephant habitats in the country fall within this range. These habitats have undergone degradation and fragmentation as a result of mining, shifting cultivation, and the presence of linear infrastructural elements such as highways, railways, and canals. Human-elephant conflict is prevalent in this area, and it is believed that despite supporting less than 10% of the country's elephant population, it is responsible for nearly 45% of all human deaths caused by elephants in India (Menon *et al.,* 2017).

3.1 Elephant occupancy and population estimate

The Central Indian landscape supports the smallest wild elephant population in India and harbors some of the country's most fragmented wildlife habitats. Within this region, elephant distribution has fluctuated substantially, with range expansions often manifesting as patch colonizations. A majority of elephants occur outside Protected Areas, and the landscape is further subdivided into smaller, heterogeneous sub-units spanning multiple territorial divisions and PAs, some of which may or may not support elephants. Despite this variability, these sub-units are ecologically significant, functioning as critical components for maintaining metapopulation dynamics and ensuring the long-term persistence of elephants in Central India.

Elephant presence was recorded in 762 cells out of 8,652 sampled cells of 100 sq.km in 2022, with a naïve occupancy of 9% (Figure 3.1). The Elephant population of Chhattisgarh state has become the source population, and played a significant role in expanding the distribution of elephants within the dry and moist deciduous landscape of eastern Madhya Pradesh and Vidarbha region of Maharashtra including areas of Gadchiroli. Elephant occupancy has been expanded towards several territorial areas of Madhya Pradesh and Maharashtra, connecting several Elephant Reserves, Tiger Reserves and Protected Areas previously unoccupied. Mayurbhanj has the larger elephant population amongst the reserves of Central India (Table 3.2).

Figure 3.1: Elephnat distribution in Central India and Eastern Ghats landscape (2023-24)

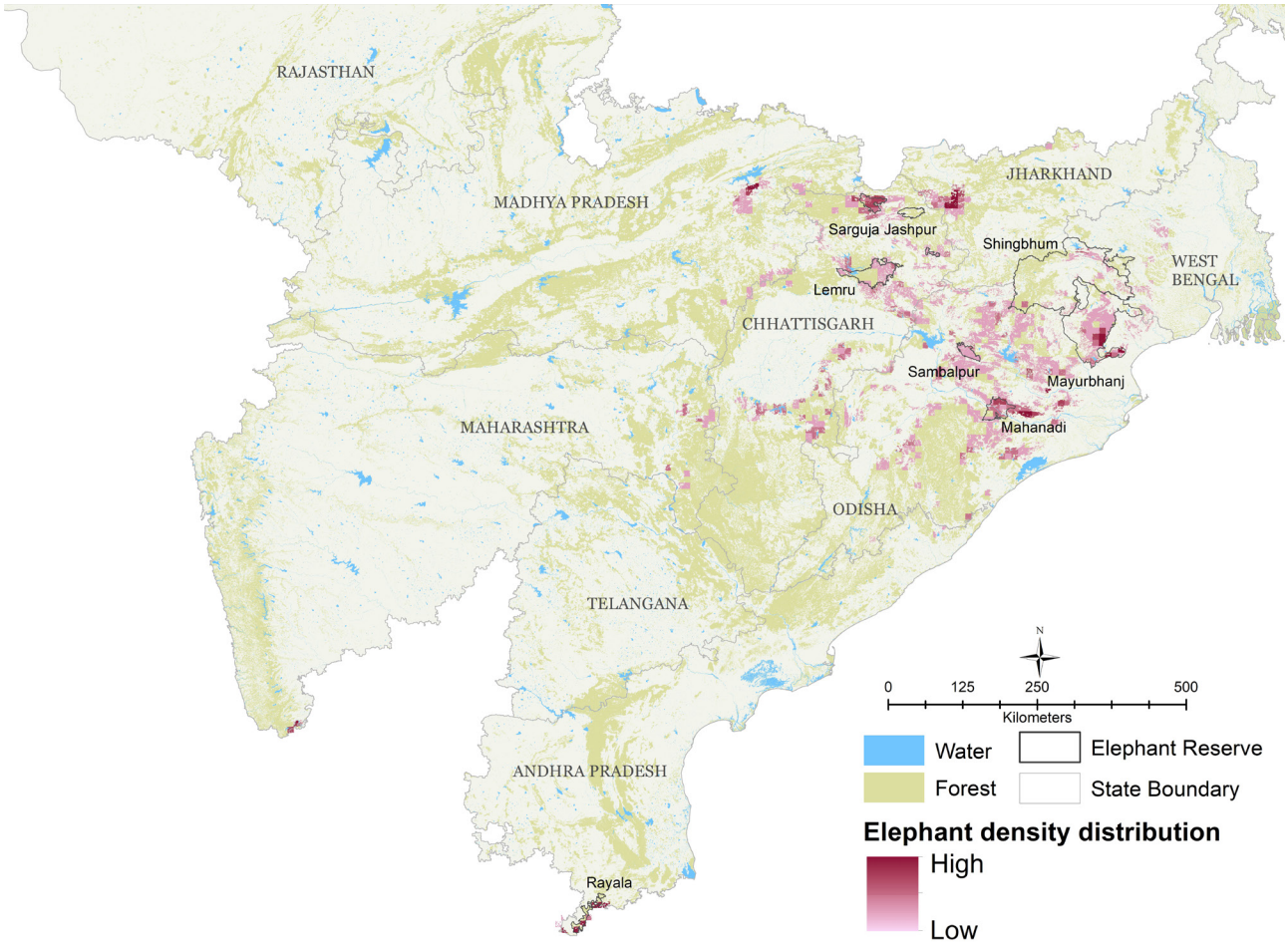

Table 3.1: Elephant population estimate of the Central India and Eastern Ghats landscape

	State	Population (CI) as per SAIEE- 2021-2025	Previous population estimate (Source - Year)
	Method	**DNA based SECR**	**Total Count**
1	Jharkhand	217 [149- 286]	679 [SAIEE 2017]
2	Odisha	912 [579- 1,246]	2,098 [Odisha Forest Department, 2024
3	Chhattisgarh	451 [297- 606]	247 [SAIEE 2017]
4	Madhya Pradesh	97 [60- 135]	7 [SAIEE 2017]
5	Maharashtra (Sindhudurg and Gadchiroli)	63 [48- 79]	-
6	West Bengal (South)*	31 [22- 41]	194 [SAIEE 2017]
7	Andhra Pradesh	120 [103- 138]	65 [SAIEE 2017]
	Central India and Eastern Ghats	**1891 [1,254- 2,528]**	**3,281**

**North Bengal is included in Northeast Landscape*

It can be inferred from our direct sighting observations that the Mean group size of elephants in the Central – Indian landscape is 4.14 (SE = 1.34, min = 1, max = 46, n = 35) and the typical group size is 18.99. The adult female to young ratio is 1.9 : 1 and adult female to adult male ratio is 1.6 : 1. In the Central Indian landscape, Odisha's elephant population reported 2.1 adult females per young elephant and adult sex ratio was 2.1 adult female : 1 adult male (Sar *et al.,* 2014).

3.2 Jharkhand

Jharkhand forests constitute 31.51% of its total geographic area (25,118 sq.km), is a mineral and forest-rich state, bordered by West Bengal, Odisha, Chhattisgarh, and Bihar. The Chhota-Nagpur plateau, characterized by deciduous forests like Palamau, Singhbhum, and Dhalbhum, constitutes crucial elephant habitats, contributing significantly to the central Indian elephant population (Rodgers and Panwar, 1985; Menon *et al.,* 2017). Jharkhand hosts two distinct elephant populations—Palamau and Singhbhum, totalling around 678 elephants as per the previous estimate in 2017 (MoEFCC, 2017). Human-elephant conflicts have intensified due to elephant migrations into areas like Hazaribagh, Ranchi, and beyond, posing significant challenges for conflict mitigation (Menon *et al.,* 2017). The current population estimate of the state is 217 (SE 35) (Figure 3.1, Table 3.1 & Table 3.2).

