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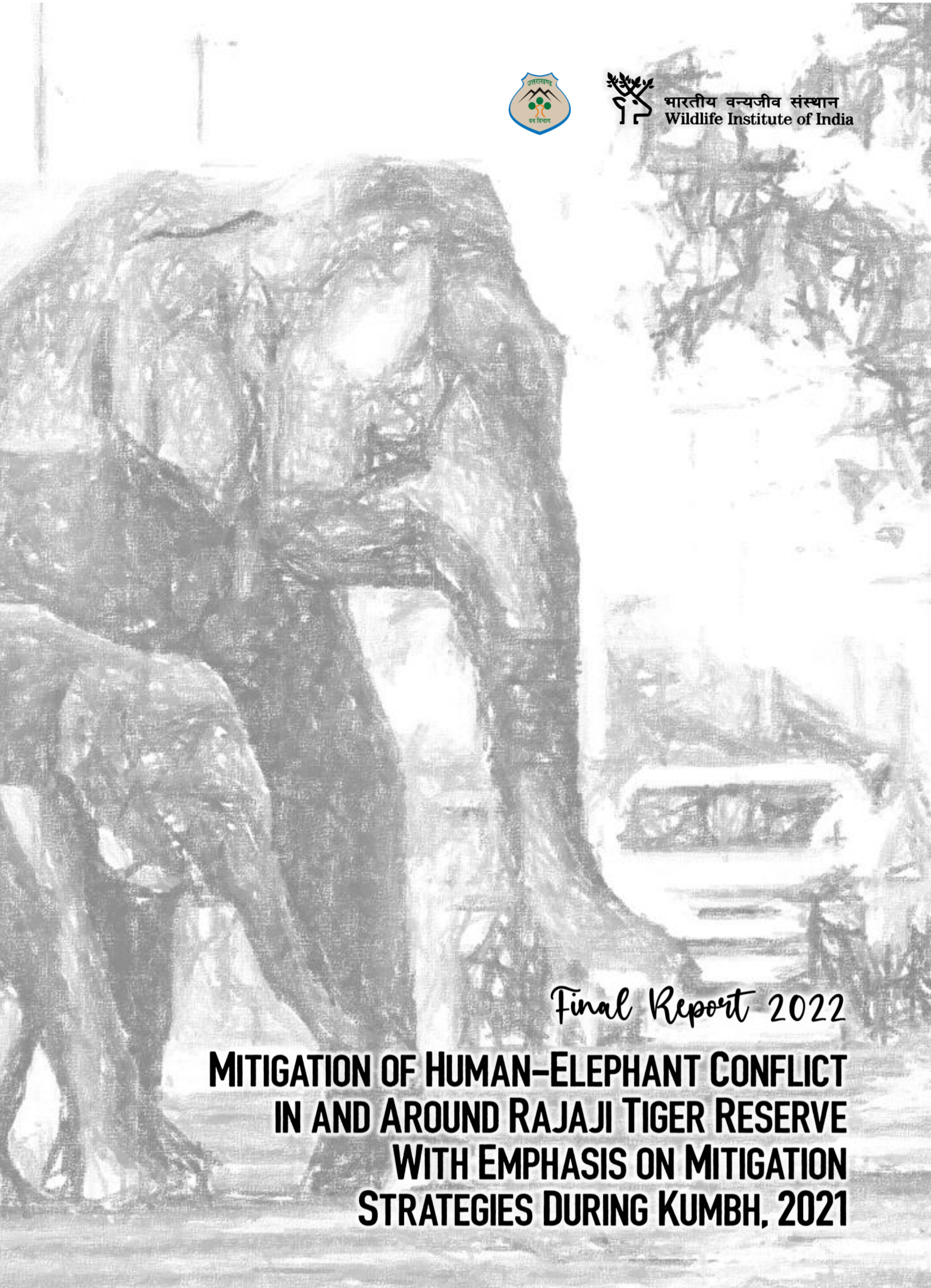

Final Report 2022

Mitigation of Human–Elephant Conflict in and Around Rajaji Tiger Reserve With Emphasis on Mitigation Strategies During Kumbh, 2021

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Citation: Nigam, P., Mondol, S., Habib, B., Lakshminarayanan, N., Das, J., Pandav B., Biswas, S., (2022). Mitigation of Human-Elephant Conflict in and around Rajaji Tiger Reserve, with Emphasis on Mitigation Strategies during Kumbh, 2021. Final Report 2022. Wildlife Institute of India-Uttarakhand Forest Department. Pp.99, TR No./2022/16

Final Report (2022)

Mitigation of Human-Elephant Conflict in and around Rajaji Tiger Reserve, with Emphasis on Mitigation Strategies during Kumbh, 2021

[A Collaborative Initiative Between Uttarakhand Forest Department and Wildlife Institute of India]

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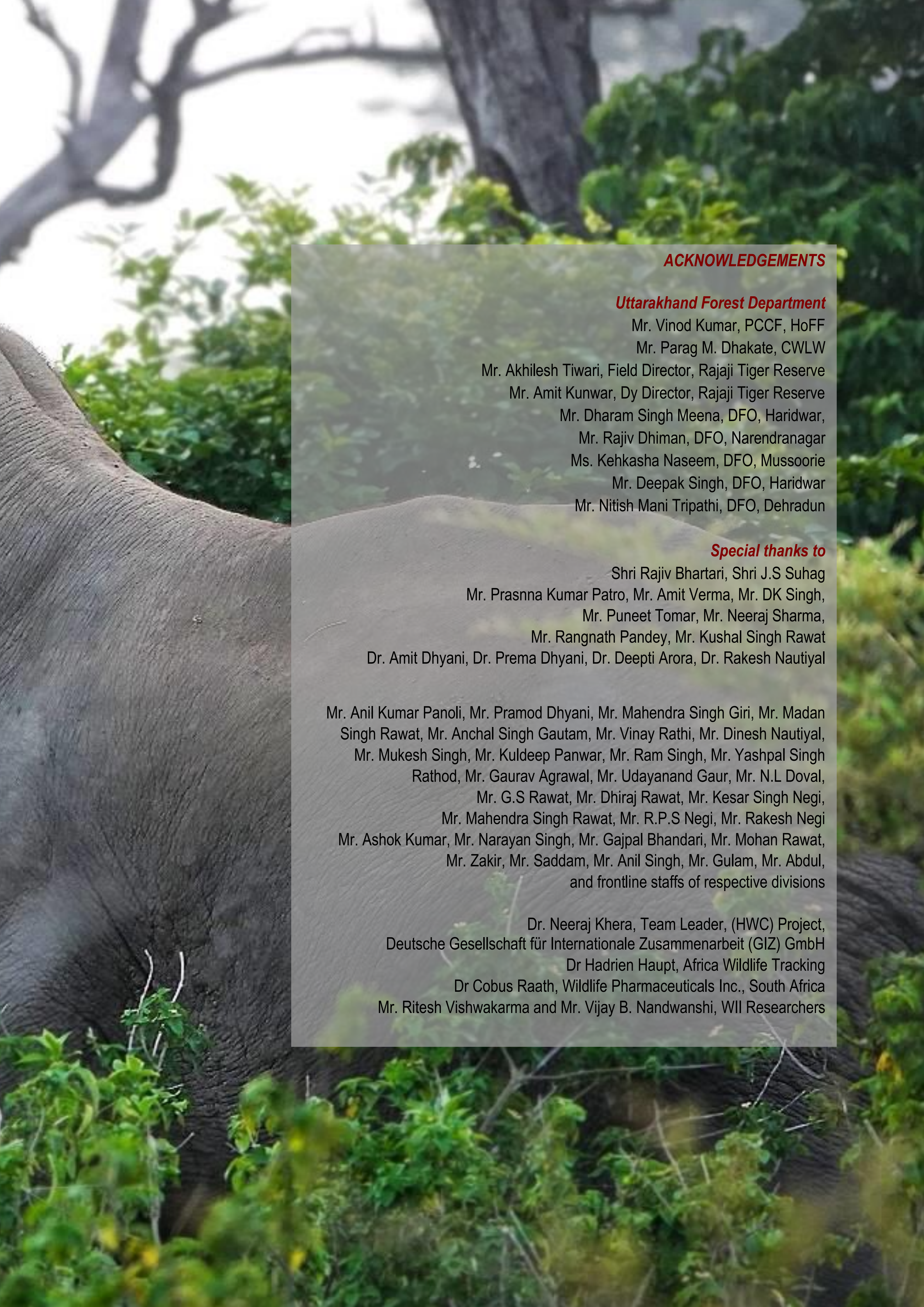

ACKNOWLEDGEMENTS

Uttarakhand Forest Department

Mr. Vinod Kumar, PCCF, HoFF
Mr. Parag M. Dhakate, CWLW
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Special thanks to

Shri Rajiv Bhartari, Shri J.S Suhag
Mr. Prasnna Kumar Patro, Mr. Amit Verma, Mr. DK Singh,
Mr. Puneet Tomar, Mr. Neeraj Sharma,
Mr. Rangnath Pandey, Mr. Kushal Singh Rawat
Dr. Amit Dhyani, Dr. Prema Dhyani, Dr. Deepti Arora, Dr. Rakesh Nautiyal

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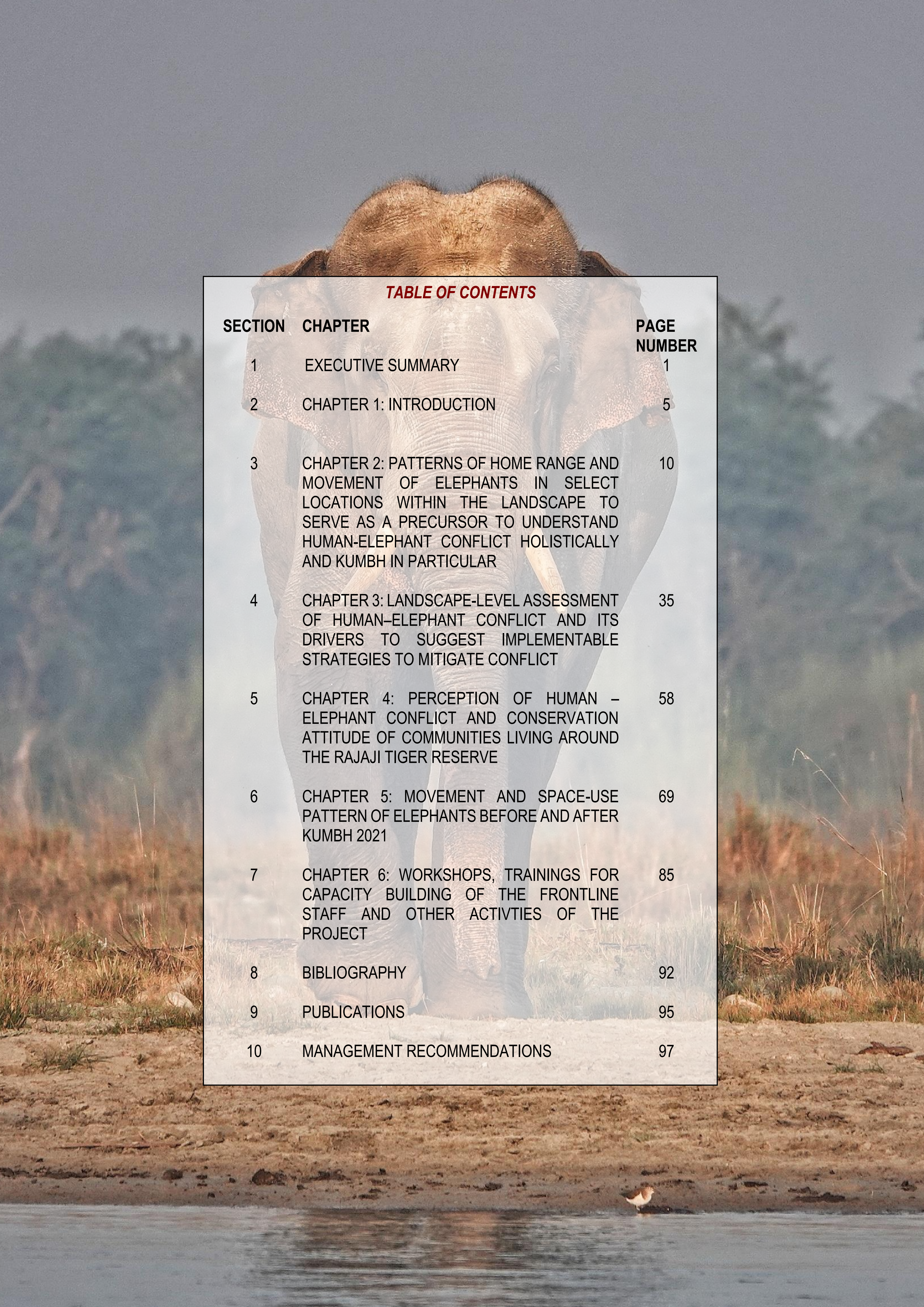

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EXECUTIVE SUMMARY

Human–Elephant Conflict (HEC) is a major threat facing elephant conservation globally. Reconciling human livelihood needs and simultaneously ensuring elephant conservation poses challenges for wildlife managers. Notwithstanding the suite of HEC mitigation strategies implemented by the Government agencies, HEC has increased in numerous areas culminating into economic, social and political challenges. Addressing HEC would require a multifaceted approach that focuses on understanding human livelihood and resource needs, as well as elephant ecology and behavior. As a step in the right direction, collating baseline information on HEC at different spatial and temporal scales to decipher broad-scale trends and patterns is critical. In addition to HEC information, advancing site-specific understanding of the spatial and behavioral ecology of elephants is invaluable in developing mitigation strategies to deal with HEC. With this background, Wildlife Institute of India in collaboration with Uttarakhand Forest Department initiated a two-year study aimed at understanding elephant home range and movement, and aspects of HEC in Rajaji landscape comprising of Rajaji Tiger Reserve and adjoining forest divisions of Haridwar, Dehradun, Lansdowne, Narendranagar and Mussoorie. Additionally, in view of Kumbh 2021, the study envisaged advancing mitigation strategies that could overlap between sites demarcated for the event where pilgrims would congregate and the elephant use areas.

The field work for the two-year study began during the month of March 2020. This report focuses on the preliminary findings of the study and the way forward. During the initial months of the study, reconnaissance surveys were carried out in Rajaji National Park (NP), Haridwar and Dehradun Forest Divisions (FDs). These surveys were aimed at collating baseline information on HEC through field visits and discussions with the forest department staffs. Alongside, efforts were made to identify elephants individually using standard, morphometric-based elephant identification. During the initial months, notwithstanding the CoVID19-pandemic related restrictions, plans were made to collar elephants. During field surveys, locations suitable for safe collaring of elephants were identified and deliberated with the forest department. In this report, activities that were carried out as part of the project for the period March 2020 to March 2022 are deliberated, preliminary findings discussed and the way forward indicated. The summary of activities are provided below

Spatio-temporal ranging patterns of elephants assessed through intensive individual-based monitoring of elephants and satellite telemetry

A total of 21 elephants were identified individually in intensive study area (eastern ranges of Haridwar FD) involving 2000 manhours of effort during March 2020 to December 2021. A manual comprising of identified elephants that use the proposed Kumbh 2021 sites had been prepared for ease of daily monitoring of elephants (Wildlife Institute of India, 2021).

