

ROLE OF SOCIAL AND ECOLOGICAL ATTRIBUTES IN HUMAN-LARGE MAMMAL INTERACTION: MULTI- SPECIES APPROACH IN TAMIL NADU, INDIA

**Thesis submitted to Bharathiar University in partial fulfillment of the
requirements for the award of the degree of**

DOCTOR OF PHILOSOPHY IN ZOOLOGY

**By
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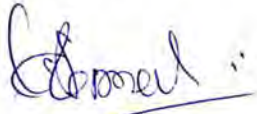
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I, Ms. Milda David, hereby declare that the thesis, entitled “**Role of social and ecological attributes in human-large mammal interaction: multi-species approach in Tamil Nadu, India**” submitted to Bharathiar University, in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy in **Zoology**, is a record of original and independent research work done by me during **January 2021- September 2025** under the supervision and guidance of **Dr. T. Ramesh**, Senior Scientist at **Sálim Ali Centre for Ornithology and Natural History (SACON)** (South India Centre of Wildlife Institute of India, MoEFCC, Govt. of India), Coimbatore, Tamil Nadu, India and it has not formed the basis for the award of any Degree/ Diploma/ Associateship/ Fellowship or other similar title to any candidate of any University.



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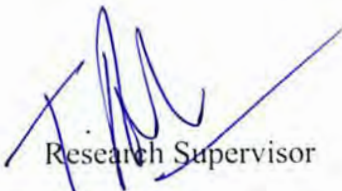
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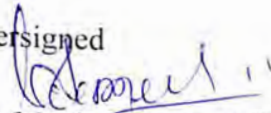
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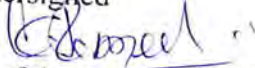
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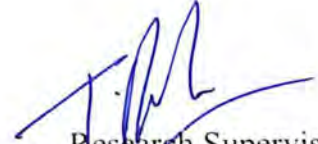
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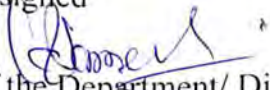
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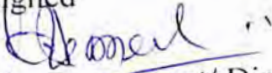
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Acknowledgement

ACKNOWLEDGEMENT

This thesis marks the conclusion of a long, winding journey that began six years ago when I joined SACON as a Project Fellow. This journey was far from easy, and I didn't walk it alone. I was carried, guided, protected, challenged, and cheered by many wonderful people. First of all, I thank God Almighty for the strength and perseverance that made this work possible.

At the heart of this journey is my PhD supervisor, Dr. T. Ramesh. Thank you, sir, for constantly encouraging me to think critically and to believe that impactful research is possible when one stays persistent. I am also immensely thankful to Dr. Riddhika, for being a steady support system throughout my PhD.

This thesis is part of a five-year project titled "Assessing anthropogenic threats to large carnivore population in the Western Ghats part of Tamil Nadu". I acknowledge the Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India, for funding this project under the Ramanujan Fellowship awarded to Dr. T. Ramesh. Without this support, my PhD wouldn't have been possible.

I am grateful to the former Principal Chief Conservator of Forests, Mr. Sundar Raj, IFS, and the Chief Wildlife Warden, Mr. P.C. Tyagi, IFS, for providing the necessary permissions. Thanks to Dr. K. Sankar (former Director, SACON), for all the logistical support during my fieldwork. I am also thankful to Dr. S. Muralidharan (former Director-in-charge, SACON), Dr. P. R. Arun (Senior Principal Scientist and former research co-ordinator) and Mr. Vaidhyanathan (former PA to Director), for all the academic and administrative support. My heartfelt appreciation to the administration of Bharathiar University, and my Doctoral Advisory Committee members - Dr. A. Manimekalan (Professor, Bharathiar University), Dr. S. Muralidharan and Dr. P. Promod (Senior Principal Scientist, SACON), for their valuable feedback during the review meetings.

I extend my gratitude to all the officials of Tamil Nadu Forest Department for their help during the fieldwork. I am highly indebted to all the Forest Range Officers for their time and co-operation during the interviews. I also deeply acknowledge the Forest Guards, Forest Watchers and Anti-Poaching Watchers who guided and safe-guarded me and my team, risking their lives along the high human-large mammal conflict zones.

I am grateful to the Gujarat Ecological Society and Kachnar Trust for recognising my work with the Hasmukh Shah Memorial Award, under Research Category (2024). I am thankful to Anusandhan National Research Foundation, SERB and British Ecological Society for the travel support that made it possible to attend 2024 Ecological Society of America Annual Meeting, held at Long Beach, California, USA, in-person. I thank International Federation of Mammalogists for the student awards at 13th International Mammalogical Congress, Alaska and Association for Tropical Biology and Conservation (ATBC) for Global Grants to support my participation in ATBC 2024.

My fieldwork was a combined effort of many people. I extend my sincere gratitude to my Research Assistant, Mr. M. Thanikodi, who helped a lot with field data collection- a lifeline in every sense! Thanks to Ms. Gayathri V., Dr. K. Ashish, James, and Madhan for their help in field data collection. I thank our jeep drivers Ranjith and Sridhar, who tackled rough terrain without hesitation. A warm thanks to all the project fellows, interns, and research scholars of SACON: Ankit, Basawaraj, Thahir, Baskaran, Karthik, Pop, Senkathirvanan, Sasi Priyan, Anurag, Tatsama, and Maxim. Thanks to the local communities who opened their doors and shared stories during the field survey- thank you for your trust.

I thank all other scientists of SACON for their unwavering support - Dr. Shomita Mukherjee, Dr. Rajah Jayapal, Dr. H.N Kumara, Dr. Manchi Shirish, Dr. S. Babu, Dr. Vidyadhar Atkore, Dr. Ashuthosh and Dr. Aditi Mukherjee. I am also thankful to the Mr. Jayakumar (Administration Officer, SACON), Mr. Aneesh (Finance Officer, SACON), Mr. Manoharan (Librarian-in-charge, SACON), Mr. Srinivasan (Computer Technician, SACON), Mr. Sundaraj (former site engineer) and all the staff members who helped with the administrative works. I thank all the hostel wardens (Dr. Shirish, Dr. Aditi, Dr. Babu, and Dr. Ashuthosh) for their support while I was a SACON hosteller. I thank all akkas and annas of SACON for the warmth and comfort they provided; thank you for the tea, small talks, and kindness that made life easier on tough days.

To Dr. Priya Davidar, my biggest inspiration in the field of conservation biology, Dr. K. Muthamizh Selvan for all the encouragement, and Dr. Anu Anto, who saw my potential during my undergraduate years and continues to be a mentor.

I am forever grateful to all my professors of Pondicherry University and to my wonderful friends- Ujali, Joanica, Akhil, Arjun, Gokul, Lobo, Anjali, Amal, Zaki, Teju, Naveen, Chandika, Sulffi, Madhuraj, Navaneetha, Ayesha, Petrina, Avishna, Dinesh, and Rennu chechi, for being

there when I needed it most. Special thanks to Elsa, whose presence in the US felt like home, and to my international family- Harshita, Kanchana, Greg, Mithun, Skiddy, Woody, and Emerald. A big thanks to my friends from Indian Institutes of Science Education and Research (IISER), Tirupati- Swati, Kartik, Chiti and Nivedha, for cheering me afar.

Extending my heartfelt gratitude to my friends from SACON- Sreeja, Aakriti, Sanyukta, Andrew, Joydeep, Avadoot, Sushanth, Praphul, Gaurav Sonawane, Kanchan, Ankit, Hitesh, Asit, Subhadra, Niveditha, Sujin, Hari, Gaurav Singh, Nithin, Arun, Divya Priya, Ritika, Bhawani, Yashaswini, Keval, Anoop and Harihara Prasad- each of you added something meaningful to my journey. A big thanks to Vicky, for being my go-to emergency contact in Anaikatti. I am thankful to many wonderful people in Anaikatti- Surya (*thambi*) and his family, Valli akka, kids of Alamaramedu, who reminded me to smile even on the darkest times.

To my grandmother (*Ammachi*), if only you were here to see this. I miss you dearly. I know you would have told the world about my achievements with pride. I am also grateful to all my cousins and extended family members for their incredible support.

Finally, to my Appa, Amma, and Aravind - my universe. You held me together when things fell apart. Appa and Amma, you made sacrifices no one knew about, never letting the weight of the world fall on my shoulders. Every step I took was because you stood behind me, steady and silent, with lots of love. Aravind, thank you for standing beside me when I lost faith in myself. Your quiet strength and belief kept me going.

To everyone who supported me along the way but whose names I may have unintentionally missed- thank you, with all my heart!

~ *Milda.*

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Citation

David, Milda. (2026). Role of social and ecological attributes in human-large mammal interaction: multi-species approach in Tamil Nadu, India. Sálim Ali Centre for Ornithology and Natural History, Bharathiar University, Coimbatore, Tamil Nadu, India. Pp 298.

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Glossary

GLOSSARY

ABR	Agasthyamalai Biosphere Reserve
AIC	Akaike's Information Criterion
APW	Anti-Poaching Watcher
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CNWLS	Cauvery North Wildlife Sanctuary
CWD	Cost-weighted Distance
EPT	Elephant-Proof Trench
FA	Fringe Area
FD	Forest Division
FRO	Forest Range Officer
GLM	Generalized Linear Model
HCC	Human-Carnivore Conflict
HEC	Human-Elephant Conflict
HGC	Human-Gaur Conflict
HLMC	Human-Large Mammal Conflict
HMC	Human-Megaherbivore Conflict
HWC	Human-Wildlife Conflict
HWI	Human-Wildlife Interaction
IDWH	Integrated Development of Wildlife Habitat
KMTR	Kalakkad Mundanthurai Tiger Reserve
LCP	Least Cost Path
MSL	Mean Sea Level
MTR	Mudumalai Tiger Reserve
NABARD	National Bank for Agriculture and Rural Development
NBR	Nilgiri Biosphere Reserve
NGO	Non-Governmental Organization
NTFP	Non-Timber Forest Produce
PA	Protected Area
RF	Reserved Forest
RSF	Resource Selection Function
SADP	Special Area Demonstration Program
STR	Sathyamangalam Tiger Reserve

TBGP	Tamil Nadu Biodiversity Conservation and Greening Project
TN	Tamil Nadu
WEGPTN	Western and Eastern Ghats part of Tamil Nadu
WLS	Wildlife Sanctuary

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Summary

SUMMARY

Escalating anthropogenic pressure and ensuing human-large mammal conflict (HLMC) incidents jeopardize the wildlife conservation goals as well as security of human life and livelihoods. It results in loss of human life and livestock, damage to crop and property, leading to negative perceptions among the local communities, and further retaliatory killing of conflict animals. Evidentially, large mammal populations are declining at a faster pace majorly due to anthropogenic pressures such as habitat loss and fragmentation, poaching, and retaliatory killing. The interface area, where the forest give way to the agricultural matrix and human settlements, is where the human-wildlife conflict (HWC) is most frequent, consequential and complex. These edge habitats act as a demographic sink, especially for wide-ranging species, having mortality rates and extinction risk within and beyond the forest reserve boundaries often higher than inside core PAs (Woodroffe and Ginsberg, 1998). It is crucial to ascertain the intensity of conflict and its ecological and anthropogenic determinants at these interface areas to develop appropriate mitigation measures to conserve the populations of large mammals, secure human life and promote co-existence in the shared landscapes. The major objectives of the study are to (a) assess socio-ecological characteristics of HLMC across the management gradients, (b) identify disparities in resource allocation between Protected Areas (PAs) and outside PAs and its effect on HWC, and (c) determine the effect of anthropogenic pressure on the distributional patterns of large mammals. My study species include tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), Asian elephant (*Elephas maximus*) and gaur (*Bos gaurus*), that contributes to a major share of HWC incidents in Tamil Nadu. A multi-species study in such large and contiguous landscape of conservation importance can bring out the actual pattern of HLMC in the State and help policy-makers to develop effective mitigation measures.

Towards the first objective, I used a systematic grid-based (5x5 km) sampling framework (n=485), across an area of 14,200 km² encompassing sixteen Forest Divisions (FD), covering PAs, Outside PAs and its Fringe Areas (FAs) of Western and Eastern Ghats part of Tamil Nadu (WEGPTN), India, namely, Kanyakumari Wildlife Sanctuary (WLS), Kalakad-Mundanthurai Tiger Reserve (KMTR), Nellai WLS, Srivilliputhur Grizzled Squirrel Sanctuary, Megamalai WLS, Coimbatore FD, Kodaikanal WLS, Theni FD, Nilgiri FD, Gudalur FD, Mudumalai Tiger Reserve (MTR), Sathyamangalam Tiger Reserve (STR), Erode FD, Dharmapuri FD, Cauvery North WLS (CNWLS) and Hosur FD. The data was collected between November 2017 and

March 2020 based on conflict incidents from tiger, leopard, dhole, elephant, and gaur for the past five years, through semi-structured interviews (n=1460) of local communities.

I identified the local people's perception towards coexistence and the socio-economic factors driving them. I observed that 90% (n=1248) of the surveyed population had a negative perception towards coexisting with wildlife, while 7% (n=103) expressed a positive perspective, and 3% (n=38) maintained an indifferent stance. Notably, 79% (n=1091) of the sampled population resided within Fringe Areas (FAs), 13% (n=178) in Protected Areas (PAs), and 9% (n=120) in Reserved Forests (RFs). Among them, 90% (n=160) of the population from PA had negative, 9% (n=16) had positive and 1% (n=2) had indifferent attitude towards coexisting with wildlife; In RFs, 73% (n=88) and 27% (n=32) had negative and positive view towards coexisting with wildlife, respectively. Whereas, in FAs, 92% (n=1000), 5% (n=55) and 3% (n=36) had negative, positive, and indifferent view towards coexisting with wildlife, respectively. Top multinomial regression models discerned the most influential variables determining the perception of local communities regarding coexistence with wildlife. These models elucidated that people's perception of coexisting with wildlife, especially large mammals, was negatively influenced by decreased availability of basic amenities, lack of conductance of awareness program, an increased perception of the rise in HLHC incidents, increased prevalence of disease in livestock, increased negative view on Forest Department, increased fear of wildlife, decreased intensity of livestock depredation and increased crop depredation.

Forty eight percent (n=694) of households reported having experienced human-carnivore conflict in the form of livestock depredations. Most of the livestock were killed by large carnivores in the mornings up until mid-day, between 6 am and 12 pm, coinciding with livestock grazing time inside the forest. Only a few tiger and leopard attacks occurred during the nights, followed by evening; the attacks were minimum during afternoon hours. Dhole attacks peaked in the early mid-evening hours and afternoon; no incidences of livestock predation by dholes occurred during night. Using the Generalized Linear Model (GLM) approach, the importance of potential predictor variables of HLHC was examined. Livestock predation risk by the tiger, leopard and dhole were found to be driven by the size of livestock species, dependency of local people on the forest, topography, proximity to the water body and forest boundary, precipitation, and forest cover. The probability of livestock depredation by tiger increased with a higher relative abundance of cow/buffalo, higher dependence of people on forests, greater proximity to water sources, shorter distance to forest boundaries, relatively

higher elevations and villages located within the forest areas, particularly in core areas of PAs; Livestock depredation risk probability from leopard increased with relatively higher abundance of goat/sheep, domestic dog, higher dependence on the forest by households and an increase in topographical slope. The probability of livestock depredation by dhole increased with higher forest cover loss, increase in the relative abundance of goat/sheep, greater dependence on the forest by households, and relatively lower precipitation. The risk of predation from leopard and dhole exhibited high spatial overlap, and predation by leopards was higher than dhole and tiger. Livestock predation by leopard and dhole was frequent in open areas of RF and buffer zones, while that from tiger occurred in densely forested core regions of PAs. Forty five percent (n=660) and ten percent (n=140) of households surveyed reported experiencing elephant and gaur conflict, respectively. Of these, both elephant and gaur are largely involved in crop damage, followed by property damage, human injury/death. Unlike large carnivores, most of the conflict incidents by elephant and gaur peaked in the night, followed by morning, evening and afternoon. Using GLM, I found that the major variables that influenced elephant and gaur conflict with man were: percentage of crop cover, distance to the water source, the number of major crops grown, the number of minor crops grown, mean annual precipitation and mean slope. The probability of human-elephant conflict increased with increased crop cover, increase in distance to the water source, number of major and minor crops grown, while the conflict decreased with an increase in mean annual precipitation and mean slope. The risk of human-gaur conflict increased with lower percentage of crop cover, increase in distance to the water source, number of major crops grown, increase in mean annual precipitation and mean slope. I found that households inside RFs to report elephant conflict the most, followed by PAs and FAs. The reported gaur conflict was more in FAs, followed by RFs and PAs. I identified ca. 175 km², 420km², 430km², 8900 km², 625 km² of the total sampled area, prone to tiger, leopard, dhole, elephant and gaur conflict with man, respectively.

I conducted a semi-structured questionnaire survey with the Forest Range Officers (FROs) of all sixteen FDs across the WEGPTN, between November 2018 and March 2020, to address the second objective. I investigated the patterns of human-wildlife interactions, employed mitigation measures and their effectiveness, poaching incidents, and availability of manpower and resources. The study highlighted the disparity in resource allocation among PAs and outside PAs though the intensity of conservation issues was similar. Over 50% of the FROs reported an increase in human-wildlife conflict incidents during the past five years. Major species involved in the conflict in PAs and outside PAs were elephant, wild pig (*Sus scrofa*),

leopard, bonnet macaque (*Macaca radiata*), followed by sloth bear (*Melursus ursinus*), sambar (*Rusa unicolor*) (more in PAs), gaur (more in outside PAs), dhole, chital (*Axis axis*), and tiger. There were no variations in the mitigation measures employed in PAs and outside PAs. The endangered species, namely tiger (only in PAs), leopard, elephant, and pangolin (*Manis crassicaudata*) were amongst the fourteen wildlife species poached in the PAs and outside PAs, although wild pig, sambar, black-naped hare (*Lepus nigricollis*), and chital dominated the list. Prevalent methods for poaching were snares, trained dogs, guns (dominant in PAs), followed by hand-made bombs, poisoning, cage traps, electric traps (only outside PAs), and food baits. Fund availability, anti-poaching camps and anti-poaching watchers were insufficient in outside PAs. Over 50% of the FROs reported a decrease in poaching incidences in the past five years with improved wildlife management strategies.

Based on the information gathered, I chose nine high-conflict zones, covering PAs and outside PAs across the WEGPTN (MTR, STR, CNWLS, Gudalur FD, Nilgiris FD, Coimbatore FD, Erode FD, Dharmapuri FD and Hosur FD) and conducted ecological sign survey and vegetation survey between May 2019 and March 2021 to ascertain the occupancy of large mammals and quantify degree of human disturbances inside the forests. Considering the average home range size of the dominant large mammal species, 10x10 km sampling grids were laid across the entire study area. I used a systematic grid-based Markovian model occupancy framework to identify the impact of ecological and anthropogenic variables (prey abundance, habitat features, direct human disturbance and habitat patchiness) on large mammal occupancy and mapped the Least Cost Pathway (LCP) and assess the Cost-Weighted Distance (CWD) analysis at a 100km² scale. I found that tiger and dhole occupancy was driven by the abundance of large and medium-sized prey. However, leopards relied on the available small prey species and utilised perforated forest patches surrounding PAs. Broadly, large mammal occupancy was more in the contiguous forests with ample water sources and decreased in habitats with increased human disturbances and habitat patchiness. I found that tiger occupancy was highly confined to the contiguous forests of PAs while the rest of the large mammal species had scattered but concentrated occupancy in PAs. All the study species exhibited least habitat selection and permeability around highly fragmented landscapes, located farther from PAs. Accordingly, as the distance from PAs increased, the CWD also increased. I identified 87, 67, 78, 77 and 81 actively used LCPs respectively for tiger, leopard, dhole, elephant and gaur. There were 17, 41, 23, 26 and 23 optimized LCPs for tiger, leopard, dhole, elephant, and gaur, respectively. Among the 17 optimized LCP for tiger, Euclidean distance value ranged from 22 to 86 km with CWD values between 25 and 150 km. From 41 optimized LCPs for leopard, the Euclidean

distance values ranged between 14 and 139 km, whereas, CWD values stretched between 34 and 1,928 km. The Euclidean distance values of dhole were between 22 and 106 km with a CWD value ranging from 24 and 512 km in the generated 23 optimized LCPs. For elephant, there were 26 optimized LCPs, with Euclidean distance extending between 22 and 86 km; however, the CWD values ranged between 24 and 134 km. Among the 23 optimized LCPs for gaur, Euclidean distance value ranged from 22 and 78 km but the CWD value extended between 24 and 116 km. The LCP maps identified several pinch points for large mammal movement particularly outside PAs, including fragmented parts of Nilgiris, Gudalur, Coimbatore, and Dharmapuri FDs, highlighting critical regions for restoring core habitat connectivity. The substantial proportion of large mammals inhabiting outside PAs demands strong efforts for habitat restoration and minimising further habitat degradation, which can also reduce the risk of HLMC.

HLMC are inevitable when natural landscapes undergo modifications. Bringing down the HLMC incidents to a tolerable limit through effective mitigation measures is the viable solution to ensure harmonious existence of people and wildlife in a forest ecosystem. Findings underscore the importance of identifying factors affecting people's perception towards coexistence, priority conflict hotspots, large mammal movement pathways, ecological and anthropogenic determinants of HLMC and large mammal occupancy, and the effectiveness of employed conflict mitigation measures. The conflict hotspot and corridor maps provide a powerful visual tool to understand patterns of HLMC and movement pattern of large mammals, respectively, at a landscape level to the stakeholders. The identified HLMC zones and the high resistance areas, regardless of PAs/outside PAs, should be provided with sufficient resources to mitigate conflict and landscape impermeability. Improved livestock husbandry practices, constructing predator-proof enclosures, and using shock-collars in high livestock depredation areas can be effective in decreasing the frequency of human-large carnivore conflict. Changing the cropping patterns, using a combination of elephant proof trench and electric fence, using early warning systems through Artificial Intelligence (AI) sensors, mobile technology and drones in the high conflict areas can reduce elephant and gaur conflict with humans. Providing timely compensation to the affected household is also an important mitigation measure to reduce the negative attitude of local communities. The study emphasises the need for forest habitat restoration by abating biotic pressure within the forest boundary, thereby enhancing prey abundance, availability of water resources, improved habitat connectivity to increase large mammal occupancy, reduce large mammal movement resistance within the forests, reduce HLMC and promote coexistence.

Chapter 1

CHAPTER 1

Introduction

Growing human population and the associated natural resource exploitation are emerging threats to wildlife in the current anthropogenic era. Large mammals are more susceptible to these changes since they are wide-ranging and depend on a broad spectrum of habitats including forests, grasslands and human-dominated mosaic habitats (Desai, 1991; DeFries et al., 2010; Karanth et al., 2010; Athreya et al., 2013). Habitat loss and fragmentation by agricultural expansion, linear infrastructure development and overexploitation of natural resources, diseases, illegal trade, poaching and decreased prey abundance are grave challenges to the large mammals in recent times (Ripple et al., 2014, 2015; Wittemyer et al., 2014; Tilman et al., 2017; Torres-Romero et al., 2020). The resource-use overlap between the human and wildlife at the human-wildlife interface area increases the risk of negative human-large mammal interactions, in the form of human casualties (Rajpurohit and Krausman, 2000; Athreya et al., 2007; Kshetry et al., 2017) and economic losses through crop damage (Nath and Sukumar, 1998; Madhusudan, 2003; Orga and Badola, 2008; Varma and Sarkar, 2008; Karanth et al., 2013a) and livestock depredation (Madhusudan, 2003; Karanth et al., 2013a,b; Miller et al., 2016a) (Figure 1.1). Any such negative interactions between human and wildlife are generally termed as ‘human-wildlife conflict’. The human-dominated mosaic habitats, agriculture and animal husbandry practices adjoining the forest patches foster wildlife to interact with humans (Harihar et al., 2009; Menon and Chaudhary, 2017). Increased resource-use overlap and deviations in the distribution range of large mammals has pushed several large mammals to the verge of extinction in the past few years (Cardillo et al., 2005; Karanth et al., 2010; Groves and Grubb, 2011; Ripple et al., 2014; Stein et al., 2025). Therefore, it is critical to study various social and ecological attributes of negative human-large mammal interactions and factors determining species distribution pattern to conserve the species and promote the human-large mammal coexistence in the future.

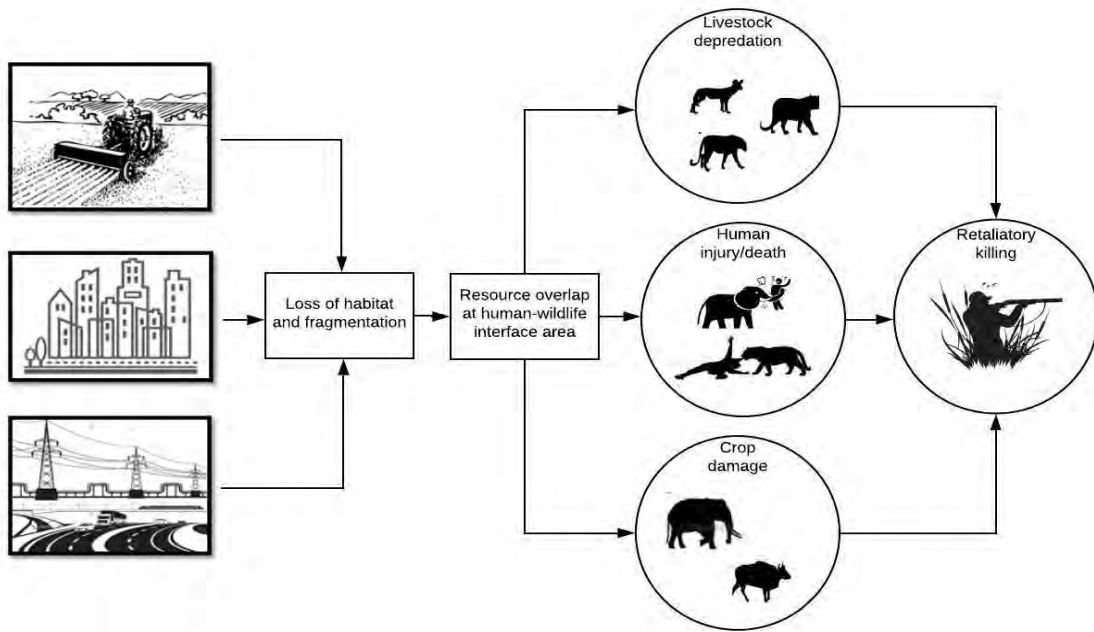


Figure 1.1 A graphical representation of the chain of events that lead to human-large mammal conflict.

1.1 Literature review

1.1.1 Role of large mammals in ecosystem functioning

Large mammals influence natural ecosystems through various processes by virtue of their size, movement and feeding behaviour. Several tropical tree species bear large or thick-skinned fruits that appear to have evolved in association with megafaunal dispersers. Studies from African and Asian forests show that species such as elephants can process fruits too large for other frugivores and transport both large and small seeds over long distances (Gautier-Hion et al., 1985; Campos-Arceiz et al., 2011). Such long-distance seed movement plays an important role in shaping landscape-level patterns, including the maintenance of connectivity in fragmented habitats, shifts in species ranges under changing climates, and the spread of invasive plants (Trakhtenbrot et al., 2005; Nathan et al., 2008).

Beyond seed dispersal, large mammals contribute to other ecological processes such as regulating primary productivity, engineering habitats, enhancing nutrient turnover and sustaining overall biological diversity (Cuaron, 2000; Lacher et al., 2019). Megaherbivores, in particular, support habitat maintenance and regeneration through their wide-ranging movements and heavy foraging, which create gaps in dense canopy patches, promoting

grassland formation and create a mosaic of microhabitats favourable to varied flora and fauna (Jones et al., 1994). Their dung deposition, selective browsing and pruning also facilitate nitrogen and phosphorus cycling, thereby influencing soil fertility and vegetation dynamics (Sitters and Venterink, 2015).

Large carnivores on the other hand perform a complementary function by regulating herbivore populations and controlling mesopredators, which in turn stabilises trophic interactions and prevents vegetation collapse arising from uncontrolled herbivore growth (Karanth and Sunquist, 1995). Their predatory activity indirectly supports scavengers and can reduce disease risk through a ‘dilution effect’, including limiting the proliferation of pathogen-carrying animals such as feral dogs (Civitello et al., 2015). The loss or decline of these apex consumers often causes trophic downgrading, resulting in ecological imbalance and cascading changes across the food web (Estes et al., 2011; Ripple et al., 2017). Together, these functions highlight that large mammals are not merely inhabitants of tropical forests but dynamic ecological drivers whose continued persistence is critical for ecosystem resilience and long-term regeneration.

1.1.2 Significance of human-wildlife interface areas

Human-wildlife interface area can be broadly referred to as the zone where human settlements, agricultural lands and wildlife habitats converge. It is a spatially dynamic area where the resource-use and movement of wildlife frequently overlap with the land-use, livelihoods and safety of human beings (Nyhus, 2016). As the spatial extent and number of human-wildlife interface zones increase within a landscape, encounters between people and wildlife become more frequent, directly contributing to higher conflict intensity. Interface areas are especially critical for large mammals as they are wide-ranging in nature and cross administrative boundaries for foraging and reproduction (Venkataraman et al., 2002; Jhala et al., 2010; Dutta et al., 2013). A study by Woodroffe and Ginsberg (1998) on the species extinction in edge habitats demonstrates that conflict with people at and beyond reserve boundaries are the primary cause of mortality in large carnivore populations, making interface areas act as demographic sinks rather than sources (Woodroffe and Ginsberg, 1998). Even within the PAs, intensifying anthropogenic stress has made the interface area most prone to conflict (Nyhus and Tilson, 2004; Karanth et al., 2013). Therefore, these areas are not just a management problem operating at the periphery of wildlife conservation, but is the area where long-term viability of wildlife is most directly determined. Studying the socio-ecological

characteristics of HLMC of multiple large mammals in interface areas will hence enhances the vision than looking exclusively within the PAs which hides the spatial and ecological complexity that actually governs conflict at this interface. Advancing the science of coexistence requires better understanding of the dynamics of human-wildlife interactions, especially in shared landscapes where the costs of living together are more pronounced and difficult to avoid.

1.1.3 Human-large mammal interactions outside Protected Areas

Historically, many large mammal species in India had occupied wide contiguous forest ranges that exceeds the current PA boundaries (Sukumar, 2003; Karanth et al., 2010). The average area of designated PAs in India is less than 300km² and has fairly high carrying capacity as compared to other countries (Karanth et al., 2004). The large mammal populations here persist in a mosaic landscape where PAs, Reserved Forests (RFs), Fringe Areas (FAs) and human-use areas are interspersed. Therefore, the conservation of large mammals predominantly depends on the conservation of PAs and surrounding RFs, as they are some of the last preserves for large mammal populations (Athreya et al., 2013; Menon and Chaudhary, 2017).

Habitat loss and fragmentation have significantly affected the distribution pattern of large mammals in PAs because of their unique habitat requirements, high geographical endemism, inherent rarity, larger body size and related life history traits (Brashares, 2003; Michalski and Peres, 2005). Generally, large bodied habitat specialists are the most vulnerable to extinction. Species like elephant, gaur, tiger, leopard and dhole have only a very minimal part of its historic range within PA boundaries and are therefore highly threatened by habitat fragmentation (e.g. Karanth et al., 2010). Many have already undergone serious range contraction and local extinction (Ceballos and Ehrlich, 2002; Madhusudan and Mishra, 2003). According to official national assessments by the National Tiger Conservation Authority (NTCA, 2022), nearly one-third of the habitat identified as suitable for Bengal Tiger (*Panthera tigris tigris*) falls outside declared Tiger Reserves (eg. Uttarakhand and Uttar Pradesh); meanwhile, the tiger range has shrunk towards PAs in many parts of southern Western Ghats.

Changing habitat composition, resource availability, and landscape connectivity within the PAs has a crucial role in human-large mammal interaction in the PA fringes. These changes can directly affect the habitat-use and movement pathways of large mammals, forcing them towards the periphery of PAs and eventually beyond PA boundaries, towards the agricultural areas, livestock enclosures and human-dominated landscapes. Soon, with the high resource-use overlap in these interface areas will lead to increased negative human-large mammal

interactions, primarily rooted in the degradation of native wildlife habitats within PAs. One of the most persistent drivers of habitat degradation is the invasion of exotic species such as *Lantana camara*, *Acacia spp.*, and *Eucalyptus globulus* into native wild habitats, particularly in southern India (Ramesh et al., 2022; Barik et al., 2025). This was facilitated by historical land-use changes especially from the colonial era; expansion of monoculture plantation and climate change, that reduced the natural forage availability to megaherbivores, thereby negatively affecting their physiology (Ramesh et al., 2022; Barik et al., 2025). Additionally, the rising livestock grazing pressure within the PAs exerts pressure on native flora by depleting the forage availability and promoting the spread of unpalatable weed species reducing the chances of viable herbivore populations within PA boundary, driving them actively outside PAs resulting in frequent negative human-large mammal interactions (Babu et al., 2012; Baskaran et al., 2012; Wolf and Ripple, 2016; Ramesh et al., 2022). The sequential cascade of habitat degradation affects megaherbivores and large carnivores differently. For megaherbivores, the replacement of native palatable grasses by invasive weeds under livestock grazing pressure will force them to forage outside PA boundaries, towards agricultural areas and human-dominated landscapes (Babu et al., 2012; Baskaran et al., 2012; Ramesh et al., 2022). Meanwhile, for large carnivores, depletion of prey population (through hunting and habitat fragmentation) within the PAs can force them for territorial expansion and increased chances of livestock depredation and retaliatory killing, which in turn amplifies the risk of localised species extinction (Wolf and Ripple, 2016; Ramesh et al., 2020). In short, the after effect of habitat deterioration within PAs, remains not just within them, but spreads to neighbouring human-dominated landscapes. India's National Human-Wildlife Conflict Mitigation Strategy and Action Plan (MoEFCC, 2021) also recognizes that habitat loss, degradation, and fragmentation along with the resultant food and water scarcity within PAs, as primary structural drivers compelling wildlife to stray into human settlements.

Studies across India have documented frequent use of agricultural landscapes, plantations, degraded forest fragments and buffer zones by adaptable species such as the Indian leopard (*Panthera pardus fusca*) and the Asian elephant (*Elephas maximus*) (e.g. Sukumar, 2003; Kumar et al., 2010; Athreya et al., 2013; Navya et al., 2014; Sidhu et al., 2017). This shifting distribution from large, continuous ranges in the past to patches of PAs and shared human-wildlife landscapes today carries important implications for conservation. It highlights the significance of a “multi-use” and managed landscapes for long-term species persistence. This pattern is especially visible in regions like the Western and Eastern Ghats, where forest patches,

plantations, agricultural fields and villages co-exist alongside natural habitats. Human settlements are located both within the forest reserve and surrounding the buffer areas. Most of such human habitations belong to the lower-income groups. The primary livelihoods of people in such habitats are agriculture, livestock rearing, collection of timber, and Non-Timber Forest Produce (NTFP) (Silori and Mishra, 2001; Davidar et al., 2008). Large mammals occurring in these areas are often in conflict and perceived as a threat to their lives and livelihood. In India, several instances of retaliatory killings by poisoning, electrocution, capture and kill, handmade bombs have occurred (Madhusudan, 2003; Gubbi, 2012). Thus, the conservation of large mammals in human-dominated regions is challenging and requires appropriate measures to minimize conflict (Kshetry et al., 2017). With global extinction rates, the need of the hour is to prioritise and protect large mammals in conflict, as retaliatory and negative perceptions pose a serious conservation concern. To develop better mitigation measures, an understanding of the spatial and temporal patterns of the large mammal interaction is essential (Crooks, 2002; Miller et al., 2016b) particularly for the larger landscape, unlike that of the studies limited to individual PA.

1.1.4 Human - large carnivore conflict in India

India upholds 23% of the global carnivore population (Srivathsa et al., 2019a), but the frequency of human-carnivore conflict (HCC) incidents is rising day by day in India. HCC has broadened its range from less populated rural settlements inside or bordering the forests to populated urban environments (e.g., Moyer et al., 2008; Jhala et al., 2009; Murphy and Macdonald, 2010; Singh et al., 2010; Athreya et al., 2013, 2016; Harihar et al., 2014; Odden et al., 2014; Kshetry et al., 2017). Accordingly, the frequency and degree of the trouble caused to the animal and from the animal increases. Large carnivores are even considered as ‘undesirable’ in many parts of India (Bradley et al., 2005; Saberwal and Rangarajan, 2003; Woodroffe et al., 2005) and stand against wildlife conservation goals (Nikolaev and Yudin, 1993; Karanth and Gopal, 2005; Miquelle et al., 2005; Nyhus and Tilson, 2010; Tilson et al., 2010). In India, the most common form of HCC is livestock depredation, human injury/death and poisoning of the conflict animal (Figure 1.2). Leopard and tiger are amongst the top-ranked species that are most frequently involved in HCC (e.g., Goyal et al., 2000; Madhusudan, 2003; Athreya et al., 2004; Graham et al., 2005; Karanth and Gopal, 2005; Singh, 2005; Barlow et al., 2010; Goodrich, 2010; Nyhus and Tilson, 2010; Dhanwatey et al., 2013; Athreya et al., 2016; Borah et al., 2018; Bakhshi, 2020). There were 902 cases of human injuries and 201 cases of

human deaths due to leopard attacks in the State of Maharashtra between 1999 and 2005 (Athreya et al., 2011), 343 human injuries and 180 human deaths in the State of Uttarakhand between 2000 to 2008 (Joshi and Agarwal, 2012) and 186 cases of leopard attacks in the state of Himachal Pradesh between 2008-2009 (Times of India, 2015). Ultimately, HCC leads to economic loss and loss of livelihood, which nurtures the retaliatory attitude in the common man. It is important to conserve these threatened species populations before it gets extinct in the wild (Mishra, 1997; Wang and MacDonald, 2006). The major reasons for the current plight of rising HCC cases are habitat loss, habitat fragmentation, urbanization (Pandey et al., 2016), loss of wild prey (McDougal, 1987; Kolowski and Holekamp, 2006, Wang and Macdonald, 2006; Gurung et al., 2009, Gusset et al., 2009; Goodrich, 2010; Yadav et al., 2021), increased livestock grazing pressure, and rising human disturbances within the forest (Mishra, 1997; Treves and Karanth, 2003; Durbin et al., 2004; Madhusudan, 2004; Packer et al., 2005; Bagchi and Mishra, 2006; Kaushik et al., 2015; Miller et al., 2015; Singh et al., 2015; Soofi et al., 2018; Sidhu et al., 2017; Naha et al., 2018; Yadav et al., 2021). Large carnivores require contiguous forests for the survival of a long-term viable population (Athreya et al., 2015; Carter and Linnell, 2016; Majgaonkar et al., 2019), but with the effect of urbanization, the remaining large patches of forests (Venter, 2014) also has been converted to small islands, because of which the animal tends to move outside the forest and interact with humans (Karanth and Gopal, 2005; Kolowski and Holekamp, 2006; Loveridge et al., 2010). The villagers residing in and around the forest are mostly dependent on the forest resources for their livelihood. The majority of these populations, herd their livestock for grazing inside the forest, legally and/or illegally (Ramesh et al., 2020). Herding the livestock inside the forest has several direct and indirect effects on wildlife and their habitat issues i.e., increased risk of epidemics from livestock to the wild animals, invasion of weeds, decreased herbivore (prey) population, increased depredation risk on livestock and further retaliatory killing by the local people (Morris, 1942; Davidar, 1975; Nikolaev and Yudin, 1993; Oli et al., 1994; Karanth and Madhusudan, 2002; Treves and Karanth, 2003; Karanth and Gopal, 2005, Miquelle et al., 2005, Dinerstein et al., 2007; Goodrich, 2010; Nyhus and Tilson, 2010; Naha et al., 2018; Ramesh et al., 2020).



Figure 1.2 (a) Leopard trapped in a barbed wire fence in Coimbatore, Tamil Nadu; (b) Leopard killed by a farmer in Krishnagiri, Tamil Nadu.

1.1.5 Human-megaherbivore conflict in India

India, which is the world's second most populated country, apparently holds the largest population of Asian elephants (*Elephas maximus*) (Williams et al., 2020, Mohanarangan et al., 2021). Therefore, the inflating human-megaherbivore conflict (HMC) incidents are not surprising. In fact, the Asian elephant is one of the top-ranked large mammal species in the wild that causes economic burden to the local people in India (Sukumar, 1990; Talukdar, 1996; Karanth and Madhusudan, 2002; Talukdar and Barman, 2003; Kumar et al., 2004; Chartier et al., 2011; Gubbi, 2012; Sahu and Das, 2012). One of the other emerging megaherbivore species in conflict with human beings is the Indian gaur (*Bos gaurus*) (Choudhury, 2002; Joshi and Madhusudan, 2010). HMC results in crop damage, property damage, and human death/injury, followed by loss of livelihood, huge economic debts, and psychological stress to humans (Lee and Graham, 2006; Joshi and Madhusudan, 2010; Walker, 2012; Chakraborty, 2018; Rohini et al., 2018; Vibha et al., 2021), wildlife death in retaliation to the economic loss caused to the humans and road/rail kills of wildlife (Sekar, 2013; Menon et al., 2017). The situation is further aggravated by changing land-use pattern, poaching, change in crops cultivated, habitat loss and fragmentation, urbanization, linear infrastructure development, increasing livestock grazing pressure inside the forest and resultant increased resource-use overlap between humans and wildlife, leading to HMC (Sukumar, 1989a, 1990, 1991; Johnsingh and Joshua, 1994; Williams et al., 2001; Jeyasingh and Davidar, 2003; Leimgruber et al., 2003; Talukdar and Barman, 2003; Gubbi, 2009; MOEF, 2010; Sahu and Das, 2012; Wilson et al., 2015a; Chakraborty, 2018; Chatterjee and Mandal, 2020; Mohanarangan et al., 2021; Nad and Roy, 2021). Linear infrastructures like railway lines and water canals, obstruct animal corridors further increase the risk of wildlife death (Menon et al.,

2005; Ramkumar et al., 2017). The predicament of finding elephants dead on the railway track are not very uncommon in India. As mentioned earlier, livestock grazing pressure decreases the food available in the forests and enhances weed growth, forcing the animals to stray outside the forest, increasing the risk of HMC. The State of Kerala, Tamil Nadu (TN), and Karnataka host the highest densities of Asian elephants in the country (Gubbi et al., 2014). The Western Ghats, central and north-eastern states of India host the largest number of gaurs in India (Sankar et al., 2020; Jhala et al., 2020). In Odisha, between 1990-2000, elephants killed 86 people and 35 individuals had injuries (Sar and Choudhury, 2006). In Karnataka, 25-30 people die annually out of elephant attacks (Karnataka Elephant Task Force, 2012). On average, 400 people are killed by elephants and nearly 100 elephants lose their lives due to retaliatory killing every year (Sridevi and Reddy, 2018) (Figure 1.3b). From 2015 to 2018, almost 2,831 people lost their lives to elephant attacks, and 490 elephants died in response to human activities (MoEF CC, 2018) (Figure 1.4). Due to crop-raiding alone, 0.5 million people suffered loss, between 2000 and 2010 (MoEF, 2010, 2012). Further, US\$ 19.2 million and US\$ 5 million were paid as compensation by the Indian government for the crop damage and loss of human life between 2014 to 2018 (MoEFCC, 2018). Southern Maharashtra, parts of Karnataka, Kerala and TN are the identified gaur conflict hotspots in India (Sankar et al., 2020). The chances of crop depredation increase when cultivated towards the fringe areas, bordering forests; in addition, irrigated water in the cultivated land attracts the animals further (Joshi and Madhusudan, 2010) (Figure 1.3a). Decreased food availability inside the forest and attraction towards the easy palatable, nutritious food available in the farmlands are also the major cause of rising crop-raiding events. Such events can create a retaliatory attitude among the villagers further aggravating the situation and impeding efforts for wildlife conservation (Parker et al., 2007; Boominathan et al., 2008; Sarker and Roskaf, 2010; Chakraborty, 2018; Vibha et al., 2021).



Figure 1.3 (a) A gaur grazing in tea plantation in Kotagiri, Tamil Nadu; (b) A tusker electrocuted in Nilgiris, Tamil Nadu.

Human-elephant conflicts

Human fatalities caused by elephant attacks increased in at least 10 states between 2020-21 (April to March) and 2023-24, with an overall rise of approximately 36 per cent. In 2023-24, three states—Odisha (154 deaths), West Bengal (99 deaths) and Jharkhand (87 deaths)—accounted for more than half of all deaths resulting from elephant attacks

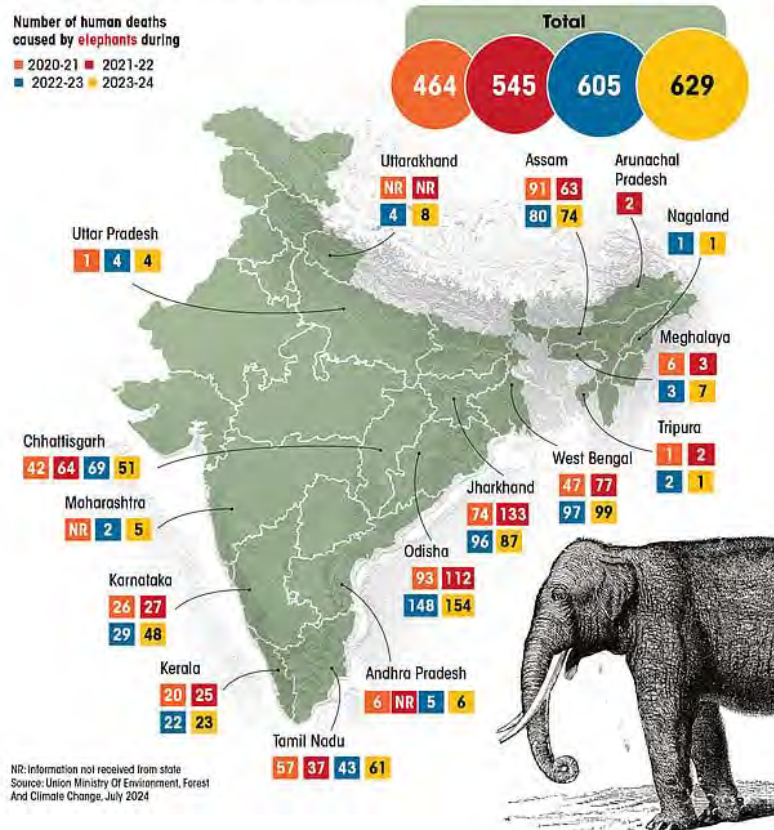


Figure 1.4 Human fatalities caused by elephants across different States of India between 2020-2024 (Image credits: Down to Earth, 2025).

1.1.6 Role of Forest Rangers in conflict management

Forest Rangers play an important role in controlling the loss of biodiversity and degradation of ecosystem through wildlife monitoring, habitat management, evaluating and implementing HWC mitigation measures, management of eco-tourism activities, engaging and educating local community (Schulze et al. 2018; Singh et al., 2021). They occupy a critical position within the wildlife management system as they are observers of conflict patterns, enforce wildlife protection laws, and are primary points of contact between the forest department and local communities. The knowledge gained from their experience through continuous field engagement forms a critical but underrated source of information to understand the HWC dynamics, identifying management lacunas and designing landscape-sensitive managerial interventions (Belecky et al., 2019; WWF, 2019). Although they act as vital links between

biodiversity, local communities, and policy-makers, implementing law in PAs worldwide, their voices have often been marginalised in conservation science, with limited attention given to the challenges they encounter in field, the institutional constraints that shape their effectiveness, and the knowledge from their practical experience working in conflict-prone landscapes (Moreto and Matusiak, 2017; Belecky et al., 2019).

Belecky et al., (2019) in a recent assessment of working conditions of FROs across 28 countries identified prevalent deficiencies in training, equipment, institutional support, and workforce deployment as systemic constraints on the effectiveness of FROs. Findings of the study highlights serious concerns about the capacity of frontline management to efficiently respond to the HWC situation that they frequently encounter. Such studies pinpoint the importance of studying the lacunas in PA management system directly from FROs for effective management of HWC.

With just less than five percent PA networks (Ghosh-Harihar et al., 2019), where wildlife frequently use peri-urban areas outside PAs, particularly agricultural matrices and human settlements, Forest Department officials become important determiners of HWC outcomes in India. In such an environment, any kind of structural imbalance or institutional deficits like insufficient resources will adversely affect the quality of conflict management. Therefore, effectiveness of HWC mitigation is highly dependent on social, ecological and institutional architecture within which managerial decisions are made and implemented. The National Human-Wildlife Conflict Mitigation Strategy and Action Plan of India (MoEFCC, 2021) recognise the need for strengthening the capacity of frontline staffs as an integral component of conflict mitigation, emphasising the importance of adequate training, resource provision, and inter-departmental coordination in improving management outcomes. Translating policy commitments into effective field practice requires a clear understanding of where institutional gaps are most acute, and this understanding can only be built through direct engagement with the practitioners themselves.

1.1.7 Ecological implications of habitat fragmentation in India

Upsurge in human population has modified native habitats, significantly impacting the biodiversity of the tropics and subtropics (Stork et al., 2009), where many biodiversity hotspots are gradually becoming isolated and dependent on surrounding landscapes for ecological coherence and connectivity (DeFries et al., 2005). Since the onset of industrialization during the post-independence period (1950s), India has experienced rapid population growth, coupled

with increased resource consumption and significant changes in land use and land cover, with a marked reduction in native forest cover (Tian et al., 2014). Constant fragmentation of large, contiguous natural habitats, along with increased human access to these fragmented forest patches, may lead to a phenomenon known as "empty forest syndrome", where forests may appear structurally intact but are ecologically depleted due to the loss of native wildlife, thereby posing a significant threat to the biodiversity (Redford, 1992; Bogoni et al., 2023). Many large mammals have disappeared from their historical ranges due to their exposure to habitat loss and fragmentation by agricultural expansion, linear infrastructure development, overexploitation of natural resources, decreased prey abundance, diseases, illegal trade, and poaching (Ripple et al. 2015; Wolf and Ripple 2016, 2017). Subsisting in the abrupt ecotones created by fragmented landscapes exposed to low to high human activity levels is a colossal challenge to many large mammal populations (e.g., Linkie et al. 2006; Kumar et al. 2010). According to the recent reports of World Health Organization (2023), India's population reached approximately 1.44 billion in 2023 and is projected to increase by 17% by 2050. Globally, India stands second in terms of road network, spread across 4.7million km and fifth in consumable hydroelectric power generation (WTI, 2015). With a population density of 479 individuals per km² (Food and Agriculture Organization and World Bank, 2022), the demand for natural resources in India is substantial and will continue to increase. The structure of many tropical forest habitats has been altered to meet the resource requirements of the growing human population. Depletion of large prey species due to habitat fragmentation and increased hunting pressure is a serious threat to the large carnivore communities (Wolf and Ripple, 2016). In the dearth of sustainable prey density and to avoid interspecific competition, the large carnivores are known to widen their territory, which further stirs the human-carnivore conflict incidents. In a rapidly urbanizing country like India (Bhagat and Mohanty, 2009), which is rich in biodiversity, building an equilibrium between economic development and environmental conservation is a serious challenge. Rising anthropogenic pressure and the associated mammalian range contraction demands broad landscape-level studies involving changes to the ecological framework to discern the primary determinants of species extinction at the local level, source-sink dynamics, and long-term survival of the species (Jones, 2011).

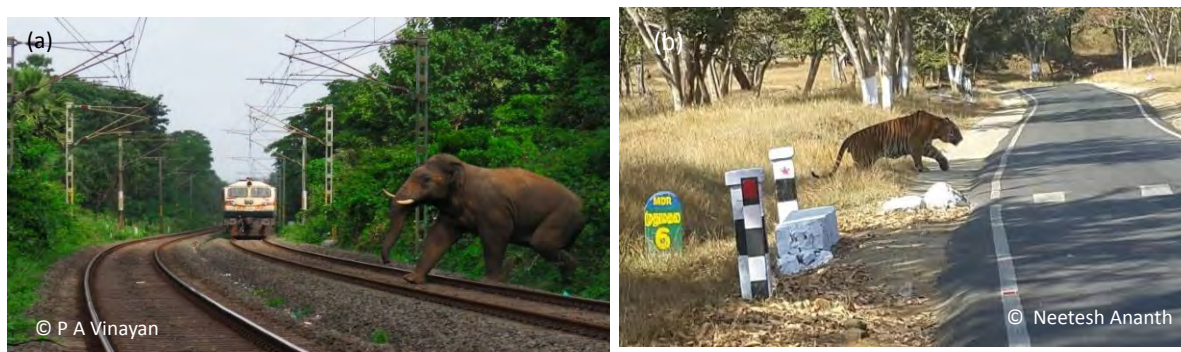


Figure 1.5 (a) An elephant crossing Palakkad-Coimbatore railway line; (b) Tiger crossing the highway through Mudumalai Tiger Reserve, Tamil Nadu.

1.1.8 Human-large mammal interactions in Western Ghats

The Western Ghats, which is a recognized globally as a biodiversity hotspot, has one of Asia's most intricate challenges for conservation: the escalating human-large mammal conflict, particularly in areas where dense human populations overlap with wildlife habitats. Region's PAs are home to some of India's largest populations of megafauna like Asian elephants, Bengal tigers, Indian leopards, dhole, and gaur amid remarkably high human population densities that further exacerbate conflict intensity (CEPF, 2025). This mountain range, extending approximately 1,40,000 km² along peninsular India's southwestern coast, supports both wildlife diversity and intensive agricultural landscapes at the same time, creating consistent friction between wildlife conservation objectives and human livelihood needs.

A study examining 1,972 households across five PAs of Western Ghats of Karnataka State documented that 64% of local community experienced crop losses while 15% suffered livestock depredation (Karanth et al., 2013), showing the prevalent nature of these encounters across PA-agriculture interface areas. Economic burdens from wildlife damage prove substantial for marginalized rural communities operating on precarious financial margins. The study shows that average annual monetary losses per household reached INR 23,010 for cultivated crops and INR 5,423 for livestock (Karanth et al., 2013), representing significant proportions of rural household incomes. However, property damage constitutes only partial conflict costs. Another data from a survey conducted amongst 5,196 households across 11 wildlife reserves in India demonstrated that human casualties represent the dominant cost of human-wildlife conflict, with injury and death costs surpassing all other property losses by several times (Gulati et al., 2021). These results emphasize need for conservation policies to prioritize reducing human casualties alongside addressing economic losses.

Species-specific damage patterns reveal disparity in impacts across wildlife taxa. A study from Southern Western Ghats region of Kerala State highlights that the conflict incidents are predominantly reported from elephants with over 59% of crop damage cases, followed by wild boar contributing 32% (Rohini et al., 2017). While megaherbivores primarily target agricultural produce, carnivores attack livestock. Another study conducted in Southern Western Ghats region of Tamil Nadu (Kalakkad-Mundanthurai Tiger Reserve), by Selvan et al., 2020 demonstrate that 49% of leopard attack was on goats, followed by dogs (48%), with seasonal variation showing 47% of attacks concentrated during monsoon periods corresponding to the dearth of natural prey availability.

Various spatial distribution analyses of conflict species consistently identify PA peripheries as human-large mammal conflict zones where wildlife movement pathways intersect agricultural matrices. Forest reserves (outside PAs) demonstrate significantly elevated conflict rates compared to designated PAs (Baskaran et al., 2024), indicating conservation management intensity that influences interaction dynamics directly. The agricultural mosaic surrounding forest reserves cultivates crops that are attractive to herbivores such as banana (*Musa paradisia*), sugarcane (*Saccharum officinarum*), jackfruit (*Artocarpus heterophyllus*), areca nut (*Areca catechu*), coconut (*Cocos nucifera*) and millet varieties like sorghum (*Sorghum vulgare*) which naturally exacerbates their raiding behaviour as elephants exhibit excellent spatial memory regarding seasonally available resources. Research suggests that agricultural landscape provide crucial dispersal habitat for wild animals and facilitate their metapopulation dynamics, potentially enabling adequate elephant protection in fragmented habitats where conflict hotspot areas paradoxically represent prime elephant habitat (Anoop et al., 2023). This ecological reality complicates ancient conflict explanations, revealing that areas experiencing highest human costs concurrently becomes critical conservation landscapes.