Severe human-elephant conflicts in diverse Forest Divisions across Jharkhand lead to a notable number of human fatalities each year, posing a significant peril to the Asian elephant population already threatened by habitat loss and corridor encroachment (Sukumar, 1989). Human activities have substantially altered elephant habitats, confining these elephants to fragmented landscapes linked solely by agricultural lands and human settlements, insufficient to fulfil their dietary and water requirements adequately. The impact extends beyond protected forest boundaries, with a significant (89.2%) human deaths observed outside forest areas (Khan *et al*., 2023). Between 2004 and 2017, 30 elephant mortalities were recorded, primarily due to diseases, electrocution, poisoning, poaching, and train accidents. Disturbingly, a study across various Forest Divisions reported 576 human fatalities caused by elephants between 2005 and 2014 (Khan *et al*., 2023). Ranchi Forest Division reported the highest human deaths (n=89) (Khan *et al*., 2023). Urgent conservation efforts are essential to mitigate threats and protect both human and elephant populations in Jharkhand.

3.3 West Bengal (South)

South Bengal poses challenges for elephant conservation, fragmented forests which act as refugia and lack of sufficient food, leads to crop raiding and associated issues among the once-migratory population (Rangarajan *et al.,* 2010; Kumara *et al.,* 2017). Between 2010 and 2018, a total of 268 human deaths were reported due to elephant encounters in the South Bengal region, while 23 elephant deaths occurred during the same period. Retaliatory killing was the major cause of elephant deaths, followed by electrocution and train accidents (Kumara *et al.,* 2017). The challenges underscore the need for effective conservation strategies to mitigate human-elephant conflicts and ensure the coexistence of humans and elephants in Southern Bengal. The population in North Bengal is described in the Northeast landscape chapter. However, the population of the southern part of West Bengal (31, SE: 5), is counted with the Central India and Eastern Ghats landscape.

3.4 Odisha

Odisha, encompassing 39.31% of its total geographic area as a forest covering 61,204 sq.km, plays an important role in elephant conservation in India. Holding approximately 57% of the elephant habitat in central India, the state accommodates a substantial elephant population spanning 11,000 sq.km, constituting 72% of the elephant population in the eastern region and approximately 7% of the India's elephant population (Padhi & Singh, 2010). These elephants predominantly inhabit major forest types, including semi-evergreen, tropical deciduous, and mixed forests, distributed across seven major river basins: Mahanadi, Baitarani, Brahmani, Budhabalanga, Rushikulya, Vansadhara, and Subarnarekha. The Mahanadi River serves as the dividing line between North and South Odisha (Swain, 2004).

Odisha has established three Elephant Reserves – Mayurbhanj, Mahanadi, and Sambalpur – covering a total area of 4129 sq.km. Responding to increasing elephant depredation and habitat fragmentation, the state plans to expand Mahanadi and Sambalpur and create two new Elephant Reserves, Brahmani-Baitarani and South Odisha. This initiative aims to incorporate vital elephant habitats, with Elephant Reserves constituting 25% of the state's forest area and hosting 90% of the elephant population. There are 912 (SE 170) elephants in Odisha (Table 3.1 & Figure 3.1).

The four major elephant population blocks area:

(a) Similipal-Kuldiha-Hadgarh and adjoining areas

(b) Satkosia-Baisipalli and adjacent areas

(c) South Keonjhar plateau and adjacent areas

(d) Madanpur-Rampur-Kotgarh and Chandrapur

The changing colonization patterns of elephants along the state reveal shifts in response to human development, with new habitats in western Odisha and south of the Mahanadi offering cooler climates, semi-perennial water sources, and marshy lands. However, anthropogenic pressures have confined elephant populations to hilly, rugged terrains where human development is slower (Lakshminarayan, 2022; Sar *et al.,* 2014). While 44 out of 50 Forest Divisions have elephants, secure habitats are primarily found in and around Similipal and Satkosia Tiger Reserve, while the remaining habitats are patchy and deteriorating.

3.5 Chhattisgarh

Chhattisgarh, with a forest area covering 44.25% (59,816 sq.km) of its total geographic area, has seen a remarkable re-colonization of elephants in recent decades. Historically extinct in the mid-20th century, elephants began moving into Chhattisgarh from Jharkhand and Odisha in 1995 due to extensive habitat loss from mineral mining in the adjoining states (Baskaran *et al.,* 2011; Menon *et al.,* 2017; Natarajan *et al.,* 2023). This expansion resulted in the establishment of three elephant populations in the state: the northern population of Sarguja circle connected to Jharkhand, the north-central population of Bilaspur circle connected to both Jharkhand and Odisha, and the south-central population connected to Odisha (Figure 3.1). The estimated elephant population in Chhattisgarh is 451 elephants (SE 79) (Table 3.1 & Figure 3.1).

Elephants in Chhattisgarh exhibit extensive movements, using forest patches, croplands, and roads, especially at night. Various areas like forests, scrublands, and uncultivated lands serve as daytime refuges, while human-used regions within their home ranges provide ample food and water resources. Their flexible home ranges lack a defined timeframe, and a study using radio collars suggests that Chhattisgarh has one of the largest estimated home ranges compared to other landscapes (Lakshminarayanan, 2017-2020). The state has declared two Elephant Reserves, namely Sarguja-Jashpur and Lemru Elephant Reserves.

Loss of orientation from their original migration paths has led to conflicts, including crop damage, house break- ins, and loss of human and livestock lives. The Surguja-Jashpur corridor, in particular, witnesses annual damage to houses, and encounters between villagers and elephants during NTFP and fuelwood collection increase the risk of human-elephant conflict. On average, 60 human lives are lost annually in the Surgu- ja-Jashpur corridor due to such conflicts (Project Elephant, Government of India, 2020).

3.6 Madhya Pradesh

Madhya Pradesh forest covers an area of 30.72% (94,689 sq.km) of its total geographic area (State of the Forest Report 2021). Moist and dry teak forest, southern dry deciduous forest, northern dry mixed deciduous, savanna and grasslands. The state is divided into four physiographic zones viz. the low laying areas in the north & north – west of Gwalior, Malwa plateau, Satpuda and Vindhyan ranges. The texts written

by Mughal chroniclers supports evidence that elephants were historically present in Madhya Pradesh in 16th – 17th century AD (Ali, 1927). By the first quarter of 20th century elephants disappeared from Madhya Pradesh. Wild elephants started venturing into the Madhya Pradesh districts of Sidhi, Singrauli, and Shahdol which are neighbouring Chhatisgarh. These elephants typically stay for 2-3 months before returning to Chhattisgarh. However, a significant shift occurred in 2017 when a group of seven elephants chose not to leave Madhya Pradesh and continued to inhabit the Sanjay Dubri Tiger Reserve in Sidhi. Subsequently, in 2018, another herd comprising 40 elephants entered Madhya Pradesh and established residence in the Bandhavgarh Tiger Reserve in Umaria. This herd has since expanded to nearly 50 elephants. Between 2021-22 about 10-12 wild elephants entered at Phen Wildlife Sanctuary & Kanha Tiger Reserve through the forests from Chhattisgarh via Anuppur & Dindori forests of Madhya Pradesh. These elephants stayed for 2-3 months at Kanha and went back to Chhattisgarh. Currently Elephants are resident to Bandhavgarh Tiger Reserve and have short term migrant presence in the Sanjay Dubri Tiger Reserve, Sidhi, Anuppur Shahdol and Dindori Forest Divisions. The current population in Madhya Pradesh is estimated to be 97 (SE 19) (Table 3.1 & Figure 3.1). The forests of Madhya Pradesh exhibit substantial potential for hosting elephants compared to Jharkhand and Chhattisgarh, attributed to effective protection measures and minimal anthropogenic disturbance. However, despite the successful establishment of the elephant population, the region faces a critical challenge in the form of human-elephant conflicts, encompassing confrontations, crop raiding, and property damage. In 2024 10 elephants died in Bandhavgarh tiger reservedue to suspected food poisoning.The unfamiliarity of local communities and forest officials with elephant management poses an additional hurdle, given the absence of elephants in the area over the past century. Addressing these issues necessitates urgent risk assessments for persistent electrocution threats, along with collaborative efforts such as habitat restoration, establishment of eco-sensitive zones, strategic land-use planning, and the integration of innovative technologies to facilitate coexistence amid tourism and highway construction disruptions. (Dutta *et al.,* 2016).