- The identified bull elephants were observed to regularly cross river Ganga. These bulls used the ranges of Haridwar FD on the eastern side of the Ganges primarily as their daytime refugia and raided crops on the western side of the Ganges. Female/mixed sex groups mostly restricted themselves inside their habitat in Shyampur, Chiriyapur, Rasiabad and ranges of eastern Rajaji Tiger Reserve and were not observed crossing River Ganga for crop raiding.
- Four elephants were satellite collared and monitored. The details of the collaring operations were provided as separate reports to Uttarakhand Forest Department (Wildlife Institute of India, 2020). Among the four elephants, one bull elephant UKM2 provided data for 428 days while UKM17, UKM4 and UKM7 provided data for 18, 52 and 44 days, respectively.
- Annual home range (100% MCP) of UKM2 was found to be 331 sq. km, which was within the range (188 – 404 sq. km) of the previously reported home range of bull elephants in the landscape.
- The monthly proportion of time spent by collared elephants in "human-use areas" varied between 0.01 to 0.35 across the year. The decline in the time spent in "human-use areas" were observed during the months of April to July 2021 (0.01 to 0.09), with the least proportion of time spent (0.01) in the month of June, 2021.
- For the collared elephants, a decline in the crop raiding frequency was observed during April 2021 (0.70) to July 2021 (0.39). Lowest frequency of crop raiding was recorded during June 2021 (n=4 events).
- 21 of 34 the bulls identified in the landscape use human-dominated areas in the west bank of River Ganga. The movement of elephant bulls from the east bank (where natural elephant habitats occur) and the west bank (where there are no elephant habitats) for raiding crops. For all the GPS fixes pooled together (for UKM2, UKM4, UKM7 and UKM17), the average distance covered by the collared bulls from the edge of the western bank of the Ganges into the human-use areas was 1058.22 (±794.6) m.
- There was high spatial overlap between sites demarcated for Kumbh and elephant use areas. Over 44% (3.28 sq. km) of the designated 7.45 sq km of proposed camping (and parking) sites overlaped with intensive elephant use areas. These areas of high overlap included Gauri Shankar (on the eastern bank) and Daksh Dweep (on the western bank of the Ganges). Of the 10 designated Kumbh areas, only *Sapt Sarovar* and *Sati Dweep – Naya Tapu complex* were not used by elephants.
- Being a braided Himalayan river, numerous islets of different sizes occur in Ganges. Some of these islets are seasonal and would get inundated during floods. But post monsoon, the draw-down pans of the islets support vegetation that provides forage and cover for elephants. Extensive use of islets in Ganga has been documented in the study, which remains a novel finding. Nine of the 21 identified bulls were observed to use the islets.
- Based on the average speed of collared bulls at dawn was calculated to be 1.35 kmph, followed by dusk – 0.89 kmph, 0.49 kmph at night and 0.19 kmph during the day.

Landscape-scale and fine-scale assessment of aspects of HEC

- Based on the secondary data on human-elephant conflict received from the forest department, it was found that in Hadirwar Forest Division, during 2015-2020, the most affected beats in the landscape are Katevad East (8.96% cases), Gaindikhata 1 (7.88% cases) and Devpura Athmal (5.6% cases) of Chiriyapur and Haridwar ranges. Similarly, the most affected range in Mussoorie Forest Division for the period 2000 to 2020 was Raipur (91 cases, 100%). Further, in the Narendranagar Forest Division, during 2015 to 2020 the most affected ranges were Kushraila (2 cases, 66.66%) and Ghigud (1 case, 33.99%).

- Between 2015-2020, Haridwar FD reported 95.6 (SD±1.5) cases of HEC due to crop damage. A total of 44.3 (SD±10.9) villages were affected during the period with sugarcane field being primarily damaged throughout the year.

- Between 2015-2020, Dehradun FD reported 87.9 (SD±3.8) cases of HEC due to crop damage. In 2015, 38% of HEC cases pertain to sugarcane. During 2016 29.3% cases of HEC pertain to wheat. During 2017, 2018, 2019 and 2020, 28.4%, 29.3%, 42.1% and 29.1% reported cases of HEC pertains to paddy. HEC was reported from an average 43.5(SD ±9) villages between 2015 to 2020 from the division.

- Between 2016-2020, Lansdowne FD reported 85 (SD±8.8) cases of crop damage by elephants. In 2016, 64% of crop raiding cases were due to Kharif crops. During 2017, 2018, 2019 and 2020, 75%, 87.1%, 46.8% and 35.29% reported cases were that of Rabi crops. An average of 14.2±4.4 villages suffered crop losses between 2015 to 2020.

- Between 2015-2020, in Narendranagar FD, two villages were affected and reported three cases of crop damage. Between 2000-2020, Raipur range of Mussoorie FD reported 91 cases of crop losses

- In Haridwar FD, between 2015 to 2020, month of October was the most affected month with 46.1 ± 22.2 cases of crop damage. In Lansdowne FD, between 2016 to 2020, month of March was the most affected month with 10 ± 8.3 cases of crop damage. In Dehradun FD, between 2015 to 2020, month of August was the most affected month with 50 ± 24.6 cases of crop damage.

Intensive monitoring of HEC and carrying out socio-economic surveys in select conflict hotspots to assess preparedness and willingness of local communities to participate in conflict mitigation

- Among the farmers surveyed, 46.7% reported that elephants were a major problem followed byanother 26.6% reporting elephants as a minor problem. Among the non-farmers surveyed in these areas, 55.4% reported elephants as a minor problem and 21% indicated elephants as a moderate problem. Farmers indicated that crop damage (81.5%) by elephants is a main challenge posed by elephants, while non-farmers (93.5%) indicated fear of elephants as the major concern of living alongside elephant habitats.

- Both farmers and non-farmers surveyed expressed their support towards elephant conservation. Farmers (85%) and non-farmers (95%) believed that elephants were intergral part of nature. Repondents perceived that the elephants raided crops as they preferred it over wild forage (farmer- 73%, non-farmer – 81.6%). While the farmers perceived that the attack on humans were due to chance encounters during crop raids (50.6%), non-farmers (56%) perceived that the attack on humans were deliberate.

- Both farmers (51.9%) and non-farmers (51.7%) reported using crackers as to drive away elephants. Farmers (71%) suggested receiving compensation as an effective conflict mitigation strategy, non-farmers (82.8) suggested use of physical barriers. Both farming (78.6%) and non-farming (76.4%) respondents agreed to participate towards HEC mitigation measures.

Movement and space-use pattern of elephants before and after Kumbh 2021

- A gradual decline in the crop raiding incidents were observed following the month of March, 2021 till June 2021 (for the collared bull – UKM2), coinciding with the end of the Maha Kumbh event of 2021. Following March, 2021, in the month of April, May and June, UKM2 had restricted its raiding to the crop fields on the eastern side of the Ganges. Time spent in the crop-fields reduced from 28.6% to 4.6% from pre-guarding to post-guarding seasons.

Our assessment indicates that well-maintained and fully functional solar fences installed by Uttarakhand Forest Department were successful in deterring the elephants from crossing Anjani chaur.

CHAPTER 1: INTRODUCTION

Ranging behaviour of an animal has major implications for designing mitigation strategy to tackle human– wildlife conflict (Fernando et al., 2008a). Understanding their ranging and space use is fundamental in establishing and maintaining protected areas to develop management strategies for the conservation of wildlife and alleviating human – wildlife conflict (HWC). Home range size and space-use of an animal are known to be influenced by the distribution of resources, presence of other conspecifics, as well as competitors and predators (Powell & Mitchell, 2012). Megaherbivores such as Asian elephant (*Elephas maximus*) is known to be distributed widely outside protected areas (PAs) into high human-use areas, understanding their ranging pattern, space-use and the influence of high-human disturbance around their natural habitat is imperative for managing of elephants in human-altered landscapes (Madhusudan et al., 2015). The Asian elephant holds an important place pertaining to pride, status, and culture across its geographical range (Fernando et al., 2008b). However, the relationship between humans and elephants around the interface of elephant range areas have experienced episodes of unpleasant interactions termed as Human-Elephant Conflict (HEC), often resulting in collateral damages (Fernando et al., 2008a).

Human-elephant conflict (HEC) is the result of complex interplay of four key factors namely the habitat, elephant population, elephant behavior, and people that leads to initiating, escalating, or sustaining HEC (Desai & Riddle, 2015; Sukumar, 1994). In order to understand HEC holistically and address its root causes, it is essential to understand how these factors function in the context of the landscape. Due to the complex interplay of the factors involved in managing HEC and the sheer scale/magnitude of it (driven by the biology and ecology of the megaherbivore), HEC management regims along, sustained and well-informed effort. Failure to understand these factors and not catering to the root causes, but only the superficial symptoms ensures that HEC persists, forcing wildlife managers and affected inhabitants to deal with constantly escalating situations (Desai & Riddle, 2015) leading to degradation of the overall conservation effort. Developing adaptive management plans based on the factors that contribute to HEC, therefor requires understanding the context and background of these factors (Desai & Riddle, 2015).

Rajaji Tiger Reserve (TR) and the adjoining areas in Haridwar and Dehradun Forest Divisions (FDs) support one of the largest sub-populations of Asian Elephants within the North-Western population that occurs along the foothills of the Himalayas (Williams et al., 2008). The main threats facing this elephant sub-population include tenuous connectivity between Eastern and Western Rajaji across River Ganga, rapid changes in land-use outside reserve, linear infrastructure and extensive lopping and overgrazing of habitats by livestock posing resource competition (especially in Haridwar FD). The HEC scenario in the Rajaji landscape, encompassing adjoining Forest Divisions is as complex as across other range states. Managing HEC to foster co-existence and tolerance in Rajaji TR and adjoining landscapes hinges on effective monitoring of elephant populations. Furthermore, monitoring elephants that regularly venture into human use areas could be useful to understand individual variations in behavior and its possible drivers. This is of particular relevance in today's context, wherein the ranging areas of several of these bulls spatially juxtapose or overlap with the proposed camping and parking sites for the Kumbh 2021.

Large mammals such as elephants, rhinos and tigers often come into conflict with people resulting in destruction of agricultural crops and casualties, thus deterring conservation efforts (Sukumar, 1991). The greater variance observed in the reproductive fitness of the males of these polygynous species have resulted in selection pressures favouring a 'high risk-high gain' strategy for promoting reproductive success (Sukumar, 1991). Crop damage by elephants is a major challenge at the forest-crop field interface (Sukumar, 1991).

Several studies on elephants ranging pattern based on their movement patterns (through telemetry studies), habitat use, demography, status of HEC, connectivity of landscape and corridors, and their feeding ecology have been carried out in the past three decades in both Africa and Asia, most focusing on the areas inside the protected area (Fernando et al., 2008a; Hoare, 1999; Mills et al., 2018; Baskaran et al. 2018a, 2018b; Williams et al. 2008; Wilson et al., 2021). The past decade has witnessed a rise in HEC in the landscape, a situation similar to several other landscapes in the country and other elephant range states. This has resulted in the creation of several HEC hotspots that now require quantification of crop and property damage as well as assessment of socio-economic aspects of local communities. The information helps in understanding the willingness and preparedness of communities to participate in conflict mitigation efforts. Elephants being wide-ranging species; the conflict hotspots also tend to be highly dynamic w.r.t. their spatiotemporal patterns that make local mitigation efforts quite challenging. To holistically understand the problem, the present study targets at a larger spatial scale covering a gradient of conflict intensity across the landscape. Further, elephants are long-lived species with average lifespan of about 50 to 60 years (Owen-Smith, 1988). Tt is thus important to assess patterns of conflict for a longer duration covering different seasons of across multiple years to make inter-seasonal and inter-annual comparisons. Such inter-seasonal comparisons are useful to determine environmental drivers of conflict.

Human-elephant conflict results in huge fiscal losses, loss of human lives and consequently antagonism towards conservation. In particular, understanding how elephants use corridors to move between habitats, zones that impede their movement and the impacts of linear developments on movement patterns are crucial, as such threats could be a subtle trigger for conflict in the locality. In some cases, addressing a threat on the habitat may serve as a strategy to avert HEC. Telemetry data provides the resolution that is required to understand fine-scale patterns of habitat use and movement by elephants and proves useful in assessment of structural, functional and fitness value of the landscapes (Wittemyer, Northrupet al., 2019).

To study the spatiotemporal dynamics of this conflict, a collaborative project was initiated between Uttarakhand Forest Department and Wildlife Institute of India in January 2020, with the objective to understand ranging and movement patterns of elephants using the landscape, the extent and nature of loss due to conflict, and the drivers of conflict in order to plan suitable mitigation strategies, with particular focus on the Kumbh.

Project objectives

The project envisages the following:

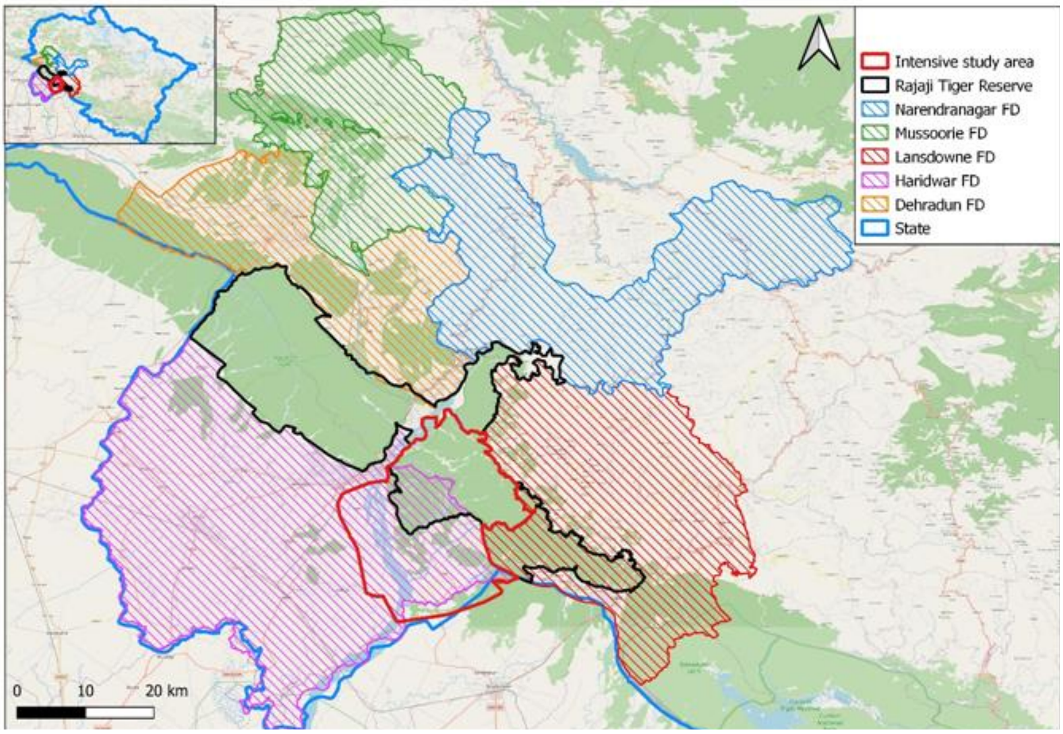
1. Investigating patterns of home range and movement of elephants in select locations within the landscape to serve as a precursor to understand HEC holistically and Kumbh in particular.
2. Landscape-level assessment (covering the entire Rajaji TR and Haridwar FD) of HEC and its drivers to suggest implementable strategies to mitigate conflict.
3. Intensive monitoring of HEC and carrying out socio-economic surveys in select conflict hotspots to assess preparedness and willingness of local communities to participate in conflict mitigation.