Habitat fragmentation is identified as the fundamental driver intensifying conflict frequency and severity. Fragmentation analysis across 20-year period in northern Western Ghats revealed that although losses in moderately and highly fragmented forests decreased between 1985 and 2005, those improvements was insufficient to compensate for intact, contiguous, native forest losses, with dense forest area within intact patches declining substantially, causing habitat degradation (Kale et al., 2010). Analysis of 34,596 geotagged human-wildlife conflict data points from southern Western Ghats collected between 2019 and 2023 revealed elephants, tigers, leopards, wild boars, and gaurs contributed 99.6% of incidences, with human-elephant conflict

accounting for 92.1% of incidents and 87.4% of total compensation paid (Pavithra et al., 2025). These datasets demonstrate conflict concentration patterns requiring targeted landscape-level interventions rather than generalized management approaches.

Traditional mitigation approaches demonstrate limited effectiveness despite widespread community deployment. Farmers employ diverse deterrent methods including night-time guarding, fencing, bursting fire crackers, cultivating unpalatable buffer crops, etc. However, evaluation of 13 reported mitigation strategies did not find any statistically significant associations with reduced agricultural losses (Karanth et al., 2013). This failure demonstrates adaptive intelligence of large mammals, particularly elephants, which rapidly habituate to repetitive deterrent stimuli. Recent study identified that households experiencing lower rainfall and operating smaller landholdings showed 68% likelihood of implementing mitigation measures (Prasad et al., 2025), suggesting complex interaction of socioeconomic and environmental variables to determine community responses.

The Western Ghats of Tamil Nadu constitute one of India's most vital regions for large mammal conservation (Jhala et al., 2010, 2019). This landscape supports relatively high densities of large mammals and hosts some of the last extensive populations of species like the Bengal tiger, Indian leopard, dhole (*Cuon alpinus*), Asian elephant, and gaur in southern India (Ramesh, 2010; Jhala et al., 2010, 2019). However, the region has experienced severe land-use change and anthropogenic pressure, leading to escalating negative human-wildlife interactions (Tamil Nadu Forest Department, 2020). Historical analyses indicate that forest cover in the central and southern Western Ghats declined by approximately 40% between the 1920s and 1990s, with natural ecosystems now occupying only about a third of the region's total area (Daniels et al., 1995; Menon and Bawa, 1997; Jha et al., 2000). The Kasturirangan report (2013) highlights that 50 million people reside within the 1,64,000 km² area of the Western Ghats, making this landscape extremely susceptible to habitat fragmentation. Adjacent Eastern Ghats Forest Ranges of Tamil Nadu also host considerable wildlife and are critical corridors for large mammals of Western Ghats; together they contribute critical habitats for country's wildlife. However, with the rising anthropogenic pressure, the Eastern Ghats Forest range are comparatively more fragmented than those of the Western Ghats (AWIFS LULC data, Bhuvan, 2017), potentially leading to different patterns in spatial extent, frequency, and species involved in conflict.

Over recent years, many large mammal species have experienced drastic range contraction and decreased detectability in their southern geographical range (Pillay et al. 2011). Habitat modification and subsequent anthropogenic pressure have led to escalated rates of human-large mammal conflicts (HLMC), particularly in the Western and Eastern Ghats Part of Tamil Nadu (WEGPTN) (eg. Ramakrishnan, 2024). Between 2016-2017 alone, the Tamil Nadu Forest Department compensated local communities for 36 elephant-caused and seven gaur-caused human deaths, 2,560 crop damages, and 81 household property damages, though many incidents go unreported (Tamil Nadu Forest Department, 2020). Retaliatory killings of conflict animals following such events, particularly crop-raiding, remain among the most serious threats to large mammal conservation in India (Madhusudan, 2003; Daniel et al., 2008; Gubbi, 2012; Sukumar and Pani, 2016; Ramkumar et al., 2018). The current situation of the Western Ghats landscape exemplifies broader challenges facing biodiversity conservation in human-dominated landscapes globally, where reconciling human livelihoods with wildlife persistence requires innovative strategies acknowledging both ecological requirements of threatened species and socioeconomic realities of resource-dependent communities coexisting with megafauna across challenged landscapes. There is a considerable research gap in identifying the species-specific socio-ecological causes of large mammal conflict in Western Ghats. The emerging trend of human-large mammal conflict incidents in the Tamil Nadu necessitates studies on the pattern of large mammal distributions. Existing localized studies focused on a single species distribution in Tamil Nadu barely assimilate the species response on the maximum acting environmental variables. There is an increasing need for a multi-species study to help in any major decision making for wildlife population management at a larger spatial scale.

1.1.9 Socio-cultural dimensions of human-large mammal conflicts in India

Understanding human-wildlife interactions in India requires examination of its deep-rooted cultural, historical and social attributes shaping the relationship between human and wildlife. The coexistence between human and wildlife began ages ago but there has been a significant transformation in how communities perceive wildlife sharing their landscape.

Although humans across Indian history have suffered losses from megafauna, their relationship has never been directly hostile. Many wildlife species, including those dangerous to humans that are involved in conflict, are integral parts of networks of reciprocity, reverence, and kinship among natives (Oommen, 2021). Religious and cultural sentiments strongly influence human

tolerance thresholds towards wild animals (Kansy and Knight, 2014; Karanth and Kudalkar, 2017). Cultural reverence for large mammals in India can be seen through diverse human practices rooted in religious and mythological traditions. Asian elephants are significantly associated with Indian culture and history, worshipped as incarnations of Lord Ganesha (the elephant-headed God in Hindu mythology) and symbolized as forms of power (Roy et al., 2022). Elephant ontologies of what each community thinks an elephant is within their collective lifeworld represent one of three main cultural-ecological variables correlating with aiding tolerance and space-sharing for peaceful coexistence, together with specific modes of subsistence and agricultural crops, and shared ethnic history of living with elephants (Thekaekara et al., 2021). Communities conceptualize these elephants in four ways broadly: as other-than-human persons accorded some form of personhood capable of mutual respect and communication, as gods, as victims, and as wild or unpredictable animals (Thekaekara et al., 2021). Recent research from eastern India highlights that despite frequent high human-elephant conflict events, most respondents maintained positive attitude towards elephants, with key factors driving their attitudes including cultural, emotional, and economic associations with elephants (Roy et al., 2022). Many at times, the economic benefits from wildlife tourism also plays a crucial role in building a positive attitude towards wildlife, especially towards megafauna (Karanth and Nepal, 2012; Kansy and Knight, 2014).

Sacred traditions associated with megafauna are not limited to elephants. Tigers hold particularly significant positions in cultural belief systems. In Rajasthan, historical and mythological dimensions profoundly influenced conservation practices, with communities protecting certain species through religious prohibitions and sacred grove designations (Sharma et al., 2013). Conservation of endangered mega animals like tigers and lions in India benefits from deep cultural roots, with religious sentiments and mythological associations providing protective frameworks that have sustained populations through centuries (Khoshoo, 1997). In Central India, specifically in Maharashtra, the indigenous *Warli* community worship Waghoba- the big cat deity, revealing interesting connection between wildlife, culture, and human life where reverence and fear coexist harmoniously (Nair et al., 2021). People in the community believe that Waghoba will always protect them from dangers associated with living alongside big cats, provided communities honour the deity through worship and perform necessary rituals, particularly the annual Waghbaras festival (Nair et al., 2021). In general, a combination of mythological beliefs, cultural associations, emotional attachments,

and tangible and intangible benefits may lead to positive attitudes despite high conflict incidents (Karanth and Kudalkar, 2017).

Perception studies and attitude surveys are imperative to understanding the socio-political composition of HWC as it reciprocates the idea of how people are affected by the existing conservation policies and the gaps in HWC management. Perception encompasses an individual's observation, understanding, interpretation, and evaluation of various subjects (Bennett, 2016). In India, PAs are often intertwined with human settlements, and have witnessed decades of coexistence between humans and wildlife, with inhabitants reliant on forest resources for their livelihoods (Karanth et al., 2006; Davidar et al., 2010). The colonial period marked a pivotal separation in traditional human-wildlife relationships. Colonial and post-colonial policies enabled creation of restricted PAs and strengthening “hands-off” approaches creating gaps in earlier organic relations between people and wildlife (Oommen, 2021). This separation proved unfavourable to long-term coexistence, as local communities began viewing wildlife as “government property”, challenging wild species presence outside PAs and questioning top-down conservation impacts on local livelihoods and rights (Oommen, 2021). In fact, tolerance in reality often acts on a gradation scale rather than just a positive or negative attitude towards wildlife. Understanding local residents' views through perception studies is vital to wildlife conservation efforts (Karanth et al., 2008; Vodouhê et al., 2010; Mir et al., 2015) because successful implementation of any wildlife conservation policy depends on positive perceptions of the local community towards wildlife and coexistence. These perceptions reflect underlying values and disvalues, where wildlife may be simultaneously valued for ecological or cultural benefits yet perceived negatively due to human-wildlife conflicts or safety threats (Dickman, 2010; Ives and Kendal, 2014).

Studies highlight a human tendency to perceive large and potentially dangerous animals more negatively, even if the losses from other taxa are similar (Dickman, 2010), leading to retaliatory events particularly focused on large mammals. Sometimes, human-large mammal conflict may stem from difference in opinions between local communities and governing bodies or between people from different cultural backgrounds (Dickman, 2010; Thekaekara et al., 2021). Inadequate access to essential facilities like education, transportation, healthcare, electricity, and water within PAs can also exacerbate community grievances and increase hostility towards policies and wildlife (e.g., Ramesh et al., 2019). Failure to address people's concerns may lead to a lack of local support for conservation efforts (Woodroffe et al., 2005) and potential

retaliatory killings of animals (Inskip and Zimmerman, 2009), as evidenced by incidents like the retaliatory killing of four tigers in Chitwan National Park, Nepal, between 2007-2014 (Dhungana et al., 2016). Individuals with positive attitudes towards wildlife are more likely to support management initiatives by authorities (Andersone and Ozolins, 2004; Kaczensky et al., 2004). Generally, individuals who have not experienced issues with certain species may have a positive perception towards that species, compared to those who experienced, often due to lack of awareness (Marker et al., 2003). However, some studies have shown positive perception of people despite regular encounters with species (Jackman and Rutberg, 2015; Booth and Ryan, 2019). Given the potential variability in people's perceptions influenced by local laws, culture, beliefs, and values, understanding the attitudes towards wildlife is imperative to providing a systematic scientific database for policy-level decision making and thereby for effective wildlife conservation and management.

1.1.10 Human livelihood dependencies

Forest-dwelling communities in the Western Ghats landscape rely on timber and non-timber forest products (NTFPs) for their livelihood while simultaneously increasing the risk of direct encounters and indirect interactions with large mammals. Many of the residents derive substantial income from collecting honey, fuelwood, medicinal plants, and gum-resin (Basavarajaiah et al., 2020); NTFP extraction contributes between 28-47% of household income across different villages in Biligirirangana Hills (BR Hills) of Karnataka State where the poorest households showed highest dependencies (Hegde et al., 1996). Recent study across southwestern India found that tribal identity, agricultural livelihoods, and daily wage dependencies significantly increased NTFP extraction patterns (Hariharan et al., 2025). They were dependent on forest products majorly because alternative means of income sources remained were unavailable or inadequate, and poverty rather than greed led to such activities (Davidar et al., 2008). Their economic dependency forces communities to venture regularly into forests where they encounter large mammals, placing both humans and wildlife at risk. Between 1973 and 2017, total forest area in the Western Ghats declined by 12,135 km², with tribal gathering grounds shrinking substantially (Vijayan et al., 2021), forcing communities to move further inside into remaining forest patches to access required resources and inevitably encountering wildlife more frequently in small spaces where both humans and animals compete for diminishing resources (Saha and Sundriyal, 2012).

Vijayan et al., (2021) found that the shrinkage of total forest cover of Western Ghats reduced their collection of NTFPs, but increased their dependency on plantation labour works for their livelihood. Slow urbanization in forested areas brought about by the mixed cultures also contribute to expanding habitat fragmentation. For instance, Jayson and Chirstopher (2008), in a study conducted in Kerala's Peppara Wildlife Sanctuary observed that intermarriage between Kanikkar tribal communities and outsiders has inadvertently intensified crop damage patterns, as non-tribal spouses with formal education introduce cultivation of attractive crops like plantains and coconuts in settlements, thereby escalating human-elephant conflict through adoption of modern agricultural practices. Similarly, natural habitat fragmentation by conversion of forest into plantations was one of the major reasons for rising human-elephant conflicts in Wayanad Wildlife Sanctuary (Vineetha et al., 2024). A study from Nigiri Biosphere Reserve (NBR) reflects the depth of loss human faced due to elephant: between 2018 and 2023, elephants damaged crops belonging to 4,073 families, destroyed property in 220 incidents, and caused 231 human casualties (Bhaskaran et al., 2024). Regulatory frameworks governing PAs escalate these challenges further, as unauthorized timber and NTFP harvesting persists as a critical management concern, generating disputes over inadequate compensation mechanisms for carnivore-killed livestock and wildlife-damaged crops, thereby trapping communities between violating legal restrictions to sustain their economy or banning resource access that their families depend upon fundamentally. Resolving these interconnected problems require holistic frameworks that acknowledge the inseparability of economic security and conflict reduction.

1.2 Rationale of the study

Human-large mammal conflict (HLMC) poses a serious threat to the conservation of large mammals and often arises as a consequence of habitat loss, habitat fragmentation, and poaching. Economic loss to the crops by elephant, gaur, and the livestock loss by leopard, tiger, and dholes affects the livelihood of local communities. Such losses can negatively affect the livelihoods of people who live near PAs, resulting in retaliatory killing of wildlife, degradation of wildlife habitat, and not complying with park regulations (Ogada et al., 2003; Woodroffe et al., 2005; Kissui, 2008). Furthermore, the PAs earn negative views from the adjoining rural communities under most circumstances, as locals are vulnerable to the establishment of a PA and the associated management actions (Mishra et al., 2003). Thus, the attitudes of local communities play a crucial role in the acceptance of management actions initiated by the concerned

stakeholders (Karanth et al., 2006; Rastogi et al., 2010). Understanding and addressing local people's attitudes and behaviour towards such human-wildlife interaction is the key to successful conservation (Wang et al., 2006a). Although the current monetary compensation schemes provided for livestock depredation and crop damage aims to effectively minimize the negative perceptions of local communities towards the conflict animals (Mishra et al., 2003; Ogra and Badola, 2008; Karanth et al., 2013a), future conservation of large mammals depends on initiatives taken to modify the attitudes of humans and develop mitigation measures based on it (Ripple et al., 2014). The spatial and temporal variations can be utilized to develop hotspot maps, and a predicted risk map of conflict can be utilized for detailed planning in developing the mitigation measures (Miller 2015; Chen et al., 2016). Spatial models of conflict must be employed in developing mitigation measures suited to the local conditions (Defries et al., 2010). Mitigation measures developed by assessing the spatial and temporal patterns of the large mammal interaction are essential for the stakeholders and local communities (Crooks, 2002; Treves et al., 2004; Defries et al., 2010; Miller et al., 2016b). The spatial maps can aid in identifying the HWC hotspots, which will help to increase the efficacy of conflict management. The conflict-hotspot maps can be utilized for detailed planning in developing better mitigation measures (Miller, 2015; Chen et al., 2016). A larger landscape-level study would help the park managers develop better management action plans. The increase in fragmentation of the large mammal habitat for agriculture and other developments warrants an understanding of the ecological factors that influence spatial patterns of HLMC. Such data sets are critical to guiding park management in minimizing the negative interactions (Ramesh et al., 2015). The management of livestock depredation, crop-raiding, and human casualties resulting from HLMC can be developed only through appropriate research studies. We need to establish the most appropriate mitigation measures that suit the local conditions by developing spatial models of the conflict pattern (Defries et al., 2010).

PAs in tropical countries is the last refuge for many large mammal species survival (Ogutu et al., 2005; Gubbi, 2012); withal they are sensitive to the effect of habitat degradation outside PAs that lead to distributional range contraction of species (Gubbi, 2012; Chen et al., 2016). The large mammals in PAs are exposed to a wide range of threats such as poisoning, poaching, encroachment, and grazing of livestock that threatens their population (Graham-Rowe, 2011; Critchlow et al., 2015). The livelihood of the people residing in the PAs and RFs of India are highly dependent on the forest resources (Silori and Mishra, 2001; Davidar et al., 2008). Large mammals occurring in these areas are often in conflict and perceived as a threat to their

lives and livelihood. Losses over a threshold period leads to a negative perception of the conflict animals (Defries et al., 2010) and eventually results in killing the animal (Madhusudan, 2003; Gubbi, 2012; Milda et al., 2020). The survival of the large mammals in PAs thus predominantly depend on the efficiency of the PA management. Park Managers or Forest Range Officers (FROs), being the backbones of PA management, have a crucial role in implementing conservation initiatives for protecting wildlife and bringing down HWC (Leader- Williams and Milner-Gulland, 1993; Rowcliffe et al., 2004). They play a vital role in maintaining the PAs through surveillance and curbing illegal activities, alleviating the HLMC, creating awareness about wildlife and conservation among the locals (Jenks et al., 2012; Ghoddousi et al., 2016). It is imperative to minimize the HLMC in the locality by the PA managers as often retaliation occurs in response to conflict. In India, the forest department has initiated several measures to alleviate the HWIs, such as electric fences, elephant proof trenches, relocation of conflict animals, and monetary compensation schemes (Lahiri-Choudhury, 1993; Datye and Bhagwat, 1995; Nath and Sukumar, 1998; Mishra et al., 2003; Sukumar, 2003; Athreya, 2006; Athreya et al., 2011; Karanth et al., 2013a). Death of humans and wildlife occurs although such measures exist to mitigate heavy economic losses due to several underlying problems. It is therefore imperative to address the issues related to the PA management from the perspective of the park managers for effective reduction of HLMC.

Globally, anthropogenic pressure has caused a decline in many large mammal species' populations through habitat conversion, poaching for trade, and commercial exploitation of natural habitat (Foley et al., 2005; Chen et al., 2016). Assessing the factors driving the large-mammal distribution in response to the ecological and anthropogenic stress will bring out the role of ecological (habitat features, prey abundance, patch size) and anthropogenic factors (agriculture practice, livestock presence, human population) influencing the distribution of large mammals. Habitat loss and fragmentation have resulted in dispersal of large mammals towards human-dominated landscapes (Menon and Chaudhary, 2017). Population connectivity of wildlife gets altered due to the isolation of forests by human habitation and development (Segelbacher et al., 2010). The habitat loss and fragmentation as a result of the developmental activities and urbanization have been challenging for the survival of the large mammals (Desai and Baskaran, 1996) because they require contiguous forest habitat to sustain their dietary and reproductive needs (Venkataraman et al., 2002; Jhala et al., 2010; Dutta et al., 2013; Lama, 2016). It also increases the risk of large mammal extinction by inbreeding and demographic/environmental stochasticity (Quinn and Harrison, 1988). In Asia, many of the

PA's are small and isolated (Dinerstein and Wikramanayake, 1993). In India, PA networks constitute only less than 5% area of the country's total landmass (Ghosh-Harihar et al., 2019) and are dependent on outside PAs (RFs) for functional integrity and ecosystem resilience. Identifying key habitats frequently utilized by wildlife (regardless of PA or outside PA) and preserving the movement pathways between them is an effective way to untangle the problem of small patch size of PAs. The dispersion of large mammals in the human habituated regions results in HLMC, and eventually, retaliatory kills. Human-induced mortality limits the survival of large mammals dispersing from one habitat to the surrounding habitat resulting in population sinks (Sukumar and Santiapillai, 1996; Woodroffe and Ginsberg, 1998; Gubbi et al., 2012; Chen et al., 2016). Due to the rising anthropogenic pressure, many large mammal species have limited their distribution to isolated landscapes when compared to the past; for example, the distribution range of leopards has reduced to less than 30% in the past three generations (Stein et al., 2025), while dhole and gaur range reduced to 40% (Karanth et al., 2010) and 80% (Groves and Grubb, 2011) respectively, in the past 100 years. The distributional range of the tiger population also declined by 7% from its historical ranges (Dinerstein et al., 2007). Asian elephant populations are absent in 95% of ranges they were present earlier (Sukumar, 2006). Besides, the land-use management and conservation strategies developed based on the habitat-use or movement pattern of a single species may not be appropriate for other sympatric species because the ability to navigate between the patches, and varying landscape configurations are species-specific (Thatte et al., 2019). Therefore, connectivity studies on multi-species are crucial to developing broadly applicable land-use management and landscape connectivity plans. Studying the ecological and anthropogenic factors determining the distribution of the large mammals at a landscape level and developing the species occupancy maps can help in effective wildlife management, and reducing human-wildlife interactions by developing region-specific mitigation measures.

The Western and Eastern Ghats part of Tamil Nadu (WEGPTN) is among India's most important tiger, co-predators and mega-herbivore conservation unit because it supports a high density of large mammals (Venkataraman et al., 2002; Jhala et al., 2010; Ramesh, 2010); particularly, these areas have the last remaining populations of large mammals in Southern India due to its contiguous forest networks (Jhala et al., 2010). Yet these areas are prone to high livestock grazing activity and habitat fragmentation due to the growing human population within and outside the PAs. There are several human settlements with agricultural lands and livestock herds within the adjacent RFs, particularly the buffer areas of the PAs (Jhala et al., 2010). Further,

the environment of these areas has been subjected to developmental activities such as the construction of hydro-electrical power stations, alteration of natural forests for the cultivation of tea, coffee, eucalyptus and wattle. In addition, retaliatory killing by electrocution, snares, poisoning the livestock carcass is found to be one of the major threats to large mammal populations in this region (Kalaivanan et al., 2010; Arumugam, 2012). Though several studies are available on large mammals in India, practically no information is available India's proposed aspects, especially covering both inside and outside the PAs in WEGPTN, Southern India. However, in this region human pressure has continued to grow with agriculture, livestock grazing, tourism and other developmental activities and human large-mammal interaction is inevitably bound to increase over the period. To avoid the establishment of the population “sinks”, the surrounding reserves in which human-caused mortality limits survival of large mammals dispersing from the reserves (Woodroffe and Ginsberg, 1998), crop-raiding, and livestock depredation resulting persecution of large mammals must be minimized through appropriate detailed research studies that is proposed to implement. The rates of HWI can be influenced by the local environmental and socio-ecological factors that include abundance of natural forage, crop and animal husbandry practices (Madhusudan, 2003; Ogada et al., 2003; Woodroffe and Frank, 2005). Large scale landscape-level approach covering multiple PAs and Non-PAs across varied socio-ecological cultural gradients is essential for national and State Governments in developing conflict mitigation policies. Henceforth, the study will evaluate the influence of ecological and anthropogenic factors on HLMC, identify the conflict hotspots examine the lacunas in PA management, identify the occupancy pattern of large mammals and map the least-cost movement pathway and pinch points of habitat connectivity of large mammals of WEGPTN landscape, to contribute to the HLMC mitigation strategies. The proposed research study will thus give a detailed outlook on different attributes of human-wildlife conflict which will be critical in developing region-specific and species-specific mitigation measures which the forest department can effectively employ in mitigating the large mammal conflict in India and elsewhere. My study particularly focused on the conflict pattern and drivers of distributions of five major large mammal species frequently involved in HLMC in WEGPTN- Bengal tiger, Indian leopard, dhole, Asian elephant, and gaur, at a broader landscape level (Figure 1.6). Although dholes are moderate in body size, their pack-hunting behaviour and their impacts on prey are comparable to those of larger carnivores such as leopards and tigers; therefore, they were considered under large mammals in the present study. According to IUCN Red List, tiger is classified as Endangered (Goodrich et al., 2022), while leopard is listed as Vulnerable (Stein et al., 2025); Asian elephant and dhole hold Endangered

status (Elephant: UCN SSC Asian Elephant Specialist Group, 2020; Dhole: Kamler et al., 2015) and Gaurs are classified as Vulnerable (Duckworth et al., 2016). Following are my research objectives:

1. Assess socio-ecological characteristics of human-large mammal conflict across the management gradients
2. Identify disparities in resource allocation between Protected Areas and outside Protected Areas and its effect on human-wildlife conflict
3. Determine the effect of anthropogenic pressure on distributional patterns of large mammals

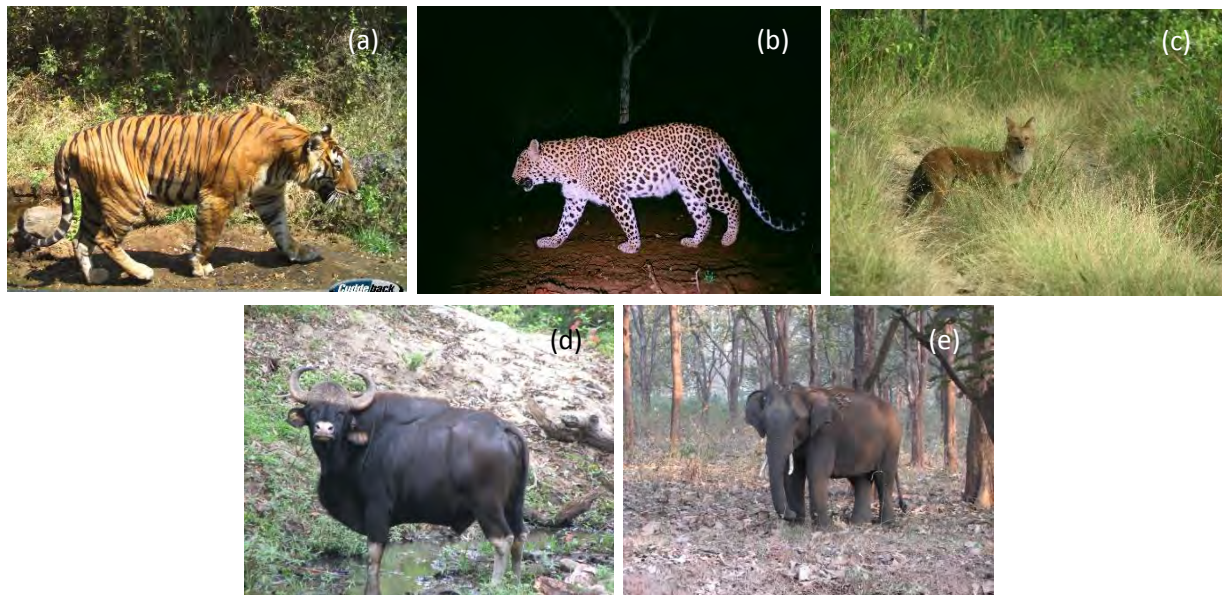


Figure 1.6 Study species: tiger (a), leopard (b), dhole (c), gaur (d), elephant (e)

1.3 Organization of the thesis

The current chapter (**Chapter I**) comprehends the background information on various attributes of human-large mammal conflict and rationale of the study, including the research objectives. **Chapter II** encompasses the details of study area including geo-climatic features, major fauna and flora, threats to the large mammals and importance of the study area. **Chapter III** encompasses the details of local people's perception on coexistence with large mammals, the major ecological and landscape attributes driving human-large mammal conflict in WEGPTN from my first objective. It includes species-specific human-large mammal conflict risk hotspot maps for the WEGPTN. **Chapter IV** discusses the effectiveness of Protected Area

management- the wildlife conservation issues and lacunas in wildlife management in PAs and outside PAs of WEGPTN, revealed by the respective Forest Range Officers from my second objective. **Chapter V** addresses my third objective and includes details on the ecological and anthropogenic factors affecting the large mammal (tiger, leopard, dhole, elephant, and gaur) distribution as well as habitat connectivity of large mammals in the WEGPTN landscape. It encompasses of large mammal occupancy maps, comparison of the occupancy patterns between the PAs and outside PAs, comparison of resistance across the Forest Divisions, and maps of resistance surface, least-cost movement pathways, and cost-weighted distances across WEGPTN. **Chapter VI** provide suggestions for HLMC management, following the conclusions obtained from each objective.

Chapter 2

CHAPTER 2

Study Area

The Western Ghats is one of 36 recognised global biodiversity hotspots (<https://www.conservation.org/priorities/biodiversity-hotspots>). The network of Western and Eastern Ghats together encompasses a major part of the total floral and faunal diversity in India. The study was conducted across the WEGPTN, covering sixteen forest divisions: Kanyakumari Wildlife Sanctuary, Kalakad-Mundanthurai Tiger Reserve (KMTR), Nellai Wildlife Sanctuary, Srivilliputhur Grizzled Squirrel Wildlife Sanctuary, Meghamalai Wildlife Sanctuary (now, converged and known as “Srivilliputhur-Megamalai Tiger Reserve”), Kodaikanal Wildlife Sanctuary, Sathyamangalam Tiger Reserve (STR), Coimbatore Forest Division (FD), Theni FD, Gudalur FD, Nilgiri FD, Mudumalai Tiger Reserve (MTR), Erode FD, Dharmapuri FD, Hosur FD, and Cauvery North Wildlife Sanctuary (CNWLS) (Figure 2.1). Each forest division contains approximately four to five forest ranges. The study area also includes FAs which cover up to 5km from the forest boundary. Although PAs and outside PAs (RFs) have similar topographical features, they vary in the species composition and degree of legal restrictions for the local community to utilize forest resources.

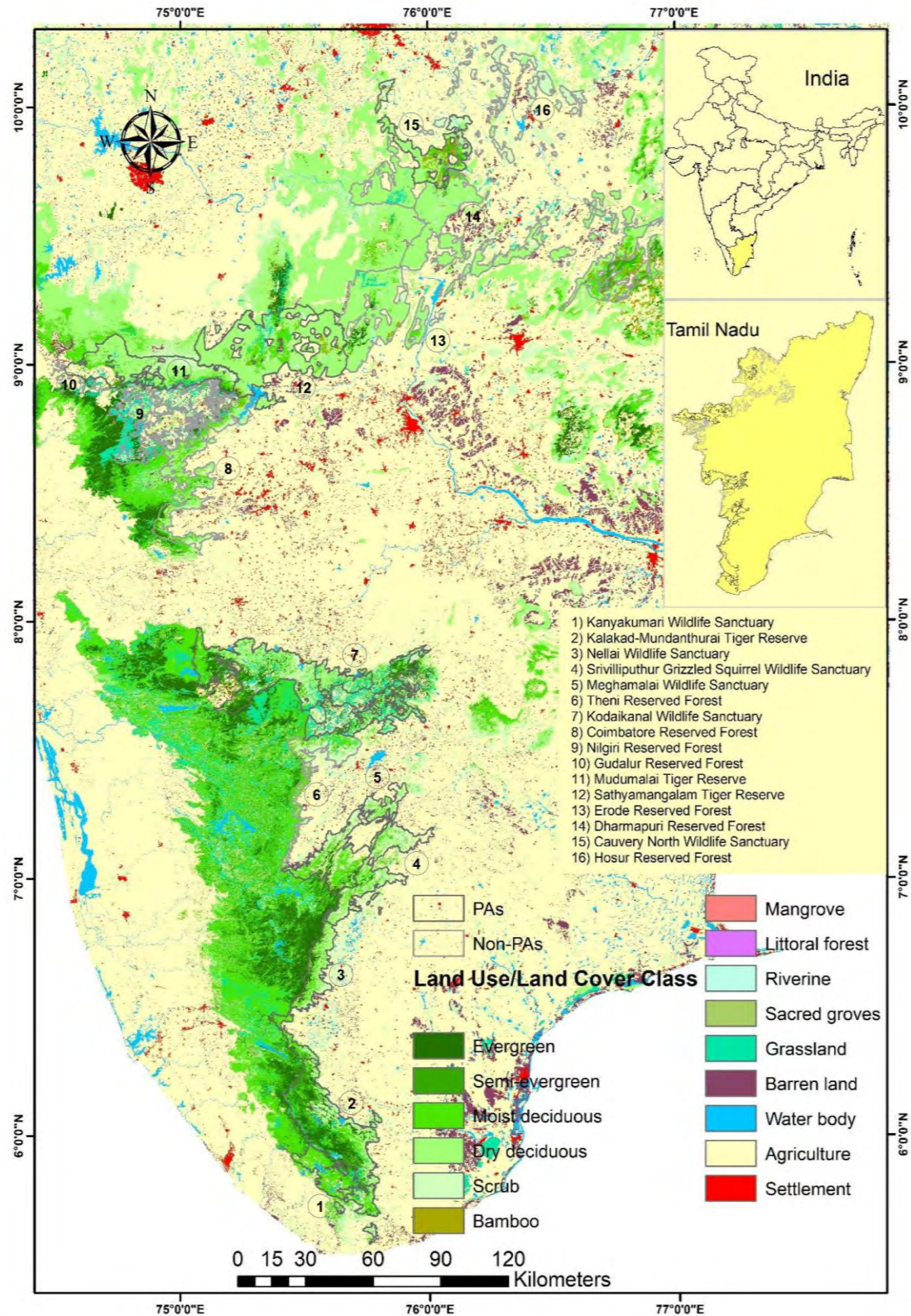


Figure 2.1 Study area covering the Western and Eastern Ghats parts of Tamil Nadu.

2.1 Geoclimatic characteristics

Running almost parallel to the Arabian Sea coastline, the Western Ghats stretch in a continuous line from the Tapti River in the north to the far south of India (Kanyakumari), with the only discontinuity at the Palghat gap (Pascal, 1988) (Figure 2.2). The vast mountain range is spread across parts of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu States. With the distinct geographical location and river basins, the Eastern Ghats of India also rich in the biodiversity. The Eastern Ghats extends across north-eastern and south-western parts of the Indian Peninsula discontinuously due to the great Indian rivers, Mahanadi, Godavari and Krishna. It covers the States of Odisha, Andhra Pradesh and TN (Pullaiah, 2004). The distinct geoclimatic features of the WEGPTN landscape makes it highly favourable habitat to unfathomable diversity of fauna and flora. Here, the average annual rainfall ranges from 600 mm in low altitude areas, to 2,000 mm in high-altitude areas. The area receives rainfall from the north-west monsoon and south-east monsoon. The altitude ranges between 200 and 2644 MSL (Mean Sea Level) with the highest Doddabetta peak ranging at 2644 m from MSL (Jayakumar et al., 2009). The mean annual temperature of the study area ranged from 5° to 40°C. The area under each forest divisions ranged from as small as 322 km² to the largest at 1,409 km². Average human population density varied spatially by a factor of ten, from 100 to over 1000 persons per km² (CIESIN, 2016).

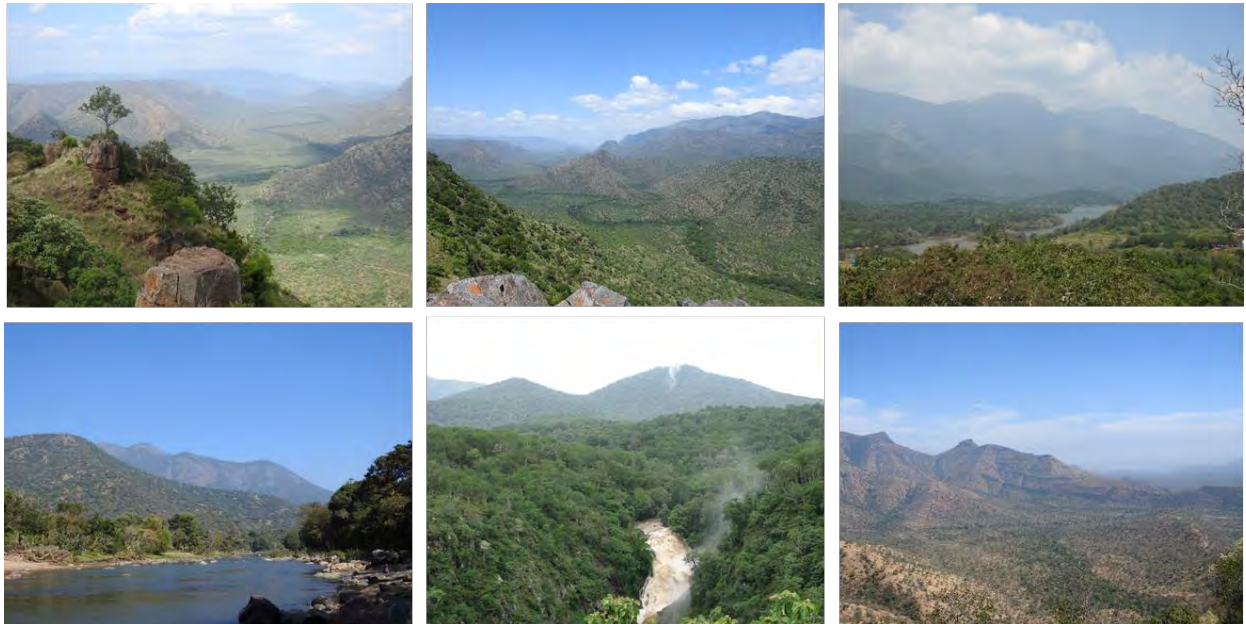


Figure 2.2 Study area landscapes.

2.2 Forest types and faunal diversity

The major forest types of WEGPTN encompass evergreen, semi-evergreen, moist mixed deciduous, dry deciduous, dry mixed deciduous, dry thorn, and riparian forests; the region also contains grasslands and *wet shola* grasslands (Champion and Seth, 1968; Roy et al., 2015). Peculiar geoclimatic features along with array of different forest types provides a diverse and unique niche for diverse faunal species.

The study area encompasses a wide number of large mammals and hosts some of the last extensive large mammal populations in southern India (Jhala et al., 2020). The continuous stretch of Nagarhole-Bandipur-Wayanad-Mudumalai-Sathyamangalam Forest Reserves, which is at the trijunction of three south Indian states (Karnataka, Kerala, and Tamil Nadu), is the largest single tiger (*Panthera tigris*) conservation unit the world with 724 individuals (Jhala et al., 2020). This complex also encompasses one of the largest populations of Asian elephants (*Elephas maximus*) with over 8,000 individuals (Ramkumar et al., 2017). Major large carnivores and omnivores found across the study area includes tiger, leopard (*Panthera pardus*), dhole (*Cuon alpinus*), striped hyaena (*Hyaena hyaena*), and sloth bear (*Melursus ursinus*); their potential wild ungulate prey includes gaur (*Bos gaurus*), chital (*Axis axis*), sambar (*Rusa unicolor*), wild boar (*Sus scrofa*), muntjac/barking deer (*Muntiacus muntjak*), four-horn antelope (*Tetracerus quadricornis*), and mouse deer (*Moschiola indica*) (Figure 2.3). Common langur (*Semnopithecus entellus*), bonnet macaque (*Macaca radiata*), black-naped hare (*Lepus nigricollis*), porcupine (*Hystrix indica*), Indian giant squirrel (*Ratufa indica*) and peafowl (*Pavo cristatus*) are also among the other small prey species found in the region (Figure 2.3). Other prey species like blackbuck (*Antelope cervicapra*), chinkara (*Chinkara gazellabennettii*) are also found in certain parts of the PA landscape.





Figure 2.3 Major prey species of large carnivores in the Western and Eastern Ghats part of Tamil Nadu: (a) gaur, (b) chital, (c) sambar, (d) common langur and (e) wild pig.

2.3 People and livelihood

The State of TN has 36 tribal communities; some of the major communities found in the study are include Irular, Kanikaran, Kaniyan, Kattunayakan, Kurumbas, Malasar, Malayali, Pallayan, Palliyan, Palliyar, Paniyan, Sholaga, Toda, Uraly. These tribal communities, who are socioeconomically disadvantaged, rely on agriculture, tea plantation work, traditional healing, and employment in the forest department for their livelihoods (Ignacimuthu and Ayyanar 2005; Ignacimuthu et al., 2008). They also depend heavily on forest resources, engaging in livestock rearing and collecting non-timber forest products such as roots, tubers, honey, and firewood, and ‘wage slavery’ (Arjunan, 2004; Arjunan et al., 2005; Davidar et al., 2005; Solavan et al., 2004; Wilsanand, 2005; Basavarajaiah et al., 2020) (Figure 2.4). Non-tribes depend on agriculture, plantation labour, animal husbandry, and small-scale industries for revenue. When compared to general public, the quality of life of the local forest-dependent community is far behind. Poverty, illiteracy, lack of job opportunities, poor healthcare facilities, malnutrition, lack of potable drinking water, etc. makes the predicament of these communities worse (Basavarajaiah et al., 2020). The health risks within these communities are high due to distant

healthcare centres and prevailing poverty. Consequently, residents often rely on herbal remedies from their traditional knowledge, which may not consistently address their illnesses (Basavarajaiah et al., 2020). Indigence has further aggravated the educational prospects of the younger generation, as many households lack the financial means to adequately support their children's schooling (Basavarajaiah et al., 2020). Moreover, resettlement and lack of awareness on their rights and legislature made the involvement of the community members in government organizations feeble and impacted the quality of their lives negatively (Ramesh et al., 2019; Basavarajaiah et al., 2020).



Figure 2.4 Forest-dwelling local community people collecting non-timber forest products.

2.4 Threats and conservation issues

The forested landscapes of the Western Ghats have undergone significant transformation due to anthropogenic land-use changes over the last century (Figure 2.5). Reddy et al., (2016) reported that approximately 35.3% of the total forest cover in the region was lost between the 1920s and 2013, primarily due to conversion into plantations, agricultural land, and degraded scrub. The rate of deforestation in these areas from 1920-1990, particularly in the British colonization period were high, and many parts of these forests were transformed into agriculture land and thus underwent extensive habitat loss (40%); the monoculture plantations like tea and coffee lead to habitat fragmentation (80% decrease in patch sizes and 400% increase in patch numbers) (Menon and Bawa, 1997). Currently, the entire stretch of the Western Ghats has a total of 20,284 habitat patches with a mean patch size of 3.92km² (Nayak et al., 2020). In the last 15 years, many of the fallow forest lands located at the foothills of the forests were transformed into centres of development, disturbing the corridors of large mammals (Ramkumar et al., 2018) (Figure 1.5).

The study area has several convoluted boundaries with several projections and indentations along with numerous small and large village enclaves within its expanse. Such an environment increases the interface zones of the forest with agriculture and human habitation areas resulting in a higher degree of crop-raiding (Babu et al., 2012). All the sixteen FDs are subjected to various developmental pressures, including the construction of hydro-electrical power stations, and the conversion of natural forests to cultivate tea, coffee, eucalyptus, and wattle. Habitat loss and fragmentation by virtue of inappropriate land-use practices inside and towards the forest fringes like infrastructure development, cultivating crops, overgrazing of the livestock, forest fires, NTFP collection (Sukumar, 1991; Silori and Mishra, 2001; Pillay et al., 2011; Venkataramana et al., 2017; Ramkumar et al., 2018; Hariharan et al., 2025), along with other threats like poaching and retaliatory killing of conflict animals (Pillay et al., 2011; Milda et al., 2020; Ramesh et al., 2020) altered the abundance and distribution pattern of many large mammals in the study area. Unsustainable NTFP collection has led to habitat loss followed by loss of biodiversity in the Western Ghats landscape (Arjunan et al., 2005). Rising anthropogenic pressure has also paved way to invasion of exotic weeds like *Lantana camara*, *Prosopis juliflora*, *Opuntia dellini*, and *Senna spectabilis* that overgrow the native plants (Johnsingh et al., 2010; Sathyanarayana and Gnanasekaran, 2013), reduces the native forage for herbivores, forcing them to venture out to human-dominated landscapes, reducing the prey density inside forests and leading to HLMC. Among all the mammals, those frequently in conflict with humans, creating economic burden to the local people are elephant, leopard, wild pig, bonnet macaque, gaur, tiger, sloth bear, sambar and chital (Milda et al., 2020, 2023b; Ramesh et al., 2020, 2021). Electrocution, snares, and the poisoning of livestock carcass, are some of the other major strategies the local people follow for poaching wild fauna in these landscapes (Kalaivanan et al., 2010; Arumugam, 2012; Sekar, 2013; Milda et al., 2020). Although livestock within PAs is prohibited, illegal grazing in the forest patches, particularly near water bodies, is prevalent. Herders frequently leave livestock unattended to graze during the day, sometimes guarded by dogs, and herds them back to the villages in the evenings. Habitat modification and easy availability of food/prey attract wild predators to human-dominated landscapes (Sukumar, 1990; Gubbi, 2012; Venkataramana et al., 2017; Ramesh et al., 2020), increase HWIs, altering the abundance and distribution of wild fauna.



Figure 2.5 Fragmented forest landscapes in the study area.

The conversion of forests into designated reserves played a pivotal role in minimizing the biodiversity loss across the region (Das et al., 2006). Particularly, the establishment of the Nilgiri Biosphere Reserve (NBR) have contributed to regulating forest cover in the southern Western Ghats (Satish et al., 2014). As a result of the improved forest conservation initiatives, the forest cover remained relatively stable between 2005-2013 (Reddy et al., 2016). Still, only about 37% of the Western Ghats is now estimated to retain its native vegetation (Kasturirangan et al., 2013) and earlier occurrences of habitat loss continue to exert ecological pressure. Forest fragmentation, as described by Bennett (1999), occurs through three progressive phases: reduction in total forest area, disintegration of large continuous tracts into smaller patches, and increasing isolation of these patches over time. Therefore, the historical forest loss and the subsequent structural changes in the Western Ghats landscape is expected to have lasting consequences for ecological process and species movement. It continues to shape current landscape dynamics and can significantly influence the viability of future habitats. This pattern severely constrains landscape connectivity, particularly for wide-ranging species, and pushes them into human-dominated spaces, fuelling the HLMC. Human

mortalities from the attack of elephant (>50 people every year), gaur (≥ 5 person every year) and large carnivores (ca. 2 people every year), livestock depredation, crop and property damage, and large mammal mortality by retaliatory killing are of serious concern in Tamil Nadu (Tamil Nadu Forest Department 2017; Milda et al. 2020). It is challenging for the local government and the State Forest Department to sustain a balance between human needs and wildlife with the accelerating negative human-wildlife interactions. Therefore, rising incidents of HLMC in WEGPTN (Ramesh et al., 2020, 2022) indirectly underscores the urgent need for interventions aimed at restoring and connecting remnant habitats for viable large mammal populations.

2.5 Intensive study area and methods

Nilgiri Biosphere Reserve (NBR) is nestled in the connecting junction of the Western and Eastern Ghats and represents one of the most ecologically sensitive and unique landscape for large mammal conservation in Asia. It constitutes a cluster of biodiverse PAs including Bandipur Tiger Reserve, Nagarhole Tiger Reserve, MTR, STR, and Wayanad Wildlife Sanctuary, forming the single largest contiguous landscape of tropical forest in South Asia (Johnsingh et al., 2009; Ramesh et al., 2010). The area is ecologically so unique that it has been recognised as a UNESCO World Heritage Site and is a part of global biodiversity hotspot with the biodiversity unmatched with elsewhere in the world (Myers et al., 2000; UNESCO, 2012).

The viability of large mammal population is one of the most distinguishing factors of NBR from other parts of Western Ghats. A recent report of National Tiger Conservation Authority (NTCA, 2022) highlights that one-fifth of India's entire tiger population is with Nagarhole and Bandipur Tiger Reserves, indicating the highest tiger population density documented elsewhere in the world. Similarly, the cluster is a stronghold area for leopards and other co-predators in the country (NTCA, 2023). Accordingly, the density and diversity of prey population is also high including gaur (*Bos gaurus*), chital (*Axis axis*), and sambar (*Rusa unicolor*) (WII, 2023). NBR hosts more than 6,000 elephants, which is the largest, contiguous population of the species compared to other parts of Asia (Menon et al., 2017; Project Elephant, MoEFCC, 2017), highlighting the significance of conservation of the landscape.

Apart from the residential population, the landscape is pivotal in maintaining regional metapopulation dynamics of large mammals. In a viable source-sink framework, source population always generate excess individuals whose dispersal subsidises demographically

fragile population the neighbouring areas (Pulliam, 1988). Studies confirm that dispersal of large carnivores like tiger and leopards occurs from Nagarhole, Bandipur and MTR into adjacent Reserved Forests, Mysore plateau and Eastern Ghats, aiding establishment of clusters as an exporter of these large carnivores across a wide landscape (Karanth et al., 2010; Mondal et al., 2013). Therefore, the landscape helps in sustaining genetic connectivity and gene flow across broader Western Ghats metapopulation, making the NBR cluster indispensable for long-term viable large mammal population even in the surrounding areas. NBR landscape acts as an anchor holding different forest reserves and wildlife corridors that are important for connectivity between PAs. These corridors facilitate the movement of all large mammals across forest boundaries enabling the genetic exchange, avoiding inbreeding depression and seasonal range shifts required for population persistence (Johnsingh et al., 2009; Wikramanayake et al., 2004; NTCA, 2023). All these factors like high density of wildlife and high forest landscape connectivity, when combined with the extensive interface area between PAs and human-dominated landscape contribute to intense and complex ground for human-wildlife interactions. Studies document high rates of crop raiding by megaherbivores like elephant and gaur, livestock depredation by large carnivores like tiger, leopard and dhole, human casualties and retaliations, predominantly along the forest fringes bordering the NBR (Madhusudan, 2003; Vijayan & Pati, 2002). The pattern of HLMC is largely determined by the distribution and movement ecology of the large mammals residing in the landscape. Therefore, studying species distribution and socio-ecological characteristics of human-wildlife interactions within this landscape provide insights that are pivotal to national conservation priorities, making the NBR an appropriate study area for in-depth HWC analysis.

Based on the results obtained from the first and second objective, we chose nine high-conflict zones identified in the WEGPTN (Milda et al., 2020; Ramesh et al., 2020), where the ecological survey was conducted for fulfilling the third objective. The intensive study area (ISA) included three PAs- Mudumalai Tiger Reserve (MTR), Sathyamangalam Tiger Reserve (STR), and Cauvery North Wildlife Sanctuary (CNWLS); and six Outside PAs (Reserved Forests) - Coimbatore Forest Division (FD), Gudalur FD, Nilgiris FD, Erode FD, Hosur FD and Dharmapuri FD (Figure 2.6). All FDs except CNWLS, Hosur and Dharmapuri FDs are parts of Nilgiri Biosphere Reserve (NBR).

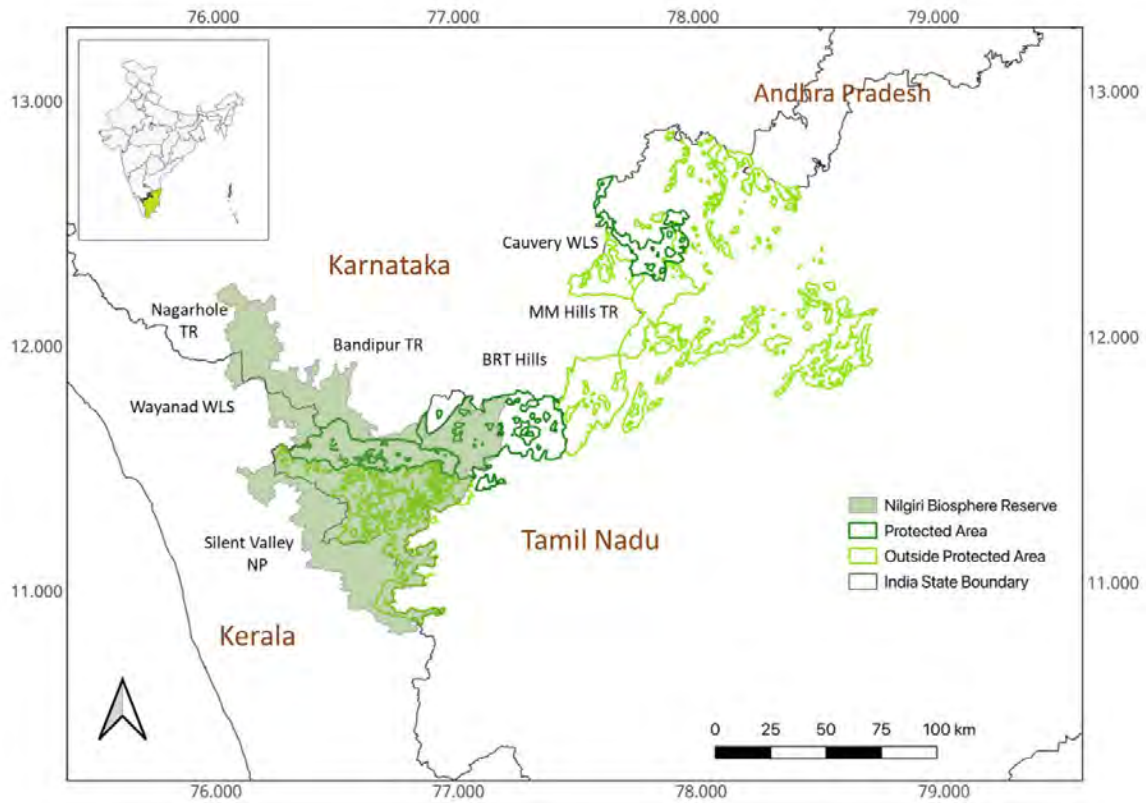


Figure 2.6 Map showing the Nilgiri Biosphere Reserve at the tri-junction of Tamil Nadu, Kerala, and Karnataka, located in southern India along with range of Protected and Outside Protected Areas of the Western and Eastern Ghats part of Tamil Nadu (study area).

A pilot survey was conducted regarding the conflict issues and the severity of conflict in the State from the local media reports and Forest Department records to maintain the authenticity of the data collection. Later a 5x5 km grid was laid extensively across the entire study area and carried out semi-structured questionnaire survey with the villagers (minimum three households per grid) to collect the socio-ecological data regarding the conflict incidents they encountered. Simultaneously, a semi-structured questionnaire survey was conducted with the Forest Range Officers of all sixteen Forest Divisions to collect data on HWC management. Lastly, from the results obtained from the questionnaire survey, nine continuous Forest Divisions that encounter the highest HLMC in the State was chosen to study the ecological and anthropogenic factors affecting the distribution and map habitat connectivity pattern of large mammals. A 10x10 km grid was laid across the ISA and carried out an ecological sign survey for a stretch of 2 km (minimum one to maximum three independent survey routes per grid) starting from the interface area, and extending towards the forest. In order to assess the habitat quality, vegetation sampling was conducted at every 400 m of the 2 km survey route.

Chapter 3

CHAPTER 3

Assess socio-ecological characteristics of human-large mammal conflict across the management gradients

3.1 Introduction

Protected Areas (PAs) in India are often intertwined with human settlements and have witnessed decades of coexistence between humans and wildlife, with inhabitants reliant on forest resources for their livelihoods (Karanth et al., 2006; Davidar et al., 2010). Understanding local residents' views through perception studies is vital to wildlife conservation efforts (Karanth et al., 2008; Vodouhê et al., 2010; Mir et al., 2015) because successful implementation of any wildlife conservation policy depends on positive perceptions of the local community towards wildlife and coexistence. Perception encompasses an individual's observation, understanding, interpretation, and evaluation of various subjects (Bennett, 2016). An individual's perception can be shaped by personal experiences and factors such as age, gender, wealth, occupation, education, values, beliefs, cultural norms, societal experiences, and expectations (Lindsey et al., 2005; Dickman, 2010; Basak et al., 2023). Studies highlight a human tendency to perceive large and potentially dangerous animals more negatively, even if the losses from other taxa are similar (Dickman, 2010), leading to retaliatory events particularly focused on large mammals. Sometimes, HLMC may stem from difference in opinions between local communities and governing bodies (Dickman, 2010). A study by Skogen et al. (2008) highlighted the scepticism of local farmers in France and Norway regarding the 'natural recolonization' of wolves, suspecting secret reintroduction by authorities. Animosity towards the privileged urban communities could also be a reason for negative perception because they often perceive that the animals that are threatening their life and livelihoods are 'protected by law', created by the elite society who barely encounter any problem (Skogen et al., 2008). Inadequate access to essential facilities like education, transportation, healthcare, electricity, and water within PAs can also exacerbate community grievances and increase hostility towards policies and wildlife (e.g., Ramesh et al., 2019). Sometimes, due to their economic vulnerability, households dependent on a single income source become more likely to harbour animosity towards life-threatening animals (Dickman, 2010). Hence, region-specific analysis of factors shaping people's perceptions, especially among the forest-dependent local community is crucial. Failure to address people's concerns may lead to a lack of local support for conservation efforts (Woodroffe et al., 2005) and potential retaliatory killings of animals

(Inskip and Zimmerman, 2009), as evidenced by incidents like the retaliatory killing of four tigers in Chitwan National Park, Nepal, between 2007-2014 (Dhungana et al., 2016). Individuals with positive attitudes towards wildlife are more likely to support management initiatives by authorities (Andersone and Ozolins, 2004; Kaczensky et al., 2004). Factors such as participation in awareness programs may aid in nurturing a positive perception towards wildlife among the local residents (Mishra et al., 2003). Generally, individuals who have not experienced issues with certain species may have a positive perception towards that species, compared to those who experienced, often due to lack of awareness (Marker et al., 2003). On the contrary, some studies have shown positive attitude of people despite regular encounters with species (Jackman and Rutberg, 2015; Booth and Ryan, 2019). Therefore, as a critical first step towards attaining large mammal conservation goals, understanding people's perception towards large mammals and their conservation through region-specific surveys are vital. This is also crucial for policy-making process because any policies restricting local resource-use without considering livelihood dependencies will only serve to fuel resentment towards both policies and wildlife held responsible for their enforcement (Ramesh et al., 2019).