3.7 Maharashtra

Maharashtra, encompassing a forested expanse of equivalent to 20.1% (61,952 sq.km), of its total geographical area, is witnessing a renewed presence of elephants. Historically, stray herds have been documented in different districts, and the range of elephants in the Western Ghats is extending northward into Maharashtra. Since the 1950s, intermittent movements have been observed, with elephants migrating from neighboring states such as Karnataka, Odisha and Chhattisgarh. In the Sindhudurg elephants raid farmlands during the night, opting for forested areas during the day for protection (Nashirbadkar, 2022). Since 2002, there has been a noteworthy expansion of elephant range in the northern Western Ghats. In 2013, Kolhapur and Sindhudurg districts observed 11 elephants, and in 2021, a herd of 22 elephants migrated from Odisha, traversing Jharkhand and Chhattisgarh before entering Gadchiroli Forest Division in Maharashtra. Despite Gadchiroli lacking a history of wild elephants, the contiguous forests across Indravati National Park in Chhattisgarh and Kolamarka Reserve in Maharashtra provided a conducive landscape (Figure 3.1). In response, the Maharashtra government designated nearly 3,000 hectares of Tillari forest as an Elephant Reserve in the Konkan-Western Ghats corridor. The elephant population in Maharashtra is estimated to be about 26 individuals in the Western Ghats region and 37 in the Gadchiroli area, totaling 63 (SE 8) (Table 3.1 & Figure 3.1).

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3.8 Andhra Pradesh

Andhra Pradesh, with a forest area spanning 37,258 sq.km, constituting 22.86% of its total geographic area (State of the Forest Report 2021), comprise of diverse forest types such as Southern dry mixed deciduous, dry deciduous scrub, Southern moist mixed deciduous, scrub, and savannah. Despite historical references in ancient texts (Arthsahtra, Vishnugupt) and Mughal chroniclers noting elephants north of Tirupati, the state remained devoid of elephants for 200 hundred years (Moosavi, 2010). However, in the early 1980s, a small herd migrated from Hosur-Dharmapuri forests of Tamil Nadu to Kuppam and Palamaner Forest Divisions of Chittoor district due to drought, and while it was presumed that the elephants would move back in the next monsoon, they did not. Rather, between 1983 and 1986, more elephants (about 39) moved from the forests of Anekal-Hosur in Tamil Nadu and Bannerghatta in Karnataka to Andhra Pradesh (Manakadan *et al.,* 2009) and ever since there has been constant seasonal movement of elephants in this area. The second distribution of elephants in Andhra Pradesh is the herd in Parvathipuram, in the north of Andhra, which is presumed to have migrated from Odisha. The Rayala Elephant Reserve corridor connects Koundinya Wildlife Sanctuary to Sri Venkateswara National Park. This corridor is home to an elephant population ranging between 50-60. In the late 1990s, it was reported by the Tribal elephant trackers of forest department that earlier, elephants were seen all over the Koundinya Wildlife Sanctuary but declined thereafter due to death and dispersal (Manakadan *et al.,* 2010) (Figure 3.1). The elephant population of 120 (SE 9) is estimated in the state (Table 3.1 & Figure 3.1). Being new to elephants and ignorant of their dangers and on how to deal with them, the state is seeing a rise in negative interaction with frequent crop raiding incidences and increasing pressure from the local people to drive the elephants back to Odisha and other areas. The records maintained by the Forest Department documented a total of 45 human fatalities, 24 elephant deaths, and nearly 4,000 cases of crop and property damage claims. Elephant mortalities due to electrocution is an emerging cause of concern (Daniel *et al.,* 2006).

Elephant habitats in the East Central landscape face fragmentation and this has prompted long-ranging elephants to venture into historically unoccupied areas, resulting in escalating conflicts with humans lacking cultural coexistence experience and posing a threat to elephant populations. The natural behavioral pattern of elephants involves local movements along traditional paths, returning to forests upon natural regeneration of their food resources. Annually, their range may encompass 300-5000 sq.km. During these movements, they often traverse Unprotected Areas and narrow corridors, leading to human-elephant conflicts, especially in these regions where elephant habitats are encircled by human pressures, including agricultural fields and linear infrastructures like roads, railways, high tension power lines, extensive mining for mineral resources, forest resource extraction, and human settlements. Electrocution and railway collisions cause a significant number of elephant fatalities, while mining and highway construction disrupt habitats, intensifying man-wildlife conflicts. A sustainable resolution involves strengthening wildlife corridors, addressing mining and infrastructure-induced habitat fragmentation, and enhancing law enforcement against poaching. Additionally, pre-emptive sensitization campaigns in newly colonized and adjacent areas are crucial for reducing human-elephant conflicts.


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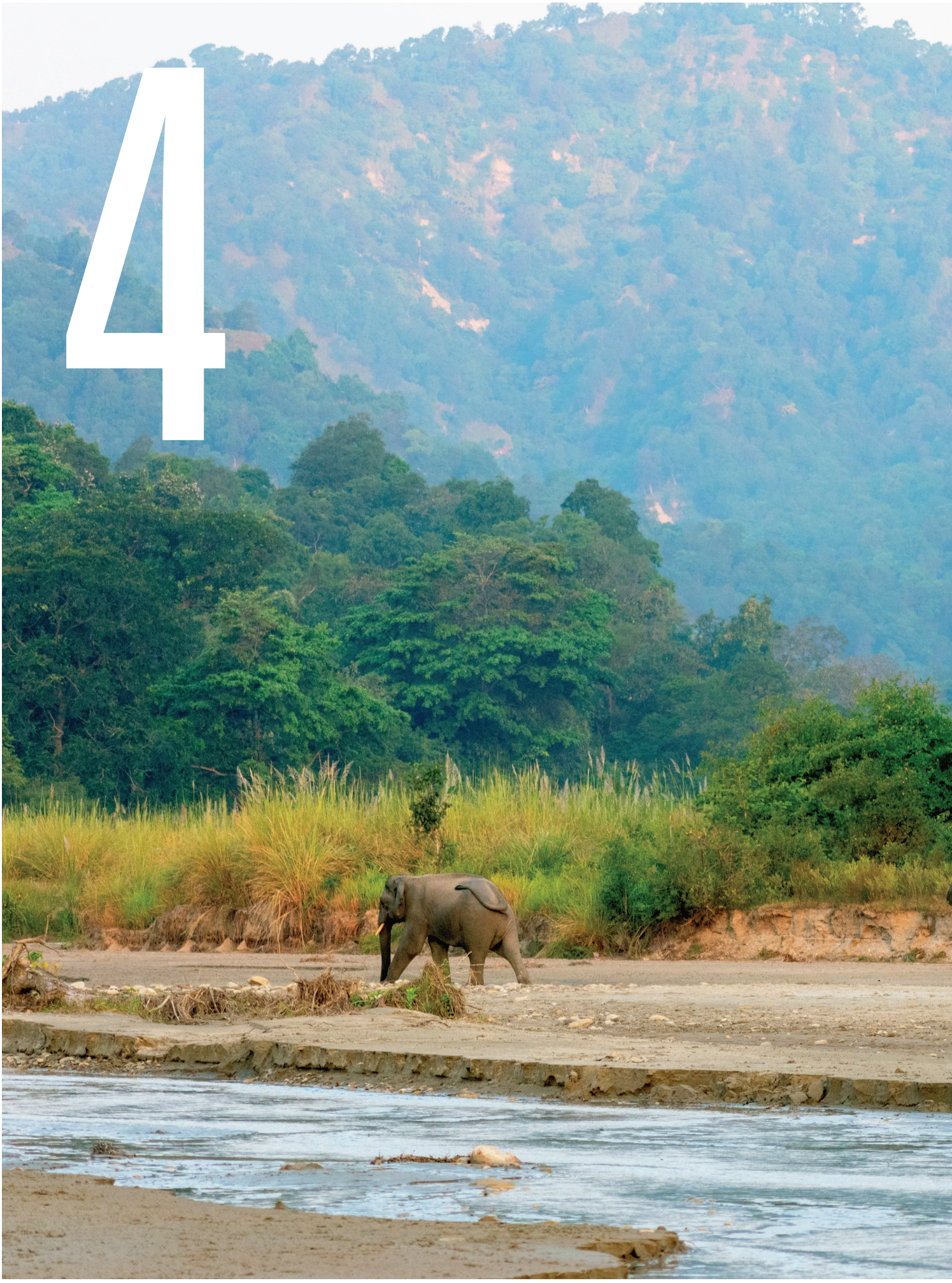

