ELEPHANT

POPULATION ESTIMATION IN KERALA 2023

[Part of synchronized elephant population estimation in the southern states]

KERALA FORESTS AND WILDLIFE DEPARTMENT

JULY 2023

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Kerala Forests and Wildlife Department

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ACKNOWLEDGEMENT

In the context of widespread propaganda spread among the public that the number of elephants in the forests of Kerala has exceeded its carrying capacity, Hon'ble Minister for Forest and Wildlife, Government of Kerala, **Shri. A.K. Saseendran** announced in the Assembly (15th Legislative Assembly in its 8th Session during February 2023) that the population estimation of elephants in Kerala would be carried out to find out the exact situation. Accordingly, the Kerala Forests and Wildlife Department carried out the elephant population estimation in the State from 17th to 19th May 2023 with the help of Parambikulam and Periyar Tiger Conservation Foundations and experts. We wholeheartedly acknowledge the guidance given on this by the Hon'ble Minister for Forest and Wildlife.

ABBREVIATIONS

APCCF	**-**	Additional Principal Chief Conservator of Forests
CWW	-	Chief Wildlife Warden
DFO	-	Divisional Forest Officer
ER	-	Elephant Reserve
FD	-	Forest Division
GOI	-	Government of India
GOK	-	Government of Kerala
IUCN	-	International Union for Conservation of Nature
KFD	-	Kerala Forests and Wildlife Department
LCL	-	Lower Confidence Limit
MoEFCC	-	Ministry of Environment, Forest and Climate Change
MSL	-	Mean Sea Level
Non-PA	-	Non-Protected Area
NP	-	National Park
PA	-	Protected Area
PCCF	-	Principal Chief Conservator of Forests
RF	-	Reserved Forest
SE	-	Standard Error
TCF	-	Tiger Conservation Foundation
TN	-	Tamil Nadu
ToT	-	Training to Trainers
TR	-	Tiger Reserve
UCL	-	Upper Confidence Limit
WG	-	Western Ghats
WLD	-	Wildlife Division
WLS	-	Wildlife Sanctuary
WP	-	Working Plan
WW	-	Wildlife Warden

DEFINITIONS

Abundance - Total number of individuals or items of interest in some defined area and time period; also known as absolute abundance.

Bias - A persistent statistical error associated with parameter estimates whose source is not random chance. More precisely, bias is the difference between the expected value of a parameter estimate and the true value of the parameter. For example, a negatively biased estimator produces estimates that, on average, are smaller than the true quantity being estimated.

Clan vs Herd

The smallest unit of social structure in elephants is a mother-offspring pair. Several related mother-offspring pair may coalesce to form a 'family' or 'bond group'. Several 'bond groups' may congregate for some time to form large 'clans'.

The basic family unit in a herd of elephants, with anywhere between 6 and 20 animals, consists of the matriarch with her calves and grand calves. Elephant herd is lead by the oldest female (known as matriarch. While the females often remain with the herd for life, the young bulls stay until around 12 to 15 years of age, when they reach puberty. They will then start to become more independent until they leave their herd completely, to either roam alone or find a loosely-knit group of male elephants to join. The adult males temporarily join various herds mainly for mating. The size of a herd can change in response to seasonal changes in the availability of fodder and water. When food and water are aplenty elephants gather in large groups called clans, which consist of different bond groups and families.

Coefficient of variation (CV) - Ratio of a standard error of a parameter estimate to the parameter estimate. The coefficient of variation is used in computing sample sizes and as a measure of relative precision when comparing degree of variation among different estimates or sets of data.

Confidence interval (CI) - A confidence interval (CI) refers to the possible range within which true values of an unknown population parameter fall. In other words, a CI is the mean of the estimate plus and minus the variation in that estimate. This is the range of values that are expected to fall between a certain level of confidence. Confidence levels are represented in percentages, ranging between 80% to 99% (normally 95%). The two numbers that make up the lower and upper ends of the CI are called the lower and upper confidence limits (LCL and UCL respectively).

Density - Total number of individuals or objects of interest per unit area (also known as absolute density). Sometimes, the concept is broadened to mean number of animals per unit resource, where resource could be suitable habitat, food abundance, etc.

Elephant Reserve - An Elephant Reserve is a designated area established to protect and preserve elephants and their habitats. It provides a safe and secure environment for elephants to live in, ensuring their survival and well-being. Further, these reserves are crucial for maintaining healthy elephant populations and the ecological balance of their ecosystems.

Home Range - A home range is described as an area (where it spends its time and encompassing all the resources the animal required to survive and reproduce), spanned by animals during their normal activities of foraging, mating, and caring for the young (Burt. 1943). Competition for food and other resources influences how animals are

distributed in space. Studies on elephants in South India shows that the home range size varied considerably among the clans (range 562–800 km²) and bulls (range 211–375 km²).

Makhna - A tusk less bull. Due of genetic disorder sometimes male elephants can't develop tusk at all. Approximately 90% of bulls in south India, 50% in north India, and 5-10% in Sri Lanka do carry tusks. A makhna compared to a tusker is equal and potential in all respects.

Sample - A group of sampling units selected during a survey.

Standard deviation (SD) - Standard Deviation (SD) is a measure which shows how much variation (such as spread, dispersion, spread,) from the mean exists. The SD indicates a typical deviation from the mean. Like the variance, if the data points are close to the mean, there is a small variation whereas the data points are highly spread out from the mean, then it has a high variance. In statistics, Variance and SD are related with each other since the square root of variance is considered the standard deviation for the given data set.

Standard error (SE) - The standard error (SE) is the approximate standard deviation of a statistical sample population. The SE describes the variation between the calculated mean of the population and one which is considered known, or accepted as accurate. The standard error is especially useful for computing a confidence interval for a parameter estimate.

Trend - A change in average status of some quantity or attribute over a defined time period.

Variance - A measure of precision; average of squared differences between a set of values and the mean of the distribution of those values.

EXECUTIVE SUMMARY

Elephants are flagship species which play a vital role in maintaining the ecological balance/ health in their habitat, by limiting the growth of vegetation, facilitating seed germination and dispersal of seeds of plants it feeds on, helping in nutrient recycling and improving fertility of forest soil. Since 1986, the Asian elephant threatened by habitat loss, degradation and fragmentation, has been listed as 'Endangered' in the IUCN Red List as the wild population had significantly declined over the years. Reliable monitoring of key elephant populations, thus, has assumed great significance in the light of further loss of forests, fragmentation and deterioration of remaining habitats.

In order to assess the size and trend of elephant population along with demographic characteristics, Kerala Forests and Wildlife Department conducted a population estimation during 17th to 19th May 2023. Both block count (direct count in sample blocks) and dung count (indirect count from dung piles of elephants) methods were adopted for estimating the elephant population in the State. The basic survey units are blocks in each Forest Division and the present survey, as in the past, covered all the four Elephant Reserves in Kerala *viz*. Wayanad, Nilambur, Anamudi and Periyar by combining the sample blocks in the Forest Divisions in respective Elephant Reserves.

The present study estimated the elephant population in the State as well as Elephant Reserves using block count and dung count methods. A total of 610 sample blocks (with an extent of 3508.8 km^2) were sampled in the State and 700 elephants were counted in 251 sightings. Given 95% confidence intervals, the block count estimated a total population of 1920 elephants (ranging between 1914 and 1926) with a density of 0.20 (SE 3.1) per km^2. The dung count method estimated 2386 elephants in the State with a density of 0.25 (SE 3.2) per km^2.

Among the Elephant Reserves, Periyar ER possesses the highest abundance of elephants from both block (811 elephants with a 95% CI 803-819) and dung (940 with 95% CI 761-1160) count methods. This was followed by the Anamudi ER where the block count estimated 696 elephants (95% CI - 689-703) and dung count estimated 729 elephants (95% CI 596-892). The population was estimated as 249 elephants (95% CI 243-25) from block count and 391 (95% CI 299-510) from dung count methods in Wayanad ER. The population of Nilambur ER was estimated at 171 (95% CI 168-173) from block count and 326 (95% CI 259-411) from dung count methods.

Out of 1298 elephants classified into various age-sex category at State-level, 58% comprised adults, 21% sub-adults, 15% calf and 6% juveniles. In adult category, the percentage of females consisted of 41.74% and males comprised 16.28% (which include 89% tuskers and remaining

makhnas). In sub-adult category, the percentage of females were higher (12.81%) compared to males (7.72%). The proportion of juvenile categories of males and females were ranging between 2 to 4.4 in the total population. The proportion of calves in the total population was 14.97% which is far higher than the juvenile categories.

Of the total of 456 detections of elephants at the State-level, sightings of single individual were accounted for 42%, and two individuals comprised 14.69%. About 99% of the sightings of single and two individuals were of adult and sub-adult males. Herd size of three to five Individuals were 27.19% and between six to ten individuals accounted for 13.6%. Herd size with more than 10 individuals comprised about two percent. The maximum number of individuals sighted in a herd was 19.

The mortality data (678 classified individuals from 2015 to 2022) maintained by the Kerala Forests and Wildlife Department shows that there is a higher mortality in calf and juvenile categories, which could be due to Elephant Endotheliotropic Herpesvirus (EEHV) which is common in the wild.

All the above estimates are precise due to the finetuned methods adopted during the survey (e.g., rationalization of blocks with manageable sizes, careful selection of non-adjoining blocks that avoided double counts, use of digital maps for clearly understanding the sample block boundary even during field work).

The present elephant population estimates, from both block and dung count methods in the State, are low compared to the previous estimate carried out during 2017. The elephant habitats in Kerala are contiguous with the forests of Karnataka and TN sharing an interstate boundary length of 957 km and thus elephants in all the ERs move across the States to meet their ecological needs. This is a natural phenomenon. During natural calamities (e.g., aberrant rainfall and adverse drought leading to water scarcity and non-availability of lush green fodder) and events of negative human activities (e.g., extensive fire), elephants are known to move between the forests of adjoining States. Shift in rainfall patterns can also have a significant impact on elephant habitats (e.g., varying fodder and water availability, and vulnerability to wildfires). In 2016, severe drought in Tamil Nadu resulted in a mass movement of elephants to the wetter forests of adjoining States and they moved back to Tamil Nadu with the onset of the monsoon in mid-2017 only. This was reflected in higher numbers in the elephant population estimation carried out during 2017 in Kerala. Thus, State-specific elephant population estimations may vary widely according to the factors mentioned above.

Shrinking habitats coupled with increasing fragmentation and climate change are also affecting movement of elephants. According to a study by WWF, the traits that make elephants vulnerable to

changing climate are ‘a declining population size, sensitivity to high temperatures, invasive plant species outcompeting their regular food sources, and disease susceptibility’. The study further adds that the variables impacting distribution of elephants are driven by land-use change, water balance in the climate, temperature change and human-induced disturbances. Thus, it is time to take initiatives towards ameliorating the impact of climate change across the elephant habitats.

Comparing the adult sex-ratio of male to female, higher skew towards females were observed during 2023 (1:2.56) than 2017 (1:1.62). But in sub-adult category, the skew towards females is less during 2023 (1:1.66) than 2017 (1:2.13). The differences of adult female to calf ratios are insignificant during 2023 (1:0.36) and 2017 (1:0.34). The ratios of tusker to makhna varied much between 2023 (1:0.12) and 2017 (1:0.34). Percentage of adult and sub-adult males in the populations are found to be lower from 2017 (44.63%) to 2023 (30.55%). The variations over the years in the age-sex ratios could possibly be due to the nature of surveys (carried out only for two days in a year and especially during the peak summer season when animals tend to congregate at locations with abundant food and water resources). A study conducted in the adjoining PAs revealed that there was considerable variability in adult sex ratios even within months across dry season. Differences in the detectability of males and females can also bias the sex ratios if the total count of males and females are used. Changes in the count of single males in the population over the years could also be attributed to the dispersal of pubertal males not just from their natal herds but also from their natal home ranges to various locations. Thus, individual turnover in an area due to dispersal of males could give fluctuations. Estimates of precise elephant sex-ratio with individual identification only could yield accurate results and thus, systematic long-term studies on sex-ratios in representative populations need to be carried out in the State concurrently to validate the population estimation.

One major aspect of elephant population estimation is the useful generation of accurate data for effectively managing HEC situations experienced in many parts of the State. Reduction in elephant habitat quality and extreme weather events such as droughts and floods invariably exacerbate HEC. The reasons for HEC across the State cannot be generalised since every Forest Division has specific problems. The developmental pressure in and around the elephant habitats drastically limits the ability of elephants to traverse fragmented landscapes. Even well-intentioned measures taken to mitigate HEC sometimes block connectivity (e.g., solar power fencing, trench, rail fence, crash guard rope fence, concrete wall, etc). This can isolate populations or prevent movement of elephants to potential habitats even within their home range. Establishing more and more such preventive measures without ensuring connectivity will only exacerbate HEC and hence much care has to be taken before establishing such preventive measures. Thus, long-term solutions of HEC and promotion of

peaceful coexistence require a simultaneous focusing of management efforts on site-specific considerations as well as formulation and application of strategic plans at the landscape level that directly address underlying anthropogenic drivers and their spatio-temporal variations.

Finally, the survey outlines a few recommendations under three headings *viz*., (i) ***conservation and management of elephant population*** (enhancing existing habitat quality by removal of invasive species and maintenance of marshy grasslands, mitigating climate change impacts, etc.), (ii) ***ensuring more periodic and precise elephant population estimation*** (which includes use of mobile applications for monitoring, precise estimates of defaecation and dung decay rates , conducting studies on age-sex category of elephants in representative elephant populations), and (iii) ***mitigating HEC*** (conducting studies on the behaviour of crop raiding animals in high-conflict areas and a permanent system to document, assess and monitor HEC issues in the State; develop-appropriate site-specific measures, involving LSGDs in conflict mitigation, decentralized resource mobilization, etc.).

CHAPTER 1: INTRODUCTION

1.1. Prelude

Conservation and management of endangered and threatened species in the wild requires adequate knowledge of their distribution and population size (Sukumar, 1989; Easa *et al*., 2002). Population density and age structure are vital parameters for understanding the population biology of a species (Mohanarangan et al., 2022). Estimation of wildlife population with accuracy (refers to how close a measured value is to the actual value) and precision (refers to how close the measured values are to each other) is highly essential in the management of wildlife population (Williams et al., 2002) and essentially a prerequisite for devising appropriate policies at the national-level for implementing on-ground conservation actions. Estimating proper density and age composition are also vital for assessing the impact of poaching and management of habitats of endangered species (Riddle et al., 2010).

Unscientific counting methods can throw up wrong figures that will weaken the conservation efforts especially for the endangered and threatened species. A precise periodic estimate will enable the managers to monitor population trends and take decisions appropriately. In addition, the outcome of such periodic population estimation exercise would help in revisiting the strategies of management of elephant populations and habitat as well as reorienting the efforts of the Forest Department in conflict mitigation measures (Easa *et al*., 2002). Estimation and mapping of elephant population in various Forest Divisions (FDs) and Elephant Reserves (ERs) would serve as an indicator for ensuring water, fodder availability and in assessing the condition of the migratory corridors. Hence, reliable monitoring of key elephant populations has assumed great significance in the light of increasing poaching pressures, loss of forests, fragmentation and deterioration of remaining habitats (Sukumar, 1989; Easa and Jayaram, 1998; Riddle et al., 2010;).

1.2. Why are elephants so important?

Elephants are flag ship species which play a vital role in maintaining ecological balance/ health in its habitat by limiting the growth of vegetation, facilitating seed germination and dispersal of seeds of plants it feeds on, helping in nutrient recycling and improving fertility of forest soil. Thus, it acts as key stone species as well for many plant species. Elephants have a positive influence on the growth of numerous plant and animal species that share its habitat. They also help to maintain the grass lands. They open up dense forest canopy by pushing down branches of fodder trees/ shrubs to browse and thus making room for fresh regeneration. They can provide water for other species by digging holes

in dry riverbeds and the wide paths they create as they wander through the forests often act as firebreaks. Thus, maintaining a healthy population of elephants is highly crucial for maintaining the overall environment/ecosystem.

Asian elephant (*Elephas maximus*), which once ranged over a large area of the Indian sub-continent, is listed under Schedule I of the Indian Wild Life (Protection) Act, 1972. Asian elephant is also listed as an endangered species (IUCN, Red List 2010) due to a decline in the population of over 50% in the past three generations. It has a long-life span (60-70 years in the wild) and also a long gestation period between 20-22 months. A female that starts calving at 18 to 20 years may deliver 10 to 12 calves in her lifetime. Calving interval among elephants depends upon the quality of habitat and other stress factors. In optimal habitats, time interval between two calves is four to five years and in less favourable conditions, calving intervals are prolonged from five to eight years. Though elephants are long-lived species, the population growth is slow compared to other mammals. This low breeding potential together with threat of poaching for ivory and reduction/ fragmentation of habitats pushed them to the status of endangered animals. In addition, selective poaching of males (since only males have tusks in Asian elephants) has resulted in populations becoming skewed towards females. This has affected breeding rates and lead to increased instances of inbreeding and decreased breeding success.

1.3. Current threats to elephants

Elephants have become increasingly isolated in habitat patches as human settlements and associated land use practices cut off their traditional migratory routes and destroyed/reduced their habitat. These Pachyderms require large space for their home range (about 700-800 km^2 for female herds and about 500 km^2 for adult males) and sizable quantity of food and water. In order to meet these basic requirements, elephants increasingly come into contact with human settlements having agricultural crops. They raid crops, destroy properties, and sometimes even kill people. Wild populations of elephants can survive only if the landscapes they live in remain intact. This was not much of an issue during the past but demographic growth, expansion of agriculture and industry and infrastructure growth have fragmented their pristine habitats, resulting in loss of their traditional movement paths and crossing points and confining them to islands. Thus, coexistence which once prevailed in forest fringes and forest enclosures, is under threat now.

1.4. Population estimations of elephants

According to current population estimates, there are about 50,000 – 60,000 Asian elephants in the wild, with more than 60 per cent in India. According to India's Ministry of Environment, Forest and

Climate Change (MoEFCC), elephant population in 2017 was 29,964 elephants in the country (Williams et al., 2020) with highest population (6,049) in Karnataka, followed by Assam (5,719) and Kerala (3,322). In 2017, dung count method yielded 5706 elephants (with an estimated density of 0.59 individuals/km^2) in Kerala.

In Kerala, state-wide population estimations of elephants were carried out periodically in the past. KFD with the backstopping of KFRI conducted wildlife population estimation in the State during 1993 (Anon, 1993), 1997 (Easa and Jayaraman, 1997) and 2002 (Easa et al., 2002). Exclusive elephant population estimations were carried out during 2005, 2007 and 2010 by KFD with the technical support of Kerala Forest Research Institute and Periyar Tiger Conservation Foundation (Sivaram et al., 2005, 2007 and 2010). Again, population estimations exclusively for elephants were carried out at state-level during 2012 and 2017 by KFD with the scientific support from Tiger Conservation Foundations (Balasubramanian and Veeramani, 2012; Balasubramanian and Easa, 2017). The 2017 estimates of elephant population in the ERs of Kerala by block and dung count methods are detailed in Table 1.1.

Table 1.1: Estimated elephant population in the ERs in Kerala during 2017

Name of ER	Block Count Method					Dung Count Method			
	Elephants counted	Estimated density [no./km^2]	Estimated population (SE)	LCL	UCL	Estimated density [no./km^2]	Estimated population	LCL	UCL
Anamudi	514	0.44	1488 (4.2)	1479	1496	0.40	1369	1105	1698
Nilambur	148	0.26	451 (3.8)	447	454	0.41	710	574	877
Periyar	454	0.3	984 (2.6)	979	989	0.49	1603	1395	1841
Wayanad	231	0.37	431 (3.5)	428	435	1.03	1211	906	1620

SE = Standard Error; LCL=Lower Confidence Limit; UCL=Upper Confidence Limit

1.5. Methods of Elephant Population Estimation

Population estimation, either by direct (observations) or indirect surveys, is crucial to determine abundance, density and distribution of wild animals (Jathanna et al., 2003; Rasmussen et al., 2005; Varma et al., 2006). Several methods are used to survey elephant populations. The appropriate technique for a particular area depends upon the question being asked, habitat, and resources available to conduct the survey. In the case of large-bodied animals such as elephants, total count in samples (directly counting all animals in the sampled subsets of population) and use of line transects

based on direct sightings or indirect signs such as dung have been commonly applied to estimate density in the wild (Barnes et al., 1995).

In total (direct) count method, all individuals of the species of the entire area/habitat are enumerated. This method gives correct result but it can be done only in limited area having good visibility, because in large area its execution is very difficult. Due to lack of visibility (caused by thick vegetation or inaccessible highly undulating terrain), there are chances that some animals or part of the area are left out. It also needs substantial expenditure and large number of enumerators and labourers. In order to overcome these impediments, 'partial-counts' (also known as sample count or block count, equivalent to the partial enumerations) are employed in wildlife management which gives reasonable accuracy. However, like other kinds of sampling, care should be taken in the selection of sample blocks so that it should be true representative of the area. In statistics, sampling is a method of selecting the subset of the population to make statistical inferences. From the sample, the characteristics of the whole population can be estimated. The method assumes that all the animals are counted in the selected representative samples by 'total count method' and, on this basis the total number of the animals (population) in the whole area is calculated statistically. In addition, size of sample block also matters in accurately counting individuals. Manageable sizes of representative sample blocks are ideally between four to six km^2, as a team can effectively perambulate the entire representative unit during the day of counting and count all individuals of the target species within the sampling blocks. This effective size was decided based on data from the population estimation exercises conducted during 2012 in Karnataka which indicated maximum detection probability for the above block sizes (Sukumar et al., 2020). Some of the sampling blocks used during the earlier estimations were either over-sized (28% of the total 615 sampling blocks) or under-sized (12% of the total) that could lead to inaccurate estimate.

On the other hand, dung count method is most commonly used technique for estimating elephant numbers in forests which provides a more precise estimate than other methods because it records the accumulated presence of animals, variation among the transects is less (Barnes, 2001) and more detection helps in better model fit in distance sampling. A high variance in the dung density would reveal that the collected data has higher variability and the data is generally further from the mean while the low variance would reveal the opposite, that the collected data is generally similar, and does not deviate much from the mean. Hence higher accuracy is due to the lower variance in dung density which results in a lower-than-expected variance for the final elephant estimate when combined with the variances of defecation and decay rates. In addition, cost involved in survey, field equipment and field training requirements for volunteers is comparatively low.

The age-sex ratio of elephants is also an essential information for assessing the demographic status and dynamics of elephant populations. During each sighting, the individuals sighted are classified into various age-sex categories. Age classification of individuals are done based on the height of the individuals. Such information is crucial for assessing the population growth and their conservation status. Age-sex classification in the field requires a specialized skill to classify the animals to various categories based on the height.

In order to get the size and trend of elephant population along with demographic characteristics, the Project Elephant Directorate, MoEF advocated synchronized population estimation (All India Synchronised Asian Elephant Population Estimation) of elephants in all elephant ranges at regular interval which would look at three aspects *viz*., elephant numbers, herd composition and distribution using the above said two techniques *viz*., block count and dung count methods. The southern states of Kerala, Karnataka, Tamil Nadu (TN), Andhra Pradesh and Goa have conducted field survey of synchronized elephant population estimation during 17th to 19th May 2023.

After considering all field constraints detailed in the above paragraphs, the methods were refined/fine-tuned to overcome the weaknesses in the survey methods and to ensure a more precise estimate of elephant population in the State (described in Methods – Chapter 2). The present survey, as in the past, covers all the four ERs in Kerala *viz*. Wayanad, Nilambur, Anamudi and Periyar (each ER is taken as a unit for estimation). More details on the ERs are detailed in Chapter 2.

1.6. Objectives

The main objectives of the elephant population estimation were to;

a. Estimate the number of elephants through sample block count (direct count) and line transect dung count (indirect count) methods.
b. Assess the population structure and age-sex ratios based on data collected from sample block count and waterhole count methods.
c. Provide ER-specific information on elephant population and age-sex ratio.
d. Examine the basic factors influencing human-elephant conflict incidences.
e. Provide recommendations for enhanced management of elephant population in the State.

CHAPTER 2: OVERVIEW OF ELEPHANT RESERVES

2.1. General description of forests of Kerala

Kerala (38,863 km²; 1.18% of India's landmass) a narrow strip of land, tucked away in the southwest corner of India, is situated between the Arabian Sea to the west and the Western Ghats to the east. Kerala lies between north latitudes 8°.17'.30" N and 12°. 47'.40" N and east longitudes 74°.27'47" E and 77°.37'.12" E. Though it covers only 1.18% of the total area of India, it supports about 3.43% of the total population of the country.

The total extent of forest in Kerala is 11524.913 km^2 (% of forest area to the total area of the state is 29.65%) (Anon, 2021), of which an extent of 6451.677 km^2 is Reserved Forests; 285.093 km^2 is proposed Reserve; 1586.147 km^2 is Vested Forests; 135.812 km^2 is Ecologically Fragile Lands and 3066.184 km^2 is under Protected Area network. But this total extent consists also of forestland devoid of elephants. Out of the total extent of 11524.913 km^2, areas used by elephants are only 9622.708 km^2 distributed under four identified Elephant Reserves (details provided under para 2.2).

Forests in Kerala are mostly confined to the mountainous highlands of WG which runs along the entire length of the State except for 30 km wide Palghat Gap. Based on forest contiguity, landscape integrity and management imperatives, forests in Kerala are divided into four Elephant Reserves (ERs), two each on either side of Palghat Gap. All the four ERs have continuity with forests of neighbouring States enabling unimpeded movement of animals across the border.

South of the Palghat Gap, the forests of Kerala are more or less continuous and lie contiguous to forests of Tamil Nadu (TN). Anamudi ER is part of a large landscape extending from Anamalai ranges to the Palanis and the High Ranges. Likewise, forests of Periyar ER which run right upto Agastyamalai hills through the narrow Aryankavu Gap, are bordered by large stretches of forests, mostly PAs on TN side.

On the northern side of the Palghat gap, the Nilambur ER starts from Palghat hills and in continuation with the Attapadi plateau merges with the composite block of Nilgiri ranges. Further north lies the Wayanad ER extending upto Kasargod FD on the Kerala side and contiguous to large forest tracts of TN and Karnataka.