Today over half of India's human population is engaged in some form of agriculture and forestry, including livestock grazing; also, the land in and around PAs are frequently exposed to diverse traditional livelihood practices (Census of India, 2011; Meiyappan et al., 2017). Although forest resource collection and livestock grazing by local people are not allowed within the PAs of India, the resistance from people's traditional belief system often over-powers law enforcement by the government sector (Ramesh et al., 2019). Livestock grazing inside Forest Reserves is a major contributor to wild prey population decline in India, through reduced forage availability (Madhusudan and Mishra, 2003), increased rate of disease transmission to wild herbivores (Rahmani, 2003), thereby switching dietary preferences of large carnivores from wild prey to domestic prey. Furthermore, depletion of food resources, biomass extraction and habitat degradation caused by humans indirectly by the spreading of weeds in their natural habitats has led to frequent crop-depredation episodes by megaherbivores (Boominathan et al., 2008; Babu et al., 2012). Thus, the overlapping resource usage and shared spaces between humans and large mammals often lead to habitat loss (Chaudhury, 2004; Kumar et al., 2004), crop damage, livestock depredation, people's retaliation by snaring or poisoning of conflict animals (Madhusudan, 2003; Kalaivanan et al., 2010; Gubbi, 2012; Khorozyan et al., 2015; Mathur et al., 2015), and human injury or threat to livelihood security (Ripple et al., 2014; Wildlife Protection Society of India, 2017; MoEF, 2010a; Mathur et al., 2015). Such forms of

human-large mammal conflicts (HLMC) frequently bring major economic loss to the forest-dependent and the forest-adjacent communities, threatening local livelihoods and economic security (Lyngdoh et al., 2014; Bargali and Ahmed, 2018). If sustained over time, many of these areas will eventually turn into “conflict hotspots” (Broekhuis et al., 2017), with majority of people turning against the wildlife conservation goals.

Some of India’s PAs are experiencing an increase in large carnivore populations due to the implementation of consistent and effective conservation measures (Jhala et al., 2020). However, negative human-carnivore interactions, especially in the form of livestock depredation, retaliatory killing of animal and direct attack on humans, are becoming more frequent, especially when high densities of large carnivores occur in fragmented small PAs (Wikramanayake et al., 2004; Kshetry et al., 2017; Sidhu et al., 2017), thereby making multispecies carnivore conservation goals even more challenging (Woodroffe et al., 2005). Along the human-wildlife interface, different large carnivore species can vary in their response to anthropogenic stressors (Harihar et al., 2007; Bhattacharjee et al., 2015; Miller et al., 2016a; Tyagi et al., 2019) and might even select relatively more domestic prey in proportion to native wild prey (Miller et al., 2016a, b; Chetri et al., 2019). Although both tiger (*Panthera tigris*) and leopard (*Panthera pardus*) are stalking hunters and prefer structurally complex heterogeneous habitat with adequate ambush cover (Ramesh, 2010), the former requires larger contiguous and less disturbed forested landscapes (Jhala et al., 2010, 2019), making them less resilient to human modifications and activity (Harihar et al., 2007; Bhattacharjee et al., 2015; Tyagi et al., 2019). On the contrary, leopard is highly adaptable, more tolerant of human-wildlife interface areas across more land-use contexts (Athreya et al., 2013; Odden et al., 2014; Kshetry et al., 2017). The pack-living dhole (*Cuon alpinus*) hunt in relatively more open habitats (Ramesh et al., 2009; Ramesh, 2010) and can utilize secondary forests, multi-use forest fragments, and agro-forest plantations (Majumder et al., 2011; Srivathsa et al., 2014, 2019b; Punjabi et al., 2017; Thinley et al., 2018). Because India’s PA managers have little jurisdiction over areas outside PA boundaries, along with the human-wildlife interface areas, there is a constant struggle in the implementation of forest conservation and community land-use policies to achieve broad conservation goals (Macura et al., 2011). Therefore, in landscapes where multiple large carnivore species overlap with human habitations, HCC mitigation strategies and management approaches will need multi-predator HCC management approach.

An increase in human-megaherbivore conflict is generally associated with the areas close to or within the forested landscapes because of the species abundance, shrinkage of its natural habitat

and reduced food availability inside the forest. Emerging tea/coffee plantations that replaced the natural grassland had a crucial role in the increased human-megaherbivore conflict in Southern India (Kumar et al., 2004). Elephant and gaur herds/individuals have habituated to the open agriculture land (tea garden/seasonal crop) where they majorly feed on the available lush green crops and grassy patches (Sukumar and Pani, 2016; Indira, 2019). Also, in the southern-most elephant (*Elephas maximus*) and gaur (*Bos gaurus*) distribution ranges of India, the invasion of lantana (*Lantana camara*), wattle (*Acacia sp.*), pine (*Pinus sp.*), and eucalyptus (*Eucalyptus globulus*) species into grasslands and other natural habitat is a primary concern as megaherbivores stray into agriculture land and human habitations for foraging due to the reduced food availability inside the forest. Seasonal variation is also a driver of human-megaherbivore conflict. They tend to involve in conflict outside the forests, predominantly during the dry season, to compensate for the lowest quality available nutrition from the forest vegetation (Ahrestani et al., 2012). Besides, megaherbivore habitats face threats from livestock grazing, competition for water resources, woodcutting, exploitation of bamboo, collection of minor forest produce, fire outbreaks, proliferation of exotic weeds like *Lantana camara*, disruption of corridor connectivity by the road and rail networks, resulting in elevated risk of human-megaherbivore conflicts (Sukumar, 2003; Johnsingh et al., 2010a; Ramesh et al., 2012c; Sukumar and Pani, 2016).

The incidents of HLMC have surged in recent years in the Western and Eastern Ghats part of Tamil Nadu (WEGPTN) (Milda et al., 2020; Ramakrishnan, 2024), a region with vital forest networks that harbours some of southern India's last remaining populations of large mammals (Jhala et al., 2010). The rising HLMC events in WEGPTN underscores the urgency of developing more scientific and efficient HLMC mitigation measures. As an alternative to deal with HLMC, the designation of some Forest Divisions were raised for improved wildlife protection measures (e.g. Mudumalai Wildlife Sanctuary (WLS) was converted to Mudumalai Tiger Reserve (MTR); Srivilliputhur WLS and Megamalai WLS were merged and converted to Srivilliputhur-Megamalai Tiger Reserve), restricting indigenous community activities within PAs and relocated the residents of PAs to new areas where people found difficult to establish their livelihood (Ramesh et al., 2019). Such measures may impose a sense of alienating local communities and undermining their contribution to future wildlife conservation efforts (Ramesh et al., 2019). Addressing the concerns of these key stakeholders is paramount, as their support is essential for successful wildlife conservation endeavours (Rohini et al., 2018). Besides, HLMC surveys on a larger spatial scale or encompassing multiple landscapes for

wide-ranging large mammals can provide detailed insights into differences in the frequency and distribution of conflict across various management systems and socio-cultural gradients (Karanth et al., 2013a, b; Srivathsa et al., 2019b). Suitable conflict risk maps are needed to guide wildlife managers and locals to minimize this HLMC. A HLMC risk model can always serve as a quantitative tool to predict the probability of HLMC events based on existing location-specific HLMC event, relating it to landscape attributes (Karanth et al., 2012; Miller et al., 2016a; Naha et al., 2020). The outcome of HLMC models helps in the prioritization of management interventions in the high conflict areas and implementation of HLMC mitigation measures including minimising retaliation across the entire landscape (Karanth et al., 2012; Miller et al., 2016a; Mpakairi et al., 2018). Thus, the study aimed to (a) examine the perceptions of local communities on coexistence with wildlife across varying forest gradients and their key determinants, (b) determine important biotic and abiotic ecological variables that explain the spatial patterns of HLMC (livestock depredation and crop raiding) and (c) identify the spatial extent and map conflict hotspot areas for each large mammal species (tiger, leopard, dhole, elephant and gaur). Previous studies in the landscape have focused only on single large mammal species, being highly localized, or limited to a few PAs. Thus, we conducted detailed research on existing HLMC incidents and studies the perception of forest-dependent local community, focusing on a larger landscape. Present study will provide systematic, scientific, socio-ecological database for policy-level decision making and thereby for effective wildlife conservation and management.

3.2 Materials and methods

3.2.1 Study Area

The study area ranged from Hosur FD of Tamil Nadu State in the north to Kanyakumari Wildlife Sanctuary in the south, which included 16 forest divisions including, Megamalai Wildlife Sanctuary (WLS), Srivilliputhur Grizzled Squirrel WLS, MTR, Sathyamangalam Tiger Reserve (STR), Kanyakumari WLS, Kodaikanal WLS, Nellai WLS, Kalakad-Mundanthurai Tiger Reserve (KMTR), Cauvery North Wildlife Sanctuary (CNWLS), Theni Forest Division (FD), Gudalur FD, Nilgiri FD, Coimbatore FD, Erode FD, Dharmapuri FD, and Hosur FD (Figure 3.1). The study area also includes FAs which covers up to 5km from the forest boundary.

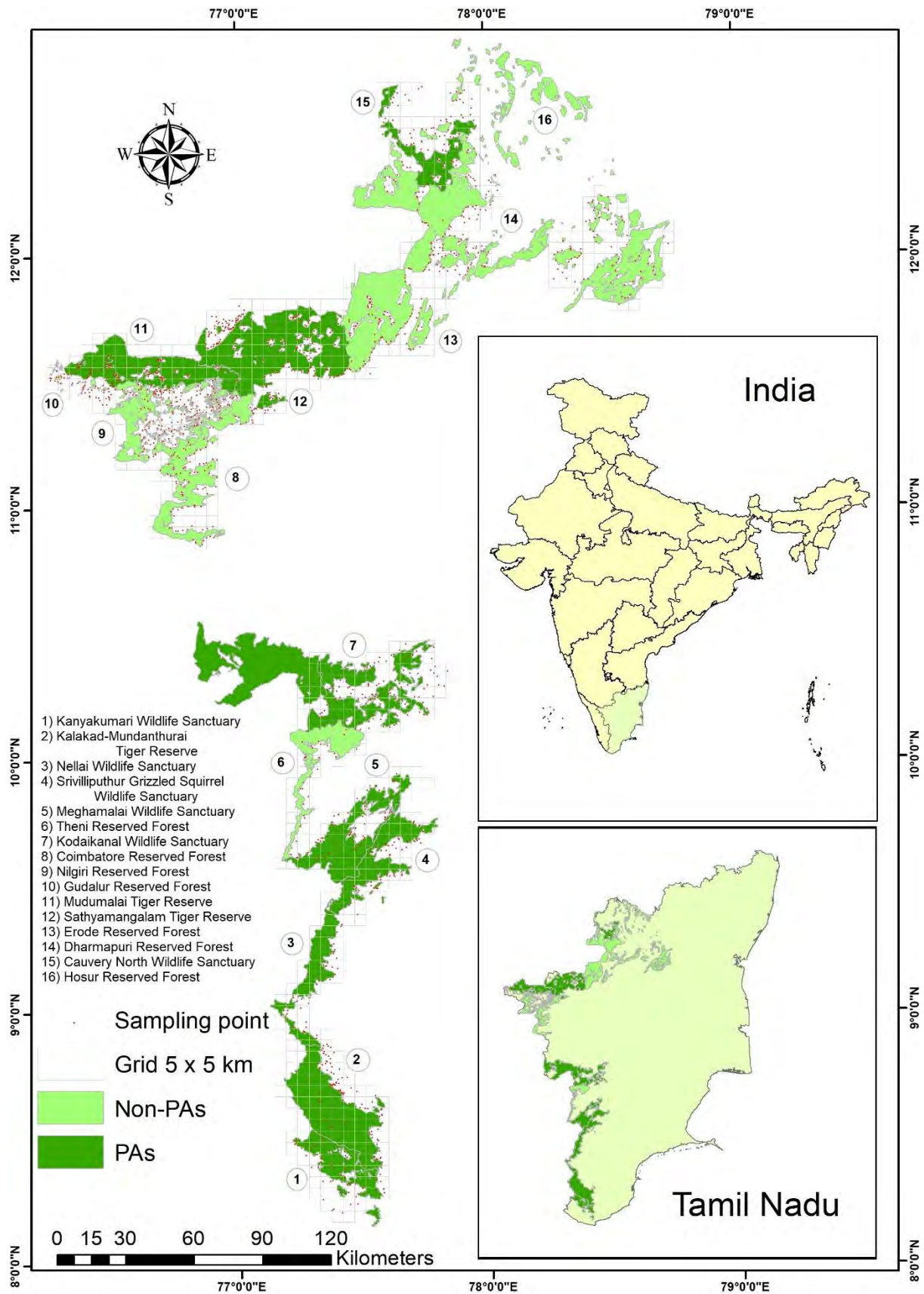


Figure 3.1 Study area showing the local questionnaire survey points in the Western and Eastern Ghats part of Tamil Nadu.

3.2.2 Data collection

To study people's perception on coexistence and HLMC pattern across the WEGPTN landscape, semi-structured questionnaire survey was conducted between November 2017 and December 2019 with the local community residing inside forest, up to 5km radius from the forest boundary. This included residents of PAs, RFs and Fringe Areas (FAs). A systematic sampling was followed by laying a 5 x 5 km (25km²) grid along the entire study area, and chosen a minimum of three household per grid, maintaining a distance of 0.5-1km between the sampling points extending at different distances from the forests. More number of grids were sampled depending on the more villages and proportion interface area present in each forest division. Also, the villages were spatially spread across the entire study area.

Before conducting the survey, compensation data on crop/livestock depredation and injury/death to human records available were checked at the forest range office in Tamil Nadu. However, it was found that most of those data were incomplete and that the reports of ground-level conflict incidences were left unrecorded. Most of the local villagers were not interested in reporting their loss to the Forest Department due to the lengthy, time-consuming procedures, in addition to the severe delay in receiving compensation. Besides, most of their livestock grazing were illegal, and hence they were afraid to report their loss to the Forest Department because of the fear of penalty. Insufficient data availability from the Forest Department prevented us from further validation.

Prior to each interview, a verbal consent was obtained from an adult household member (above 18 years of age) who had been a resident of the area for at least five years, after clearly explaining the study's purpose to ensure voluntary participation and adherence to ethical guidelines. Ethical approval was granted by the technical committee of the Tamil Nadu State Forest Department and is included in the official permission issued by the department. Since the analysis was done at a household-level and that each household reported multiple cases of conflict incidences, the GPS point of a representative household also was noted. The interviews were organized in the regional language (Tamil), and each interviewee was considered as a representative of their entire household. An overview of the research background was given initially, explaining the relevance of the topic and highlighted the positive impact it could bring to their lives. The survey began with collecting the basic demographic data of the interviewee, like their name, age, gender, number of members in the house, annual income, occupation, educational qualification, followed by the details like availability/accessibility to basic

amenities (hospital, school, transportation, drinking water, ration, etc.). Then enquired if they encountered any loss due to large mammals (crop damage, livestock depredation, property damage, loss of life or injury), frequency of conflict, livelihood dependence, the area of cropland they manage, the type of crops grown, and extent (area) to which they have suffered crop loss due to raiding megaherbivores, prevalence of livestock and crop diseases, fear of the conflict animal, location of livestock grazing, water for livestock, conductance of awareness programs, and support from the State Forest Department that could possibly drive the perception of local people towards wild animals.

Ultimately 1460 questionnaire surveys were conducted across an area of 14,200 km². The conflict data was limited to experiences from the past five years. In the initial stages of data collection, different forest divisions were visited, tested whether locals were able to recollect the number of conflict incidences and identify the conflict species. Since the study area contains largely rural and forest-dwelling communities, most of them had experienced wildlife conflict incidents sometime in their life. Therefore, recollecting the conflict incidents and identifying the conflict species was not a difficult task for them. Additionally, the images of the carnivore specie, carnivore kills and other indirect signs (track, scat, scratch, rake, and signs on the carcass) were shown from the identification material we carried, to make the identification easy and accurate. Distinct differences in evidence associated with the behaviour of each predator while attacking their natural prey and livestock were also explained to them. For example, felids primarily direct their initial attacks on to the head, face, and neck, whereas, dholes attack the flanks and hind legs in packs (Ramesh, 2010). For distinguishing the age of the livestock predated, any cattle less than a year old was considered as calves and greater than that as adult cattle, as such distinction made it easier for the locals to understand. All records were based on the available evidence and witness accounts. It included: the time of attack, number and species of livestock killed or injured, location of the attack and nature of the interaction between community and predator, and the large carnivore species involved. As actual timing for livestock predation can be tough to recollect, coarser intervals were used to assign the time of the predation events (morning (6 am-12 pm), afternoon (12 pm-4 pm), evening (4 pm-8 pm), and night (8 pm-12 am)). Data of less than 2% of cases were excluded for further analysis as those interviewees were uncertain about the species identity. Also, the data of the respondents who provided incomplete/inappropriate responses on their perception and related demographic data (n=71), were excluded from subsequent analyses. Since the study focused on individual perceptions of coexisting with wildlife, special emphasis was given on obtaining honest

responses to avoid any potential misinterpretation. Although utmost care was taken to ensure a reliable data, we accept the snag of a questionnaire-based sampling.

3.2.3 Predictor Variables

A total of 19 socio-economic and demographic variables that are critical for determining the disposition of the local people to coexist with wildlife such as location, age, gender, income, education, occupation, availability of basic amenities like school, hospital, transportation, facilities, assistance available from the forest department, disease for livestock, water scarcity, drought, frequency of crop depredation, frequency of livestock depredation, water availability for livestock, forest dependency of the household, fear of wild animals, view towards forest department, status of wildlife conflict, and conductance of awareness program was examined for the study (Table S3). The continuous data of people's view towards coexisting with wildlife were categorized into three classes 1, 2 and 3 indicating positive, indifferent and negative attitude, respectively.

Livestock depredation is the most common form of human-carnivore conflict in the State and globally (Inskip and Zimmerman, 2009; Treves et al., 2004; McInturff et al., 2020). So, a possible fine-scale livestock predation map across the State was prepared using the conflict frequency data, analyzed at the household level. Due to restriction in the forested areas, most of the livestock are in general left for grazing at a closer distance (ca. around 1-2km) from the household, therefore selected 1km² for spatial variable extraction. Also, the respondents reported livestock predation largely happens within 1-2km around the household where livestock are kept. Accordingly, only information on spatial variables at 1 km spatial resolution were extracted because most of the spatial variables such as slope, elevation, annual mean precipitation, temperature and human density were available at that scale and then to each of the household sampling points.

Using ArcMap 10.3, subsampling grids (1 km x 1 km) were overlaid across the sampling area. Land cover layers were obtained for 2015 - 2016 (AWIFS LULC data, Bhuvan, 2017) that had 18 classes: "built-up" or developed, kharif crop, rabi crop, zaid crop, double/triple crop, currently fallow, plantation, evergreen forest, deciduous forest, degraded/scrub forest, littoral swamp, grassland, wasteland, water bodies, mining, and others. For my study, they were reclassified into the following 11 classes: "built-up", crop, fallow, plantation, evergreen forest, deciduous forest, degraded/scrub forest, littoral swamp, grassland, wasteland, and water

bodies, using the reclassify tool in ArcMap 10.3. The following natural land-cover vegetation classes: evergreen forest, deciduous forest, and degraded/scrub forest, were then collectively defined as “natural forest cover”. I extracted information only on spatial variables at 1 km spatial resolution and then to each of the household sampling points. Later, calculated the percentage of forest cover and crop cover in each 1 km x 1 km grid separately by multiplying the no. of pixels with forest and crop to total no. of pixels in a grid. Before calculating the differences, the percentage of forest cover and crop cover was calculated separately from both 2006 and 2016 layers. Natural forest cover loss and gain, and crop loss and gain, was measured by calculating the difference between 2006 and 2016 layers at 62 m spatial resolution using a 1 x 1 km grid (AWIFS LULC data, Bhuvan, 2017), using ArcMap 10.3 (ESRI, 2014). We then assigned these variables to the household sampling points falling within the respective grid.

Other spatial variables such as slope, elevation, annual mean precipitation and temperature were further extracted from WorldClim (Hijmans et al., 2005) and human population density (CIESIN, 2016) at 1 km spatial resolution and then to each of the household sampling points falling within respective 1 x 1 km grid. Using the Euclidean distance tool in ArcMap 10.3, the distance to forest area boundary (Tiger Reserve, Sanctuary and RF), natural forest cover, water body and road, were measured for each household. Forest dependency was characterized by assigning higher scores to households dependent on more categories of forest use, including NTFPs, firewood collection, livestock grazing, and miscellaneous. The forest dependency categories were not quantified values. If a person is dependent on one source of income, that family is most likely to get revenue from various other activities apart from forest resources. Hence, the score was assigned based on the number of representations which reflect the ground reality of sociological variable and people’s dependency across a vast landscape. A score of “3” were assigned for villages located inside PAs, “2” for those located in RFs, and “1” for villages located in the FAs; higher score represents greater exposure of the village to HLMC, partially a reflection of an expected higher relative predator abundance or occupancy in these habitats. Potential domestic preys were classified into three major groups based on body size: cow-buffalo, goat-sheep and domestic dog. Livestock abundance was calculated as the number of livestock per household. Because some farmers grow multiple crops in their farmlands, and this can lead to differential crop loss or loss of crops in varying proportions, households were considered as having “diverse crop types” (*i.e.*, the number of major (primary) crops grown per household) if ≥ 1 acre of each crop was grown per household, and those crops constituted more

than 10% of the total landholding (agricultural area) per a household. Any crops not meeting these criteria were considered minor or secondary crops.

3.2.4. Data analysis

3.2.4.1 People's perception on coexistence

All the analysis were executed in Program R, version 4.3 (R Development Core Team, 2020). Pearson's correlation coefficient test was carried out with all the 19 predictor variables, to check the presence of any highly correlated variables ($r \geq 0.6$) (Graham, 2003) in Program R, using package *ggcorrplot* (Kassambara and Kassambara, 2019). However, none of the variables were found to be highly correlated.

In order to reduce the dimensionality of the data, Principal Component Analysis (PCA) was conducted using package *FactoMineR* (Lê et al., 2008) and plotted them using package *factoextra* (Kassambara and Mundt, 2017) in Program R. After which five variables (drought, water for livestock, gender, age, and forest dependence) were eliminated which were either least contributing to the data set or highly overlapping with the dimensions of other variables. Two outlier variables were also eliminated (assistance from Forest Department and income), making the total number of variables for the subsequent analyses to 12.

Finally, a multinomial logistic regression model was performed in program R using packages *MASS* (Venables and Ripley, 2002) and *MuMIn* (Barto'n, 2013) to analyse the variations in the perceptions of local people towards coexisting with the wildlife with according to varying multiple socioeconomic and demographic variables. Candidate models with various combinations were then developed and the best models demonstrating the people's perception were chosen based on the difference in Akaike's Information Criterion (AIC) ($\Delta AIC < 2$) and model weights (w_i) (Burnham and Anderson, 2002) for the final interpretations (Table 3.1, 3.2; Figure 3.2).

3.2.4.2 Patterns of human-large mammal conflict

Chi-square (χ^2) tests were conducted to compare overall frequencies of livestock loss (i.e., no. of livestock predation cases) at household-level among different carnivore species, management regimes or land protection status, and for each time (morning, afternoon, evening and night). To identify spatial patterns of large carnivore conflict, the number of livestock loss from each carnivore species was considered as the response variable at household-level. To identify megaherbivores conflict hotspots, the presence or absence of conflict from each

megaherbivore species was considered as the response variable at the household scale. Using a Generalized Linear Model (GLM) approach, I examined the importance of following potential predictor variables for livestock depredation: natural forest cover, natural forest cover change (loss and gain), distance to road, household location - within PAs, abundance of cow-buffalo, goat-sheep, domestic dog, human population density, annual mean precipitation, distance to forest boundary, forest dependence, elevation, distance to water and slope. Using a binomial GLM, I examined the influence of the following potential predictor variables for crop depredation: natural forest cover, natural forest cover change (loss and gain), crop cover type, crop cover change (loss and gain), number of major crops grown, number of minor crops grown, distance to nearest road, village location, human population density, annual mean temperature, annual mean precipitation, distance to nearest forest boundary, distance to nearest natural forest cover, forest dependence, elevation, nearest distance to water, and slope.

To assess the likely predictors of predation risk for each carnivore (tiger, leopard and dhole) and develop a predation risk probability map, GLMs were fitted assuming a Poisson distribution in program R version, 3.0 (R Development Core Team, 2018). There was evidence of over dispersion for leopards and dhole data. So, a GLM with a negative binomial family ($\theta = 1$) (Hilbe, 2011; Cameron and Trivedi, 2013) was used to control for potential over dispersion of leopard and dhole data. To develop a crop depredation risk probability map for elephant and gaur, GLMs were fitted assuming a binomial distribution in Program R, version 3.0 (R Development Core Team, 2018).

Before model construction, I first checked for multiple correlations among predictor variables using a hierarchical Pearson correlation co-efficient test (Graham, 2003) conducted in the 'corrplot' package of program R, version 3.0 (Wei and Simko, 2017). I removed highly correlated ($r > 0.50$) variables (in livestock depredation removed crop cover, crop change, distance to natural forest cover, and temperature; in crop depredation I removed crop change, distance to natural forest cover, and temperature) for further statistical analyses and standardized the final variable set using a Z-transformation before final analyses.

Null deviance and residual deviance values were used to assess model fit. An information-theoretic approach was used to evaluate model strength of evidence and fitness based on Akaike's Information Criterion (AIC_c) corrected for relatively small sample sizes; relative AIC differences (Δ) and weights (w_i) were evaluated (Burnham and Anderson, 2002) to identify models best explaining predation predictor variables. Using 'MuMIn' package in R

(Grueber et al., 2011), multi-model averaging was applied using candidate models with $\Delta AIC < 2$ for final inferences (Burnham and Anderson, 2002). All analyses were performed using Program R Package, version 3.0 (R Development Core Team, 2018), other packages like MASS (Venables and Ripley, 2002), *rJava* (Urbanek, 2010), *glmulti* (Calcagno and de Mazancourt, 2010) and MuMIn (Bartoń, 2013). Finally, the R package ‘*effects*’ (Fox et al., 2014) were used to plot the response curves of the top model covariates for the dependent variable.

Using the package ‘*gstat*’ (Pebesma and Graeler, 2019) in Programme R Package version 3.0 (R Development Core Team, 2018), a spatial interpolation (Kriging) was used to infer or “predict” incidents of livestock predation and crop depredation in unsampled areas based on data from the top model for the probability of livestock loss. Several statistical distribution models, including spherical, circular, exponential, Gaussian, Matern, and M. Stein’s parameterization, were fit to the data to test for their suitability for each species. Matern and linear family distribution models were applied to the overall data set for all species combined. Employing an automatic interpolation method, Gaussian, M. Stein’s parameterization, and spherical distribution models, explained the patterns of conflict for tigers, leopards and dholes, respectively. Spherical distribution, an automatic interpolation method, and M. Stein’s parameterization models, was used to explain the patterns of conflict for elephant and gaur, respectively. Using the package ‘*automap*’ (Hiemstra et al., 2009), maps of conflict patterns of livestock predation risk and crop damage were developed for respective species across the entire landscape, including unsampled grids. All weighted sum values predicting livestock predation risk were calculated for all three carnivore species using the Spatial Analyst tool in ArcMap 10.3 to estimate cumulative predation risk. To compare predation risk overlap metrics for predation risk maps, the package ‘*spaa*’ (Zhang, 2015) was used to quantify Schoener’s niche overlap metric (D), which ranges from 0 (i.e., niche models have no overlap) to 1 (i.e., niche models are identical). The total predicted frequency of predation risk for each predator was divided into three categories in equal proportion (low, medium and high), based on which areas were identified and reported accordingly.

3.3 Results

3.3.1 People’s perception on coexistence

It was observed that 90% (n=1248) of the surveyed population had a negative perception towards coexisting with wildlife, while 7% (n=103) expressed a positive perspective, and 3%

(n=38) maintained an indifferent stance. Notably, 79% (n=1091) of the sampled population resided within Fringe Areas (FAs), 13% (n=178) in Protected Areas (PAs), and 9% (n=120) in Reserved Forests (RFs). Among them, 90% (n=160) of the population from PA had negative, 9% (n=16) had positive and 1% (n=2) had indifferent attitude towards coexisting with wildlife; In RFs, 73% (n=88) and 27% (n=32) had negative and positive view towards coexisting with wildlife, respectively (Figure 3.3). Whereas, in FAs, 92% (n=1000), 5% (n=55) and 3% (n=36) had negative, positive, and indifferent view towards coexisting with wildlife, respectively (Figure 3.3).

Majority of the participants were male (84%; n=1160), with the remaining 16% (n=229) being female. The age class of the respondents spanned from 18 to over 60 (Figure 3.4a). Household income ranged from zero to a maximum of INR 6,00,000 (Figure 3.4b). Education levels ranged from no formal education to higher secondary and above (Figure 3.4c). In terms of occupation, 67% (n=927) were identified as farmers, 24% as daily-wage labourers, and the remaining 9% (n=122) as merchants, priests, autorickshaw drivers, or forest department employees.

Regarding access to basic amenities, 27% (n=379) of households reported having all essential facilities within a 5km radius, while the remaining households lacked some basic amenities. A significant proportion (79%; n=1094) reported insufficient assistance from the State Forest Department, with only 21% (n=295) expressing satisfaction. Regarding livestock, 66% (n=917) reported common occurrences of fatal diseases, while 34% (n=472) reported their absence. Water sources for livestock were predominantly private (70%; n=970), whereas 24% (n=329) lacked nearby water sources, and 6% (n=90) relied on public sources. Water scarcity was prevalent in 56% (n=775) of households.

Seventy-two percent (n=1007) of households reported crop depredation events by large mammals (elephant, gaur, wild pig, sambar, and chital), while 28% (n=382) did not experience any in the past five years. Similarly, 51% (n=712) of the respondents did not encounter livestock depredation from large carnivores (tiger, leopard, or dhole), while 49% (n=677) reported such incidents in the past five years. Despite living near forests, 53% (n=730) of households were not dependent on forest resources, while 47% (n=659) relied on them for livelihood. Majority of the population (69%; n=954) expressed fear of wild animals, whereas 31% (n=435) claimed fearlessness. Public attitudes towards the State Forest Department were

predominantly negative (58%; n=810), with 22% (n=311) expressing positivity and 19% (n=268) being indifferent.

As expected, 90% (n=1251) reported an increase in HLMC frequency and intensity, 5% (n=76) reported a decrease in incidents, and 4% (n=62) reported relatively stable over situation over the past five years. Despite the potential impact of awareness programs on perceptions, 91% (n=1265) reported no exposure to such programs, while only 9% (n=124) acknowledged having received awareness initiatives from the State Forest Department/Governmental or Non-Governmental Organisations (NGOs).

Top models discerned the most influential variables determining the perception of local communities regarding coexistence with wildlife (Table 3.1, 3.2). They are: (1) availability of amenities, (2) conductance of awareness programs, (3) perception of the status of HLMC, (4) intensity of crop depredation, (5) prevalence of disease in livestock, (6) individuals' perception on the Forest Department, (7) fear of wildlife, and (8) intensity of livestock depredation. These models elucidated that people's perception of coexisting with wildlife, especially large mammals, was negatively influenced by decreased availability of basic amenities, reduced conductance of awareness program, an increased perception of the rise in HLMC incidents, increased prevalence of disease in livestock, increased negative view on Forest Department, increased fear of wildlife, increased intensity of livestock and crop depredation (Table 3.2, Figure 3.2).

Table 3.1 Summary of AICc model selection using Multinomial Logistic Regression explaining factors influencing the predicted probability of people's perception to coexisting with wildlife.

Component models:	df	logLik	AICc	ΔAIC	weight
1+2+3+5+7+8+9	9	-454.63	927.38	0	0.25
1+2+3+5+7+8	8	-456.22	928.54	1.16	0.14
1+2+3+4+5+7+8	9	-455.35	928.84	1.45	0.12
1+2+3+4+5+7+8+9+10	11	-453.69	929.57	2.19	0.08
1+2+3+4+5+7+8+9+11	11	-453.76	929.71	2.32	0.08
1+2+3+4+5+7+8+9+12	11	-453.91	930.02	2.63	0.07

1+2+3+4+5+6+7+8+9	11	-454.04	930.27	2.88	0.06
1+2+3+4+5+7+8+10	10	-455.2	930.55	3.17	0.05
1+2+3+4+5+6+7+8	10	-455.35	930.86	3.47	0.04
1+2+3+7+8+9	8	-457.94	931.99	4.61	0.03
1+2+3+4+7+8+9	9	-457.3	932.73	5.35	0.02
1+2+3+4+7+8	8	-458.97	934.04	6.66	0.01
1+2+3+7+8	7	-459.99	934.06	6.67	0.01
1+2+3+4+5+6+7+8+9+10+11+12	14	-453.23	934.76	7.37	0.01
2+3+4+5+7+8	8	-459.62	935.35	7.96	0

Term codes: 1- Amenities, 2-Awareness program, 3-Conflict status, 4-Crop depredation, 5-Disease for livestock; 6-Education, 7-View on Forest Department; 8-Fear; 9-Livestock depredation; 10-Occupation; 11-Water availability for livestock; 12-Water scarcity.

Table 3.2 Estimated model averaged beta coefficient estimate of top models ($\Delta AIC < 2$) that demonstrates the variables explaining the factors affecting perception of local community on coexistence in the Eastern and Western Ghats part of Tamil Nadu.

Predictor variable	β Estimate	Std. Error	Z value	P value	Significance	95% CI for β
Amenities	-0.04	0.12	-0.35	0.7250		(-0.28, 0.20)
Awareness Program	-1.52	0.55	-2.78	0.0055	**	(-2.60, -0.44)
Conflict Status	0.20	0.20	0.96	0.3380		(-0.19, 0.59)
Crop Depredation	-0.12	0.16	-0.73	0.4670		(-0.43, 0.19)
Livestock Disease	1.00	0.35	2.89	0.0038	**	(0.31, 1.69)
View on Forest Department	0.64	0.18	3.58	0.0003	***	(0.29, 0.99)
Fear	1.02	0.33	3.11	0.0019	**	(0.38, 1.66)
Livestock Depredation	-0.46	0.24	-1.90	0.0570	.	(-0.93, 0.01)

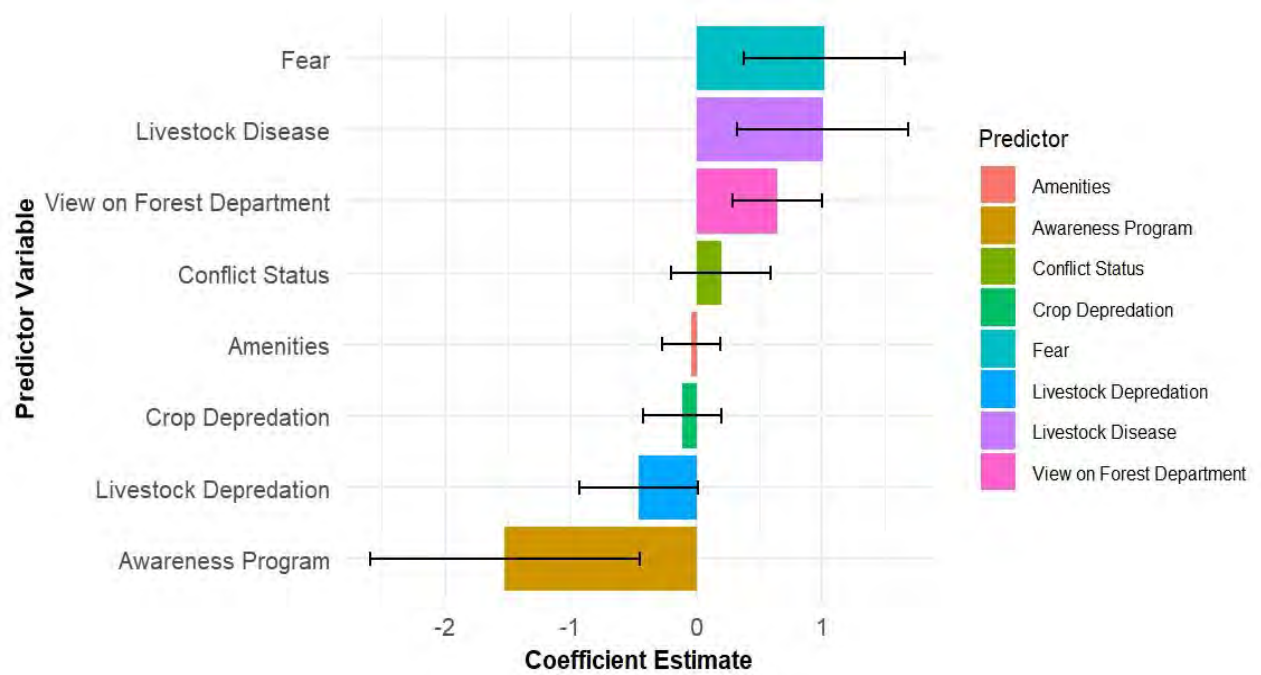


Figure 3.2 Estimated beta coefficients for the model average of the three top ranked models that demonstrates the variables explaining the factors affecting negative perception of local community on coexistence in the Eastern and Western Ghats part of Tamil Nadu.

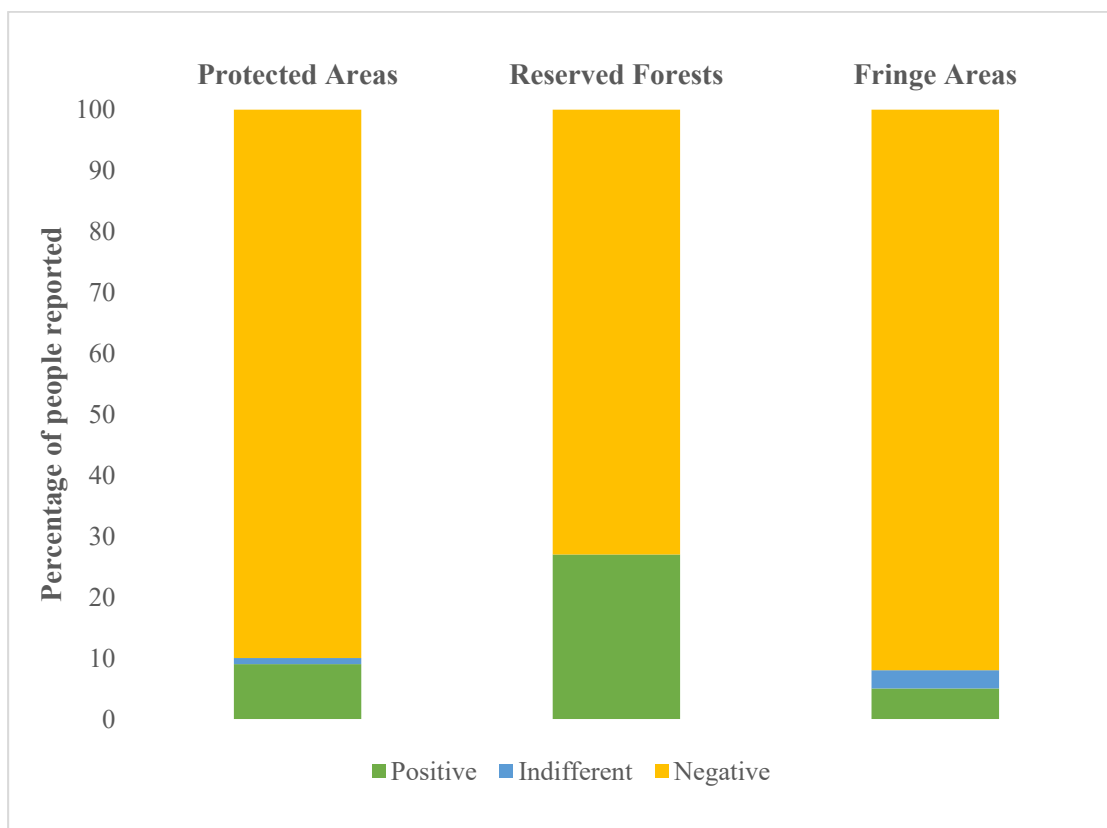


Figure 3.3 Percentage of people reporting their attitude towards coexisting with wildlife across different forest management gradients.

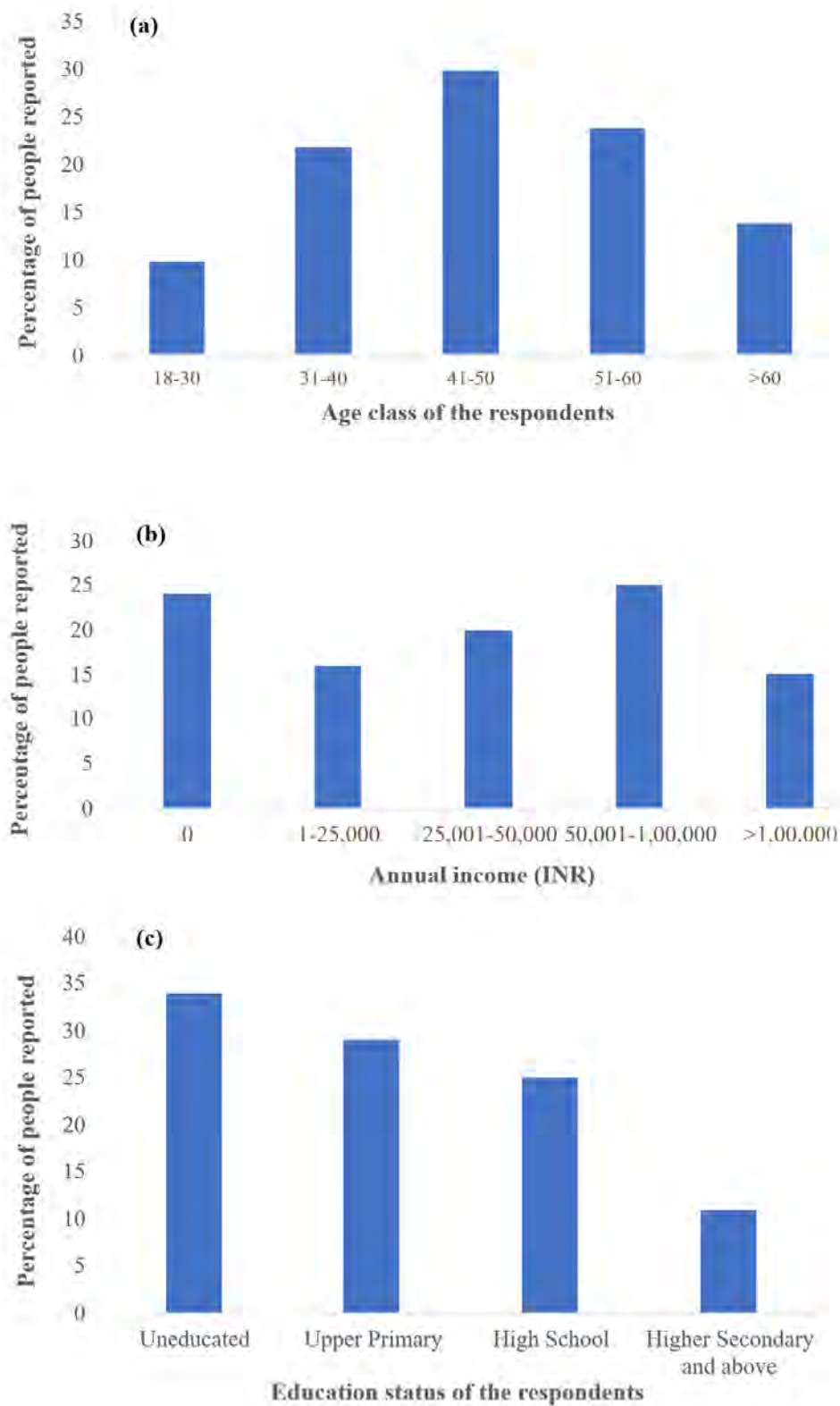


Figure 3.4 (a) Age-class distribution of the respondents, (b) Annual income of the respondents (INR), (c) Level of formal education acquired by the respondents.

3.3.2 Patterns of human-carnivore conflict

Forty-eight percent (n=694) of households surveyed reported experiencing HCC, or the loss of livestock due to large carnivores. Of these, 78% suffered more than one incident of livestock predation; 866 predation events were recorded, of which two-thirds were by leopards (n=576), approximately 19% by dholes (n=165), and 14.4% by tigers (n=125). The households inside RFs were the most likely to report livestock losses (71%), followed by PAs (58%) and lastly, FAs (42%). The percent of livestock depredated by each carnivore species varied significantly across management systems ($\chi^2 = 15.39$, $df = 4$, $P < 0.005$). Among carnivores, those households reporting livestock loss by tigers were highest inside PAs (25%); RFs (14%) and FAs (5%) experienced less human-tiger conflict. Households reporting the highest rates of livestock loss due to the predation of leopard and dhole, occurred in RFs (62% and 29% respectively), followed by PAs (44% and 11% respectively) and FAs (36% and 9% respectively). Seven hundred and ninety-one families (54.2%) were engaged in at least one source of forest-dependent practice for their livelihood (e.g., NTFP, firewood collection, livestock grazing and miscellaneous). Among them, people living inside RFs (91%) and PAs (70.1%) were much more dependent on forest resources for their livelihood compared to people living amidst the FAs (47%). Households from RFs reported keeping more goat/sheep (58%) than those from PAs (40%) and FAs (42%). Similarly, more households in RFs reportedly kept cow/buffalo (77.5%) than those from PAs and FAs (51% each). The proportion of households owning domestic dogs were also highest in RFs (60%), followed by FAs (44.6%) and PAs (42%). Finally, the respondent reported only four fatal attacks on humans by large felids in our study area.

Over the five years investigated, tiger predation incidences mostly involved adult cattle (79.1%, $n = 106$), although they did take goats/sheep to a lesser extent (20.9%, $n = 28$). In contrast, predations by leopards were more diverse; twice as many cases involving goats (45.6%, $n = 341$) was documented as adult cattle (17.7%, $n = 132$). However, leopards also took calves (7.6%, $n = 57$), and a substantial number of incidences related to predations of domestic dogs (29%, $n = 217$). Almost three-quarters of livestock predation cases involving dholes were those of goats (73.4%, $n = 152$), and the rest were of calves (26.6%, $n = 55$). Unsurprisingly, differences in the proportion of different types of livestock depredated by all three large carnivore species varied significantly overall ($\chi^2 = 229.24$, $df = 6$, $P < 0.0001$). On average, tigers reportedly killed 2.64 ± 0.18 cattle and 3.6 ± 0.46 goats per households they impacted

over the five years. Despite more incidents involving goats and sheep than adult cattle, leopards killed similar numbers per household they affected (4.1 ± 0.19 and 4.0 ± 0.49 respectively); they also killed 2.7 ± 0.40 calves, and 2.28 ± 0.12 dogs, per affected household. Dholes killed 4 ± 1.30 calves and 4 ± 0.29 goats/sheeps. Most of the livestock were killed by large carnivores in the mornings up until mid-day, between 0600 and 1200 hrs (Tiger- 51.2%; Leopard – 35.5%; Dhole – 39.2%). Only fewer tiger and leopard attacks occurred during the night (19.4%; 28.7%), followed by evening (18.2%; 20.6%); the fewest attacks occurred in the afternoon hours (11.2%; 15.3%). Dhole attacks peaked in the early-mid evening hours (33.0%) and afternoon (27.8%); no incidences of livestock predation by dholes occurred overnight. Overall, significant variation was detected in the proportion of livestock attacked by each carnivore species across different times of the day ($\chi^2 = 42.83$, $df = 6$, $P < 0.0001$).

Following major variables influence were associated with risk of livestock predation by the three large carnivores in the study: (1) forest dependence, (2) village location, (3) natural forest cover loss, (4) number of cow and buffalo per household, (5) number of goat and sheep per household, (6) the number of domestic dogs per household, (7) distance to water, (8) distance to forest boundary, (9) elevation, (10) annual mean precipitation and (11) slope (Figure 3.5, 3.6, 3.7; Table 3.3, 3.4). Livestock predation risk probability by tiger alone was best explained by a model $< \Delta 2AICc$ ($wt = 0.63$) that included six variables: (1) higher relative abundance of cow/buffalo, (2) higher dependence of people on forests, (3) greater proximity to water sources, (4) shorter distance to forest boundaries, (5) relatively higher elevations and (6) villages located within the forest areas, particularly in core areas of PA's (Figure 3.5). The best model predicting livestock predation risk by a leopard ($< \Delta 2AICc$; $wt = 0.83$) included (1) relatively higher abundance of goat/sheep, (2) relatively high abundance of domestic dog, (3) higher dependence on the forest by households, (4) an increase in topographical slope (Figure 3.6). Finally, for the top model predicting livestock predation risk from dholes ($wt = 0.71$), showed that (1) greater forest cover loss, (2) increase in the relative abundance of goat/sheep, (3) greater dependence on the forest by households, and (4) relatively lower precipitation, were all important (Figure 3.7). The cumulative predation risk showed that the HCC was very localized to a few regions (Figure 3.8, 3.9).

Several areas of relatively high tiger predation risk were identified within the Nilgiri Biosphere Reserve, including large parts of the Nilgiri FD, Mudumalai and Sathyamangalam covering approximately 125 km²; we also identified another cluster of predations across an area of 50 km² in the Megamalai Wildlife Sanctuary (Figure 3.8a). For leopards, we identified many more

high predation risk hotspots, including parts of the Sathyamangalam Tiger Reserve (60 km²), and the Nilgiri eastern slopes of Mudumalai Tiger Reserve (50 km²), parts of Srivilliputhur Wildlife Sanctuary (180 km²), Megamalai Wildlife Sanctuary (90 km²) and a few areas Nellai Wildlife Sanctuary (40 km²) (Figure 3.8b). For dhole, high predation risk areas was identified in the Nilgiri eastern slopes of Mudumalai (30 km²), parts of Sathyamangalam (60 km²), and large areas in Srivilliputhur (200 km²) and Megamalai (140 km²) (Figure 3.8c).

Interestingly, areas of predation risk by tiger had less spatial overlap with leopard (0.53) and dhole (0.51), whereas spatial overlap between leopards and dholes was high (0.89). The cumulative predation risk map showed that certain sections of the Nilgiris, eastern slope of Mudumalai, parts of Sathyamangalam, Megamalai and Srivilliputhur, are the most important hotspot areas for all large carnivores combined (Figure 3.9). Predation risk modelling (PRM) suggested that households located closer to and within forested areas have a higher risk of conflict with large predators, with the highest risk levels inside and adjacent to PAs, and the lowest in agricultural areas along the fringes. Also, my study clearly showed that there is variation in the spatial pattern of conflict clusters across the landscape according to the “predation niche” of each species.

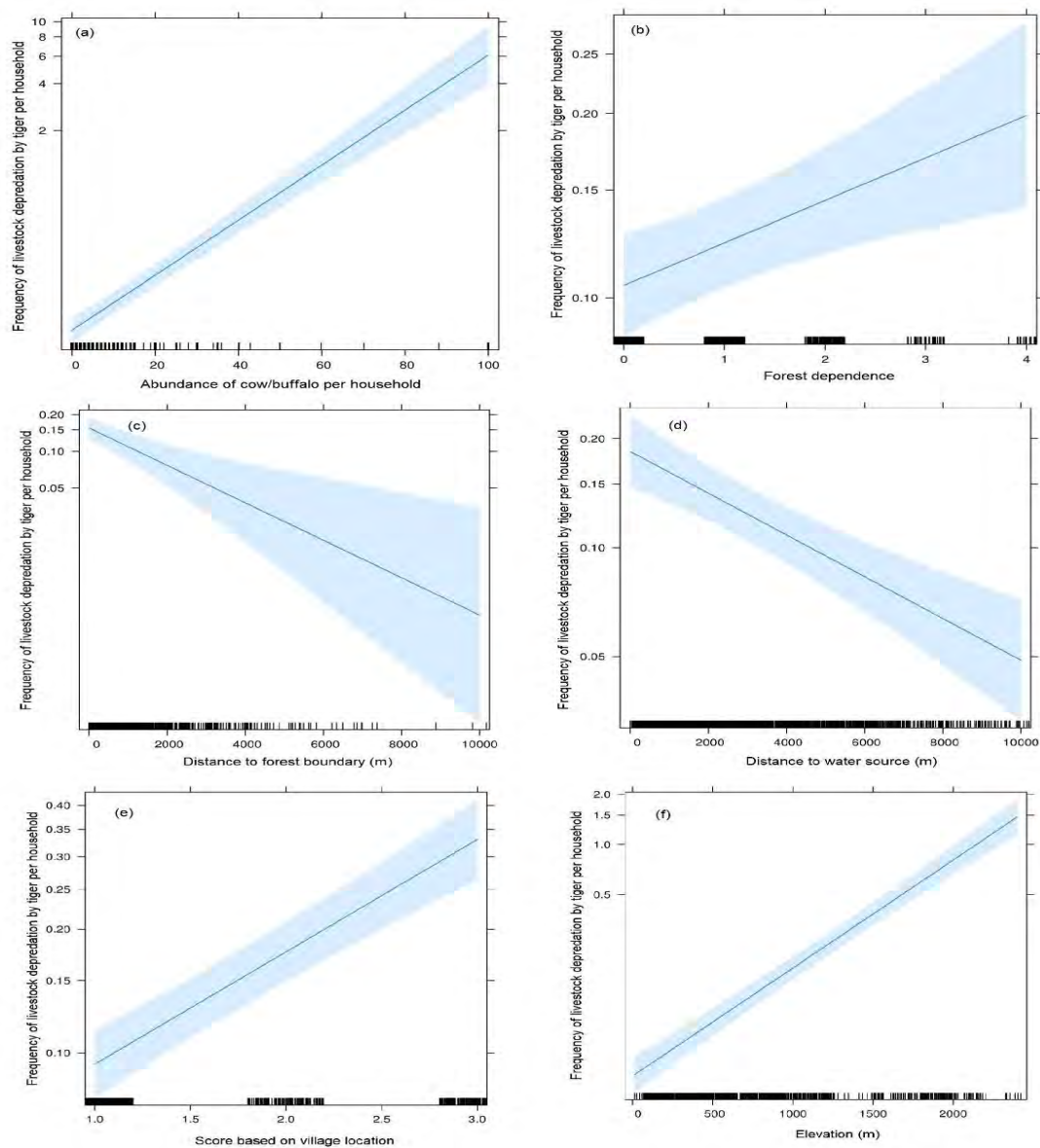


Figure 3.5 Top model explaining the frequency of livestock depredation by tiger per household in response to (a) abundance of cow/buffalo, (b) forest dependence, (c) distance to forest boundary, (d) distance to water source (e) nearness to village and (f) elevation.