Study area

The overall study area includes Rajaji Tiger Reserve (TR) and its adjoining forest divisions – Haridwar, Dehradun, Lansdowne, Narendranagar and parts of Mussoorie Forest Divisions (FDs) (Figure 1.1). The overall area of the study area is 7284 sq. km. Physiographically, the landscape is part of the western Terai-Arc landscape. The landscape is recognized as one of the most productive ecosystems in the world as far as large mammals are concerned. The major vegetation in the landscape comprises of tropical dry and moist deciduous forests, scrub vegetation, alluvial grasslands and forest plantations primarily of *Tectona grandis* and *Eucalyptus spp* (Johnsingh et al., 2004). Vegetation communities, include (i) Sal (*Shorea robusta*) dominated forests along with its associates (ii) Sal-mixed forests of *Shorea robusta* – Kamala tree *(Mallotus philippensis)* – Small flowered crape myrtle *(Lagerstroemia parviflora)* series (iii) riverine forests of black cutch (*Acacia catechu)* – North Indian redwood (*Dalbergia sisoo)* – Malabar plum *(Syzygium cumuni)* series (iv) mixed forests of *Lagerstroemia parviflora* – Indian elm *(Holoptelea integrifolia)* – Chamror *(Ehretia laevis)* – Haldu (*Adina cordifolia)* – Axlewood *(Anogeissus latifolia* series) (v) forest plantations (Johnsingh et al, 2004). With respect to faunal aspects, along with flagship species like tiger (*Panthera tigiris*), and Asian elephants (*Elephas maximus*), the area is also home to sambar (*Rusa unicolor*), chital (*Axis axis*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), leopard (*Panthera pardus*), hyena (*Hyaena hyaena*) and diverse avifauna and herpetofauna. Major crops grown in the area includes sugarcane (*Saccharum officinarum*), paddy (*Oryza sativa*), wheat (*Triticum aestivum*), maize and millets. Although seasonal rainfall is imperative for growing crops such as paddy, agriculture in the landscape is largely sustained by network of irrigation systems.

While the legal protection rendered by the government checks the impact of anthropogenic activities within the Rajaji TR boundary, rapidly and radially expanding cities on the outskirts of the reserve and cascading effect of developmental activities (road, rail networks) has seen rapid change in the land-use and land cover in the landscape. An estimated population of about 368 elephants is found in this area (Wild Asiatic Elephant Population Estimation Uttarakhand, 2015). The area receives maximum rainfall between mid-June to September, followed by the onset of winter from November through February and the dry season between January to May. The driest month is November with 4mm of rainfall. With an average of 375 mm, most precipitation is recorded in the month of July.

Figure 1.1: Study area in the Rajaji Tiger Reserve and the adjoining Forest Divisions



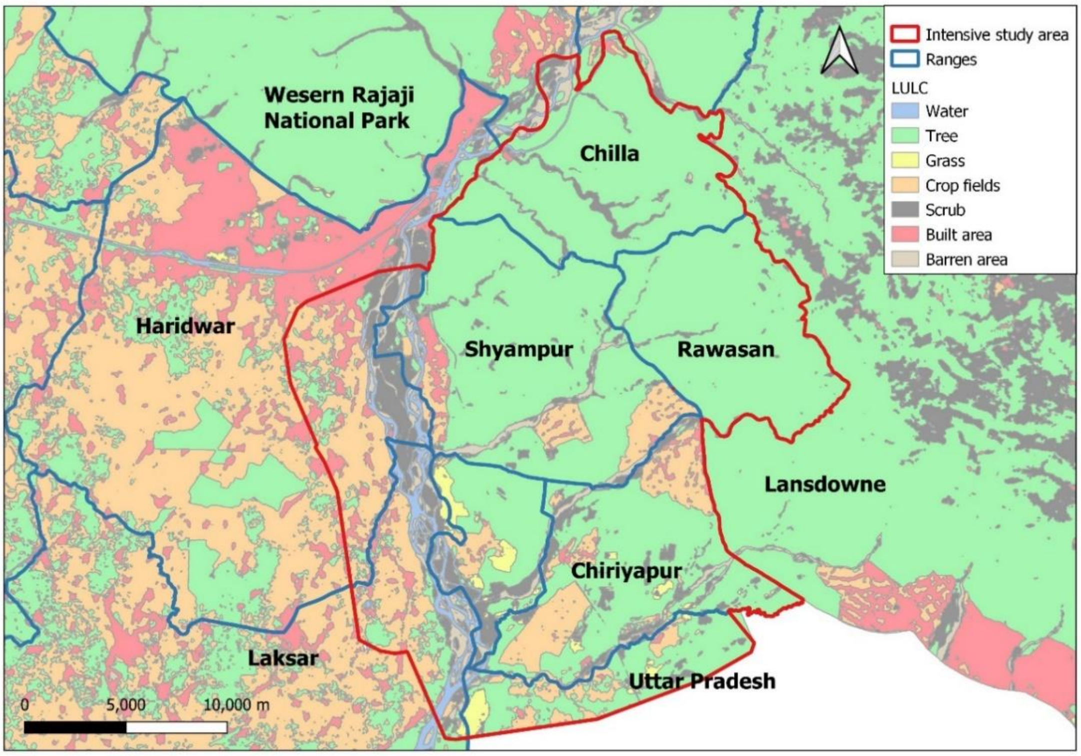


Figure 1.2: Intensive study area including ranges of Haridwar Forest Division and Rajaji Tiger Reserve.

The total human population of districts in the study area is 4.3 million (https://www.census2011.co.in).The livestock population mostly comprising of cattle, buffalo, goat and poultry is more than 1.7 million (https://ahd.uk.gov.in). Major occupation of the communities dwelling along the wildlife habitat includes pastoralism, agriculture and animal husbandry. Major crops grown in the area includes sugarcane, paddy, wheat, maize and millets. Although seasonal rainfall is imperative for growing crops such as paddy, agriculture in the landscape is largely sustained by network of irrigation systems (https://haridwar.kvk4.in/district-profile.html).

Although the larger study area comprises of the entire Rajaji landscape as described above, based on the immediate needs to manage HEC around the proposed Kumbh 2021 camping site; monitoring of elephant movement, habitat use and physical barriers was initiated during March 2020 and centered around Shyampur, Haridwar, Chidiyapur, and Laksar ranges and Rasiyabad unit of the Haridwar Forest Divisions. Among these areas, two major daytime refugias for elephants viz. Dassowalla forests and Anjani Chaur (in Rasiyabad unit and Shyampur range respectively) were identified based on continuous monitoring and due to their strategic importance of being juxtaposed to sites demarcated for Kumbh 2021, these two sites were intensively monitored. Additionally, Shyampur canal bank and islets in river Ganga were regularly monitored to register and identify elephants as part of photographic inventory of elephants. During foot tracking, elephant signs were recorded in addition to all possible direct sightings. In case of direct sighting, photographs were recorded which were used to build an elephant ID database for identified elephants based on their morphological features.

CHAPTER 2: PATTERNS OF HOME RANGE AND MOVEMENT OF ELEPHANTS IN SELECT LOCATIONS WITHIN THE LANDSCAPE TO SERVE AS A PRECURSOR TO UNDERSTAND HUMAN-ELEPHANT CONFLICT HOLISTICALLY AND KUMBH IN PARTICULAR

Introduction

Ranging behavior of elephants in the landscape has its implication on Human-Elephant Conflict (HEC) and can provide important insights on habitat requirement, management interventions that can help in optimizing habitat conditions and identifying areas that are critical for elephants. Pinpointing elephants' positions periodically, using high-resolution satellite collars can provide fine-scale details about their space use, movement pattern and habitat selections. It helps in generating high-quality visual representations showing how elephants traverse the mosaic landscape. It is also possible to visualize their intensive-use 'core' areas and identify habitats that can be improved to support elephants. Moreover, collared elephants can provide details on patterns of conflict as well-seasonality of damages to crops and property, and their general time-activity patterns. Such details can help us formulate site-specific conflict management strategies and in providing evidence-based policy recommendations to the Uttarakhand Forest Department.

To collect imperative information pertaining to the above-mentioned aspects, as part of the project, effort was made to collar elephants in the landscape, that intensively use the human-use areas in the potential Kumbh, 2021 sites so as to develop fine-scale plan to avoid any untoward incident.

As a part of the project objective, assessment of spatio-temporal ranging pattern of elephants was attempted with the objective of investigating patterns of home range and movement of elephants in select locations within the landscape to serve as a precursor to understand HEC holistically and Kumbh in particular.

Methods

Monitoring of elephants (Pre-collaring)

Between March 2020 to July 2021, Wildlife Institute of India (WII) field team surveyed the eastern and western ranges of Haridwar FD intensively and documented the ranging pattern of elephants involved in HEC. Elephant movement was tracked using re-sighting records, referring to the ID database, and individual specific usage of the intense study area was noted during the on-ground tracking exercise. This was preceded by intense ground survey for a year to build an individual ID database by identifying elephants based on unique morphological features (Vidya, et al., 2014). The physical features used to ID the individuals included the tusk patterns (in case of tusked males); tail and tail brush patterns; ear folds, tears, nicks, and shape and other unique marks such as warts, cuts, (healed) major wound marks etc.

Figure 2.1: Photo plate of some of the identified bull elephants in the intensive study area

Animal Capture and Collaring

Preparatory activities: Being part of the ongoing project wherein monitoring had been continuous since March 2020, preparatory measures for the collaring, particularly with regard to tracking elephants to understand potential capture sites was already in place. The team mapped coarse scale movement of identified individuals, which helped in ascertaining ideal locations to smoothly carry out the operation. Among the identified individuals, potential targets for collaring and monitoring were chosen based on their age and size classes, and their association patterns (as understood through close observations). Veterinary aspects of the preparatory measures included procurement of narcotics and reversals from the M/S Wildlife Pharmaceuticals Inc., South Africa. Other basic and emergency medications were also stocked appropriately.

Collars for the operation were provided by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The units were produced by M/S Africa Wildlife Tracking Inc. and were iridium satellite based. These collars were kept ready by syncing the time intervals appropriately before the operations, and mock drills on deploying them were carried out at various locations in Haridwar Forest Division, to provide hands-on experience to the field tracking team. Other accessories including toolkits, ropes, and equipment were procured according to a checklist prepared previously, and were kept organized for immediate use. Most crucial aspect of preparation for any animal handling exercise was experienced tracking team, who can not only assist in monitoring the animals, but can also aid in tracking the animals as soon as they are darted. To strengthen the existing tracking team, two trackers belong to the *Malasar* community, who have been engaged in *mahout* profession since generations, and had a fair understanding of elephants, their ways and lives from Kozhikamuthi in the Anamalais were added to the team since December 2020. In addition, select individuals from the Uttarakhand Forest Department brought fine-scale knowledge of the sites, which further contributed to intense tracking during the operation. Once suitable conditions prevailed, select identified bulls were chemically immobilized and collared during phase I and phase II operations that were conducted between October and December 2020.

The behvaioural and physiological states were categorized and measured as follows (based on field observations)

Non-*musth*, crop raiding (**NMCR**): When the animal was observed to be in physiological state of non-*musth* and was raiding crops every night during the period of observation.

Musth, crop raiding (**MCR**): When the animal was observed to be in physiological state of *musth* and was raiding crops every night

Non-*musth*, non-crop raiding (**NMNCR)**: When the animal was observed to be in physiological state of non-*musth* and rarely raided crop (less than 0.01 proportion of the period).

Table 2.1: Telemetry data used for behavioural and physiological states of collared bull elephants:

S.No.	Elephant ID	State	Period (no. of days of data)
1	UKM2	Overall	24th December 2020 to 24th December 2021 (366 days)
2	UKM2	NMCR	24th December 2020 to 2nd March 2021, 26th April 2021 to 11th May 2021, 17th July 2021 to 24th December 2021 (246 days)
3	UKM2	NMNCR	12th May 2021 to 16th July 2021 (66 days)
4	UKM2	MCR	3rd March 2021 to 25th April 2021 (54 days)
5	UKM4	NMCR	26th December 2020 to 16th February 2021 (52 days)
6	UKM7	NMCR	15th October 2020 to 23rd November 2021 (40 days)
7	UKM17	NMCR	27th December 2020 to 13th January 2021 (18 days)

Analysis

Analysis was performed to understand the following aspects of the spatio-temporal ranging behaviour of collared bull elephants:

***Proportion of space (habitat and human-use area) used by the individuals in their respective areas**:* Minimum convex polygons (Mohr, 1947) (MCP,100% - available area) and 95% fixed Kernel Density Estimation (KDE) and 50% KDE (Worton, 1989) (used area) polygons were overlaid on land-use land-cover (LULC) layer. The use of 100% MCP enables us to find and understand the area available for an individual to range within. As most of the studies in the past have reported their home range estimations in terms of MCP. Hence, deriving 100% MCP was imperative to compare with home range estimations of previous studies. KDE were used to derive utilization distribution of animals based on the clustering of GPS fixes (kernel density). These 95% and 50% contours of utilization distributions enabled defining the intensity of space-use. i.e. 50% KDE was defined as the "core" area, with higher intensity of use, as compared to the contour of 95% KDE.

Time spent during different behavioral and physiological states, hours of the day, month and overall period: Proportion of GPS fixes falling inside each LULC were obtained.

***Annual pattern of crop raiding incidents on monthly basis**:* GPS fixes of collared elephants (till collar drop off) falling inside "crop-fields and built-area" classes of LULC layer on each day of the month were recorded and used to quantify proportion of crop raids per month. i.e. number of crop-raid nights divided by number of days in the month (observed).

Spatial extent to which the collared elephants raided crops on the western side of the Ganges: Distribution of GPS fixes from the edge of the western bank of the Ganges, into the human-use areas were measured.

***Movement pattern of the collared bulls**:* Speed at different hours of the day (based on the interval) were measured. To achieve this, step-lengths at different hours (intervals) of the day were derived from the time stamp of the GPS fixes and divided with their corresponding temporal resolution (time or interval). For the non-collared elephants in the area, all the sighting and re-sighting records served as the basis for their respective MCP, to get idea about their ranging pattern.

All the analyses were performed using R statistical software (R Core Team, 2021) , QGIS (QGIS Development team, 2021) , ArcGIS 10.8 (ESRI, 2011) and MS excel (Microsoft corporation, 2013) in tandem.