In general, the ERs in Kerala are delineated based on the forest contiguity in Kerala. At the same time, each ER lies contiguous to large stretches of forests and PAs on TN and Karnataka sides. The

approximate lengths of boundaries shared with other States are Wayanad 242 km (TN and Karnataka), Nilambur 212 km (TN), Anamudi 214 km (TN) and Periyar 289 km (TN), thus totalling a boundary length of 957 km for the entire State.

2.2. Formation and Administration of ERs

The Government of Kerala (GoK) has declared four ERs (ER) namely Wayanad ER, Nilambur ER, Anamudi ER and Periyar ER in Kerala (Fig. 2.1) vide G.O (P) No. 19/2002/F&WLD dated 2nd April 2002 (Annexure 2.1). Initially the GoK had designated the Field Director (Project Tiger) as Field Coordinator for Anamudi and Periyar ERs and the Conservator of Forests (Wildlife), Palakkad as Field Coordinator for Wayanad and Nilambur Reserves (vide G.O. (Rt) No. 125/2002/F&WLD dated 30th June 2002). Considering the composition of FDs in various ERs, the GoK subsequently appointed separate field coordinators for each ER vide G.O. (Rt) No. 361/2002/F&WLD dated 30th October 2002 (Annexure 2.2). This G.O designated the Conservator of Forests (Wildlife), Palakkad as Field Coordinator for Wayanad ER, Conservator of Forests, Olavakkod, Palakkad as Field Coordinator for Nilambur ER, Conservator of Forests, Thrissur as Field Coordinator for Anamudi ER and Field Director (Project Tiger), Kottayam as Field Coordinator for Periyar ER.

2.2.1. Wayanad ER

Wayanad ER is spread over in four revenue districts of Kerala *viz.,* Kasargod, Kannur, Wayanad and Kozhikode and lies between 11°28’ and 12°7’ N latitude and between 75°28’ and 76°36’ E longitude. The Protected Areas (PAs) such as Aralam, Kottiyur, Wayanad and Malabar Wildlife Sanctuaries (WLSs) and the territorial divisions such as Kannur, Kasargod, Wayanad North, and parts of Wayanad South and Kozhikode FDs constitute this ER (Fig. 2.2).

Considering the contiguity of forests, Meppadi Range in South Wayanad FD and part of Thamarassery Range in Kozhikode FD are excluded from this ER and added into Nilambur ER. As per the Forest Statistics – 2021, the total extent of Wayanad ER[1] is 1339.342 km^2 (as on 31.03.2021). After excluding an extent of 166.89 km^2 of entire Meppadi Range of Wayanad South FD and part of Thamarassery Range in Kozhikode FD (Table 2.1) which are devoid of elephants, actual area used by elephants in the ER 1172.45 km^2. Out of this actual forest areas used by elephants in the ER, 504.129 km^2 (about 43%) is under PA status. The remaining areas are managed as territorial FDs (FDs).

[1] As per G.O (P) No. 19/2002/F&WLD dated 2nd April 2002, the total extent of the ER is 1200 km^2 which is only approximation. Hence, we used the figures given in the Forest Statistics – 2021 for preparing this report.

Fig. 2.1: Map showing Elephants Reserves in Kerala

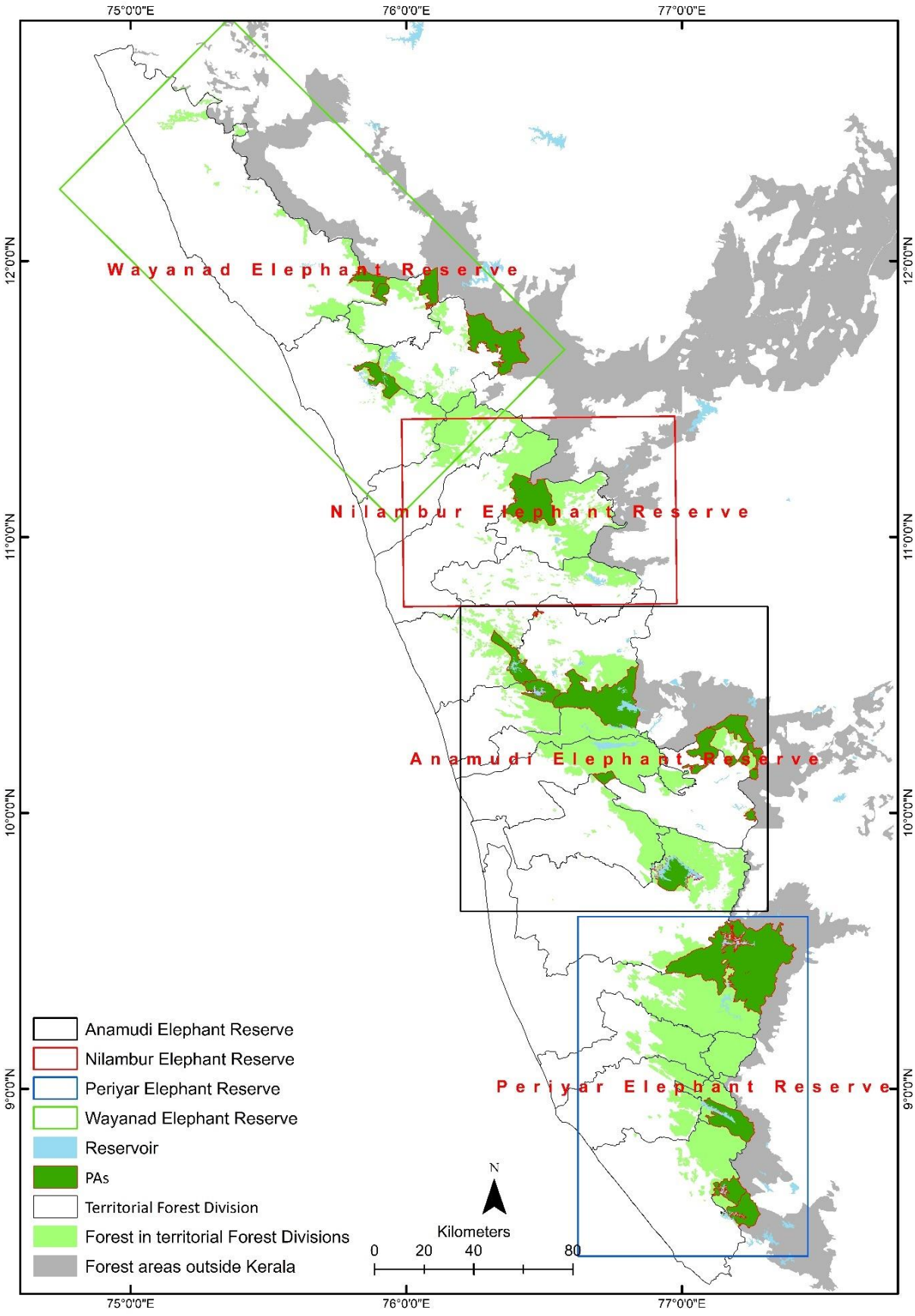


Fig. 2.2: Constitution of Wayanad ER

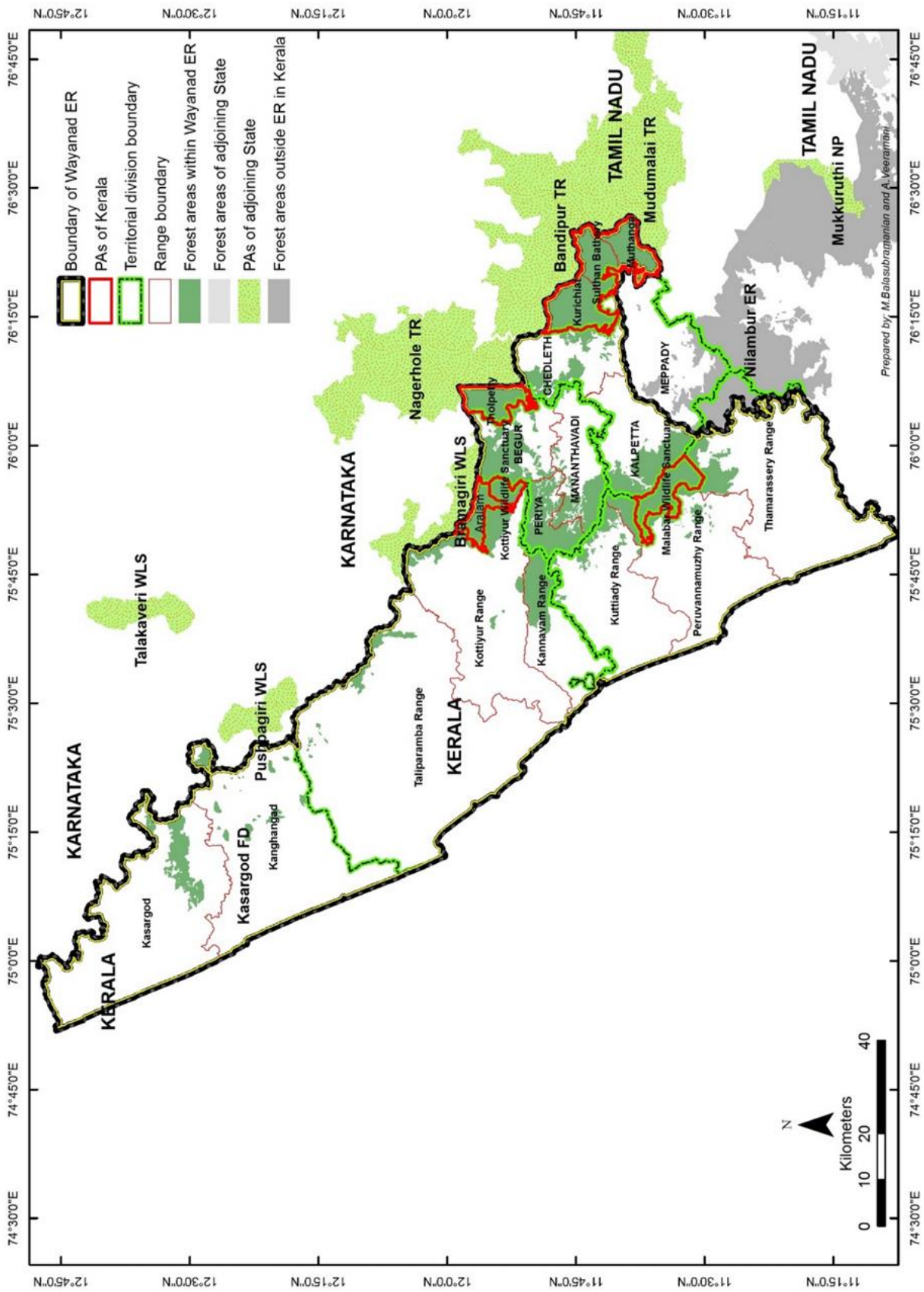


Table 2.1: Details of Divisions and Ranges under Wayanad ER

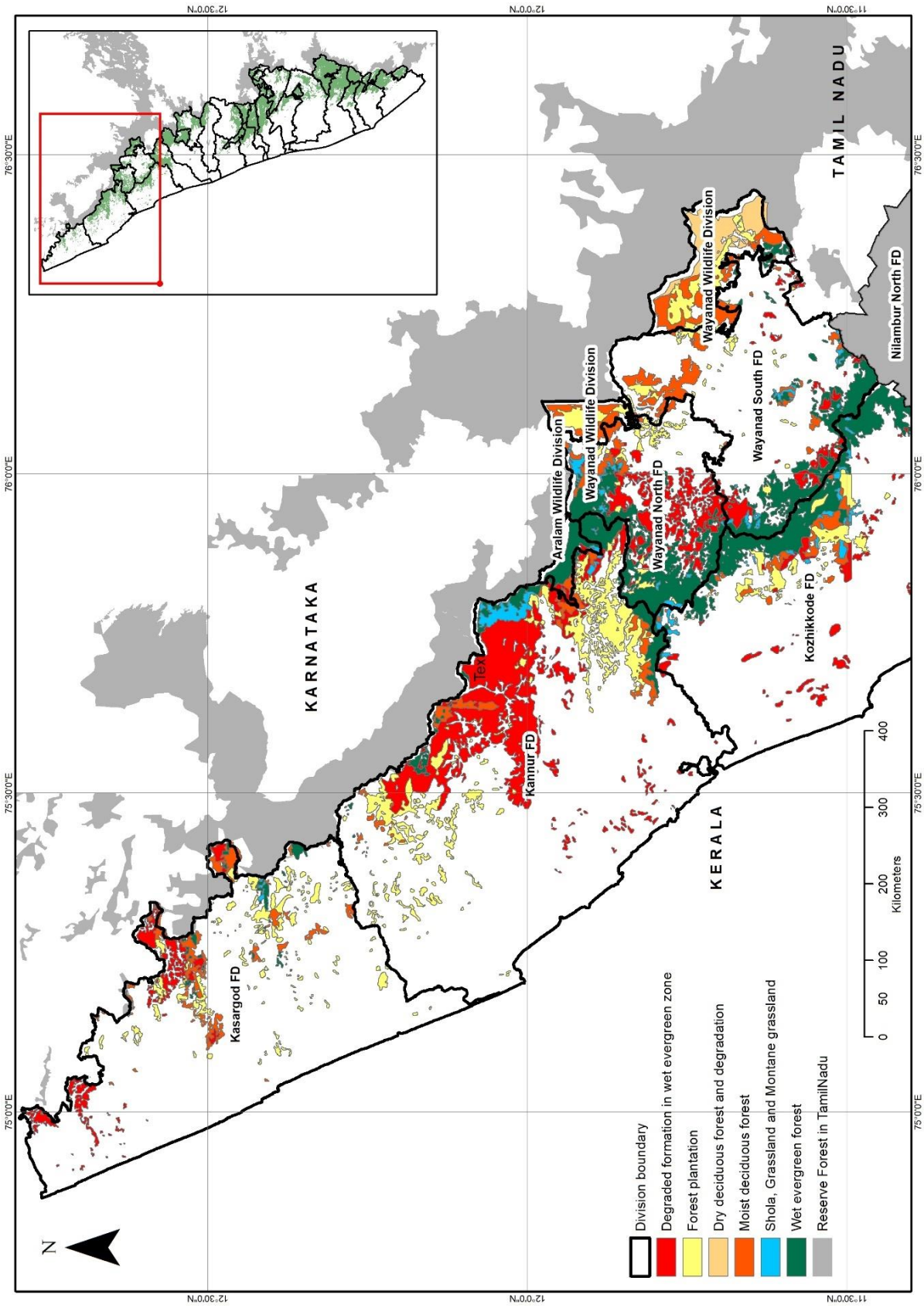
SN	FD (FD)/Range	Extent (km^2)	Extent (km^2) devoid of elephants	Extent (km^2) of elephant habitat
1	Kasargod FD	122.91	44.00	78.91
2	Kannur FD	158.651	44.15	114.50
3	Aralam WLD (Aralam & Kottiyur WLSs)	85.38	0.000	85.38
4	Wayanad North FD	224.099	35.32	188.78
5	Wayanad WLS	344.534	1.80	342.73
6	Wayanad South FD (Out of total 295.228 km^2, 116.465 km^2 of Meppadi Range under this Division is added to Nilambur ER)	178.763	31.82	146.94
7	Kozhikode FD (Out of total 310.005 km^2 which include 74.215 km^2 of Malabar WLS carved out from Peruvannamozhi Range, an extent of 85 km^2 which is part of Thamarassery Range is added to Nilambur ER)	225.005	9.80	215.21
	Grand Total	**1339.342**	**166.890**	**1172.45**

Source: Kerala Forest Statistics 2021 **(Anon, 2021)**

The northern-most FDs of Kasargod and Kannur form the northern part of Wayanad ER. The habitats in these forests are highly fragmented as well as degraded and many parts are physically located far from each other. Only a fraction of these forests that are found on the interstate boundary of Karnataka and Kerala have elephant distribution. These habitats also cannot sustain the elephants as they are highly degraded, fragmented and dominated by sub-optimal habitats (mostly semi-evergreen) (Fig. 2.3). Elephants, mostly lone habitual crop raiders, from Karnataka side visits these habitats seasonally. A few small herds also occasionally visit these areas. Availability of fodder for elephants in these habitats is also minimal due to nature of soil (mostly laterite). The major attractions for elephants to these areas could be the existence of perennial water source meandering through these forest habitats and the cultivated crops.

Aralam and Kottiyur WLSs are located on the southern side of above FDs. The habitats in these Protected Areas (PAs) are also mostly dominated by semi-evergreen and evergreen forests with a few patches of grasslands on top of the hillocks and ridges located on the interstate boundary (Fig. 2.3). Hence, these small areas are not ideal habitats to sustain elephants. A few herds as well as bulls operate in the Aralam Farm region located adjoining to the Aralam WLS (which was a prime habitat for elephants before converting as farm) and have congenial terrain with fodder (including cultivated crops) and water availability. People who reside within the farm region often end up in conflicts with elephants.

Fig. 2.3: Major vegetation types of Wayanad ER



These habitats are further contiguous towards east with Wayanad North FD that connect to Tholpetty Range of Wayanad WLS (which is well connected to Bandipur and Nagerhole TRs of Karnataka towards east and north and acting as a potential habitat for elephants) and parts of Wayanad South FD (Chedeleth Range). This stretch of forests in Begur Range of Wayanad North FD and Tholpetty Range of Wayanad WLS act as a potential habitat for elephants and contain elephants in reasonable density. These areas also have a few perennial water sources both within and outside Kerala. However, this stretch of forests have significant extent of teak planted a century back during colonial times.

Large numbers of human settlements exist amidst the forests especially in Wayanad North and South FDs. Elephant corridors such as Begur-Brahmagiri and Thirunelli-Kudrakode connect Tholpetty Range of Wayanad WLS to Begur Range of Wayanad North FD. Some of the human settlements on the corridor were relocated in the recent past as part of securing the elephant corridors.

The forests of Aralam and Kottiyur WLSs are further connected towards south through the forests of Periya and Mananthavady Ranges of Wayanad North FD, Kozhikode FD and Kalpetta Range of Wayanad South FD. The habitats are mostly dominated by semi-evergreen and evergreen (sub-optimal habitats) (Fig. 2.3) and have sporadic movements of elephants seasonally.

Three Ranges *viz*., Kurichiat, Sulthan Bathery and Muthanga Ranges of Wayanad WLS is located on the south-eastern side of Wayanad ER which is well connected with the forests of Bandipur Tiger Reserve (TR) on the north and north east and Mudumalai TR on the east and south east. Though the bordering areas of these three Ranges have potential habitats for elephants, major part of these Ranges have large number of human settlements. A few have already been relocated as part of securing the habitat. A few perennial streams exist within this forest patch.

However, the existing habitat is degraded due to various exotic species such as Lantana, Eupatorium, Mikania and most importantly Senna which almost covered about more than 35% of the WLS (Vinayan, 2023).

Significant extent of the Wayanad WLS consists of teak plantations. In nutshell, in the entire stretch of the Wayanad ER, only the forests of Wayanad WLS and Begur Range of Wayanad North FD (together constitute about 400 to 450 km^2) support a good population of elephants as they have contiguous forests in the adjoining States which are parts of the larger landscape unit for elephant conservation in southern India.

2.2.2. Nilambur ER

Nilambur ER falls in four revenue districts of Kerala *viz.,* Malappuram, Kozhikode, Wayanad and Palakkad. Geographically, it is located between 10°50' and 11°33' N latitude and between 76°02' and 76°05' E longitude. Forest areas under the jurisdiction of Nilambur North, Nilambur South, Mannarkkad, Palakkad, Kozhikode (part of Thamarassery Range), Meppadi Range of Wayanad South and Silent Valley National Park divisions are encompassing the ER (Fig. 2.4). Though notified extent of Nilambur ER is 1419 km^2, actual extent of the Reserve is 1899.763 km^2 of which 113.41 km^2 is reported as areas devoid of elephants. Thus, the total area effectively used by elephants is 1786.353 km^2. The details of FDs and Ranges falling in Nilambur ER are given in Table 2.2.

Table 2.2: Details of Divisions and Ranges under Nilambur ER

SN	FD/Range	Extent (km^2)	Extent (km^2) devoid of elephants	Extent (km^2) of elephant habitat
1	Wayanad South FD (Out of total 295.228 km^2, 178.763 km^2 is added to Wayanad ER)	116.465	0.000	116.465
2	Kozhikode FD (Out of total 310.005 km^2, 225.005 km^2 is added to Wayanad ER)	85	0.000	85.000
3	Nilambur North FD	439.987	20.10	419.887
4	Nilambur South FD	326.787	7.60	319.187
5	Silent Valley WLD	237.491	0.000	237.491
6	Mannarkkad FD	430.326	26.90	403.426
7	Palakkad FD	263.707	58.81	204.897
	Grand Total	**1899.763**	**113.41**	**1786.353**

Source: Kerala Forest Statistics 2021 **(Anon, 2021)**

Nilambur North and South FDs are connected to forests of Nilgiri South FD in TN on the east which further connect to forests of Mudumalai TR in TN. Forests of Silent Valley National Park, Mannarkad and Palakkad FDs are also directly connected to Mukurthy WLS and Coimbatore FD in TN. Elephants seasonally movement between the forest areas of Kerala and TN.

Of the total extent of forests in Nilambur ER, plantations of various species including hardwood, softwood, miscellaneous and bamboo, reed, cane constitute about 193 km^2, of which teak alone constitute 113 km^2. The remaining forest is of primary evergreen and semi-evergreen, and degraded formation of wet evergreen zone (Fig. 2.5). Moist and dry deciduous forests are found in part of Mannarkad and Palakkad FD located on the interstate boundary. Due to the nature of vegetation and extensive monoculture in the territorial FDs within the ER, the areas can be considered as sub-optimal habitats for elephants.

Fig. 2.4: Constitution of Nilambur ER

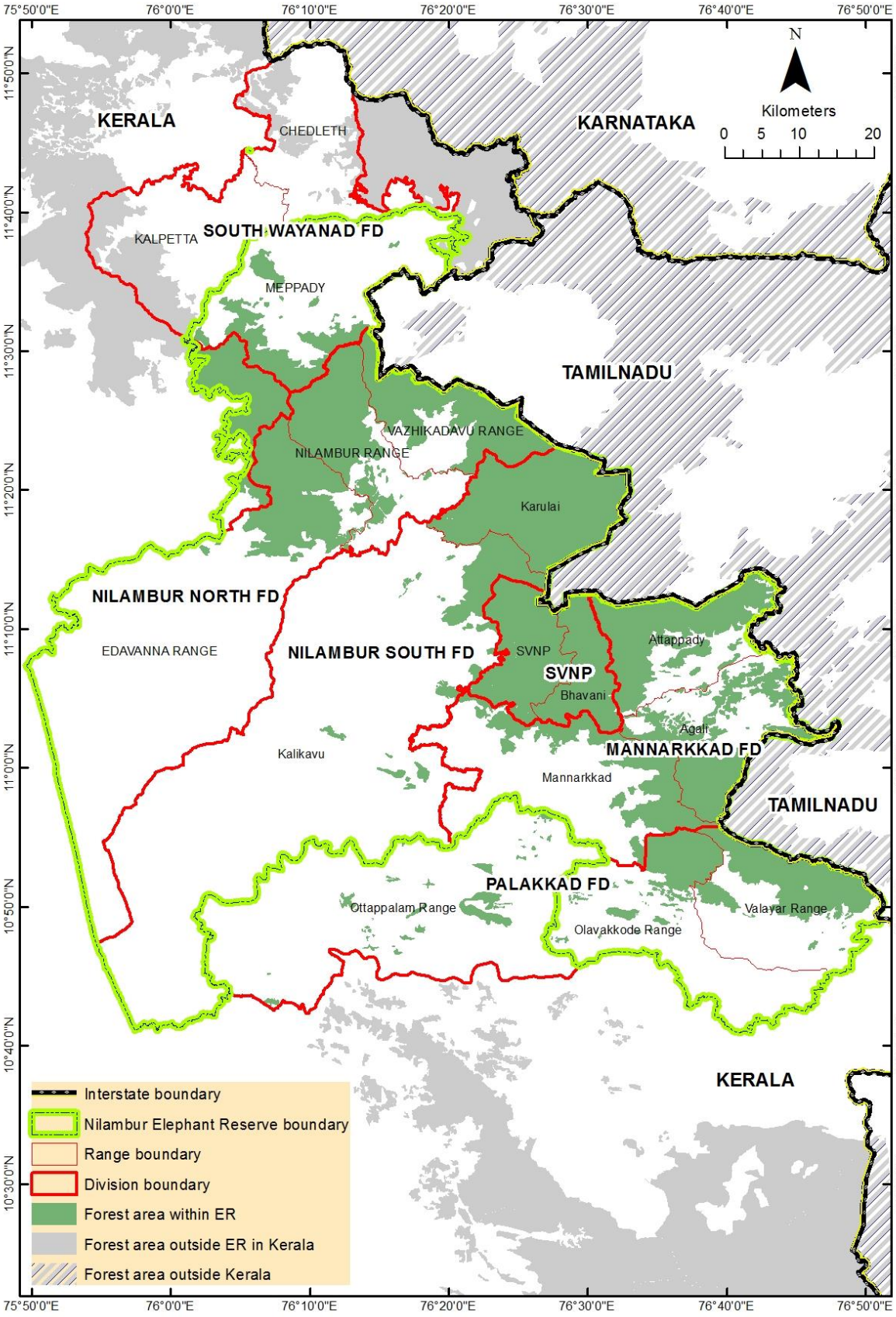
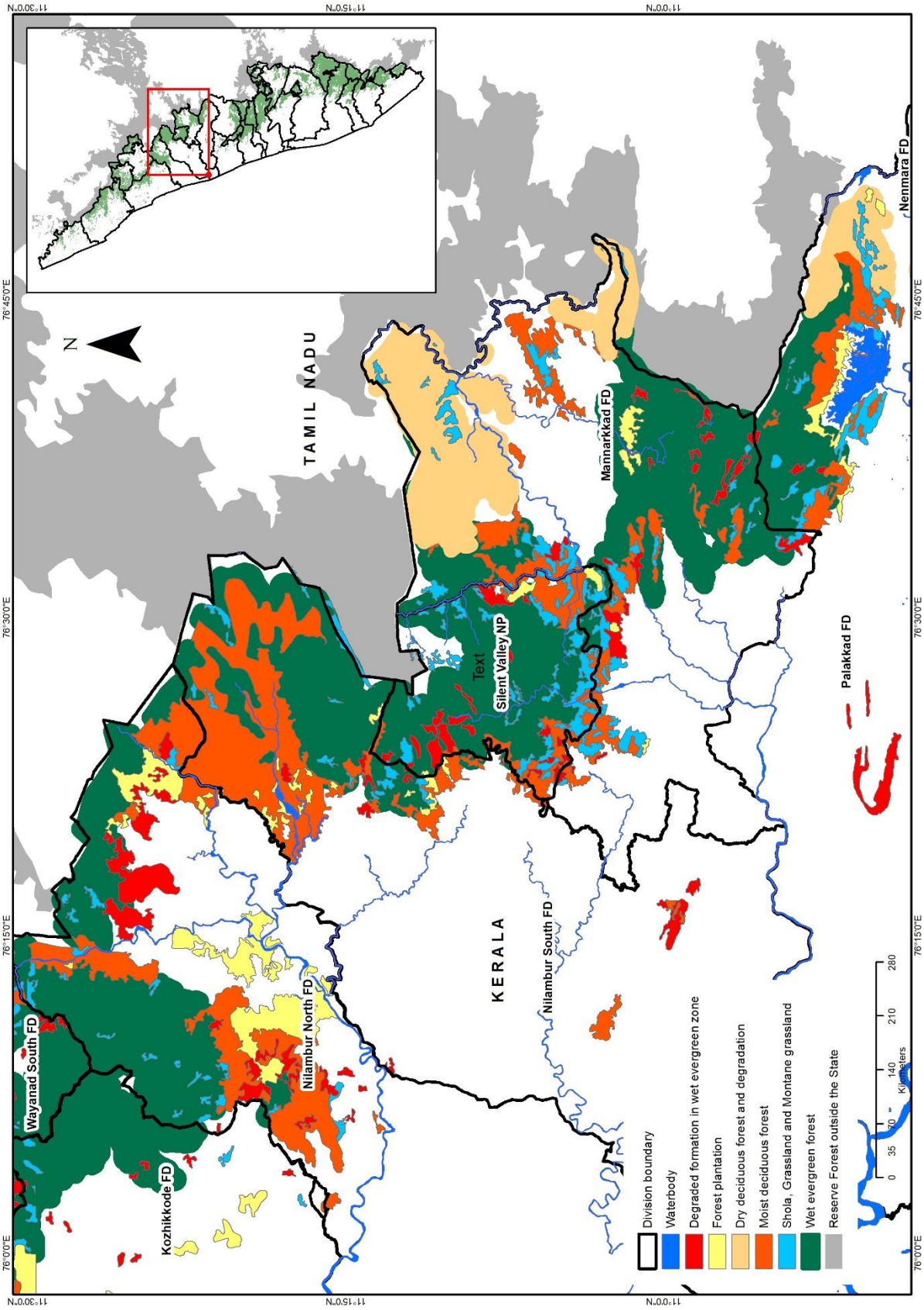


Fig. 2.5: Major vegetation types of Nilambur ER



However, the areas have a good network of perennial streams and rivers. The entire elephant habitats in the ER are severely infested with exotic weeds such as Lantana, Eupatorium and Mikania. Apart from enclosures of human habitations found amidst the forests, human habitations are found extensively along the entire peripheral areas.