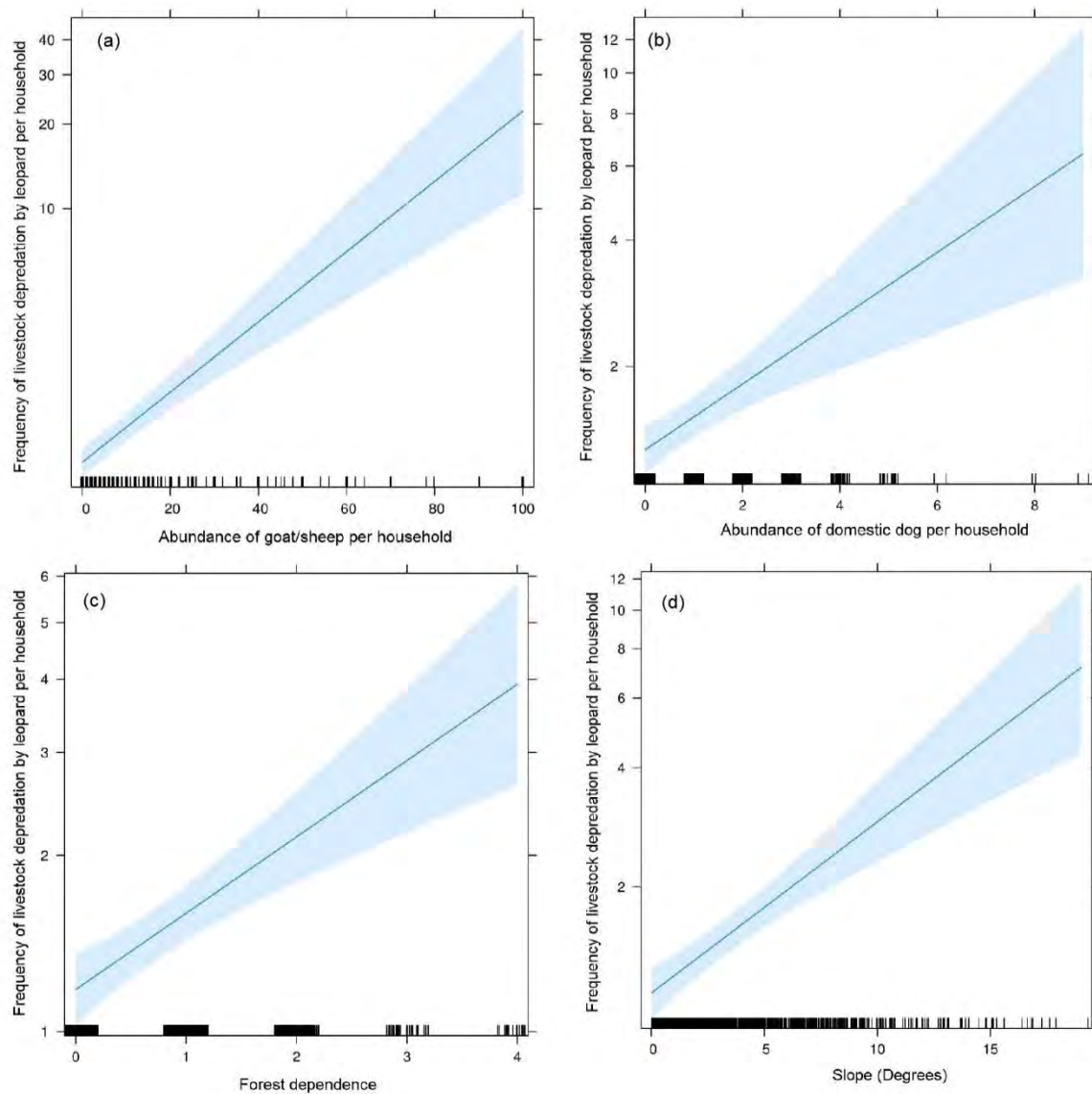


Figure 3.6 Top model explaining the frequency of livestock depredation by leopard per household in response to (a) abundance of goat/sheep per household, (b) abundance of domestic dog per house hold, (c) forest dependence and (d) slope.

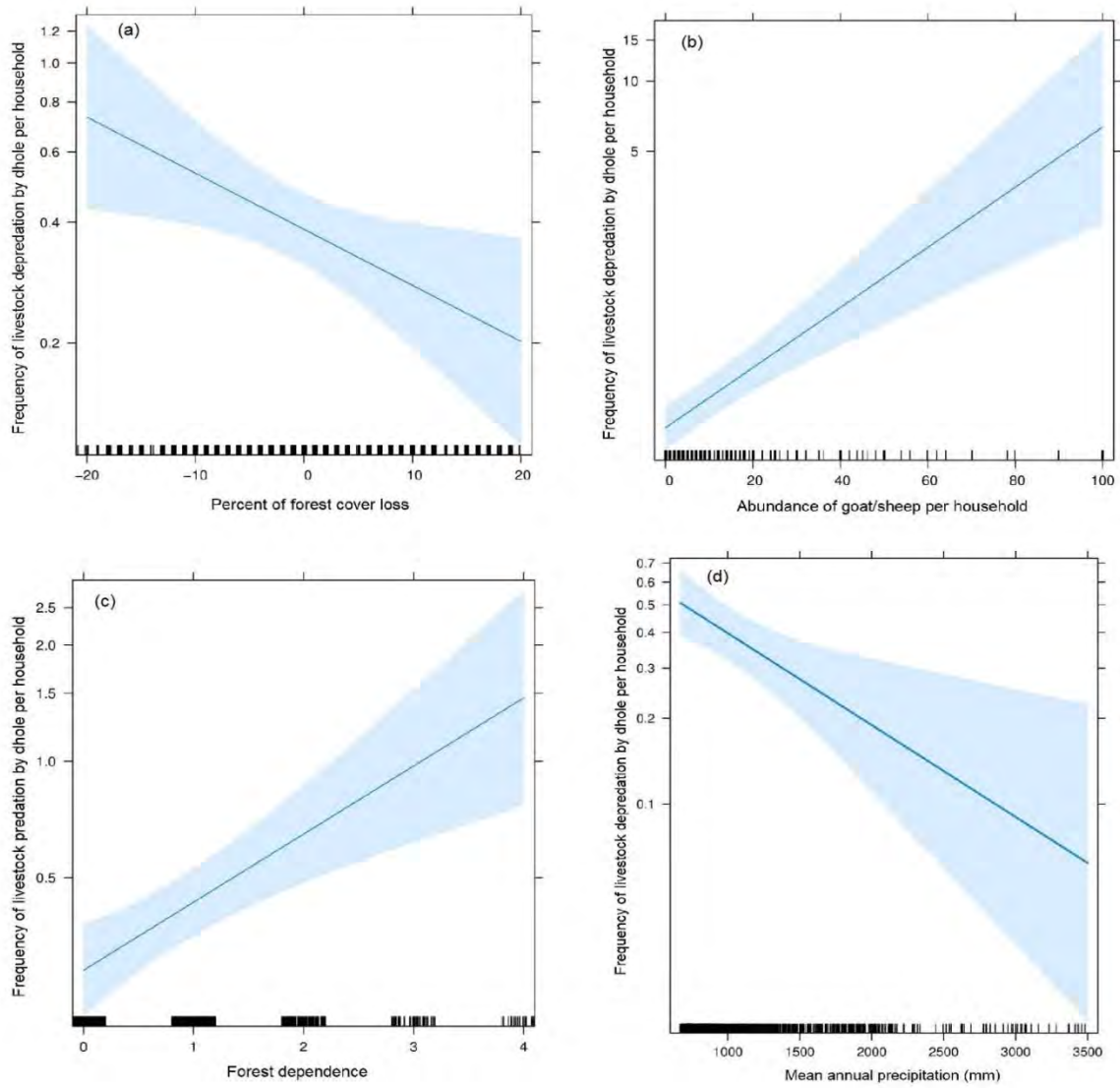


Figure 3.7 Top model explaining the frequency of livestock depredation by dhole per household in response to (a) percent of forest cover loss, (b) abundance of goat/sheep per household, (c) forest dependence and (d) mean annual precipitation

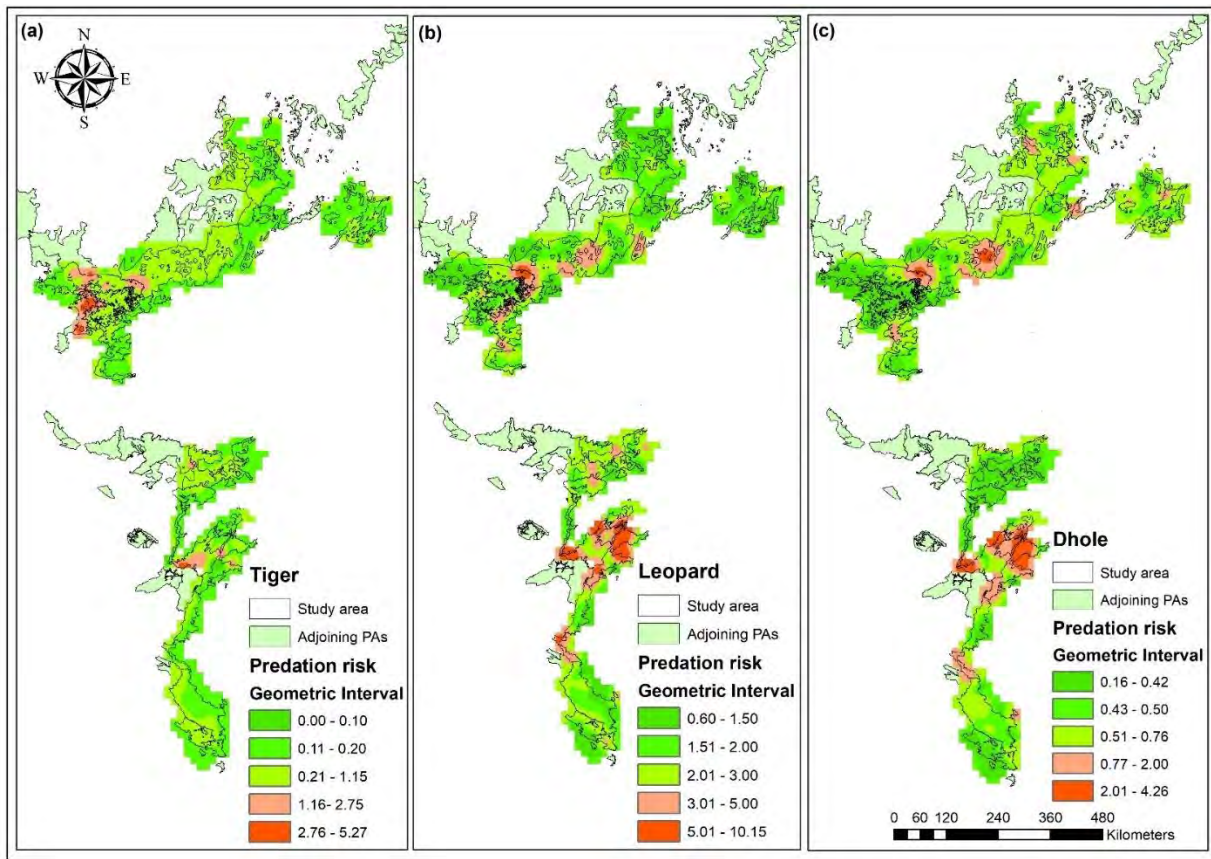


Figure 3.8 Predation risk maps showing predicted frequency (Number of livestock killed for the last five years) of livestock depredation from tiger (a), leopard (b) and dhole (b) in the Western and Eastern Ghats parts of Tamil Nadu.

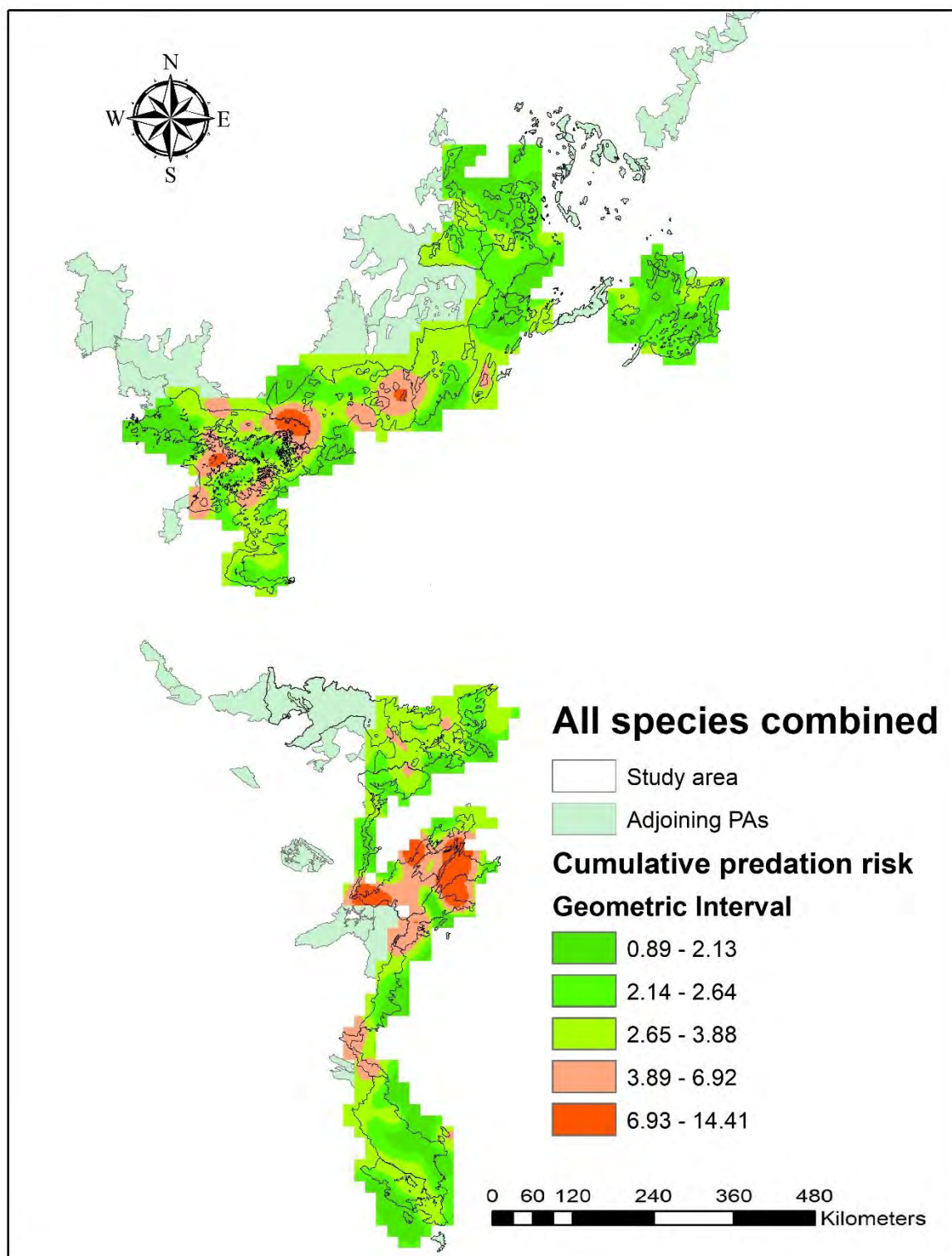


Figure 3.9 Predation risk map showing the cumulative predicted frequency (no. livestock killed for the last five years) of livestock predation in the Western and Eastern Ghats parts of Tamil Nadu.

Table 3.3 Summary of AICc model selection Generalized Linear Models explaining factors influencing predation risk by tiger, leopard and dhole in the Western and Eastern Ghats parts of Tamil Nadu.

Model	df	logLik	AICc	Δ AIC	weight
Tiger					
Cow_buff+DistForestBdry+DistWater+Elevation+ForestDepScore+VillageLoc	7	-906.15	1826.37	0.00	0.63
Cow_buff+DistForestBdry+DistRoad+DistWater+Elevation+ForestDepScore+VillageLoc	8	-906.13	1828.37	2.00	0.23
Cow_buff+DistForestBdry+DistRoad+DistWater+Elevation+ForestDepScore+Precip+VillageLoc	9	-905.74	1829.60	3.23	0.13
Cow_buff+DistForestBdry+DistRoad+DistWater+Elevation+VillageLoc	7	-910.55	1835.17	8.80	0.01
Leopard					
Domesticdog +ForestDepScore+Goat_sheep+slope	6	-2320.06	4652.17	0.00	0.83
Cow_buff+ Domesticdog +ForestCovLG+ForestDepScore+Goat_sheep+PopDens+slope	9	-2318.69	4655.51	3.33	0.16
Domesticdog +ForestCov+ForestDepScore+Goat_sheep+Precip+Slope	8	-2322.67	4661.45	9.27	0.01
Dhole					
ForestCovLG+ ForestDepScore+Goat_sheep+Precip	5	-1185.68	2381.39	0.00	0.70
DistWater+ForestCovLG +ForestDepScore+Goat_sheep+PopDens+Precip	7	-1184.67	2383.42	2.02	0.26
Cow_buff+DistForestBdry+ForestCov+ForestDepScore+Goat_sheep+Slope	7	-1186.90	2387.88	6.48	0.03
Cow_buff+DistWater +ForestCov+ForestDepScore+Goat_sheep+PopDens+Slope+VillageLoc	9	-1186.01	2390.15	8.76	0.01

df - Residual degrees of freedom, *logLik* - Log likelihood, *AICc* - corrected Akaike's Information Criterion, Δ *AICc* - change in *AICc* between each model, *wi* - Akaike weight, *Cow_buff* - abundance of cow/buffalo, *DistForestBdry* - distance to forest boundary, *DistWater* – distance water source, *DistRoad* – distance to road, *Domesticdog* - abundance of domestic dog, *ForestDepScore* - local's dependence on forest, *ForestCov* - percent forest cover, *ForestCovLG* – percent forest cover loss and gain, *Goat_sheep* – abundance of goat and sheep, *Temp* – mean annual temperature, *PopDens* - human population density, *Precip* - precipitation, *Slope* – mean slope, *VillageLoc* - village location

Table 3.4 Estimated beta coefficients for the top ranked models that explains the probability of explaining factors influencing predation risk by tiger, leopard and dhole in the Western and Eastern Ghats parts of Tamil Nadu.

Models	Estimate	Standard error	P value
Tiger			
Cow_buff	0.0407	0.0024	0.0000
ForestDepScore	0.1599	0.0505	0.0015
DistForestBdry	-0.0004	0.0001	0.0011
VillageLoc	0.6291	0.0631	0.0000
DistWater	-0.0001	0.0000	0.0000
Elevation	0.0015	0.0001	0.0000
Leopard			
Domesticdog	0.1805	0.0427	0.0000
ForestDepScore	0.3003	0.0603	0.0000
Goat_sheep	0.0289	0.0036	0.0000
Slope	0.0997	0.0158	0.0000
Dhole			
ForestDepScore	0.4057	0.1009	0.0000
ForestCovLG	-0.0323	0.0133	0.0156
Goat_sheep	0.0297	0.0052	0.0000
Precip	-0.0004	0.0002	0.1222

Cow_buff - abundance of cow/buffalo, *DistForestBdry* - distance to forest boundary, *DistWater* – distance water source, *Domesticdog* - abundance of domestic dog, *ForestDepScore* - local's dependence on forest, *ForestCovLG* – percent forest cover loss and gain, *Precip* - precipitation, *Slope* – mean slope, *VillageLoc* - village location

3.3.3 Patterns of human-megaherbivore conflict

Overall, 1460 questionnaires were conducted on the presence/absence of elephant and gaur conflict, and consequences of that conflict, i.e., human death/injuries, and/or crop-raiding. Approximately 45% (n=660) and 10% (n=140) of households reported elephant and gaur conflict, respectively. Both elephant and gaur mostly caused crop damage (44% and 9.2%, respectively), followed by property damage (6% and 0.41%, respectively) and human injury/death (5.55% and 1.03%, respectively). Households inside reserve forests (non-PAs) were most likely to report elephant conflict (62% of all households), followed by those inside PAs (44% of all households) and fringe areas (43% of all households). Gaur conflict was higher in fringe areas (11%) than in reserve forest (6.3%) and protected area (5.1%). Human injury and death by elephants (n=81) were reported much more from PAs and reserve forests (9.28%

and 19.72% respectively) then in fringe areas (3.11%). The proportion of human-elephant conflict resulting in crop and property damage did not differ much across management systems (PAs: 43.81%, 4.12%; non-PAs: 35.92%, 3.52%; fringe areas: 42.17%, 5.34%). Gaur-related conflict resulted in property damage and injury to death $\leq 1\%$ of the time ($n=15$) for all three management categories. Crop damage caused by gaur however was reported in PAs and fringe areas (8.76% and 9.43%) each more than twice as much as in reserve forest (4.23%). Nearly all conflict caused by elephants ($n = 633$) and gaur ($n= 134$) occurred at night (97.47% and 97.76%, respectively), with little conflict occurring in the morning (4.11%, 7.46% respectively) and evening (1.42%, 10.45% respectively). A total of 17 crops were grown ($n=1137$) among all communities, of which the five primary crops most grown were vegetables (predominantly, cabbage, pumpkin, tomato, cauliflower, and beans) (32%), millets (17.50%), banana (16.01%), fruit orchards (predominantly jackfruit, mango, watermelon, and guava) (14.78%), rice paddy (9.23%), and coconut (9.06%) (Figure 3.10). The primary crops most involved in human-elephant conflict (HEC), and more often consumed by elephants ($n= 638$) were maize (20.69%) and millets (19.75%), followed by banana (13.17%), vegetables (11.60%), sugarcane (7.84%) and rice paddy (6.47%) (Figure 3.11). For gaur ($n = 135$), vegetables were the primary crops (37.04%) most frequently consumed, followed by fruit orchards and banana (11.11% each), and lastly, maize (5.19%) (Figure 3.12). Coconuts were the major secondary crop consumed most frequently by elephants (11.44%), whereas all other minor crops combined for $<5\%$ of conflict incidents (Figure 3.11). Gaur often consumed a greater diversity of secondary crops, including vegetables (13.33%), millets (8.15%), and coffee (5.96%) (Figure 3.12).

Among the variables most influencing both elephant and gaur conflict were the percentage of crop cover, distance to nearest water source, number of major crops, mean annual precipitation, and mean slope (Table 3.5, 3.6). The number of minor crops only influenced susceptibility to elephant conflict. The predicted probability of HEC was best explained by a model $<\Delta 2$ AICc that included these six variables ($wt = 0.81$). HEC increased with: per cent of crop cover, distance to nearest water source, the number of major crops and minor crops grown, whereas conflict decreased with mean annual precipitation, and mean slope (Figure 3.13). The best model predicting conflict with gaurs ($<\Delta 2$ AICc; $wt = 0.81$) also included the five first variables mentioned. HGC increased as: crop cover proportion decreased, distance to the water source increased, more major crops were grown, mean annual precipitation increased, and mean slope increased (Figure 3.14). Variables for all the top models contributed substantially, and other

variables had relatively minor or no contribution to predicting the probability of conflict for both elephant and gaur.

The predicted high human-elephant conflict hotspot areas (0.5-1) were in and around the fringe areas (FAs) of Coimbatore FD, MTR, STR, Erode FD, Dharmapuri FD, CNWS and Hosur FD (Figure 3.15). This zone covered a total area of ca. 7000 km². The model also predicted additional clusters of 900 km² of high HEC in the FAs of Theni FD and Srivilliputhur. The model predicted gaur conflict hotspot areas (0.5-1) as clusters encompassing Nilgiri FD (150 km²), Kodaikanal FD (225 km²), parts of Theni (125 km²), Sathyamangalam (75 km²), Kanyakumari WLS (50 km²) and Harur FD (50 km²) (Figure 3.15); these areas cumulatively covered 625 km². Spatial hotspots areas predicted for HEC were much larger (ca. 40% of the sampled area) than for gaur (ca. 3% of the sampled area), the former being distributed more contiguously along forest divisions, whereas conflict areas predicted for gaur were more patchily distributed.

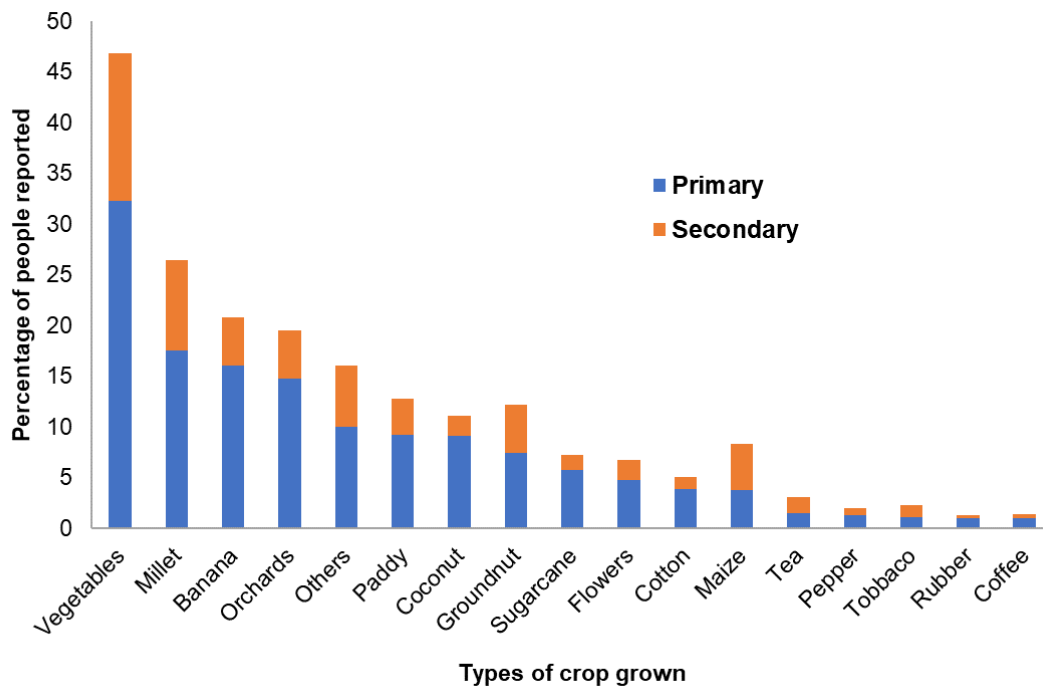


Figure 3.10 Different types of primary (major) and secondary (minor) crops grown by local people in the Western and Eastern Ghats part of Tamil Nadu.

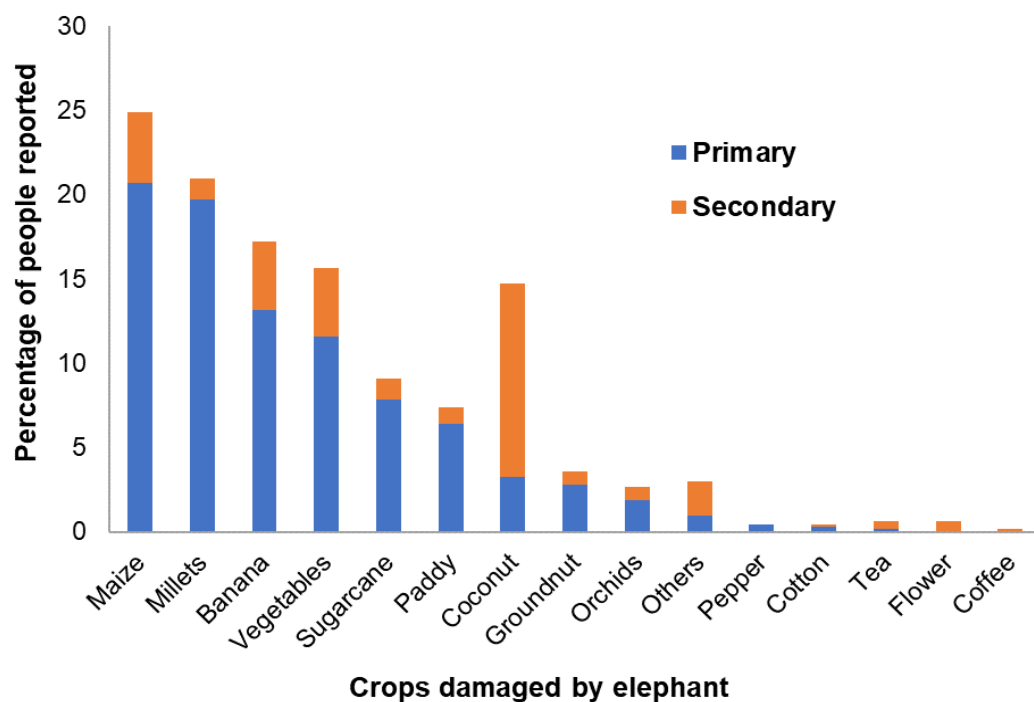


Figure 3.11 The primary (major) and secondary (minor) crop varieties damaged by Asian elephant in the Western and Eastern Ghats part of Tamil Nadu.

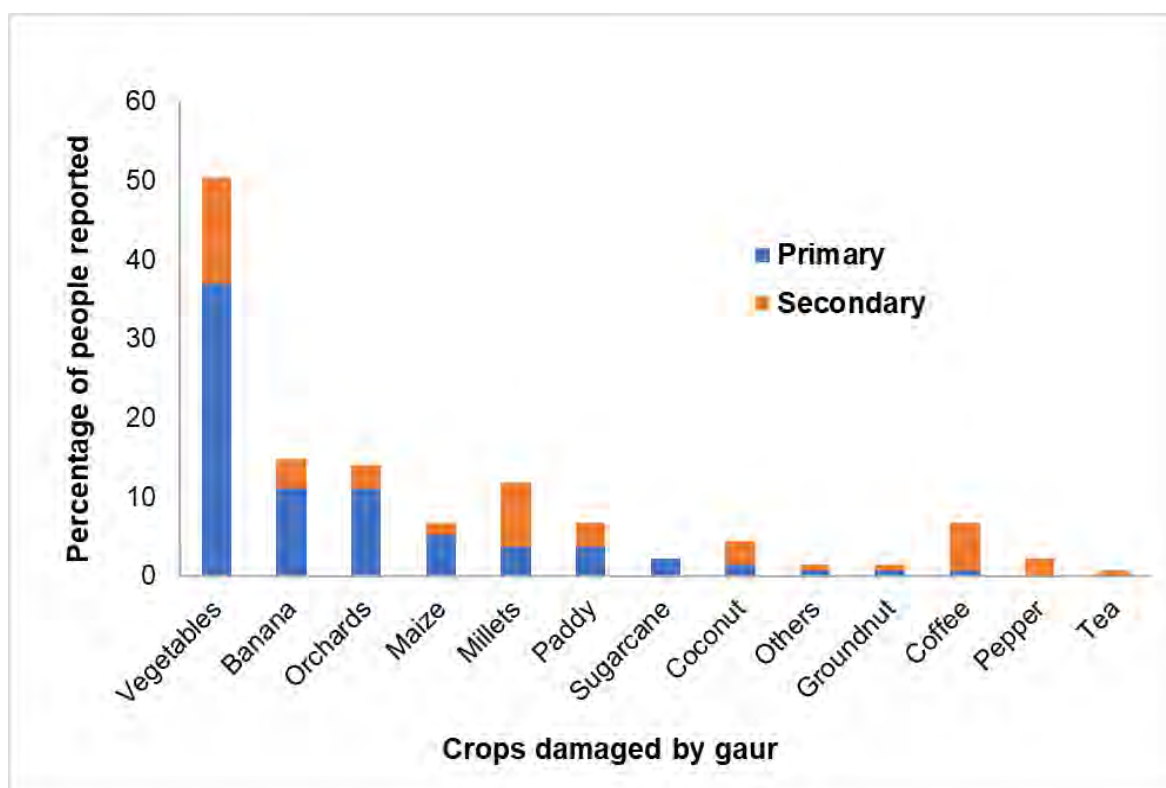


Figure 3.12 The primary (major) and secondary (minor) crop varieties damaged by Indian gaur in the Western and Eastern Ghats part of Tamil Nadu

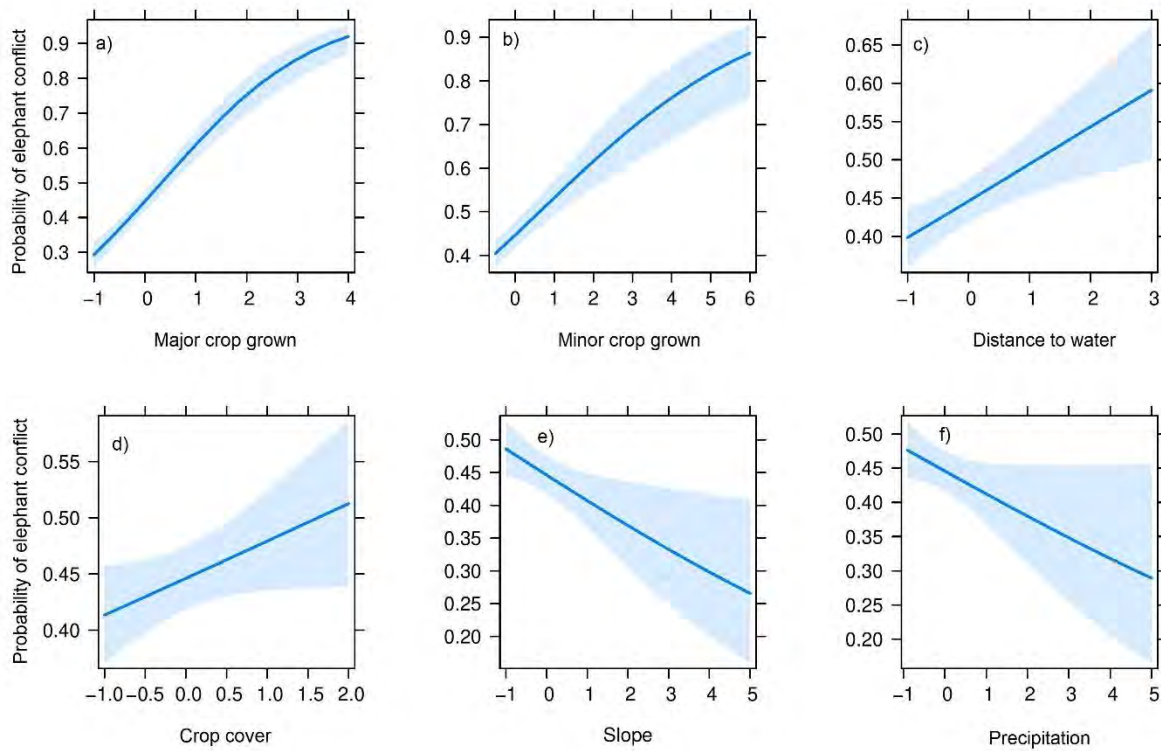


Figure 3.13 Top model explaining the predicted probability of conflict by elephant in response to the number of major crops grown (a), number of minor crops grown (b), distance to nearest water (c), percent crop cover (d), slope (e) and mean annual precipitation (f)

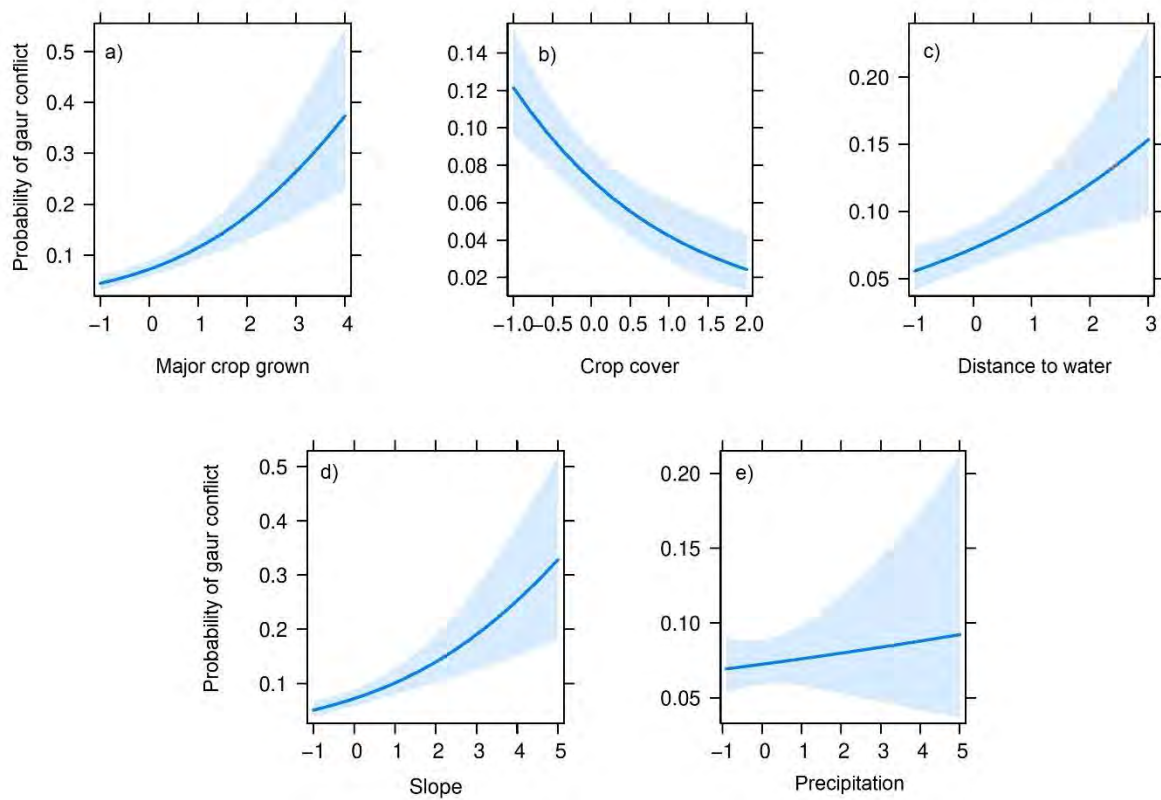


Figure 3.14 Top model explaining the predicted probability of conflict by gaur in response to the number of major crops grown (a), percent crop cover (b), distance to water (c), slope (d) and mean annual precipitation (e)

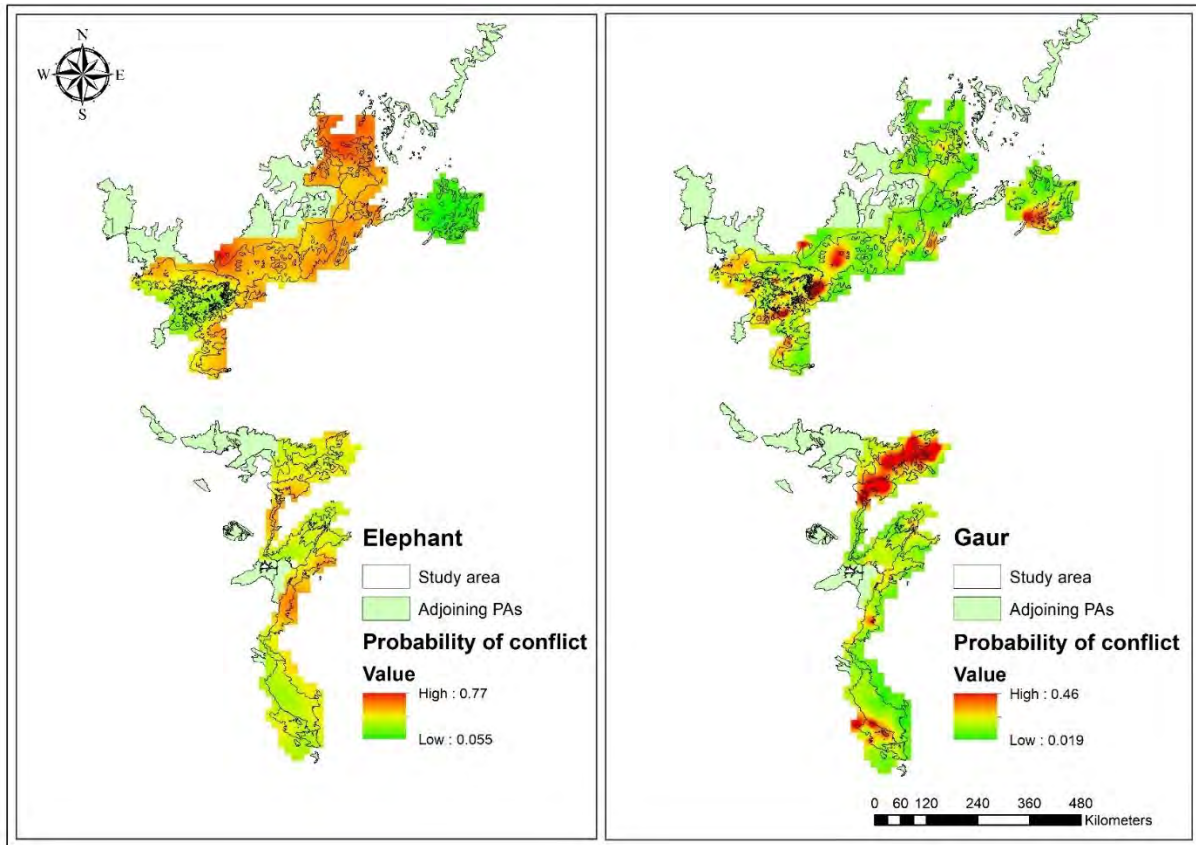


Figure 3.15 Predicted conflict hotspots from elephant and gaur in the Western and Eastern Ghats part of Tamil Nadu

Table 3.5 Summary of AIC_c model selection Generalized Linear Models (GLM) explaining factors influencing the predicted probability of human-elephant and human-gaur conflict in the Western and Eastern Ghats part of Tamil Nadu.

Model	df	logLik	AICc	ΔAIC	weight	R ² Value
Elephant						
CropCov+DistWater+MjCropGrown+MnCropGrown+Precip+Slope	7	-891.19	1796.46	0.00	0.81	0.20
CropCov+DistWater+MjCropGrown+MnCropGrown+Precip	6	-894.37	1800.79	4.33	0.09	0.19
CropCov+ForestDepScore+MjCropGrown+MnCropGrown+Precip+Slope	7	-893.75	1801.58	5.12	0.06	0.19
CropCov+ForestDepScore+MjCropGrown+MnCropGrown+Precip	6	-896.01	1804.08	7.62	0.02	0.19
ForestDepScore+MjCropGrown+MnCropGrown+Precip+Slope	6	-896.31	1804.67	8.21	0.01	0.18
CropCov+MjCropGrown+MnCropGrown+Precip	5	-899.43	1808.90	12.44	0.00	0.18
Gaur						
CropCov+DistWater+MjCropGrown+Slope	5	-413.93	837.89	0.00	0.57	0.16
CropCov+DistWater+MjCropGrown+Precip+Slope	6	-413.78	839.62	1.73	0.24	0.15
CropCov+DistWater+MjCropGrown+MnCropGrown+Precip+Slope	7	-413.32	840.72	2.82	0.14	0.14
CropCov+DistForestBdry+ForestDepScore+MjCropGrown+Precip+Slope	7	-415.47	845.01	7.12	0.02	0.14
CropCov+DistForestBdry+MjCropGrown+Precip+Slope	6	-416.75	845.57	7.67	0.01	0.13

Model	df	logLik	AICc	ΔAIC	weight	R ² Value
CropCov+ForestDepScore+MjCropGrown+Precip+Slope	6	-416.96	845.99	8.09	0.01	0.13
CropCov+ForestDepScore+MjCropGrown+MnCropGrown+Precip+Slope	7	-416.45	846.97	9.08	0.01	0.13
CropCov+DistWater+MjCropGrown+MnCropGrown+Precip	6	-422.93	857.92	20.03	0.00	0.12

df - Residual degrees of freedom, *logLik* - Log likelihood, *AICc* - corrected Akaike's Information Criterion, $\Delta AICc$ - change in *AICc* between each model, *wi* - Akaike weight, *CropCov* – percent crop cover, *DistForestBdry* - distance to forest boundary, *DistWater* – distance to water source, *ForestDepScore* - local's dependence on forest, *MjCropGrown* – Number of major crop grown, *MnCropGrown* - Number of minor crop grown, *Precip* - mean annual precipitation, *Slope* – mean slope, *R² Value* – to measure model fit.

Table 3.6 Estimated beta coefficients for the top ranked models that explain those factors influencing the probability of crop depredation by elephant and gaur in the Western and Eastern Ghats parts of Tamil Nadu.

Models	Estimate	Standard error	P value	Variable contribution
Elephant				
MjCropGrown	0.6631	0.0644	0.0000	1.0000
MnCropGrown	0.3441	0.0578	0.0000	0.9900
DistWater	0.1949	0.0589	0.0009	0.9000
CropCov	0.1336	0.0700	0.0562	0.9800
Slope	-0.1600	0.0642	0.0127	0.8800
Precip	-0.1367	0.0721	0.0580	1.0000
Gaur				
MjCropGrown	0.5002	0.0918	0.0000	1.0000
CropCov	-0.5906	0.1146	0.0000	1.0000
DistWater	0.2858	0.0877	0.0011	0.9500
Slope	0.3655	0.0814	0.0000	1.0000
Precip	0.0526	0.0971	0.5880	0.4300

CropCov – percent crop cover, DistWater – distance to water source, MjCropGrown – Number of major crops grown, MnCropGrown - Number of minor crops grown, Precip - mean annual precipitation, Slope – mean slope.

3.4 Discussion

3.4.1 People's perception on coexistence

Human perception studies are gaining much attention in the recent times as they are an important tool to achieve wildlife conservation goals. In India, perception of people towards wildlife were either positive, rooted in compassion towards wildlife, understanding its right to live in the wild

or religious reverence (Jasmine et al., 2015; Rohini et al., 2018), or negative, due to the time and money people invest to mitigate the loss caused by the wildlife (Saberwal et al., 1994; Sekhar, 1998). Such perception studies are pivotal in areas that encounter frequent episodes of HLMC, largely driven by the retaliatory attitude of local people (Deccan Herald, 2023; Chaitanya, 2024).

Developing positive mindset towards coexisting with wildlife is the critical to wildlife conservation and minimize the frequency of HLMCs. However, my study unveiled that 90% of the surveyed population are not pleased with the idea of coexisting with the large mammals, contradicting the findings elsewhere in India (e.g. Jasmine et al., 2015; Rohini et al., 2018), which is a matter of grave concern. Research suggests that accumulation of the negative perception on wildlife may lead to a total shift in public attitude to wildlife, from supportive to antagonistic view, undermining the conservation goals (Butler et al., 2003). Negative perception of people increased with decreased availability of basic amenities, reduced conductance of awareness program, an increased perception of the rise in HLMC incidents, increased prevalence of disease in livestock, increased negative view on Forest Department, increased fear of wildlife, increased crop depredation and increased intensity of livestock depredation. The landscape-level study on people's perception on large mammals, across different management gradients provides critical insights to the existing HLMC situation and the areas for improvement. With the rising HWC incidents across the state, it is important to understand the local perceptions on coexistence, as they are crucial in formulating policies that considers the perspectives of the key stakeholders, the local people. The study provides insight on complex relationships between individuals and wildlife, individuals and PAs, as well as individuals and park managers. With the rising human population, developing strategies for mindful coexistence is pivotal to wildlife conservation.

The perceptions of local residents towards coexisting with wildlife varied slightly across the management systems. Although, majority of the residents of all three management systems had a negative perception, the highest was observed among the residents of FAs, followed by PAs and RFs. This may be attributed to the loss from increased HLMCs in FAs, where there is an increased availability of resources like fodder, water and easy prey, thus attracting wild animals to human-dominated landscapes (Ramesh et al., 2020, 2022). My findings overlapped with the results of other similar studies (Mhlanga et al., 2019; Ramesh et al., 2019) who observed negative attitude of residents adjoining PAs, citing frequent encounters with wildlife.

Ensuring accessibility to amenities like school, hospital, potable and running water, electricity, transportation and communication facilities is fundamental to having public support towards management and policies concerning PAs (Kaltenborn et al., 2006; Karanth et al., 2006; Skogen et al., 2008). In a society where greater proportion of the people consider wildlife as ‘the property of Forest Department’, lack of these basic amenities will further introduce animosity towards wildlife and stand against the concept of coexistence with wildlife.

The economy of the population in the study area is majorly dependent on agriculture, which is often threatened by the crop depredation events by wild animals (Mohanarangan et al., 2021; Ramesh et al., 2021). Studies from India shows that 72% of the compensation payment by government was for the crop, property and livestock loss from HWC that contributed 94% of the economic loss by the common man (Karanth et al., 2018). The results demonstrated an increase in the negative perception of local people towards coexistence with increase in crop depredation. Studies show that support of the local community towards wildlife conservation initiatives reduced when large mammals like elephants become a threat to their crops, property and livelihood (Hariohay et al., 2018; Abdullah et al., 2019). In such cases, the chances for people to stand against coexistence with wildlife and choose retaliatory killing is high (Muchapondwa, 2003; Wang et al., 2006b; Ramesh et al., 2019)

Although frequency of livestock depredation by large carnivores are less in the study area, as compared to other parts of India (Ramesh et al., 2020), an increase in negative perception was hypothesized with the increase in livestock depredation. As expected, the results demonstrated that the probability of negative perception of coexistence increased with increased livestock depredation (Zimmermann et al., 2005; Hariohay et al., 2018). The economic loss that people face due to loss of livestock and delayed compensation will further increase negative, sometimes retaliatory attitude towards carnivores. Poisoning carcass in response to the livestock loss is common in the study area (Ramesh et al., 2020). When compensation is adequately and effectively administered on time, people will feel more financially secure and less burdened by the economic losses associated with wildlife predation. As a result, people will be inclined to tolerate the presence of wildlife and support coexistence efforts, even albeit livestock depredation events. Many at times, the compensation given for the crop damage will be not sufficient enough to cover the overall losses that an individual face, when compared to livestock depredation. Majority of the

residents in the study area are less educated or illiterate. Education is a key determinant of perception on wildlife conservation (Badola, 1998; Karanth et al., 2008). Lack of education and awareness about wild animals and how to respond while confronting them, are the root causes to misconceptions about wildlife, leading to a negative perception towards coexistence. The study showed that lack of awareness program increased the negative attitude towards coexistence with wildlife. A recent study by Basak et al., (2023) found that the positive attitude of human towards wildlife was majorly because of the people's consideration about wild animals as a part of nature. A pro-conservation attitude can be developed by educating and spreading awareness among the local people (Mir et al., 2015) because awareness campaigns has shown to increase the public tolerance towards wildlife and curtail the HWC frequency (Sekhar, 1998; Karanth and Madhusudan, 2002; Mishra et al., 2003). For example, the intense crop raiding by nilgai (*Boselaphus tragocamelus*) and blackbuck (*Antelope cervicapra*) were a threat to many people in northern parts of India, which could have led to severe HWC repercussions was managed successfully by the local people from the tolerance developed from the awareness programs (Sekhar, 1998; Karanth and Madhusudan, 2002).

The study highlighted that increase in HLMC incidents increase the probability of negative perception towards coexistence. Sometimes due to the perception that the frequency and intensity of HWC has increased, people consider coexistence unsafe and stand against it. This can be the result of hyper-awareness, where surplus information from various sources manifest fear among the local community (Dickman, 2010). Hyper-awareness of risk at individual and community level can be dangerous, where individual/community exaggerate about the HWC they encountered, and the losses faced, elevating fear among non-victims which will not only cause a negative perception towards coexistence, but also increases the risk of direct persecution of the animal or habitat conversion to make it unsuitable for the species (Dickman, 2010).

Forest department and their staffs are critical to shaping the attitude of the local people towards wildlife. The results emphasize that the negative perception towards coexistence increases with the increased negative attitude of public towards Forest Department. Wildlife conservation actions and coexistence will be possible only through the combined efforts of Forest Department and local people. People tend to be more co-operative towards wildlife conservation when the Forest Department provides necessary support to mitigate HWC or compensate for the loss they faced.

Hostility towards Forest Department will only instigate the local people to choose for retaliatory killing of the conflict animal, not coexisting with them. There could be many reasons for negative attitude towards Forest Department: (1) when people feel there are no efforts initiated from the Forest Department for mitigating HWC (Abdullah et al., 2019), (2) when people are not receiving timely and appropriate compensation for the losses they faced from wildlife, (3) when people feel that they are not valued or valued less than the wildlife (Mir et al., 2015), or (4) when they are not considered while framing laws, especially during the decisions for resettlement or declaration of PAs, disturbing their daily activities or livelihood (Vodouhê et al., 2010; Ramesh et al., 2019).

Wildlife associated diseases to livestock and humans (zoonotic) is rarely discussed in wildlife perception studies. Interestingly, the results showed significant positive correlation of diseases to livestock and people's negative perception against coexistence with wildlife. The perception that the wildlife transmit fatal diseases to their livestock and its effect on livelihood can bring antagonistic attitude towards wildlife coexistence. However, it can be because of false perception about the disease transmission also, where, perceived risk of disease transmission is different from the actual risk (Siemer et al., 2007). A study by Siemer et al., (2007) conducted in Wisconsin, US, found that 90% of the surveyed population had little/conditional tolerance towards the chronic wasting disease (CWD) transmitted to human, livestock and pets by the white-tailed deer (*Odocoileus virginianus*); 50 % were extremely worried about the disease and 38% believed that the white-tailed deer will introduce serious health risk; but in reality, the area (during the time of study) had no deer-associated diseases.

Along with other physical impacts, psychological impacts from fear of the wild animal, especially of those which cause social instability by causing significant threat to lives of human and livestock, property and livelihood of people, has recognized to have a positive correlation with annihilation pathway chose by people against the animal (Rohini et al., 2018) inevitably leading to a negative perception towards coexisting with wildlife. In fact, fear induces many indirect effects on the livelihood of local people like hypertension resulting from lack of sound sleep (Rohini et al., 2018), or psychological stress from expecting the attack of animal or changes in the daily working hours (Sutton, 1998). Fear can be introduced among unaffected people through the circulated news about the negative consequences of the animal attack and may stand against the conservation goals (Wilson et al., 2015a).

3.4.2 Patterns of human-carnivore conflict

The identification of those factors associated with or potentially causing livestock predations by large carnivores is becoming an increasingly important tool for their management and conservation around the world (Naha et al., 2020). The analysis indicated that variables such as human dependence on the forest, the location of a village, loss of forest cover, domestic livestock abundance, proximity to water resources and forest boundaries, topography, and the amount of precipitation in combination explained the HCC risk patterns in human-wildlife interface areas of the Western and Eastern Ghats complex of Tamil Nadu. Although some spatial risk patterns for state-wise analyses can also be obtained from secondary sources (Athreya et al., 2015), the predictive spatial risk maps showed the existence of carnivore predation risk gradients across almost 22,525 km², of which 14,200 km² (approximately 63%) of the total area of inference, was sampled. Although I relied on a single source of local's reporting on human-large carnivore conflict the large predictive predation risk map helps in asserting the relative conflict status of sympatric large carnivores for major PAs and RFs networks of the Western and Eastern Ghats of Tamil Nadu. The conflict hotspot map also highlighted areas prone to high livestock loss from large predators. A large number of households surveyed across such a large landscape also minimizes sampling bias and represents a greater sampling effort and a better coverage than other studies (Karanth et al., 2012; Karanth et al., 2013 a, b). Interestingly, relative to other parts of India (Prashant, 2004; Dhanwatey et al., 2013; Kshetry et al., 2017), there were only a very few cases of human casualties from large felid attacks in the study area indicating a general absence of direct HCC, attributed to the high abundance of domestic and wild prey species. Therefore, the large carnivore conflict is predominantly related to livestock predation in the study area.

The results indicate that the patterns of livestock predations by large carnivores varied across management systems and land use type, as well as inter-species variation in resource use (e.g., habitat, livestock type). Relative to tigers, the study reported much higher livestock predation rates by leopards and dholes in RFs and associated buffer zones. The data also suggests that the risk of livestock predation from tigers across Tamil Nadu PAs is comparatively lesser than in the parts of Central India (Karanth et al., 2012; Miller et al., 2016b) and Uttarakhand (Bargali and Ahmed, 2018). The scale of livestock predations by the leopard, however, was comparable to that endured by other PAs elsewhere (Karanth et al., 2013a; Karanth et al., 2013b, Athreya et al., 2015). Overall,

livestock predations occurred mostly in the morning hours, consistent with regional carnivore activity patterns (Ramesh et al., 2012b) and overlapping times of peak livestock grazing activity.

Tiger preyed more livestock, mainly adult cow/buffalos, from households located inside PAs compared to RFs and FAs. It is most likely to be attributed to the higher abundance of tigers in core areas of PAs, which are more densely forested and generally subject to less anthropogenic influence (Ramesh, 2010; Kalle et al., 2011; Jhala et al., 2020). Those tigers principally preyed cow/buffalos are likely due to a preference for larger prey (Ramesh et al., 2012a). The overall higher livestock loss in RFs compared to PAs and FAs may be due to the disproportionately cumulative impact of predation patterns by leopard and dhole. Other studies in India (Athreya et al., 2007; Ramesh et al., 2012a, 2012b; Kshetry et al., 2017) and elsewhere (Khorozyan et al., 2017) corroborate the selection of smaller-bodied livestock species by leopards, particularly along with the human-wildlife interface where a lower abundance of natural prey may be expected (Pillay et al., 2011).

Leopards in the study region preyed dogs at a lower rate than goats and calves. It was lesser when compared to the rate at which they took dogs in more urbanized landscapes (Edgaonkar and Chellam, 2002; Athreya et al., 2016). The dogs lost to leopard predation were ironically mostly livestock herding/guarding dogs of agro-pastoral communities, a pattern consistent with other studies (Butler et al., 2014; Khorozyan et al., 2017). Every household kept at least one or two domestic livestock guarding dogs, which roamed freely when sheep or goats grazed in RFs and FAs. Livestock predation by dhole in the study was comparatively lower than around select PAs of northeast India, which appears to experience higher livestock loss by dholes relative to large felids (Lyngdoh et al., 2014); this may be due to differences with Eastern Himalayan landscapes in large felid density as compared to the Ghats landscapes of southern India (Jhala et al., 2010, 2019; Kalle et al., 2011).