For analysis of the ranging/ space-use pattern of collared elephants, latest land-use land-cover (LULC) (Karra et al., 2021) layer was derived and reclassified into "habitat" and "human-use areas" (Table 2.2).

Table 2.2: Reclassification of original LULC classes

S.No.	Original class	Reclassified class
1	Water	Habitat
2	Tree	
3	Grassland	
4	Barren land	
5	Scrub	
6	Built area	Human-use area
7	Crop field	

Results

Morphological identification of conflicted elephants

Based on the intensive on-foot monitoring of elephants, it was observed that all the elephants crossing the Ganges to raid crops on the western side of Ganges were exclusively bull elephants. Female elephants restricted their movement to the forest patches on the eastern side of the Ganges, contiguous with the eastern ranges of Rajaji TR. A total of 34 bull elephants of varied age class were documented, of which 21 bulls were observed to regularly raid crops in the intensive monitoring area. The bull elephants were named based on their state name, sex and order of first sighting record. i.e. UKM1 was the first bull elephant from Uttarakhand identified in this project. Among the identified bull elephants UKM2, UKM4, UKM7 and UKM17 were collared during the phases of collaring operation. The detailed list of identified bull elephants and their photographic database has been shared as a reference manual with the Haridwar FD prior to Kumbh 2021.

Collaring details

During the first phase, animal identified as UKM07 was collared on the 15th of October 2020 at Dassowala area. The collar-team and the tracking team took position overlooking river Ganga so as to locate elephants as they cross the Ganges. The bull identified for collaring, UKM07 was observed at the lure site feeding on sugarcane. The animal was remotely darted using narcotic- Etorphine hydrochloride at appropriate dosages. The bull came in lateral recumbency and after ensuring sedation safe for approach and handling; the animal was approached and collared. The physiological parameters were monitored continuously. Drug reversal was carried out using Naltrexone hydrochloride. As part of the phase II collaring exercise, three adult bulls were collared in Rasiyabad unit and Shyampur range jurisdictions of the Haridwar FD between the 23rd and 27th of December 2020. The animals were part of 21 identified bull and were being continuously monitored since March 2020. The three animals, identified as UKM02, UKM04, and UKM17 were then similarly immobilized and collared on 24th, 26th and 27th of December 2020 respectively. The reports of the phase I & phase II collaring had been submitted to the Uttarakhand Forest Department. Details of collared individuals are provided in table 2.3.

Satellite-based tracking of collared individuals

The satellite data obtained from the four collared animals validated several of the field-based observations collected by the team since March 2020, both in terms of their ranging patterns, their behavioral and physiological aspects. With regard to their ranging and use of the landscape, it was evident that, all four collared elephants and the individuals associated with these, in addition to other identified animals in the region, extensively used the human-dominated landscape, covering major village enclaves on the western bank of Haridwar FD viz., Bishenpur, Bhogpur, Katarpur-Alipur, Jagjeetpur, Devpur-Ahatmal etc., on the eastern bank such as Shyampur, Gajiwali, Bahar Peeli, Peeli Padav, Nalowala, Gaindikhata, and upto Chattha (in Uttar Pradesh).

Space-use pattern (based on MCP and KDE) of collared bull elephants with respect to their behavioral and physiological states

UKM2, UKM4, UKM7 and UKM17 provided data/fixes for 40, 366, 52 and 18 days respectively. During the tracking period, for non-*musth* crop raiding (NMCR) period, 100% MCP for UKM2, UKM4, UKM7 and UKM17 comprised of 82.3, 299.18, 75.6 and 117.27 sq. km. During NMNCR state, 100% MCP for UKM2 was 64.89 sq. km. *Musth*, crop raiding (MCR) state for UKM2 witnessed the animal cover 157.76 sq. km (100% MCP). Overall tracking days (366) for UKM2 showed the animal cover an area of 331.07 sq. km under the 100% MCP. For all the collared bulls combined, the total area under 100% MCP was 316 sq. km. (Table 2.5).

Table 2.3: Details of collared individuals

Sl. No	Date of collaring	Location of capture	Individual ID	Remarks	Photos
1	15th Oct 2020	Dassowalla	UKM07	Tracking data available for 40 days. Got electrocuted on 23rd of November 2020 in Bishanpur Kundi (Islet)	
2	24th Dec 2020	Dassowalla	UKM02	Collar functional with more than 366 days of data as on 24th December 2021	
3	26th Dec 2020	Gurukul islet	UKM04	Tracking data available for 52 days. Collar dropped by animal on 16th February 2021.	
4	27th Dec 2020	Anjani Chaur	UKM17	Tracking data available for 18 days. Collar dropped by animal on 13th January 2021	

During the tracking period, for non-*musth* crop raiding (NMCR) period, 95% KDE for UKM2, UKM4, UKM7 and UKM17 comprised of 11.23, 77.33, 19.91 and 23.03 sq. km. During NMNCR state, 95% KDE for UKM2 was 30.77 sq. km. *Musth*, crop raiding (MCR) state for UKM2 showed the animal cover 40.73 sq. km. (95% KDE). Overall tracking days (366) for UKM2 showed the animal cover an area of 100.18 sq. km under the 95% KDE. For all the collared bulls combined, the total area under 95% KDE was 106.03 sq. km.

During the tracking period, for non-*musth* crop raiding (NMCR) period, 50% KDE for UKM2, UKM4, UKM7 and UKM17 comprised of 1.88, 7.85, 1.97 and 2.85 sq. km. During NMNCR state, 50% KDE for UKM2 was 6.05 sq. km. *Musth*, crop raiding (MCR) state for UKM2 witnessed the animal cover 6.05 sq. km. (50% KDE). Overall tracking days (366) for UKM2 saw the animal cover an area of 12.75 sq. km under the 50% KDE. For all the collared bulls combined, the total area under 50% KDE was 15.47 sq. km. (Table 2.4, Figure 2.2).

Table 2.4: Space used in terms of the available area (100% MCP, in sq. km.) and use areas (95% and 50% KDEs, in sq. km.)

Sl. No	Individual ID	Age, Sex	Tracking days	GPS fixes	Physiological and behavioural state covered	Area (100% MCP)	Area (95% KDE)	Area (50% KDE)
1	UKM07	Adult male, above 30 years	40	920	Non-*musth*, crop raiding (NMCR)	82.30	11.23	1.88
2	UKM02	Adult male, above 25 years	366	10417	Non-*musth*, crop raiding (NMCR),	299.18	77.30	7.85
					Non-*musth*, non-crop raiding (NMNCR)	64.89	30.77	6.05
					Musth, crop raiding (MCR)	157.76	40.73	6.05
					Overall	331.07	100.18	12.75
3	UKM04	Adult male, above 30 years	52	1169	Non-*musth*, crop raiding (NMCR)	75.60	19.91	1.97
4	UKM17	Adult male, Around 20 years	18	384	Non-*musth*, crop raiding (NMCR)	117.27	23.03	2.85
5	All combined				Non-*musth*, crop raiding	316	106.03	15.47

Figure 2.2: MCP/KDE of collared elephants at different behavioural and physiological states

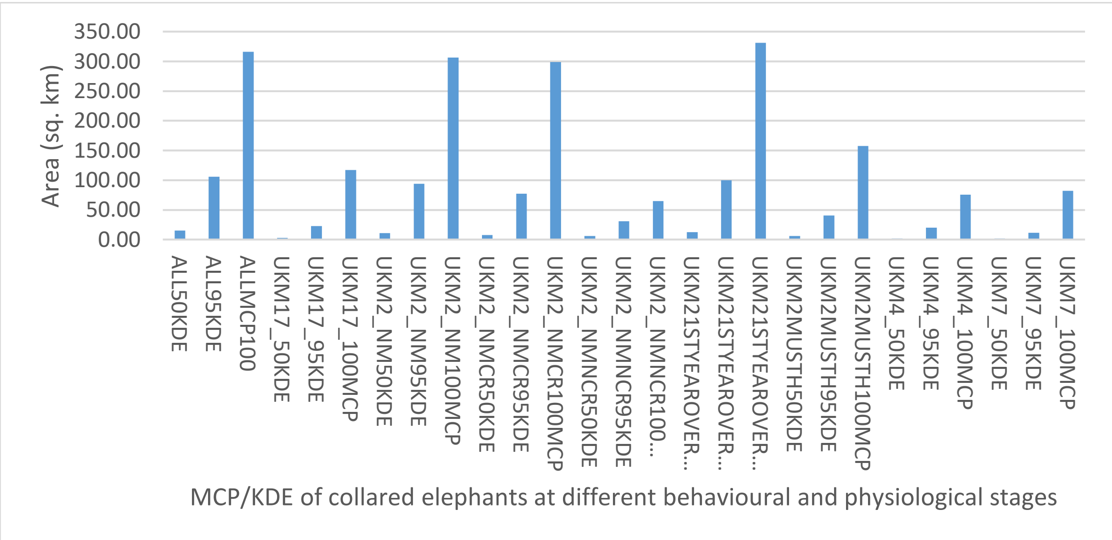


Table 2.5: Proportion of time spent and area covered in "habitat" and "human-use areas" by the collared bull elephants, across their physiological and behavioural states

S.No.	Animal ID	Behavioural and Physiological state	Time spent		Area covered - MCP (100%) (1)		Area covered - KDE (50%) (3)		Area covered - KDE (95%) (2)	
			Habitat	Human-use area	Habitat	Human-use area	Habitat	Human-use area	Habitat	Human-use area
1	UKM2	NMCR	0.76	0.24	0.70	0.30	0.81	0.19	0.68	0.32
2	UKM4	NMCR	0.73	0.27	0.59	0.41	0.83	0.17	0.60	0.40
3	UKM7	NMCR	0.70	0.30	0.61	0.39	0.60	0.40	0.69	0.21
4	UKM17	NMCR	0.71	0.29	0.79	0.21	0.77	0.23	0.81	0.19
5	UKM2	NMNCR	0.99	0.01	0.89	0.11	0.99	0.01	0.98	0.02
6	UKM2	MCR	0.84	0.16	0.77	0.23	0.87	0.13	0.81	0.19
7	UKM2	Overall	0.81	0.19	0.71	0.29	0.83	0.17	0.74	0.26
8	ALL	NMCR	0.76	0.24	0.84	0.16	0.78	0.22	0.82	0.18

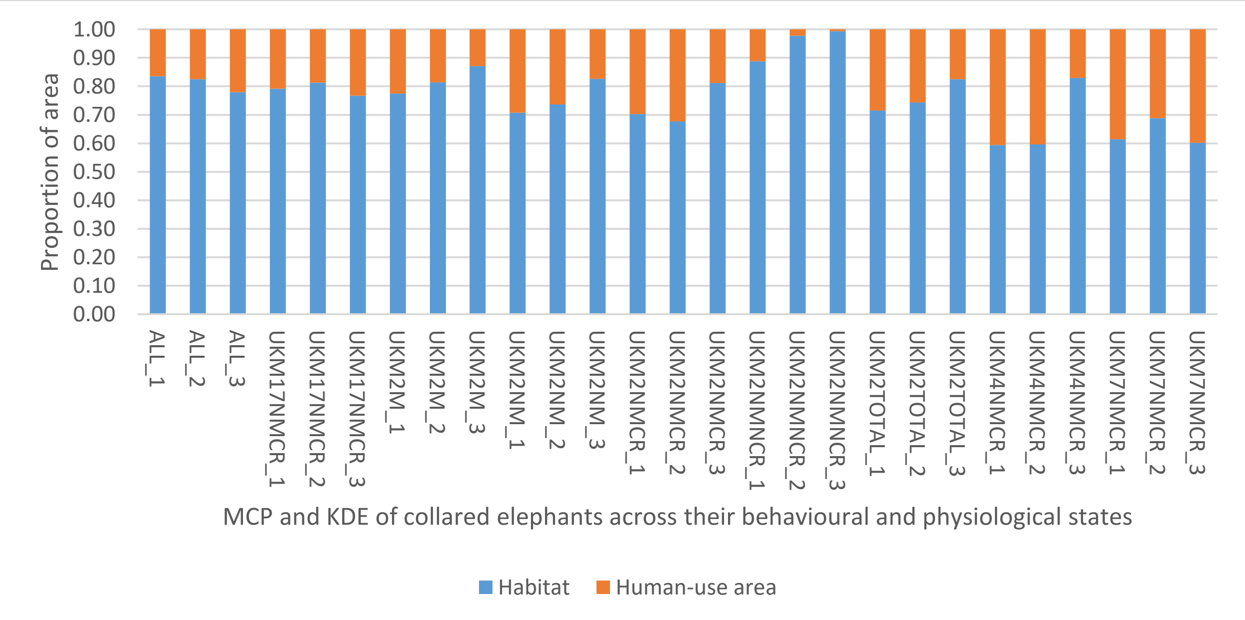


Figure 2.3: Proportion of area used in habitat and human-use areas as per the MCP and KDE polygons.
*ALL = All bulls combined during non-*musth* crop raiding season, NMCR = Non-*musth*, crop raiding, M = *Musth*, NM = Non-*musth*, Total = for the complete year. 1 = 100% MCP, 2 = 95% KDE, 3 = 50% KDE.