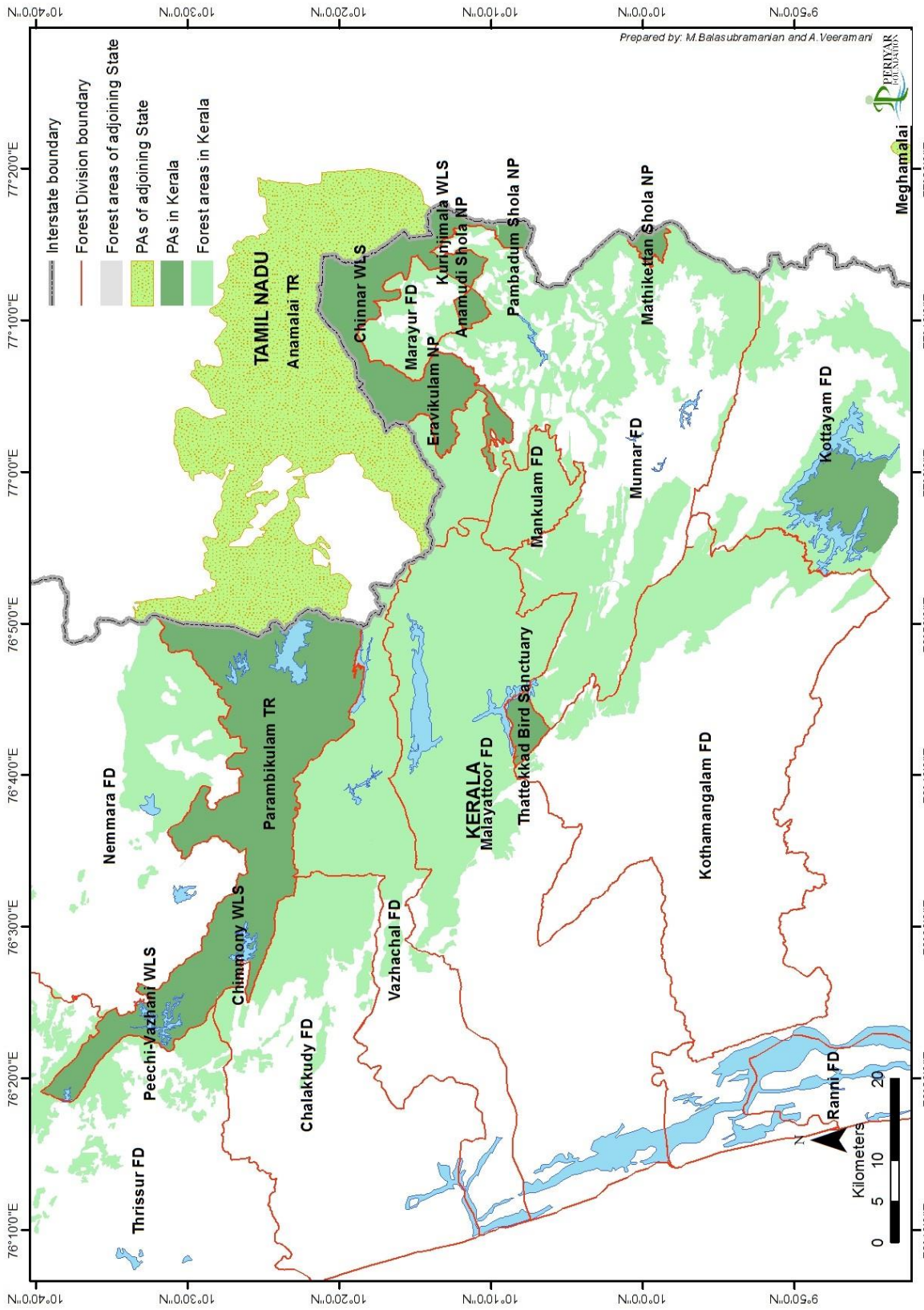
The existence of railway line in Palakkad FD hinders the movement of elephant and often leads to train hits. A study carried out by the Palakkad FD reveals that both lone tuskers and herds are operating in the region. Conflict is found to be high during the month of May when ripened jack fruit, palm and mango are available. Human-elephant conflict is also high in other FDs in the ER. The elephants that had access to water in the Upper Bhavani River are presently prevented by electric fencing on either side of the river. This is also one of the reasons for the intensified human-elephant conflict in the ER.

Forest areas of Ottapalam Range in Palakkad FD are excluded from analysis since elephants are absent there.

2.2.3. Anamudi ER

Anamudi ER, spreads over 4 revenue districts in the State *viz.,* Palakkad, Thrissur, Ernakulam and Idukki, is located south of the Palakkad Gap and north of Kumily-Kottayam Road (NH 183) in Kerala (lies between 9°42’ and 10°13’ N and between 76°33’ and 77°59’ E). It is contiguous with the Anamalai ER and Kodaikanal WLS of TN on the east. However, the connectivity of this ER with the Periyar ER in the south is practically lost in Kerala though the southern portion of the landscape abuts a narrow-forested slope of Theni FD. The ER comprises a greater part of the High Ranges, Nelliampathy Hills, part of Anamalai Hills in Kerala as well as rain shadow regions in Idukki. Thus, the forest areas in the ER receive both high and low rainfall with varying elevations and is home to the varied diversity in flora and fauna. The ER comprises of the territorial FDs such as Nenmara, Thrissur, Chalakkudi, Vazhachal, Malayattoor, Kothamangalam, Mankulam, Marayoor Sandal Division, Munnar and part of Kottayam (Ayyappankovil and Nagrampara Ranges) as well as Wildlife Divisions (WLDs) such as Prambikulam TR, Peechi WLD (comprising of Peechi Vazhani and Chimmony WLSs), Idukki WLD (comprising of Thattekkad and Idukki WLSs) and Munnar WLD consisting of Eravikulam NP and Shola NPs (Mathikettan, Anamudi and Pampadum Shola NPs), Chinnar and Kurinjimala WLSs thus constituting a vast stretch of forests in the State. The forests of Idukki WLS and adjoining Ayyappankoil and Nagarampara Ranges in Kottayam Division are ecologically isolated from rest of the habitats in the Anamudi ER due to the irrevocable loss of connectivity (Fig. 2.6).

Fig. 2.6: Constitution of Anamudi ER



This landscape is significant being the catchment of important west -flowing rivers in the State *viz*., Periyar, Bharathapuzha and Chalakkudi River and east-flowing river Pambar. The landscape with complex nature of its geography, high environmental sensitivity as well as possible impacts of climate change makes it a region of great ecological significance. The ER is characterized by its wide altitudinal gradient ranging from 100 m above MSL on either side of the Ghats to 2694 m at Anaimudi Peak, the highest point south of the Himalaya. Total extent of the FDs under Anamudi ER is 4159.95 km^2 and the notified area of ER is 3728 km^2. But subsequent revisions show that out of the total area, only an extent of 3405.64 km^2 have elephant distribution as the balance 754.31 km^2 (which include parts of Thrissur, Kothamangalam, Kottayam etc FDs) have forest areas devoid of elephants. The details of FDs and Ranges falling in Anamudi ER are given in Table 2.3.

Table 2.3: Details of FDs and Ranges under Anamudi ER

SN	FDs/Range	Extent (km^2)	Extent (km^2) devoid of elephants	Extent (km^2) of elephant habitat
1	Nenmara FD*	310.697	37.100	273.597
2	Chalakkudy FD**	226.1	15.680	210.420
3	Vazhachal FD***	198.194	44.500	153.694
4	Thrissur FD#	213.147	182.507	30.640
5	Malayattoor FD	610.939	51.700	559.239
6	Mankulam FD	90.057	0.000	90.057
7	Munnar FD##	400.277	0.000	400.277
8	Marayoor FD	64.176	8.000	56.176
9	Kothamangalam FD	318.311	20.250	298.061
10	Kottayam FD (Kumily, Ayyappankovil and Nagarampara Ranges) +	499.284	265.592	233.692
11	Parambikulam TR++	643.66	22.900	620.760
12	Peechi and Chimmony WLSs	213.504	52.300	161.204
13	Idukki WLD - Thattekkad Bird Sanctuary	25.16	9.000	16.160
14	Idukki WLD – Idukki WLS	105.364	40.110	65.254
15	Munnar WLD	241.077	4.670	236.407
	Grand Total	**4159.947**	**754.309**	**3405.638**

* removed an extent of 46.27 km^2 (buffer zone of PKMTR) from the total extent of FD

** removed an extent of 11.41 km^2 (buffer zone of PKMTR) from the total extent of FD

*** removed an extent of 155.22 km^2 (buffer zone of PKMTR) from the total extent of FD

forests that are contiguous to Peechi WLD is only 30.64 km^2. Hence remaining area in the division is considered as areas devoid of elephants.

removed an extent of 372.98 km^2 is CHR area from the total extent 773.257 km^2.

\+ removed the entire Kumily Range with an extent of 265.592 km^2 as the area is devoid of elephant and entire Nagarampara Range and Ayyappankovil Ranges are included in Anamudi ER.

++ added the removed areas of buffer zone from Nemmara, Chalakkudy & Vazhachal FDs to to the total extent of Parambikulam TR

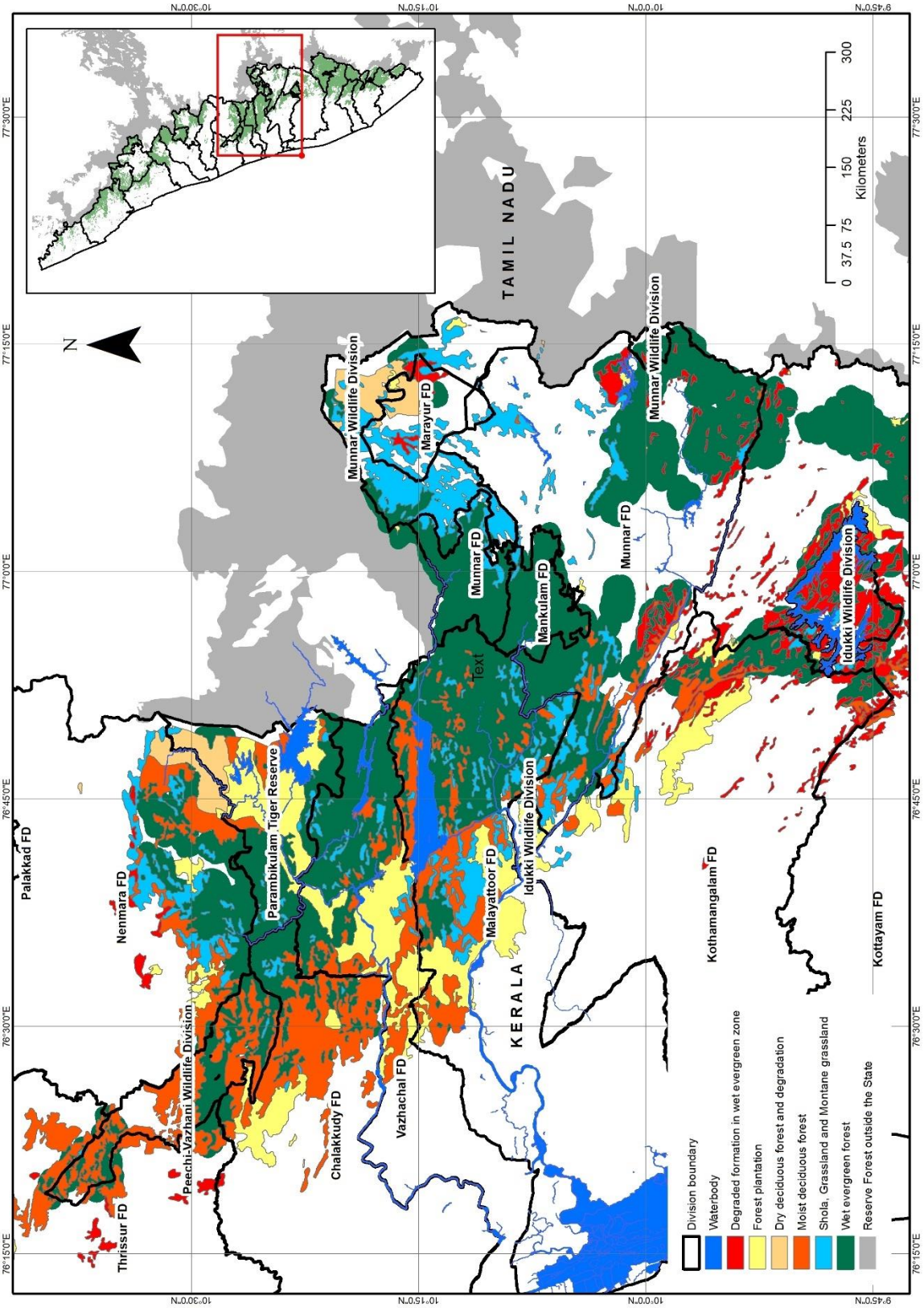
Source: Kerala Forest Statistics 2021 **(Anon, 2021)**

Peechi-Vazhani WLD (having two PAs namely Peechi-Vazhani and Chimmony WLSs), located on the northern part of the ER is having seasonal elephant distribution. Majority of forest in these PAs are of degraded moist deciduous forests with patches of semi-evergreen forest in the higher reaches (Fig. 2.7). Two reservoirs namely Peechi and Chimmony exist within this region that meet the water requirement of the elephants. A few human habitations also exist within the Sanctuary limit.

The forest of Peechi WLD is connected to Nemmara FD and Parambikulam WLS. Majority of forest areas in Nemmara FD are of evergreen to semi-evergreen with a few patches of moist deciduous forests on the eastern boundary of the FD. Shola grasslands as well as montane grasslands exist on the upper reaches. Elephants regularly use the Pothundy Reservoir in Nemmara FD. In other areas too, no water scarcity is experienced in this division due to the existence of a few perennial streams originating from the forest. Both government owned (KFDC) as well as private estates exist within as well as on the boundary of forests in Nemmara FD. Elephants from Parambikulam TR seasonally visit the forest areas of this FD and sometime intrude into the estate areas. Parambikulam TR which has sizable elephant habitat is location on the south of Nemmara FD. While Parambikulam and Sungam Ranges in Parambikulam TR have optimal elephant habitats, Orukomban and Karimala Ranges composed of mainly evergreen and semi-evergreen forests. Elephant from Parambikulam TR is known to utilize the adjoining Anamalai TR in TN (located on the eastern side Parambikulam TR) as well as Vazhachal, Chalakkudy and Malayattoor FDs in Kerala (located on the southern side Parambikulam TR).

The three reservoirs *viz*., Thunakadavu, Peruvaripallam and Parambikulam) along with a few perennial rivers/streams in Parambikulam TR meets water requirements of elephants during pinch periods. Vazhachal FD has mostly evergreen and semi-evergreen forests with substantial extent of teak plantations. Chalakkudy FD comprises of mainly teak plantations interspersed with moist deciduous forests in degraded state. Malayattoor FD, though consisting of degraded moist deciduous forests and large extent of teak plantations, is well known for elephants. Large extent of reed brakes exists in Vazhachal and Malayattoor FDs. Elephants in the stretch use the reservoirs of Sholayar and Poringalkuthu in Vazhachal FD and Edamalyar in Malayattoor FD. Numerous human habitations of indigenous communities exist amidst the forest in Vazhachal and Malayattoor FDs and the entire fringe areas are occupied by large plantations and small farms.

Fig. 2.7: Major vegetation types of Anamudi ER



Elephant distribution in Anamudi ER remains contiguous from Peechi WLD on the northwest to Munnar FD on the southeast and Munnar WLD on the northeast. The Idukki WLS and Kothamangalam FD is physically separated from the above unit due to topographical constraints of steep contours and land use (settlement and cultivation). Settlements as well as the steep terrain between the southwestern part of Munnar FD and the northeastern part of the Kothamangalam FD seem to act as barriers to elephant movement in spite of forest contiguity between these two areas. Munnar FD and Theni FD in TN are presently separated by plantations of tea and cardamom, though elephants continue to move through some of these plantations.

The forest areas ranging from Parambikulam TR to Malayattoor and parts of Munnar and adjoining areas are highly potential areas for elephants. The elephant congregation at Anakkulam on the border between Malayattoor and Mankulam FDs has been attracting visitors and researchers since colonial times.

The rainfall gradient from east to west, along with the complex topography, results in heterogeneous vegetation types. The vegetation in the entire Anamudi ER widely varies from lowland tropical dry thorn forest mostly on the eastern side, mid-elevation tropical dry and moist deciduous forests, high elevation tropical semi-evergreen and evergreen forests to stunted montane forests (locally known as sholas) and grasslands (Fig. 2.7).

Parts of forest areas of Thrissur and Kothamangalam FDs and Kumily Range in Kottayam FD are excluded from analysis since there is no report of elephant in these regions.

2.2.4. Periyar ER

Periyar ER is spread over the revenue districts of Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam and Idukki. The ER lies between 8°30’ and 9°34’ N latitude and between 76°52’ and 77 °25’ E longitude. Periyar ER is contiguous with Meghamala-Srivilliputhur TR, Nellai WLS and Kalakkad-Mundanthurai TR in TN.

The vast stretch of forests extending from north of Aryankavu pass to Periyar TR forms the major part of Periyar ER. Periyar ER comprise of forest areas of Periyar TR, Kottayam (Erumely Range), Ranni, Konni, Achencoil, Punalur, Thenmala, and Thiruvananthapuram territorial FDs, Shenduruny, Neyyar, and Peppara WLS and ABP Range of Trivandrum WLD (Fig. 2.8 and Table 2.4).

Fig. 2.8: Constitution of Periyar ER

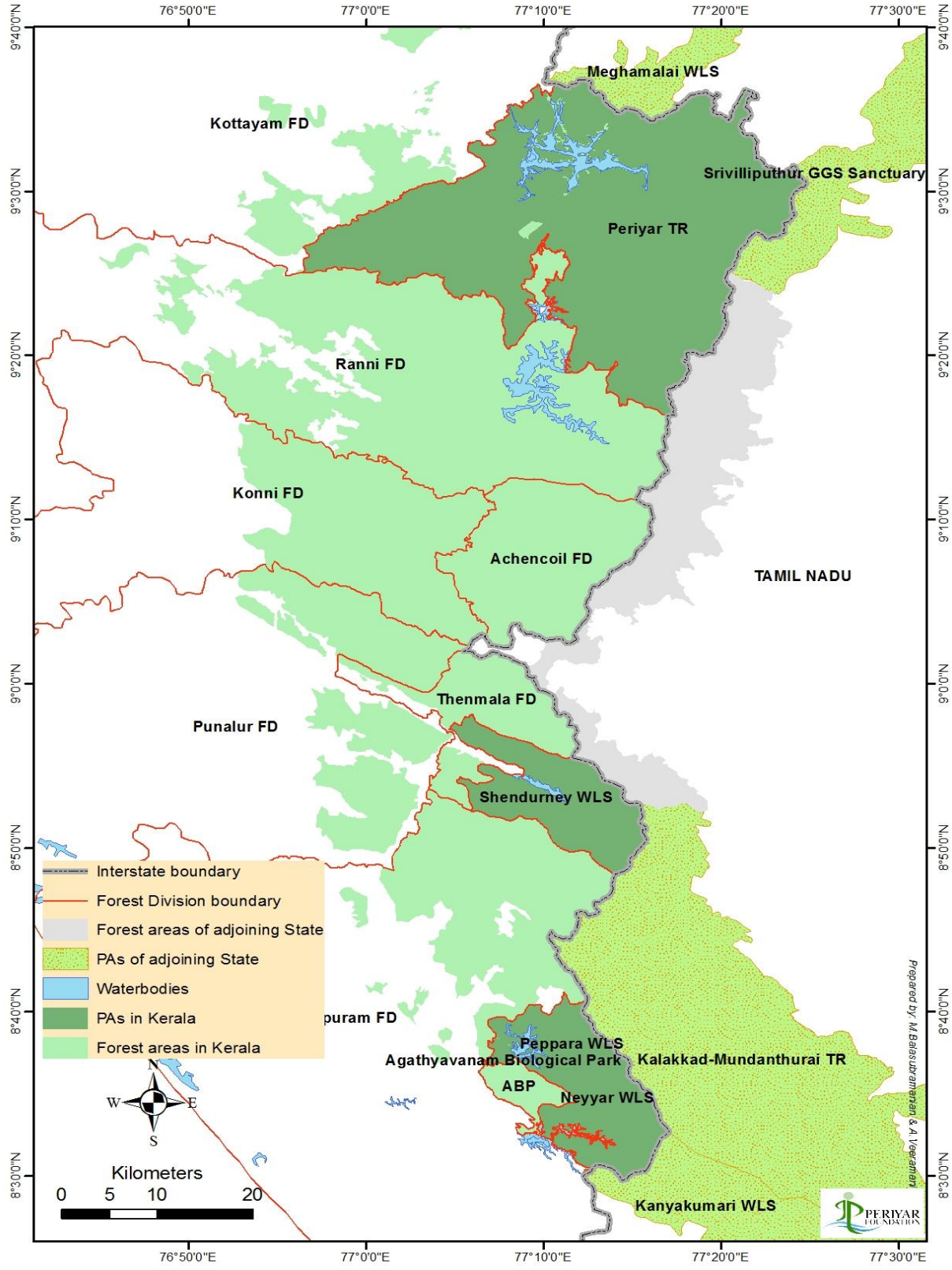


Table 2.4: Details of forest areas under Periyar ER

SN	FDs/Range	Extent (km^2)	Extent (km^2) devoid of elephants	Extent (km^2) of elephant habitat
1	Periyar TR (East)	709.675	28.000	**681.675**
2	Periyar TR (West)	216	6.000	**210.000**
3	Shendurney WLS	172.233	21.300	**150.933**
4	Thiruvananthapuram WLD	211.98	15.500	**196.480**
5	Kottayam FD (Erumeli Range)	164.318	66.180	**98.138**
6	Ranni FD	911.122	108.690	**802.432**
7	Konni FD	331.655	6.000	**325.655**
8	Achencoil FD	285.869	0.000	**285.869**
9	Punalur FD	275.707	234.260	**41.447**
10	Thenmala FD	148.944	10.500	**138.444**
11	Thiruvananthapuram FD	372.494	45.300	**327.194**
		3799.997	**541.73**	**3258.267**

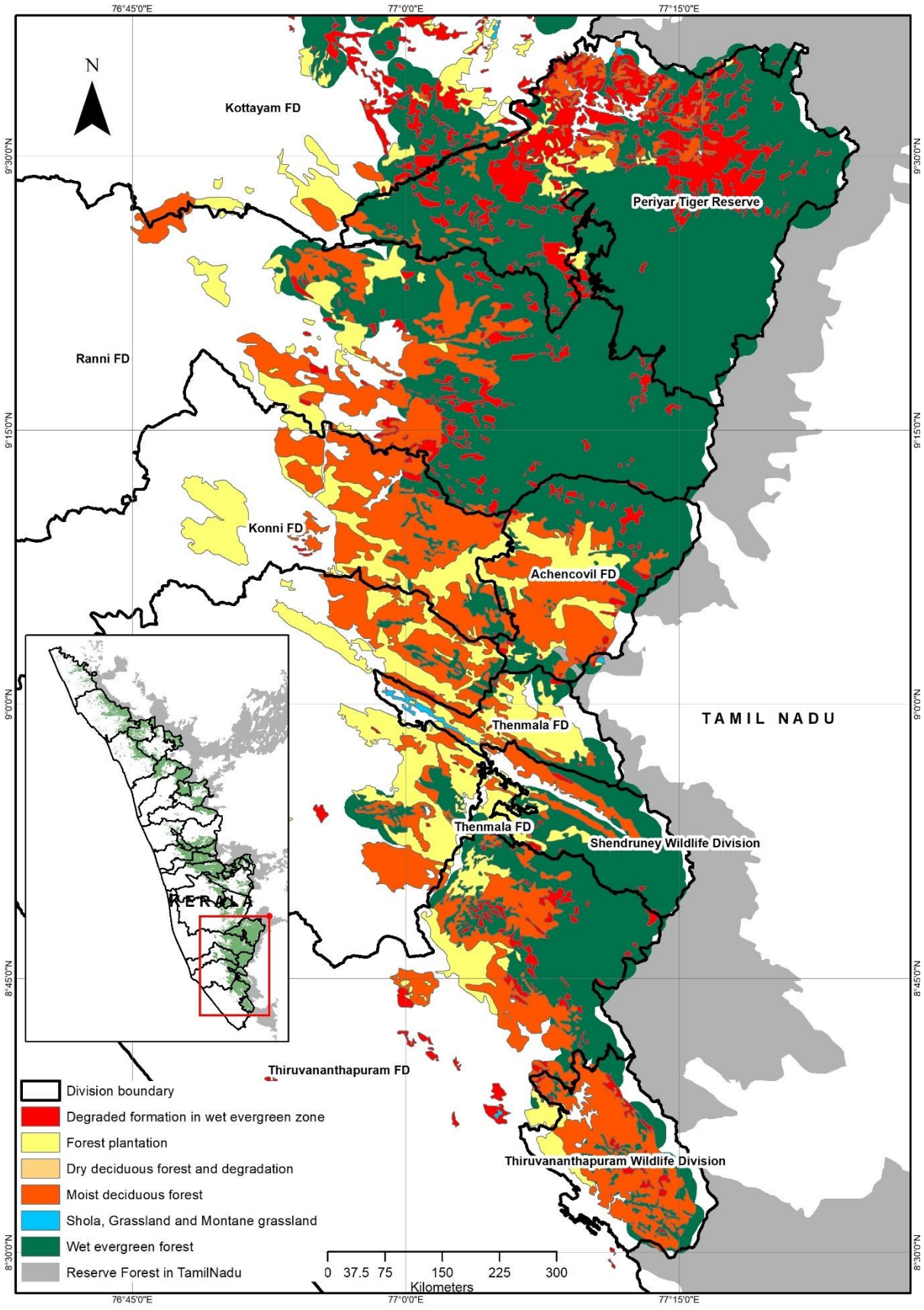
Source: Kerala Forest Statistics 2021 **(Anon, 2021)**

The forest areas around the Periyar Lake in Periyar TR is an excellent habitat of elephants and elephants from this area disburse to Meghamalai- Srivilliputhur TR (in TN) located on the eastern side of Periyar TR, and Ranni FD located on the south. The forest of Periyar TR extended towards south through the FDs of Ranni, Konni, Achencoil, Punalur and Thenmala FDs (upto Ariyankavu Pass). On the east, these forests extend to Theni FD in TN. On the south of the Pass, forest is contiguous from Thenmala and Thiruvanathapuram FDs to Neyyar and Peppara WLSs on the South. These areas are further connected towards east with the forests of Kalakkad-Mundanthurai TR and Kanyakumari WLS in TN.