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The Shivalik Hills & Gangetic Plains

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4. Shivalik Hills & Gangetic Plains

The Shivalik Hills and Gangetic Plains host the northwesternmost population of Asian elephants. Since 1700 A.D., their distribution in this region has contracted drastically with the expansion of agriculture (Moosvi, 2010). Forster (1798) noted elephant hunting for tusks north of Haridwar, and records indicate their former range extended to the Indus. However, climatic change and human settlement have confined them to fragmented habitats east of the Yamuna up to the Gandak (Sukumar, 2010; Moosvi, 2010). At present, elephant distribution is largely restricted to the Terai and Shivalik hills of Uttarakhand and Uttar Pradesh, with occasional sightings in Bihar, Himachal Pradesh, and Haryana. In Uttar Pradesh (Pilibhit and Dudhwa Tiger Reserves, connected to Suklaphanta, Nepal) and in Bihar (Valmiki Tiger Reserve), elephants move seasonally across the Indo–Nepal border. The landscape includes two designated Elephant Reserves: Shivalik (Uttarakhand) and Terai (Uttar Pradesh).

4.1 Elephant occupancy and population estimate

Sign survey was carried out in 23 Forest Divisions and Protected Areas in the state of Uttarakhand, Uttar Pradesh and Bihar. Elephants were detected in 124 cells of 100 sq km out of the 351 sampled cells. This resulted in a naïve occupancy of 35%.

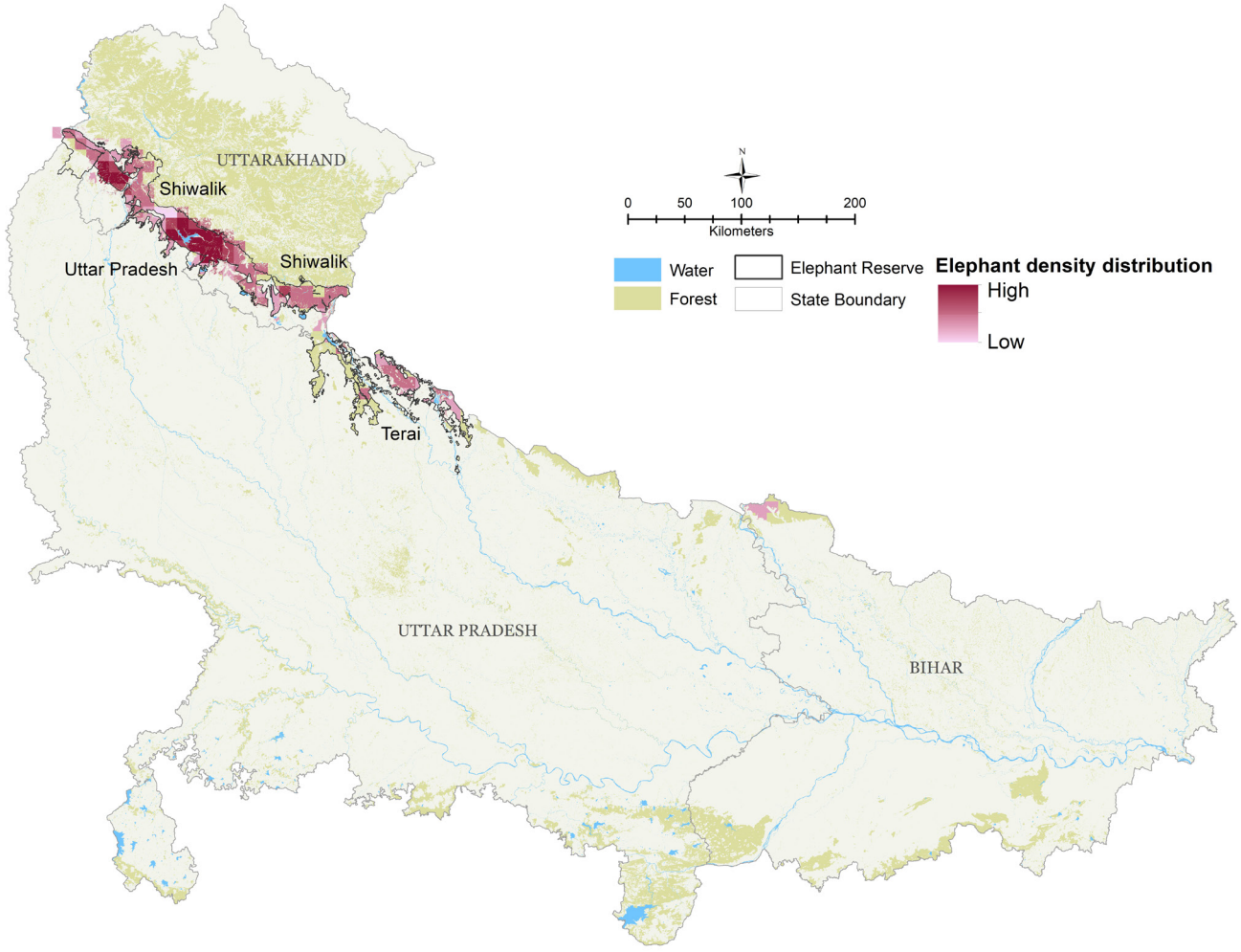
Three Tiger Reserves viz., Rajaji, Corbett and Dudhwa Tiger Reserves and one Forest Division (Lansdowne) were sampled using area search method based genetic sampling for individual identification of elephants and remotely sensed camera trap for abundance estimation of elephants. In area search method, a total of 800 sq.km in four sampling sites were sampled, a total of 92 cameras were deployed in May-June 2023 and October - November 2023 for a period of 30-40 days in these 4 sites. This yielded a total of 187 camera traps, 1758 elephant images.

Table 4.1: Elephant population estimate of the Shivalik Hills & Gangetic Plains

State	Population (CI) as per SAIEE- 2021- 2025	Previous population estimate SAIEE- 2017
Method	**DNA based SECR**	**Total Count**
Uttarakhand	1792 [1,502-2,083]	1,839
Uttar Pradesh	257 [103- 330]	232
Bihar	13 [NA]	NA
Haryana	NA	7
Himachal Pradesh	NA	7
Shivalik Hills & Gangetic Plain	**2,062 [1,700- 2,425]**	**2,085**

The current population estimate for the landscape is 2,062 (SE 185) (Table 4.1& Figure 4.1) which is distributed between Yamuna in west and Gandak river in the east (Figure 4.1). Shivalik Elephant Reserve has the largest (78%) population in this landscape. The Elephant population in Terai is fragmented, due to habitat degradation, increasing linear development and burgeoning human activities in the landscape, leading to increasing conflict over time. While some of the linear development projects have and are undergoing mitigation, collision with trains and electrocution continues to be a major reason for elephant mortality in the landscape.

Figure 4.1: Elephant distribution in Shivalik and Gangeitc Plain landscape (2023-24)



It was observed that the mean group size of elephants in Shivalik and Terai landscape is 4.40 (SE = 0.65, min = 1, max = 14, n = 56) and the typical group size is 8.88. The adult female to young ratio is 1.8 : 1 and adult female to male ratio is 2 : 1. In Shivalik & Terai landscape the mean group size was 6.8, the Adult female to young ratio was 3.7 : 1 and adult female to adult male sex ratio was 2.2 : 1. (Williams *et al.*, 2007).