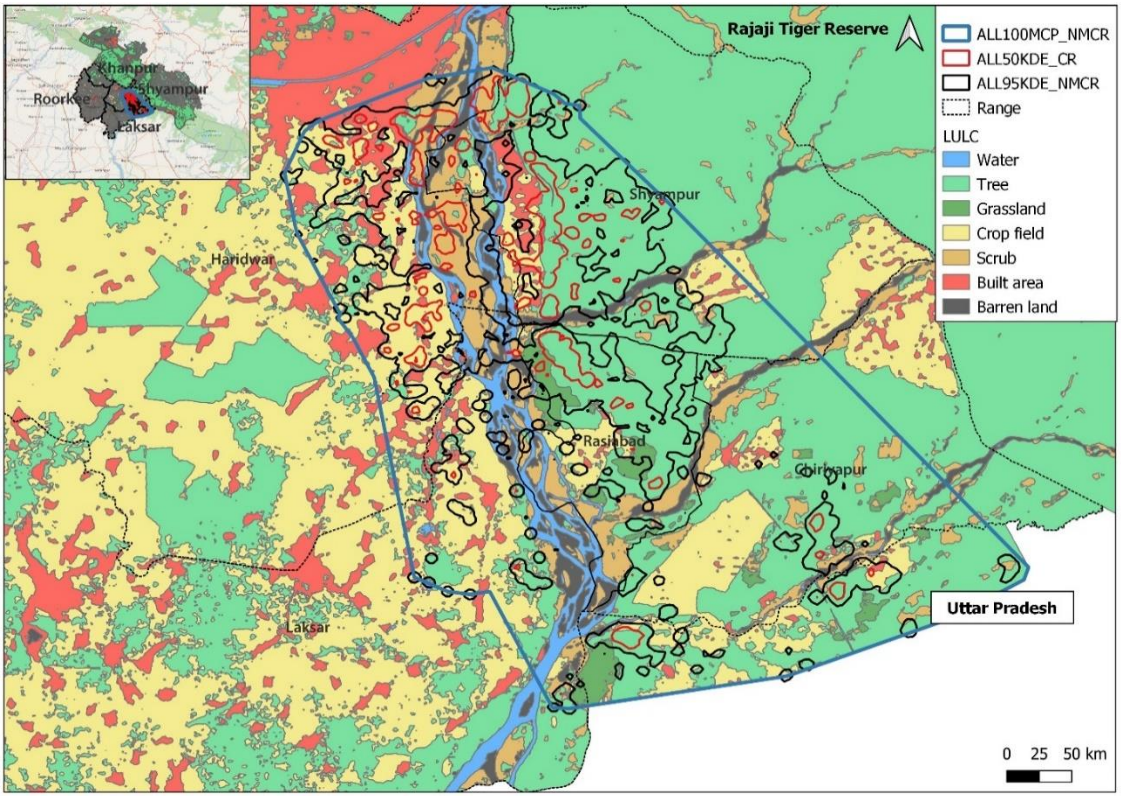


Figure 2.4: 100 % MCP and 95% and 50% KDE of all the collared bulls (combined), during non-*musth* (NM), crop raiding (CR) state

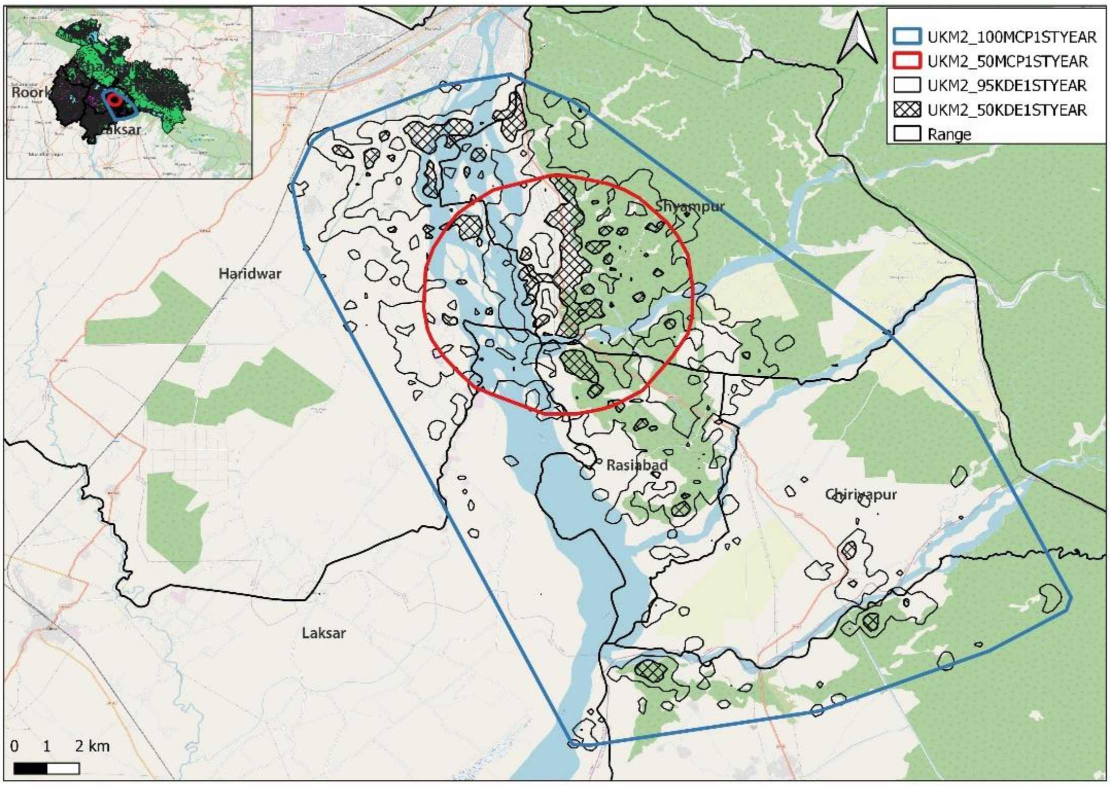


Figure 2.5: Overall space-use pattern of UKM2 for the first year. Sightings (n = 177)

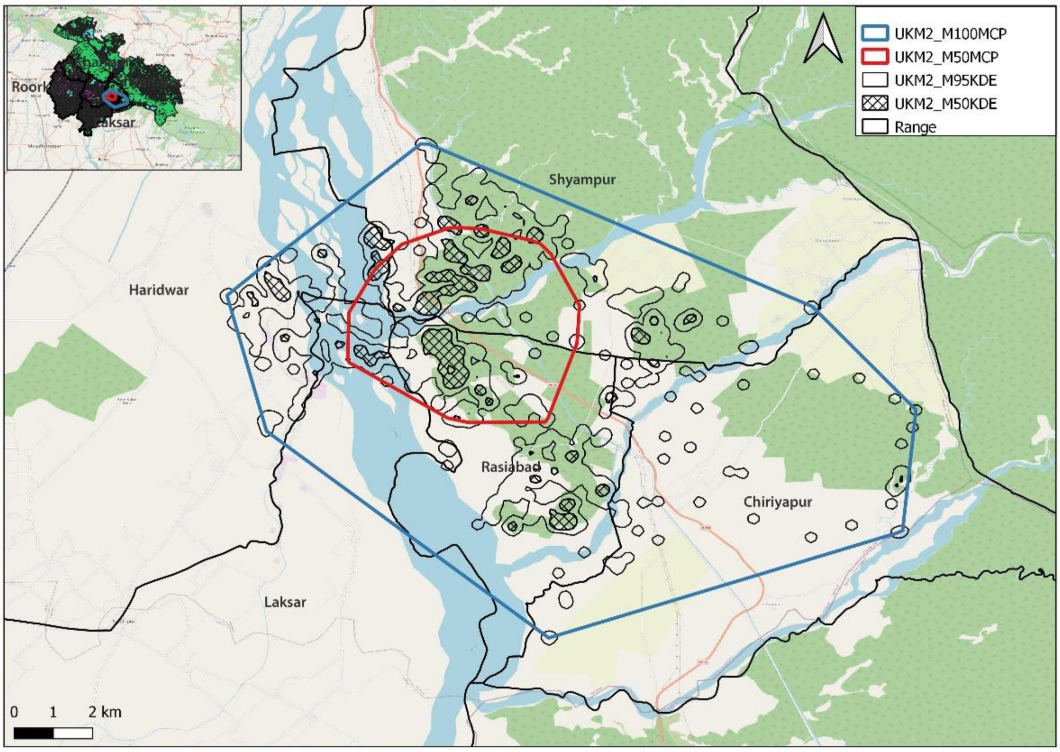


Figure 2.6: Space-use pattern of UKM2 during *musth* (M)

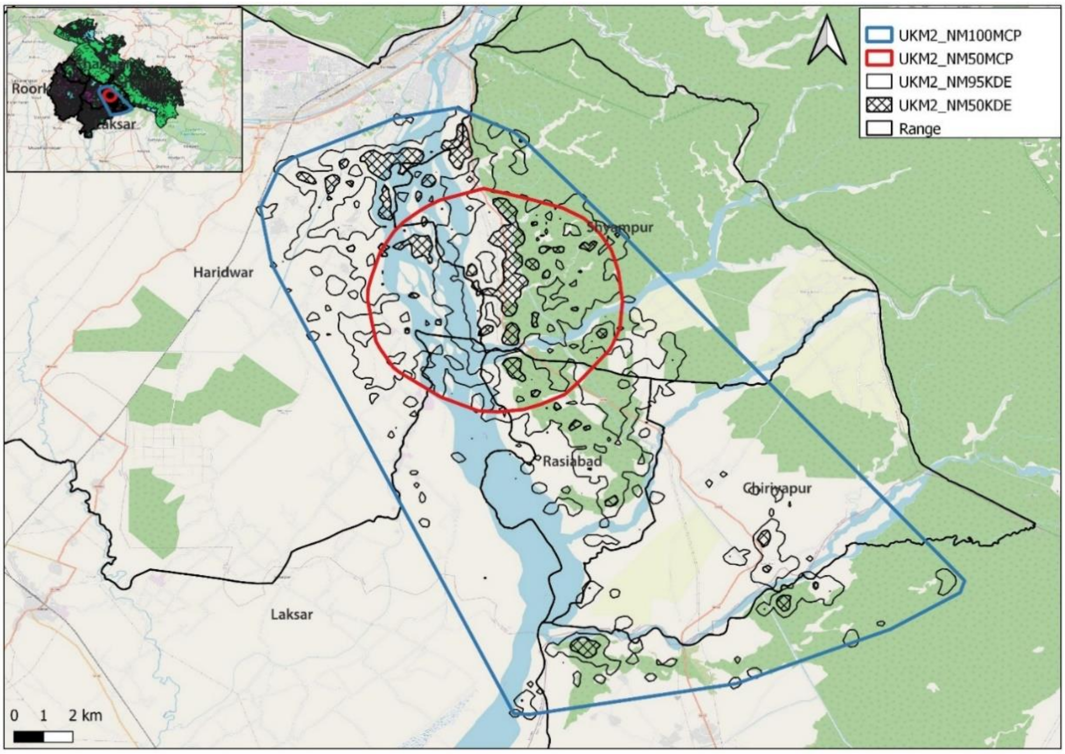


Figure 2.7: Space-use pattern of UKM2 during non-*musth* (NM) state

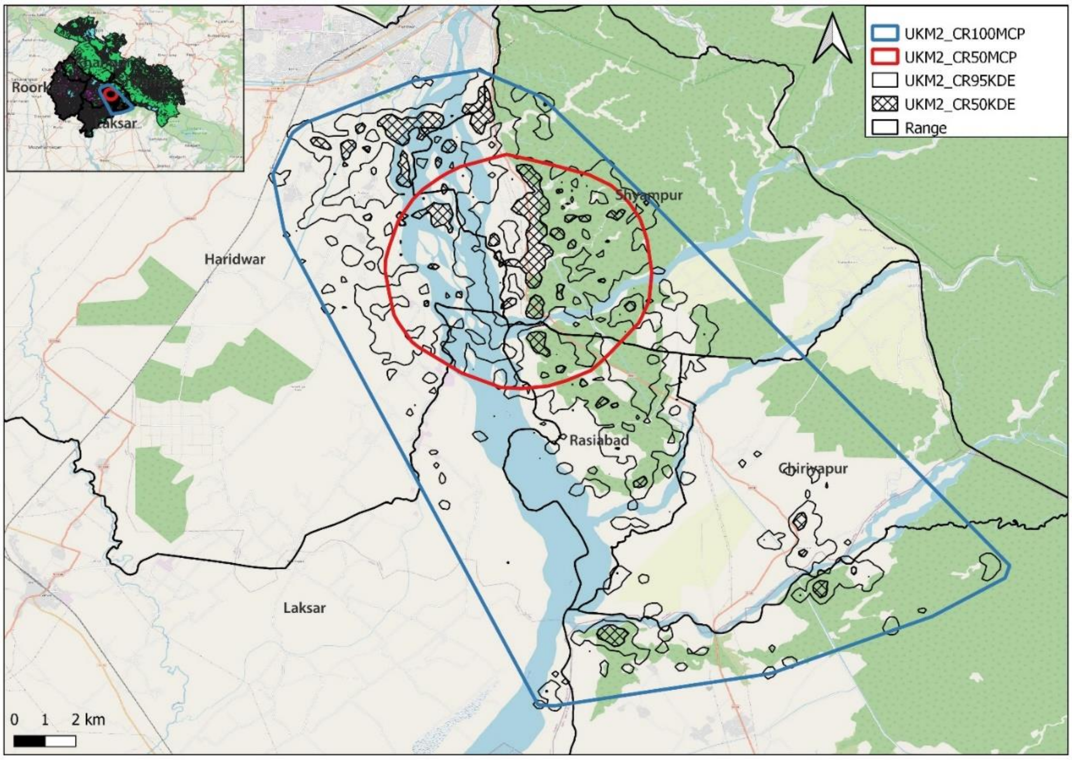


Figure 2.8: Space-use pattern of UKM2 during crop-raiding season (CR)

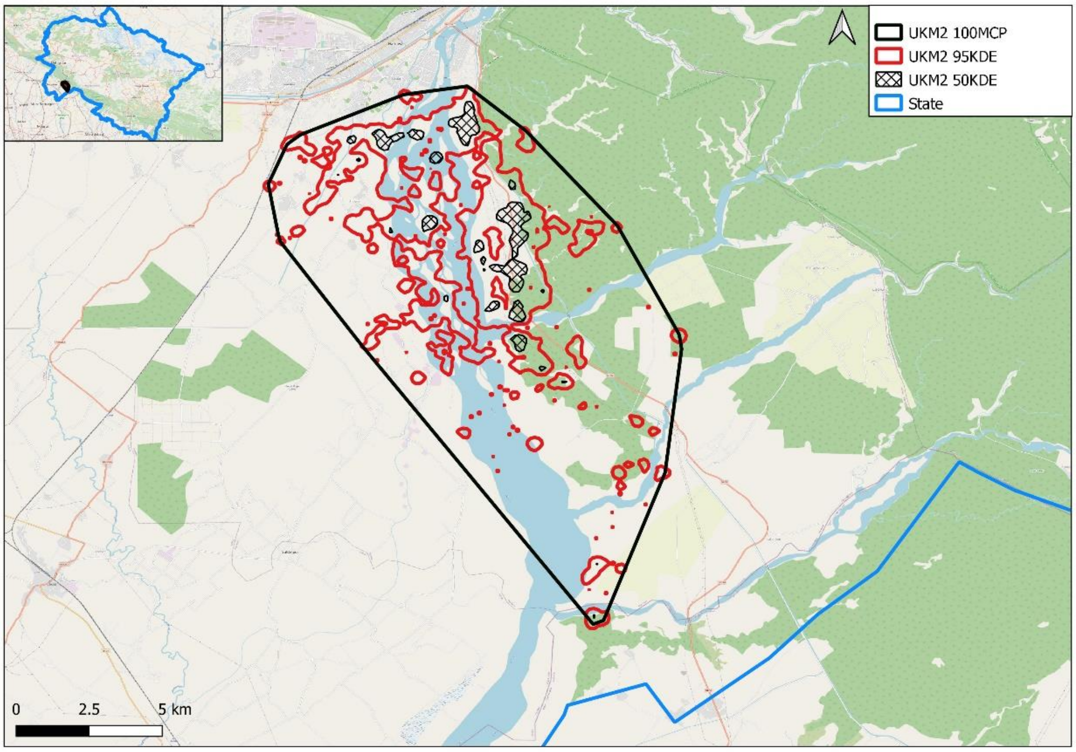


Figure 2.9 Space-use pattern of UKM2 during crop-raiding season (Kharif season)