Reservoirs such as Periyar, Kallada, Kakki, Pamba and Neyyar existing in the ER meet the water requirement of all wild animals. In addition, major perennial rivers/streams such as Neyyar, Karamana Ar, Vamanapuram Ar, Kallada Ar, Ithikkara Ar, Kallar, Achencovil Ar, Periyar, Azhutha Ar, Pamba Ar, Manimala Ar, Meenachil Ar, etc meandering through the Periyar ER also support the wild animal population during the pinch periods.

The dominant vegetation is evergreen and found in partially in all FDs in the ER. Periyar TR, Ranni and Achencoil FDs and Shendruney WLS have significant extent of evergreen forests. Semi-evergreen forest is found in Achencoil, Kottayam, Punalur and Thenmala FDs. Moist deciduous forest is also found in certain parts of all FDs in the ER and dominate in Neyyar, Peppara WLSs and Konni FD. Significant extent of plantations of teak, eucalyptus and miscellaneous type form the major man-made forests in this ER (Fig. 2.9).

Fig. 2.9: Major vegetation types of Periyar ER



Marshy meadows/grasslands (vayals) are also found in some of the FD amidst the evergreen and semi-evergreen forests which is the major foraging ground for the elephants in the ER. Exotic weeds such as Lantana, Eupatorium and Mikania are the major exotic species found throughout the habitats in the ER. Apart from plantation crops of rubber and tea, major crops cultivated around the ER are plantain, tapioca, pepper, coconut, etc.

There are numerous settlements/enclosures within the Periyar ER; the majority of these are tribal settlements. A total of about 260 enclosures exists within the ER with a human population of about 15000 people. Some non-tribal families are also residing inside the Periyar ER in areas like Shendurney WLS. Estates such as Downtown (Pachakkanam), Rosemala, Kallar, Rockwood, Ponmudi, Bonacaud, etc are found in the heart of the elephant habitat. The people residing within and around the region of Periyar ER, directly and indirectly depend on the forests for their livelihood. A major break in the ER is the Aryankavu Gap which has only a tenuous forest connectivity.

Forest areas of Anchal Range in Punalur FD are excluded from analysis since there is no elephant reported in these regions.

CHAPTER 3: SURVEY UNITS & METHODS

3.1. Survey Units

The basic survey units are blocks in each FD. The estimation ER-level have been carried out by combining the sample blocks in the divisions in respective ERs. The details of the ERs in Kerala including the extent sampled for block count [sample block] and dung count [line transect] are given in Table 3.1. The figures in the Forest Statistics – 2021 have been used for the present data analysis and preparation of this report.

Table 3.1: Details of ERs and extent sampled in Kerala

Name of ER	Total extent [km^2][1]	Area devoid of elephants [km^2][2]	Actual elephant habitat [km^2]	No. of sampled blocks & transects	Extent of sampled block [km^2]	Length of transects [km]
1. Wayanad ER	1339.342	166.890	1172.45	89	517.9	130.85
2. Nilambur ER	1899.763	113.41	1786.353	118	670.5	170.90
3. Anamudi ER	4159.947	754.309	3405.638	197	1159.2	292.68
4. Periyar ER	3799.997	541.73	3258.267	206	1161.2	300.97
TOTAL	**11199.049**	**1576.339**	**9622.708**	**610**	**3508.8**	**895.40**

[1] Figures are based on the Forest Statistics 2021

[2] Figures are based on the report of 'Wild Elephant Census of Kerala State – 2010' – Thrissur FD has been added in the table.

Note: The figures such as total extent of the FDs/ERs, area devoid of elephants and actual elephant habitat do not tally with the figures of previous estimations since the present analysis uses the latest information (Forest Statistics 2021).

3.2. Organization of the Programme

The elephant population estimation in Kerala 2023 was carried out as per the direction and guidance of the Principal Chief Conservator of Forests (PCCF) & Head of Forest Force (HoFF) and Principal Chief Conservator of Forests (Wildlife) and the Chief Wildlife Warden (CWW), Kerala. A special meeting, convened by HoFF and CWW and attended by the senior forest officers held on 20th February 2023, elaborately discussed the methods used during previous elephant population estimations carried out in the State. During the meeting, the methodology to be adopted for elephant population estimation in Kerala during 2023 was discussed in detail and finalized (The minutes of the meeting of HoFF is attached as Annexure 3.1).

The CWW overall supervised the population estimation exercise at State-level. Additional PCCF (Administration) was appointed as the Nodal Officer at State-level. the Additional PCCF

(Vigilance& Forest Intelligence) monitored the field-level activities through vigilance and flying squad teams at division-level. Field Directors of Periyar and Parambikulam TRs, as coordinators of southern and northern regions respectively, coordinated the trainings and field-level exercises. The circle-heads and division-heads supervised and monitored all the activities related to elephant population estimation at Circle and Division-level respectively.

3.3. Workshops and Trainings

In connection with the Elephant Population Estimation - 2023, a state-level workshop cum training to trainers (ToT) was organized at Periyar TR during 22nd to 23rd March 2023. The ToT was attended by the Range Forest Officers selected at Division-level in State (who also acted as Division-level Coordinators), Wildlife Assistants and Conservation Biologist in the State. A total of 47 persons attended the ToT training (a list of personnel attended ToT is attached as Annexure 3.2). The professionals working in Parambikulam and Periyar Tiger Conservation Foundations made presentations as well as field demonstrations of block and dung count methods including laying of transects and data collection procedures.

Following the ToT, trainings were imparted by a core-team at Division-level at various locations in Kerala. The schedule for imparting trainings is attached as Annexure 3.3. A total of 1382 frontline staff were trained for executing the elephant population estimation in the State.

Parambikulam and Periyar Tiger Conservation Foundations with Field Directors as Executive Directors (as state-level nodal agency) and Deputy Directors of Parambikulam and Periyar TRs (as Secretary of TCFs) coordinated the training; supported in printing and supplying data books at division-level. A detailed guideline and data books prepared by Parambikulam Tiger Conservation Foundation in local language (Malayalam) were distributed to each block at division-level during the Division-level field trainings. The professionals of PaTCoF prepared a database, carried out statistical analysis and prepared the report.

3.4. Survey Methods and Statistical Analysis

The State-level programme on 'Population Estimation of Elephants in Kerala – 2023' was carried out between 17th and 19th May 2023. Surveys were carried out in the selected sample block in each FDs in all ERs in Kerala. Enumeration was carried out in each block by personnel trained for the purpose. On 17th May block count method was adopted. On 18th, dung count method was used along

the line transect to enumerate the population and on 19th, count in all possible areas including waterhole was adopted.

3.4.1. Selection of sample blocks in Kerala

Elephant population estimate was carried out in Kerala using sampling method. Hence sample blocks were randomly selected from each FD taking into account the diverse vegetation types, altitudinal and disturbance gradients. The entire forested area in the ERs of the state was divided into sample blocks using the natural features such as trek paths, roads, streams, rivers, mountain ridges, settlements, etc. During previous elephant population estimations, the sizes of the sample blocks were of 8-10 km^2 and even more. It was felt that the sizes of blocks were larger and it was impossible to enumerate the entire sampling block within a day and ensure counting all elephants in the sample block. Hence, all the sample blocks that were larger or smaller in size were rationalized well before the execution of field work.

The blocks were digitized using GIS software (QGIS 3.24). The sample blocks were randomly selected to cover all vegetation in different altitudinal and disturbance gradients in each FD. For random selection of blocks, we used 'join by location' to add the polygon attributes to the corresponding points. Then used 'research tools/random selection within subset' to select the right number/percentage of points from each polygon value. While selecting the sample blocks, care was taken to select non-adjacent polygons to avoid double counting. The selected blocks were overlaid on topo-sheets (1:50,000 scale) and given to the respective DFOs/WWs at division-level for conducting elephant population estimation.

The block count method for estimating elephant population estimation has already been discussed in Chapter 1 (para 1.5). Based on the recommendations of the high-level meeting held on 20th February 2023, the block count method was finetuned and the sampling blocks in the State were rationalized with manageable sizes (four to six km^2). The basic univariate statistics of the rationalized sampling blocks used for elephant population estimation in Kerala during 2023 are detailed in Table 3.2. The sampling blocks used for population estimation during 2023 varied overall between 4 km^2 and 7.09 km^2 extent with a mean of 5.76 km^2 (SE 0.03). The details of sample blocks with varying sizes are summarized in Fig. 3.1.

The selected sample blocks overlaid on the toposheets were exported to ‘MBtile’ format (which is an open specification based on the SQLite database that can contain raster or vector tilesets) in the

GIS platform to use it as a 'moving map' in 'Locus Map' (which is a multi-functional Android navigation app adding advanced online and offline GPS capabilities to Android mobile phones being widely used by field staff) to carry out the survey strictly within the sample blocks. The staff, by using this mobile App, conveniently carried out the survey by confining the sampling strictly within the sampling block, unlike in previous estimations. Hence, the latest digital advances were effectively utilized in this survey for more accurate and precise estimation.

Table 3.2: Univariate statistics of sampled blocks in Kerala

Mean	5.76
Standard Error	0.03
Median	5.81
Standard Deviation	0.85
Sample Variance	0.72
Range	3.08
Minimum (size of block-km^2)	4.00
Maximum (size of block-km^2)	7.09
Sum (total extent of sampled blocks-km^2)	3508.80
Count (number of sampled block-km^2)	610
Largest size of sample block	7.09
Smallest size of sample block	4.00
Confidence Level (95.0%)	0.07

Fig. 3.1: Sampled block in various size categories

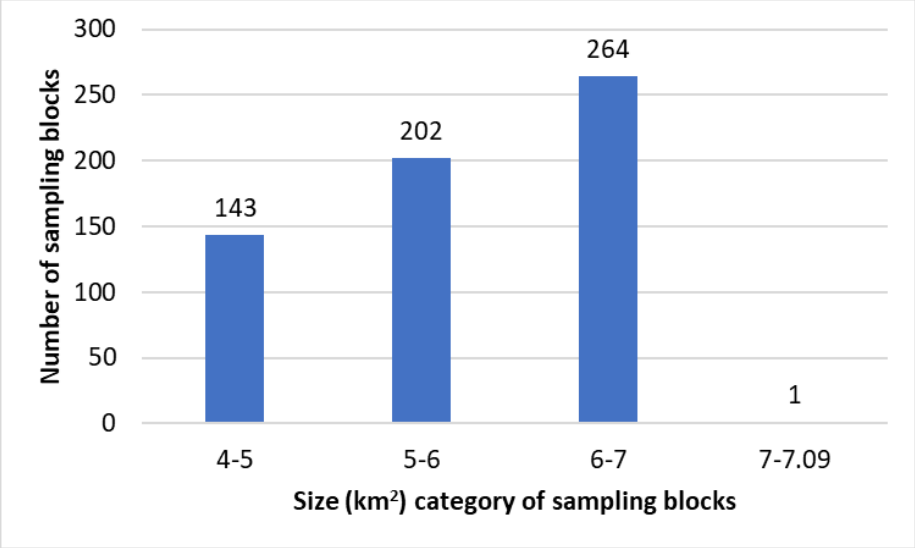
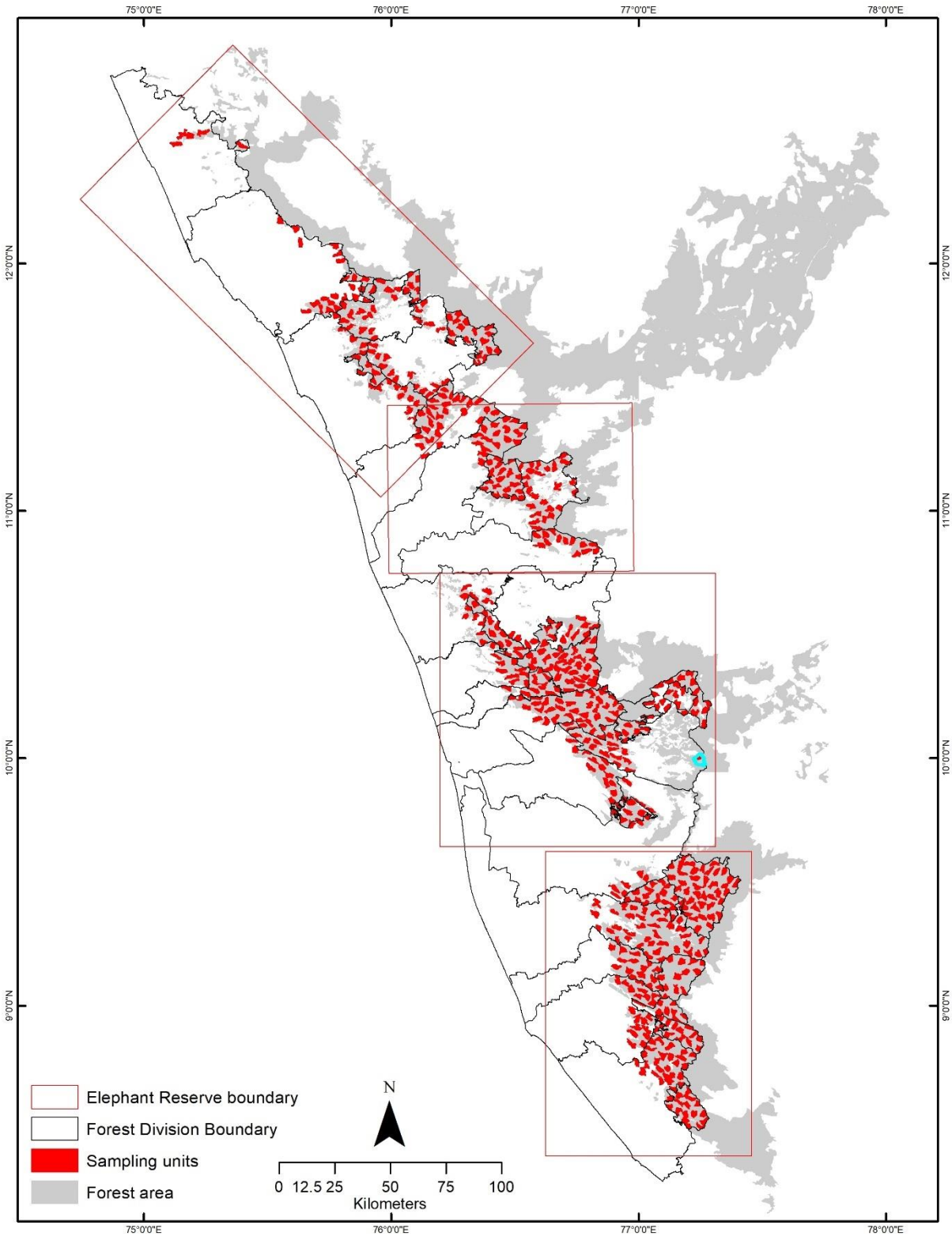


Fig. 3.2: Map showing sampled blocks for block count method in Kerala



3.4.2. Data Collection and Field Exercise

3.4.2.1. Block count

On first day (17th May, 2023), the staff counted the elephants by block count method (direct count) within the demarcated blocks. Selected blocks were visited by a team of one or two trained staff with watchers early in the morning and the search continued till evening.

The entire block was searched in zigzag so as to cover the entire area to count all elephants in the sampling block. Care was taken to avoid missing any elephants during the count. Each sighting was recorded for age and sex *viz*. male (adult (with separate note of Makhna), sub adult and juvenile) female (adult, sub adult and juvenile) and calf (height-based age category is given in Table 3.3). If the age and sex of elephant sighted was uncertain, it was noted as unclassified. Time, location, GPS position and habitat parameters of each sighting were also noted.

Table 3.3: Height-based age classification of elephants

Category	Age and height
Calf	<1 year old; upto 120 cm height
Juvenile	1 – 5-year-old; 121 to 180 cm height
Sub-Adult	5 – 15-year-old; 181-210 cm for female and 181-240 cm for male
Adult	>15-year-old; >210 cm for female and >240 cm for male

Block count method was carried out in all the PAs and FDs in Kerala and a total of 610 sample blocks with an extent of 3508.80 km^2 were sampled. The locations of sampled blocks in Kerala are shown in Fig. 1.3.

3.4.2.2. Dung count

On second day (18th May 2023), the dung piles of elephants were counted along a transect line (Burnham *et al.,* 1980) laid within the sample block. One of the basic assumptions of line transect method is 'the transect is a straight line'.

Due to highly undulating terrain in Kerala, laying a transect with a length of 2 km in a straight line was always found to be difficult in most of the forest areas during the previous estimations. Hence, the length of the transect line was suggested to be 1.5 km, against 2 km used during previous estimations, so as to avoid straight line issues and at the same time, fatigue factor of field staff during the survey. However, the exact length of each transect was noted along with starting and ending positions with GPS.

On sighting dung piles from the transect, information such as perpendicular distance of the centre of the pile (to the nearest 1 cm) and age of dung pile (a category adapted from Barnes and Jensen, 1987 shown in Table 3.4) were recorded using the following:

- **Fresh**: pile (moist or dry) with fully or partially broken boluses (equal to the Categories A and C in the classification)
- **Old:** pile completely disintegrated, forms a flat mass and can be seen from any distance (equal to the Category D)
- **Very Old**: – almost decayed with only remnants (minute pieces) of dung piles that are visible only on the transect line or one meter on either side of the transect (equal to the Category E)

Table 3.4: Stages of decay as per Barnes and Jensen, 1987

Stage	Condition of dung pile
A	Pile intact, very fresh, moist, with odour
B	Pile intact, fresh but dry, no odour
C1	More than 50% of the pile is distinguishable, some has disintegrated
C2	Less than 50% of the pile is distinguishable, the rest has disintegrated
D	Pile completely disintegrated, forms a flat mass
E	Decayed to the stage where it would be impossible to detect at 2-m range in the undergrowth, and it would not be seen unless directly underfoot

The ‘very old; category is envisaged as the dung piles deposited during previous season or more than 5-6 months old, completely decayed with only remnants. During previous estimations, this ‘very old’ category mentioned above were recorded as ‘old’ so that they had also to be included in the analysis that had led to imprecise estimation. Moreover, the marked dung piles (for decay experiment carried out during 2017) were monitored till they enter into stage ‘E’. In order to avoid such mistake, stage ‘E’ category was separately recorded as ‘very old’ to exclude from the analysis.

In order to measure the dung piles along the transect, a nylon rope with a length of 50 meter was used for exactly measuring the transect length while laying out in the field and a steel tape (5 m length) to measure the perpendicular distances of dung piles from the transect line.

Precision of the survey was retained by ensuring through repeated instructions that only one observer had to walk along the transect line [on the rope] and record the observed dung piles on either side of the transect. Perpendicular distances to centre of dung piles were measured nearest of 1 cm using steel measuring tape and recorded along with the age of each dung pile, habitat type, etc.

Dung count method was carried out in all the FDs in Kerala and a total of 610 transects (with a total length of 895.40 km) were laid for the purpose. The length of transects varied overall between 0.65 km and 1.65 km with a mean of 1.47 km (SE 0.004) (Table 3.5).

Table 3.5: Univariate statistics of sampled transects in Kerala

Mean (length of transects)	1.47
Standard Error	0.004
Median	1.50
Mode	1.50
Standard Deviation	0.10
Sample Variance	0.01
Range	1.00
Minimum (transect length)	0.65
Maximum (transect length)	1.65
Sum (total length of transects in km)	895.40
Count (total number of transects)	610
Largest (transect length)	1.65
Smallest (transect length)	0.65
Confidence Level (95.0%)	0.01

3.4.2.3. Elephant count in all possible areas including waterholes

On the third day (19th May 2023), elephant count was carried out in areas of each FD with possibility of sighting elephants. Water bodies (waterholes, ponds, streams and rivers) within the blocks were observed for identifying the elephants to know the population structure. Areas with possibilities of sighting elephant were also visited to make observations.

This exercise was carried out only to supplement information on the population structure of elephants. Each sighting of elephants was recorded for age and sex categories with details as in the case of sightings in block count method. Observations were made from a safe place from morning to evening on the waterhole or from perambulation in areas of possible sightings of elephants.

A database has been created using the data collected from the field. In order to assess the population at state-level, statistical analysis was carried out as detailed in section 3.4.3. The entire data was scrutinized and analysed resulting in the report by Parambikulam Tiger Conservation Foundation (PaTCoF) with the guidance of HoFF, CWW, APCCF (Vigilance& Forest Intelligence) and in association with eminent scientists in the field.

3.4.3. Statistical Analysis

3.4.3.1. Estimation of actual elephant habitat

As the extent of habitat with actual elephant occurrence is a critical factor while extrapolating elephant population, the areas actually used by elephants [or the areas devoid of elephants] were estimated during past population estimation carried out during 2005. Large water bodies and human settlements were accounted as areas devoid of elephants. Figures obtained after deducting areas devoid of elephants from the total forest area were used in the report for extrapolating the elephant density at ERs. The details of areas devoid of elephants in each FD are given in Annexure 3.4.

3.4.3.2. Elephant Population Estimation by Block Count Method

The sample block count data of each FD and ER [stratum] were analysed separately using the formula provided in Lahiri-Choudhury (1991) to arrive at estimates of elephant density, number of elephants and statistical confidence limits [95%] along with variance and standard error [SE]. The sum of estimates across ERs in the State of Kerala was estimated using the following formula:

Estimate of total number of elephants (Y) in the region or FD is - Y = (y/x) * X

Where y = total number of elephants counted in the sample blocks
x = total area sampled
X = total area of forest with elephant distribution

Variance of the estimated elephant population in the i^{th} stratum

$$\mathrm{Var}(\hat{N}_i) = \frac{{A_i}^2}{n_i(n_i-1)} \sum_{j=1}^{n_i} \frac{(y_{ij}-y_i)^2}{(x_{ij}-x_i)^2}$$

Standard Error (SE) of N_i in the i^{th} stratum

95% Confidence Limit [CL] for $N_i = N_i \pm 1.96\ SE\ (N_i)$

$$SE\ (\hat{N}_i) = \sqrt{\widehat{\mathrm{var}}(\hat{N}_i)}$$

Where D_i = Estimated density of elephants [number of elephants/km^2] in the i^{th} stratum
A_i = Total area of the i^{th} stratum
n_i = Number of blocks sampled in the i^{th} stratum
y_{ij} = Number of elephants sighted in the j^{th} block of the i^{th} stratum
y_i = Total number of elephants in the sample blocks of the i^{th} stratum
x_{ij} = Area of j^{th} sample block of the i^{th} stratum
x_i = Total area of the sample blocks in the i^{th} stratum
N_i = Estimated elephant population in the i^{th} stratum

Estimation of age/sex ratio and population characteristics: The characteristics of the elephants through sample block method and count made on final day of enumeration in all possible areas of elephant encounter were analysed for age/sex classification. Ratio of adult male to adult female [AM:

AF], sub-adult male to sub-adult female [SAM: SAF], adult female to calf [AF: calf], tusker to makhna and percent males in adult and sub-adults were estimated and provided in the format given in the guideline circulated by MoEF.