Livestock loss patterns varied among forest divisions with land-use management, local dependence on the forest, and livestock grazing regulations. For reducing livestock predation risk inside PAs, better measures are required to manage livestock grazing. The predation risk map can be shared with forest rangers to inform locals to avoid areas of high conflict. This approach might build trust and relationships between forest staff and locals. It also demands improved livestock management practices, such as the implementation of livestock stall-feeding near core areas

(Goodrich, 2010; Karanth et al., 2012; Miller et al., 2016b). The findings suggest that species-specific variation in large carnivore conflict patterns.

The integration of landscape attributes to produce large scale carnivore conflict risk maps improves the development of conflict mitigation measures (Karanth et al., 2013a; Karanth et al., 2013b). The model clearly showed that the risk of attacks on cattle by a tiger was highest near water sources and forest boundary areas, and for villages located inside the forested core areas of PAs; tiger predation risk decreased towards FAs. This is consistent with predation patterns exhibited by tigers in forested areas elsewhere across the region (Wang and Macdonald, 2006; Karanth et al., 2013a; Soh et al., 2014; Miller et al., 2016b). Other authors also found that communities illegally grazing free-ranging livestock inside PAs led to an increase in livestock predations by tigers in core forested areas (Jhala et al., 2010, 2019; Ramesh et al., 2012b). For tigers, the findings of Karanth and Kudalkar (2017) were comparable to ours in the Central Indian landscape; they found that livestock predations increased at higher elevations (> 2000 m), whilst those by leopards increased in gentle slope areas. The topography is also influential in predicting large felid kill risk patterns at varying spatial scales (Rostro-García et al., 2016).

Dhole predation risk increased with increasing forest cover loss and in areas of lower precipitation characterized by open scrub-jungle habitats (Pillay et al., 2011). Forest cover loss also influenced local extinction probabilities of dhole in select PAs of the Western Ghats in Karnataka (Srivathsa et al., 2019a). Reduction in forest cover can lead to a reduction in habitat quality and low availability of wild prey (Puri et al., 2020) increases the conflict and retaliation effect, which subsequently increases the extinction probability of the species. Therefore, the reduced natural prey biomass in low precipitation areas may have contributed to increasing livestock predations by dholes as elsewhere (Kolowski and Holekamp, 2006; Goodrich, 2010; Mukeka et al., 2019).

Overall livestock risk patterns suggested cattle were more vulnerable in dense forest areas whereas, goat and sheep were more vulnerable to predation in open vegetation, a pattern also reported in Central India's PAs (Miller et al., 2016b). Smaller livestock, such as goat and sheep, often graze in large herds in the dry scrub open habitats in our landscape, which was consistent with predation patterns exhibited by both leopards and dholes. Increased livestock grazing adjacent to forest patches is likely one reason for high conflict closer to PAs. In forested FAs, livestock sharing the same water sources as wildlife may contribute to livestock predations. Also, species-specific

predation patterns reflect ecological differences among large carnivore species, including habitat and spatial partitioning (Rostro-García et al., 2016), inter/intra-guild competition for domestic prey and variation in selection of domestic prey size (Ramesh et al., 2012b), and landscape-scale attributes (Puri et al., 2020). Leopard and dhole, for example, may occupy suboptimal habitats or habitats where there is less chance of encountering tigers; this spatial avoidance among co-predators may force leopards and dholes more often into forest edges, PA boundaries, and buffer zones (Seidensticker et al., 1990; Ramesh et al., 2012b).

HCC is a recurring problem across this forested, southern India landscape for several indispensable reasons. The absence of alternate grazing areas for most households, the location of households inside or very close to forested areas, and illegal grazing actually inside restricted use landscapes, often occur alongside other land uses and livelihoods (Karanth and Nepal, 2012; Karanth et al., 2012). Although livestock predation patterns varied by carnivore species, the overall average livestock loss for all carnivores (0.71 head/ household/ year) recorded was much higher than for Ranthambore National Park (0.38 head/ household/ year), Kanha National Park (0.16 head/ household/ year) and Nagarhole National Park (0.27 head/ household/ year) (Karanth et al., 2013b). However, the livestock predation rates were less than for Sariska Tiger Reserve (26.5% of the households affected in three years) (Sekhar, 1998), Kaziranga National Park (1.2 head/ household/ year; Borah et al., 2018), the Valparai Plateau in the Anamalai Hills (3.6 head/ household/ year; Sidhu et al., 2017), the Trans-Himalayas (1.6 head/ household/ year; Mishra, 1997) and selected PAs of Bhutan (1.29 - 3.26 head/ herd/ year; Wang and Macdonald, 2006; Jamtsho and Katel, 2019). We recorded a higher rate of livestock loss in PAs and RFs than in FAs suggests that livestock protection measures are warranted to address HCC across the various land management systems.

We identified major tiger predation risk hotspot areas covering parts of Nilgiri FD, Mudumalai and Sathyamangalam, where tiger abundance is relatively high in Tamil Nadu and contains a major source population relevant to adjoining human-wildlife interface areas. Aside from this major cluster, we identified another smaller tiger conflict area near Megamalai Wildlife Sanctuary. All of these interface areas also had a high abundance of buffalo and cows. We, of course, identified many more leopard predation risk hotspot areas, principally where the tiger conflict reports were lower, as well as a few medium risk areas for dhole conflict in Dharmapuri and Hosur. In areas

where conflict patterns of both leopard and dhole overlapped, the risk to livestock predation was even greater. Despite often high predation risk, people were less likely to report compensations to the Forest Department when smaller livestock (e.g., goats, sheep) were killed by leopards and dholes. Very often there would be a lack of field evidence (e.g., carcass remains, tracks and sign, photographic proof of large carnivore species attacking the prey) to provide as proof to forest managers for verifying claims. However, households were more likely to report large-bodied livestock loss (e.g., cows and buffalo), especially from tigers. Other authors observed a similar lack of reporting livestock losses in PAs of Madhya Pradesh and Karnataka states (Karanth et al., 2012; Karanth et al., 2013a). We also acknowledge the limitations of the interview-based surveys as recollecting ability varies among respondents which can affect reliable reporting of the actual number of livestock predation incidents. Overall, the maps revealed the highest risk levels in forest patches present inside and adjacent to PAs, and the lowest risks were in agricultural areas in FAs. It is evident from the findings that successful management of human-large carnivore conflict will require state-level planning which incorporates conflict issues from RFs, FAs, and PAs at the landscape level.

3.4.2 Patterns of human-megaherbivore conflict

The study has led to practical and actionable information regarding the current spatial patterns and drivers of human-megaherbivore conflicts. For the first time, the study highlights hotspots of this conflict across the human-wildlife interface of a large network of PAs and other land use types in the Western and Eastern Ghats of Tamil Nadu, southern India. The study outcome benefit farmers from the vulnerable risk area identified by growing alternate crops which are less preferred by megaherbivores that reduce the probability of human-megaherbivore conflict.

The conflict hotspot map highlighted many households that were vulnerable to elephant and gaur conflict, indicating a need for better land use planning. We found that cropland cover, the number of major and minor crops, proximity to the nearest water source, mean annual precipitation, and mean slope, all predicted the likelihood of megaherbivore conflict hotspots along human-wildlife interface areas of the WEGPTN. Elephant conflict hotspots were predicted to occur in lower plain (i.e., flat) terrains characterized by agricultural fields and lower precipitation, whereas gaur conflict hotspots were more likely to occur in undulating terrain amidst tea/coffee plantations and other crops. The high elephant and gaur conflict zones we predicted occurred across ca. 40% and

ca. 3% of the total area sampled (22,525 km²), respectively. Relative to the large area predicted for human-elephant conflict, we identified proportionally much less area for human-gaur conflict across reserve networks, which although patchily distributed, suggested a rise in human-gaur conflict and newly emerging hotspot areas.

Reduction in quality and availability of elephant habitats in the narrow stretch of forested areas of fragmented landscape force elephants to use agricultural areas beyond their natural habitat in the human-wildlife interface areas. During the process, the conflict between human and elephant becomes inevitable which leads to casualties on both sides (Sukumar, 1990; Venkataramana et al., 2017). Therefore, we identified spatial determinants of elephant conflict which are urgently required to develop HEC mitigation. We found that crop cover and diversity of major and minor crops near the forested landscape act as important drivers of elephant conflict in the study area. With the extension of irrigated cultivations near forest boundaries, elephants have become increasingly attracted to forage on nutritious crops like maize, millets, banana, vegetables, sugarcane, and rice paddies. Although cultivated crops have higher digestible energy and are lower in protein and fibre (Sukumar, 1990; Sekar, 2013), increasing crop consumption may reflect fluctuations in availability of natural forage in PAs (Branco et al., 2019). Greater levels of habitat fragmentation and reduction in overall habitat quality in reserve forests (Kumar, 1994; Sivaganesan and Johnsingh, 1995; Sukumar and Ramesh, 1995; Santiapillai, 2003; Babu et al., 2012), could explain the increase in elephant-related conflict compared to situations in PAs and fringe areas. Over time, the reserve forests of southern India have shrunk in size and shape to narrow, more linear areas due to increasing deforestation rates and landscape-scale proliferation of human settlements (Puyravaud et al., 2019, Kumar et al., 2004). The forests connecting the Nilgiri hills across the Western and Eastern Ghats are important elephant corridors (Ramkumar et al., 2018), and also areas of high HEC where local communities are dependent on forest resource extraction. Overgrazing by livestock in the forested areas and fuelwood collection from fringe and enclave villages, results in a reduction of native trees and forage availability for herbivores and thus overtime their natural habitat witnessed invasion of weeds such as Lantana, Eupatorium, etc. in a vast area of lower and mid-elevation thorn and dry deciduous forest suppressing the growth of native species including grass (Sekar, 2013; Kumar, 1994; Babu et al., 2012; Sivaganesan and Johnsingh, 1995). The loss of food plants and changing cropping patterns with elephant attractive crops drives the elephants into the agricultural areas (Sukumar and

Ramesh, 1995; Santiapillai, 2003). Besides, elephant corridors are hindered with human settlements, rising urbanization pressure, and changing land-use patterns from agriculture to housing (Ramkumar et al., 2018).

The intrusion of elephants into human settlements and irrigated croplands in search of water and forage is now common in these regions (Sukumar, 2006). This could at least in part explain the importance of water sources to HEC incidents. Areas with low mean annual rainfall experienced more HEC, possibly because rainfall or lack thereof directly affects the availability of fodder within natural habitats; this drives animals outside such habitats in search of food. Since rainfall pattern had a significant role in controlling the vegetation dynamics and the availability of water, elephants migrated accordingly to the most suitable habitats, particularly in the dry seasons of the year (Birkett et al., 2012; Bohrer et al., 2014) which can result in HEC incidents. Several prior studies have reported on HEC patterns during the monsoon (Stewart-Cox and Ritthirat, 2007; Joshi and Singh, 2008; Webber et al., 2011; Chen et al., 2016; Naha et al., 2019), which also coincided with the harvest seasons for maize, sugarcane, wheat, and rice paddies.

The results depicted that increasing steepness of a landscape reduces the probability of HEC. Slope was a major topographical factor that influences the elephant movement and habitat selection in other studies as well (Sappington et al., 2007; Kanagaraj et al., 2019), i.e., landscape steepness probably limited the distribution and behaviour of crop-raiding elephants. Due to better accessibility to food and much effortless movement following their body size, elephants mostly preferred lowland areas. Similar observations of Naha et al., (2019) indicated that even though there were reports of crop-raiding by elephants rarely at even 1000 m high altitude, relatively less incidents of human casualties were reported. Though slope has lesser influence on elephant's habitat selection when compared to other factors (Aini et al., 2015), they try to avoid steep slopes and hills because of overheating of their body, increased fear and risk of injury and limitations in forage and water availability (Wall et al., 2006). Meanwhile, a recent study by Kanagaraj et al., (2019) points out the increased probability of unidirectional range shifts of Asian elephant distribution towards higher elevations in India upcoming years predominantly due to climate changes and increasing anthropogenic pressures.

Overall, we found human-gaur conflict (HGC) to be highly localized in WEGPTN. The patchy clusters of HGC were predicted to occur in Gudalur RF, Nilgiris RF, Coimbatore RF, Harur FD,

Theni FD, and core regions of Sathymangalam TR. A large continuous HGC hotspot area was predicted for Kodaikanal WLS, and a small forest patch in Kanyakumari WLS. With respect to overall spatial area, the HGC hotspots we predicted in the Nilgiri FD, Gudalur FD, and Kodaikanal WLS, were all relatively large. This could be because these Forest Divisions also protect remnant montane and mid-elevation grassland patches on their slopes. In recent years, these have been increasingly converted to plantations of tea and coffee, and are also at increased risk from invasive plant species (Joshi et al., 2018; Arasumani et al., 2021). Gaurs are grazers and are highly dependent on the availability of grasslands (Schaller, 1967; Chetri, 2003); the extensive loss of grasslands in the Western and Eastern Ghats of Tamil Nadu (Joshi et al., 2018) may have contributed to low forage availability, forcing gaur to venture into open fringe habitats. Gaur herds and individuals have increasingly been spotted in tea gardens and seasonal croplands at the periphery of PAs, where they have been observed feeding on available understory grass cover in exotic tree plantations (Indira, 2019; Sankar et al., 2020; Chaiyarat et al., 2021). It is in these patch areas that local people have become susceptible to chance encounters with gaur at odd hours (Indira, 2019; Sankar et al., 2020). Encroachment into and cultivation of private forest areas adjacent to the forested landscape are known to escalate the scale of conflict in forest ecosystems of the Nilgiris FD and Kodaikanal WLS. During 2016-18, six human deaths and 36 injuries were attributed to gaur attack, and 31 crop-raiding incidents were reported in the Nilgiris Forest Division alone (Indira, 2019). Such incidents are most prevalent in tea/coffee estates. The increasing localised gaur conflict cases reported in southern India (Joshi and Madhusudan, 2018; Sankar et al., 2020) therefore suggest that forested landscapes with undulating, “hilly” boundaries that interface with rural communities need to be regularly monitored so that the change in conflict pattern can be better understood and more effective mitigation measures can be enforced.

The association between HGC and the diversity of major crops at these interface areas further supports the idea that the variety of crops grown at different seasons likely provides more foraging opportunities at a given locality throughout the year. This relationship warrants an in-depth investigation of HGC hotspots to study crop-visitation rates of gaur, and a comparison of nutrient levels between natural and human-modified forage. Such findings could better inform management guidelines for highly degraded grassland patches, or even help to restore grassland habitats and keystone species, in conflict-prone Forest Divisions. One study in Mookambika WLS,

Karnataka, reported that the most crop-raiding cases in rice paddy, sugarcane, and ragi fields occurred during summer, particularly in the farms located inside the core area relative to those located in the periphery of the sanctuary (Prashanth et al., 2013).

During the dry season, gaur populations were also attracted to water sources like wells, tanks set up by local villagers, and irrigated crop fields. These conditions often lead to more overlap between gaur and humans, especially at water sources. The annual rainfall pattern also influences HGC, and this could be related to the suitable habitat of gaur in high-altitude undulating slopes (Ramesh et al., 2012c). The presence of disproportionately smaller tiger populations in selected high-altitude areas in Tamil Nadu, and thus lower predation pressure on gaur, may have led to an increase in gaur populations in some Forest Divisions (Ramesh et al., 2012a; Ramesh et al., 2012c). Sprawling tea estates may have also led to a recent expansion of the gaur population in the Nilgiris Biosphere Reserve (Sankar et al., 2020). In such landscapes, gaur would inhabit small forest pockets interspersed with human habitations.

Wildlife species using human-modified landscapes increase the likelihood of negative human-animal interactions (Madhusudan and Mishra, 2003). These landscapes can disrupt the coexistence balance between people and gaur, changing otherwise empathetic behaviour to hostile behaviour. Gaur populations can also become resident outside of the forest, or take shelter in small insular forest patches, depredating crops, and creating fear and apprehension in local communities. In addition, improper waste disposal in the Upper Nilgiris and Kodaikanal due largely to unregulated touristic activity, is also a major problem; gaur herds have increasingly been observed feeding at these garbage dumps (Sankar et al., 2020). Habituation to such areas however can also lead to greater vulnerability of gaur to human retribution following negative interactions, such as when gaur attack humans and cause severe injury or death. Unlike elephants, HGC seemed to increase in more topographically complex areas, as gaur frequently forage along the hill slopes in fragmented landscapes. Sankar et al., (2013) even noted that gaur used areas with steep slopes more in the monsoon season than in summer and winter in Bandhavgarh.

Chapter 4

CHAPTER 4

Identify disparities in resource allocation between Protected Areas and outside Protected Areas and its effect on human-wildlife conflict

4.1 Introduction

Protected Areas (PAs) are treated as the pillars of biodiversity conservation and the establishment of such management systems are usually linked to the accomplishment of conservation policies (Milatović et al., 2019). PAs cover less than 5% of total land area in India, and they preserve most of the country's remaining biodiversity (Karanth et al., 2008; Dinerstein et al., 2017; Ghosh-Harihar et al., 2019). Conserving the rest of biodiversity, spread across forest areas other than PAs containing many of the threatened and endangered species, are also equally important because without adequate protection the survival of tropical biodiversity is highly implausible (Bruner et al., 2001). In India, PAs have a higher level of legal protection, which include Tiger Reserve/Sanctuary and National Park when compared to areas outside PAs including Reserved Forests (RFs), Community Reserve (or village forest), Unclassed Forests etc. (Macura et al., 2011; Naniwadekar et al., 2015). The PAs and RFs are topographically similar with varying levels of protection measures under the State Forest Department as more relaxed access given for resource extraction to locals in RF. Due to the status as RFs for many forest divisions where locals have some rights on the land and hence the landscape continued to experience significant habitat destruction from permitted or illegal livestock grazing and exploitation of natural resources (Velho et al., 2016; Forest Survey of India, 2019). Once RFs are legally upgraded to buffer zones of PAs, full protection measures and better infrastructure facilities would be made available for them because of the better resource availability under PAs for wildlife management. However, many RFs are managed outside PAs jurisdictions (Macura et al., 2011; Ghosh- Harihar et al., 2019). PAs, together with its network of forests, such as RF habitats are vital in maintaining tropical biodiversity (Velho et al., 2016). In the study, all the RFs lying outside the PAs, will be hereafter termed as 'outside PAs'. With the leniency in legal restrictions, the vast expanse outside PAs that allows resource use by local communities is one of the main challenges of outside PAs as it alters their efficacy in biodiversity protection (Velho et al., 2016; Forest Survey of India, 2019). Outside PAs has a crucial role in biodiversity conservation as they mainly act as a corridor and buffer for

many of the PAs. Degradation of these wildlife habitats adjacent to PAs will make a considerable impact on the ecological functioning of PAs (Laurance et al., 2012).

Human-Wildlife Conflict (HWC) has always been a serious threat to wildlife conservation along with habitat loss and fragmentation (Crooks et al., 2017). Human-large mammal conflicts (HLMC) are one amongst the most challenging plights in terms of wildlife conservation and securing human life and livelihoods. Large mammals are wide-ranging animals that require large, contiguous habitats to sustain their dietary and reproductive needs nevertheless, many PAs in India are small and isolated (Dinerstein and Wikramanayake, 1993; Ghosh-Harihar et al., 2019). Forest fragmentation as a result of anthropogenic developmental activities and urbanization hinders the free movement of large mammals and alters their population connectivity (Segelbacher et al., 2010), resulting in the migration of large mammals in the vicinity of human-wildlife interface areas (Menon and Chaudhary, 2017). In many parts of the developing world, mammals inhabit landscapes beyond reserves where they come into conflict with the local communities (Woodroffe et al., 2005; Inskip and Zimmermann, 2009). Increasing human-wildlife interaction can lead to an economic loss (crops and livestock loss), injury or even mortality to humans which are mostly contributed by large mammals such as Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*), leopard (*Panthera pardus*), tiger (*Panthera tigris*) and dhole (*Cuon alpinus*). Since large mammals are integral species for the functioning of the ecosystem, a decline in their numbers can drastically destabilize the ecosystem (Morrison et al., 2007; Beschta and Ripple, 2009). However, the efficiency of PA management fails when localized threats like hunting, habitat encroachment, livestock grazing, and forest fire persist (Bawa et al., 2007; Aiyadurai et al., 2010). Although India's wildlife laws prohibit hunting, the hunting pressure still exists and also varies across taxa and regions due to the weakness in law enforcement (Aiyadurai et al., 2010). In India, several instances of retaliatory killings of wildlife by poisoning, electrocution, capture, and use of handmade bombs are also widely reported (Madhusudan, 2003; Gubbi and Linkie, 2012; Bhupathy et al., 2013). With the increasing global species extinction rates, there is a need to prioritize and protect wildlife species experiencing severe conflict, as retaliatory and negative perceptions of people pose a serious concern for species conservation. Here, merely establishing PAs are not enough, effective human-wildlife management beyond PA boundaries such as RFs are also equally important for achieving conservation success in India.

In India, the State Forest Department has initiated several measures to alleviate the conflict such as constructing check dams, electric fences, Elephant-Proof Trenches (EPT), relocating conflict animals and providing monetary compensation schemes to local villagers (Nath and Sukumar, 1998; Mishra et al., 2003; Sukumar, 2003; Athreya, 2006; Athreya et al., 2011; Karanth et al., 2013a). Although such measures exist to mitigate conflict, heavy economic losses, death of human and wildlife due to lack of proper maintenance of physical barriers, and monitoring of mitigation measures. Hence, it is important to implement mitigation plans and monitor how effective the mitigation measures are, in minimizing the conflict.

PA conservation requires effective law-enforcement policies at all levels, including ranger patrols, intelligence gathering, and effective criminal justice systems (Challender and MacMillan, 2014; Tranquilli et al., 2014; Rauset et al., 2016). Forest range officers (FROs) play a vital role in maintaining wildlife habitats through surveillance and curbing illegal activities, alleviating human-mammal conflict creating awareness about wildlife and conservation among the locals (Stokes, 2010; Jenks et al., 2012; Ghoddousi et al., 2016). The efficiency of law enforcement is crucial to the success of ranger patrols when patrols are perceived to be more effective in improving law enforcement (Milner-Gulland and Leader-Williams, 1992; Fischer et al., 2014). Improved conservation strategies by the stepping-up of anti-poaching efforts by FROs that helped in recovering the small population of Indochinese tigers in Thailand is an example (Duangchantrasiri et al., 2016). FROs, being the backbones of PA management, have a crucial role in implementing conservation initiatives for protecting wildlife and bringing down HWC (Leader Williams and Milner-Gulland, 1993; Rowcliffe et al., 2004). The effectiveness of FROs in minimizing threats can be diminished with the lack of adequate training, experience, education, monetary funds, manpower, equipments, etc. (Di Minin and Toivonen, 2015). Therefore, effective enforcement also requires their needs and limitations to be carefully addressed for the effective functioning of wildlife habitats regardless of the protection status of their habitats (Bruner et al., 2001). This will typically bring down HWC along with illegal activities in and around PAs.

In general, the PAs have better wildlife protection measures than outside PAs in India. Since both management systems support similar wildlife species and habitats, outside PAs demand equal priority in terms of HWC management and forest protection. Currently, government investment in terms of financial aid and manpower is largely focused on PAs (Ghosh-Harihar et al., 2019).

Management failure of wildlife habitats is a considerable challenge in PAs (Damania et al., 2008). Because of the insufficient and uneven allocation of funds, many initiatives and ground-level conservation measures are unfulfilled, especially outside PAs are highly neglected in this aspect. With this disparity, a greater understanding of conservation issues in terms of HWC management, poaching status, and resource allocation is essential through interview-based surveys of forest officials. The importance of this conservation concern across 16 PAs and outside PAs is demonstrated in the Western and Eastern Ghats of Tamil Nadu (TN), which support a relatively high density of large mammal populations (Jhala et al., 2010; Ramesh et al., 2012c, d). These PAs and outside PAs encompass human settlements within and surrounding buffer areas; most of which predominantly belong to lower-income groups. The locals in these regions are socioeconomically vulnerable, dependent on the forest for agriculture, livestock rearing and non-timber forest produce collection such as firewood, roots, tubers, and honey for livelihood (Solavan et al., 2004; Arjunan et al., 2005; Davidar et al., 2008). Large mammals living in these areas are often in conflict and perceived as a threat to their lives and livelihood (Madhusudan, 2003; Jayson and Christopher, 2008; Gubbi, 2012; Karanth et al., 2013a, b; Sekar, 2013; Kumar and Raghunathan, 2014; Senthilkumar et al., 2016). The TN State Forest Department has been applying several mitigation measures to control the increasing HWC through compensation schemes to the victims for the loss of crop/damage to properties/casualty or death caused by wild animals, constructing early warning alarm systems and physical barriers such as elephant-proof trench, electric fencing, and solar fencing (Karanth et al., 2018; Tamil Nadu Forest Department, 2019). FROs being the mediators between the local community and the wildlife has a substantial role in conserving wildlife and safeguarding humans and their properties from wild animal attacks.

Inclusion of a broad, mosaic forest landscape in species conservation planning requires management of HWC issues in and around PA networks i.e. assessment and measure of current HWC scenarios are required in both PAs and outside PAs, through rangers, which could help in more effective implementation of wildlife conservation actions in PAs. The ability of FROs to implement management schemes and deal with the HWC effectively largely depends on their education and experiences in wildlife areas and external factors like availability of monetary funds, equipment, and manpower for conflict mitigation (Critchlow et al., 2015). The study aimed at identifying the disparities in resource allocation between PAs and outside PAs that could be the possible drivers of HWC incidents. I expected that the availability of resources for wildlife

management would be crucial for HWC mitigation, as the lack of manpower, equipment, and monetary shortage can impair the mitigation measures initiated by the regional forest division particularly, in outside PAs. I also expected that species-specific conflict incidences and poaching vary between outside PAs and PAs.

4.2 Materials and methods

4.2.1. Study area

The Western Ghats Mountains in southern India is one of 36 global biodiversity hotspots (<https://www.conservation.org/priorities/biodiversity-hotspots>). The study area ranges from Cauvery North Wildlife Sanctuary in the north to the Kanyakumari Wildlife Sanctuary in the south, covering sixteen Protected and Reserved Forest areas lying in the Western and Eastern Ghats region of Tamil Nadu (Figure 4.1): Meghamalai Wildlife Sanctuary (WLS), Kanyakumari WLS, Kodaikanal WLS, Srivilliputhur Grizzled squirrel Sanctuary, Nellai WLS Sathyamangalam Tiger Reserve (STR), Kalakad-Mundanthurai Tiger Reserve (KMTR), Mudumalai Tiger Reserve (MTR), Nilgiris Forest Division (FD), Cauvery North WLS, Coimbatore FD, Theni FD, Dharmapuri FD, Hosur FD, Erode FD, and Gudalur FD. Each forest division contains approximately four to five forest ranges in it.

4.2.2 Data collection and analyses

I conducted a semi-structured questionnaire survey of FROs across 16 Forest Divisions covering PAs and outside PAs in the Western and Eastern Ghats of TN (Figure 4.1, 4.2). The survey was conducted between November 2018 and March 2020 with 79 FROs of the TN Forest Department. In the absence of the FRO, the immediate experienced senior forester of the particular division was interviewed. In each of the sixteen forest divisions, ca. four to five forest ranges were covered for the survey. Each interview session lasted for about 40 minutes. Each interview began with a brief introduction about the research work, explaining the purpose of the assessment, and giving them an outline of how the questions should be answered. All the officers were willing to cooperate and spend their time for the interview. However, they expressed their unwillingness to some questions which they felt were sensitive to wildlife management. The questions were focused on how the disparity in resource allocation between PAs and outside PAs affect HWC management

issues in the respective ranges. The goal was to compare the HWC management issues between PAs and outside PAs by analysing the qualifications of the rangers in terms of education and experience in the field of wildlife management, training, availability of equipment and manpower available, conflict mitigation measures employed, funding support for tackling conflict in each range, the status of conflict for the past five years and species involved, the total number of anti-poaching watchers, anti-poaching camps, compensation schemes, the status of poaching and methods used to poach and awareness programs to the locals (See table S4.1 for details).

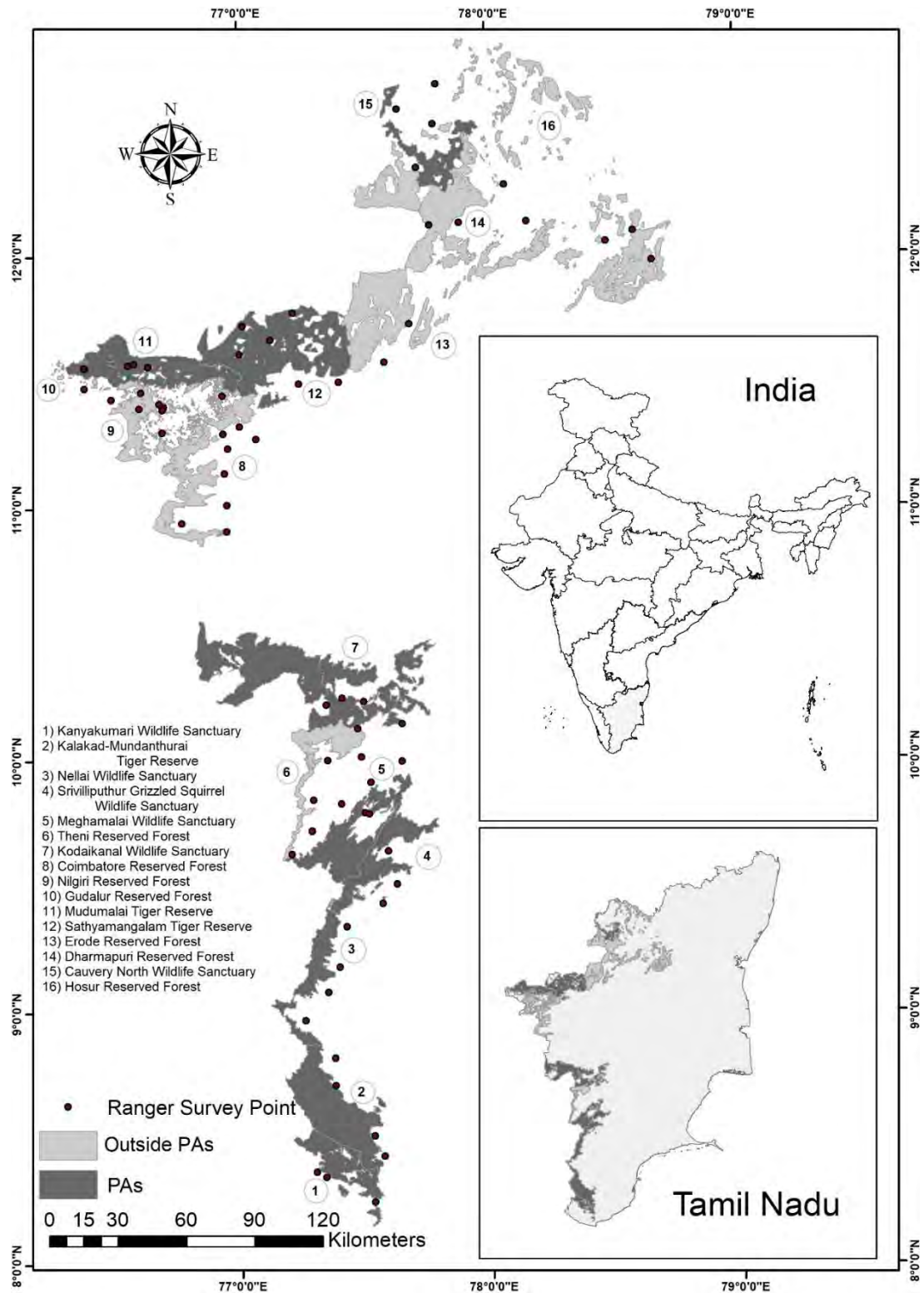


Figure 4.1 Study area showing Forest Ranger survey points across Protected and outside-Protected Areas in the Western and Eastern Ghats parts of Tamil Nadu, southern India.

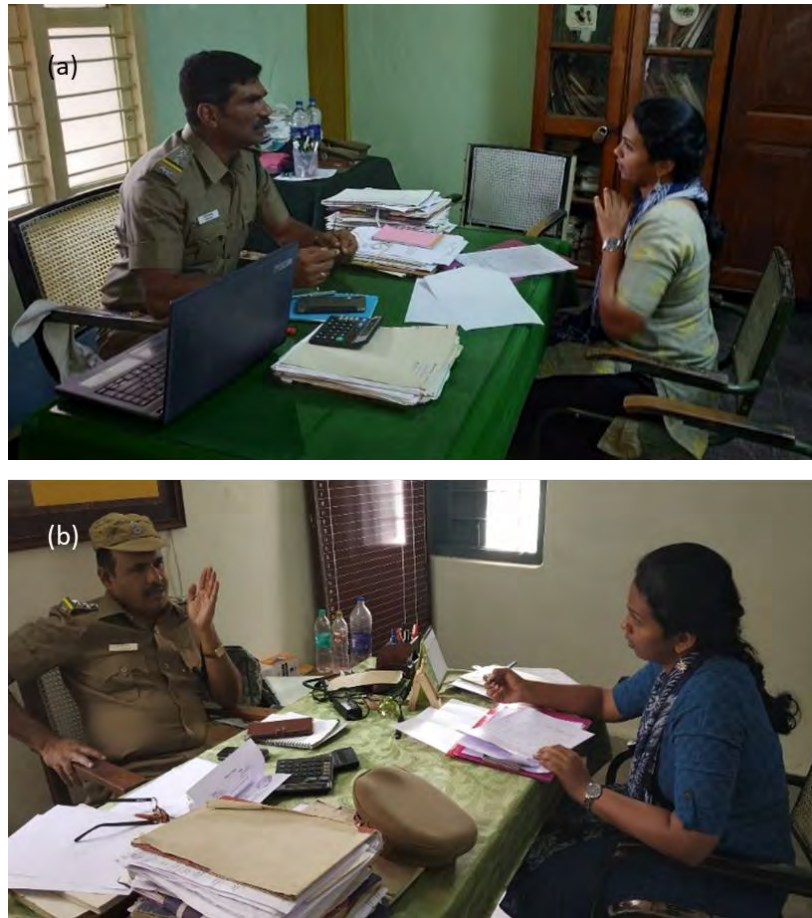


Figure 4.2 Interviewing the Forest Range Officers (a,b).

Simple descriptive statistics was used to analyse questionnaire data. Considering the nature of the collected data, percentage calculations were performed followed by plotting histograms. Since all FROs did not respond to every question inquired, patterns from the percentage of FROs who responded were inferred. It was calculated by dividing the total number of positive respondents for individual answers over the total number of FROs responded to the given question and was expressed in percentage. For this, the total number of responses for a particular answer (X) over the total number of responses received for a given question (N), was expressed in percentage ($X/N \times 100$). Further, these percentages were applied for plotting histograms to compare the variation between PAs and outside PAs. A non-parametric Mann-Whitney U test was applied to test the differences of individual effect of each question between PAs and outside PAs (Zar, 1999) using program PAST (Hammer et al., 2001).

4.3 Results

A total of 79 FROs belonging to 43 ranges in PAs and 36 ranges outside PAs were interviewed. Some of the questions asked were not answered, and quantified information was not given by FROs, either due to the lack of relevant data or their reluctance to share sensitive information.

4.3.1 Human-wildlife conflict

The survey showed that the major large mammals involved in the conflict (>50%) in PAs (N=43) were elephant, wild pig, leopard and bonnet macaque (*Macaca radiata*), followed by sloth bear, sambar (*Rusa unicolor*), dhole, gaur, chital (*Axis axis*), and tiger. Outside PAs (N=36), the major conflict species (>50%) were elephant, wild pig, leopard, and bonnet macaque, followed by gaur, dhole, chital, sambar, tiger and sloth bear (Figure 4.3a). Most of the species involved in the conflict were the same in PAs and outside PAs, although the intensity of conflict contributed by each species was different in each management system (Mann-Whitney $U = 32$; $z = 1.324$, $p = 0.183$). Species such as sloth bear and sambar conflicts were much higher in PAs when compared outside PAs whereas gaur conflict was more outside PAs. Almost 50% of FROs (PAs, N=39; outside PAs, N=36) reported a substantial increase in conflict incidents in their ranges during the past five years (Figure 4.3b). I found that human casualties were mainly caused by the elephant attacks; Ca. over 50 human deaths were reported from both PAs and outside PAs every year. Human mortalities were frequently reported in Coimbatore, Sathyamangalam, Mudumalai, North Cauvery, Hosur, Gudalur, Dharmapuri and Erode Forest Divisions. Tiger and leopard largely attacked livestock rather than humans, although a few incidents of leopard attacks on humans were reported. In parts of Nilgiri and Kodaikanal, the Gaur conflict has caused human death/injury to ≥ 5 people every year. Sloth bear conflicts were prevalent in Kalakad Mundanthurai Tiger Reserve, Nellai, Meghamalai, Srivilliputhur, Sathyamangalam, Nilgiris, Gudalur, and Mudumalai Tiger Reserve, wherein each division around 3-4 human injuries occurred every year. Wild pig and bonnet macaque conflicts in terms of crop damage and human attack were widely reported across all the forest divisions.

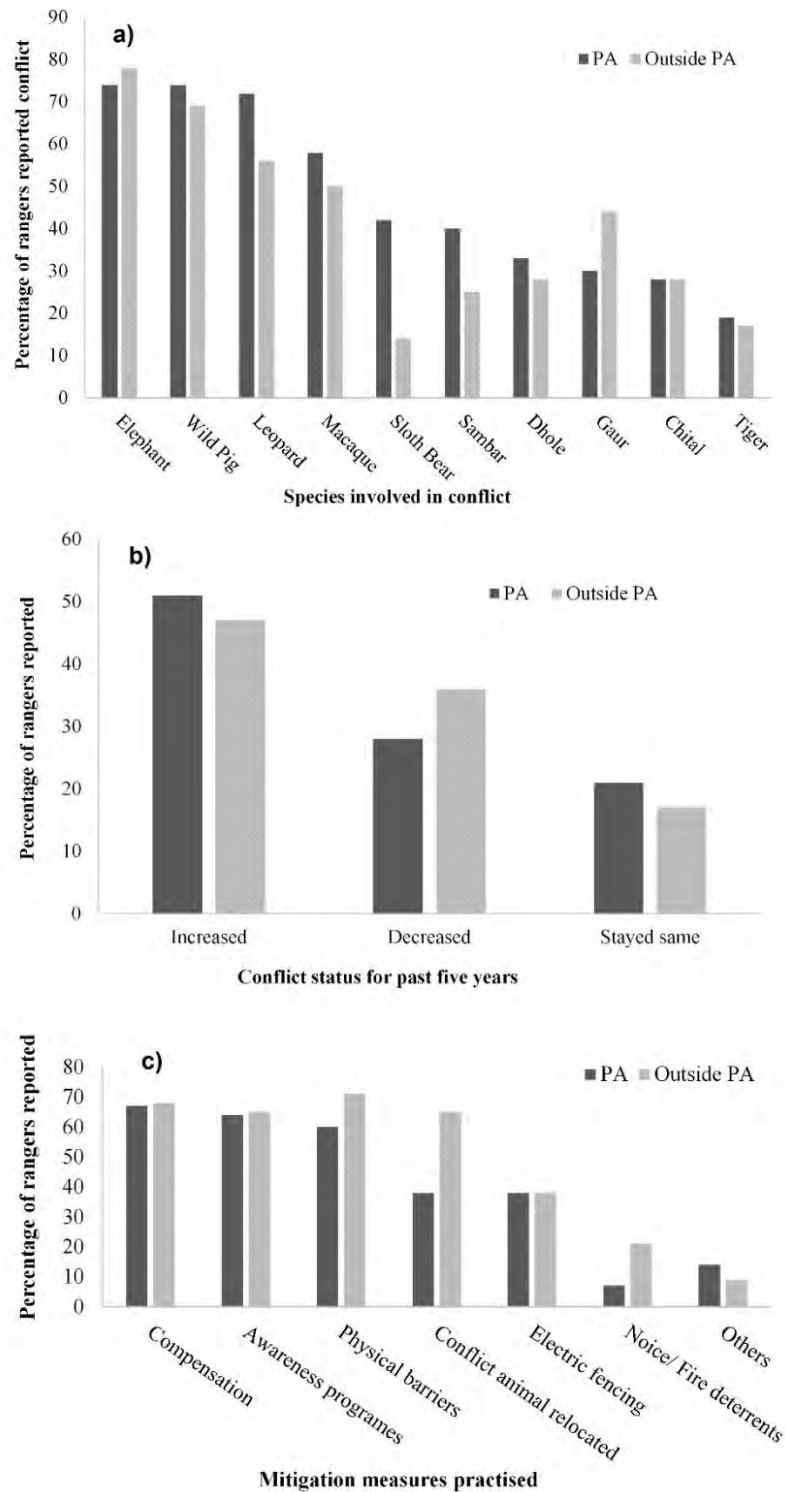


Figure 4.3 Major mammalian species involved in conflict (a), status of human-wildlife conflict (b) and mitigation measures practiced by the State Forest Department (c) in Protected and outside Protected Areas (outside PA).

4.3.2 Human-wildlife conflict mitigation

Several mitigation measures were implemented across forest ranges in PAs and outside PAs to tackle HWC (Figure 4.3c, 4.4) like granting compensation (67% PA; 68% outside PA) to the villagers for their damage/loss of property/livestock/agriculture. The State Forest Department provided compensation up to INR 4,00,000 (US\$ 5,238) for human death, INR 30,000 (US\$ 393) - INR 90,000 (US\$ 1,179) for human injury, up to INR 30,000 (US\$ 393) for cattle depredation, up to INR 3,000 (US\$ 39) for goat depredation, up to INR 25,000 (US\$ 327) for crop damage per acre and INR 700 (US\$ 9) per coconut tree. Other major mitigation measures (>60%) rangers reported from PAs (N=42) and outside PAs (N=34) were conducting awareness programs for the locals, constructing physical barriers such as EPT and electric fencing, relocating conflict animals, followed by usage of noise/fire deterrents and other initiatives like raising fodder plantations, free supply of seeds, conducting veterinary camps and constructing percolated ponds. There was little difference in the mitigation measures practised in PAs and outside PAs (Mann-Whitney $U = 20.5$; $z = 0.448$; $p = 0.647$). These measures were enforced with the support of several State/Central Government sponsored schemes such as Project Tiger, Project Elephant, Nilgiri Biosphere Reserve (NBR), (Agasthyamalai Biosphere Reserve (ABR), Special Area Demonstration Program (SADP), Tamil Nadu Biodiversity Conservation and Greening Project (TBGP), Compensatory Afforestation Fund Management and Planning Authority (CAMPA), National Bank for Agriculture and Rural Development (NABARD) projects and (Integrated Development of Wildlife Habitat (IDWH). Because of the high number of elephant conflict incidents in the Coimbatore Forest Division, a project named 'Project Kaliru' was commenced during 2015. On average, the minimum and maximum amount spent per range for conflict mitigation were 20,000-11,00,000 INR and 30,000 – 20,00,000 INR spent for conflict mitigation each year in PAs and outside PAs, respectively. Regardless of these schemes and mitigation measures, there were several practical difficulties reported in mitigating HWC because of the lack of public awareness, change in the cultivated crop, lack of monetary funds, lack of manpower, lack of equipments and training, poor maintenance of trenches and fencing, less and delayed compensation, and lesser number of conflict animal relocations.



Figure 4.4 Mitigation measures deployed by the Forest Department to mitigate human-elephant conflict: (a) combination of elephant-proof trench, hanging solar fence and spike pillar fence (b) solar fence.

4.3.3 Poaching

The species generally poached (>50%) in PAs (N=36) were wild pig, sambar, black-naped hare (*Lepus nigricollis*), followed by chital, tiger, monitor lizard (*Varanus indicus*), jungle fowl (*Gallus gallus*), Asian elephant, barking deer (*Muntiacus muntjak*), peafowl (*Pavo cristatus*), leopard, Malabar giant squirrel (*Ratufa indica*) and gaur. In outside PAs (N=34), species commonly poached (>40%) were wild pig, black-naped hare, and chital, followed by sambar, barking deer, jungle fowl, peafowl, gaur, elephant, leopard, monitor lizard, pangolin and Malabar giant squirrel (Figure 4.5a). There was a minor difference in the number of species poached between PAs and outside PAs (Mann-Whitney $U = 83.5$; $z = 0.647$; $p = 0.5128$). The frequency of commonly employed methods for poaching differed between PAs and outside PAs (Mann-Whitney $U = 27$; $z = 1.1606$; $p = 0.2449$) (Figure 4.5b.). In PAs (N=20), 55% of the rangers reported the use of snares and trained dogs by the locals to poach wildlife followed by the usage of guns, hand-made bombs, poisoning, nets, and knives also, rarely by cage traps and food baits. In outside PAs (N=24), snares and guns were the most commonly used techniques for poaching wildlife (63% each), followed by trained dogs, hand-made bombs, poisoning, cage traps, electric traps. Other methods here included nets and knives and food baits.

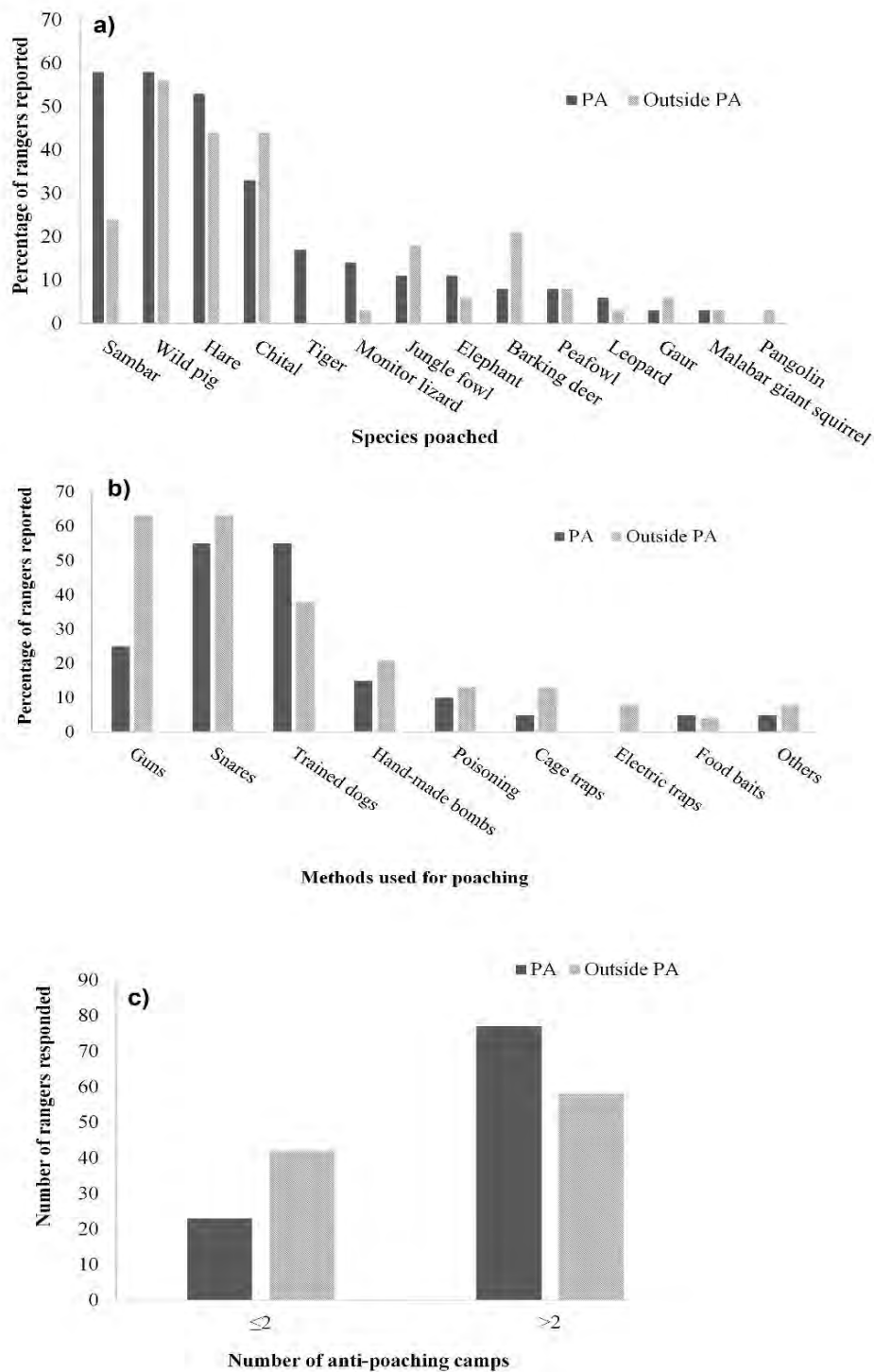


Figure 4.5 Major species poached (a), common methods employed for wildlife poaching (b) and number of anti-poaching camps per range (c) in Protected and outside-Protected Areas (outside PA).

4.3.4 Manpower and availability of resources

Manpower is an integral part of conflict mitigation and controlling wildlife crimes. The survey showed that the majority of the rangers (PAs, N=43; outside PAs, N=36) had qualified degree (72%, PA and 71%, outside PA) with at least 2 years of experience in wildlife areas (67%, PA and 75%, outside PA). Basic training in wildlife management and forestry was provided to all the forest rangers across PAs and outside PAs. The Forest Department employed some villagers as APWs (Anti-Poaching Watchers), fire watchers, staff in eco-tourism development sectors, and various eco-development committees to help develop a positive perception towards wildlife conservation. In PAs (N=39), 77% of forest ranges had >2 Anti-Poaching camps, unlike 58% in outside PAs (N=26) (Figure 4.5c). More number of APWs (>10) were deputed per anti-poaching camps in PAs (18%) than outside PA (3%) (Figure 4.6a); nonetheless, there were some forest ranges in outside PAs without any APWs. Basic equipments like Global Positioning System (GPS), portable two-way radios, firearms, map, torch, and mobile phones were commonly available for most of the forest ranges in PAs and outside PAs. However, FROs highlighted the need for more effective training in wildlife management for the field forest watchers. On an average 1-2 four-wheeler vehicles were available for each Forest Range Office in both PA and outside PAs. The average patrolling effort spent was 5-10km/day on foot and 20-40km/day by four-wheel vehicle. Although 70% of the forest ranges in PAs and outside PAs had insufficient funds, 21% of the forest ranges in PAs received satisfying funds unlike 6% of forest ranges in forest outside PAs (Mann-Whitney $U = 3$; $z = 0.436$; $p = 0.7$) (Figure 4.6b).

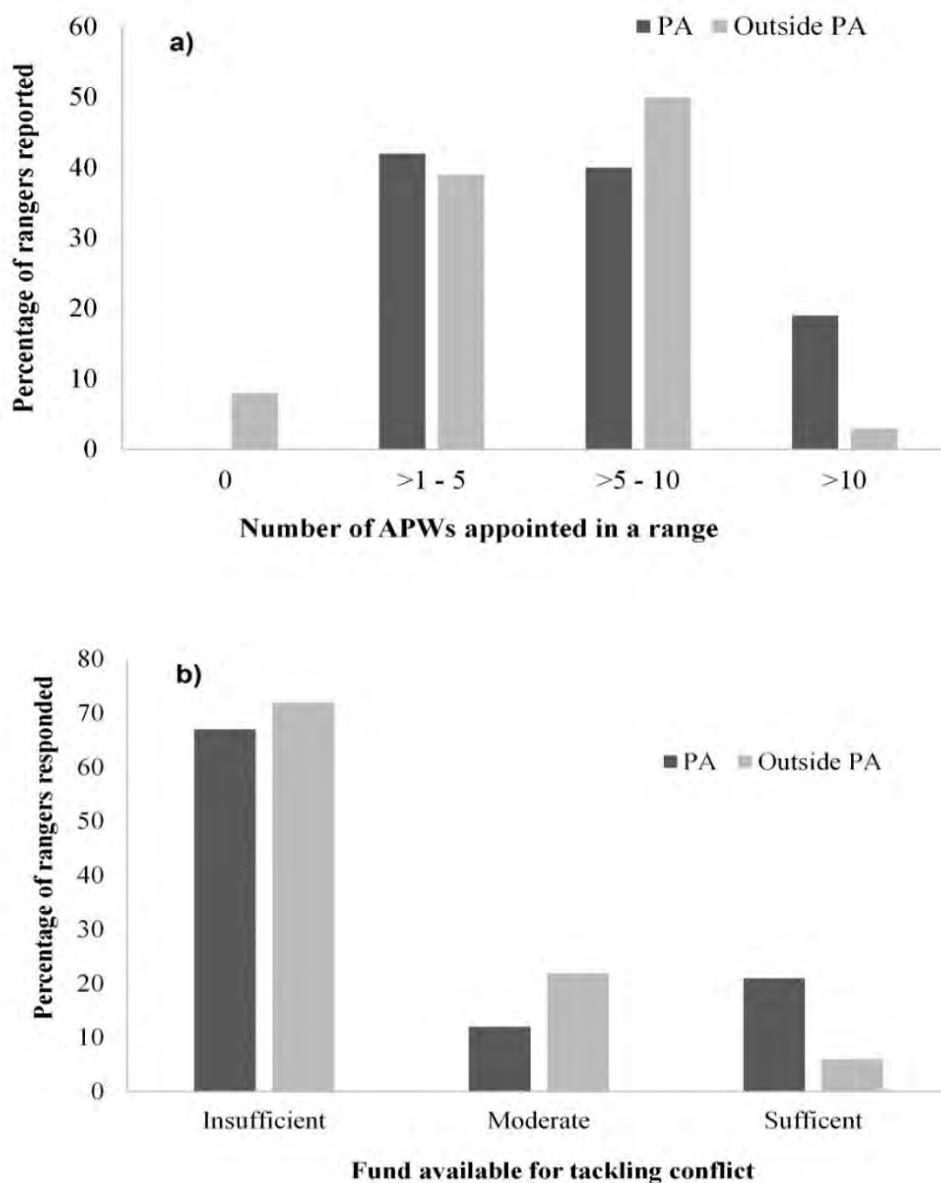


Figure 4.6 Number of Anti-Poaching Watchers (APWs) employed per range (a) and Percentage of rangers reported fund availability for tackling the human-wildlife conflict (b) in Protected and Outside-Protected Areas.

4.4 Discussion

With escalating human populations, and the resultant habitat loss and fragmentation, PAs become the ‘last refuge’ for many threatened wildlife species (Laurance et al., 2012; World Database on Protected Areas, 2016). Currently, these conservation islands are typically encircled by expanding human-dominated landscapes which increase the HWC incidents, especially with the wide-ranging mammals (Manral et al., 2016). In India, over 70% of PAs are less than 200 sq.km and highly dependent on the surrounding outside PAs that act as buffer and corridor for wildlife movement (Velho et al., 2016; Ghosh-Harihar et al., 2019). FROs carry an important role in wildlife habitat management and there are only a few studies that explicitly focus on them (Jenks et al., 2012; Ghoddousi et al., 2016; Moreto et al., 2016; Critchlow et al., 2017). The study in India focused on probably the least concerned outside PAs, unlike other studies that largely centred on PAs. Outside PA are often undervalued and receive little attention although they have high potential to hold/support large contiguous populations of megafauna such as Asian elephant and tiger (Ghosh-Harihar et al., 2019). Therefore, the situation outside PAs becomes vulnerable due to weaker wildlife management measures leading to faster habitat degradation and the decline of wildlife because of the lack of financial aid and resource availability. India has over 600 designated PAs under 5% of total area, where special state and central government funding is provided to enhance protection and management capabilities, and address local livelihood issues dependent on these forested habitats to maintain viable populations of wildlife (Ghosh-Harihar et al., 2019). PAs have the privilege of being ‘protection islands’ with better wildlife protection measures although both management systems support similar issues. The study revealed major areas of differences and lacunas in wildlife management in PAs and outside PAs. Particularly, outside PAs expects impartial preference in terms of resource allocation for wildlife management although almost over 70% of faunal species flourish outside PAs (Ghosh-Harihar et al., 2019).

Landscape-level wildlife conservation emphasizes the importance of habitat connectivity as a source to encourage gene flow through species dispersal which enhances the persistence of wildlife and reduces the risk of local extinction of species (Sanderson et al., 2010; Gubbi et al., 2017), especially in India. HWC management is one of the major priority actions required in such landscapes where the human population is interspersed within forest networks with high resource overlap. The survey indicated that nearly 50% of the Forest Ranges had an increase in the conflict

incidents during the past five years. The potential causes for this are the expansion of human settlement into natural forest areas, disruption of the corridors of many large mammal species which require large and contiguous habitat (Venkataraman et al., 2002; Jhala et al., 2010; Dutta et al., 2013), availability of water sources in the adjoining agriculture landscape, availability of easy forage and change in the crop cultivated, attracting more wild animals to human-dominated landscapes. These changes become crucial because it is not only posing consequences for biodiversity and ecosystem health but also questions health, safety, and public welfare (Distefano, 2005).