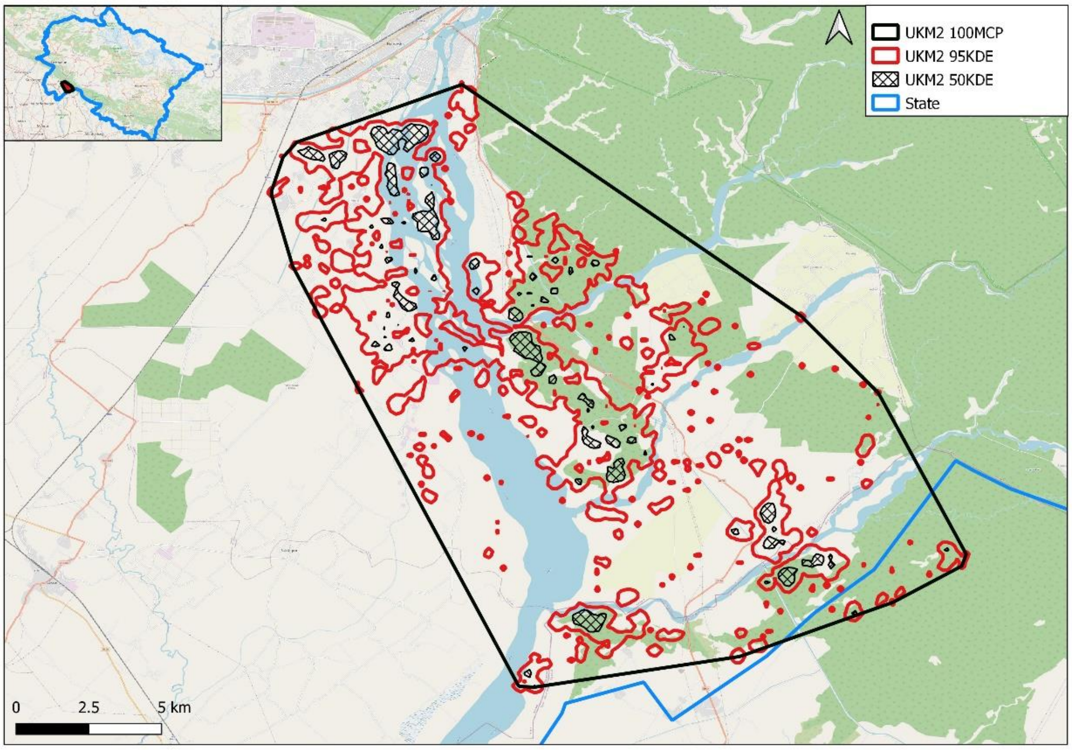


Figure 2.10 Space-use pattern of UKM2 during crop-raiding season (Rabi season)

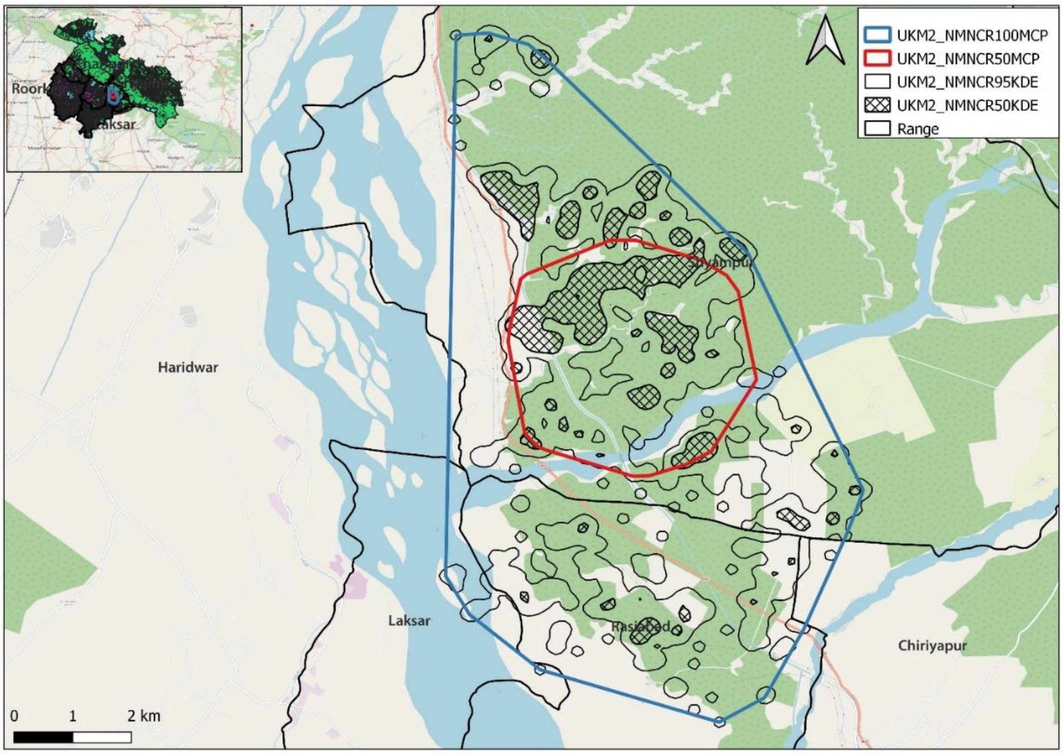


Figure 2.11: Space-use pattern of UKM2 during non-*musth*, non-crop raiding state (NMNCR)

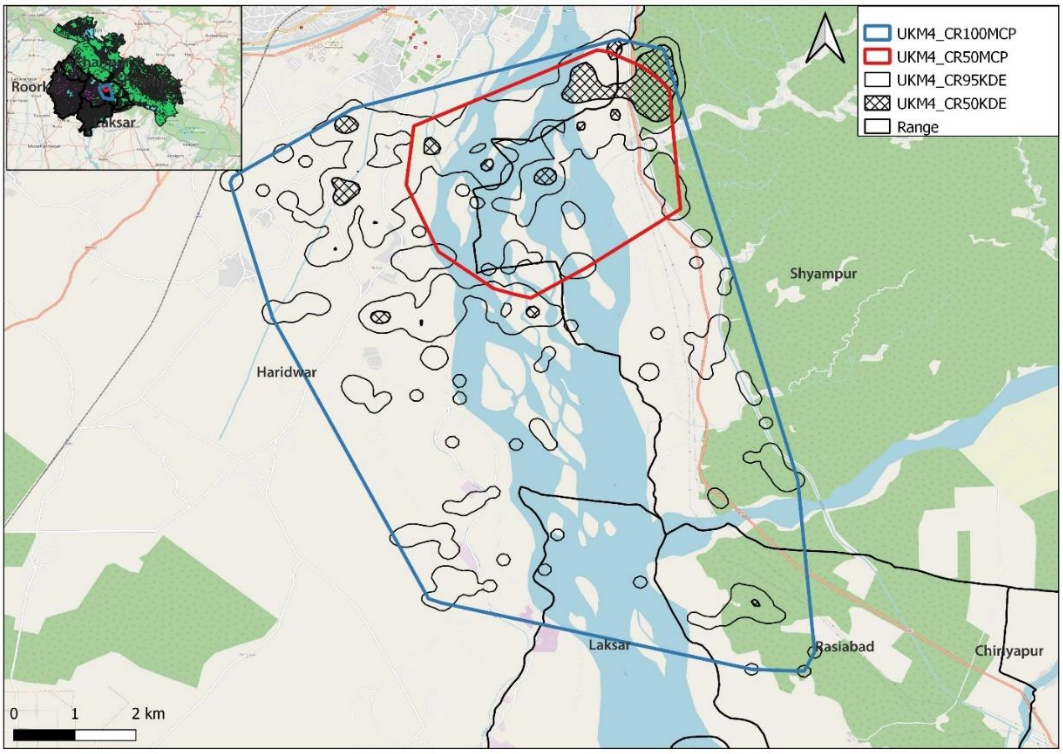


Figure 2.12: Space-use pattern of UKM4 during non-*musth*, crop raiding (NMCR) state. Sightings (n=58)

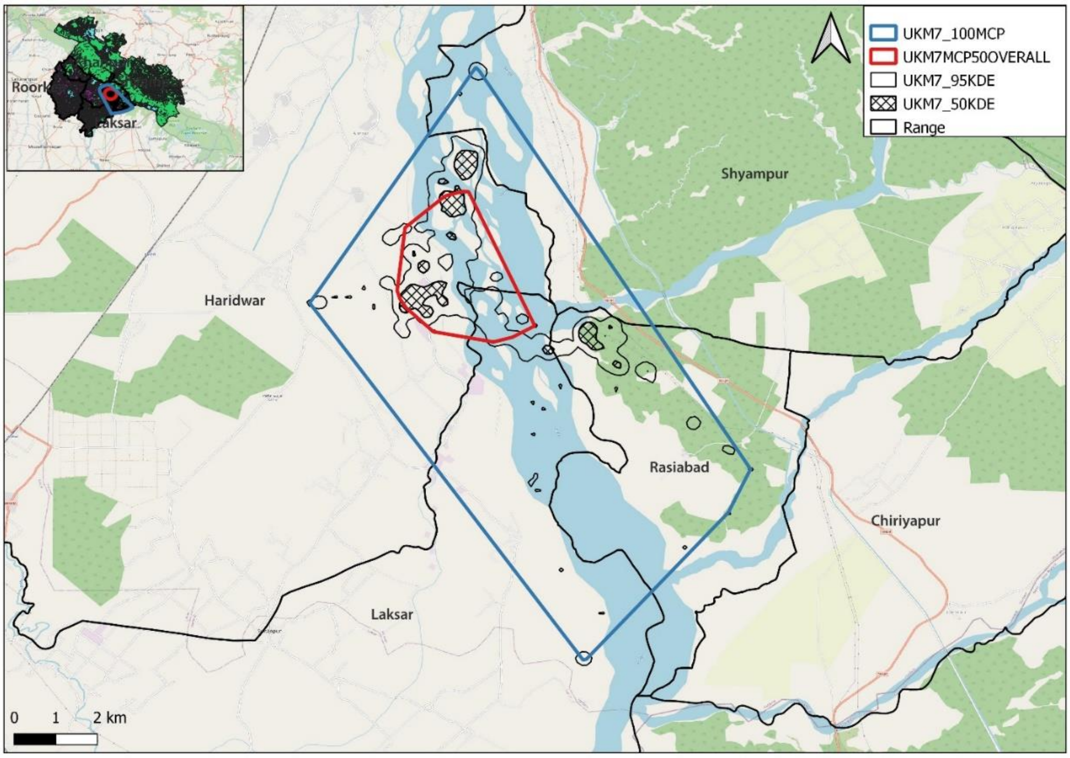


Figure 2.13: Space-use pattern of UKM7 during non-*musth*, crop raiding (NMCR) state. Sightings (n=24)

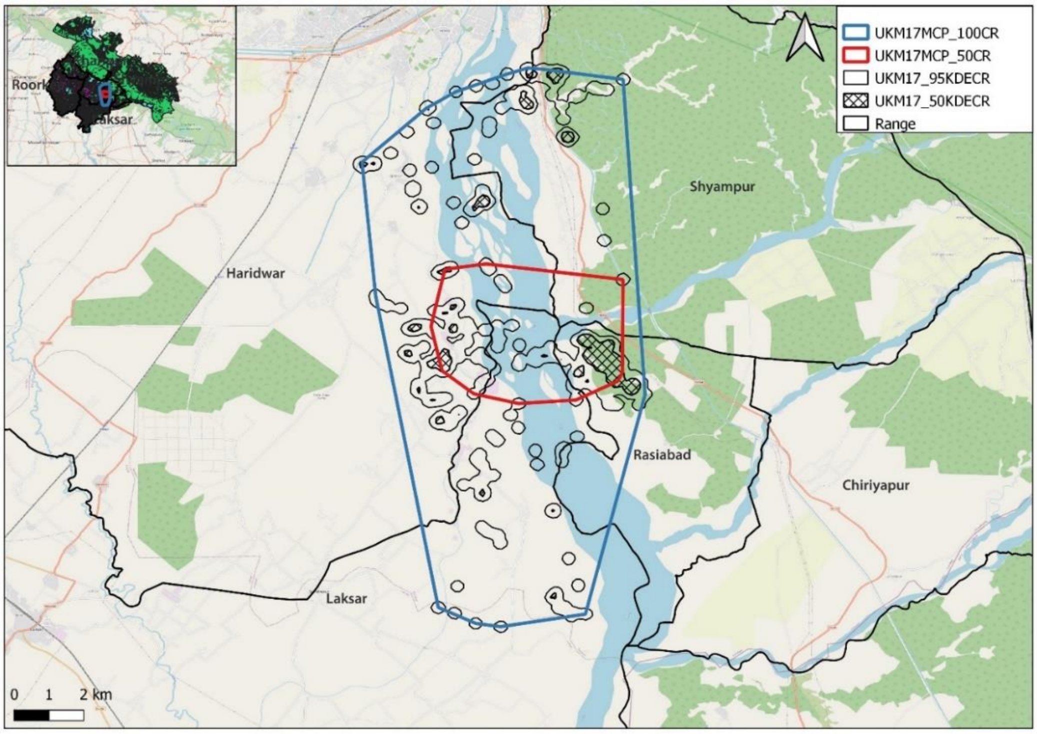


Figure 2.14: Space-use pattern of UKM17 during non-*musth*, crop raiding (NMCR) state. Sightings, n = 39.

Diel pattern of space-use of collared bull elephants

The diel pattern of space-use based on the GPS fixes falling inside "habitat" and "human-use areas" during the non-*musth* crop raiding (NMCR) state suggests that elephants took refuge in the "habitat" classes (primarily comprising of trees and scrub) mostly during the daylight hours (6:00 AM to 8:00 PM) and mostly used "human-use areas" (crop-fields and built areas), from 8:00 PM to 6:00 AM (Figure 2.15).