3.4.3.3. Elephant Population Estimation by Dung Count Method [Line Transect Sampling]

A total of 610 transects were laid covering a distance of 895.40 km to estimate dung density across the FDs in Kerala).

The perpendicular distances collected from line transect dung count data were used to estimate dung density using computer programme DISTANCE Version 7.0 Release 1 developed by Thomas *et al.* (2010). The key formula used for the dung density estimation is given below:

$$\hat{D} = \frac{n\hat{f}(0)}{2L}$$

$$\hat{f}(0) = \frac{1}{\int_0^w g(x)}$$

Where D is the dung density, n is the number of dung piles, and L is the total length of the transects walked for recording dung piles.

The Variance of D is approximately

$$\hat{D} \pm z_\alpha \cdot \sqrt{\widehat{var}(\hat{D})}$$

(Z = $Z_{0.025}$ = 1.96 for a 95% confidence interval)

The Standard Error (SE) is calculated using the formula given below:

$$SE = \sigma / \sqrt{n}$$

Where σ = the population standard deviation and
√n = the square root of the sample size

An approximate 100 (1 -2 α % Confidence Interval) is given by

$$\widehat{Var}(\hat{D}) = \hat{D}^2 \cdot \{\frac{\widehat{var}(n)}{n^2} + \frac{\widehat{var}\,[\hat{f}(0)]}{[\hat{f}(0)]^2}\}$$

Where n = number of dung piles enumerated
w = perpendicular distance to dung piles
L = length of transect [km]
g (x) = the probability density function of detecting a dung pile in the survey area
x = perpendicular distance [m]

Truncation (cut-off width), class intervals (bins) of perpendicular distances and model selection for dung density estimates: In probability density function, the frequency of detection of dung piles reduces with increasing distance from the transect line. However occasionally dung piles are detected at distances far from the transect line especially in open areas or in grasslands. These observations are usually rare with negligible frequency. If the entire data set is used as such for model fitting and analysis these 'outliers' may be 'noise' influencing the model robustness and precision of estimates. Hence these outliers need to be scrubbed from the data-set so that it does not fail the model.

The truncation of perpendicular distances can be determined in many ways. Buckland et al. (1993) suggested that measures (5% to 10% of the data points) of dung piles that are encountered at the higher end may be removed from the analysis. Another widely used method is using 'box and whisker plot' (also known as boxplot) which is especially useful when large numbers of observations are involved for indicating whether a distribution is skewed and whether there are potential unusual observations (outliers) in the data set. Hence boxplots which are ideal for comparing distributions because the centre, spread and overall range are immediately apparent, were used to calculate the cut-off width. An outlier is any value that lies more than one and a half times the length of the box from either end of the box. The cut-off width in the boxplot is calculated as one-and-a-half times the inter-quartile range (ICR) which is just the width of the box in the boxplot used as a measure of how spread-out the values are. In order to infer a truncation or a cut-off value in a given data set using boxplot, the quartiles Q_1 (Quartile 1 or the median of the lower half of the data set) and Q_3 (Quartile 3 or the median of the upper half of the data set) are decided. Quartiles 2 (Q_2) is the median or middle quartile. Hence the interquartile range, $IQR = Q_3 - Q_1$ is a measured as noise or scale for the data set. Points that are beyond the quartiles by one-and-a-half *IQR*'s will be deemed potential outliers**.** In order to set up a formal mechanism, denote the above distance by h; i.e., $h = 1.5\ I\ QR = 1.5(Q_3 - Q_1)$. Next, the lower and upper inner fences were denoted by LIF = $Q_1 - h$ and UIF = $Q_3 + h$. Hence points beyond these fences are potential outliers and picked up the cut-off value.

After deriving the cut-off width, the data set was categorised into groups or bins (summarise in ranges) with the distance classes of equal (or unequal) intervals. If the cut off value decided from the boxplot is 15, then the data set were grouped into bins numbering from 15, 14, 13… and upto four. Since too a few bins would result in over-smoothing the data with loss of detail of the underlying distribution and induce unnecessary spikes that might result in failure to recognize trends, the minimum bin value has been decided as four. The data were then analysed for these different class intervals using the detection functions such as Half Normal, Uniform, Hazard Rate and Negative

Exponential. Negative exponential can be useful when very spiked data are collected but usually is only recommended to salvage a survey gone badly wrong (as the negative exponential has no 'shoulder'). A mixture model approach is usually more reliable when data are very spiked (see e.g., Buckland, 1992; Buckland et al., 2001). (from website: http://converged.yt/RDistanceBook/distance-moredf.html). Then, 'CV width' was calculated by deducting the value of density estimates of lower confidence limit (LCL) from the value of upper confidence limit (UCL). Finally, a product value for each set of analysis was derived by multiplying the value of Coefficient of Variation (CV) with 'CV width'. The lowest product value was considered as the best fit model or optimal model for the given data set and used for estimating the elephant density.

This density was converted into elephant density through Monte Carlo simulations using the programme GAJAHA Ver. 2.0 (Santosh and Sukumar, 1995; Prasad and Sukumar, 2006; Archana and Sukumar, 2007) by incorporating elephant defecation rate and elephant dung decay rate following Barnes & Jenson (1987). The key formula used for the estimation is as follows:

$$\text{Elephant density [number/km}^2\text{]} = [D/DR] \times DDR$$

Where D = Dung Density; DR = Defecation Rate and DDR = Dung Decay Rate

In the absence of specific data for different elephant habitats in the State, the defecation rate of 13.51±0.51 (published recently by Mohanarangan *et al.*, 2022) was used for the present analysis instead of using the defecation rate estimated during early nineties (as 16.33 dung piles/day and SE = 0.8 calculated by Watve (1992). The decay rates estimated during 2017 at ER-level were used (Table 3.6) that had met the criterion (marking sufficient number of samples with 80% decay of marked dung piles). The elephant population in each ER was estimated by multiplying density estimates with their respective extent of elephant habitat. The analysis has strictly been carried out in accordance with the guidelines issued by MoEF and presented in this report.

Table 3.6: Decay rates (estimated during 2017) used for estimating elephant population from the dung count method in various ERs in Kerala

SN	Name of ER	Decay rate (SE)
1	Wayanad ER	0.00729 (0.72)
2	Nilambur ER	0.00729 (0.72)
3	Anamudi ER	0.00699 (1.14)
4	Periyar ER	0.00735 (2.71)

The results are presented in the following chapters in a sequence of State-level estimation followed by four Elephant Reserves and FDs in the State. The results obtained in the present enumeration have been compared with the exercises carried out in the past.

CHAPTER 4: RESULTS

4.1. Block Count Method

Out of the 610 sample blocks (with an extent of 3508.8 km^2) sampled in the State, a total of 700 elephants were counted in 251 sightings (Table 4.1). The density of wild elephants in State was thus estimated at 0.20 (SE 3.1) per km^2 and population at 1920 with 95 per cent confidence interval, ranging from 1914 to 1926.

Among the ERs in Kerala, the highest population was estimated in Periyar ER. A total of 289 elephants were counted during block count method in Periyar ER. The total sampled area was 1161.2 km^2 (in 206 blocks) and the total extent of the forests having elephant distribution in Periyar ER was 3258.27 km^2. Using these figures, the total population of elephants in Periyar ER was estimated as 811 (95% CI 803-819) which is the highest estimated population among the ERs in Kerala (Table 4.1).

The density was also high (0.25/km^2 SE = 3.9) in Periyar ER. A total of 237 elephants were counted in Anamudi ER in 72 sightings in an area of 1159.2 km^2. The extrapolated number of elephants in the Anamudi ER was 696 (95% CI – 689-703) for the total extent of 3405.64 km^2. The density was estimated as 0.20/km^2 (SE 3.5) (Table 4.1).

In Wayanad ER, a total of 89 sample blocks (with an extent of 517.9 km^2) were surveyed and counted 110 individuals in 48 sightings. This has yielded a total extrapolated population of 249 individuals in the total extent of 1172.45 km^2 with elephant distribution in the ER. The elephant density per km^2 was at 0.21/km^2 (SE 2.8) (Table 4.1).

The population of elephants estimated in Nilambur ER (for the total extent of 1786.35 km^2 having elephant distribution) was the lowest (171 with 95% CI – 168-173) among the ERs in the State. The number of elephants counted in the ER was 64 in 29 sightings in the sample blocks with an extent of 670.5 km^2. The estimated density in Nilambur ER was 0.10/km^2 (SE = 1.5) (Table 4.1).

The age-sex classification of elephants counted during block count method is described along with the Waterhole Count data in para 4.3.

4.2. Dung Count Method

The distance analysis results with best fit models derived from the lowest product values for the ERs are summarized in Table 4.2. Hazard Rate and half-normal detection function models (with varied bin sizes) were considered as the best fit or optimal models for all the ERs in Kerala. The entire

output of analysis performed for various ER in Kerala along with the selected bins and detection functions are summarized in Annexure 4.1.

Table 4.1: Details of elephant population estimation through block count method

Name of ER	Number of Sample Blocks	Extent (km^2) sampled	Total Extent (km^2) of elephant habitat	Total number of sightings	No. of elephants counted	Extrapolated elephant number	Density	Standard Error	95% LCL	95% UCL
State-level	**610**	**3508.8**	**9622.71**	**251**	**700**	**1920**	**0.20**	**3.1**	**1914**	**1926**
Wayanad ER	89	517.9	1172.45	48	110	249	0.21	2.8	243	255
Nilambur ER	118	670.5	1786.35	29	64	171	0.10	1.5	168	173
Anamudi ER	197	1159.2	3405.64	72	237	696	0.20	3.5	689	703
Periyar ER	206	1161.2	3258.27	102	289	811	0.25	3.9	803	819

LCL = Lower Confidence Limit; UCL = Upper Confidence Limit

Table 4.2: Summary of distance analysis results for various models for the data sets of ERs in Kerala

ER name	Model name	ESW/EDR	D	D LCL	D UCL	D CV	CV Width	Product
WAYANAD	5 Hazard Rate	4.98	617.71	473.31	806.17	0.13	332.87	44.88
NILAMBUR	7 Half-normal	4.27	338.68	268.77	426.77	0.12	158.00	18.54
ANAMUDI	5 Half-normal	3.26	413.90	338.39	506.25	0.10	167.86	17.22
PERIYAR	4 Hazard Rate	3.26	530.02	429.32	654.33	0.11	225.01	24.14

ESW: Effective strip Width; EDR: Effective Detection Radius; D: Mean dung density estimates/km^2; LCL: Lower Confidence (95%) Limit; UCL: Upper Confidence (95%) Limit; D CV: coefficient of variation of average dung density estimates/km^2

The dung density estimates from the best fit models in the ERs revealed that the dung densities varied across the ER having a lower density of 338.39 dung piles/km^2 in Nilambur ER and a higher dung density of 530.02 dung piles/km^2 in Wayanad ER.

The estimated elephant populations at each ER in Kerala from the dung count method is given in Table 4.3. The dung density (D) for each ER given in Table 4.2 was converted to elephant density using the defecation rate of 13.51±0.51 and decay rate given in Table 3.6 under para 3.4.3.3.

Again, Periyar ER has the highest population of elephants (940 with 95% CI 761-1160) from dung count method. This is followed by Anamudi ER having an estimated population of 729 elephants (with 95% CI 596-892). Wayanad ER with 391 elephants (95% CI 299-510) stand at the third place. Nilambur ER has the lowest estimated elephant population (326 – 95% CI 259-411) (Table 4.3).

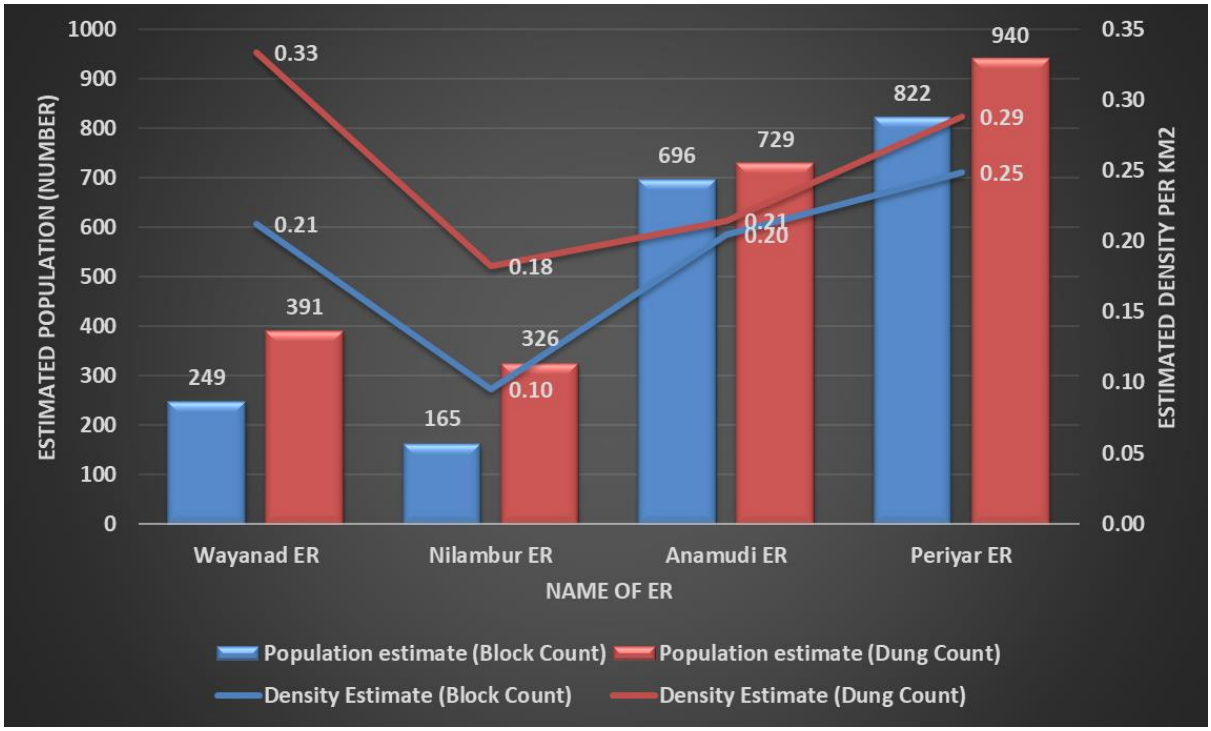
Density estimation at Elephant Reserve-level indicates Wayanad ER has the highest density (0.33/km^2) which is followed by Periyar ER (0.29/km^2) and Anamudi ER (0.21/km^2). The Nilambur ER has the lowest density (0.18/km^2) from dung count method (Table 4.3).

Table 4.3: Estimated elephant population from dung count method

Name of ER	Estimated Elephant Density and Population			
	Density/km^2	Number	LCL	UCL
Wayanad ER	0.33	391	299	510
Nilambur ER	0.18	326	259	411
Anamudi ER	0.21	729	596	892
Periyar ER	0.29	940	761	1160
Total		**2386**		

The comparison of estimated population and density of elephants through block and dung count methods are shown in Fig. 4.1.

Fig. 4.1: Estimated density and abundance of elephants in various ERs in Kerala

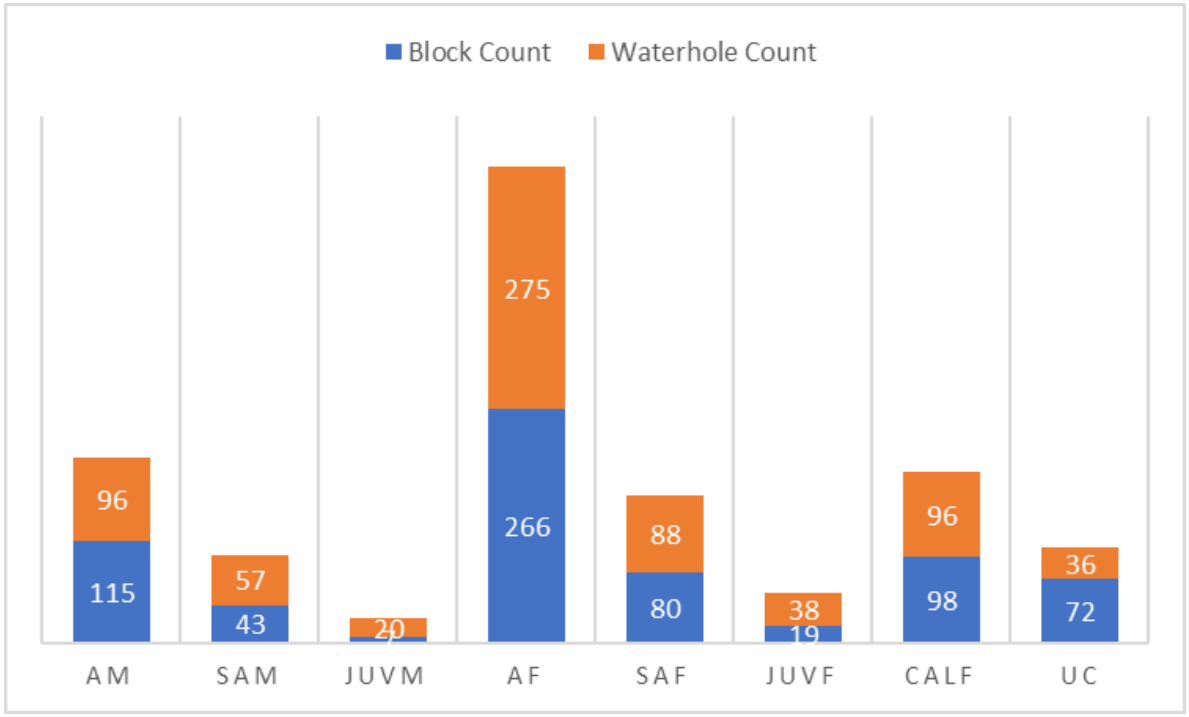


4.3. Elephant count for age-sex ratio

In order to assess the age-sex categories of the elephant population at each ER, the data collected on the 1st day (block count) and 3rd day (elephant count in all possible areas and waterhole) were pooled. A total of 700 elephants (251 sightings) were counted on the first day and 706 elephants

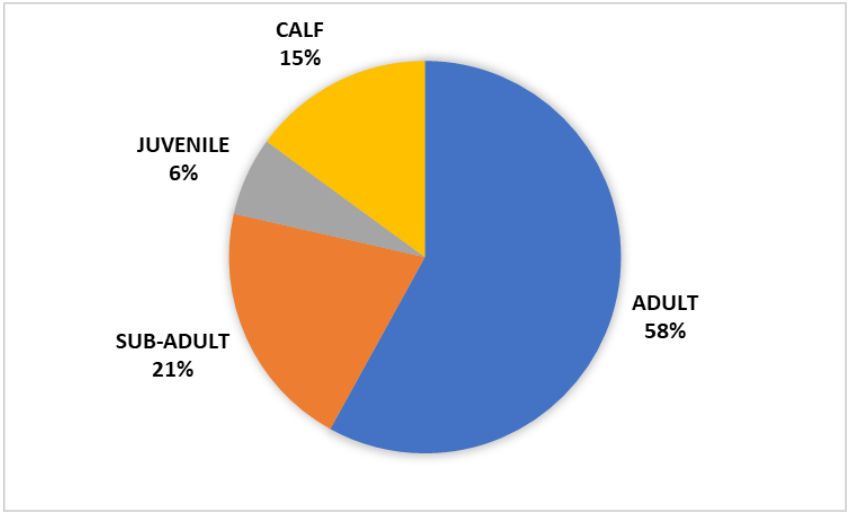
(205 sightings) on the third day. The number of elephants counted in various age-sex categories are given in Fig. 4.1.

Fig. 4.1: Number of elephants counted in block and waterhole count methods in Kerala



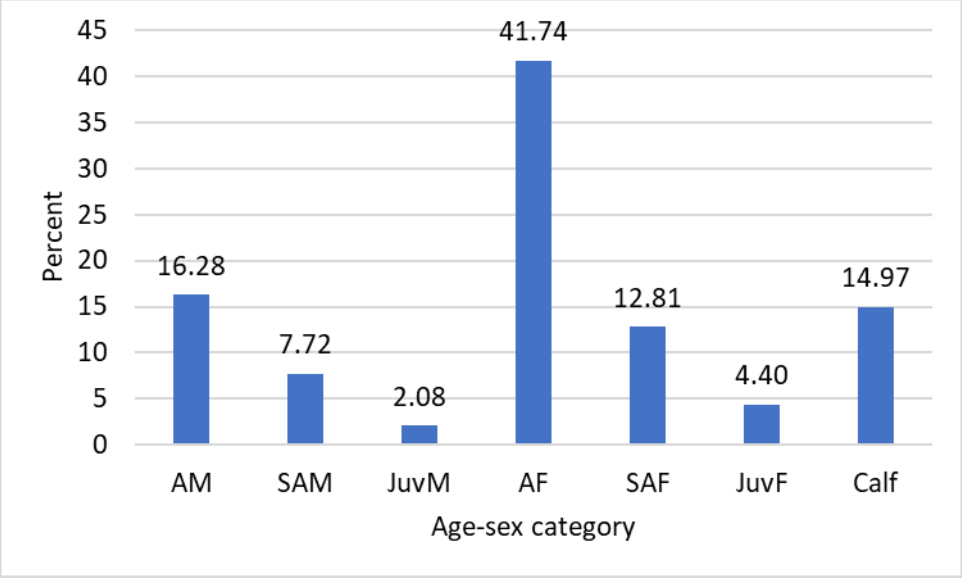
Out of the total 1406 individual elephants counted on both days, 108 individuals (7.7%) remained unclassified. Hence, in the remaining 1298 classified elephants, adults comprised of 58%, followed by sub-adults (21%), calf (15%) and juveniles (6%) (Fig. 4.2).

Fig. 4.2: Composition of age-categories of elephant population in Kerala during 2023



Among the 1298 classified elephants, adult males comprised of 16.28% (Fig. 4.3). Out of 211 adult males recorded, 89% were tuskers and remaining 11% were makhanas. The percentage of adult female in the population consisted of 41.74% which is followed by calf (14.97%) and sub-adult female (12.81%). The proportion of juvenile categories of males and females were ranging between 2 to 4.4 in the total population.

Fig. 4.3: Composition of various age-sex categories of elephants counted in Kerala



The overall age-category of elephants recorded in various ERs in Kerala shows that adults composed of 55 to 57% in all ERs except Wayanad ER where 66% of the total population were adults. The sub-adult category was ranging from 19 to 23% in all ERs except Wayanad ER (13%). The percentage of juveniles constituted 6.67% to 7.13% in all ERs except Wayanad (2.24%). The percentage of calf were comparatively higher (about 19%) in Wayanad and Nilambur ERs and less (about 13%) in Anamudi and Periyar ERs. (Fig. 4.4).

The age-sex composition of elephants recorded in various ERs in Kerala reveals that adult female comprised of 42 to 44% in all ERs except Nilambur ER where this category was only 32% in the total population. The adult males in the total population varied from 22 to 24% in Wayanad and Nilambur ERs, and 13 to 15% in Anamudi and Periyar ERs. In sub-adult category, females constituted 9% each in Wayanad and Nilambur ERs and 14% in Anamudi and Periyar ERs. Juvenile male constituted one to three percent in all the ERs and juvenile female comprises of five to six percent in all ERs except Wayanad ER where this category could not be recorded. The percentage of calf in the total population

in Wayanad and Nilambur ERs consisted of 19% each, but in Anamudi and Periyar ERs, the percentages were 13 and 14% respectively (Fig. 4.5).

Fig. 4.4: Composition of age categories of elephants recorded in various ERs in Kerala

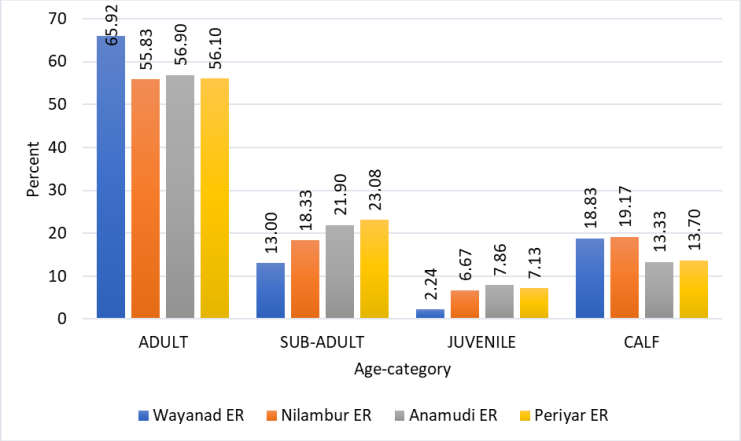
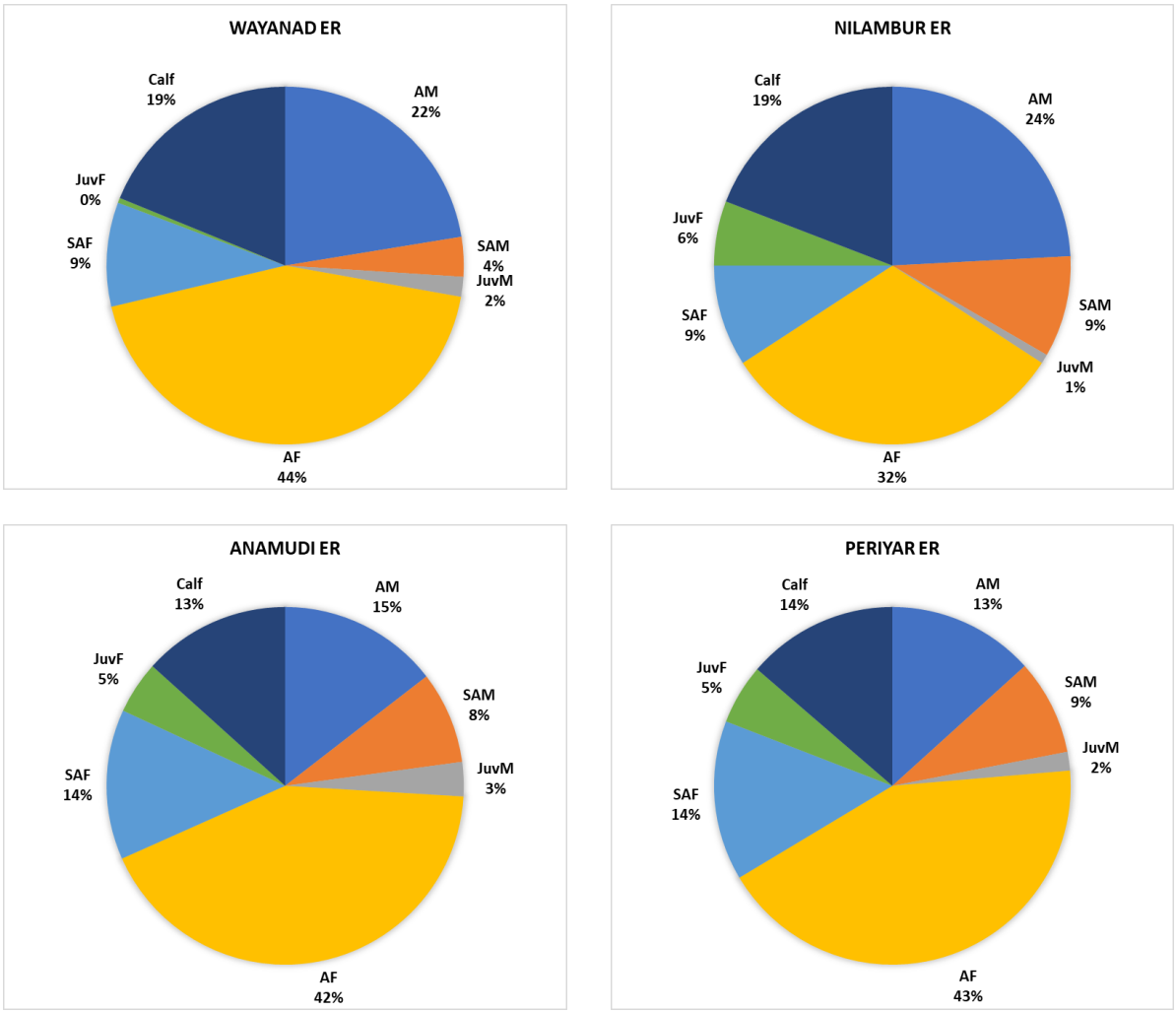


Fig. 4.5: Composition of age-sex categories of elephants recorded in various ERs in Kerala



The overall sex ratio at State-level showed a gradual skew towards females from sub-adult (1:1.66) to adult (1:2.56) age classes (Table 4.5). Similar skews were also observed in all ERs except Wayanad ER where the skew was higher in sub-adult category and low in adult category. Among the sub-adult category alone, the male to female ratio varied from 1:1 (in Nilambur ER) to 1:1.67 (in Periyar ER) with a high skew in Wayanad ER (1:2.63).