The study revealed high human mortality to elephants with over 70% of forest ranges having human-elephant conflicts in both PAs and outside PAs. This has been owing to elephant straying for water and food; moving to agricultural areas, getting accustomed to nutritious cultivated crops like maize, corn, sugarcane, banana etc. (Sukumar, 1994). On the other hand, injury/death of elephants or death while crossing roads, railway lines and irrigation canals constructed in the forest or across their corridors were also frequent in TN (Baskaran et al., 2006, 2013; Sekar, 2013). During the year 2016-17 alone, HWC incidents had led to death of thirty-five humans, seventy-eight elephants, and seven tiger deaths in the state of TN (Tamil Nadu Forest Department, 2019). Human-elephant conflict was reported highest in parts of Coimbatore, Sathyamanagalam, North Cauvery WLS, Gudalur, Mudumalai, Hosur, Erode and Dharmapuri Forest Divisions.

Similarly, species such as wild pig, and bonnet macaque were often attracted to cultivated crops in the interface areas. Besides, wild pigs damage ground vegetation, forest plantations, orchards and also act as carriers of infectious diseases (Chauhan et al., 2009). They often attack humans, causing them minor to severe injuries. Getting habituated with the close interaction with people, in temples and tourist spots, they frequently exhibit undesirable behaviour which is closely associated with provisioning, like human-directed aggression, snatching food, handbags, entering and damaging property, fouling and raiding garbage (Imam et al., 2002; Chauhan and Pirta, 2010).

I found that most of the species involved in HWC were the same in PAs and outside PAs. However, the intensity of conflict contributed by each species varied in both systems, like- sloth bear and sambar conflicts were higher in PAs, whereas gaur conflicts were reported higher outside PAs. These conflicts were commonly associated with landscapes closer to or within forested landscapes.

The rise in gaur conflict outside PAs is attributed to the invasion of many exotic plantations such as wattle, (*Acacia auriculiformis*), pine (*Pinus spp.*), and eucalyptus (*Eucalyptus spp.*) into the grassland and other natural vegetation cause the gaur population venturing into agriculture land and human habitation for foraging due to reduction in food availability in forest areas. Mostly the gaur herd/individuals get habituated to the nearby open agriculture land (tea gardens/seasonal crops) in virtue of the high food availability where they mainly feed on the available lush green grassy patches (Indira, 2019; Sankar et al., 2020). Sloth bear and sambar conflicts were mostly limited to PAs as they generally prefer less disturbed habitats. The study showed that tiger, leopard, and dhole conflict were mainly in the form of livestock depredation; only a few incidents of leopard attacks on humans were reported. Herders often leave their cattle inside the forest area for grazing, that could increase the risk of cattle depredation by large carnivore species (Ramesh et al., 2019).

The study indicated that there was not much variation in the mitigation measures practised in PAs and outside PAs. However, compensation provided to the victims to balance their economic loss and reinforce tolerance of wildlife rarely satisfied locals as it does not meet the expected market value and there would often be major delays in availing compensation for the loss (Madhusudan, 2003; Mishra et al., 2003; Ogra and Badola, 2008; Gubbi, 2012). As a result, many villagers were reluctant to report conflict incidents to the Forest Department to claim compensation for their loss. Some of the mitigation measures were uneconomical; for instance, the estimated cost of digging a trench was over US\$ 2160 per km in TN (Fernando et al., 2008). Moreover, fences often damaged by large mammals such as elephants were very common and they could circumvent barriers where fencing became ineffective. However, in many cases, it failed to meet the expected outcome because of the high cost of maintenance (Gubbi and Linkie, 2012). With the adequate and impartial allocation of funds and protection measures to outside PAs, I anticipated a decline in HWC and a recovery of suitable habitat conditions for sustaining threatened wildlife species in both PAs and outside PAs of the Nilgiri landscape. I understand that establishment of PAs and providing legal cover alone would not be sufficient; actual changes on the ground for improved institution mechanisms for outside PAs are also needed (Velho et al., 2016; Ghosh-Harihar et al., 2019) as we are already in the brink of many vital species' annihilation.

The study showed that the TN State Forest Department implemented several measures for reducing HWC such as constructing electric fences, solar fences, EPT, relocation of conflict animals, providing monetary compensation schemes for victims, and conducting awareness programs for the villagers. The results showed that relocating conflict animals and usage of noise/fire deterrents were more frequently executed outside PAs rather than in PAs which underlines the enormity of unmanaged conflict cases outside PAs. However, conflict animal relocation was a misstep in many circumstances as it led to an increase in HWC incidents in the relocated sites instead of abating the number of conflict cases as found in other studies (Nath, et al., 1998; Athreya et al., 2011). Therefore, sustainable wildlife habitat management is urgently required outside PAs. Fodder plantations to divert the attention of the wild animals wandering out of the forests in search of food to agricultural lands were practised in some forest divisions. The study highlights that conflict mitigation measures need strong financial backing in both PAs and outside PAs as the persistence of conflict issues remain the same. Alternative approaches like bio fencing- using unpalatable crops or those which could be repelling to wild herbivores surrounding their crop of interest could be encouraged as a cheaper and more effective method as proposed (Maikhuri et al., 2001; Mehta et al., 2020). Rangers reported that awareness programs supported in reducing the retaliatory attitude of the villagers to some extent. Since several species were involved in the conflict and their conflict intensity varied, the mitigation measures practised also should be of multiple species oriented for better management outcomes.

In India, poaching has been recognized as one of the major threats to wildlife conservation in the historical extinction and the population decline of many wildlife species (Rangarajan, 1998; Velho et al., 2016). Although the enactment of Wildlife (Protection) Act, 1972 came into force, hunting was widespread across the country and even today it is a serious threat to wildlife (Madhusudan and Karanth, 2002; Aiyadurai et al., 2010). The survey clearly showed that a wide range of wildlife species were poached in PAs and outside PAs, including endangered species such as tiger, leopard, Asian elephant, and pangolin. Other than hunting for meat and medicinal purpose there were generally two major reasons; either killing for retaliation to their loss, or attraction towards income from local or urban markets (Madhusudan and Karanth, 2002). Wild pig was the most extensively poached species, mainly for meat and in retaliation for crop damage in both PAs and outside PAs. Sambar poaching was reported very high in PAs when compared with outside PAs and tiger poaching was reported exclusively in PAs. This can be attributed to their abundance in undisturbed

habitats like PAs (Jhala et al., 2010; Jhala et al., 2020). Frequency of poaching chital, gaur, barking deer, jungle fowl, and pangolin were more common outside PAs as locals had effortless access to resource extraction, also these species often strayed into human-modified landscapes like tea/coffee estates and forest fringes. The study reflected the intensity of poaching and its preference which differed in PAs and outside PAs. Snares and guns were the most commonly used methods of poaching outside PAs while snares and trained dogs in the fringe areas were preferred in PAs. Handmade bombs, poisoning, food baits, electric traps, and cage traps were the other methods commonly used for poaching. Madhusudan and Karanth (2002), explains the reason for the variation in methods preferred for poaching as a result of improved law enforcement effort in PAs. Considering the range of species poached and large areas of natural habitat remaining outside of formally declared PAs, an improved, and coordinated institutional mechanism is needed to control prevailing poaching occurrence across the management systems for the successful functioning of PAs by bringing both PAs and outside PAs under the same conservation values in terms of human-wildlife conflict management.

Manpower and resource availability are crucial components in human-wildlife management where FROs play a vital role in safeguarding wildlife and their habitats through surveillance and curbing illegal activities, alleviating the HLMC, creating awareness about wildlife conservation among the locals (Jenks et al., 2012; Ghoddousi et al., 2016; Duangchantrasiri et al., 2016). Along with FROs, APWs also had a very crucial role in reducing the number of illegal activities as they were regularly engaged in patrolling. It was already shown that illegal activity occurrence could be decreased with improved ranger patrol efficiency (Duangchantrasiri et al., 2016; Critchlow et al., 2017). The study reinforces the importance of manpower and application of effective management strategies as over 50% of the ranges reported improved manpower and resources such as equipment and a decline in the number of poaching incidents through regular enhanced patrolling. Withal, there was a shortage of a sufficient number of staff in many forest divisions, outside PAs. More APWs and anti-poaching camps per forest range were allotted to PAs, while there were certain outside PAs devoid/have a few of any APWs. All the basic equipments were sufficient in many PAs but were lacking in some outside PAs, regardless of the frequent HWC scenarios they had to encounter. Wildlife conservation is probably considered as a non-priority sector for many of the State Governments, so they allot less and delayed flow of funds (Manral et al., 2016). Nearly 70% of the FROs pointed out that the monetary funds they receive were insufficient for effective conflict

mitigation measures (compensation schemes, EPT, and fencing). Higher reporting of insufficient fund availability outside PAs can affect the successful implementation of management measures as evident from the intensity of species poached and methods used to poach in outside PAs than PAs. My study underlined the need for effective and equal wildlife management strategies and efforts for the management of PAs at broader landscape-level. Understanding the seriousness of HWC, wildlife policy legal framework should support PAs and outside PAs impartially, especially in India.

Chapter 5

CHAPTER 5

Determine the effect of anthropogenic pressure on distributional patterns of large mammals

5.1 Introduction

Habitat fragmentation and the ensuing changes in the natural landscape configuration represent a pressing global threat to wildlife, necessitating urgent and targeted conservation efforts (Wilson et al., 2015b). It has paved way for a myriad of changes in the ecological dynamics of the native ecosystem through reduction in the patch size, increased edge effect, movement barriers, and bottleneck areas. Growth of edge habitats can amplify the risk of human-wildlife conflict, especially with the large mammals with extensive home ranges (Michalski et al., 2006; Puyravaud et al., 2019). Consequently, core forest-dwelling large mammal species are forced to rove outside the forest and exploit the resources from the human-altered landscape frequently through livestock depredation (Inskip and Zimmermann, 2009; Athreya et al., 2016) or crop damage (Sukumar and Pani, 2016; Indira, 2019). Constant fragmentation of large, contiguous natural habitats, along with increased human access to these fragmented forest patches, may lead to a phenomenon known as "empty forest syndrome", where forests may appear structurally intact but are ecologically depleted due to the loss of native wildlife, thereby posing a significant threat to the biodiversity (Redford, 1992; Bogoni et al., 2023). Intense habitat loss and fragmentation further disrupt functional large mammal corridors (Menon et al., 2005), and decrease the allelic richness among large mammal community, increasing the chances of species extinction risk (Lino et al., 2019). Many have already disappeared from their historical ranges due to their exposure to habitat loss and fragmentation by agricultural expansion, linear infrastructure development, overexploitation of natural resources, decreased prey abundance, diseases, illegal trade, and poaching (Ripple et al. 2015; Wolf and Ripple 2016, 2017). However, the consequences of these anthropogenic pressures may vary among individual species; some completely avoid them (Punjabi et al. 2017; Jhala et al. 2020; Ramesh et al. 2020) while others utilize the habitat heterogeneity offered by the modified habitats (Bateman and Fleming 2012; Athreya et al. 2013), either of them increasing the risk of local extinction of the species in long run. Therefore, species-specific, landscape-level studies on the impact of anthropogenic disturbances and landscape

modification are essential to understand changing patterns of habitat use in large mammals, while ensuring quality landscape linkages between forest reserves for their dispersal and genetic exchange.

Tropical forests are highly vulnerable to land-use changes (Stork et al., 2009) and the structure of many forest habitats has been altered to meet the resource requirements of the growing human population. Subsisting in the abrupt ecotones created by fragmented landscapes exposed to low to high human activity levels is a colossal challenge to many large mammal populations (e.g., Linkie et al., 2006; Kumar et al., 2010). Besides, degraded, or fragmented habitats with reduced vegetation cover is highly unfavourable and challenging for the survival of large wild prey species and ambush predators (Karanth and Sunquist, 2000). Depletion of large prey species due to habitat fragmentation and increased hunting pressure is a serious threat to the large carnivore communities (Wolf and Ripple, 2016). In the dearth of sustainable prey density and to avoid interspecific competition, the large carnivores are known to widen their territory, which further stirs the human-carnivore conflict incidents such as road kills, livestock depredation, retaliatory killing by humans and may augment localised extinction risk of the species (Ramesh et al., 2021). In India, the conservation of biodiversity is mostly limited to the Protected Area (PA) networks due to better wildlife management measures. The expanse of the total PA networks is less than 5% of the total landmass (Ghosh-Harihar et al., 2019) and animals utilize the area outside PA as a corridor for movement (Milda et al., 2020). Therefore, studies analysing large mammal occupancy in both PAs and outside PAs are critical in evaluating the large mammal distribution pattern and associated wildlife management measures.

The Western and Eastern Ghats part of Tamil Nadu (WEGPTN) is among India's most vital conservation region for many large mammal species (Jhala et al., 2010). Currently, the region is exposed to severe land-use change and anthropogenic pressure that has led to rising human-wildlife interactions (Tamil Nadu Forest Department, 2017; Milda et al., 2020). Over the years, many large mammal species like tiger, elephant, and leopard have experienced drastic range contraction and decrease in detectability in their southern geographical range of the Western Ghats (Pillay et al., 2011). Rising anthropogenic pressure and the associated mammalian range contraction demands broad landscape-level studies involving changes to the ecological framework to discern the primary determinants of species extinction at the local level, source-sink dynamics,

and long-term survival of the species (Jones, 2011). There is a considerable research gap in identifying the species-specific ecological and anthropogenic determinants of large mammal occupancy and species dispersal pattern in the high human-large mammal conflict zones of WEGPTN. The emerging trend of human-large mammal conflict incidents in the Tamil Nadu necessitates studies on the patterns and factors influencing large mammal distributions. Existing localized studies on species distribution in Tamil Nadu barely assimilate the species response on the maximum acting environmental variables. Also, such studies hardly help in any major decision making for wildlife population management at a larger spatial scale. Therefore, in this study I am focusing on the occupancy and habitat connectivity patterns of five flagship large mammal species: tiger, leopard, dhole, elephant, and gaur particularly in the Western and Eastern Ghats part of Tamil Nadu (WEGPTN). All of these species exhibit strong reproductive potential and frequently disperse in search of new territory, food, and mates, playing a crucial role in maintaining genetic diversity. Ensuring their movement through well-connected and ecologically functional wildlife corridors is vital for reducing the HLMC and sustaining viable populations. The study aimed to (a) develop species-specific occupancy maps of large mammals across the forest landscapes of WEGPTN, (b) determine the maximum acting environmental and anthropogenic variables in explaining the current occupancy pattern of all large mammals in the landscape, (c) measure the effect of forest fragmentation intensity on the large mammal occupancy, (d) quantify and map species-specific habitat preferences across ecological and anthropogenic gradients, (e) develop species-specific resistance surfaces and cost-weighted distance map, and (f) identify core connectivity areas, least-cost movement paths, and movement pinch points, where further degradation could result in irreversible disruption of functional connectivity in the landscape, specifically for each large mammal species.

5.2 Materials and methods

5.2.1 Study Area

The study was conducted across nine high-conflict zones, covering PAs and outside PAs, identified in the WEGPTN (Milda et al. 2020; Ramesh et al. 2020, 2022) between November 2017-December 2019. These areas include Mudumalai Tiger Reserve (MTR), Sathyamangalam Tiger Reserve (STR), Cauvery North Wildlife Sanctuary (CNWS), Gudalur Forest Division (FD), Nilgiris FD, Coimbatore FD, Erode FD, Dharmapuri FD and Hosur FD (Figure 5.1). Among them,

MTR, STR, Gudalur FD, Nilgiris FD, and parts of Coimbatore FD, fall as a part of Nilgiri Biosphere Reserve (NBR) (Tamil Nadu Forest Department, 2017). Both the PAs and outside PAs have similar topographical features but vary in the species composition and degree of legal restrictions for the local community to utilize forest resources.

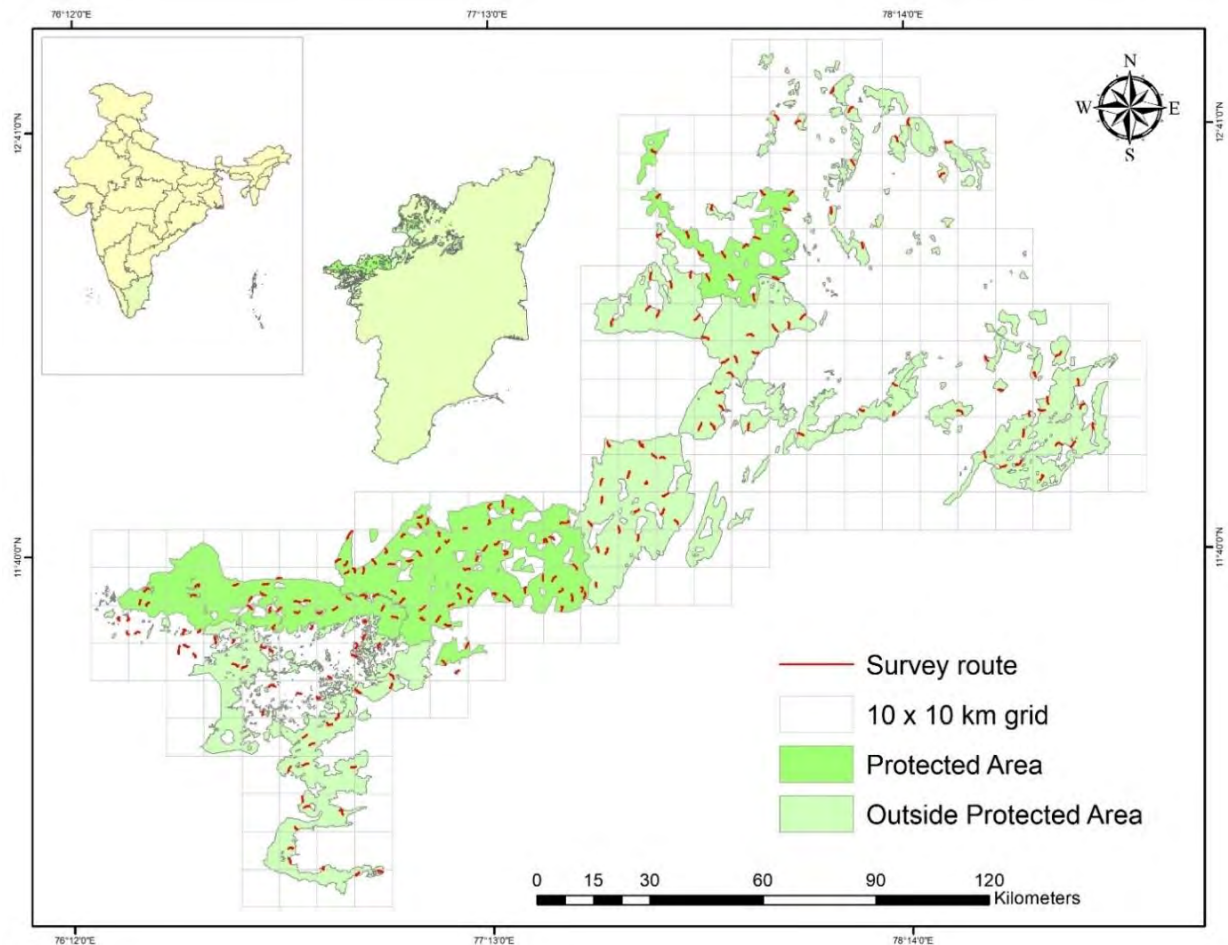


Figure 5.1 Study area showing the 2 km survey routes across the Eastern and Western Ghats part of Tamil Nadu.

5.2.2 Ecological survey

I performed an ecological survey between May 2019 and March 2021 to ascertain the occupancy of large mammals and quantify the degree of human disturbances inside the forests. Sign surveys were performed to quantify the occupancy of different large mammal species, in the representative high conflict interface areas of the study sites. Considering the average home range size of the study species (tiger: 18 - 98.8 km² (Karanth and Sunquist, 2000), leopard: 8 -65 km² (Odden et al., 2014)

dhole: 54.2 - 83.3 km² (Venkataraman et al., 1995), elephant: 250 -1000 km² (Sukumar, 2006) and gaur: 32-169 km²(Sankar et al., 2013)), 10 x10 km sampling grids were laid across the entire study area, to keep the sampling efforts spatially explicit and independent from each other and taking into account of all study species habitat-use pattern. However, for elephant the term ‘occupancy’ was considered as ‘site use’ so that the assumption of ‘occupancy’ is not violated because elephant has an extensive home range size. The field data collection was exercised on 2 km survey routes covering the human-wildlife interface area (Figure 5.1). Each 2 km survey route was subdivided into five 400 m segments and were used as spatial replicates to record occurrence of large mammals and presence of anthropogenic disturbances from each 100 km² grid which were treated as “sites” in the analysis. In total, 113 sampling units were sampled, each grid cell with a minimum of one to a maximum of three survey routes (spatial replicates), to estimate the large mammal distribution across the study area. To maximize the representation of the spectrum of habitat and disturbance gradient, I started the trail at random points from the edge of the nearest village settlements towards the forest (Karanth et al., 2006).

Species presence within a segment was confirmed either through direct sighting or by indirect sign evidence such as pawprints, hoofmarks, diagnostic vocalizations, feedings, rakes, scrapes/signs of digging, scats, scrapes, fecal pellets etc. on typical animal travel routes (Kolipaka, 2014). The survey was carried out continuously throughout the year, regardless of the dry/wet season. I carried out vegetation sampling at every 400m segment of the survey routes, using 10m, 5m and 1m radii circular plots for trees, shrubs and herbs, respectively (Jhala et al., 2021). To account anthropogenic disturbances, direct and indirect evidence of human and livestock were noted; habitat quality was assessed using certain habitat features, recorded from each plot (Jhala et al., 2010). To analyze the extend of habitat fragmentation in the study area, landscape fragmentation analysis extension tool v.20 (Parent, 2009) was used in Arc Map 10.3 (Figure S5.1). The tool classifies the total area under six fragmentation indices: patch (most fragmented), edge, perforated, core one, core two, and core three (least fragmented) (arranged in decreasing order of fragmentation). In addition, road length, river length (indicating availability of water source), forest cover, and its loss and gain were also extracted from spatial layers for every grid. Since season and sampling effort varied across grids, both were used as covariates in the modelling to reduce associated biases in the data. Settlement density and population density were measured as

a covariate of human disturbance at landscape-level and river length as a landscape-level habitat variable, from the spatial layers.

5.2.3 Predictor variables

Large mammal occupancy is highly determined by the habitat type, vegetation type, degree of human disturbance (Karanth et al., 2006), and extend of habitat fragmentation (Tilman et al., 2017). Large carnivore occupancy is highly driven by abundance of suitable wild prey species also (Wolf and Ripple, 2016). Therefore, all the variables were grouped broadly into four categories to explain the predominant ecological and anthropogenic factors that could affect the large mammal occupancy: (a) prey abundance, (b) habitat features, (c) human disturbances, and (d) habitat fragmentation as a proxy of prey availability, habitat quality, direct human disturbance and habitat patchiness, respectively (Table S5.1).

5.2.4 Data analysis

5.2.4.1 Occupancy modelling

I analyzed the impact of ecological variables on the large mammal distribution using the first-order Markovian model (Hines et al., 2010). This model utilizes spatial replicates to report occupancy and the detection probability of the species, unlike the standard model that uses temporal replicates (MacKenzie et al., 2002). Using temporal replicates may not be logistically feasible or may be practically difficult to execute in certain areas (Whittington et al., 2015). Markovian occupancy model particularly analyses the spatial dependence between the neighboring segments. By using segment-level occupancy, the model particularly accounts for the spatial auto-correlation so that the spatial dependence of the adjacent replicates is considered. The model has an assumption of ‘spatial closure’, where occupancy in one segment (spatial replicate) assumes that the neighboring segments are also occupied by the same species (Hines et al., 2010). Therefore, Markovian occupancy model is highly suitable for large mammal species having wide home range, provided that the sampling area is similar or close to the home range of the study species (e.g., Karanth et al., 2011; Punjabi et al., 2017). The distance that the animal walks may exceed the length of the chosen segment. So, the sign evidence for the animal is highly likely to be present in the adjacent segments (Hines et al., 2010). Following are the parameters estimated by the model: ψ - the probability of site-level occupancy of the species; θ_0 - the probability of species present on the segment, given

absence on preceding segment; θ' - the probability of species present on the segment, given presence on preceding segment; p - the probability of segment-level detection of the species, given presence. Here, θ_0 and θ' are the parameters for species detection that shows the extent of spatial dependence among the neighboring segments. So, equal values of θ_0 and θ' indicate that the segments are independent of each other.

I first tested the correlation among the identified variables using Pearson's correlation test and removed the highly correlated variable ($r \geq 0.80$) (i.e., forest cover). I conducted Markovian model (correlated-detection) analysis using program Presence version 12.7 (Hines, 2006) to identify the best predictors of large mammal site use. The presence and absence of the individual large mammal species were recorded in the input data form as 1 and 0 respectively, for each segment. Before modelling, all the continuous variables were standardized by z score transformation (Donovan and Hines, 2007). From the resultant models for each large mammal species, I first constructed univariate models using the variables that had the lowest AIC value and model weight. Keeping θ_0 and θ' constant, global occupancy models of each species were developed incorporating the variables with the lowest AIC value (Burnham and Anderson, 2002) under each variable category (i.e., prey abundance, habitat features, human disturbance, and habitat fragmentation). Then, I chose the best detection covariates (survey-specific) for each species, keeping the global occupancy model constant (MacKenzie et al., 2018). Finally, candidate model sets for each species were developed individually to identify the important predictors for site use by combining the best detection covariates for each species. All models with $\Delta AIC < 2$ was considered as the strongly supported predictor models (Burnham and Anderson, 2002). The residuals of the top models for each study species were further tested for spatial autocorrelation at site-level with Moran's Index (Legendre, 1993) using Spatial Autocorrelation (Moran's I) tool in Arc Map 10.3. The Variance Inflation Factor (VIF) of the variables in the top model was estimated to check the degree of collinearity among the variables (Zuur et al., 2010). The beta coefficient estimates and standard error values of the top models were used to determine the magnitude of the effect of the covariates and the direction of its influence on the species site use, respectively (Table 1). Using the occupancy (Ψ) values obtained from the top models, a predictive map of the individual large mammal species' occupancy was developed for WEGPTN (Fig. 2).

5.2.4.2 Corridor mapping

To evaluate landscape permeability and delineate energy-efficient dispersal routes for large mammals, I used the field derived presence/absence data, across heterogeneous WEGPTN landscape. The approach included developing (1) resource selection functions (RSFs), (3) resistance surfaces, (4) identification of focal points of connectivity, and (5) least cost path (LCP) modelling and CWD (cost-weighted distance) mapping, for each species.

To model habitat selection and identify areas of higher suitability for movement, I developed species-specific RSFs using the exponential form of the selection function. I developed species-specific RSF models using presence/availability data at the level of 10 x 10 km grid under a 'use-availability' design (Manly et al., 2002). Species 'presence' was defined as detection along any of the 2km survey routes within a grid, based on the direct or indirect sign evidences. A grid was treated as 'available' if no detections occurred across all surveyed routes within it, while acknowledging that these reflect non-detection rather than confirmed absence. If the species was detected on at least one segment of any route within the grid, the entire grid was classified as a 'used' location. This binary classification (presence vs. availability) was used as the response variable in the RSF model. In cases where multiple routes occurred within a single grid, the detection history from all routes was aggregated. This approach aligns with the assumption that wide-ranging mammals can traverse large areas, and presence at any point within a grid reflects potential habitat use across that grid. Rather than constructing RSFs from an entirely new and arbitrary set of variables, I identified the most ecologically relevant covariates using the top Akaike's Information Criterion (AIC) models from the Markovian occupancy analysis, performed at the same scale across the study area (Milda et al., 2023a). This ensured consistency across the analytical framework avoiding data dredging. I included the covariates such as abundance of varied sizes of prey, habitat characteristics, direct human disturbances and fragmentation indices for the analyses. All spatial layers (vegetation (Roy et al., 2015), river length (Lin et al., 2021)) were consistent to same resolution and projection. These covariates were then used in a Generalized Linear Model (GLM) with a binomial (logit) link in Program R (v4.3.0), utilizing the MASS (Ripley et al., 2013) and *sp* (Pebesma et al., 2012) packages to model resource selection based on presence/availability points. The models were validated using AUC (Area Under the Curve) values, calculated with the pROC package in R program (Xavier et al., 2011). Predictor variables were standardized prior to analysis, and multicollinearity was assessed using Variance

Inflation Factor (VIF) (retained values < 3) (Zuur et al., 2010) to ensure model robustness. Thus, while occupancy modelling guided the selection of covariates, the RSF outputs were generated independently using a GLM framework, producing a continuous surface of relative probability of use across the landscape. Using package *raster* (Hijmans et al., 2015), RSF outputs were rasterized, representing the relative probability of habitat selection.

I assumed that areas of higher habitat selection (higher RSF values) facilitate permeability, while areas of low suitability impose movement resistance. Therefore, I transformed each species' RSF raster into a resistance surface by inverting the values ($\text{Resistance} = 1 - \text{RSF}$) using the packages *raster* (Hijmans et al., 2015) in program R version, 3.0 (R Development Core Team, 2018). This approach is based on the rationale that animals are more likely to move through areas with higher habitat suitability and avoid unsuitable or disturbed areas. These resistance layers were subsequently used for habitat connectivity modelling. Core habitats for each species were considered as areas with RSF values above 70th percentile and were interpreted as 'focal points' of connectivity. These high-probability regions are areas that are likely to act as ecological anchors for animal movement between fragmented or disjunct habitats. This threshold-based approach allowed us to standardize focal point identification across species and compare connectivity pathways.

Least-cost paths (LCP) represent the most energy-efficient, high movement probability routes, with minimum cumulative cost, based on resistance values assigned to a region. CWD was also calculated using resistance raster to represent the cumulative cost of movement across the landscape. CWD integrated both geographic distance and habitat resistance, enabling the identification of areas with high movement cost and assessment of landscape connectivity for each species. I modeled LCPs between the identified focal points using the resistance surfaces described above. LCP and CWD analyses were conducted in ArcMap v.10.3 using the Linkage Mapper toolbox extension (v1.1) (McRae and Kavanagh, 2011). Linkage mapper uses graph theory for modelling ecological connectivity and calculates the LCP. It considers the core habitats as 'nodes' and corridor paths as 'edges'. The graph theory used by the Linkage Mapper is widely applied for identifying potential connecting Forest Reserves (Minor and Urban, 2007) and promote habitat connectivity by improving the quality of the landscape matrix surrounding the PAs (Lookingbill et al., 2010). For each species, I identified potential corridors by linking focal points

within and across sampled grids and visualized the resulting optimal movement pathways. I mapped all the possible active LCPs of each large mammal species, along with optimized pathways (commonly labelled as ‘inactive LCP sticks’) that are simplified and non-redundant that can be used for landscape conservation planning, using the Linkage Mapper tool; the tool identifies a ‘minimum spanning tree’, which is a shortened network of routes that connects all the nodes which has minimum cost of movement. The integrative approach that includes habitat selection, resistance modeling and LCP corridor mapping, allowed us to spatially identify key linkages and priority zones for maintaining or enhancing large mammal connectivity across the study landscape.

5.3 Results

I conducted ecological survey in 213 survey transects, each of 2km length, comprising an area of 426 km² across 113 100 km² grids, in the PAs and outside PAs of WEGPTN. I observed that the large mammal occupancy was higher in PAs than outside PAs of WEGPTN, although outside PAs supported substantial population of large mammals (Figure 5.1). The naïve occupancy probability was 0.30, 0.53, 0.29, 0.70 and 0.68, respectively, for tiger, leopard, dhole, elephant and gaur in WEGPTN and was different from the estimated occupancy for 113 100 km² grid cells across WEGPTN (see Table 5.1, for estimated occupancy and detection probability). I observed that the null model $\psi(\cdot)$, $\theta_0(\cdot)$, $\theta'(\cdot)$, $p(\cdot)$ for all large mammals exhibited considerable variation between the probability of presence on segment, given absence on the previous segment and probability of presence on segment, given presence on the previous segment; tiger $\theta_0 = 0.12$ ($\pm$ SE 0.02), $\theta' = 0.40$ ($\pm$ SE 0.05); leopard $\theta_0 = 0.12$ ($\pm$ SE 0.03), $\theta' = 0.87$ ($\pm$ SE 0.07); dhole $\theta_0 = 0.05$ ($\pm$ SE 0.01), $\theta' = 0.73$ ($\pm$ SE 0.11); elephant $\theta_0 = 0.30$ ($\pm$ SE 0.56), $\theta' = 0.92$ ($\pm$ SE 0.02); gaur $\theta_0 = 0.24$ ($\pm$ SE 0.44), $\theta' = 0.92$ ($\pm$ SE 0.02), indicating the dependency of each segment on its neighboring segments. The residuals of the top models for tiger, leopard and dhole did not exhibit any spatial autocorrelation (Moran’s I for tiger= 0.04 (P=0.19); leopard=0.06 (P=0.12); and dhole= -0.06 (P=0.24)). However, top-model residuals for elephant and gaur showed spatial autocorrelation to certain extent (Moran’s I for elephant= 0.35 (P=0.00); gaur= 0.17 (P=0.00)). The VIF values of all the covariates in the top model were below 3, that confirmed low collinearity among the variables (Table 1). I identified 34 highly used 100km² cells (above 70th percentile) by each large mammal species across both PAs and outside PAs of the study area landscape. The AUC values of the selected

models (Table 1) of tiger, leopard, dhole, elephant and gaur were 0.89, 0.78, 0.79, 0.88, and 0.92, respectively, indicating high model discrimination.

5.3.1 Effect of covariates on large mammal occupancy

Based on the β coefficient estimates of the global models (Table 5.1), I found the best models that explained the large mammal occupancy at a scale of 100km², and identified the best predictors of large mammal occupancy and detection.

I confirmed that large mammal occupancy is higher in the contiguous forest habitats, with abundant natural resources and almost fewer human interventions. I found that increased shrub cover/density had a strong negative correlation with the occupancy of tiger and elephant. Whereas dense canopy cover supported leopard occupancy; tree density and grass cover

Table 5.1 Estimated beta coefficients for the top ranked models that demonstrates the variables explaining the occupancy and detection of large mammals in the Eastern and Western Ghats of Tamil Nadu.

Species	Model No.	Covariates		Estimate	Standard Error	VIF
		Occupancy	Detection			
Tiger	1	ChitalSambar		0.46	0.36	1.15
		SD		-2.15	1.19	1.03
		Livestock		-0.84	0.39	1.14
			HumSGT	-2.00	0.75	
	2	LargePrey		0.33	0.49	1.48
		SD		-1.96	1.19	1.05
		Livestock		-0.85	0.43	1.44
			HumSGT	-2.04	0.76	
Leopard	1	SmallPrey		0.64	0.18	1.32
		CanopyCov		0.26	0.16	1.33
		Livestock		-0.47	0.18	1.04
		Perforated		0.63	0.29	1.07
		CoreThree		0.55	0.18	1.27

			Season	-1.09	0.15	
			GC	-0.23	0.12	
Dhole	1	ChitalSambar		0.34	0.33	1.06
		RiverL		0.64	0.27	1.15
		LivestockSGT		-1.40	0.58	1.19
		CoreThree		0.37	0.28	1.13
			GH	0.18	0.14	
Elephant	1	ShrubCov		-0.30	0.09	1.31
		RiverL		0.63	0.09	1.17
		Livestock		-0.82	0.09	1.43
		CoreOne		-0.89	0.12	1.33
	2	ShrubCov		-0.30	0.09	1.32
		RiverL		0.64	0.09	1.20
		Livestock		-0.83	0.09	1.44
		CoreOne		-0.90	0.12	1.34
			GC	11.48	6.44	
			HumSGT	-27.12	10.25	
Gaur	1	TD		0.33	0.10	1.60
		GrassCov		0.35	0.10	1.45
		Livestock		-1.28	0.15	2.22
		CoreThree		0.20	0.09	1.22
			GC	1.08	0.57	

VIF- Variance Inflation Factor, ChitalSambar- Relative abundance of chital and sambar, SD- Shrub density, Livestock- Relative abundance of livestock, HumSGT- Direct sighting of humans, LargePrey- Relative abundance of sambar and gaur, SmallPrey- Relative abundance of black-naped hare, mouse deer and barking deer, CanopyCov- Percentage of canopy cover, GC-Percentage of grass cover (survey-specific covariate), RiverL- Total length of river, LiveSGT- Direct sighting of livestock, GH-Grass height, ShrubCov- Percentage shrub cover, TD-Tree density, GrassCov- Percentage grass cover (site-specific covariate)

bolstered gaur occupancy. I observed that elephant and dhole occupancy was higher in the forest patches with abundant water resources. The detection probability of leopard, gaur and elephant marked highest in the forests with high grass cover and dhole with increase in grass height. I

observed that the occupancy of large carnivores showed a strong positive correlation to the abundance of large prey species inside the forest habitat. The tiger occupancy was found to be driven by abundance of gaur, sambar, and chital and dhole by chital and sambar abundance. However, leopard occupancy was higher where small prey species (black-naped hare, mouse deer and barking deer) were abundant. I found that, among all other forms of anthropogenic disturbances, abundance of livestock inside the forest habitat had the strongest negative repercussion and decreased the large mammal occupancy. Besides, the chances of detection of tiger and elephant decreased with increased human sighting. I ascertained that unfragmented contiguous forests are fundamental to the higher occupancy of large mammals. Unfragmented, contiguous forests increased the probability of occupancy of leopard, dhole, and gaur; small habitat patches decreased the occupancy of elephants. Leopard occupancy was high in large contiguous forests as well as in perforated habitats.

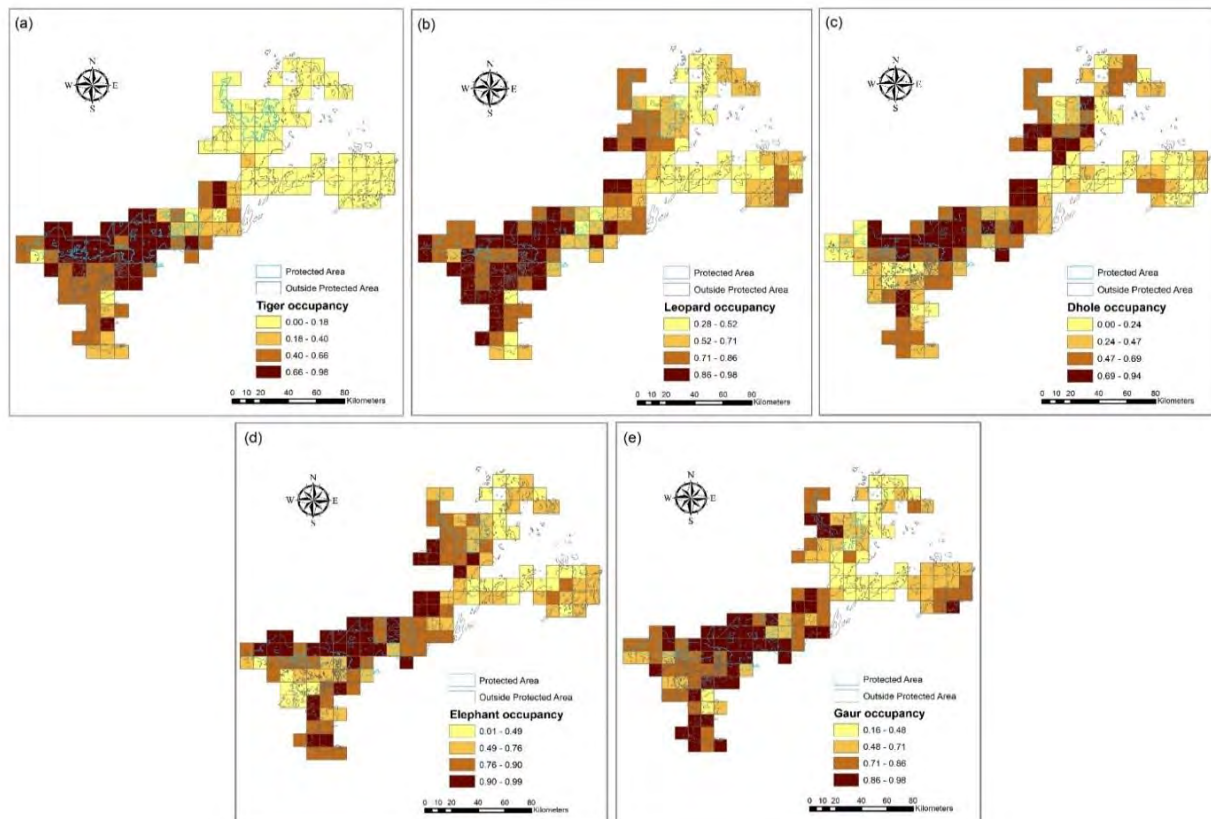


Figure 5.2 Occupancy patterns of tiger (a), leopard (b), dhole (c), elephant (d) and gaur (e) in the Eastern and Western Ghats part of Tamil Nadu.

I generated landscape-level site occupancy maps using model-based probability estimates from the top model, demonstrating the gradation of large mammal species occupancy across WEGPTN (Figure 5.2). I recorded high occupancy of large mammals in NBR (gaur 97%; leopard 93%; elephant 90%; tiger 81% and dhole 58%) followed by Erode FD, CNWS, Hosur FD and Dharmapuri FD. The occupancy map implies that the tiger occupancy is exceptionally confined towards the core forest areas (NBR); leopard and dhole had scattered but concentrated distribution towards PAs and less disturbed forested habitats; elephant and gaur occupancy was prevalent across WEGPTN, although NBR had the highest occupancy (Figure 5.3).

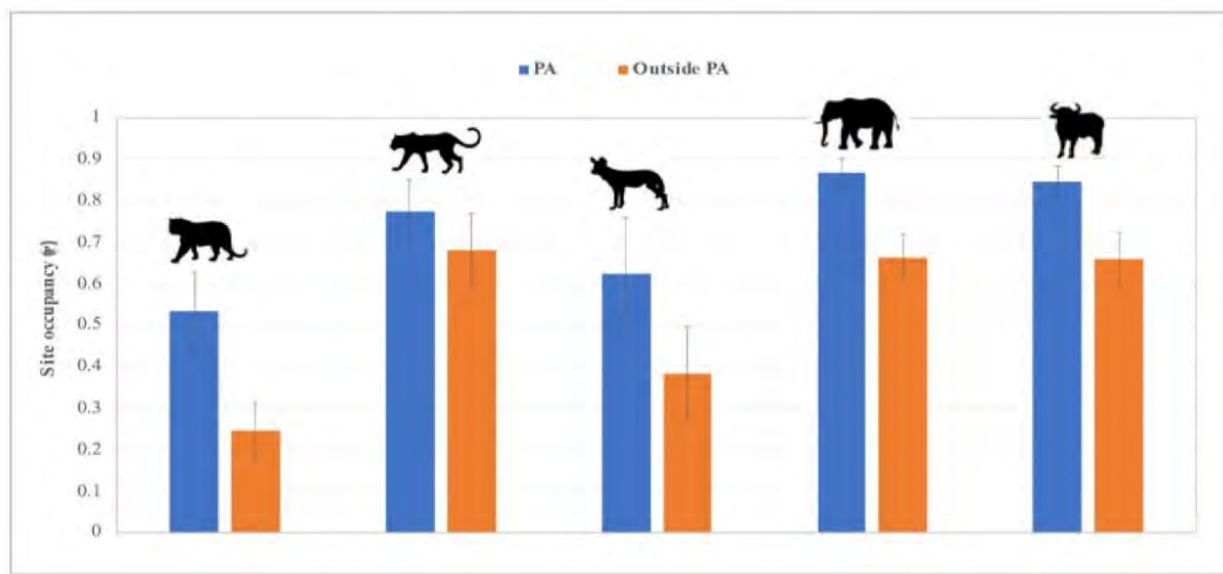


Figure 5.3 Occupancy pattern of large mammals across PAs and outside PAs in the Eastern and Western Ghats part of Tamil Nadu.

5.3.2 Resource selection function

The study highlights the difference in habitat preference amongst the large mammal species. Broadly, all species, except leopard exhibited a higher preference for PAs compared to outside PAs. The habitat use of tiger was highly concentrated towards PAs with some sporadic usage in connecting Outside PAs (Figure 5.4). I found approximately 1,600 km² area highly selected by tiger, primarily located in the STR, MTR, and parts of Coimbatore FD; adjacent FDs including Nilgiris and Erode were also moderately used. Habitat preference of leopard was concentrated towards outside PAs, particularly located at the edges of PAs, but avoided highly fragmented

outside PAs (Figure 5.5). Nearly 800 km² area of the landscape was identified as highly used by leopard, located towards Coimbatore FD, Nilgiris FD, STR, Erode FD and Hosur FD. Habitat use of dhole was quite prominent in open RFs, although PAs had most favourable habitats (Figure 5.5). I recognized 1,200 km² area, situated in parts of MTR, STR, Erode FD, Dharmapuri FD and Hosur FD as the habitats most chosen by dhole. Although the habitat selection pattern of elephant was concentrated towards PAs, the adjoining RFs also had high values (Figure 5.6). Around 1,800 km² area extending in MTR, STR, and Coimbatore FD, and Erode FD was found to be the most used habitat by elephant. Habitat selection pattern of gaur was relatively discontinuous in nature; although concentrated towards the PAs, they also exploited the isolated habitats located outside PAs (Figure 5.7). Although gaur habitats were spread across almost all parts of the study area, approximately 1,200km² area located in MTR, STR and Erode FD was found to be the most promising habitat for gaur (Figure 5.8).

5.3.3 Resistance surface

The study also helped in differentiating the permeability of the landscape towards different species through resistance area mapping. Overall resistance for large mammal movement was highest in Hosur and Dharmapuri FDs and least for MTR and STR (Figure 5.9). Dharmapuri FD, Hosur FD and the adjacent CNWLS, spanning approximately 3,100km² were found to be highly resistant to tiger movement. About 1,800km² area acted as a barrier to the connectivity of leopard, primarily located in Dharmapuri and parts of Hosur FD. Whereas, 600km² area spread across Hosur FD, Dharmapuri FD and Gudalur FD was highly impermeable to the free movement of dhole across various FDs. Meanwhile, for elephant, 800km² of area in Hosur FD and Nilgiris FD were impervious for dispersal. Movement resistance for gaur was highly concentrated towards 700km² area located in Hosur FD.

5.3.4 Least cost path

The study pinpointed the core areas of habitat connectivity and the least cost paths connecting them. The LCP represent the most efficient movement routes between the available habitat patches because it connects the pathways with least movement resistance. The LCP analysis was carried out for each species independently based on the developed resistance surface obtained from RSF modelling and showed the animal avoidance of habitats having high habitat fragmentation. We

identified 87, 67, 78, 77 and 81 actively used LCPs respectively for tiger, leopard, dhole, elephant and gaur. There were 17, 41, 23, 26 and 23 optimized LCPs for tiger (Table S5.2), leopard (Table S5.3), dhole (Table S5.4), elephant (Table S5.5) and gaur (Table S5.6), respectively. CWD and Euclidean distances between the focal connectivity points along each optimized route were also extracted for all species. Generated CWD map underscores the overall ecological cost of movement across the landscape, from one forest range to the other. Among the 17 optimized LCP for tiger, Euclidean distance value ranged from 22 to 86 km with CWD values between 25 and 150 km. From 41 optimized LCPs for leopard, the Euclidean distance values ranged between 14 and 139 km, whereas, CWD values stretched between 34 and 1,928 km. The Euclidean distance values of dhole were between 22 and 106 km with a CWD value ranging from 24 and 512 km in the generated 23 optimized LCPs. For elephant, there were 26 optimized LCPs, with Euclidean distance extending between 22 and 86 km; however, the CWD values ranged between 24 and 134 km. Among the 23 optimized LCPs for gaur, Euclidean distance value ranged from 22 and 78 km but the CWD value extended between 24 and 116 km.

Pinch points are locations where permeability is likely to be constrained or concentrated, making them especially critical for maintaining the functional integrity of a corridor. Parts of Nilgiris FD, Gudalur FD, Coimbatore FD, and Dharmapuri FD were identified as common pinch points of habitat connectivity for large mammals collectively, in the WEGPTN landscape.

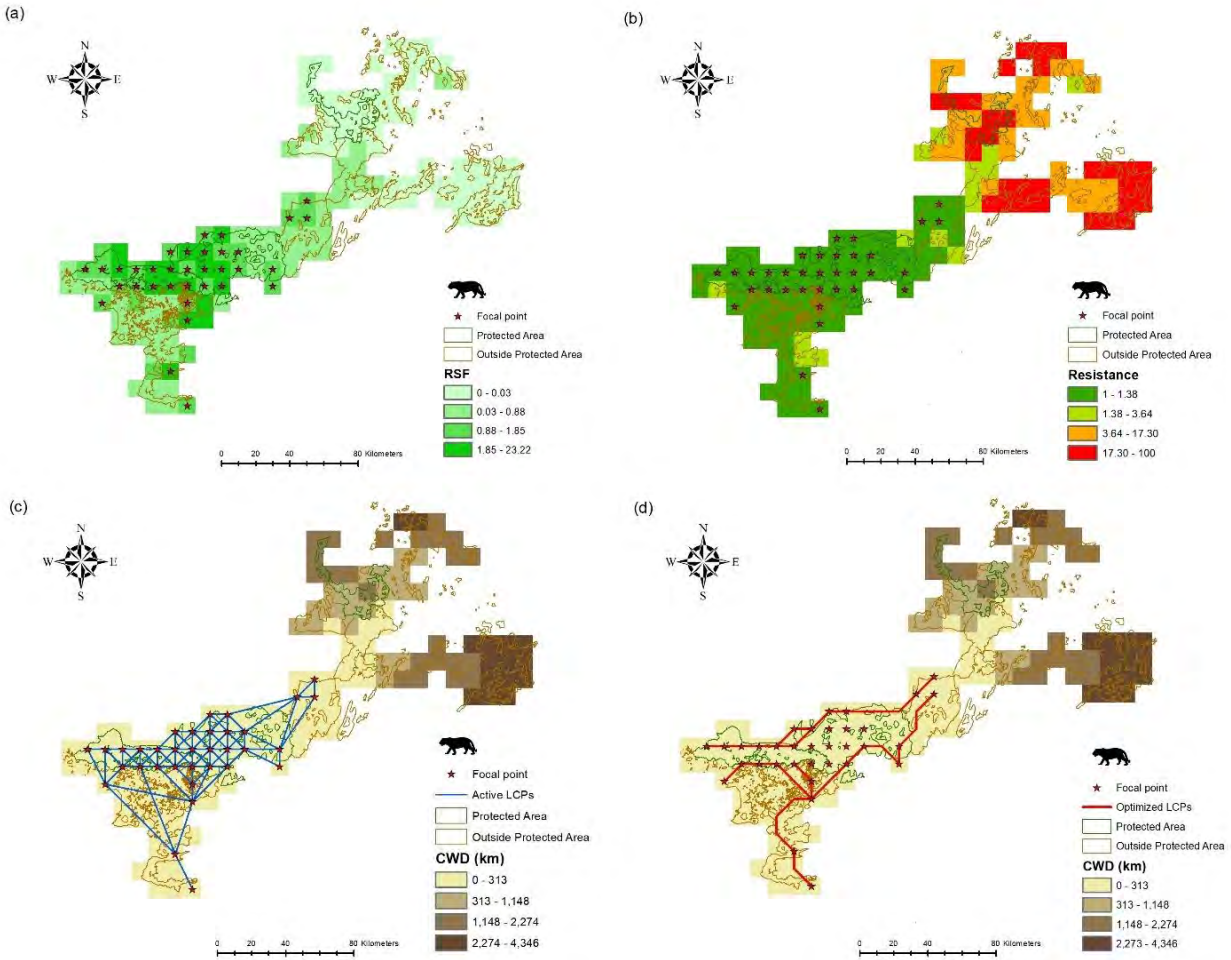


Figure 5.4 (a) Resource selection function, (b) cost surface, (c) active least-cost paths and (d) optimized least-cost paths of tiger across Western and Eastern Ghats landscape of Tamil Nadu (**RSF** - Resource Selection Function (relative probability of species habitat-use based on environmental factors); **Resistance** - cost surface (a raster map where each cell represents relative difficulty in moving through the landscape); **LCP** - Least Cost Path (most energy-efficient movement path of a species with least cumulative resistance); **CWD** - Cost-Weighted Distance (effective distance between the source (core area) and destination that reflects both geographic distance and cumulative 'cost' (difficulty and mortality risk) required to navigate across a cell)).

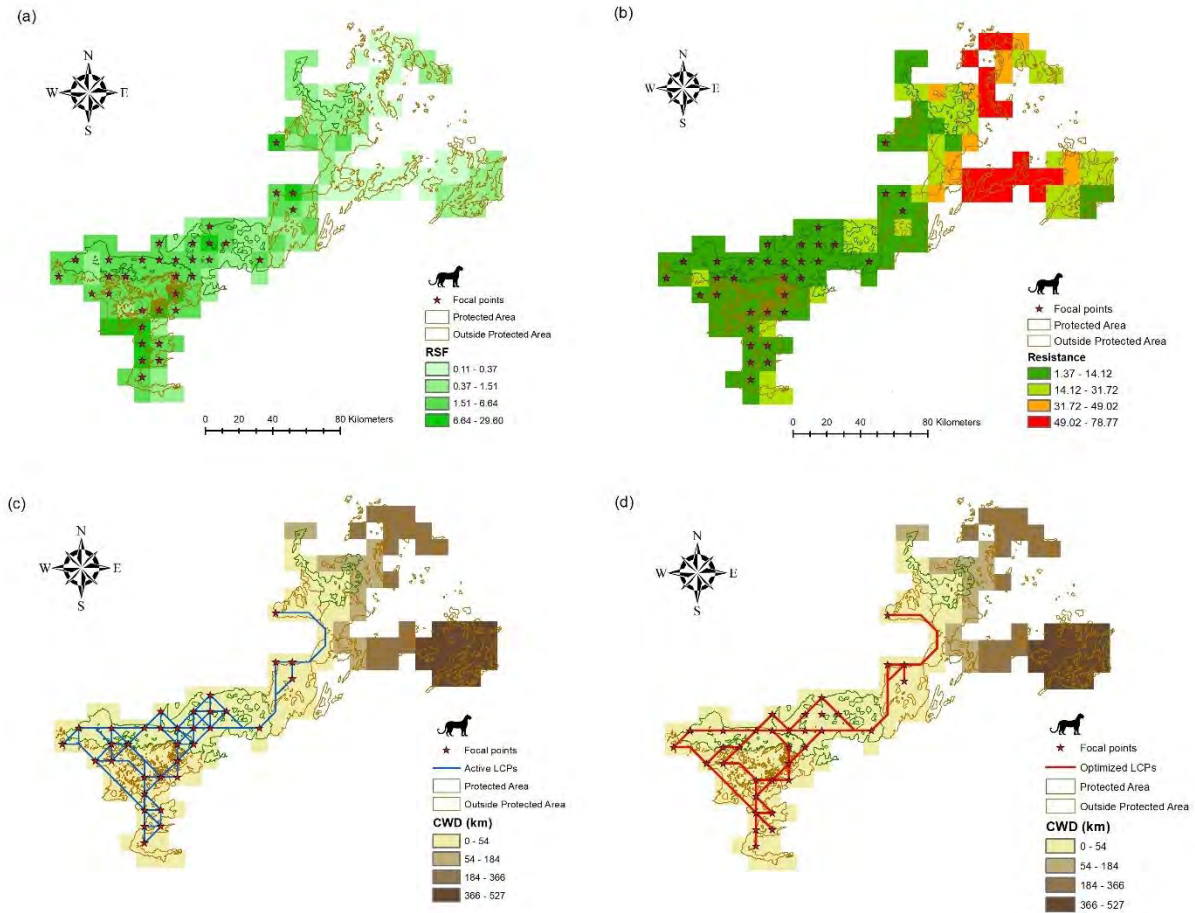


Figure 5.5 (a) Resource selection function, (b) cost surface, (c) active least-cost paths, and (d) optimized least-cost paths of leopard across Western and Eastern Ghats landscape of Tamil Nadu (*RSF* - Resource Selection Function (relative probability of species habitat-use based on environmental factors); *Resistance* - cost surface (a raster map where each cell represents relative difficulty in moving through the landscape); *LCP* - Least Cost Path (most energy-efficient movement path of a species with least cumulative resistance); *CWD* - Cost-Weighted Distance (effective distance between the source (core area) and destination that reflects both geographic distance and cumulative ‘cost’ (difficulty and mortality risk) required to navigate across a cell)).