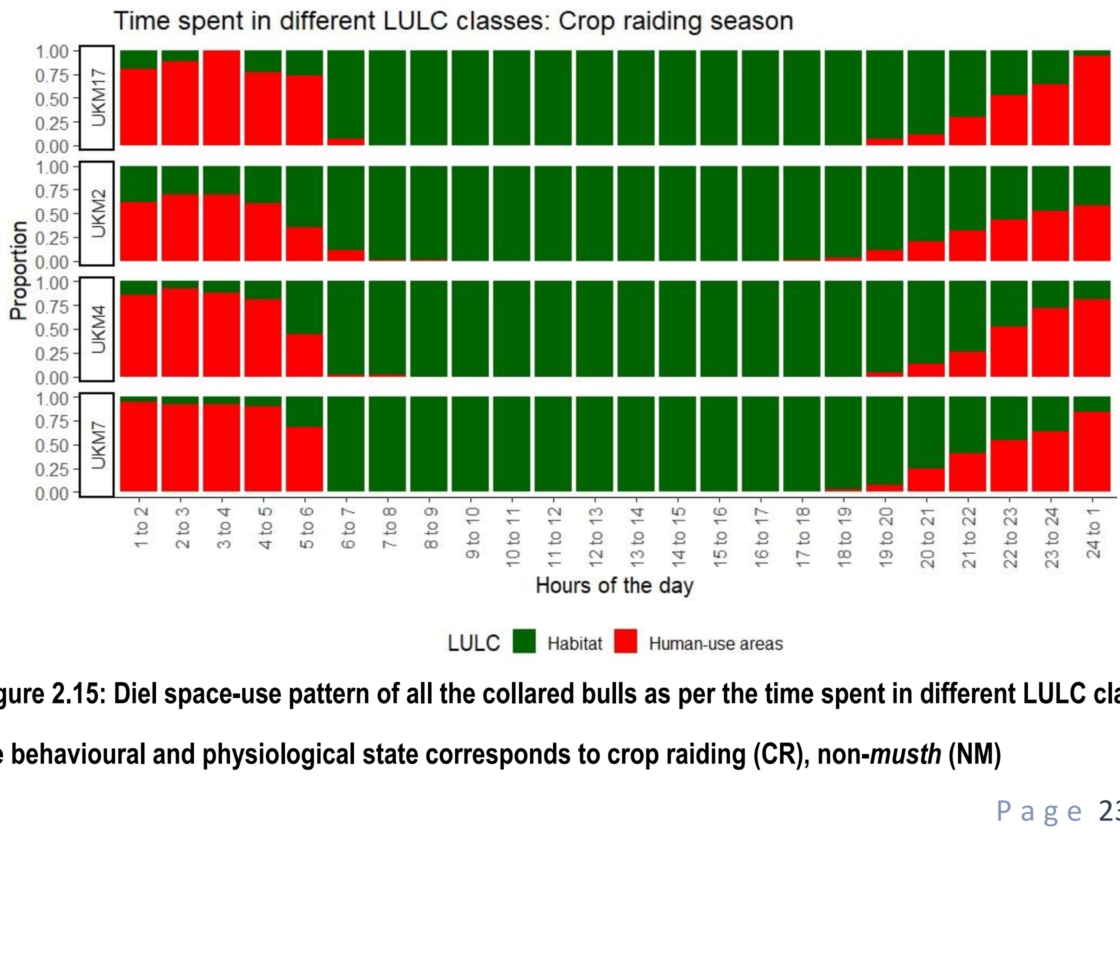


Figure 2.15: Diel space-use pattern of all the collared bulls as per the time spent in different LULC classes.

The behavioural and physiological state corresponds to crop raiding (CR), non-*musth* (NM)

Overall space-use pattern of collared bull elephants

During the non-*musth* crop raiding state (NMCR), all the collared bulls exhibited similar space-use pattern, based on the time spent in “habitat” and “human-use areas”. The proportion of time spent in “habitat” ranged between 0.71 to 0.76, while it ranged between 0.29 to 0.24 in “human-use areas”. However, UKM2 (Brahma) showed drop in the proportion of time spent in “human-use areas” from 0.24 in NMCR to 0.16 in MCR and 0.01 in NMNCR (Figure 2.16).

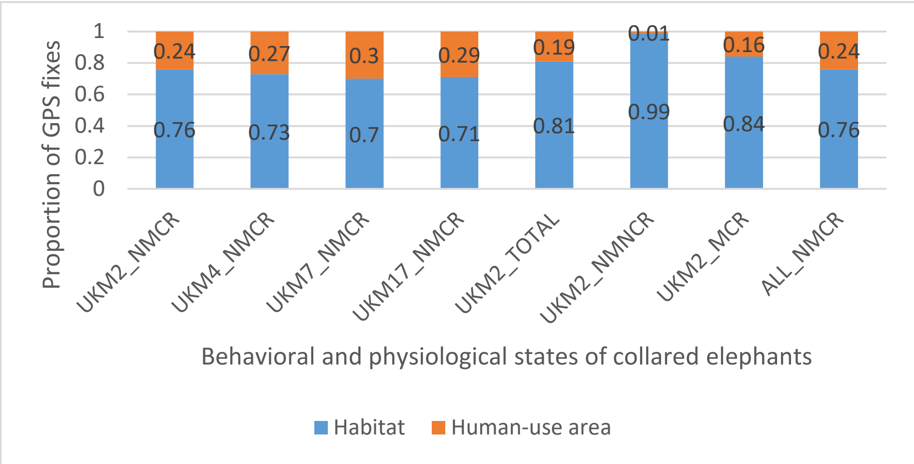
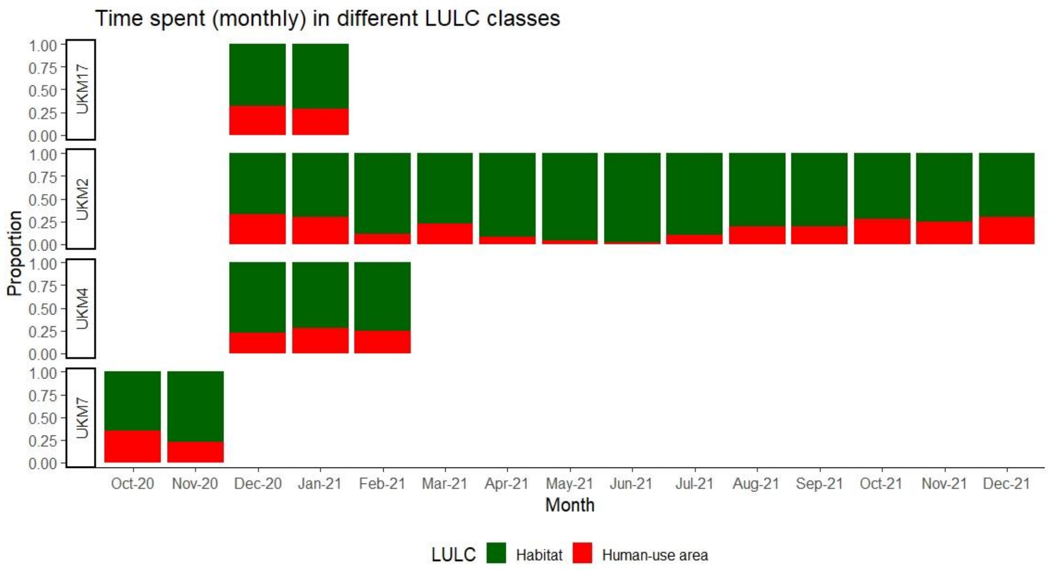


Figure 2.16: Proportion of time spent in "habitat" and "human-use areas" by collared elephants, across their physiological and behavioural states



Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sugarcane												
Paddy												
Wheat												
Maize												

Figure 2.17: Monthly space-use pattern of collared bull elephants, based on time spent (GPS fixes) in LULC classes along with availability of major crop types in the study area, based on primary data collection.

The monthly proportion of time spent by collared elephants in "human-use areas" varies between 0.01 to 0.35 across the year. The dips in the time spent in "human-use areas" are observed from the months of April to July 2021 (0.01 to 0.09), with the least proportion of time spent in the month of June, 2021 (0.01) (Figure 2.17).

Diel space-use pattern of UKM2 across the behavioral and physiological states

Both MCR and NMCR states showed similar pattern of space-use at different hours of the day, with daylight hours spent in habitat (daytime refuges) and hours between evening and early mornings exhibiting variable use of "human-use areas". However, during the NMNCR state, UKM2 spent most of its time in "habitat" and hardly any time in the "human-use areas" across the 24 hours (Figure 2.18).

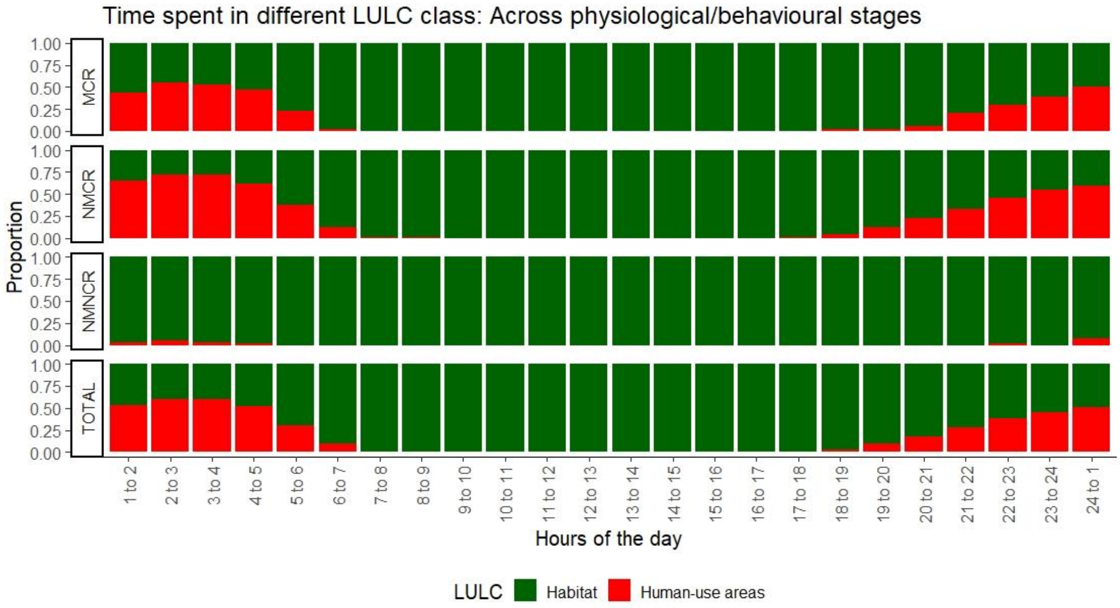


Figure 2.18: Time spent by UKM2 in different LULC classes at different hours of the day, across different behavioural and physiological states

Pattern of crop-raiding incidents around the year

A dip in the proportion of crop raid nights between April 2021 (0.70) to July 2021 (0.39) was observed, with lowest number of crop raids (4) in the month of June, 2021 (Figure 2.19).

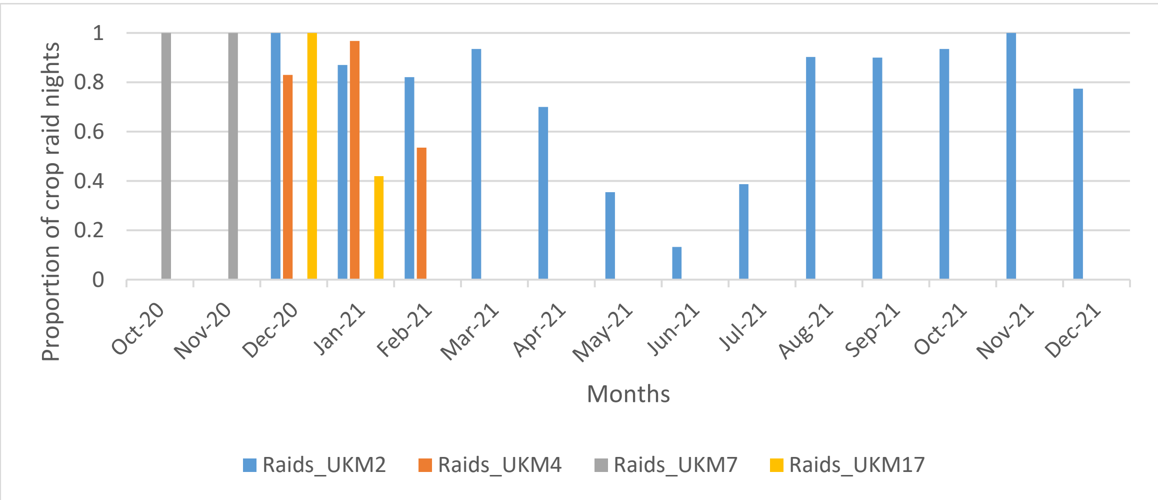


Figure 2.19: Monthly pattern of crop raids for UKM2, UKM4, UKM7 and UKM17

Spatial extent to which the collared bulls raided crops on the western side of the Ganges was documented. For this, the distribution of GPS fixes from the edge of the western bank of the Ganges, into the human-use areas was measured. For all the GPS fixes pooled together (for UKM2, UKM4, UKM7 and UKM17), the average distance covered by the collared bulls from the edge of the western bank of the Ganges, into the human-use areas was found to be 1058.22 (±794.6) m (Figure 2.20).

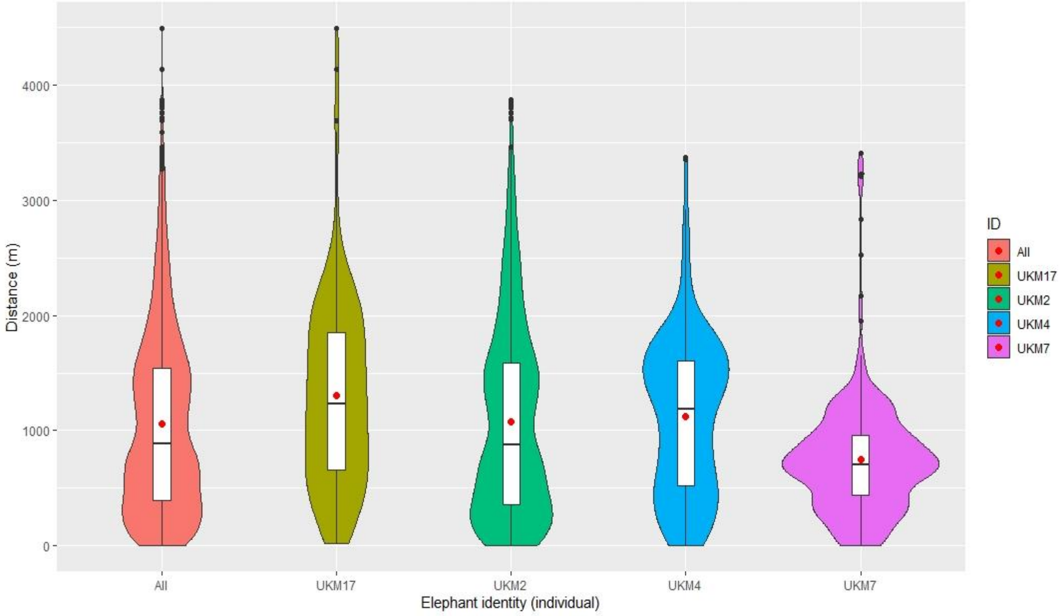


Figure 2.20: Distance covered from the western bank of the Ganges, into the human-use areas during crop raiding season

Diel movement pattern of all the collared bulls during non-*musth*, crop raiding state (NMCR)

Plotting the speed (mean ± standard deviation) of the collared bulls at different hours of the day suggested crepuscular behaviour with speed of movement peaking during early morning and evening hours. Speed of movement is relatively less during the daylight hours (Figure 2.21).