Ratio of tusker and makhna showed a skew towards tusker (1:0.12) at State-level. In adult male category, the proportion of makhnas were higher in Periyar ER (tusker to makhna ratio 1:0.18) followed by Wayanad ER (1:0.14) and very less in Nilambur and Anamudi ERs (1:0.07). Overall, at State-level, 30.55 percent of the population consisted of adult and sub-adult population males. Among the ERs, Nilambur ER has much higher percentage (44.94%) and the remaining ERs were ranging between 27% to 33%.

Fig. 4.5: Ratio and percentage of age-sex category

Ratio and percentage of age-sex category	State-level	Wayanad ER	Nilambur ER	Anamudi ER	Periyar ER
Ratio of AM: AF	1:2.56	1:1.94	1:1.31	1:2.92	1:3.21
Ratio of SAM: SAF	1:1.66	1:2.63	1:1.00	1:1.63	1:1.67
Ratio of AF: Calf	1:0.36	1:0.43	1:0.61	1:0.31	1:0.32
Ratio of Tusker: Makhna	1:0.12	1:0.14	1:0.07	1:0.07	1:0.18
% Males in adult and sub-adults	30.55	32.95	44.94	29.00	27.73

Of the total of 456 detections of elephants at the State-level, sightings of single individual were accounted for 42%, and two individuals comprised of 14.69%. About 99% of the sightings of single and two individuals were of adult and sub-adult males. Herd size of three to five Individuals were 27.19% and between six to ten individuals accounted for 13.6%. Herd size with more than 10 individuals comprised of about two percent. The maximum number of individuals sighted in the herd was 19 (Fig. 4.6).

Elephant Reserve-wise detection shows that single individuals were sighted more than 55% in Wayanad and Nilambur ERs and about 36% in Anamudi and Periyar ERs. Detections of two individuals comprised of about 9% in Wayanad and Nilambur ERs and 16-17% in Anamudi and Periyar ERs. Herd sizes of three to five and six to ten varied from 18 to 31% and 11 to 14% respectively. Sightings of more than 10 individuals were rare in all ERs (Fig. 4.7).

Fig. 4.6: Herd composition of elephants detected in Kerala during the population estimation exercise

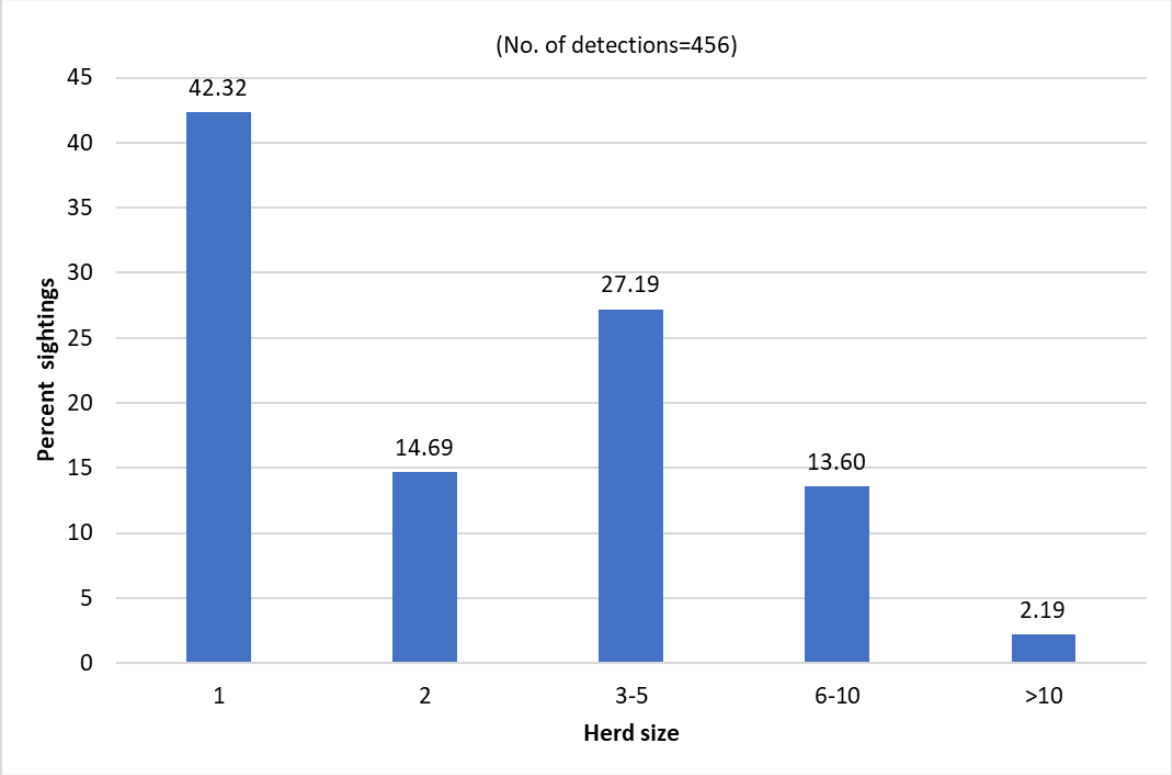
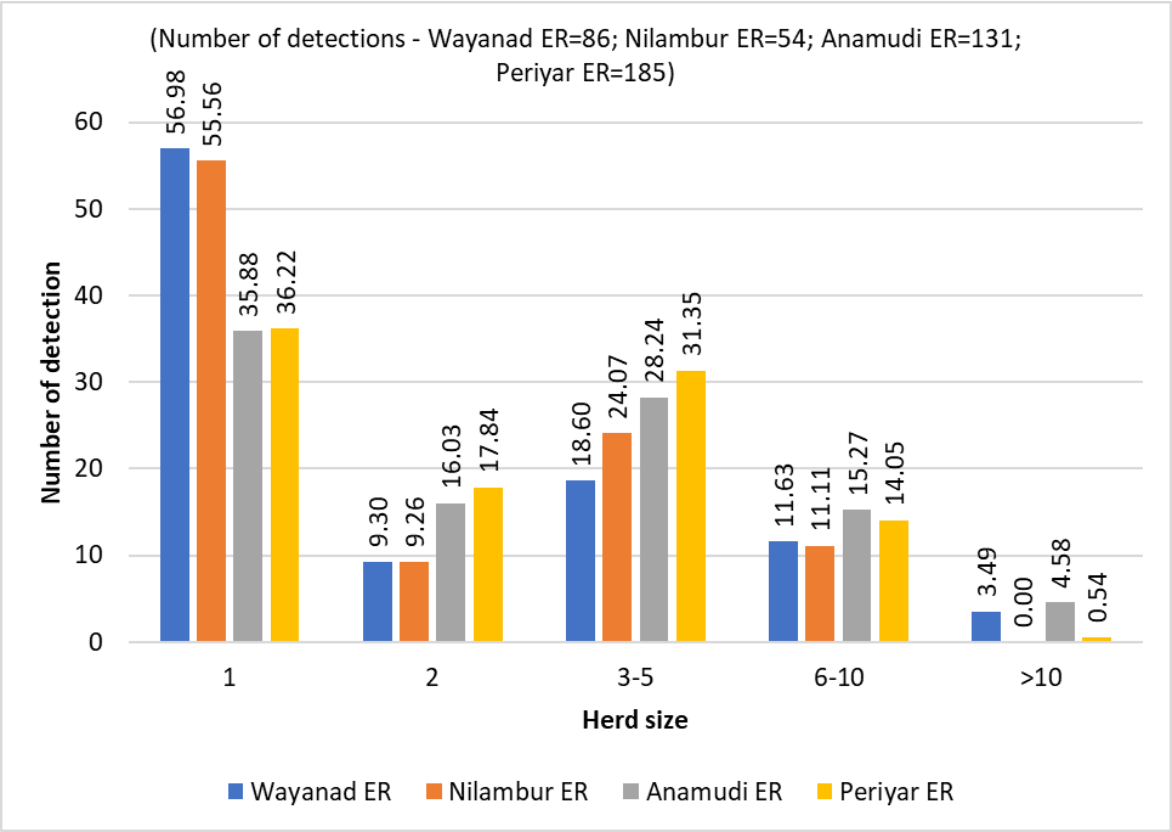
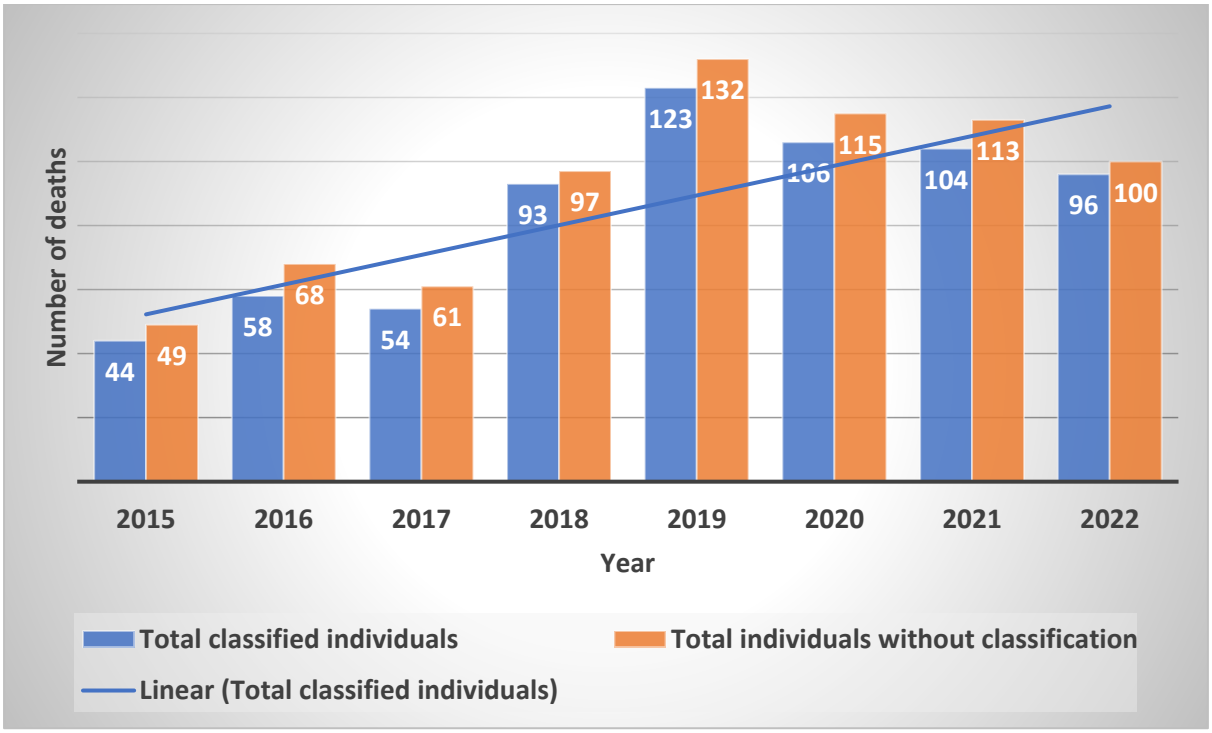


Fig. 4.7: Herd composition of elephants detected in various ERs during the population estimation exercise



The age-specific mortality, as it significantly contributes to the demography and population growth, is vital for understanding elephant population dynamics. The elephant mortality records (a total of 735 deaths during the years between 2015 and 2022, out of which 57 individuals could not be classified) maintained by KFD shows that there was a sharp increase in the death rate over the years with a higher mortality during 2019 (Fig. 4.8).

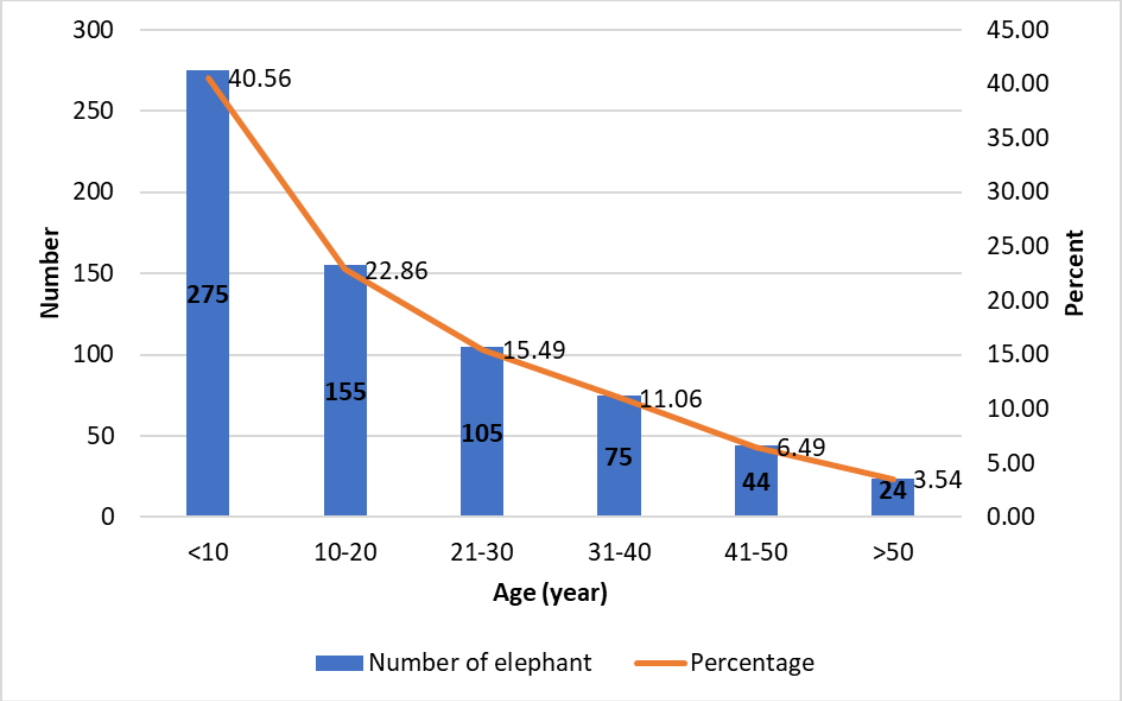
Fig.4.8: Year-wise mortality of elephants in Kerala



The data also reveals that a high mortality rate in the age-category of less than 10 years old (Fig. 4.9) and the death rate was gradually reduced with increasing age.

The higher mortality rate in the young age-categories could be due to Elephant Endotheliotropic Herpesvirus (EEHV) or Elephantid betaherpesvirus 1 (ElHV-1), which are common among elephants in the wild. EEHVs have co-existed with elephants for millions of years, yet may cause fatal haemorrhagic disease, typically in elephants below 10 years of age. If the immunity of elephants is low or it is genetically weak, then the chance of infection increases. Many studies conducted in Asia, both in wild and captivity, reveal that around 80% mortality caused by EEHV or ElHV-1 was found in calves below the age of 8 years.

Fig.4.9: Number of elephant death in various age category in Kerala



CHAPTER 5: DISCUSSION AND RECOMMENDATION

5.1. Discussion

Population monitoring of any threatened species is critical to their effective conservation. The present study estimated the elephant population in the State as well as Elephant Reserves using block count and dung count methods. Given 95% confidence intervals, the block count method revealed a total population of 1920 elephants (ranging between 1914 and 1926) with a density of 0.20 (SE 3.1) per km^2. The dung count method estimated 2386 elephants in the State with a density of 0.25 (SE 3.2) per km^2.

Population estimates at Elephant Reserve-level using block and dung count methods also revealed different yet precise estimates. Periyar ER, having a large extent of elephant habitat (3258.27 km^2) with the highest estimated densities in block count (0.25/km^2) and dung count (0.29/km^2) methods, contains high abundance of elephants (822 in block count and 940 in dung count) in the State (Fig. 4.1). Anamudi ER, with an elephant distribution extent of 3405.64 km^2 and having almost similar estimated densities of block (0.20/km^2) and dung (0.21/km^2) count methods, has estimated abundance of 696 individuals in block count and 729 individuals in dung count methods and the variation between these two estimates are insignificant. The high variation in the density estimations among the two methods (0.21 individuals/km^2 in block count and 0.33 individuals /km^2 in dung count) in Wayanad ER reflected high differences in the extrapolated abundance too (249 elephants in block count and 391 in dung count methods). Nilambur ER, though having comparatively larger elephant distribution area (1786.35 km^2) than Wayanad ER, has low density as well as abundance among the ERs in the State.

The estimates are more precise compared to the previous surveys due to the finetuned methods adopted during the survey (e.g., rationalization of blocks with manageable sizes, careful selection of non-adjoining blocks that avoided double counts, use of digital maps for clearly understanding the sample block boundary even during field work). However, the present elephant population estimates, from both block and dung count methods in the State, are low compared to the previous estimate carried out during 2017 which needs to be expounded carefully.

The elephant habitats in Kerala are contiguous with the forests of Karnataka and TN sharing an interstate boundary length of 957 km and thus elephants in all the ERs move across the States to meet their ecological needs. This is a natural phenomenon. Elephants, being a large-bodied herbivorous

mammal weighing up to 5000 kg, consume 250-300 kg. of green fodder (thus they have to feed up to 18 hours a day) and 150-200 l. of water each day, depending upon their body weight. To meet this enormous appetite, the pachyderms need extensive areas and thus they obviously have to move across the States. A study conducted in Nilgiris (Baskaran et. al., 2018) revealed that clans range between 562–800 km² while bulls range between 211–375 km² in Nilgiris. In sub-optimal habitats the home range size was found to increase.

During natural calamities (e.g., abrupt rainfall and adverse drought leading to water scarcity and non-availability of lush green fodder) and events of negative human activities (e.g., extensive fire), the elephants are known to move between the forests of the adjoining States. Shift in the rainfall patterns can also have a significant impact on elephant habitats (e.g., varying fodder and water availability, and vulnerability to wildfires). In 2016, severe drought in Tamil Nadu resulted in a mass movement of elephants to the wetter forests of adjoining States and they moved back to Tamil Nadu with the onset of the monsoon in mid-2017 only (Sukumar *et al.,* 2020). This was reflected in higher numbers in the elephant population estimation carried out during 2017 in Kerala. Moreover, the unusual intermittent rainfall during peak summer in the adjoining States (e.g., April and May, 2022) reduced the risk of fire (https://www.thehindu.com/news/ national/karnataka/rains-in-bandipur-nagarahole-abate-forest-fire-threat/article65320784.ece) and that could be a reason for the reduction in the reported elephant population in Kerala. Thus, State-specific elephant population estimations may vary widely according to the factors mentioned above.

Shrinking habitats coupled with increasing fragmentation and climate change are also affecting the movement of elephants. According to a study by WWF, the traits that make elephants vulnerable to changing climate are 'a declining population size, sensitivity to high temperatures, invasive plant species outcompeting their regular food sources, and disease susceptibility'. The study further adds that the variables impacting the distribution of elephants are driven by land-use change, water balance in the climate, temperature change and human-induced disturbances. Similarly, a study conducted over a 30-year period in Gabon showed that the amount of fruit available to elephants dropped by > 80% due to climate change affecting the trees (https://www.iucn.org/news/species-survival-commission/ 202108/shrinking-spaces-worlds-largest-land-animal). The reduction in trees resulted in a vicious cycle of diminishing elephant health, declining elephant numbers, lowering reproductive rates, less seed dispersal and a reduction in the quality of their own forest habitats. This phenomenon could be occurring across the forested tropics of both Africa and Asia. Thus, it is time to take initiatives towards ameliorating the impact of climate change across the elephant habitats.

Among the elephants detected during the survey, sightings of single individuals of adult males were more (>42%) than clans. Sightings of clans were meagre throughout but very rare in Wayanad and Nilambur ERs. As the bulls have comparatively smaller home range size than the herds/clans, they can withstand adversities in the sub-optimal habitats (having poor availability of food and water) during harsh climates. But the clans (with young ones), requiring larger areas to meet their ecological needs, have to seek better habitats as they cannot tolerate the harsh climate resulting in poor quality habitats. Hence, it is possible that the clans could have descended to adjoining forests having better habitat qualities.

Comparing the adult sex-ratio of male to female, higher skew towards females were observed during 2023 (1:2.56) than 2017 (1:1.62). But in sub-adult category, the skew towards females is less during 2023 (1:1.66) than 2017 (1:2.13). The differences of adult female to calf ratios are insignificant during 2023 (1:0.36) and 2017 (1:0.34). The ratios of tusker to makhna varied much between 2023 (1:0.12) and 2017 (1:0.34). Percentage of adult and sub-adult males in the populations are found to be lower from 2017 (44.63%) to 2023 (30.55%). The variations over the years in the age-sex ratios could possibly be due to the nature of surveys (carried out only for two days in a year and especially during the peak summer season when animals tend to congregate at locations with abundant food and water resources). A study conducted by Gupta et. al. (2016) revealed that there was considerable variability in adult sex ratios even within months across dry season. Differences in the detectability of males and females can also bias the sex ratios if the total count of males and females are used. Changes in the count of single males in the population over the years could also be attributed to the dispersal of pubertal males not just from their natal herds but also from their natal home ranges to various locations. Thus, individual turnover in an area due to dispersal males could give fluctuations. Estimates of precise elephant sex-ratio with individual identification only could yield accurate results and thus, systematic long-term studies on sex-ratios in representative populations (best locations could be Periyar TR, Parambikulam TR, Wayanad WLS) need to be carried out in the State concurrently to validate the present estimates.

Currently, HEC has emerged as one of the most challenging problems in the conservation and management of elephant populations across the country. Reduction in elephant habitat quality, extreme weather events such as droughts and floods and development of linear infrastructure in the elephant corridors exacerbate HEC. The reasons for HEC across the State cannot be generalised since every Forest Division has specific problems. Fragmentation of habitats drastically limit the elephant's ability to traverse their home ranges. Even well-intentioned measures taken to mitigate HEC

sometimes block connectivity (e.g., solar power fencing, trench, rail fence, crash guard rope fence, concrete wall, etc). This can isolate populations or prevent movement of elephants to potential habitats even within their home range. Establishing more and more such preventive measures without ensuring connectivity will only exacerbate HEC and hence much care has to be taken before establishing such preventive measures. Thus, long-term solutions of HEC and promotion of peaceful coexistence require a simultaneous focusing of management efforts on site-specific considerations as well as formulation and application of strategic plans at the landscape-level that directly address underlying anthropogenic drivers and their spatio-temporal variations.

5.2. Recommendation

5.2.1. Conservation and management of elephant population

- ***Enhance the existing habitat quality to sustain the elephant population***. A critical issue presently being faced by the forest managers is how to maintain biodiversity in the face of natural and man-made perturbations in the habitat. Biological invasions, one of the anthropogenically mediated ecological perturbations, are represented mostly by the alien species introduced accidentally or purposefully outside their native geographical distribution ranges. Invasion by alien plants affects the survival of local species, damages soil quality and affects groundwater availability. It also indirectly affects animals by intruding into the food chain. Natural calamities that occurred in the state during 2018 also intensified the dispersal of these invasive alien species to other areas. Wide spread growth of invasive alien plants such as Lantana, Eupatorium, Mikania and Senna have become a serious environmental issue in Kerala. The available habitats for the megaherbivores including elephants have significantly degraded and shrunken due to these species which sometime lead herbivores to seek fodder from farm lands located within and around the forests. Hence, in order to conserve, protect and manage biodiversity, invasive alien species are to be managed to restore habitats to sustain the herbivore populations.

- ***Manage micro-habitats (e.g., marshy grasslands) to sustain the wild animal population***. Among the micro-habitats, marshy grasslands (locally known as *vayals*) play a major role in managing and maintaining herbivores populations. The *vayals* are the prime habitat that provide lush green fodder for all herbivores including elephants. These micro habitats are distributed in majority of the FDs/PAs in Kerala and generally face threats due to invasion of exotic species as well as woody species. Since the vayals are wetland systems, soil moisture plays a regulating role. Due to frequent fire in and surroundings of the *vayal* ecosystem, the

soil moisture levels are gradually decreased and ultimately dry up the entire land which results in conversion of the micro-habitat into woodland. This eventually affect the availability of fodder for herbivore populations including elephants. Hence, maintenance of the marshy grasslands has become an activity of critical importance even in territorial FDs.