4.2 Uttarakhand

Elephants in this landscape can be found upto 2500 m elevation, the population estimate is 1,792 (SE 148). In Uttarakhand last direct count was conducted in the year 2007, which resulted in a count of 1,346 elephants. Later in the year 2012, Asian nature conservation foundation, innovation centre at the Indian Institute of Sciences, Bangalore led by Dr R. Sukumar conducted elephant estimation in the state through dung decay method and estimated 1,558 elephants (SE 610). The Corbett-Rajaji is the largest elephant population in North-West India, the habitat of which has been fragmented by diversion of land for non-forestry purposes, overgrazing excessive lopping of trees for forage and canal, road, and railroad has caused fragmentation (Johnsingh *et al.*, 1990, Joshua & Johnsingh, 1995, Williams *et al.*. 2001, Joshi & Puri, 2019). Reports of conflicts between humans and elephants in this area have increased since 1990 (Johnsingh & Panwar 1992).

The Uttarakhand population in 2002 was estimated to be 1,346 (MoEFCC, Project Elephant), which increased in 2017 to 1,797 elephants. According to publicly available information, there was another synchronized elephant estimation carried out by Uttarakhand and Uttar Pradesh, where the population of Uttarakhand in 2020 was estimated to be 2026, however the report is not available publicly.

4.3 Uttar Pradesh

Two distinct elephant groups, originally in Sukla Phanta and Bardia of Nepal, began migrating to India around 1960 due to extensive habitat destruction in Nepal (Singh,V., 1978; Singh, K., 1995). Initially, they would migrate between Nepal and India from June to July, returning to Nepal by March-April. However, since 1991, they have been residing year-round in Duhwa and its surrounding areas (Salim, 1996). The elephant count in Dudhwa was 46 in 1993 (Salim, 1996), and subsequent estimates were 380 (2002), 291 (2012), and 232 (2017) (MoEFCC, Project Elephant). Presently, the population is estimated at 257 (SE 37), distributed from Pilibhit Tiger Reserve to Dudhwa Tiger Reserve, with some individuals moving between India and Nepal. (Table 4.1 & Figure 4.1).

4.4 Bihar

The population of elephants in Bihar are present in Valmiki Tiger Reserve, they are not resident elephants, but are those elephants that move from Parsa and Chitwan National Parks of Nepal, as there exists a good corridor connectivity, currently and historically. Not only for elephants, but movement between these areas, across the border exists for rhinos, leopards and tigers as well. As per the information received, on an average, the group size was found to be around 10-15 individuals, and recently a group of 13 individuals was sighted. This is listed in the table as is, and is not an estimate.

4.5 Major population blocks

Major distribution of elephants in this landscape are in 6 sub-populations:

• Yamuna to Ganga block
This population is distributed in Shivalik Forest Division, Dehradun Forest Division and Rajaji Tiger Reserve. This population was estimated to be around 300 elephants in the previous census (2017). Major threats for this population's connectivity are increasing human population around the corridor, industrialization of areas near corridor and railway expansion.

• Ganga-Khoh block
This population comprises of Gohri and Chilla range of Rajaji Tiger Reserve and Haridwar, Lansdowne and Bijnore Forest Divisions. This population was estimated to be between 250-300 elephants in 2017. Two corridors have been identified for this population (Rawasan –Sonanadi corridor via Lansdowne and Bijnore Forest Division) (Tiwari *et al.,* 2017). Expansion of habitation around Laldhang-Kotdwar forest route and the town of Kotdwar in the last 3 decades has been a major cause of concern for elephant, tiger and leopard movement in the area.

• Khoh-Gola block
This is the largest population block of this north western elephant population that comprises of Lansdowne Forest Division, Corbett Tiger Reserve, Ramnagar, Terai West and Terai Central Forest Divisions. The previous estimated number for this block was 1,000 elephants with major contribution from Corbett Tiger Reserve. This population being largest also has some of the most severe and urgent threats to elephant population and movement such as: i) large population of people dependent on forest, ii) network of national (NH121) and state (SH41) highways, iii) an ever increasing pressure from the resorts along the Kosi river that have caused hard boundary for elephant and tiger movement and iv) sand and boulder mining in Nihal and Gola river and sand mining in Kosi river bed. Movement between Terai Central and Terai East is completely impaired due to Indian Oil depot, railway sleeper factory, ITBP camp and encroachments. Five corridors have been identified in this population block (Tiwari *et al.,* 2017). Among these Chilkiya-Kota (also known as Dhangari-Sunderkhal corridor) is the most crucial corridor.

• Gola- Sharda block
This population is spread across Terai East and Haldwani Forest Division and Pilibhit Tiger Reserve. The habitat in this area is highly fragmented and movement between Khatima and Surai range across the Sharda Canal in Terai East Forest Division is limited due to the four lane highway (connecting Khatima

to Tanakpur).

• Dudhwa Tiger Reserve block

Elephant move across sugarcane and agriculture fields to move to between Dudhwa National Park, Katerniaghat and Kishanpur Sanctuaries of Tiger Reserve. Elephants also moves between Bardia and Suklaphanta of Nepal to Dudhwa and Pilibhit Tiger Reserves of India.

Major threat to the elephant population in this region is fragmentation and slow degradation of habitat caused due to encroachments. The occupants around forest areas and migrant communities near the forest fringes and hills depend on forests for fuelwood, timber, NTFP collection and livestock grazing. The forests have also been cleared for creating mono-cultures of teak and eucalyptus which has further deteriorated the quality of forest. *Lantana camara* and *parthenium spp.* dominated invasion has degraded the habitat quality and forage quality in the forests for elephants. Uttarakhand and Uttar Pradesh have seen an increase in linear infrastructure projects in the last two decades and this has fragmented and in some extreme cases isolated elephant population is these areas. Mitigation measures for linear infrastructure, including ways to solve the current railway collision issue are crucial to reduce elephant mortalities in this landscape, and to increase connectivity between large forest patches to ensure safe passage for elephants. It is also very important to ensure that habitat quality in elephant bearing areas of Uttar Pradesh and Uttarakhand are improved, this will provide long-term sustenance of the elephant population in this landscape.