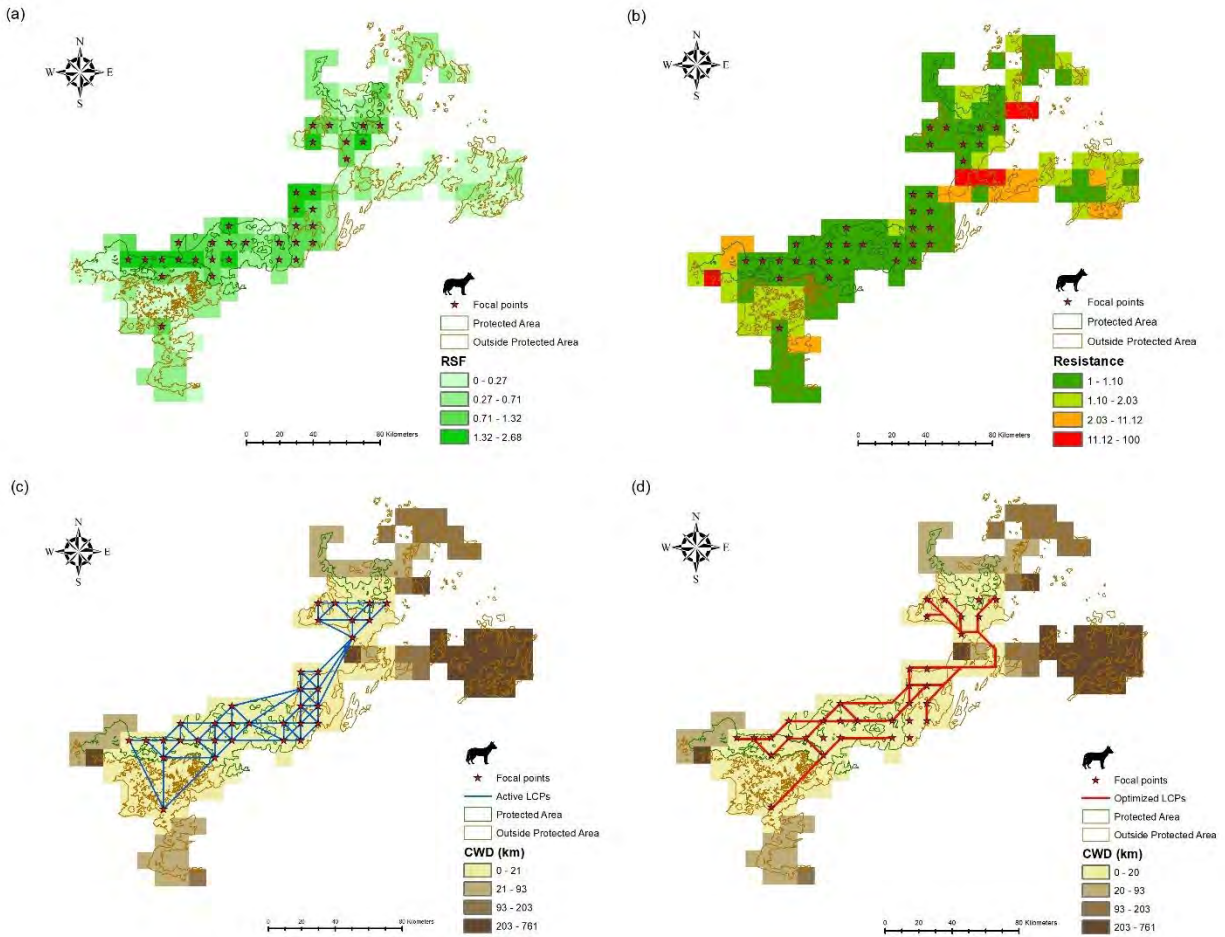


Figure 5.6 (a) Resource selection function, (b) cost surface, (c) active least-cost path, and (d) optimized least-cost paths of dhole across Western and Eastern Ghats landscape of Tamil Nadu (**RSF** - Resource Selection Function (relative probability of species habitat-use based on environmental factors); **Resistance** - cost surface (a raster map where each cell represents relative difficulty in moving through the landscape); **LCP** - Least Cost Path (most energy-efficient movement path of a species with least cumulative resistance); **CWD** - Cost-Weighted Distance (effective distance between the source (core area) and destination that reflects both geographic distance and cumulative ‘cost’ (difficulty and mortality risk) required to navigate across a cell)).

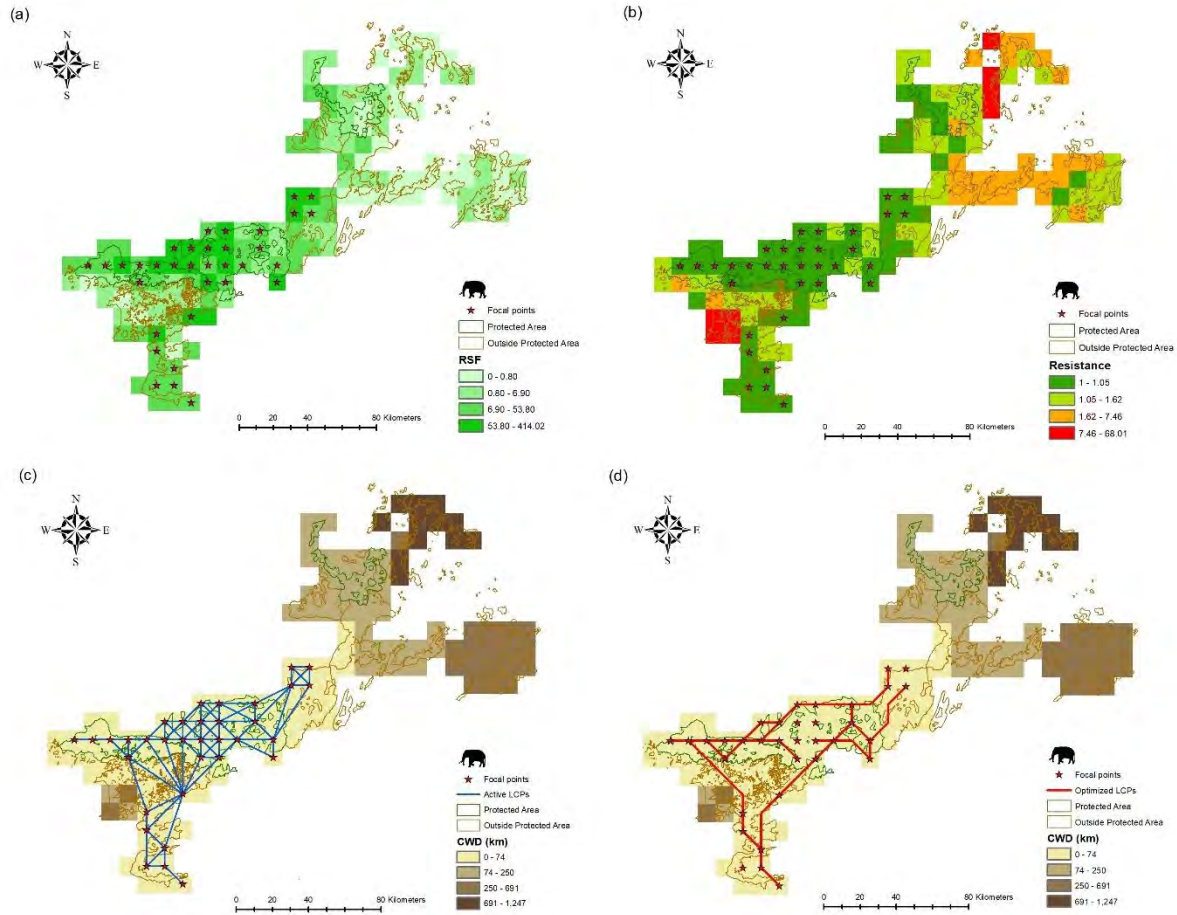


Figure 5.7 (a) Resource selection function, (b) cost surface (c) active least-cost paths and (d) optimized least-cost paths of elephant across Western and Eastern Ghats landscape of Tamil Nadu (**RSF** - Resource Selection Function (relative probability of species habitat-use based on environmental factors); **Resistance** - cost surface (a raster map where each cell represents relative difficulty in moving through the landscape); **LCP** - Least Cost Path (most energy-efficient movement path of a species with least cumulative resistance); **CWD** - Cost-Weighted Distance (effective distance between the source (core area) and destination that reflects both geographic distance and cumulative ‘cost’ (difficulty and mortality risk) required to navigate across a cell)).

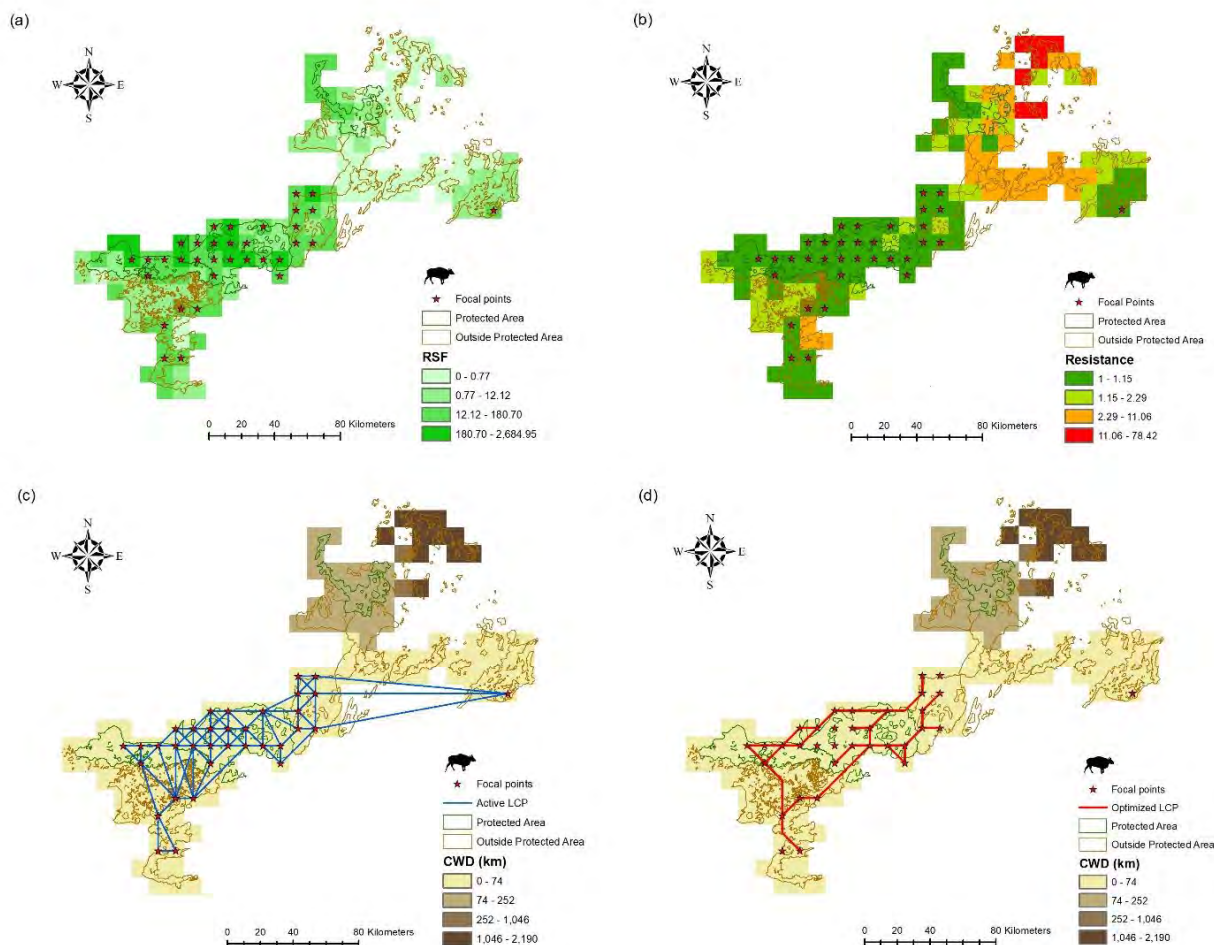


Figure 5.8 (a) Resource selection function, (b) cost surface, (c) active least-cost paths and (d) optimized least-cost paths of gaur across Western and Eastern Ghats landscape of Tamil Nadu (**RSF** - Resource Selection Function (relative probability of species habitat-use based on environmental factors); **Resistance** - cost surface (a raster map where each cell represents relative difficulty in moving through the landscape); **LCP** - Least Cost Path (most energy-efficient movement path of a species with least cumulative resistance); **CWD** - Cost-Weighted Distance (effective distance between the source (core area) and destination that reflects both geographic distance and cumulative 'cost' (difficulty and mortality risk) required to navigate across a cell)).

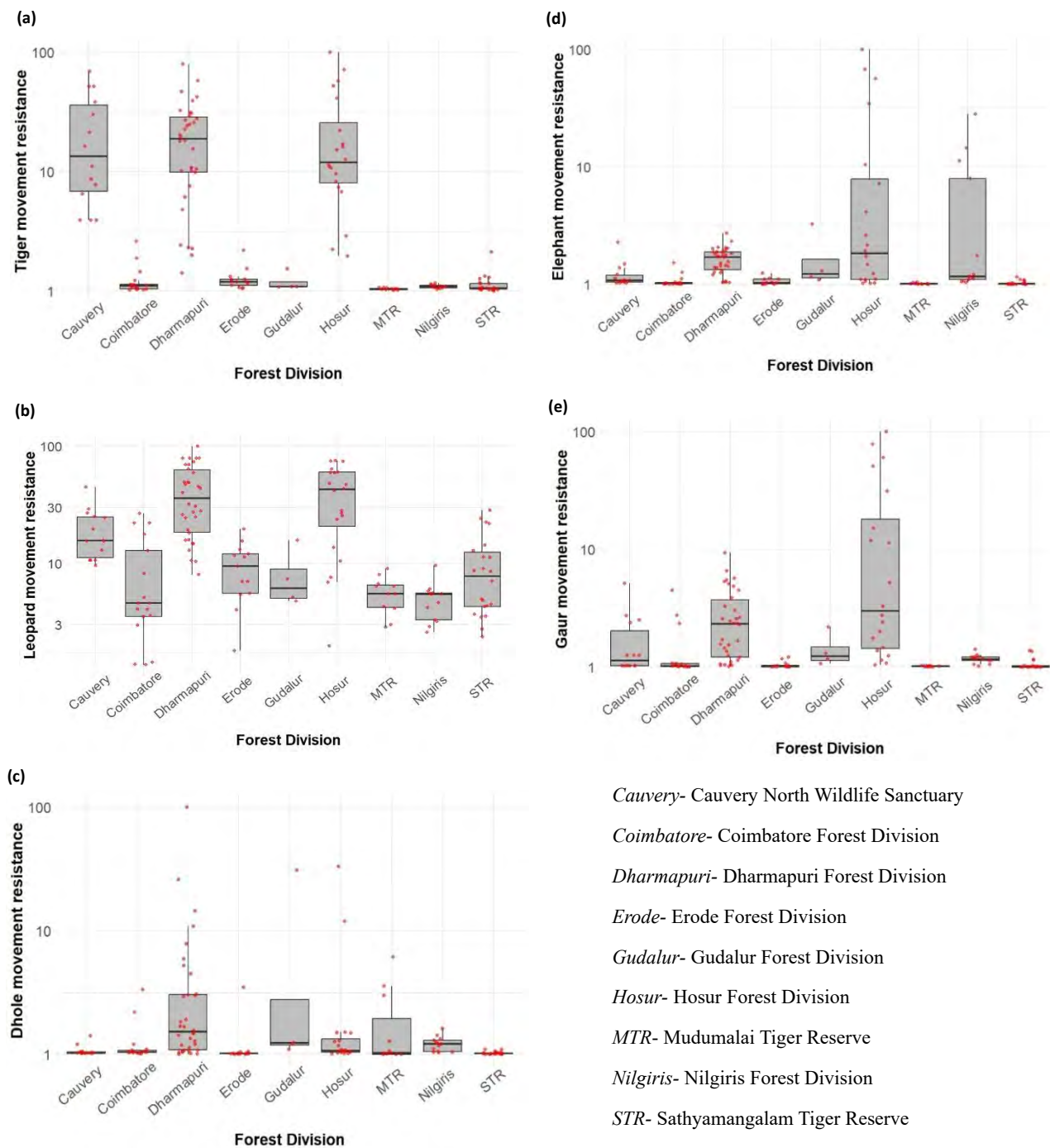


Figure 5.9 Movement resistance (log scale) of (a) tiger, (b) leopard, (c) dhole, (d) elephant, and (e) gaur across various Forest Divisions of the Western Ghats part of Tamil Nadu.

5.4 Discussion

Surging anthropogenic pressure in the current era has led to the extirpations and range contractions of many large mammal species, globally (Ripple et al., 2015; Wolf and Ripple, 2017). Landscape-level studies explaining the impact of human pressures on large mammal distribution is vital to conserve their population from further extinction. The study confirmed contiguous forests are the most favorable habitats for the occupancy of large mammals. The results indicated that habitat quality, abundance of large to medium-sized prey species, intensity of human disturbance, and area of contiguous forest patches were the principal determinants of large mammal occupancy in WEGPTN. The landscape-level occupancy maps explained the variation of large mammal occupancy in WEGPTN and highlights the areas that require immediate managerial interventions to minimize the negative human-wildlife interactions in future. The maps also demonstrate the species-specific occupancy pattern of multiple large mammal species (tiger, leopard, dhole, elephant and gaur) across gradients of anthropogenic pressure. Furthermore, the habitat occupancy and connectivity maps will help in developing management action plans for habitat restoration and improve habitat connectivity by maintaining the wildlife corridors for the sustenance of viable large mammal populations. I identified higher occupancy of large mammals, across 11,300 km² area of WEGPTN, especially towards NBR, due to its contiguous forest patches of the PAs network.

5.4.1 Habitat degradation affecting species occupancy

Habitat quality and extent of habitat degradation are crucial determinants of habitat selection by a species (Karanth et al., 2006; Puri et al., 2020). The results confirm the necessity of contiguous forest habitats with sufficient water sources in sustaining the population of large mammal species. The decreasing trend of elephant occupancy in forests with dense shrub cover is predominantly due to the reduced forage availability. High livestock grazing pressure and the infestation of the native grasslands with exotic weeds like *Lantana camara*, especially in the low rainfall areas forces the elephant to forage outside the forest area (Babu et al., 2012; Baskaran et al., 2012), increasing the risk of negative human-elephant interactions. Tiger also exhibited a decreased occupancy in the areas with high shrub cover because the proliferation of weeds decreased the abundance of habitat sensitive large

prey species in the wild and may cause tigers to depredate on the easy large domestic prey like cattle, expediting the risk of negative human-tiger interactions (Ramesh et al., 2020).

I observed increased dhole and elephant occupancy towards the forest area with higher availability of water bodies, because both the species have shown an increased affinity towards water sources to quench and for cooling their body (Acharya, 2007; Ramesh et al., 2022). For dhole, water bodies are also an energy-efficient lurking spot for prey capture (Acharya, 2007). Correspondingly, negative human-wildlife interactions are frequent at forest fringe areas of dry forest areas located farther from water sources (Ramesh et al., 2020, 2022). Leopard's arboreal nature increases the probability of its dependence on dense canopy cover. It provides a good refuge and a relatively safe location for feeding on the kills by avoiding competitors (Stander et al., 1997). Moreover, the canopy cover also facilitates them to depredate on common langur, an important prey of leopard in Western Ghats (Ramesh et al., 2012a). High occupancy pattern of gaur in forests with high grass cover and tree density re-affirms the dependency of gaur towards mixed forests with grasslands interspersed among the woody vegetation since it provides the forage, as well as a safe hideout from the predators (Ramesh et al., 2022).

5.4.2 Loss of prey density affecting large mammal occupancy

Wild prey abundance is an important determinant of large carnivore occupancy (Wolf and Ripple, 2017). I observed that large carnivore occupancy was highly driven by the abundance of large to medium-sized prey to meet their energy requirements (Ramesh et al., 2012b). Depletion of large prey for the diet-specific species like tiger and dhole may lead to their range contraction and probably the local extirpation of the species itself (Wolf and Ripple, 2017). In highly disturbed forests of Dharmapuri and Hosur the availability of large prey species was very sparse, which could be the probable reason for decreased occupancy of tiger. However, I observed that the leopard occupancy was higher in the forest rich in small prey species. Dietary partitioning of carnivores in the MTR demonstrated that a major portion of leopard diet is composed of large to medium sized prey species like chital and sambar (Ramesh et al., 2012a). This indicates that leopard utilize the available small prey species in the fragmented forest patches having scarce population of large/medium sized prey (Steinmetz et al., 2021) to avoid competitive exclusion so as to co-exist with the habitat specialist co-predators like tiger and dhole and is less favorable for the long-term

viability of leopard population. As per the optimal foraging theory, the chances of large carnivores to depredate the easy target large sized livestock will be higher in the absence/decline of wild prey, leading to increased risk of negative human-large carnivore interactions (Ramesh et al., 2020).

5.4.3 Human disturbances affecting species occupancy

Livestock grazing pressure is an emerging threat to the large mammal occupancy last few decades (Soofi et al. 2018). The study also depicts a negative correlation of large mammal occupancy with increased anthropogenic disturbances, especially in the form of livestock grazing as it depletes the available forage and the habitat transformation that follows (e.g., the emergence of weeds) (Wolf and Ripple 2016; Ramesh et al., 2022). High occupancy of the large mammal species inside the PAs- MTR and STR in WEPTN may be attributed to the privilege of “Protected Area” having very restricted human interventions. It was determined that the occupancy of elephant and gaur declined in forests with livestock abundance and intense grazing pressure. The prolonged exposure to livestock grazing pressure and the subsequent proliferation of weed/shrub cover reduced the occupancy of elephants drastically in WEPTN because these fast-spreading, unpalatable weeds replaced the native palatable grass species, forcing elephants to move outside the forested area for foraging, increasing the risk of negative human-wildlife interactions further (Babu et al., 2012; Ramesh et al. 2022). Madhusudan (2004) showed that large herbivore species exhibit clear patterns of spatial segregation in the forest that is exposed to high livestock grazing pressure. This indirectly affects the large carnivore population whose diet is primarily dependent on the large to medium size herbivore species like sambar, chital and gaur. In disturbed forests, tigers restrict their range to core forest areas to abate the risk of species extinction due to unavailability of wild prey species (Jhala et al., 2020). Similarly, I observed a lesser leopard occupancy in the areas where there is increased livestock herding inside forests, associated with the low large/medium prey abundance. I found that dhole also avoided occupying areas with high grazing pressure. Studies imply low occupancy of dhole in areas with high livestock grazing pressure because of the decreased large prey abundance and hesitation to appear in human vicinity who generally accompany the herd (Acharya, 2007; Punjabi et al, 2017)

5.4.4 Habitat fragmentation affecting species occupancy

Habitat loss and fragmentation is a rising threat to the large mammal population (Tilman et al., 2017). The study indicates that large mammal species show a strong positive correlation of occupancy in contiguous, unfragmented forests as they tend to occupy contiguous forests pertaining to its wide-ranging nature and habitat requirements. The occupancy map demonstrates the limited occupancy of large mammals towards outside PAs, reaffirming their sensitivity towards habitat disturbance and fragmentation. Habitat fragmentation had a negative repercussion especially on tiger occupancy due to decreased large prey abundance and increased human disturbances in fragmented landscapes (Linkie et al., 2006). Tiger showed a clear pattern of preference for undisturbed, contiguous forests. It also implies a range constriction of tiger from highly potential habitats of WEGPTN in near future upon intensified habitat fragmentation. In contrast to other large mammals, I observed that leopard occupancy was high in perforated forests as well as in contiguous forest patches. This indicates the plasticity of the species to survive in highly fragmented landscapes and avoiding intra guild competition. The study shows a high occurrence of tiger and dhole towards PAs of WEGPTN and thus increased probability of competition for leopard over the resources rendered by contiguous forest habitat. Perhaps, leopards are known for their broad habitat preference, from PAs to the suburban ecosystems (Stein and Hayssen, 2013). Increasing occurrence of leopard towards the urban landscapes also implies the increased risk of highly negative human-wildlife interactions. Incidents of leopard attacking livestock primarily from open forests and forest fringes were common in the WEGPTN (Ramesh et al., 2020). It is a classic example of how species adapt to the high anthropogenic pressure over years of exposure to human disturbances and habitat modifications (Odden et al., 2014). I found that dhole occupancy increased in contiguous forest habitats. Dhole occupancy was comparatively low in WEGPTN and is declining in many parts of Western Ghats due to habitat fragmentation (Punjabi et al., 2017) and excessive poaching of its prey species (Milda et al., 2020). The study specifies that elephant occupancy decreased in small forest patches (<250 acres). Currently, habitat loss and fragmentation by agricultural activities and infrastructure development are the major threats to the species and their corridors (Baskaran et al., 2012). Although a pattern of temporary elephant dependency on the agricultural crop plants and plantations towards the fringe areas of forest exits (Ramesh et al., 2022), natural vegetation is vital for maintaining viable population (Kumar et al., 2010). I detected high gaur occupancy in the contiguous forests than fragmented landscapes.

However, adaptability of gaur to human-dominated landscapes (eg. tea estates and coffee plantations) was also observed in those areas (Ramesh et al., 2022) but like other large mammals, the long-term viability of the species is uncertain. High occupancy of the large mammal species in small, fragmented landscapes may be one of the major reasons for the escalating human-wildlife interactions in WEGPTN. The augmented risk of negative human-wildlife interactions with the species like elephant, gaur and leopard, that utilize the modified landscapes becomes serious concern.

5.4.5 Resource selection and movement resistance

I identified approximately 1,800km² area for elephant; 1,600 km² area for tiger; and 1,200km² area for dhole and gaur, and 800 km² area for leopard as highly selected habitats by the species in the WEGPTN landscape. The habitat selection was found to be the highest in the continuum of STR and MTR and least in the fragmented parts of Hosur and Dharmapuri FDs. Poor habitat suitability for large mammals in Hosur and Dharmapuri FDs is predominantly ascribed to factors such as reduced prey density, intense livestock grazing pressure, weed infestation and direct human disturbances within forest boundaries (Milda et al., 2023a).

Tigers are highly territorial and typically occupy contiguous forest habitats characterized by high densities of large-bodied prey, low livestock presence, and minimal weed cover (Biswas et al., 2022; Milda et al., 2023a). Similarly, we found high habitat preference of tigers in contiguous PAs like MTR and STR. Roshani et al., (2024) pointed out that human disturbed landscapes were highly unsuitable for tigers and core habitats promoted the dispersal of species. Surprisingly, I found highly used tiger habitats, sporadically beyond the PAs. The patches of Coimbatore FD, located in close association with core habitats like MTR and Anamalai Tiger Reserve (ATR); and Erode FD adjacent to STR had high habitat selection, emphasizing the need to extend the habitat protection measures beyond the designated Tiger Reserves. On the contrary, Hosur and Dharmapuri FDs were highly impermeable to tiger movement, owing to the degraded habitat conditions. Consequently, CNWLS, although being a PA, had weak habitat suitability and connectivity, as it is bounded by highly fragmented Dharmapuri and Hosur FDs, decreasing its connectivity with nearby core habitats (BRT Tiger Reserve, MM Hills, Cauvery WLS and Bannerghatta National

Park). Therefore, it is pivotal to restore the degraded patches of these outside PAs to expand the tiger distribution across the south Indian landscape.

Leopard in the study area tends to occupy the habitats with small prey, high canopy cover, and less livestock density (Milda et al., 2023a). The results portrayed that most used habitats by leopard were outside PAs- Coimbatore FD, Nilgiris FD, Erode FD and Hosur FD, although STR was also preferred. In contrast to tiger, we found a very different pattern of habitat selection by leopard as it chose parts of outside PAs located adjacent to PAs, which are currently altered and disturbed due to anthropogenic pressure. Leopards have always exhibited remarkable habitat flexibility, with their distribution spanning from core PAs to human-dominated areas (Stein and Hayssen, 2013). In recent years, leopard sightings have become increasingly common in low-quality, human-modified landscapes such as tea and coffee plantations and densely populated human settlements in India (e.g., Navya et al., 2014; Kshetry et al., 2017; Sidhu et al., 2017). This can also be considered as spatial partitioning to avoid competition between co-predators like tiger in the landscape, their long-term survival in these human-altered landscapes and sustained tolerance of the public towards leopard presence is highly unlikely. The movement resistance map clearly shows high permeability of landscape towards leopards in PAs and high resistance in highly fragmented habitat patches located far from PAs. I identified selected parts of Hosur and Dharmapuri FDs having highest permeability (e.g. Urigam, Kottappatti) while some parts of the same FD are completely impermeable for movement (e.g. Rayakottai, Morappur); therefore, a holistic improvement throughout both the FDs can improve its habitat connectivity to core PAs.

Dhole occupies forests rich in medium-sized prey density, sufficient fresh water sources, and less livestock abundance (Milda et al., 2023a). The resource-use pattern of dhole is quite different from that of tiger and leopard; they utilized a wider habitat range along both dense and open forests of WEGPTN. Nevertheless, Punjabi et al., (2017) pinpointed that despite the widespread availability of suitable habitat within the Western Ghats, population distribution of dhole has a declining trend along the Northern Western Ghats. Some critical obstructions to its movement was identified along selected parts of Gudalur, Dharmapuri and Hosur FDs, although the habitat suitability was high along the WEGPTN landscape. Such patterns are likely linked to intensified habitat fragmentation through encroachment, agriculture plantations, direct human pressures, and scarcity of wild prey, which are prevalent characteristics of these resistant landscapes. High resistance in these outside

PAs hampers the connectivity of the FDs of WEGPTN with surrounding core habitats. For example, high dhole movement resistance in Gudalur FD affects the connectivity between MTR and connected Silent Valley National Park; the habitat impermeability in Dharmapuri and Hosur affects the connectivity between CNWLS and Erode FD connected with STR. Since most of the landscape is highly favorable habitat for dhole, some targeted alterations to the fragmented parts of WEGPTN landscape, could make a significant difference to the dhole dispersal.

With an estimated population of over 8,000 individuals, the Western and Eastern Ghats together represent one of the most important and ecologically suitable habitats for the long-term conservation of elephants (Ramkumar et al., 2017). The study area contains ten identified major elephant corridors, critical for conservation: Tali – Bilikkal, Bilikkal – Javalagiri, Chamarajanagar – Talamalai at Muddahalli, Kallhatti – Sigur at Glencorin, Avarahalla – Sigur, Kalmalai – Singara and Avarahalla, Moyar – Avarahalla, Mudumalai – Nilambur via O' Valley, Jaccanaire Slope - Hulikal Durgam, and Anaikatti North – Anaikatti South (Ramkumar et al., 2017). Elephant occupancy was observed highest in areas containing minimal weed infestation, abundant waterbodies, and lower densities of livestock (Milda et al., 2023a). I recognized highly suitable elephant habitats across both PAs (MTR and STR) and outside PAs (Coimbatore FD and Erode FD). The fragmented patches of Nilgiris FD and Hosur FD was observed to hinder the habitat contiguity with the adjacent core habitats. Nilgiris FD, lying in close proximity to MTR is a critical habitat for restoring the functional connectivity between other outside PAs (Coimbatore FD and Gudalur FD) for elephant movement. Besides, the loss and degradation of native habitats have driven elephants to expand their movements into agricultural landscapes and areas of human habitation, resulting in an increase in the rates of human-elephant conflict along many parts of the study area, especially Coimbatore FD, Hosur FD and Nilgiris FD (Babu et al., 2012; Baskaran et al., 2012; Ramesh et al., 2022). It is noteworthy that Coimbatore FD, that has one of the highest habitat suitability values for elephant, accounts for highest rates of human-elephant conflict, which seeks immediate managerial attention.

Quality landscapes with densely interspersed trees and grass cover, and low livestock abundance are highly preferred by gaur (Milda et al., 2023a). In contrast to elephants, habitat suitability for gaur was not spatially continuous across the study area; adjacent grids often exhibited sharp variation, with some neighboring high-suitability grids displaying notably low values. This pattern

was less evident within contiguous PAs such as STR and MTR, where habitat conditions were more consistently favorable. Although the presence of natural vegetation is crucial for sustaining viable gaur populations (Kumar et al., 2010), the species demonstrates considerable versatility to modified landscapes. However, increasing cattle grazing pressure within natural forested areas drives the animal to use agricultural plantations which poses an emerging threat to their long-term persistence (Milda et al., 2023a). In recent years, gaurs have been commonly observed in high-elevation tea plantations, where they are known to forage on the tender foliage of tea plants, also increasing the risk of human-gaur conflict (Ramesh et al., 2022). Hosur FD was the most impermeable habitat for gaur dispersal, attributed to high habitat disturbances and lesser fodder availability. The escalating rate of human-gaur conflict in the study area warrants the need for restoring habitat quality by eliminating the weed cover and cattle grazing pressure within the forested landscape.

5.4.6 Least-cost paths and cost-weighted distances

The continuity of large mammal habitats in the NBR is at serious risk due to increasing infrastructure development, and human-induced disturbances (Puyravaud et al., 2017). The Southern Indian Railway lines, National Highways, and the hydroelectric projects have adversely affected the landscape contiguity between the core habitats and outside PAs (WTI, 2015; Ramkumar et al., 2017). Nayak et al., (2020) highlights that in India, any forest greater than 10km² area is under risk of size reduction, with already 18,250 large forests split into small patches (reduced to more than 50% decrease in patch size) by virtue of linear infrastructures. Navigating through these habitat patches is subjected to various risks, but a high connectivity landscape can ensure successful movement of the animal with least energy (Taylor et al., 1993), which in turn is vital for long-term persistence of large mammals. WEGPTN is a mosaic landscape where natural forests, modified agricultural landscapes and human settlement occur in close spatial association. When large mammals like elephant encounters human-altered landscapes or large infrastructures they choose to avoid and return through the path they arrived or somehow navigate through the modified landscape, risking both their own lives and those of humans or take high energy routes that may imperil their lives (Ramakrishnan, 2008). Therefore, identifying energy efficient movement pathways specifically for each species is key to large mammal conservation. The results

demonstrated that CWD increased with increased distance from PAs, with the highest values observed in fragmented landscapes, indicating reduced landscape permeability in these regions.

MTR and STR, which are contiguous with Bandipur TR and Wayanad Wildlife Sanctuary are the primary core forests of the study area. However, these core areas alone are insufficient to conserve tropical biodiversity (Rosenzweig, 2003) and require the support of adjoining forested landscapes for long-term persistence. Many outside PAs in the study area might seem deceptively small, but plays an important role in connecting core habitats because these marginal habitat patches serve as population sinks in a metapopulation landscape (van Aarde and Jackson, 2007). The Gudalur and Nilgiris FDs are forest patches adjacent to MTR and are crucial areas of connectivity that could connect core habitats like MTR and Mukurthy National Park, but are highly fragmented due to anthropogenic pressure, mostly related to agricultural plantations and tourism activities. The fragmentation and encroachment have affected wildlife to such an extent that the wild animals encounter human almost daily. Human-wildlife interactions are common in the Gudalur-Nilgiris landscape, especially with bonnet macaque, wild pig, elephant, gaur and leopard (Arunachalam, 2019; Milda et al., 2023b; Karthick and Ramakrishnan, 2018; Ramesh et al., 2022,2020). Improving connectivity of these forest divisions with MTR will be crucial to enhance connectivity along multiple land-uses including Coimbatore FD. Other studies have also demonstrated the importance of Sathyamangalam-Nilgiris stretch in biodiversity conservation (Pokhariya et al., 2023). Although not a PA, Coimbatore FD is connected to PAs like ATR, Silent Valley National Park, MTR and STR and therefore is a critical corridor for wildlife movement. Yet, adjacent fragmented Nilgiris FD often makes the path difficult to navigate to PAs. Currently, with the increasing risk of urbanization, the foothills of Coimbatore FD have turned into a HLHC hotspot especially for elephants and the number of fatalities to the animal as well as humans is increasing each year (Ramkumar et al. 2018). If the connectivity of the landscape with MTR is maintained and enhanced, frequency of conflict incidents can be reduced. Erode FD which is connected to STR also provides a suitable habitat for large mammal species. However, due to high fragmentation, many species lose connectivity further north, towards Dharmapuri FD, CNWLS and Hosur FD. Unlike other PAs, CNWLS has lesser efficiency in hosting large mammals because it is surrounded by highly fragmented Hosur and Dharmapuri FDs. Yet it forms a critical connecting link between the Western and Eastern Ghats ranges. The connectivity of CNWLS with Cauvery Wildlife Sanctuary, Bannerghatta National Park, and BRT Tiger Reserve is critical to

maintaining large mammal movement. A major part of Dharmapuri FD falls in the Eastern Ghats and it provides a convenient habitat for many large mammals like elephant, dhole and gaur. The presence of Hogenakkal Waterfalls has led to increased tourism activity across Dharmapuri FD. The habitat degradation in this area has increased the frequency of human-elephant conflict, especially in the form of crop raiding. Hosur, located near the metropolitan city of Bengaluru, is a highly industrialized region. The forests within the Hosur FD have undergone considerable degradation due to mining, stone quarrying, hunting, proliferation of weeds and encroachment. Frequent HLMC, especially with the elephants venturing into agricultural areas moving between Bannerghatta National Park has decreased the tolerance of local people towards wildlife and coexistence. The preservation of these bottleneck regions is vital to conservation, as their removal or degradation could severely disrupt structural and functional connectivity across habitat networks (Dutta et al., 2016). Hence, the study highlights that it is important to consider PAs and surrounding landscapes as interconnected ecological units rather than isolated systems (Gardner et al., 2009) for sustained persistence of large mammals.

Chapter 6

CHAPTER 6

Conclusion

Intensifying habitat fragmentation and anthropogenic pressures reshape the human-wildlife interface area leading to increased human-large mammal conflict (HLMC), which is one of the pressing challenges in tropical biodiversity conservation. The present research work used a large-landscape scale, multi-species approach, integrating a socio-ecological dimension to high conflict areas across the Western and Eastern Ghats part of Tamil Nadu (WEGPTN), spanning 14,200 km² area.

The predation risk mapping across approximately 22,525 km² revealed that conflict among sympatric large carnivores follows distinct species-specific spatial pattern, driven by a combination of forest dependence of the household, livestock size, and forest cover. The study highlighted that human-elephant conflict risk was associated with crop cover, crop diversity, proximity to water, terrain, and precipitation; while gaur conflict was linked to recent land-use shifts along forest fringes. The study observed that high-intensity conflict hotspots were consistently associated with fragmented landscapes, indicating habitat connectivity as a structural determinant of conflict intensity rather than an outlying management concern.

The study results confirmed that large mammal occupancy across WEGPTN is associated with the presence of contiguous forests with adequate water and prey density, and absence of habitat fragmentation and human disturbances. Particularly, habitat-specific tiger occupied contiguous, undisturbed, core Protected Area (PA) while other large mammal species had a scattered but PA-centred distributions, underscoring the importance of contiguous undisturbed forest habitats. Study indicated the flexibility of leopard to utilise fragmented outside-PA patches, underscoring its functional importance in degraded matrix habitats. These findings collectively point toward enhancing the prey base within PAs, and directing targeted management actions at PA-agriculture interface areas. High movement resistance for large mammals in extremely disturbed landscapes reinforces the importance of strengthening corridor functionality for long-term viable large mammal populations.

The Forest Ranger survey revealed that weak management and inadequate resources beyond PA boundaries contribute to habitat degradation, wildlife population decline, and escalating human-

wildlife conflict in Outside PAs, even though the conservation challenge intensity across PAs and Outside PAs was found to be broadly comparable. This emphasizes the importance of extending conservation effort meaningfully beyond formal PA boundaries to adjoining Reserved Forests, ensuring that landscape-scale protection reflects ecological realities rather than administrative ones.

Results of the study highlighted that socio-economic conditions, health, and safety concerns are as influential in shaping attitudes toward wildlife as direct conflict experience itself. The study explained that integrating local perceptions into PA management through participatory planning, benefit-sharing, livelihood diversification, and targeted awareness campaigns has good potential to reduce retaliatory attitudes and foster coexistence. Institutional trust emerged as an independent predictor of tolerance, suggesting that governance transformations focused at transparency and community inclusion can improve coexistence outcomes even if there is no significant reduction in actual conflict frequencies. In short, the present study calls for conservation planning that is multi-species in scope, landscape-scale in extent, and socio-ecologically integrated in approach, because that is the only scale at which the true architecture of conflict, and the real opportunities for coexistence, become fully visible.

My study provides the following suggestions based on its findings:

1. Generated conflict hotspot maps can be utilized for directing resources including deployment of anti-poaching watchers, compensation funds, physical deterrents, and awareness programmes toward high-risk zones, complementing existing divisional planning.
2. In high carnivore conflict zones, measures such as predator-proof livestock enclosures, stall feeding for calves and lactating females, physical deterrents like shock-collars for livestock, livestock-guarding dogs, and decentralised village-level livestock insurance schemes could usefully complement existing compensation frameworks (Rossler et al., 2012; Ravenelle and Nyhus, 2017). Strengthening protocols for proper disposal of livestock carcasses would further reduce the risk of their misuse in predator poisoning.
3. In elephant and gaur conflict hotspots, bio-fencing with unpalatable crops, beehive fencing, cover scent sprays, and acoustic and olfactory repellents represent cost-effective,

community-implementable deterrents that could supplement physical barriers, particularly in areas where infrastructure maintenance has been challenging (Mehta et al., 2020).

4. Promoting crop pattern modification in forest-edge agricultural areas, by cultivating less palatable alternatives alongside improved forage availability and water augmentation within forest interiors could serve as a structural, longer-term complement to deterrent-based megaherbivore conflict reduction efforts.
5. Early Warning Systems integrating mobile-based participatory reporting, drone surveillance, and AI-assisted camera trap monitoring could be scaled up in high conflict areas, such as the Madukkarai model in Coimbatore Forest Division (The Hindu, 2025).
6. Deepening participatory governance mechanisms through formal community representation in PA management planning and transparent communication can strengthen the institutional trust that the study identified as an independent predictor of wildlife tolerance.
7. Including a decentralised, village-managed insurance scheme, complementing to the existing compensation processes could help address the processing delays that communities consistently associated with institutional distrust and reduced coexistence support (Mishra et al., 2003; Khan et al., 2018).
8. Benefit-sharing options to local communities that supports local tourism, as well as other regional income generation, such as energy sources (i.e., biogas, solar power) is recommended to build support locally for conservation initiatives (Dhanwatey et al., 2013).
9. Site and species-specific, ecologically grounded awareness programmes on wildlife species involved in conflict can help address disproportionate fear toward wildlife and contribute to more balanced community attitudes.
10. Investing in access to basic amenities such as healthcare, drinking water, road connectivity, and electricity in forest-fringe villages could be considered, given the study's finding that amenity deprivation is an important predictor of negative coexistence attitudes.
11. Expanding livestock health services like including systematic vaccination, vector control, and accessible veterinary support in fringe communities can reduce the livestock disease

burden that the study identified as a contributing factor towards negative wildlife perception.

12. Consistent wildlife management investment by bringing more uniformity in resource allocation in staffing, anti-poaching infrastructure, and operational funding, in high conflict areas regardless of the management regime (PA or outside-PAs) can aid in more efficient conflict mitigation.
13. Strengthening the governance framework for Reserved Forests, in recognition of their documented ecological function as source-connected buffers, corridors, and demographic overflow habitats, could help extend effective management coverage meaningfully beyond administrative PA boundaries.
14. Ecological restoration in degraded forest patches, with a focus on managing invasive species such as *Lantana camara*, *Parthenium*, *Prosopis*, wattle, pine, and eucalyptus, could improve large mammal habitat quality, support prey recovery, and reduce wildlife foraging in agricultural area and other human-dominated landscapes.
15. Establishing artificial water sources within the Forest Reserves like check dams, waterholes, and percolation ponds in the drier zones of WEGPTN, with site-selection following soil water isotope-based methods, could help reduce outward dispersal of large mammals from forest interiors during dry season.
16. Reducing livestock grazing pressure inside Forest Reserves through incentivised stall-feeding arrangements can not only protect livestock from wildlife depredations, but improve the habitat quality of forests.
17. Targeted habitat management at identified connectivity pinch points in Nilgiris, Gudalur, Coimbatore, and Dharmapuri Forest Divisions following the resistance maps developed in this study could help restore landscape permeability at precisely the locations where fragmentation and conflict risk spatially converge.
18. Formal notification and legal protection of identified wildlife corridors from developmental encroachment, combined with encouraging native timber or agroforestry

arrangements on private lands within narrow corridors, can enhance corridor width and long-term functional connectivity (Ramkumar et al., 2017; Menon et al., 2017).

19. Mitigation measures such as adequately dimensioned underpasses with soil-lined floors and native vegetation would help reduce the barrier effect of linear infrastructure on large mammal movement (WII, 2016; Arun et al., 2019).
20. Periodic updating of occupancy maps, and resistance surfaces, and least-cost path models at intervals of three to five years could sustain the adaptive management to track changes in large mammal distribution and corridor functionality.

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Appendices



Questionnaire for local community with respect to human-wildlife conflict in Tamil Nadu, India

Lat:	Name of the interviewer:					
Long:	Date and Time:					
Name of the nearest PA	Distance from the nearest PA:					
Section A. Personal details of the respondent						
1.(a) Name	1.(b) Age		1.(c) Sex	M	F	O
2. Name of the village:						
3. Address and contact number:						
4. Occupation/source of income:						
5. Annual income:						
6. Education qualification:						
7. Role in family						
8. Members in the household (<i>excluding the respondent</i>)						
Role in family		Age		Education qualification		
9. How long have you lived here:						
10. Do you have the following basic necessities in your locality, If not how far you need to go (km)						
Hospital	School	Job	Transportation facilities	Drinking water		

11. Access to Govt. schemes								
Ration		Medical facilities		Human vaccination			Loans	
Livestock vaccination		Education		Others				
12.What are the difficulties faced by you in your locality								
Lack of basic facilities		Low income	Wildlife conflict		Lack of government/forest department assistance			
Disease prevalence		Water scarcity		Others				
Section B. Details of crop husbandry								
1.List the crops cultivated in your land								
Crop	Paddy	Banana	Sugarcane	Maize	Millets	Vegetables	Groundnuts	Others
Area in acres								
2.Location and area of your agriculture land								
3. List the months (Tamil) in which you grow crops								
Citthirai	Vaikasi	Aani	Aadi	Āvaṇi	Puraṭṭāsi			
Aippasi	Kārttikai	Mārkazhi	Thai	Māsi	Pankuni			
4. List the months (Tamil) in which crop raiding occurs								
5. Write the sources of income for months you don't cultivate crops								
6. List below the major threats to your crops (Low, medium and High)								
Disease	Drought	Crop raiding	Pest	Others				
Section C. Details of animal husbandry								
1.Number of livestock raised								
Species	Cow	Buffalo	Goat	Sheep	Chicken	Pig	Feral dogs	Others
Adults								
Young								

2(a).Where does your livestock graze (adjacent to forest, inside forest, within the village)					
2(b). Location					
3.How does your livestock graze (<i>Unattended, herded by children, herded by adult, guarded by dogs</i>)					
4(a). Location of watering hole for the livestock					
4(b). How far is the watering hole from your house					
5. Where does your livestock remain in the night hours and how is it protected					
6. List below the major threats to your livestock (Low, Medium, High)					
Disease		Wildlife predation	Theft	Others	
7. Whether any cases of disease were observed in your livestock, If yes name the diseases					
Anthrax		Foot and mouth	Sheep and goat pox	Cow pox	
Contagious bovine abortion		Mastitis	Black quarter	Leptospirosis	
Hemorrhagic septicemia		Vibrionic abortion	Rinder pest	Metabolic disease	
Rabies		Others			
8.Are you aware of the insurance scheme YES NO					
9(a). Have you insured your cattle YES NO					
9(b). List the reason for not insuring your cattle					
Unaware		Not interested to insure		Don't have money to afford	
Others					
Section D. Details of man-animal conflict					
1.Your views on wildlife					
2. Is there presence of wildlife in your area; If yes name some of the mammals and how often you encounter them (weekly, biweekly, monthly, every six months, more than six months).					
Species	Presence	Encounter rate	Species	Presence	Encounter rate
Tiger			Sloth bear		

Leopard			Wild pig		
Dhole			Deer		
Elephant			Primates		
Gaur			Others		

3. Name the wild animals that you revere as gods

4. Is there any wildlife conflict in your locality YES NO

5. What are the basic difficulties that you face due to conflict

Loss of livelihood		Loss of crops	Loss of livestock	Loss of property
Loss of humans	Injury to humans	Loss of pet animals	Lack of sleep	Fear
Others				

6. Details of livestock depredation

		Species of livestock injured or killed	Cow	Buffalo	Time of conflict (M, A, E, N)	Season (W,D)	Location of kill site		Distance to PA
Tiger		Injured							
		Kill							
Leopard		Injured							
		Kill							
Dhole		Injured							
		Kill							
Others		Injured							
		Kill							

7. Details of crop damage

	No. of conflicts	Crop depredated	Crop stage	Area in acres		Time of conflict (M, A, E, N)	Season (W,D)	Location	Distance to PA
Elephant									
Gaur									

Sloth bear									
Wild pig									
Deer									
Macaques									
Others									

8. Details of direct human conflict

Conflict animal		Loss of lives	Injury to human	Loss of property	Chased by animal	Sighting of conflict animal	Location of conflict (<i>inside village, inside forest, adjacent to forest</i>)	If others mention below

9. While performing which of the following activity you were attacked/sighted the conflict animals

Conflict animal	Herding livestock	NTFP collection	Recreation	Collecting water	Collecting firewood	Religious rituals	Hunting

10. Location of maximum conflict occurrence (*inside village, inside forest, adjacent to forest*)

Section E. Details of compensation

1. Are you aware of the compensation program						YES	NO
--	--	--	--	--	--	-----	----

2. Have you applied for the compensation, If yes fill the details below						YES	NO
Conflict animal	Details of conflict		Loss in rupees	Amount compensated	Average time taken for receiving compensation	Whether the compensation provided is satisfactory/ not satisfactory	

3. Is the compensation program satisfactory, If no state the reasons why						YES	NO
Low amount paid as compensation	Time delay in compensating	Involves lot of travelling and spending money	Attitude of forest department				
Longer procedure	Others						

5. Past scenario of conflict (Reduced, stayed same, increased)- If reduced or increased, state the reason					

6. List the reasons behind the conflict					
Proximity to forest	Increase in human population	Presence of humans in the forested areas	Encroachment	Easy forage	Drought/lack of water
Increase in conflict animal population		Grazing inside forested areas		Others	

7. List the general measures taken by you to prevent conflict

Measure	Approximate amount spent	Effectiveness
Electric fencing		
Human/Animal guarding		
Fire and noise deterrent		
Trench		
Natural deterrent (Chilli, bees)		
Changing crops		
Trapping/Killing		
Others		

8. List the measures taken by the forest department to curb the conflict in your locality

Capture and relocate	Erect electric fences	Elephant trenches	Noise/Fire deterrents
Awareness program	Compensation	Others	

9. Is the mitigation measure taken by the forest department effective, If no state the reasons why,

YES NO REASON:

10. What do you suggest be done to prevent conflict

Relocation of the animal	Kill the conflict animal	Physical barriers /Trenches	Noise/ Fire deterrent
Electric fencing	Others		

12(a). Does the forest department conduct grievance meetings regarding the conflict	YES	NO
12(b). Do you think conducting grievance meetings benefit you	YES	NO
12(c). In what way it benefits you		

13. Your views on human coexistence with wildlife			
Intolerable	Moderately tolerable	Tolerable	Tolerable provided proper measures are taken

14(a). Do you think it is vital to conserve the wildlife	Agree	Disagree	Unsure
14(b). State the reasons why			

Section F. General details of the respondent

1(a). Do you feel living at closer proximity to forest is beneficial	YES	NO
1(b). List the beneficial reasons		
Source of income/livelihood	Aesthetic beauty and peace	Not sure
Source of food	Others	

2. How are you dependent on the forest				
NTFP	Water	Medicine	Religious needs	Firewood collection
Herding livestock	Hunting	Fodder for cattle	Others	

3(a). Do you think that the forest area is degraded for the past five years	YES	NO	
3(b). What are the reasons for forest degradation			
Grazing	Forest fire	Development	Lack of rains

Encroachment	Others		
4. Does the forest department provides you with job opportunities, if yes how are you involved			
5(a). Are you part of community based conservation measures		YES	NO
5(b). If yes how are you involved			
6(a). Do the forest department conduct any awareness programs		YES	NO
6(b). Does the awareness program benefit you		YES	NO
7(a). Respondents views on the forest department	Positive	Indifferent	Negative
7(b). If negative state the reasons why			
8(a). Does any local NGO or other organisation is involved in your wellbeing		YES	NO
8(b). Name of organisation_____ work done_____			
8(c). Name of organisation_____ work done_____			



**Questionnaire for forest officials in respect to human-wildlife conflict management
in Tamil Nadu, India**

Lat:		Name of the interviewer:			
Long:		Date	Time: From	to	am/pm
Section A. Personal details of respondent					
1.(a) Name:		(b) Age		(c) Sex	M F
2.Contact No:					
3.(a) Division:		(b) Range:			
4.(a) Current position held:		(b) Education status:			
5.(a) Years of experience _____ (b) Years of experience in this range _____					
6. Years of experience (a) Inside wildlife areas _____ (b) outside wildlife areas _____					
7. Previous assignment details _____					
8. Do you also tend to duties in other ranges, If yes, name them _____ location _____ and the time (<i>months, weeks</i>) spent in other ranges _____					
9. Participation in training programmes, If attended, what is the duration _____ and choose from below the type of training attended					
Forestry	Wildlife Management	(others) _____			
Section B. Details of the Range					
1(a). No. of villages within the range:		(b) Human population in the range:			
2(a). No. of household:		(b) Average no. of members per household:			
3. No. of livestock owned in the range: (i) cow _____ (ii) buffalo _____ (iii) goat _____ (iv) sheep _____					

4. No of vehicles available in the range: (i) Four wheeler _____ (ii) Two wheeler _____			
5(a). No of check dams in the range:		(b) No. of water holes maintained by the range:	
6. Are there any perennial water sources in the range, if so what is the current status			
7. No. of anti-poaching camps: (i) Active camps _____ (ii) non active camps _____ (iii) floating camps _____			
8. When was the first anti-poaching camp set up (<i>year</i>)			
9. No. of anti-poaching staff employed per camp			
10. Anti-poaching patrolling carried out By foot _____ by vehicles _____			
11. Average distance covered by anti-poaching patrol/ day (<i>By foot</i>)			
12. Average distance covered by anti-poaching patrol/ day (<i>By vehicle</i>)			
13. Equipments available for anti-poaching watchers (<i>Choose the equipments available</i>)			
GPS	Walkie-talkie	Torch	Arms
Maps		Mobile	
(Others)			
13. List below the schemes provided by the government to mitigate the human wildlife conflict			
Name of the Scheme	State/Central Govt.	Amount allocated for the range	Mitigation measure
14. Fund availability for tackling human-wildlife conflicts		Sufficient	Moderate
			Insufficient

15. How much money do you expect to conserve wildlife in the locality

16. Trainings provided for the forest watchers

Training provided	Agency providing training	Training location

17. What type of trainings are essential in your range

18. Details of local community employed with the forest department under various schemes

Name of the scheme	Designation/type of work done	Number of villagers employed	Wage paid for the job (per day/month)

Section C. Details of the human-wildlife conflict within the range

1. Conflict animals in the area (*for the past 5 years*)

	Tick if Conflict occurs for this species	No. of conflict/yr	Loss of livestock injured/killed	Loss of crops (acres)	Human injury/death	No. of conflict animals killed	No. of road kills	Total amount compensated
Tiger								

Leopard								
Elephant								
Gaur								
Wild dog								
Sloth bear								
Deer								
Wild pig								
Macaques								
others								
	Total amount spent as compensation for human-wildlife conflict							

2. Details of mitigation measure practised for the past 5yrs

	Relocation	Physical barriers	Noise/ Fire deterrent	Electric fencing	Compensation	Awareness programmes	others	Amount spent
Tiger								
Leopard								
Elephant								
Gaur								
Wild dog								

Sloth bear								
Wild pig								
Macaques								
Deer								
(Others)								
	Total amount spent on mitigating the human-wildlife conflict							

3. What are the practical difficulties in mitigating the human-wildlife conflict

4. Past scenario of conflict (*past 5 yrs- Reduced, stayed same, increased*) _____ and choose the reason for the change

Increase in human density	Availability of easy forage	Forest fragmentation	Drought	Increase in the numbers of conflict animal
Illegal grazing inside the PA		Water scarcity	Encroachment	(Others)

5. Does financial constraints/shortage of staff limit your ability to manage human wildlife conflict

YES

NO

6. What are the facilities needed for mitigating the wildlife conflict

Financial support	Public support	Scientific research	Training programme for field staff
Provision of facilities to local communities		Awareness programmes for local communities	Support of NGO and other local bodies

7. Details of Relocation

Conflict animal		Relocation date	Relocated from	
-----------------	--	-----------------	----------------	--

	Reason for relocation		<i>Lat long</i>	<i>Name of location</i>	Status of conflict post relocation (reduced, stayed same, increased)

8. Compensation schemes

a. How many times can a single person apply for compensation schemes/year

b. Do you feel that the locals are satisfied with the compensation schemes YES NO

if no state the reasons _____

9. What methods would you suggest be employed to mitigate the conflict _____

10. Do you work with any NGOs in conflict management, If so name them _____ and how are they involved _____

11. No. of cases recorded in the range (*past 5 years*)

Species	Year	Item seized	Method used for poaching	Person produced in court/pending

12. What are the general methods employed for poaching in and around the range

Guns	Poisoning	Snares	Cage Traps	Electric traps	Trained dogs	Hand-made bombs
Food baits	Pitfalls	(Others)				

13. Past scenario of illegal activities (*past 5 yrs- Reduced, stayed same, increased*) _____,

If changed state the reason _____

14. Do the local villagers graze inside the protected areas, If yes list the details below

a. No. of livestock grazing inside the forest _____

b. No. of tribes/locals who remain inside the forest for grazing _____ and their livestock numbers _____

c. Approximate area grazed by livestock _____

d. State the average distance travelled by livestock from the reserve boundary

e. What are the negative impacts of grazing observed

Loss of habitat	Diseases	Livestock lifting and conflict	Indirect influence on poaching	Reduction in food plants for the herbivores
Guard dogs kill/injure wildlife		(Others)		

15. Apart from the stringent laws what other measures do you think is necessary to control the illegal activities

16. Are there any cases of disease outbreaks for the past 5 years in your range, If so fill the details below

Disease	Month and Year	Suspected reason for spread	Affected animals	No. animals died of the disease	Measures taken to control	Amount spent

17. Perceptions of local communities on wildlife

Positive

Indifferent

Negative

If positive fill the details below

- Do the locals feel positive about coexisting with the conflict animals YES NO
- Do they feel responsible for the conflict in the area (due to their expansion into the forest areas, encroachment) YES NO
- Are the locals interested in mitigating the conflict in their locality YES NO
If yes, how do you think they can be involved in mitigating the conflict

If negative fill the details below

- What are the reasons that makes the villagers have negative attitude towards the conflict animals

- Do the people retaliate by harming the conflict animals (poisoning, snaring etc) YES NO
If yes, how do they retaliate _____

18. Role of local communities on conflict management

19. Awareness programmes conducted for villages on wildlife and conflict management, If yes who are the target groups _____ and how often do you conduct such programmes _____

20. What are the Eco-development initiatives taken in the range

21. Any further information to be noted

Thank you for your patience in providing the necessary information for the study.