- ***Prevent age-specific mortality among elephants through proven measures***. The age-specific mortality, as it significantly contributes to the demography and population growth, is vital for understanding elephant population dynamics. The mortality data (from 2014-15 to 2022-23) maintained by the Kerala Forest Department reveals that there is higher mortality in calf and juvenile categories (Fig. 1.1). The higher mortality rate in these age-category (< 10 years old) could be due to Elephant Endotheliotropic Herpesvirus (EEHV) or Elephantid betaherpesvirus 1 (ElHV-1), which are common among elephants in the wild. If the immunity of elephants is low or it is genetically weak, then the chance of infection increases. Around 80% mortality rate is found in calves below the age of 8 years. Thus, proven treatments successfully adopted elsewhere need to be explored and adopted to minimize the deaths in younger age category.

- ***Mitigate climate change impacts through appropriate measures to be evolved site-specifically***. In the last few decades, Kerala has witnessed the impacts of climate change. This has led to degradation of forests and enhanced aridity in the forest areas. This has also affected wild animals and also their behavioural patterns. This needs more attention and site-specific actions.

5.2.2. Ensuring more precise elephant population estimation

- ***Explore the possibility of using mobile applications*** (similar to MSTrIPES application for tiger monitoring) for monitoring and estimating the elephant populations and assessing the habitats.
- In the light of changing environment and climate factors being experienced now-a-days, ***conduct dung decay experiment at landscape-level in Kerala every time well in advance*** (at least 8 to 10 months prior to the population estimation exercise) for getting precise decay rates. The ***defecation rate shall also be assessed using the captive elephants in Wayanad WLS*** for getting more accurate defecation rate for population estimation. Accurate estimates of these two factors are highly crucial for estimating exact population size.

- ***Conduct studies on factors that facilitate or impede elephant movement within and across Elephant Reserves***.

- ***Conduct long-term studies on age-sex category of elephants in representative elephant populations in the State*** (Periyar TR, Parambikulam TR and Wayanad WLS)

5.2.3. Mitigate HEC

- ***Conduct long-term studies on the behaviour of crop raiding animals in the high-conflict areas to effectively address the conflict issues***. HEC is a major conservation concern in elephant range areas in the country including Kerala. A variety of management strategies have been developed and are practiced at different scales for preventing and mitigating human-elephant conflict. HEC remains prevalent as majority of the existing prevention strategies are driven by site-specific factors that only offer short-term solutions, while mitigation strategies frequently transfer conflict risk from one place to another. Merely upgrading or enhancing preventive structures alone will not suffice. HEC in the State is specific in every FD, varying from habitat quality, behaviour of bulls, interruption in the movement paths due to expansion of linear infrastructure (e.g., roads) and preventive structures to mitigate HEC (well-intended establishments of solar power fencing, trench, rail fence, crash guard rope fence, concrete wall created, but led to blockage of migratory routes) and level of tolerance in society. Hence the proposed long-term study should identify the shared resource use between humans and elephants at different spatial and temporal scales highlighting the anthropological, geographical, ecological and cultural knowledge to develop long-term solutions to mitigate HEC in the State. Site-specific solutions should be based on this.

- ***A permanent and dynamic system to document, assess and monitor the HEC issues in the State*** should be instituted to effectively address the issue.

- **Develop appropriate site-specific measures involving LSGDs in conflict mitigation, decentralized resource mobilization, etc**.

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Annexure 2.1

GOVERNMENT OF KERALA

Abstract

Forest & Wildlife Department – Project Elephant – Elephant Reserves – Declared - Order issued.

FOREST & WILDLIFE (F) DEPARTMENT

G. O(P) No: 19/2002/F&WLD., Dated, Thiruvananthapuram, 02.04.2002

Read :- 1) Letter No. 7-2/00(PE)(vi) dated 14.08.2002 from the Director, Project Elephant, Government of India.

2) Letter No. WL -11-2502/99 dated 02.11.2001 from the Chief Conservator of Forests (Wildlife), Thiruvananthapuram.

ORDER

As per the letter read as first paper above, the Director, Project Elephant, Government of India has conveyed the consent for setting up 4 Elephant Reserve in Kerala viz., Wayanad Elephant Reserve (Nilgiri – Eastern Ghats), Nilambur Elephant Reserve (Nilambur Silent Valley), Anamudi Elephant Reserve (Anamalai - Parambikulam) and Periyar Elephant Reserve (Periyar area) and requested that notifications for the Elephant Reserves may be issued and communicated to Government of India.

Government have examined the matter in details and are pleased to declare the following are described in the schedule below as Elephant Reserves under the Central Scheme of Project Elephants.

(1) Wayanad Elephant Reserve (Nilgiri – Eastern Ghat)

Schedules

A. Name, location, area etc.

Name	-	Wayanad Elephant Reserve
District	-	Wayanad, Kannur, Kozhikode
Protected Areas and Forest Divisions	-	Wayanad Wildlife Sanctuary, South Wayanad, North Wayanad, Kannur and Kozhikode Forest Divisions
Area	-	1200 Square kilometre
Present legal status	-	394.4km^2 Of the Reserve is in protected area (PA) and 805.6km2 is Reserve Forests (RF).

B. Description of Area

The Reserve fells between 11^{0}20' and 12^{0}7'N Lat and between 75^{0}28' and 76^{0}36'E Long. This includes the forests under the administrative forest divisions of south Wayanad (Except Meppadi Range), Wayanad Wildlife Sanctuary, North Wayanad, Kannur and Kozhikode. The Reserve Forest of Hill Dale, Tirunelli, Kannavam, Kottiyur, Periy, Begur, Edakkode, Kartikulam, Judirakode, Padiri, Kurichiyat, Kuppadi, Rampur, Alathur, Kallur, Mavinhalla, Edathara, Nulpuzha, Nemminad and Lady Smith form the major portion of this part of the Elephant Reserve. These areas are already notified as Wildlife Sanctuary and Reserve Forests under Wildlife (Protection) Act and Forest Acts.

(2) Nilambur Elephant Reserve (Nilambur – Silent Valley)

Schedule

A. Name, Location, area etc.

Name	-	Nilambur Elephant Reserve
District (Civil)	-	Malappuram, Kozhikode and Palakkad
Protected area and Forest Divisions	-	Silent Valley National Park, Part of Palakkad, Mannarghat, Nilambur North and South, Kozhikode and South Wayanad Forest Divisions
Area	-	1419 Km^2
Legal Status	-	89.52 Km^2 of the Reserve is National Park adn 1329.48 Km^2 is reserve forests.

Description of the area

The reserve falls between $10^0$50' and $11^0$33' North Latitude and $76^0$02' and $76^0$05' East Longitude. The reserve could be considered as three segments

1. Palakkad Hills consisting of Walayar and Davakkode Ranges of Palakkad Forest Division and Agali Range of Mannarkd Forest Divisions.

2. The Nilambur Silent Valley Part comprising Attappadi and Mannarghat Ranges of Mannarghat Forest Division, Silent Valley Wildlife Division, Nilambure South Division.

3. The Meppadi Region including the Nilambur, Vazhikkadavu and Edavanna Ranges of Nilmbur –North Division, Part of Thamarassery Range of Kozhikode Division and Meppadi Range of South Wayanad Forest Division. These areas are already notified as Wildlife Sanctuary and Reserve Forests under Wildlife (Protection) Act. And Forest Acts.

(3) Anamudi Elephant Reserve (Anamalai - Parmbikulam)

Schedules

A. Name, Location, Area etc.

Name	-	Anamudi Elephant Reserve
District	-	Thrissur, Palakkad, Ernakulam and Idukki
Protected areas and Forest Divisions	-	Parambikulam, Peechi, Chinnar, Thattekkad, Chimmony and Idukki Wildlife Santuries, Eravikulam National Park, Nenmara, Chalakkudi, Thrissure, Vazhachal, Mankulam, Munnar and Malayattoor Fores Divisions
Area	-	3728 Km^2
Legal Status	-	780 km^2 of the reserve is protected Area (PA) and 2948 km^2 is Reserve Forests (RF).

B. Description of the Area

The Reserve falls between 9042' and 10013' North Latitude and 76033' and 77059' east Longitude. The Forest Ranges Under the administrative control of Nenmara, Parambikulam, Chalakkudy, Thrissur, Vazhachal, Malayattoor, Mankulam, Munnar and part of Idukki Wildlife Division constitute the Elephant reserve. The major Reserve Forests include the Nelliyampathy, Koadaseri, Thekkady, Malayattoor, Anamudi, KUDAKKAD, Ayyappankovil,

Nagarampara, Thodupuzha, Kaliyar, Neriamangalam and Cardaomon Hill Reserve, Parambikulam, Chimony, Peechi, Idukki and Chinnar Wildlife Sanctuaries and Eravikulam National Park falls within this area. These areas are already notified as Wildlife Sanctuaries and Reserve Forests under Wildlife (Protection) Act end Forest Act.

(4) Periyar Elephant Reserve (Periyar)

Schedules

A. Name, location, area etc.

Name	-	Periyar Elephant Reserve
District	-	Idukki, Kollam, Pathanamthitta and Thiruvananthapuram
Protected Areas and Forest Divisions.	-	Periyar Tiger Reserve, Neyyar, Peppar and Shenduruny Wildlife Sanctuaries, Ranni, Konni, Achencovil and Thiruvananthapuram Foresst Divisions.
Area	-	3742 km^2
Legal Status	-	1058 km^2 of the Reserve is protected Area (PA) and 2684 km^2 is Reserve Forest.

B. Description of the areas

The Reserve falls between $8^0$30' and $9^0$34' North Latitude and $76^0$52' and $77^0$25' East Longitude. The vast Stretch of Forests extending from north of Araynkavu pass to Periyar Tiger Reserve forms the major part of the Elephant Reserve. This includes the Reserve Forests of Achencoil, Konni, Ranni, Gudrickal, Kumaramperur, Mount Plateau end Periyar Lake. On the southern side thin Elephant Reserve extends from south of aryankavu pass to the forest areas in Neyyar Wildlife Sancturay and is contiguous with Mundanthurai Kalakkadu Forests of Tamilnadu. The area is better known as Ashambu hills. Thils includes the Kalamala, Kottoor, Yeroor, Palode, Kulathupuzha and Aryankavu Reserve Forests. These areas are already notified as wildlife Sanctuary and Reserve Forests under Wildlife (Protection) Act and Forest Acts.

By Order of the Governor
(Sd/-)
E.K. BHARAT BHUSHAN
SECRETARY TO GOVERNMENT

To

The Director, Project Elephant, Government of India.
(With Covering letter)
The Chief Conservator of Forests (Wildlife), Thiruvananthapuram.
Stock file /Office Copy.

Forwarded /By Order

Section Officer

Annexure 2.2

GOVERNMENT OF KERALA

Abstract

Forest & Wildlife Department – Project Elephant Scheme – Elephant Reserves in Kerala – Field Coordinators Designated- Modified - Order issued.

FOREST & WILDLIFE (F) DEPARTMENT

G. O (P) No: 361/2002/F&WLD., Dated, Thiruvananthapuram, 30.10.2002

Read:- 1. G.O. (Rt) No. 125/2002/F&WLD. Dtd. 30.06.2002.
2. Lr. No. WL. 11/4312/02 dated, 11.09.2002 from the Chief Conservator of Forests (Wildlife)

ORDER

In the Government Order read as 1st paper above Government have issued orders designating the Field Director (Project Tiger Reserve) as Field Co-ordinator for Anamudi and Periyar Elephant Reserve and the Conservator of Forests (Wildlife), Palakkad as Field Co-ordinator for Wayanad and Nilambura Reserves.

In the letter read as 2nd above, the chief Conservator of Forests (Wildlife) has reported that considering the composition of various Elephant Reserves, it is better to appoint separate field co-ordinators for each of the Elephant Reserves.

Government have examined the matte in details and are pleased to designate the Conservator of Forests (Wildlife), Palakkad as Field Co-ordinator for Wayanad Elephant Reserve, Conservator of Forest, Olavakkode, Palakkad as Field Co-ordinator for Nilambure Elephant Reserve, Field Director (Project Tiger) Kottayam as Field Co-ordinator for Periyar Elephant Reserve.

The Government Order read as 1st paper above stands modified to that extent.

(By Order of the Governor)

M. ARCHANGELO
Under Secretary.

Annexure 3.1

Minutes of a meeting chaired by HoFF related to elephant population estimation in Kerala

Minutes of the meeting on Wild Elephant Population Estimation in Kerala and Tiger Population Estimation in Wayanad Landscape during 2023 held at the Conference Hall, Forest Headquarters, Vazhuthacaud, Thiruvananthapuram on 20.02.2023

Elephant Population Estimation

The meeting commenced at 11.00 am with Principal Chief Conservator of Forests & Head of Forest Force in Chair. The list of participants attached. The Principal Chief Conservator of Forests (WL) & Chief Wildlife Warden welcomed the participants and gave a brief introduction. A presentation was done by the Chief Conservator of Forests (WL), Palakkad and Dr.M.Balasubramoniam on the methodology carried out in elephant population estimation of 2017. Head of Forest Force suggested some modifications. The following decisions were taken:

1. The wild elephant population estimation 2023 will be conducted at State level under the overall supervision of Chief Wildlife Warden, Kerala. The Addl. Principal Chief Conservator of Forests (Administration) will be the Nodal Officer at State Level and the Field Directors of Periyar and Parambikulam Tiger Reserves will co-ordinate the activities in Southern and Northern regions respectively.
2. The field exercise for wild elephant population estimation will be conducted from 17th to 19th May 2023 considering the fact that the same was carried out on 17th to 19th May during the previous estimation of 2017.
3. The trainings for the frontline staff, watchers and volunteers will be conducted from 17th April 2023 onwards.
4. It was decided to involve one volunteer per block from neighbouring EDCs/VSSs in all Forest Divisions.
5. The blocks which are more than 6 km^2 will be rationalized to 4-6 km^2 (manageble size) and the additional sample blocks will be randomly selected from the neighbouring areas. The blocks in the inter-state border will be avoided and the closely located neighbouring sampling blocks will also be avoided and equal number will be taken from the adjoining areas if necessary.
6. The transect length for dung count method is decided as 1.5 km and vegetation data will be collected at every 200 m interval along the transect.
7. The defecation rate for dung count will be used from a latest study conducted at Mudumalai TR (published during 2022).
8. Dung decay rate will be used from 2017 elephant population estimation for each Elephant Reserve rather than mean decay rate estimated at State Level.

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9. A Training of Trainers will be conducted during first week of April at Periyar Tiger Reserve for the professionals working in Tiger Conservation Foundation, Conservation Biologists working in other PAs, Wildlife Assistants and Deputy Directors (Wildlife Education).
10. Trainees in SFTI, Walayar and Arippa will also be trained and involved in the elephant population estimation, 2023.
11. Sufficient data books will be printed by Tiger Conservation Foundations.
12. The areas that are presently being extensively used by elephants and were not included in Elephant Reserve notification will also be covered in the present survey and analysis.
13. Data collection on change in elephant habitat will also be undertaken during the present survey.
14. To analyze the change in elephant habitat, a study will be conducted by using satellite imageries.
15. The three-day field exercise include (i) block count in the sample blocks on the first day; (ii) dung count and vegetation enumeration along a transect within each sample block on the second day; and (iii) human-wildlife interaction related information (such as movement of elephants nearby human habitations, water availability, croppping pattern, etc.) will be collected from the sample blocks having proximity to human habitations on the third day.
16. Details such as existing preventive measures, compensation details, animal mortality, water availability, corridor etc. will be collected at Division level for including in the report.
17. The elephant survey details such as tracks and transects with elephant sightings will be recorded using Mobile Application (Locus).

Tiger Monitoring in Wayanad Landscape

1. In order to precisely estimate the existing tiger population in Wayanad Landscape, camera traps are proposed to be deployed in the areas where camera traps were already deployed during 2018 and 2022 as part of 'All India Tiger Estimation' (AITE) mandated by NTCA.

2. The population estimation exercise will be carried out in Wayanad Landscape that include part of Kannur Forest Division on the north, entire Aralam and Kottiyur Wildlife Sanctuaries, parts of Wayanad North and South Forest Divisions and entire Wayanad Wildlife Sanctuary on the south.

3. Tiger estimation in Wayanad Landscape will be conducted from first week of April 2023 by pooling the camera traps from the Tiger Conservation Foundations. Presently, the camera traps existing in Parambikulam and Periyar Tiger Conservation Foundations are in the field for the annual monitoring of tigers in both the Tiger Reserves. The Phase IV exercise will get over only by 20th March 2023. During the 3rd and 4th weeks of March, the camera traps will be removed from the field and cleaned for deploying in Wayanad Landscape.

4. The camera traps will be deployed in 312 locations that were used for deploying camera traps during 2018 and 2022 as part of AITE mandated by NTCA.

5. The proposed tiger monitoring exercise will yield the minimum number of tigers in Wayanad Landscape with tiger density and sex-ratio. In addition, each individual tiger captured in the camera traps will be given a unique ID and mapped with the minimum area used during the camera trap deployment period (for incorporating the database maintained by Kerala Forest Department).

6. The Field Director, Palakkad and CCF, Kannur will jointly monitor the camera trap deployment.

After detailed discussions and a thorough review of the draft reports, the final reports of 'Elephant Population Estimation in Kerala – 2023' and 'Tiger Population Estimation in Wayanad Landscape – 2023' will be prepared and submitted on or before 15th July 2023.

The meeting ended at 1.00 p.m.

Principal Chief Conservator of Forests &
Head of Forest Force

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List of Participants

1. Shri.Bennichan Thomas IFS, Principal Chief Conservator of Forests & HoFF
2. Shri.Ganga Singh IFS, Principal Chief Conservator of Forests (WL) & CWW
3. Shri.Jayaprasad.D, Principal Chief Conservator of Forests (P & D)
4. Shri.Noyal Thomas, Principal Chief Conservator of Forests (FM)
5. Shri. P.Pugazhendi IFS, Addl. Principal Chief Conservator of Forests (Admn)
6. Shri.Sanjayan Kumar IFS, Chief Conservator of Forests (SC), Kollam
7. Shri.Pramod P.P, Chief Conservator of Forests & FD, Kottayam
8. Shri.Vijayanandan.K, Chief Conservator of Forests (EC), Palakkad
9. Shri.Anoop K.R, IFS, Chief Conservator of Forests (Central Circle), Thrissur
10. Shri.Arun.R.S, Chief Conservator of Forests (HRC), Kottayam
11. Smt. Silpa V Kumar IFS, TA to Head of Forest Force
12. Shri.Samuel Vanlalngheta Pachuau, IFS, TA to PCCF (FM)
13. Shri.Patil Suyog Subhash Rao, IFS, Deputy Director, Periyar East
14. Smt. Deepa K.S, IFS, Chief Conservator of Forests (Northern Circle)
15. Shri.Sujit.R, Deputy Director, Parambikulam Tiger Reserve
16. Shri.Vinayan.R, Deputy Conservator of Forests (WL)
17. Shri.Radhakrishnan S.R, Deputy Conservator of Forests (PE)
18. Shri.Anil.B, Assistant Conservator of Forests (BDC)
19. Shri.Benny Joseph, Deputy Director (Wildlife Education)
20. Dr.M.Balasubramoniam, LTME
21. Shri.Vishnu Vijayan, Biologist, Parambikulam Tiger Reserve
22. Shri.Clince P Jose, Conservation Biologist, South Wayanad
23. Shri.Vishnu.O, Conservation Biologist, Wayanad Wildlife Sanctuary.
24. Shri.Samuel George, Conservation Biologist, Peechi Wildlife Division
25. Shri.Anoop Vijayakumar, Conservation Biologist, PTCF
26. Shri.Ramesh Babu.M, Conservation Biologist, PTCF.
27. Shri.Rajesh Kumar.N, Conservation Biologist, Silent Valley National Park
28. Shri.Yathumon.M.A, Conservation Biologist, Aralam Wildlife Division

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Annexure 3.2

List of personnel attended ToT held on 22nd and 23rd March 2023 at Periyar TR

SN	Name and Designation of Personnel
1	Shri. Prasad P, Asst. Wildlife Warden, Aralam WLS
2	Shri. C.T. Ouseph, Asst. Wildlife Warden, Iukkii WL
3	Shri. Mohammed Raphy K.M., Asst. Wildlife Warden, Peechi WL
4	Shri. C.K. Sudheer, Asst. Wildlife Warden, Shendruney
5	Shri. N. Ganesan, Asst. Wildlife Warden, SVNP
6	Shri. Arun R.C. , Range Forest Officer, Anchenkovil
7	Shri. Prem Shamir K.P., Range Forest Officer, Chalakudy
8	Shri. Akhil V.A., Range Forest Officer, Malayattoor
9	Shri. Kannan S., Range Forest Officer, Kottayam
10	Shri. Biju K.V., Range Forest Officer, Kozhikode
11	Shri. Prasad Kumar B., Range Forest Officer, Mankulam
12	Shri. K.R. Krishnadas, Range Forest Officer, Nenmara
13	Shri. Boby Kumar K.P., Range Forest Officer, Nilambur North
14	Shri. Jyothish J., Range Forest Officer, PTR West
15	Shri. B. Dileep, Range Forest Officer, Punalur
16	Shri. N. Roopesh, Range Forest Officer, RRT, Wayanad
17	Shri. R. Sreeraj, Range Forest Officer, Shendruney WL
18	Shri. Dhaniklal G., Range Forest Officer, Thrissur
19	Shri. Remya S., Range Forest Officer, TVM Teritorial
20	Shri. Reahulal T., Range Forest Officer, TVM Wildlife
21	Shri. Ratheesh K.V., Range Forest Officer, Ranni
22	Shri. Delto L Markose, Range Forest Officer, Vazhachal
23	Shri. Sanoj S., Range Forest Officer (Trainee), Konni
24	Shri. Shaik Rasheed K.M., Range Forest Officer (Trainee), Kothamankalam
25	Shri. Vimal P., Range Forest Officer (Trainee), Kozhikode
26	Shri. Rajesekaran P., Range Forest Officer (Trainee), Mannarkad
27	Shri. Sanjaykumar H., Range Forest Officer (Trainee), Nilambur south
28	Shri. Vibinchandran V., Range Forest Officer (Trainee), Thenmala
29	Shri. Biju P Nair, Dy. Range Forest Officer, Marayur
30	Shri. Rajithbabu, Dy. Range Forest Officer, Palakkad
31	Shri. A. Sandhosh, Section Forest Officer, Shendruney WL
32	Shri. Hari C.M., Beat Forest Officer, Aralam WLS
33	Shri. Reney R Pillai, Deputy Director, Wildlife Education, Kottayam WLD
34	Shri. Ajeesh A.J., Wildlife Assistant, Munnar WD
35	Shri. B. Shaiju, Wildlife Assistant, Shendruney WL
36	Shri. Nisha P.A., Wildlife Assistant, SVNP
37	Shri. Rahul Ravindran, Wildlife Assistant, Wayanad WL
38	Shri. Rajesh, Wildlife Assistant, Neyyar WS
39	Shri. Salish J Menachey, Wildlife Assistant, Peechi WL

SN	Name and Designation of Personnel
40	Shri. Vishnu Vijayan, Conservation Biologist, Parambikulam
41	Shri. Samual George, Conservation Biologist, Peechi WL
42	Shri. Rajeshkumar N., Conservation Biologist, SVNP
43	Shri. Clince P Jose, Conservation Biologist, Wayanad south
44	Shri. Vishnu, O., Conservation Biologist, Wayanad WL
45	Shri. Anoop, V., Conservation Biologist, PTCF, Periyar Tiger Reserve
46	Shri. Ramesh Babu, Conservation Biologist, PTCF, Periyar Tiger Reserve
47	Dr. M. Balasubramanian, Lead Wildlife Monitoring Expert, PaTCoF, Parambikulam TR

Annexure 3.3

Details of Division-level training and participation

SN	Forest Division	Venue	Date of training	No. of participants
Training carried out by Parambikulam Tiger Conservation Foundation				
1	Kasargod FD	Forest IB, Parappa	17-04-2023	24
2	Kannur FD, Aralam and Kottiyur WLSs	Dormitory, Valayamchal, Aralam WLS	18-04-2023	34
3	Wayanad North FD and Tholpetty Range of Wayanad WLS	Dormitory, Begur, Tholpetty Range	19-04-2023	49
4	Wayanad WLS (except Tholpetty Range) and Wayanad South FD	Gajah, Sulthan Battery	20-04-2023	58
5	Kozhikkode FD and Malabar WLS	RFO Complex, Thamarassery	24-04-2023	40
6	Nilambur North and South FDs and Karimpuzha WLS	Vanasree Complex, Divisional Forest Office, Nilambur	25-04-2023	96
7	Silent Valley NP	Dormitory, Mukkali	26-04-2023	62
8	Mannarkad FD	Vanasree Complex, Divisional Forest Office, Mannarkad	27-04-2023	37
9	Palakkad FD	Dormitory, Dhoni	28-04-2023	34
10	Trainees at Forestry Training School, Walayar	Forestry Training School, Walayar	29-04-2023	52
11	Nemmara FD	Forest IB, Nelliyampathy	03-05-2023	39
12	Peechi-Vazhani and Chimmony WLSs and Thrissur FD	Vanasree Complex, Wildlife Warden Office, Peechi	04-05-2023	70
13	Chalakkudy FD and Vazhachal FD	Dormitory, Vazhachal	05-05-2023	76
14	Malayattoor FD and Thattekkad BS	Vanasree Complex, Divisional Forest Office, Malayattoor	06-05-2023	71
15	Parambikulam TR	Nature Study Hall, Anapady	10-05-2023	87
			Sub-Total	**829**
Training carried out by Periyar Tiger Conservation Foundation				
16	Mankulam FD	VSS Meeting Hall Under Mankulam FD	17-04-2023	19
17	Munnar FD and Munnar Wildlife Division (except Chinnar WLS)	Dormitory, Wildlife Warden Office, Munnar	18-04-2023	66
18	Marayur FD and Chinnar WLS of Munnar WLD	Dormitory, Chinnar WLS	19-04-2023	24
19	Kothamangalam FD	Kothamangalam	06-05-2023	22
20	Idukki WLS and Kottayam FD (except Erumely Range)	Dormitory, Idukki WLS	09-05-2023	30
21	Periyar East FD, Kumily Range of Kottayam FD and KFDC, Gavi	Rajiv Gandhi Complex, Thekkady	11-05-2023	42
22	Periyar West FD and Erumely Range of Kottayam FD	Community Hall, Kuzhimavu	04-05-2023	35
23	Ranni FD	Training Hall near Vadaserikkara IB, Vadaserikara	03-05-2023	68
24	Konni FD and Pathanapuram Range of Punalur FD	Training Hall near Konni IB, Konni	02-05-2023	32
25	Achenkovil FD	Inspection Bugalow at Achenkovil	29-04-2023	18
27	Punalur FD	Eroor Eco-Complex, Punalur FD	28-04-2023	27
28	Shendurney WLS and Thenmala FD	Dormitory, Shendurney WLS	08-05-2023	46
29	Anchal Range of Punalur FD	Punalur	08-05-2023	27