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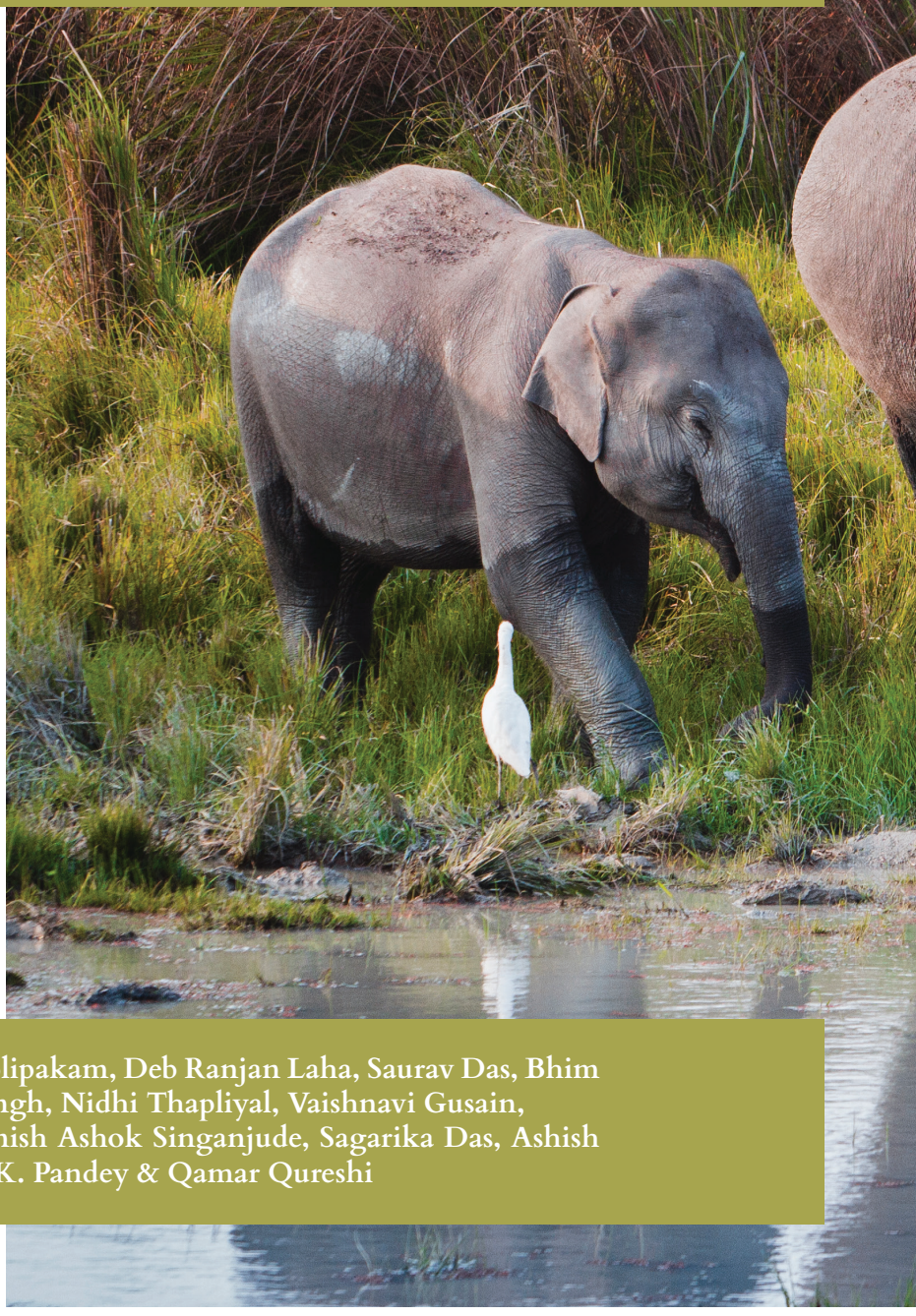
North Eastern Hills & Brahmaputra Flood Plains



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5

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5. North Eastern Hills & Brahmaputra Flood Plains

The North East region of India harbors all four of the country's mega-herbivores and sustains the world's largest population of the greater one-horned rhinoceros. The region's cultural and ethnic diversity is reflected in many tribal communities that follow animist traditions, recognizing non-human entities as integral to their worldview. This worldview has historically embedded the conservation of charismatic fauna such as tigers and elephants within the ethos of local societies (Gupta and Guha, 2022; Jhala *et al*., 2018). Despite this cultural affinity, the elephant population in the North East is highly fragmented, occupying discontinuous habitats that stretch along the foothills of the eastern Himalaya—from northern West Bengal in the west through Assam, Arunachal Pradesh, Nagaland, and Manipur in the east, to Mizoram, Tripura, and Meghalaya in the southeast. Given its extensive international borders, this landscape supports elephant populations that are nearly contiguous with Nepal, Bhutan, Myanmar, and Bangladesh (Daniel, 1980; Chowdhury, 1999).

5.1 Elephant occupancy and population estimate

The majority of the elephant population in this landscape is in Assam, encompassing 11 elephant reserves. The initial sampling yielded 1,031 elephants (SE 175) in Manas and 423 (SE 63) in the Buxa landscape of North Bengal, across a combined 772 km². Because Phase I and III coverage was limited, a landscape-wide model could not be fitted. Following the MoEFCC (2017) distribution of 32,355 km² of elephant range in the Northeast (excluding the 772 km² sampled), we applied the prior density of 0.26 elephants·km^{-2} to the remaining 32,255 km², yielding 8,412 elephants. Adding the Manas (1,031) and Buxa (423) estimates gives an approximate landscape total of 9,866. This is not a modelled estimate and should be treated strictly as an interim approximation necessitated by data limitations.

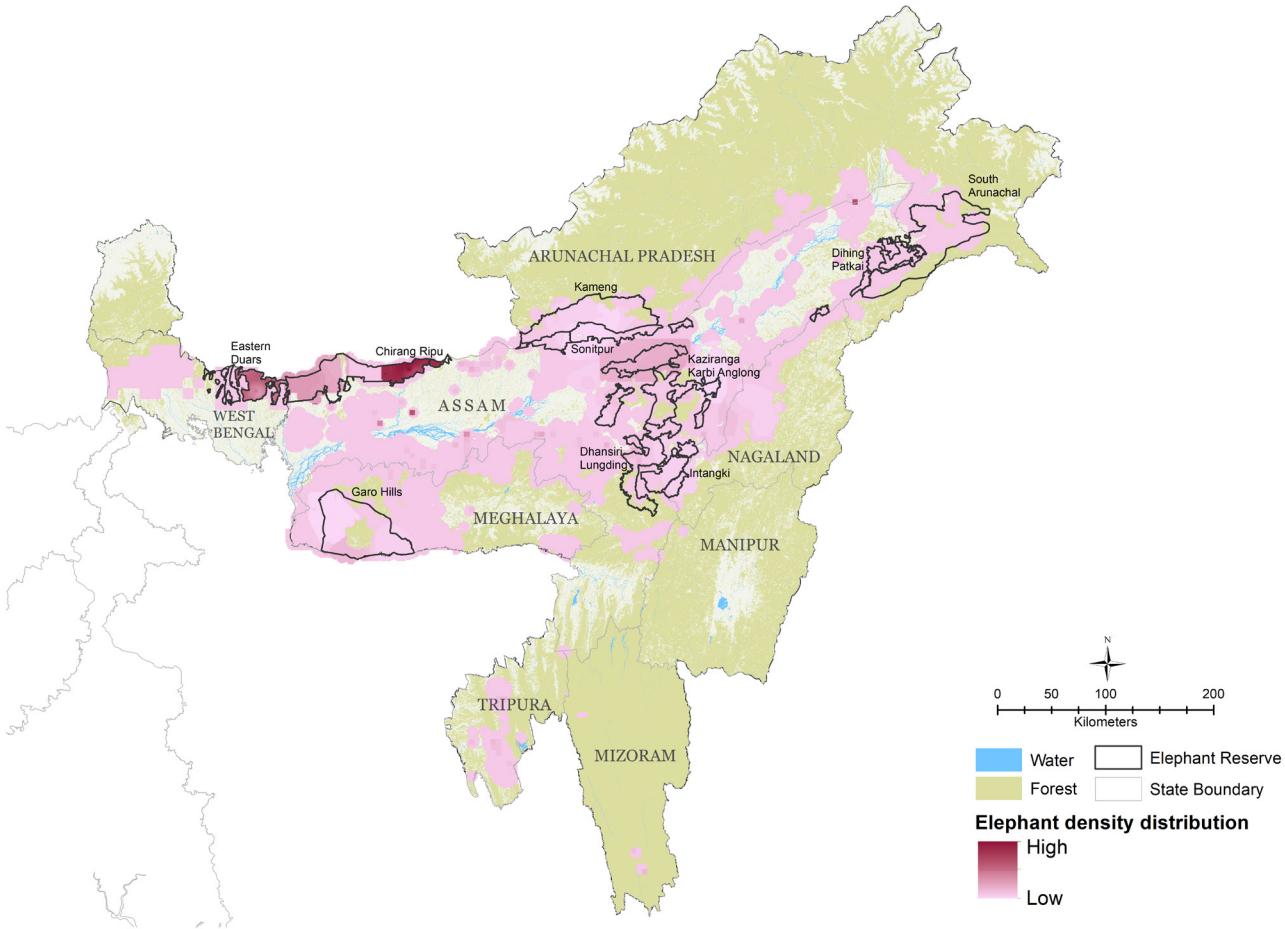
The population estimation exercise was repeated in December, 2024 - January, 2025 due to limited data in Phase I of All India Tiger Estimation exercise in 2023, which is largely in the tiger bearing states of this landscape as Phase I data is available from limited areas. The elephant estimation exercise, from the combined surveys, was carried out in 976 cells of which 558 cells have elephant presence. The population estimate for this landscape, using genetic mark-recapture from 15 sites, is 6,559 (SE 570) (Figure 5.1).