Table S3. Description of the socio-economic variables used in the questionnaire survey, along with *a priori* prediction on the possible effect of these variables on people's perception towards coexisting with the wildlife.

Variable	Hypothesis and supporting literature	Score	Description
Location	The risk of negative perception on coexistence will be highest in Fringe Areas (Nyhus & Tilson, 2004)	1 2 3	House located in Fringe Area House located in Reserved Forest House located in Protected Area
Age	Individuals of age class 18-30 and >60 will have positive perception on coexistence (Kaltenborn et al., 2006)	1 2 3 4 5	18-30 31-40 41-50 51-60 >60
Gender	Females will have positive perception on coexistence (Kaltenborn et al., 2006)	1 2	Male Female
Income	Higher the income generated, lower the risk of negative perception on coexistence (Allendorf et al., 2006)	0 1 2 3 4	No income 1-25,000 25,000-50,000 50,000-1,00,000 >1,00,000
Education	Higher the education, lower the risk of negative perception on coexistence (Baral & Heinen, 2007)	0 1 2 3	No formal education Up to Upper Primary Up to High School Higher Secondary and above
Occupation	Farmers will have more negative perception on coexistence (Røskaft et al., 2007)	1 2 3	Farmer Daily-wage labourer Others

Amenities	Higher the availability of amenities, higher is the chance of positive perception on coexistence (Allendorf et al., 2006)	0 1 2 3 4 5 6	Weighted score was assigned to each household if they were utilizing the basic amenities like hospital, transportation, ration, drinking water, vaccination, and livestock treatment facilities in less than 5km distance. E.g. if a household utilizes all six amenities they are assigned with a score, “6”
Assistance from Forest Department	Higher the assistance from Forest Department, lower the risk of negative perception on coexistence (Karanth et al., 2012)	0 1	Assistance from Forest Department is available No assistance from Forest Department
Disease for livestock	Higher the risk of livestock diseases, higher the risk of negative perception on coexistence (Ogra, 2008)	0 1	No prevalence of livestock disease Prevalence of livestock disease
Water scarcity	Higher the prevalence of water scarcity, higher the risk of negative perception on coexistence (Ogra, 2008)	0 1	No scarcity of water Scarcity of water prevalent
Drought	Higher the risk of drought, higher the risk of negative perception on coexistence (Dickman, 2010)	0 1	No drought Drought prevalent
Crop depredation	Higher the risk of crop depredation, higher the risk of negative perception on coexistence (Hariohay et al., 2018)	0 1 2 3 4	Weighted score was assigned to each household according to their experience of crop depredation incidents from elephant, gaur, wild pig, and sambar. e.g if a respondent experiences crop depredation event by any three animals, then the household will be assigned with a score “3”

Livestock depredation	Higher the risk of livestock depredation, higher the risk of negative perception on coexistence (Wang et al., 2006b)	0 1 2 3 4	Weighted score was assigned to each household according to their experience of livestock depredation incidents from tiger, leopard, dhole, hyaena, jackal. e.g if a respondent experiences livestock depredation event by any two animals, the household will be assigned with a score “2”
Water availability for livestock	Higher the availability of water, lower the risk of negative perception on coexistence (Dickman, 2010)	0 1 2	No water source available Private water source Public water source
Forest dependence	Higher the dependency on forest will have positive perception on coexistence (Baral & Heinen, 2007)	0 1	Not directly dependent on forest resources Directly dependent on forest resources
Fear	Higher the fear, higher the risk of negative perception on coexistence (Rohini et al., 2018)	0 1	Not afraid about wild animals Afraid about wild animals
View on Forest Department	Higher the positive view on Forest Department, higher the positive perception on coexistence (Karanth et al., 2012)	0 1	Negative view towards Forest Department Positive view towards Forest Department
Status of conflict	Higher the human-wildlife conflict incidents higher the risk of negative perception on coexistence (Dickman, 2010)	1 2 3	Frequency and intensity of HLMC has increased Frequency and intensity of HLMC has stayed the same Frequency and intensity of HLMC decreased
Awareness program	Higher the conductance of awareness program, lesser risk of negative perception on coexistence (Karanth et al., 2012)	0 1	Awareness programmes are not conducted Awareness programs are conducted

Table S5.1 Description of the site and survey-specific covariates, along with *a priori* prediction on occupancy and detection of the large mammals across the Eastern and Western Ghats of Tamil Nadu. All the covariates were z-transformed prior to the analysis.

Covariate name	Covariate type	Predicted relationship	Approach used for quantification	Data Source
<i>Prey abundance</i>				
Large prey	Site-specific	+	Calculated sum of proportion of segments where sign evidence of each large prey species (sambar and gaur) presence were recorded, across survey transect in a grid	Field data
Medium prey	Site-specific	+	Calculated sum of proportion of segments where sign evidence of each medium prey species (wild pig, chital and blackbuck) presence were recorded, across survey transect in a grid	Field data
Small prey	Site-specific	+	Calculated sum of proportion of segments where sign evidence of each small prey species (black-naped hare, mouse deer and barking deer) presence were recorded, across survey transect in a grid	Field data
*ChitalSambar	Site-specific	+	Calculated sum of proportion of segments where sign evidence of chital and sambar presence were recorded, across survey transect in a grid	Field data
<i>Habitat features</i>				

Tree/stem density (per ha)	Site-specific	+	Calculated density of trees from 10 m radii plots survey transect in a grid	Field data
	Survey-specific	+	Calculated density of trees for every 10 m radius plot at every 400 m segment of survey transect	Field data
Mean GBH (cm)	Survey-specific	+/-	Calculated the mean of measured GBH of trees for every 10m radius plot at every 400m segment of survey transect	Field data
Percentage of canopy cover	Site-specific	+	Calculated the average of visually quantified percentage of canopy cover at four places in each 10m radius plot from survey transect in a grid	Field data
Percentage of shrub cover	Survey-specific	-	Calculated the average of visually quantified percentage of shrub cover for every 5m radius plot at every 400 m segment of survey transect	Field data
Shrub density (per ha)	Site-specific	-	Calculated the density of shrub clumps at four places in each 5m radius plot from survey transect in a grid	Field data
	Survey-specific	-	Calculated the density of shrub clumps at four places for every 5m radii plots at every 400m segment of survey transect	Field data
Grass height (cm)	Survey-specific	+/-	Calculated the average of the measured grass height at five places, for every 10m radii plots at every 400m segment of survey transect	Field data
Percentage of grass cover	Site-specific	+	Calculated the average of visually quantified percentage of grass cover at five places in each 10m radius plot from survey transect in a grid	Field data

River length	Site-specific	+	Calculated total length of rivers within each 10x10km grid, using summary tool in Arc Map 10.3	Spatial layer (Lin et al., 2021)
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Human disturbance

Wood cutting/lopping	Site-specific	-	Recorded the presence/absence of wood cutting/lopping across survey transect in a grid	Field data
Grass/bamboo cutting	Site-specific	-	Recorded the presence/absence of grass/bamboo cutting across survey transect in a grid	Field data
Human/livestock track	Survey-specific	-	Recorded the presence/absence of human/livestock track at every 400m segment of the survey transect	Field data
	Site-specific	-	Calculated the proportion of segments where human/livestock track was detected across survey transect in a grid	Field data
Human sighted	Survey-specific	-	Recorded the presence/absence of human seen within 100m distance at each sampling plot of 400m segment of the survey transect	Field data
	Site-specific	-	Calculated the proportion of segments where humans were sighted within 100 m distance from each sampling plot across survey transect in a grid	Field data

Livestock sighted	Survey-specific	-	Recorded the presence/absence of livestock sighted within 100 m distance at each sampling plot of 400 m segment of the survey transect	Field data
	Site-specific	-	Calculated the proportion of segments where livestock were sighted within 100m distance from each sampling plot across survey transect in a grid	Field data
Livestock abundance	Site-specific	-	Calculated the sum of proportion of segments where sign evidences for each livestock (cow, buffalo, goat, and sheep) presence were recorded, across survey transect in a grid	Field data
Population density	Site-specific	-	Calculated the mean of population density across each 10x10km grid using extract tool in Arc Map 10.3	Spatial layers (CIESIN, 2018)
Settlement density (in km ²)	Site-specific	-	Calculated area of settlement in each 10 x10 km grid using Spatial Analyst tool (tabulate area) in Arc Map 10.3	Spatial layers (Roy et al., 2015)
Season	Site-specific	+/-	Classified wet season and dry season as 1 and 0 respectively based on the sampling period of survey grid	Field data
Sampling effort (m)	Site-specific	+/-	Calculated total distance surveyed across survey transect in a grid	Field data

Habitat fragmentation

Forest cover (in km ²)	Site-specific	+	Calculated area of forest cover, using spatial analyst tool (tabulate area) in Arc Map10.3	Spatial layers (Roy et al., 2015)
Forest cover loss/gain (in km ²)	Site-specific	-/+	Calculated area of forest cover loss/gain, using spatial analyst tool (tabulate area) in Arc Map 10.3	Spatial layers (Bhuvan et al., 2017)

Patch (km ²)	Site-specific	-	Calculated area of patch, using landscape fragmentation analysis extension tool v.20 (Parent, 2009) in Arc Map 10.3	Spatial layers (Roy et al., 2015)
Edge (km ²)	Site-specific	-	Calculated area of edge, using landscape fragmentation analysis extension tool v.20 (Parent, 2009) in Arc Map 10.3	Spatial layers (Roy et al., 2015)
Perforated (km ²)	Site-specific	-	Calculated perforated forest area, using landscape fragmentation analysis extension tool v.20 (Parent, 2009) in Arc Map 10.3	Spatial layers (Roy et al., 2015)
Core One (km ²)	Site-specific	+/-	Calculated core (<250 acres) forest area, using landscape fragmentation analysis extension tool v.20 (Parent, 2009) in Arc Map 10.3	Spatial layers (Roy et al., 2015)
Core Two (km ²)	Site-specific	+	Calculated core (250-500 acres) forest area, using landscape fragmentation analysis extension tool v.20 (Parent, 2009) in Arc Map 10.3	Spatial layers (Roy et al., 2015)
Core Three (km ²)	Site-specific	+	Calculated core (>500 acres) forest area, using landscape fragmentation analysis extension tool v.20 (Parent, 2009) in Arc Map 10.3	Spatial layers (Roy et al., 2015)
Road length	Site-specific	-	Calculated total length of road within each 10x10km grid using summary tool in Arc Map 10.3	Spatial layers (Meijer et al., 2018)

**GBH-Girth at Breast Height. ChitalSambar- Large carnivores feed largely (>80%) on chital and sambar (Ramesh et al., 2012). With the high occurrence of aggressive prey species such as wild pig that represent the medium prey category, actual prey may be misrepresented as the major prey species. So, a separate category is made exclusively for chital and sambar*

Table S5.2 Summary of optimized least cost path metrics of tiger across various forest ranges in the Western Ghats and Eastern Ghats part of Tamil Nadu.

Link No.	Forest Range 1	Forest Range 2	Euc_Dist (km)	CWD (km)	LCP (km)	CWD: Euc_Dist	CWD: LCP	Length_eff
1	Madukkarai	Coimbatore South	50.00	79.75	72.43	1.59	1.10	0.69
2	Madukkarai	TN Palayam	86.02	150.60	138.99	1.75	1.08	0.62
3	Coimbatore South	Singara/Masinagudi	36.06	40.64	38.28	1.13	1.06	0.94
4	Coimbatore South	Sigur	22.36	25.14	24.14	1.12	1.04	0.93
5	Coimbatore South	TN Palayam	53.85	70.85	66.57	1.32	1.06	0.81
6	O' Valley	Singara/Masinagudi	22.36	25.63	24.14	1.15	1.06	0.93
7	O' Valley	Sigur/Kattabettu	31.62	36.11	34.14	1.14	1.06	0.93
8	Bhavanisagar	TN Palayam	30.00	41.63	38.28	1.39	1.09	0.78
9	TN Palayam	Bargoor/Thattakkarai/ Chennampatti	44.72	55.58	48.28	1.24	1.15	0.93
10	Nelakotta/Bitherkka du	Jeeragahalli	50.99	56.40	54.14	1.11	1.04	0.94
11	Nelakotta/Bitherkka du	Thalavadi/Hassanur	72.80	80.96	78.28	1.11	1.03	0.93
12	Mudumalai	Jeeragahalli	41.23	45.82	44.14	1.11	1.04	0.93

13	Theppakkadu	Jeeragahalli	31.62	35.49	34.14	1.12	1.04	0.93
14	Masinagudi	Jeeragahalli	22.36	25.01	24.14	1.12	1.04	0.93
15	Jeeragahalli	Thalavadi/Hassanur	22.36	24.96	24.14	1.12	1.03	0.93
16	Thalavadi/Hassanur	Chennampatti	63.25	87.56	68.28	1.38	1.28	0.93
17	Geermalam	Chennampatti	53.85	77.32	58.28	1.44	1.33	0.92

Euc_Dist-Euclidean distance; *CWD*- Cost-weighted distance; *LCP*- Length of the least cost path; *Length_eff*- Length efficiency (Euclidian distance/Shape length).

Table S5.3 Summary of optimized least cost path metrics of leopard across various forest ranges in the Western Ghats and Eastern Ghats part of Tamil Nadu.

Link No.	Forest Range 1	Forest Range 2	Euc_Dist (km)	CWD (km)	LCP (km)	CWD: Euc_Dist	CWD: LCP	Length_eff
1	Boluvampatti	O' valley	58.31	243.11	62.43	4.17	3.89	0.93
2	Coimbatore south/Boluvampatti	Periyanaikkanpalayam	14.14	54.45	20.00	3.85	2.72	0.71
3	Coimbatore south/Boluvampatti	O' valley	50.00	210.51	52.43	4.21	4.02	0.95
4	Coimbatore south	Sirumugai/Mettupalayam	31.62	102.29	48.28	3.23	2.12	0.65
5	Coimbatore south	T.N Palayam	84.85	417.81	110.71	4.92	3.77	0.77
6	Periyanaikkanpalayam	Coonoor/Mettupalayam	22.36	33.97	24.14	1.52	1.41	0.93
7	Periyanaikkanpalayam	Parsons valley	36.06	164.36	44.14	4.56	3.72	0.82
8	Periyanaikkanpalayam	Coonoor/Mettupalayam	20.00	66.40	28.28	3.32	2.35	0.71

9	Periyanaikkanpalayam	Sirumugai/Mettupalayam	22.36	96.25	38.28	4.30	2.51	0.58
10	Karamadai	Parsons valley	28.28	150.26	34.14	5.31	4.40	0.83
11	Coonoor	Sirumugai/Kothagiri	22.36	58.02	24.14	2.59	2.40	0.93
12	Coonoor	Masinagudi/Sigur	30.00	171.59	58.28	5.72	2.94	0.51
13	Coonoor	Nilgiri slopes/Jeeragahalli	31.62	142.19	48.28	4.50	2.94	0.65
14	Coonoor/Mettupalayam	Parsons valley	31.62	149.91	34.14	4.74	4.39	0.93
15	Coonoor/Mettupalayam	Nilgiri slopes/Kothagiri	22.36	62.17	24.14	2.78	2.58	0.93
16	Coonoor/Mettupalayam	Masinagudi/Sigur	31.62	141.64	48.28	4.48	2.93	0.65
17	Coonoor/Mettupalayam	Nilgiri slopes/Jeeragahalli	30.00	112.24	38.28	3.74	2.93	0.78
18	Sirumugai/Mettupalayam	Nilgiri slopes/Bhavanisagar	22.36	79.56	24.14	3.56	3.30	0.93
19	Sirumugai/Mettupalayam	Sathyamangalam/Hassanur	36.06	124.25	38.28	3.45	3.25	0.94
20	Sirumugai/Mettupalayam	T.N Palayam	58.31	353.30	68.28	6.06	5.17	0.85
21	Parsons valley	Masinagudi/Sigur	28.28	100.55	28.28	3.56	3.56	1.00
22	Sirumugai/Kothagiri	Masinagudi/Sigur	28.28	113.56	34.14	4.02	3.33	0.83
23	Sirumugai/Kothagiri	Nilgiri slopes/Jeeragahalli	22.36	84.16	24.14	3.76	3.49	0.93
24	Sirumugai/Kothagiri	Sathyamangalam/Hassanur	28.28	88.25	28.28	3.12	3.12	1.00
25	Charambadi/Pandalur	Naduvattam/Pykara	30.00	182.45	38.28	6.08	4.77	0.78

26	Charambadi/Pandalur	Theppakkadu	31.62	212.21	34.14	6.71	6.22	0.93
27	Naduvattam/Pykara	Masinagudi/Sigur	22.36	87.50	24.14	3.91	3.62	0.93
28	Nilgiri slopes/Bhavanisagar	T.N Palayam	41.23	273.74	44.14	6.64	6.20	0.93
29	Nelakotta/Bitherkkadu	Jeeragahalli	50.99	286.60	54.14	5.62	5.29	0.94
30	Nelakotta/Bitherkkadu	Urigam	138.92	1927.65	226.57	13.88	8.51	0.61
31	Theppakkadu	Jeeragahalli	31.62	147.15	34.14	4.65	4.31	0.93
32	Nilgiri slopes/Jeeragahalli	Thalavadi	22.36	98.49	24.14	4.40	4.08	0.93
33	Nilgiri slopes/Jeeragahalli	Geermalam	28.28	120.21	28.28	4.25	4.25	1.00
34	Jeeragahalli	Thalavadi	20.00	127.49	28.28	6.37	4.51	0.71
35	Jeeragahalli	Geermalam	31.62	185.26	42.43	5.86	4.37	0.75
36	Jeeragahalli	Urigam	92.20	1696.30	180.71	18.40	9.39	0.51
37	Hassanur/Kadambur	Thattakarai	42.43	501.15	68.28	11.81	7.34	0.62
38	Geermalam	Thattakarai	44.72	562.39	82.43	12.58	6.82	0.54
39	Geermalam	Urigam	64.03	1573.09	154.85	24.57	10.16	0.41
40	Bargoor/Thattakarai/Chennampatti	Thattakarai	14.14	65.40	20.00	4.62	3.27	0.71
41	Thattakarai	Urigam	30.00	1032.76	78.28	34.43	13.19	0.38

Euc_Dist-Euclidean distance; *CWD*- Cost-weighted distance; *LCP*- Length of the least cost path; *Length_eff*- Length efficiency (Euclidian distance/Shape length).

Table S5.4. Summary of optimized least cost path metrics of dhole across various forest ranges in the Western Ghats and Eastern Ghats part of Tamil Nadu.

Link No.	Forest Range 1	Forest Range 2	Euc_Dist (km)	CWD (km)	LCP (km)	CWD: Euc Dist	CWD: LCP	Length_eff
1	Karamadai	TN Palayam	80.62	89.61	86.57	1.11	1.04	0.93
2	Sigur/Kattabettu	Theppakkadu	22.36	24.35	24.14	1.09	1.01	0.93
3	Sigur/Kattabettu	Nilgiri slopes/Jeeragahalli	22.36	24.30	24.14	1.09	1.01	0.93
4	Nilgiri Bhavanisagar	slopes/ Nilgiri slopes/Jeeragahalli	22.36	24.24	24.14	1.08	1.00	0.93
5	Nilgiri Bhavanisagar	slopes/ TN Palayam	41.23	44.89	44.14	1.09	1.02	0.93
6	Theppakkadu	Jeeragahalli	31.62	34.33	34.14	1.09	1.01	0.93
7	Masinagudi	Jeeragahalli	22.36	24.28	24.14	1.09	1.01	0.93
8	Nilgiri Jeeragahalli	slopes/ Thalavadi	22.36	24.26	24.14	1.08	1.00	0.93
9	Nilgiri slopes/Jeeragahalli	Geermalam	28.28	28.45	28.28	1.01	1.01	1.00
10	Jeeragahalli	Geermalam	31.62	34.53	34.14	1.09	1.01	0.93
11	Jeeragahalli	Urigam	106.30	511.73	194.85	4.81	2.63	0.55
12	Hassanur/Kadambur	Thattakarai/Bargoor	31.62	34.75	34.14	1.10	1.02	0.93

13	Kadambur	Geermalam	31.62	34.59	34.14	1.09	1.01	0.93
14	Kadambur	Thattakkarai	22.36	24.48	24.14	1.09	1.01	0.93
15	Anthiyoor	Hogenakkal	53.85	406.80	92.43	7.55	4.40	0.58
16	Anthiyoor	Hogenakkal	67.08	406.75	92.43	6.06	4.40	0.73
17	Anthiyoor	Palacode	80.62	421.06	106.57	5.22	3.95	0.76
18	Geermalam	Thattakkarai	44.72	56.61	54.14	1.27	1.05	0.83
19	Geermalam	Urigam	70.71	474.34	156.57	6.71	3.03	0.45
20	Geermalam	Urigam	78.10	478.78	160.71	6.13	2.98	0.49
21	Thattakkarai	Urigam	31.62	427.47	108.28	13.52	3.95	0.29
22	Chennampatti	Urigam	30.00	417.41	98.28	13.91	4.25	0.31
23	Hogenakkal	Anchetty/Urigam	22.36	24.45	24.14	1.09	1.01	0.93

Euc_Dist-Euclidean distance; CWD- Cost-weighted distance; LCP- Length of the least cost path; Length_eff- Length efficiency (Euclidian distance/Shape length).

Table S5.5. Summary of optimized least cost path metrics of elephant across various forest ranges in the Western Ghats and Eastern Ghats part of Tamil Nadu.

Link No.	Forest Range1	Forest Range2	Euc_Dist (km)	CWD (km)	LCP (km)	CWD: Euc_Dist	CWD: LCP	Length_eff
1	Madukkarai	Coimbatore south	22.36	24.42	24.14	1.09	1.01	0.93
2	Madukkarai	Sirumugai/Mettupalayam	50.00	65.30	58.28	1.31	1.12	0.86
3	Madukkarai	TN Palayam	86.02	133.68	124.85	1.55	1.07	0.69
4	Boluvampatti	Periyanaikkanpalayam	22.36	24.37	24.14	1.09	1.01	0.93
5	Coimbatore South	Karamadai	22.36	24.31	24.14	1.09	1.01	0.93
6	Periyanaikkanpalayam	Nelakotta/Bitherkkadu	64.03	78.30	72.43	1.22	1.08	0.88
	Karamadai	Nelakotta/Bitherkkadu	56.57	68.25	62.43	1.21	1.09	0.91
7	Sirumugai/Mettupalayam	TN Palayam	53.85	68.38	66.57	1.27	1.03	0.81
8	Singara/Masinagudi	Nelakotta/Bitherkkadu	31.62	34.44	34.14	1.09	1.01	0.93
9	Singara/Masinagudi	Mudumalai	22.36	24.32	24.14	1.09	1.01	0.93
10	Singara/Masinagudi	Nilgiri slopes/Jeeragahalli	22.36	24.27	24.14	1.09	1.01	0.93
11	Nilgiri slopes/ Bhavanisagar	Nilgiri slopes/Jeeragahalli	22.36	24.20	24.14	1.08	1.00	0.93
12	Bhavanisagar	TN Palayam	30.00	39.34	38.28	1.31	1.03	0.78
13	TN Palayam	Kadambur	22.36	24.42	24.14	1.09	1.01	0.93
14	TN Palayam	Bargoor/Thattakkarai/ Chennampatti	44.72	49.15	48.28	1.10	1.02	0.93
15	Nelakotta/Bitherkkadu	Jeeragahalli	50.99	54.57	54.14	1.07	1.01	0.94

16	Nelakotta/Bitherkkadu	Thalavadi/Hassanur	72.80	78.73	78.28	1.08	1.01	0.93
17	Mudumalai	Jeeragahalli	41.23	44.45	44.14	1.08	1.01	0.93
18	Theppakkadu	Jeeragahalli	31.62	34.38	34.14	1.09	1.01	0.93
19	Masinagudi	Jeeragahalli	22.36	24.29	24.14	1.09	1.01	0.93
20	Sathyamangalam/Hassanur	Kadambur	22.36	24.33	24.14	1.09	1.01	0.93
21	TN Palayam	Geermalam	22.36	24.45	24.14	1.09	1.01	0.93
22	Jeeragahalli	Thalavadi/Hassanur	22.36	24.20	24.14	1.08	1.00	0.93
23	Thalavadi/Hassanur	Thattakarai	53.85	66.01	64.14	1.23	1.03	0.84
24	Geermalam	Thattakarai	44.72	55.97	54.14	1.25	1.03	0.83
25	Geermalam	Thattakarai	28.28	35.37	34.14	1.25	1.04	0.83

Euc_Dist-Euclidean distance; CWD- Cost-weighted distance; LCP- Length of the least cost path; Length_eff- Length efficiency (Euclidian distance/Shape length).

Table S5.6. Summary of optimized least cost path metrics of gaur across various forest ranges in the Western Ghats and Eastern Ghats part of Tamil Nadu.

Link No.	Forest Range1	Forest Range2	Euc_Dist (km)	CWD (km)	LCP (km)	CWD: Euc_Dist	CWD: LCP	Length_eff
1	Coimbatore south	Coonoor/Mettupalayam	30.00	38.74	38.28	1.29	1.01	0.78
2	Coimbatore South	Sirumugai/Mettupalayam	31.62	48.79	48.28	1.54	1.01	0.65
3	Coimbatore South	TN Palayam	78.10	116.34	114.85	1.49	1.01	0.68
4	Karamadai	Theppakkadu	44.72	52.05	48.28	1.16	1.08	0.93
5	Sirumugai/Mettupalayam	TN Palayam	53.85	67.55	66.57	1.25	1.01	0.81
6	Theppakkadu	Nilgiri slopes/Jeeragahalli	22.36	24.29	24.14	1.09	1.01	0.93
7	Nilgiri Bhavanisagar	slopes/ TN Palayam	40.00	48.53	48.28	1.21	1.01	0.83
8	Nilgiri Bhavanisagar	slopes/ Sathyamangalam	22.36	24.18	24.14	1.08	1.00	0.93
9	TN Palayam	Sathyamangalam	22.36	24.35	24.14	1.09	1.01	0.93
10	TN Palayam	Anthiyoor	22.36	24.24	24.14	1.08	1.00	0.93
11	Theppakkadu	Jeeragahalli	31.62	34.29	34.14	1.08	1.00	0.93
12	Theppakkadu	Thalavadi/Hassanur	53.85	58.49	58.28	1.09	1.00	0.92
13	Masinagudi	Jeeragahalli	22.36	24.23	24.14	1.08	1.00	0.93
14	Sathyamangalam	Geermalam	22.36	24.29	24.14	1.09	1.01	0.93
15	Sathyamangalam/TN Palayam	Anthiyoor	22.36	24.29	24.14	1.09	1.01	0.93

16	TN Palayam	Anthiyoor	22.36	24.30	24.14	1.09	1.01	0.93
17	TN Palayam	Thattakarai/Bargoor	22.36	24.33	24.14	1.09	1.01	0.93
18	Jeeragahalli	Thalavadi/Hassanur	22.36	24.20	24.14	1.08	1.00	0.93
19	Hassanur	Geermalam	22.36	24.29	24.14	1.09	1.01	0.93
20	Anthiyoor	Bargoor/Thattakkarai/ Chennampatti	22.36	24.37	24.14	1.09	1.01	0.93
21	Thalavadi/Hassanur	Thattakarai	53.85	69.00	64.14	1.28	1.08	0.84
22	Geermalam	Thattakarai	44.72	58.97	54.14	1.32	1.09	0.83
23	Geermalam	Thattakarai	28.28	38.63	34.14	1.37	1.13	0.83

Euc_Dist-Euclidean distance; CWD- Cost-weighted distance; LCP- Length of the least cost path; Length_eff- Length efficiency (Euclidian distance/Shape length).

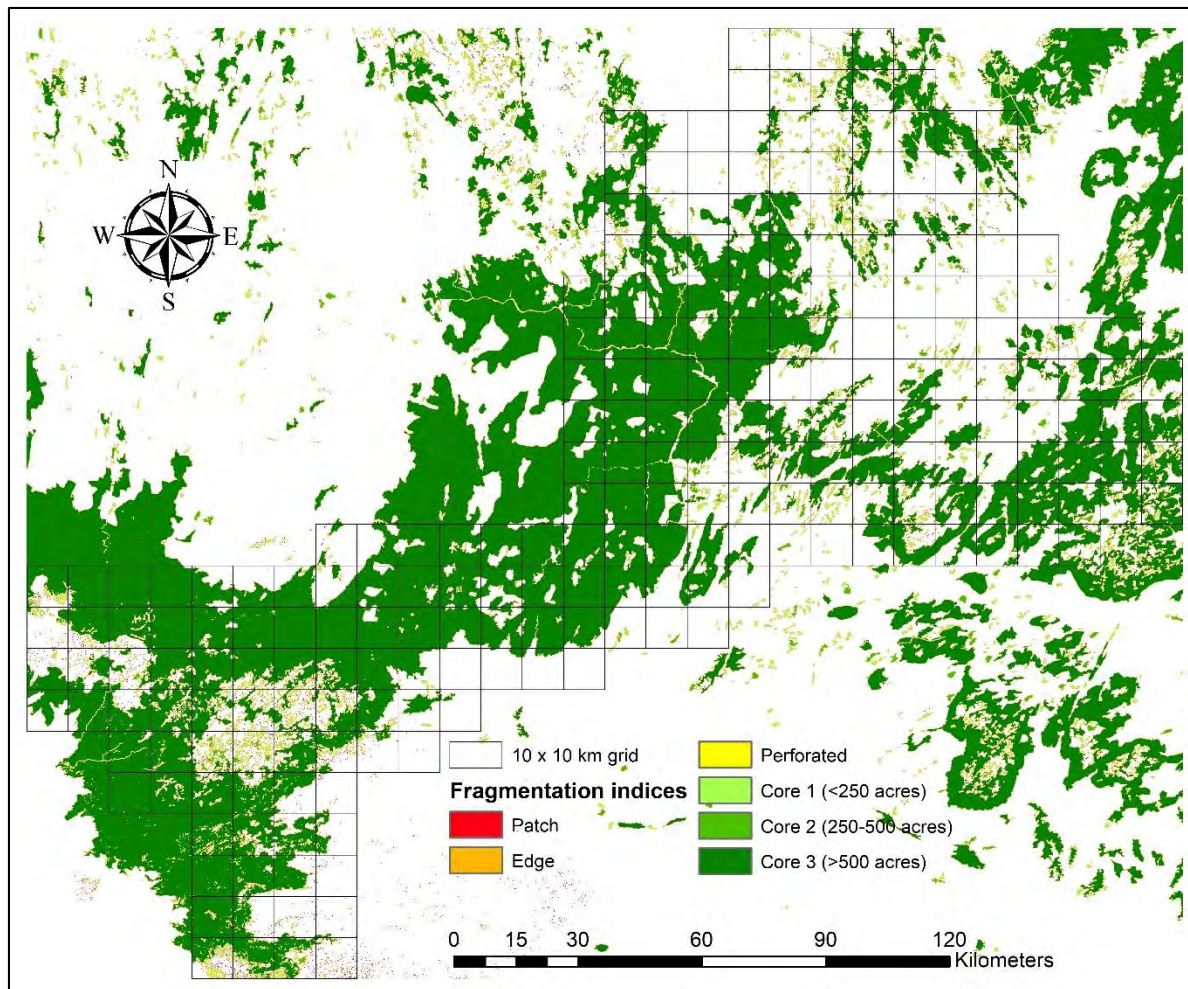


Figure S5.1 Intensity of fragmentation in the Eastern and Western Ghats part of Tamil Nadu



Photo plate 1. Agricultural fields adjacent to the natural forest habitat.



Photo plate 2. Interviewing villagers residing in forest fringe area.

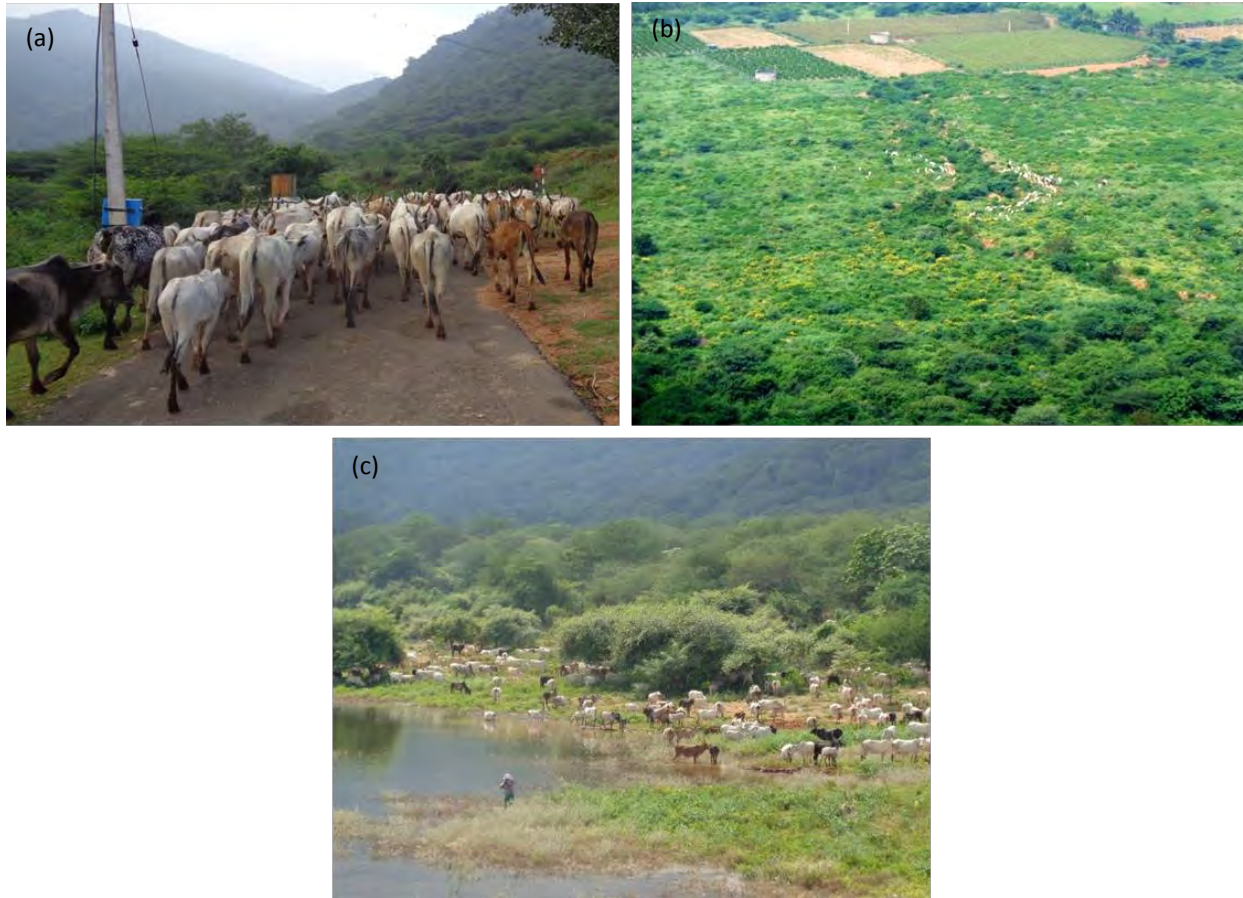


Photo plate 3. Livestock herded to the forest from human-wildlife interface area (a, b); livestock utilising the water source inside the forested area (c).



Photo plate 4. Exploring indirect sign evidences of large mammals, prey species and human disturbances along the human-wildlife interface area within the Forest Reserve (a); conducting vegetation survey (b); hoof marks of gaur (c); pug marks of leopard (d).



Photo plate 5. Faecal pellets of (a) leopard, (b) spotted deer, (c) dhole, (d) elephant, (e) tiger, (f) black-naped hare.



Photo plate 6. Elephant herd moving from Denkanikota (Hosur Forest Division, Tamil Nadu State) towards Bannerghatta National Park (Karnataka State).

Publications

Publications

- **Milda, D.**, Ashish, K., Ramesh, T., Kalle, R., and Thanikodi, M. (2023). *Evaluation of anthropogenic pressure on the occupancy patterns of large mammals in the Western and Eastern Ghats. Landscape Ecology*, 38(2), 409-422.
- Ramesh, T., **Milda, D.**, Kalle, R., Gayathri, V., Thanikodi, M., Ashish, K., and Giordano, A. J. (2022). *Drivers of human-megaherbivore interactions in the Eastern and Western Ghats of southern India. Journal of environmental management*, 316, 115315.
- **Milda, D.**, Ramesh, T., Kalle, R., Gayathri, V., and Thanikodi, M. (2020). *Ranger survey reveals conservation issues across Protected and outside Protected Areas in southern India. Global Ecology and Conservation*, 24, e01256.
- Ramesh, T., Kalle, R., **Milda, D.**, Gayathri, V., Thanikodi, M., Ashish, K., and Giordano, A. J. (2020). *Patterns of livestock predation risk by large carnivores in India's Eastern and Western Ghats. Global Ecology and Conservation*, 24, e01366.

Conference Proceedings

- **Milda, D.**, Ashish, K., Ramesh, T., and Kalle, R., (2024). *Wild horizons: insights to large carnivore conservation in fragmented habitats. 2024 Ecological Society of America Annual Meeting, held at Long Beach, California, USA (ESA 2024) (August, 2024) (Oral presentation).*
- **Milda, D.**, Ashish, K., Ramesh, T., and Kalle, R., (2023). *Living amidst anthropogenic pressure: a large mammal conservation perspective. 13th International Mammalogical Congress, held virtually at Anchorage, Alaska, USA (IMC-13) (July, 2023) (Oral presentation).*
- **Milda, D.**, Ashish, K., Ramesh, T., and Kalle, R., (2023). *Patterns of large mammal occupancy patterns across anthropogenic gradients of the Western and Eastern Ghats in southern India. The 59th Annual meeting of the Association for Tropical Biology and Conservation (ATBC) 2023 (July, 2023) (Oral presentation).*
- **Milda, D.**, Ashish, K., Ramesh, T., and Kalle, R., (2023). *Surviving amidst anthropogenic pressure: a large mammal conservation perspective. Young Scientist Conference, India International Science Festival 2022 (January, 2023) (Poster presentation).*

- **Milda, D., Ramesh, T., Kalle, R., Gayathri, V., and Thanikodi, M.** *Barriers to wildlife conservation: Forest Ranger's perspective on human-wildlife interaction in southern India. International Congress for Conservation Biology (ICCB) held Virtually, Rwanda, organised by Society for Conservation Biology's (SCB), Washington DC. USA. (December, 2021) (Speed talk).*
- **Milda, D., Ramesh, T., Kalle, R., Gayathri, V., and Thanikodi, M.** *Ranger survey reveals conservation issues across Protected and outside Protected Areas in southern India. International Poster Presentation Competition, 2020 (October, 2020) (Poster presentation).*



Evaluation of anthropogenic pressure on the occupancy patterns of large mammals in the Western and Eastern Ghats

David Milda¹ · K. Ashish² · Tharmalingam Ramesh³ · Riddhika Kalle⁴ · M. Thanikodi

Received: 24 August 2022 / Accepted: 29 December 2022
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Abstract

Context Habitat loss limits the dispersal of wide-ranging large mammals. It is pivotal to study the ecological and anthropogenic factors driving the habitat occupancy of large mammals for their long-term conservation and reduction of negative human–wildlife interactions.

Objective To evaluate how the habitat occupancy pattern of the large mammals varies across a gradient of anthropogenic pressures.

Methods We conducted ecological sign surveys across nine forest divisions including Protected Areas (PAs) and outside PAs, along the Western and Eastern Ghats of Tamil Nadu, India. We used

systematic grid-based Markovian occupancy model to study the effect of ecological and anthropogenic variables (prey abundance, habitat features, direct human disturbance and habitat fragmentation) on tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), elephant (*Elephas maximus*) and gaur (*Bos gaurus*) occupancy at 100 km² scale.

Results Tiger and dhole occupancy was driven by the abundance of large and medium-sized prey. However, leopards also relied on the available small prey species and utilised fragmented forest patches. Large mammal occupancy increased in contiguous forests with water availability and decreased in landscapes with increased human disturbances and habitat fragmentation. Tiger occupancy was highly confined towards contiguous PA network while the rest of them had scattered but concentrated occupancy towards PAs.

Conclusions The dependency of large mammals on contiguous forests suggests improving the quality and connectivity of forested habitats for their dispersal and reducing negative human–wildlife interactions. The low occupancy areas require urgent habitat management intervention to reduce grazing pressure and restore degraded habitats to sustain viable large mammal population at landscape-level.

Keywords Carnivores · Habitat fragmentation · Herbivores · Human disturbance · Large mammal distribution · Prey density

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10980-022-01592-9>.

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Published online: 06 January 2023

Springer



Research article

Drivers of human-megaherbivore interactions in the Eastern and Western Ghats of southern India

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ARTICLE INFO

Keywords:

Asian elephant
Conflict hotspots
Risk mapping
Human-wildlife conflict
Crop damage
Indian bison
Megaherbivore
Human-wildlife interface

ABSTRACT

The global effort to protect megaherbivore populations is largely dependent on how human-wildlife conflict is identified, prioritized, and remedied. We examined the socio-ecological and landscape-scale factors determining spatial patterns of human-megaherbivore (Asian elephant *Elephas maximus* and gaur *Bos gaurus*) interactions across sixteen Forest Divisions in Tamil Nadu, India. Using a systematic grid-based design, we conducted questionnaire-based surveys of 1460 households at the human-wildlife interface adjacent to Protected Areas, Reserve Forest and Fringe Areas. We specifically collected information on elephant and gaur conflict incidents (e.g., human death/injuries, property damage, and crop-raiding), cropland type, extent of crop area and area lost to crop-raiding, from each household. We found that human-elephant conflict increased with percentage of crop cover, diversity of major and minor crops grown, proximity to water source, flat terrain, and lower rates of precipitation. Human-gaur conflict was greatest with a high diversity of major crops, proximity to water source, moderate precipitation, and more undulating terrain. We identified ca. 7900 km² hotspot area of contiguous high-intensity elephant conflict. For gaur, we identified high-frequency conflict hotspot areas covering ca. 625 km², which were patchily distributed, highly localised, and attributed mostly to the recent changing land-use patterns. Our findings will help policymakers and park managers in developing landscape-scale human-wildlife conflict mitigation plans in the identified conflict hotspots.

1. Introduction

Megaherbivores have a far-reaching impact on the functioning and balancing of the ecosystem. They are important pollinators and seed dispersers that support ecosystem processes and are proficient in maintaining the forest structure (Danell et al., 2003; Campos-Arceiz and Blake, 2011; Malhi et al., 2016). Among the megaherbivores, the elephant is a critical 'ecosystem engineer' that maintains the structure and heterogeneity of the landscape (Campos-Arceiz and Blake, 2011). Their ability to consume and disperse large piles of different varieties of seeds makes them efficient seed dispersers (Schupp et al., 2010; Corlett, 2017; Tan et al., 2021) or rather 'mega-gardeners of the forest' (Campos-Arceiz and Blake, 2011). Additionally, they are 'habitat facilitators' for various large and small mammal species; as they browse the canopy, the openness of the habitat will be retained with improved grass

productivity that provides a safe refuge for the prey species, thereby decreasing their predation risk (Coverdale et al., 2016). Ungulates like gaur have a crucial role in maintaining the grasslands, controlling plant growth and density, and are the major prey for the large carnivores such as tigers (Danell et al., 2003; Asokkumar et al., 2016). Withal, the populations of large mammalian species have experienced a dramatic decline due to habitat alteration, poaching, and other anthropogenic causes, globally (Ceballos and Ehrlich, 2002; Foley et al., 2005). In India, the increasing and related threats of habitat loss and fragmentation (Choudhury, 2004; Kumar et al., 2004) present a grim challenge to maintaining already diminishing migratory and dispersal corridors for wide-ranging species (Tilman et al., 2017). This is noteworthy because India and other tropical countries are considered as the last refuges of many large mammals (Oguru et al., 2005; Gubbi, 2012). Under the pressures of growing human populations, increasing conflict between

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<https://doi.org/10.1016/j.jenvman.2022.115315>

Received 6 March 2022; Received in revised form 4 May 2022; Accepted 12 May 2022
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Original Research Article

Ranger survey reveals conservation issues across Protected and outside Protected Areas in southern India

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ARTICLE INFO

Article history:

Received 21 June 2020

Received in revised form 31 August 2020

Accepted 31 August 2020

Keywords:

Forest ranger survey

Human-wildlife conflict

Human-wildlife management

Outside protected area

Protected area

Poaching

ABSTRACT

Intensifying human-wildlife interaction requires effective human-wildlife management strategies. In India, forests designated as Protected Areas (PAs) have better wildlife protection measures unlike Reserved Forests (outside PAs) which are undervalued, although both support similar kinds of wildlife. Wildlife conservation planning and policy-level decision making become incomplete without addressing wildlife management issues outside PA along with PAs as the former act as a buffer/corridor for PAs. We conducted a semi-structured questionnaire survey with the Forest Range Officers (FROs) belonging to nine PAs and seven outside PAs across the Western and Eastern Ghats part of Tamil Nadu State, southern India. We collected information on the human-wildlife interactions, mitigation measures carried out, poaching incidents, and availability of manpower and resources. Over 50% of the FROs reported an increase in Human-Wildlife Conflict (HWC) incidents for the past five years. Major species involved in conflict in PAs and outside PAs were elephant (*Elephas maximus*), wild pig (*Sus scrofa*), leopard (*Panthera pardus*), bonnet macaque (*Macaca radiata*), followed by sloth bear (*Melursus ursinus*), sambar (*Rusa unicorn*) (more in PAs), gaur (*Bos gaurus*) (more in outside PAs), dhole (*Cuon alpinus*), chital (*Axis axis*), and tiger (*Panthera tigris*). There were no variations in the mitigation measures employed in PAs and outside PAs. The number of schemes ($N = 8-10$) available for wildlife management was similar, but to a certain extent, the fund availability was more insufficient outside PAs than in PAs. Tiger (only in PAs), leopard, elephant, and pangolin (*Manis crassicaudata*) were amongst the fourteen wildlife species poached in the PAs and outside PAs, although wild pig, sambar, black-naped hare (*Lepus nigricollis*), and chital dominated the list. Prevalent methods for poaching were snares, trained dogs, guns (dominant in PAs), followed by hand-made bombs, poisoning, cage traps, electric traps (only outside PAs), and food baits. Over 50% of the FROs reported decreases in poaching incidences with improved wildlife management strategies for the past five years. PAs had a higher number of anti-poaching camps with anti-poaching watchers than outside PAs. Our study highlighted the disparity in resource allocation among PAs and outside PAs though the intensity of conservation issues was similar. Inadequate availability of resources affected the effective management of conflict species which leads to increase risk of HWC. This is the first study to highlight the success/failure of human-wildlife management depending on reducing lacunas in management effectiveness of PAs and outside PAs for managing at a larger landscape level beyond PAs.

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<https://doi.org/10.1016/j.gecco.2020.e01256>

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Patterns of livestock predation risk by large carnivores in India's Eastern and Western Ghats

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ARTICLE INFO

Article history:

Received 10 July 2020

Received in revised form 10 November 2020

Accepted 10 November 2020

Keywords:

Conflict mitigation

Human-wildlife conflict hotspots

Human-wildlife interface

Large carnivores

Livestock predation

Predation risk

ABSTRACT

Large scale spatial patterns of livestock predation risk from multiple co-predators are fundamental to applied conservation planning. Here, we examined important ecological, social, and landscape attributes explaining spatial patterns of human-carnivore interactions. We used a systematic grid-based framework, across an area of 14,200 km² of sixteen Forest Divisions at the human-wildlife interface encompassing Protected Areas, Reserved Forest and Fringe Areas at the human-wildlife interface in the Eastern and Western Ghats, India. The data was collected on livestock depredation incidents from the tiger (*Panthera tigris*), leopard (*Panthera pardus*), and dhole (*Cuon alpinus*) for the past five years, through semi-structured interviews ($n = 1460$) of local communities. We examined socio-ecological (i.e. livestock abundance and forest dependency) and landscape attributes (i.e. forest cover, climate and topographic) influencing the depredation events from each carnivore species. We found that livestock predation risk by the tiger, leopard and dhole was driven by the size of livestock species, the dependency of local people on the forest, topography, proximity to water body and the forest boundary, precipitation, and forest cover. Risk of predation from leopard and dhole exhibited high spatial overlap, and predation by leopards was higher than dhole and tiger. Livestock predation by leopard and dhole was frequent in open areas of Reserved Forest and buffer zones, while that from tiger occurred in densely forested core regions of Protected Areas (PAs). Our predictive risk maps (ca. 22,525 km²) showed species-specific predation patterns, reflected ecological differences among large carnivores with regards to their habitat and spatial partitioning for domestic prey. Our predictive predation risk map and factors associated with livestock predations provides powerful visual guidance and tools for PA managers in developing multi-species conflict mitigation strategies. We recommend diversifying local economic livelihoods and benefit-sharing options for local communities to minimize their forest dependency.

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<https://doi.org/10.1016/j.gecco.2020.e01366>

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Ecological Society of America
1990 M St, NW, Suite 700
Washington, DC 20036

20 August 2024

To Whom It May Concern,

This letter is to certify that Milda David recently attended the 2024 ESA Annual Meeting held August 4-9 in Long Beach, California.

The Long Beach Convention Center was the primary location for meeting activities, although some optional activities and social events took place at other locations nearby.

The formal scientific program included plenary sessions, symposia, organized paper sessions, and contributed paper sessions. In addition, informal sessions such as short courses, workshops, scientific field trips, and numerous business meetings for specific groups took place. A variety of social, networking, and career-oriented events were also offered to complement the scientific program.

As an integral part of this exciting program, Ms. Milda David presented "Wild horizons: insights to large carnivore conservation in fragmented habitats" (abstract #COS 206-1) at 3:30 PM PDT on Thursday, August 8, 2024. This presentation was part of a Contributed Oral session titled, COS 206: "Habitat Structure, Fragmentation, Connectivity 2."

For more detailed program information, please visit the meeting website (www.esa.org/longbeach2024). If you require any further assistance, please contact me using the information shown below.

Sincerely,

Monica Rowe
Meetings Coordinator
Ecological Society of America
mrowe@esa.org



<http://www.mammalogyinternational.org/>

27 July 2023

Milda David
Salim Ali Centre for Ornithology and Natural History
Tamil Nadu, India

Dear Milda,

Thank you for participating in the 13th International Mammalogical Congress!

This letter is to confirm that you were a recipient of an International Federation of Mammalogists Student Travel Award, which allowed you to participate virtually in IMC-13, which was held from 14-20 July 2023, in Anchorage, Alaska. During the congress, you shared your recent research in the form of a virtual oral presentation:

Living amidst anthropogenic pressure: a large mammal conservation perspective
Saturday, 15 July, 8:00 am – 5:00 pm

I trust that you found the congress to be a fun and exciting experience that has contributed importantly to your professional development.

It was unfortunate that you were not able to travel to Anchorage to join us in person. I look forward to seeing you at future congresses.

Best regards,

Eileen A. Lacey
President, International Federation of Mammalogists
Museum of Vertebrate Zoology
University of California, Berkeley, CA, USA 94720-3140
Email: ealacey@berkeley.edu



**59th ANNUAL MEETING OF THE
ASSOCIATION FOR TROPICAL
BIOLOGY AND CONSERVATION**

Certificate of attendance

This certifies that

Milda David

has attended the 59th Annual Meeting of the
Association for Tropical Biology and Conservation
"Balancing Science, Conservation, and Society"
held in Coimbatore, India, from July 02-06, 2023.

RAMESH KRISHNAMURTHY
CHAIR
ATBC 2023

LUCIA G. LOHMANN
Executive Director
ATBC



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94





Society for Conservation Biology

CERTIFICATE OF PRESENTATION

THIS CERTIFICATE IS AWARDED TO

Milda David

For presenting: Barriers to wildlife conservation: Forest Ranger's perspective on human-wildlife interaction in southern India

On December 17, 2021

at the 2021 International Congress for Conservation Biology

A handwritten signature in black ink, appearing to read 'Anthony J. Lynam'.

Tony Lynam
President, Society for Conservation Biology

ICCB2021

THE FUTURE IS NOW:
SUSTAINING BIODIVERSITY
FOR TODAY AND TOMORROW





Certificate of Merit

is presented to

David Milda

Sâlim Ali Centre for Ornithology and Natural History (SACON), Coimbatore,
Tamil Nadu, India

for the poster on

*Ranger survey reveals conservation issues across Protected
and outside Protected Areas in southern India*

by

David Milda, T. Ramesh, Riddhika Kalle, V. Gayathri and M. Thanikodi

in **Group B (MTech/MPhil/PhD or equivalent)**

within the **Life Sciences** discipline at the

International Poster Presentation Competition (IPPC) 2020

organized by NYAB, INYAS, SLAYS and TYSA

held in September-October 2020.

Mohammed Abdul Basith, PhD
President / National Young Academy of Bangladesh

Chandra Shekhar Sharma, PhD
Chair / Indian National Young Academy of Sciences

Lt.Col. Asanka Palenettla, PhD
President / Sri Lankan Academy of Young Scientists

Sasitorn Srisawadi, PhD
Co-Chair / Thai Young Scientists Academy