SN	Forest Division	Venue	Date of training	No. of participants
30	Thiruvananthapuram FD	Training Hall, Kottoor	26-04-2023	38
31	Thiruvananthapuram Wildlife Division and ABP	Training Hall, Kottoor	25-04-2023	30
32	Trainees at Forestry Training School, Arippa	Forestry Training School, Arippa	24-04-2023	29
			Sub-Total	**553**
			Grand Total	**1382**

Annexure 3.4

Details of Forest Divisions in the Elephant Reserves

SN	FDs/Range	Extent (km^2)	Extent (km^2) devoid of elephants	Extent (km^2) of elephant habitat
	ANAMUDI ER			
1	Nenmara FD*	310.697	37.100	273.597
2	Chalakkudy FD**	226.1	15.680	210.420
3	Vazhachal FD***	198.194	44.500	153.694
4	Thrissur FD#	213.147	182.507	30.640
5	Malayattoor FD	610.939	51.700	559.239
6	Mankulam FD	90.057	0.000	90.057
7	Munnar FD##	400.277	0.000	400.277
8	Marayoor FD	64.176	8.000	56.176
9	Kothamangalam FD	318.311	20.250	298.061
10	Kottayam FD (Kumily, Ayyappankovil and Nagarampara Ranges)+	499.284	265.592	233.692
11	Parambikulam Tiger Reserve++	643.66	22.900	620.760
12	Peechi and Chimmony WLSs	213.504	52.300	161.204
13	Idukki WLD - Thattekkad Bird Sanctuary	25.16	9.000	16.160
14	Idukki WLD – Idukki WLS	105.364	40.110	65.254
15	Munnar Wildlife Division	241.077	4.670	236.407
	Sub-Total	**4159.947**	**754.309**	**3405.638**
	PERIYAR ER			
1	Periyar Tiger Reserve (East)	709.675	28.000	681.675
2	Periyar Tiger Reserve (West)	216	6.000	210.000
3	Shendurney WLS	172.233	21.300	150.933
4	Thiruvananthapuram Wildlife Division	211.98	15.500	196.480
5	Kottayam FD (Erumeli Range)	164.318	66.180	98.138
6	Ranni FD	911.122	108.690	802.432
7	Konni FD	331.655	6.000	325.655
8	Achencoil FD	285.869	0.000	285.869
9	Punalur FD	275.707	234.260	41.447
10	Thenmala FD	148.944	10.500	138.444
11	Thiruvananthapuram FD	372.494	45.300	327.194
	Sub-Total	**3799.997**	**541.73**	**3258.267**
	NILAMBUR ER			
1	Wayanad South FD (Out of total 295.228 km^2, 178.763 km^2 is added to Wayanad ER)	116.465	0.000	116.465
2	Kozhikode FD (Out of total 310.005 km^2, 225.005 km^2 is added to Wayanad ER)	85	0.000	85.000
3	Nilambur North FD	439.987	20.10	419.887
4	Nilambur South FD	326.787	7.60	319.187

SN	FDs/Range	Extent (km^2)	Extent (km^2) devoid of elephants	Extent (km^2) of elephant habitat
5	Silent Valley Wildlife Division	237.491	0.000	237.491
6	Mannarkkad FD	430.326	26.90	403.426
7	Palakkad FD	263.707	58.81	204.897
	Sub-Total	**1899.763**	**113.41**	**1786.353**
	WAYANAD ER			
1	Kasargod FD	122.91	44.00	78.91
2	Kannur FD	158.651	44.15	114.50
3	Aralam Wildlife Division (Aralam & Kottiyur WLSs)	85.38	0.000	85.38
4	Wayanad North FD	224.099	35.32	188.78
5	Wayanad Wildlife Sanctuary	344.534	1.80	342.73
6	Wayanad South FD (Out of total 295.228 km^2, 116.465 km^2 of Meppadi Range under this Division is added to Nilambur ER)	178.763	31.82	146.94
7	Kozhikode FD (Out of total 310.005 km^2 which include 74.215 km^2 of Malabar WLS carved out from Peruvannamozhi Range, an extent of 85 km^2 which is part of Thamarassery Range is added to Nilambur ER)	225.005	9.80	215.21
	Sub-Total	**1339.342**	**166.890**	**1172.45**
	Grand Total	**11199.049**	**1576.339**	**9622.71**

Annexure 4.1

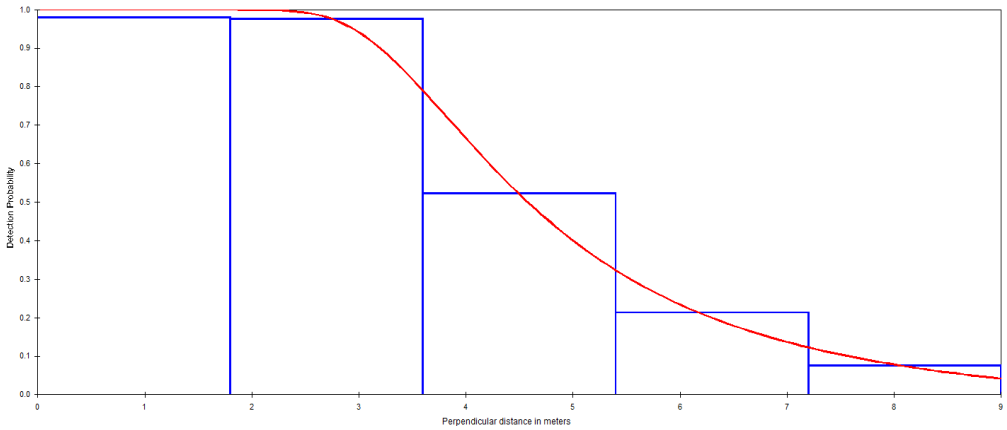
Details of dung analysis in Distance software

WAYANAD ER

Distance analysis results of various models for the data sets of Wayanad ER

Name	AIC	ESW/EDR	D	D LCL	D UCL	D CV	CV Width	Product
5 HR	2173.16	4.98	617.71	473.31	806.17	0.13	332.87	44.88
4 Uniform	1843.74	4.68	657.71	507.75	851.98	0.13	344.23	45.03
5 Uniform	2177.32	4.64	662.85	511.89	858.33	0.13	346.45	45.25
8 HR	2936.26	4.81	639.17	490.21	833.39	0.13	343.18	46.10
9 HR	3085.86	4.68	657.56	504.49	857.07	0.13	352.58	47.30
9 Negative	3089.04	4.53	678.61	520.90	884.07	0.13	363.17	48.62
6 HR	2459.34	4.65	661.81	505.55	866.37	0.14	360.83	49.25
4 HR	1846.06	4.71	652.59	497.53	855.97	0.14	358.43	49.29
8 HN	2937.70	4.38	701.97	539.89	912.72	0.13	372.83	49.52
4 HN	1842.33	4.39	700.64	538.66	911.33	0.13	372.67	49.57
9 Uniform	3087.05	4.55	676.14	516.69	884.80	0.14	368.11	50.16
6 HN	2459.78	4.31	713.49	548.73	927.71	0.13	378.98	50.34
7 Uniform	2727.95	4.96	619.79	467.91	820.97	0.14	353.06	50.41
7 HN	2731.10	4.84	635.61	481.15	839.65	0.14	358.50	50.67
9 HN	3088.27	4.25	723.86	556.80	941.03	0.13	384.23	51.00
5 HN	2174.82	4.88	630.78	476.43	835.13	0.14	358.70	51.12
6 Uniform	2460.91	4.32	711.23	545.10	927.99	0.13	382.89	51.58
7 HR	2728.45	4.69	656.28	496.92	866.76	0.14	369.84	52.22
8 Uniform	2936.99	4.66	660.61	500.58	871.80	0.14	371.22	52.26
8 Negative	2938.99	4.66	660.61	500.58	871.80	0.14	371.22	52.26
5 Negative	2179.23	4.56	674.72	508.88	894.60	0.14	385.72	55.27
7 Negative	2733.39	4.57	672.72	503.44	898.92	0.15	395.48	58.31
6 Negative	2462.82	4.25	722.96	545.46	958.23	0.14	412.77	59.07
4 Negative	1844.27	4.33	709.74	533.37	944.43	0.15	411.07	59.69

Plots showing the detection probability for the data sets of Wayanad ER

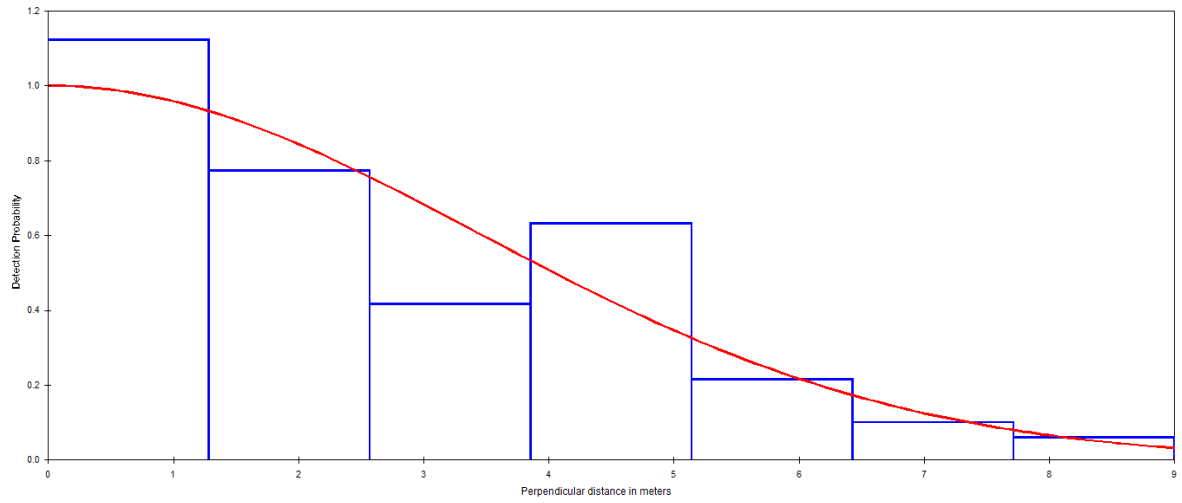


NILAMBUR ER

Distance analysis results of various models for the data sets of Nilambur ER

Name	AIC	ESW/EDR	D	D LCL	D UCL	D CV	CV Width	Product
7 HN	1652.97	4.27	338.68	268.77	426.77	0.12	158.00	18.54
7 Uniform	1654.78	4.30	335.91	264.97	425.85	0.12	160.88	19.39
9 Uniform	1863.53	4.02	359.54	284.55	454.29	0.12	169.73	20.16
5 HN	1330.36	4.00	361.60	286.36	456.60	0.12	170.24	20.16
6 HN	1477.37	3.83	376.90	298.88	475.28	0.12	176.40	20.76
9 HN	1862.30	3.76	384.60	305.44	484.28	0.12	178.83	20.91
4 Uniform	1097.92	3.68	392.94	305.77	504.95	0.13	199.18	25.43
8 HN	1777.88	3.52	410.85	318.57	529.84	0.13	211.27	27.37
8 Uniform	1778.57	3.47	416.65	323.33	536.92	0.13	213.59	27.58
6 Uniform	1475.35	3.46	417.85	323.12	540.37	0.13	217.26	28.46
5 Uniform	1330.15	3.59	402.33	309.44	523.11	0.13	213.66	28.59
9 Negative	1861.27	3.55	407.20	312.83	530.04	0.13	217.21	29.19
4 HN	1097.89	3.49	413.60	318.16	537.67	0.13	219.51	29.35
6 Negative	1478.17	3.36	429.73	331.67	556.78	0.13	225.11	29.71
4 Negative	1097.86	3.43	420.77	322.44	549.07	0.14	226.63	30.76
8 Negative	1778.30	2.83	509.84	395.29	657.58	0.13	262.28	33.99
5 Negative	1330.77	2.95	490.04	376.78	637.33	0.13	260.54	34.90
8 HR	1780.74	3.64	396.69	295.05	533.36	0.15	238.31	36.07
9 HR	1864.30	3.60	401.12	296.87	541.99	0.15	245.11	37.73
7 HR	1652.85	3.81	379.52	277.44	519.15	0.16	241.71	38.76
6 HR	1480.21	3.65	395.73	278.65	562.01	0.18	283.36	50.99
5 HR	1332.67	3.64	396.90	268.49	586.72	0.20	318.23	63.95
7 Negative	1648.54	2.61	554.65	370.80	829.65	0.21	458.85	95.07
4 HR	1098.02	3.43	421.73	236.07	753.41	0.30	517.34	156.24

Plots showing the detection probability for the data sets of Nilambur ER

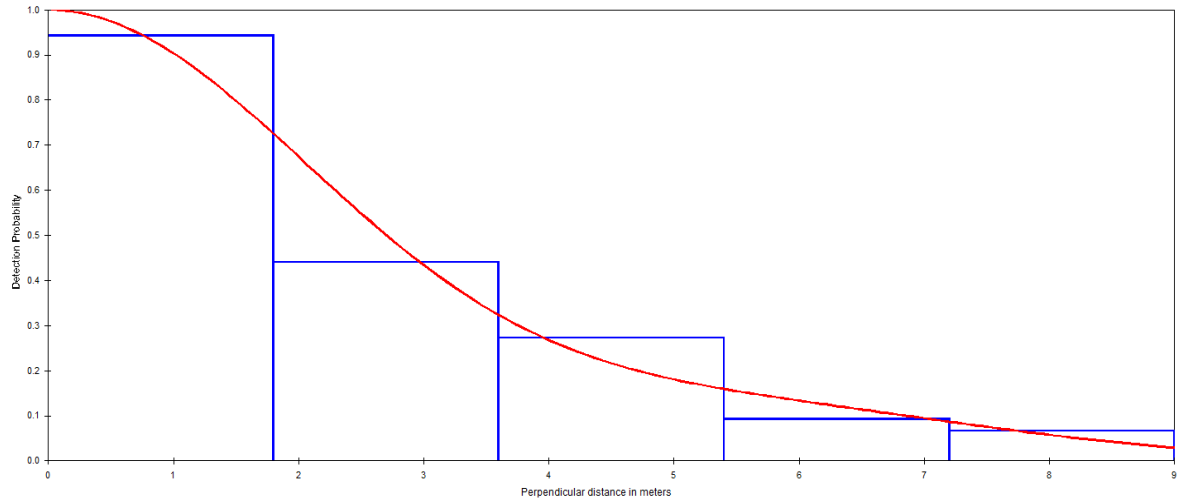


ANAMUDI ER

Distance analysis results of various models for the data sets of Anamudi ER

Name	AIC	ESW/EDR	D	D LCL	D UCL	D CV	CV Width	Product
5 HN	1980.86	3.26	413.90	338.39	506.25	0.10	167.86	17.22
4 HN	1636.74	3.07	440.24	360.38	537.81	0.10	177.44	18.09
4 Uniform	1636.74	3.03	446.20	364.78	545.80	0.10	181.02	18.57
5 Uniform	1977.04	3.08	438.16	354.49	541.57	0.11	187.09	20.21
8 Uniform	2684.59	2.70	501.06	406.32	617.90	0.11	211.58	22.60
9 Uniform	2858.12	2.66	508.12	412.58	625.77	0.11	213.19	22.63
9 HN	2856.49	2.64	511.69	415.61	629.97	0.11	214.35	22.72
8 HN	2685.45	2.64	511.55	415.36	630.01	0.11	214.65	22.79
5 Negative	1971.60	2.52	535.26	436.43	656.46	0.10	220.04	22.88
7 HN	2474.00	2.61	518.74	420.82	639.43	0.11	218.61	23.31
6 Uniform	2225.65	2.64	511.78	413.79	632.98	0.11	219.19	23.75
6 HN	2225.42	2.71	497.89	399.65	620.27	0.11	220.62	24.74
7 Negative	2482.81	2.19	617.35	503.65	756.72	0.10	253.07	26.24
9 Negative	2856.26	2.16	625.37	509.63	767.38	0.10	257.76	26.87
6 Negative	2226.03	2.18	619.10	491.35	780.07	0.12	288.72	34.07
8 Negative	2684.18	2.23	606.69	474.82	775.18	0.13	300.35	37.62
8 HR	2685.58	2.50	539.82	393.95	739.71	0.16	345.76	55.86
9 HR	2858.86	2.40	563.78	405.77	783.32	0.17	377.56	63.72
7 HR	2484.55	2.42	559.02	369.71	845.25	0.21	475.54	101.32
5 HR	1976.30	2.83	476.99	296.07	768.46	0.25	472.39	116.52
4 Negative	1636.74	1.65	819.12	556.51	1205.64	0.20	649.13	129.11
6 HR	2226.53	2.29	589.01	367.28	944.60	0.24	577.31	140.98
4 HR	1636.75	2.06	657.12	240.35	1796.59	0.55	1556.24	852.77

Plots showing the detection probability for the data sets of Anamudi ER

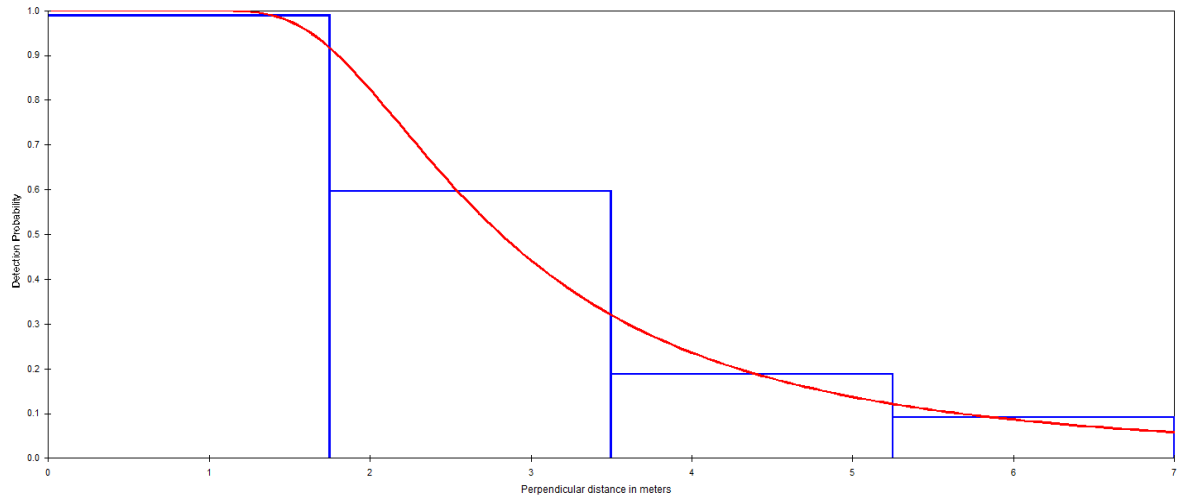


PERIYAR ER

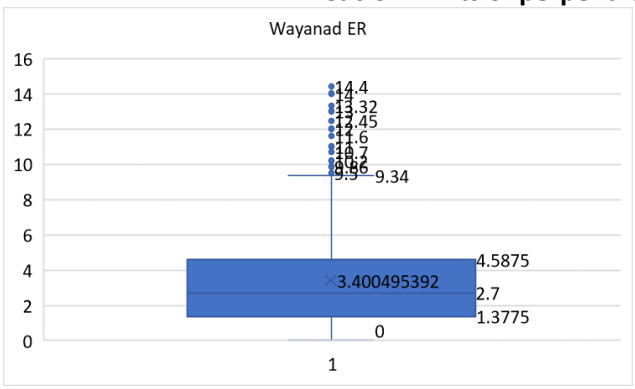
Distance analysis results of various models for the data sets of Periyar ER

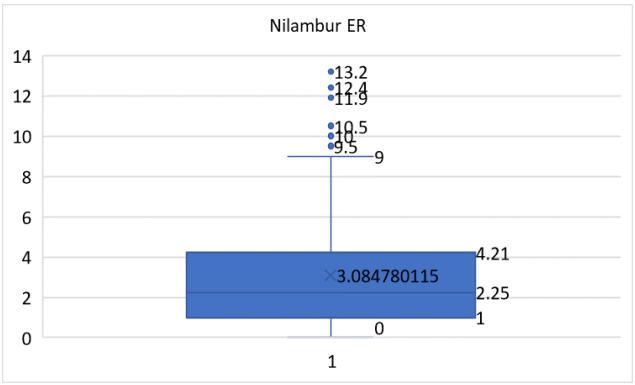
Name	AIC	ESW/EDR	D	D LCL	D UCL	D CV	CV Width	Product
4 HR	2253.67	3.26	530.02	429.32	654.33	0.11	225.01	24.14
5 Uniform	2751.77	3.07	562.96	457.44	692.81	0.11	235.37	24.87
5 HR	2750.78	3.19	542.65	438.39	671.71	0.11	233.31	25.36
4 Uniform	2253.63	2.96	583.82	474.57	718.22	0.11	243.65	25.69
4 Negative	2255.63	2.96	583.82	474.57	718.22	0.11	243.65	25.69
5 HN	2751.51	2.89	598.40	483.17	741.11	0.11	257.94	28.10
6 HN	3104.09	3.14	551.45	441.07	689.46	0.11	248.38	28.29
7 HN	3378.34	3.01	574.70	460.48	717.26	0.11	256.78	29.01
4 HN	2254.85	3.19	542.47	430.91	682.90	0.12	251.98	29.60
7 HR	3377.69	2.95	586.75	467.39	736.59	0.12	269.20	31.23
6 HR	3101.52	2.88	599.83	476.27	755.45	0.12	279.18	32.86
7 Negative	3383.87	2.87	601.73	474.19	763.56	0.12	289.37	35.19
5 Negative	2751.76	2.65	653.58	518.42	823.98	0.12	305.56	36.12
6 Negative	3107.81	2.89	598.53	468.21	765.12	0.13	296.91	37.24

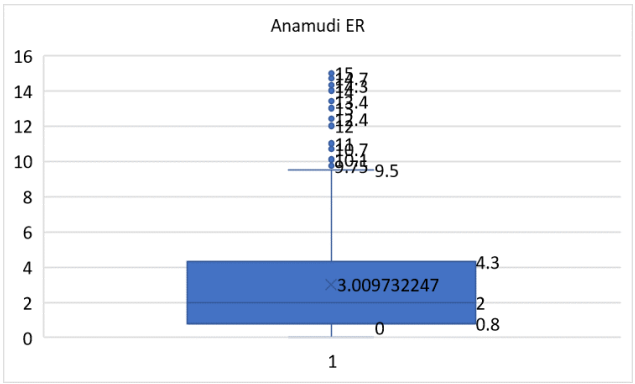
Plots showing the detection probability for the data sets of Periyar ER

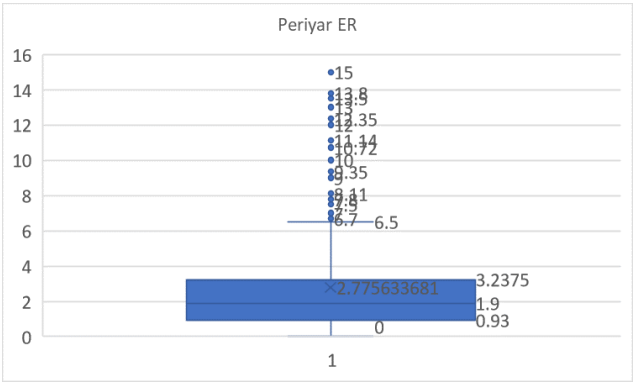


Cut-off limits of perpendicular distances of dung piles









Annexure 4.2

Individuals of various age-sex categories counted on first (block count) and third (waterhole count) days in various ERs

Name of ER	*Count Method*	*No. of blocks*	*No. of sighting*	*Total Number*	*AM*	*SAM*	*JM*	*Makhna*	*AF*	*SAF*	*JF*	*Calf*	*Unknown*
Anamudi	**BC**	197	72	237	27	11	3	3	86	33	6	33	35
	WC	197	59	230	30	24	10	1	92	25	14	23	11
	Sub Total		**131**	**467**	**57**	**35**	**13**	**4**	**178**	**58**	**20**	**56**	**46**
Nilambur	**BC**	118	29	64	13	7		1	17	7	2	8	9
	WC	118	25	70	14	4	1	1	21	4	5	15	5
	Sub Total		**54**	**134**	**27**	**11**	**1**	**2**	**38**	**11**	**7**	**23**	**14**
Periyar	**BC**	206	102	289	37	22	4	7	123	36	10	36	14
	WC	206	83	273	23	24	5	4	105	42	19	37	14
	Sub Total		**185**	**562**	**60**	**46**	**9**	**11**	**228**	**78**	**29**	**73**	**28**
Wayanad	**BC**	89	48	110	22	3		5	40	4	1	21	14
	WC	89	38	133	22	5	4	1	57	17	0	21	6
	Sub Total		**86**	**243**	**44**	**8**	**4**	**6**	**97**	**21**	**1**	**42**	**20**
Combined	**BC**	**610**	**251**	**700**	**99**	**43**	**7**	**16**	**266**	**80**	**19**	**98**	**72**
	WC	610	205	706	89	57	20	7	275	88	38	96	36
	Sub Total		**456**	**1406**	**188**	**100**	**27**	**23**	**541**	**168**	**57**	**194**	**108**
	Grand Total	**610**	**456**	**1406**	**188**	**100**	**27**	**23**	**541**	**168**	**57**	**194**	**108**

BC=Block Count; WC=Waterhole Count; AM=Adult Male; SAM=Sub-Adult Male; JM=Juvenile Male; AF=Adult Female; SAF=Sub-Adult Female; JF=Juvenile Female