Our findings from the entire North-east landscape show that the mean group size of elephants in the landscape is 7.97 (SE = 2.05, min = 1, max = 55, n = 29) and the typical group size is 22.70. The adult female to young ratio is 1.2 : 1 and the adult female to adult male ratio is 1.5 : 1). The mean group size reported in North Bengal landscape was 8.9 with 3.1 : 1 adult female to young ratio and 2.2 : 1 adult female to adult male ratio (Das *et al*., 2016). Choudhury (1999) reported adult female to adult male ratio is 1.6 : 1, female to calves ratio is 1: 0.5, while Sukumar (2003) reported female to male ratio from Buxa 2.8 : 1 and Jaldapara 2.6 : 1

Table 5.1: Elephant population estimate of the North Eastern Hills & Brahmaputra Flood Plains.

State	Population (CI) as per SAIEE- 2021- 2025	Previous population estimate Source- Year
Method	**DNA based SECR**	**Total Count, +Block Sample Count & *Dung Count**
Arunachal Pradesh	617 [555- 680]	1,614 [SAIEE - 2017]
Assam	4,159 [3,395- 4,924]	5,828*++ [Assam Forest Department 2024]
Manipur	9 [8- 11]	9 [SAIEE - 2017]
Meghalaya	677 [585- 770]	1,754 [SAIEE - 2017]
Mizoram	16 [13- 18]	7 [SAIEE - 2017]
Nagaland	252 [207- 298]	446* [SAIEE - 2017]
Tripura	153 [140- 167]	102* [SAIEE - 2017]
West Bengal (North)	676 [541- 812]	488 [SAIEE - 2017]
North Eastern Hills & Brahmaputra Flood Plains	**6,559 [5,444- 7,680]**	**10,248**

Figure 5.1: Elephant distribution in North Eastern hills and Brahmaputra flood plains landscape.



5.2 Arunachal Pradesh

Located on the northern bank of the Brahmaputra River, the forested landscapes of Arunachal Pradesh serve as important refuges for the Asiatic elephant. The state supports an estimated elephant population of 617 (SE 32). These elephant population is primarily distributed along the foothills of the Eastern Himalayas adjoining Assam.

Arunachal Pradesh has two designated Elephant Reserves: Kameng and South Arunachal Pradesh. The majority of the elephant population is found in the Kameng Elephant Reserve, which shares its boundaries with Bhutan to the north and with Manas and Nameri Tiger Reserves to the south, extending eastward to the D'Ering Wildlife Sanctuary. The South Arunachal Pradesh Elephant Reserve, encompassing Kamlang and Namdapha Tiger Reserves as well as the Deomali, Changlang South, Nampong, and Namsai forest divisions, supports a comparatively smaller elephant population. However, it remains ecologically significant due to its connectivity with the Dehing-Patkai Elephant Reserve of Assam. A recent photographic record of a wild elephant in Namdapha Tiger Reserve further underscores the importance of this area in maintaining transboundary habitat connectivity.

Despite the cultural association with elephants (Laine, 2020), the elephant population in Arunachal Pradesh faces multiple threats, including habitat degradation due to illegal logging, traditional shifting agriculture, development projects, weed invasion, disruption of corridors by linear infrastructure, escalating human-elephant conflict, and poaching.

5.3 Assam

Assam hosts the largest elephant population in the landscape, with an estimated 4159 (SE 390) individuals. Elephants in the state inhabit a diverse and complex landscape, ranging from the Terai and Dooar belt of Himalayan foothills to the fertile floodplains of the Brahmaputra River. The population is broadly categorized into north and south bank of the Brahmaputra.

The state has five Elephant Reserves: Chirang-Ripu, Sonitpur, Dehing-Patkai, Dhansiri-Lungding, and Kaziranga-Karbi Anglong, which are the strong hold of elephant population and, along with number of protected areas and reserve forests, act as key habitats for elephants for not only Assam, but also the adjoining states in the North East.
However, Assam also experiences some of the highest levels of human-elephant conflict in the country. Habitat fragmentation, especially large-scale forest clearance in Sonitpur and Golaghat districts, has led to frequent negative interactions. Major threats to the elephant population include large-scale deforestation for tea and agriculture, loss of natural habitat due to weed invasion, linear infrastructure fragmenting habitats and corridors, intense human- elephant conflict and retaliatory killings, and significant amount of poaching of wild elephants.

5.4 Manipur

Located to the east of Assam and bordered by Nagaland, Mizoram, and Myanmar, Manipur is predominantly mountainous with a broad central valley. The population of 9 (SE 1) elephants has been estimated in area bordering Nagaland. The state boasts high biodiversity due to varied topography and climate, with six major forest types including tropical wet evergreen, subtropical pine, and montane wet temperate forests (Rahmani *et al*., 2016).

Part of the Indo-Malayan biogeographic region, Manipur is home to several endemic and threatened species, including the state animal- the brow-antlered deer (Rucervus eldii) whose population has declined over time. Elephant presence has been historically reported from the Anko range along the Indo-Myanmar border (Choudhury, 1999) and the eastern banks of the Barak River (MoEFCC, 2017). However, elephants were not recorded in the 2017 census, and recent sampling efforts were hampered due to exigent circumstances.

5.5 Meghalaya

Known for its hill communities and rich natural heritage, Meghalaya has a forest cover of 76% (ISFR 2021) and supports the second-largest elephant population in the region, estimated at 677 (SE 47). Elephants are mainly found in the Garo Hills, Khasi Hills, and to a lesser extent in southern Jaintia Hills, with the South Garo Hills hosting the largest share.

Meghalaya's landscape is primarily a plateau with narrow plains along its borders. Major forest types include subtropical pine, tropical wet evergreen, and moist deciduous forests (Rahmani *et al*., 2016). The Garo Hills Elephant Reserve is the only elephant reserve in the state and shares an international boundary with Bangladesh, where elephants frequently migrate.

5.6 Mizoram

Situated in the southern part of the landscape, Mizoram shares its borders with Assam, Manipur, Myanmar, Bangladesh, and Tripura. The terrain is largely hilly, with altitudes ranging from 500–800 m and peaking at 2,157 m in the Blue Mountains (Rahmani *et al*., 2016). A small elephant population is distributed across Mamit district and the Lai and Mara Autonomous District Councils, estimated at 16 (SE 1). Mizoram's forests are contiguous with Myanmar and the Chittagong Hill Tracts of Bangladesh (Choudhury, 1999).

5.7 Nagaland

Located at the juncture of Indian, Indo-Malayan, and Indo-Chinese biogeographic regions, Nagaland is highly biodiverse and 74% forested. The elephant population is contiguous with Arunachal Pradesh and Assam, estimated at 252 (SE 23).

Nagaland has two Elephant Reserves: Intanki and Singphan, the latter being the smallest in the country. Intanki is contiguous with Assam's Dhansiri-Lungding Elephant Reserve and is an important habitat in the eastern part of the landscape. The vegetation includes East Himalayan moist mixed deciduous forests, bamboo brakes, and Sal-dominated hill forests (Champion and Seth, 1968).

5.8 Tripura

Tripura, located in the northeastern hills, is part of the Indian sub-region of the Oriental Zoogeographic region (Gupta, 1998), and its biodiversity shares affinities with Indo-Malayan and Indo-Chinese regions. The state's forests are primarily tropical evergreen, semi-evergreen, and moist deciduous (Champion and Seth, 1968).
The elephant population, estimated at 153 (SE 7), is mainly distributed across the Gomti, Khowai, and South Tripura districts.

5.9 West Bengal (North Bengal)

The *Dooars* and adjoining hilly districts of northern West Bengal has a network of protected areas including Chapramari Wildlife Sanctuary, Gorumara and Jaldapara National Parks, and Buxa Tiger Reserve. These areas, though fragmented, form a contiguous elephant habitat through several reserve forests. Eastern Dooars Elephant Reserve is the only Elephant Reserve in the North Bengal Dooars. Estimated elephant population of North Bengal Dooars is 676 (SE 69), the second largest in this landscape. The southern Bengal population of 31 is not included in this landscape but is a part of Central India Landscape.

The floodplains of the region are highly productive facilitating agriculture, and tea plantations, hence densely populated. Additionally, its strategic geopolitical location as a link to northeastern India and neighboring countries with peninsular India, has led to dense linear infrastructure and development activities. These factors have resulted in severe habitat fragmentation, increased human-wildlife conflict, and restricted elephant movement across the landscape.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Elephant Population Blocks in Northeast India:

The elephant population in Northeast India is distributed across ~14 distinct population blocks spanning protected and forested areas, many of which extend across state boundaries (Choudhury, 1999). Of these, four major blocks hold the majority of elephants.

1. Northern West Bengal and North Bank of the Brahmaputra
This block spans northern West Bengal, eastern and northern Assam, and western to eastern Arunachal Pradesh, with transboundary linkages to Nepal, Bhutan, and Bangladesh. Although once contiguous, large-scale logging and encroachment, especially in Kachugaon and Kokrajhar (Assam), have fragmented habitats. Eastern Dooars Elephant Reserve is the only notified reserve in northern West Bengal.

West Bengal's forested landscape (11,879 km²) once supported large elephant herds, particularly in West Medinipur (O'Malley, 1911). Following colonial-era land transitions (Palit, 1991), few elephants remained until restoration via Joint Forest Management in the 1980s prompted recolonization. The South Bengal population migrates annually (Sep–Feb) from Dalma WLS (Jharkhand) into West Bengal districts, supported by moist deciduous forests. Current estimates are 676 (SE 69) in North Bengal and 31 (SE 5) in South Bengal, with the former counted under the Northeastern landscape, and the latter under Central India and Eastern Ghats. In Assam, the population spans from east of Sankosh River through Kokrajhar to Tinsukia, and adjacent districts in Arunachal Pradesh. Key areas include Chirang Ripu Elephant Reserve and Manas TR, which ensure transboundary connectivity (Lahkar *et al*., 2007). Further east lie Sonitpur and Kameng reserves, encompassing Nameri and Pakke TRs. Easternmost populations occur in Dulung RF (Lakhimpur), Kobu Chapori (Dhemaji), Dibru-Saikhowa NP (Assam), and D'Ering WLS and forests of Lower Dibang (Arunachal). Historical habitat degradation severed connectivity between north and south bank populations (Choudhury, 1995; Tiwari *et al*., 2017). Orang TR supports a small, isolated herd (Choudhury, 1999).

Vegetation varies widely: tropical moist deciduous (Sal-dominated) in northern West Bengal and western Assam, transitioning to semi-evergreen and tropical wet evergreen along Bhutan and Arunachal foothills. Marshes and grasslands (e.g., Jaldapara NP, Manas TR, Orang TR, Dibru-Saikhowa NP) feature Saccharum, Arundo, and Phragmites spp. Notable swamp forests are in Dibru-Saikhowa.
Habitat degradation due to infrastructure development (e.g., NH 31, NH 715, Trans-Arunachal Highway), logging, and deforestation for agriculture has fragmented this landscape (Qureshi *et al*., 2023; Choudhury, 2004). These changes have severely disrupted corridor connectivity, leading to increased human-elephant conflict (Das *et al*., 2012).

2. South Bank of Brahmaputra – Eastern Areas
This population, once connected to the north bank, became isolated during the 1970s–80s due to deforestation for agriculture and settlements (Choudhury, 1995, 1999). Despite this, elephants still use tea gardens and croplands (Tiwari *et al*., 2017). Geographically, this block spans Lohit, Lower Dibang, Changlang, and Tirap (Arunachal); Tinsukia, Dibrugarh, Sivasagar, Jorhat, Golaghat (Assam); and parts of Nagaland. Key reserves include South Arunachal (Kamlang and Namdapha TRs), Dehing-Patkai, and Singphan (Nagaland), India's smallest elephant reserve (23.5 km²).

The habitat is tropical wet evergreen rainforests with Dipterocarpus, Shorea, Mesua, and Artocarpus spp. Assam Valley forests dominate the western fringe with Terminalia and Tetrameles spp. Hollongapar Gibbon WLS holds an isolated population due to past habitat loss (Choudhury, 1999).

3. South Bank of Brahmaputra – Central Areas
Situated between the Brahmaputra floodplain, Karbi plateau, Diyung basin, and Meghalaya foothills, this population spans Golaghat, Karbi Anglong, Hojai, Dima Hasao, and parts of Meghalaya. Kaziranga-Karbi Anglong ER is central here, holding holding a major population of elephants across ~5050 km² (Tiwari *et al*., 2017). Seasonal migrations from Karbi plateau to Kaziranga occur via fragmented corridors, often through tea plantations (Goswami *et al*., 2019).

Vegetation ranges from semi-evergreen and moist deciduous forests to wet grasslands in Kaziranga (Saccharum, Arundo, Vetiveria spp.). Western and southern areas (e.g., Dhansiri-Lumding) lack Sal but retain moist deciduous elements (Shorea, Adina spp.). Habitat fragmentation has intensified due to deforestation,

expansion of tea estates, and infrastructure projects. Golaghat experienced widespread forest loss up to 2015 (Tiwari *et al*., 2017), while NH 715 and Numaligarh Refinery development have restricted elephant movement, elevating conflict (Das *et al*., 2022).

4. South Bank of Brahmaputra – Western Areas

This transboundary block between Assam and Meghalaya includes Kamrup, Goalpara, and Garo/Khasi hills. Elephants occasionally move into Bangladesh (Tiwari *et al*., 2017), though border fencing restricts this, with major populations in Garo Hills ER (Meghalaya) includes Balpakram NP, Siju WLS, and Nokrek NP. Only ~9% of the reserve is under forest department control; most is community land under jhum cultivation (Tiwari *et al*., 2017).

Habitats vary from moist deciduous (Sal-dominated) to semi-evergreen and wet evergreen along valleys. Plateau grasslands (e.g., Balpakram) feature Alloteropsis, Imperata, and Cymbopogon spp. (Choudhury, 1999). Jhum cultivation, limestone mining, and road construction are major threats in Garo and Khasi hills. Between 2001 and 2007, ~4100 crop-raiding cases and 30 human and 35 elephant deaths were reported in Garo Hills (Kaul *et al*., 2010).

Other Populations

Several smaller, fragmented populations persist: Dhansiri-Intanki (Assam/Nagaland), Amchang WLS (Assam), Barail-Jaintia hills, and southern Assam. The Barak valley holds sparse elephant groups; the Patharia Hills herd (6 females) is isolated and non-viable (Talukdar *et al*., 2017). Tripura's population is contiguous with Bangladesh (Choudhury, 1999), while Mizoram (Dampa, Ngengpui) and Manipur hold minimal elephant populations (MoEFCC). The Amchang WLS which holds a small population of elephants isolated by urban expansion and NH 715 (Choudhury, 1999). Urbanization and linear infrastructure have isolated Amchang, while road and railway expansion in Dhansiri-Intanki have curtailed elephant movement. Habitat degradation has left these populations vulnerable to conflict and genetic bottlenecks (Choudhury, 2004).

Northeast India, bordering five countries, has seen extensive infrastructure development, deforestation for agriculture and plantations, and fossil resource extraction, disrupting habitat and connectivity (Choudhury, 2004; Tiwari *et al*., 2017; Jhala *et al*., 2020). HEC is severe: Assam alone recorded 875 human and 825 elephant deaths between 2010 and 2020 (Das *et al*., 2022). Conflict-related crop loss and property damage are widespread, and compensation schemes struggle to keep pace (Naha *et al*., 2019). Most HEC incidents occur outside PAs. Assam's lowland semi-evergreen forests along the Himalayan foothills have faced drastic cover loss since the 1970s (Fernando *et al*., 2008). Political unrest and insurgency have exacerbated habitat loss in Kameng and Sonitpur reserves (Rangarajan *et al*., 2010; Hazarika and Saikia, 2013).


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