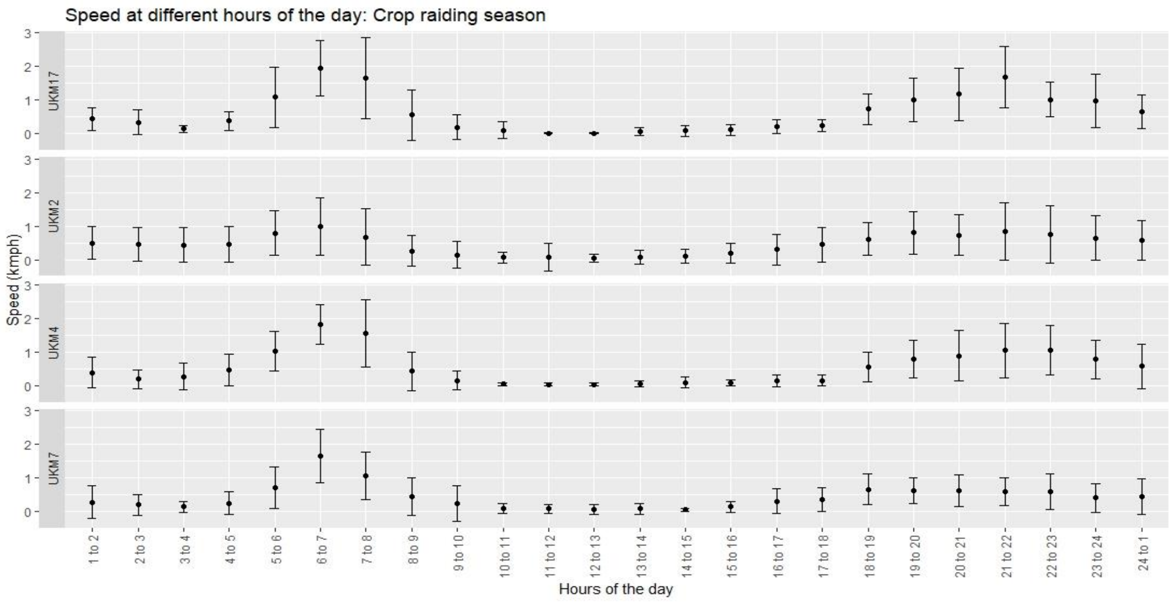


Figure 2.21: Speed of movement at different hours of the day, for all the collared bull elephants, during crop raiding season

Diel movement pattern of UKM2, across behavioural and physiological states

For, different behavioural and physiological states of UKM2, the diel movement pattern (average speed) showed similar crepuscular behaviour with lower variance between the average speed across the hours of the day during the NMNCR state (Figure 2.22).

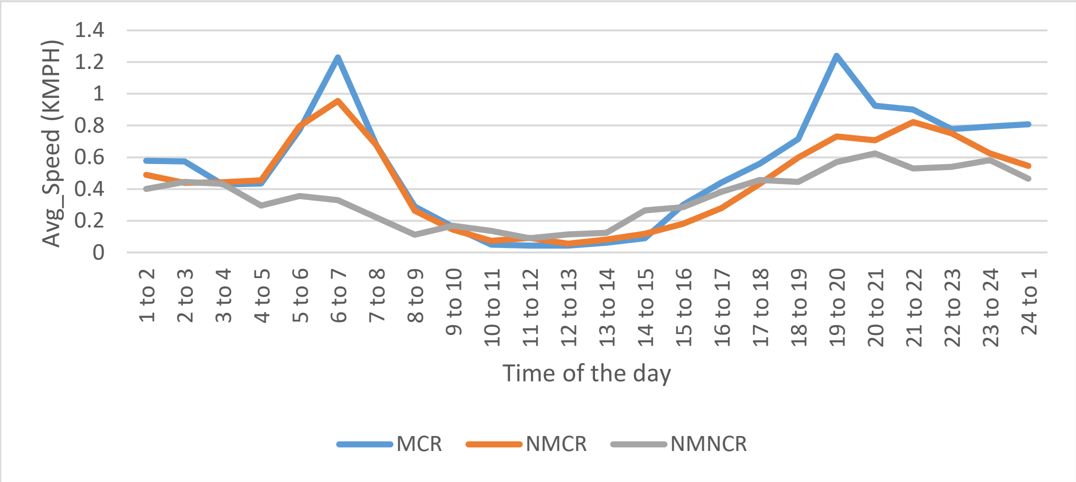


Figure 2.22: Speed at different hours of the day of UKM2, across different behavioural and physiological states. MCR = *Musth*, Crop raiding, NMCR= Non-*musth*, crop raiding and NMNCR = Non *musth*, no crop raiding

Spatial ranging pattern (MCP) of non-collared elephants based on direct sighing and re-sighting

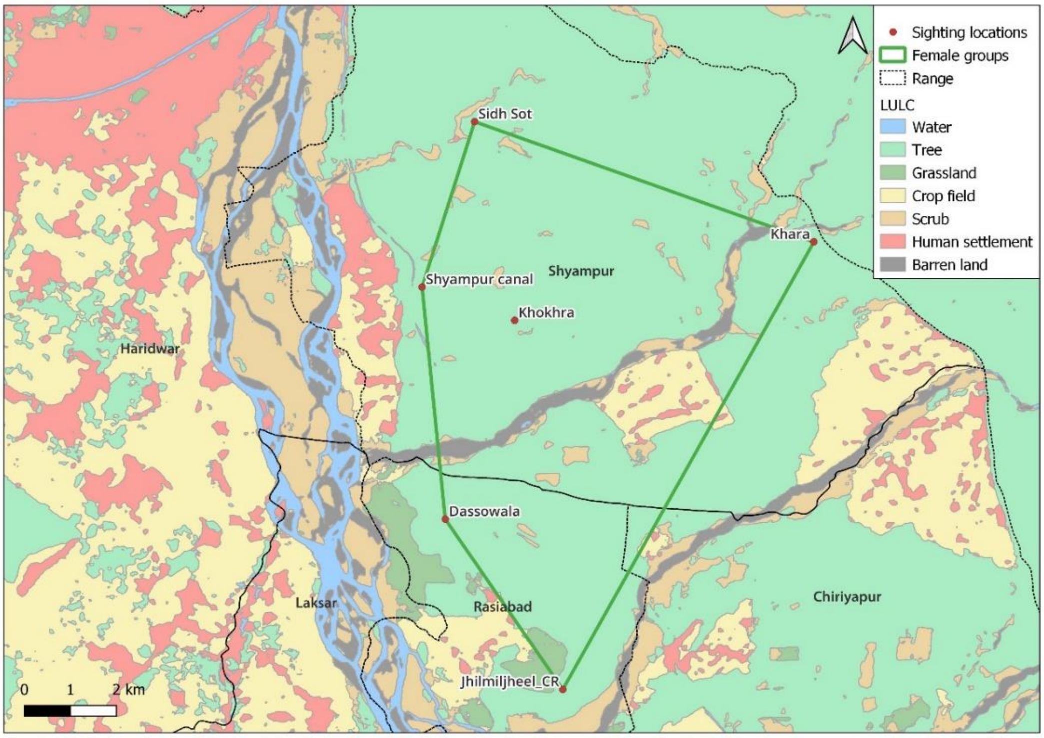


Figure 2.23: Spatial ranging pattern of family groups in the study area. Sightings, n = 20.

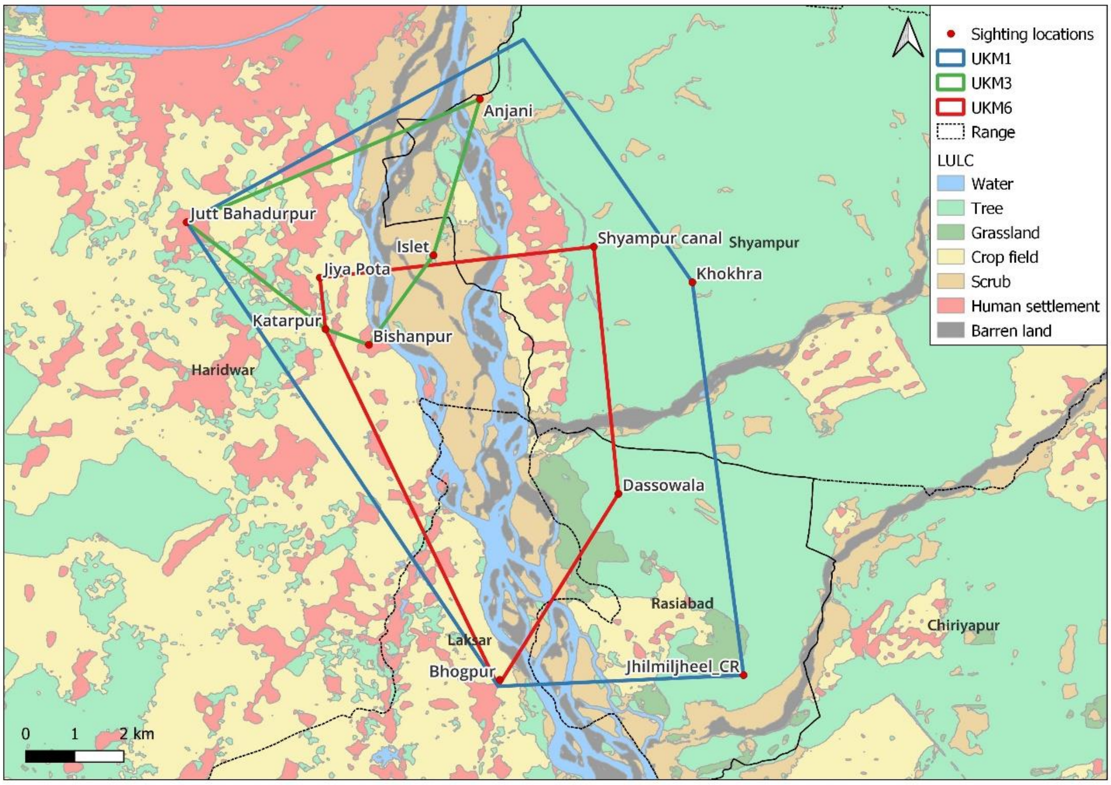


Figure 2.24: Spatial ranging pattern of UKM1 (sightings, n = 101), UKM3 (sightings, n = 33) and UKM 6 (sightings, n = 18)

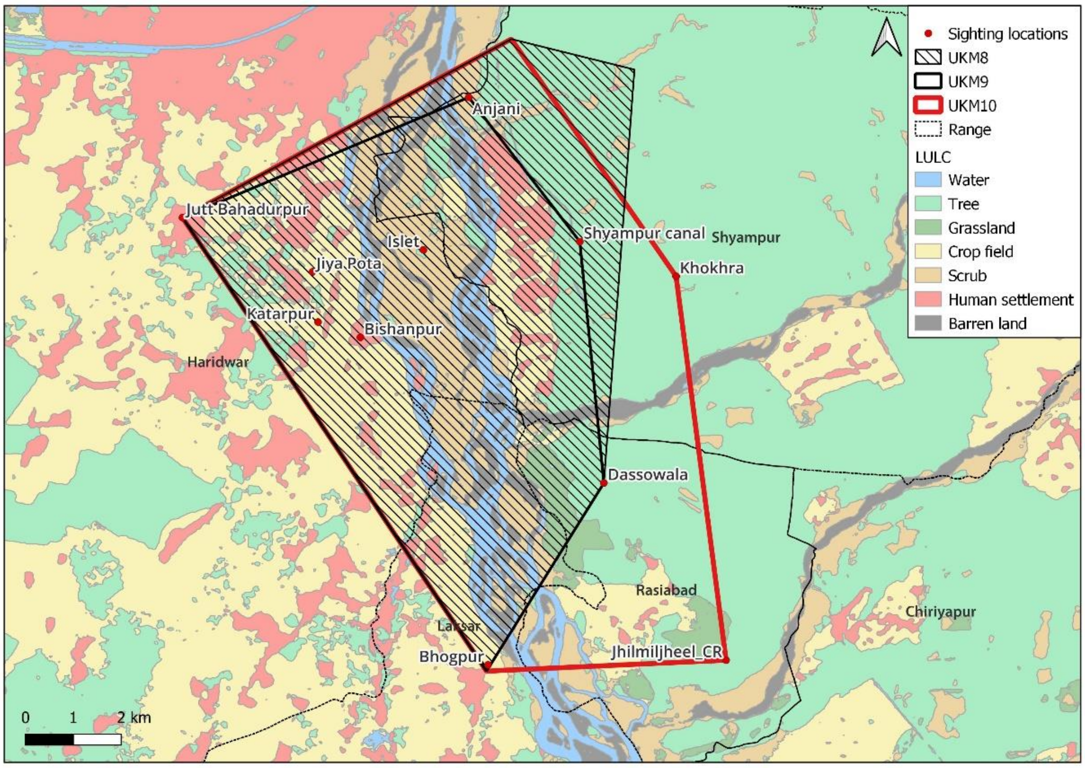


Figure 2.25: Spatial ranging pattern of UKM8 (sightings, n = 70) , UKM9 (sightings, n = 54) and UKM10 (sightings, n = 46)

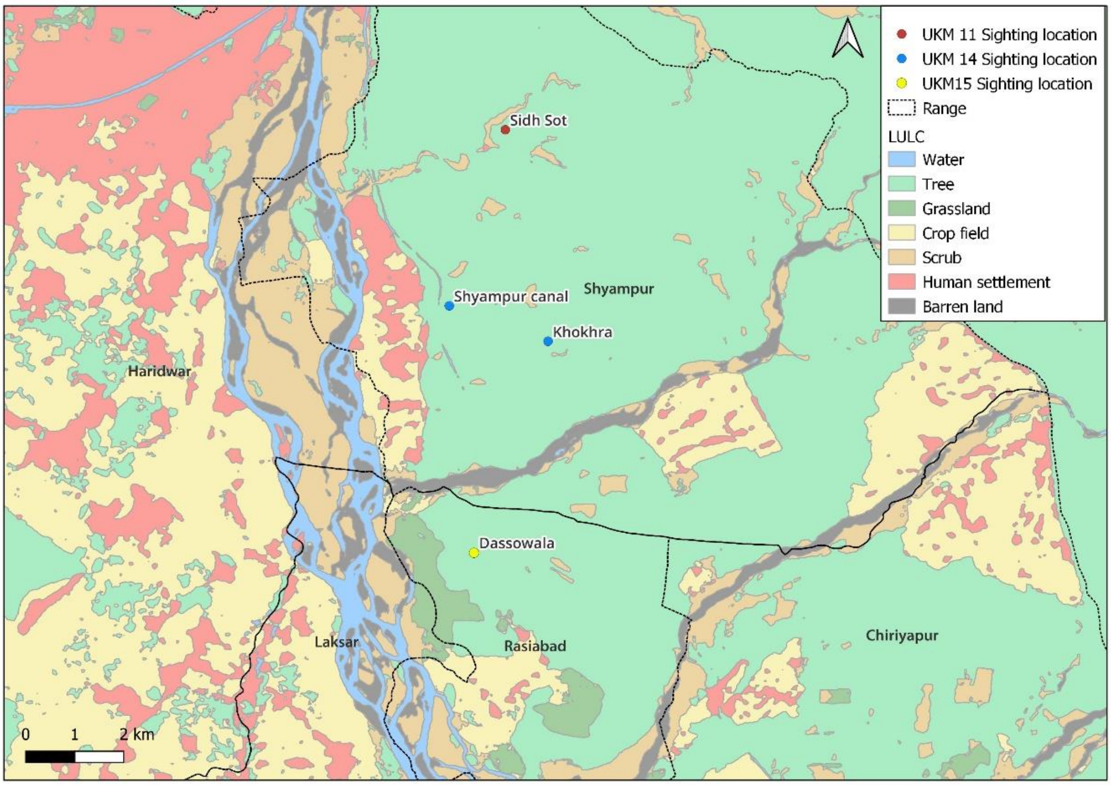


Figure 2.26: Sighting locations of UKM11 (sighting, n = 1), UKM14 (sightings, n = 2) and UKM15 (sighting, n = 7)

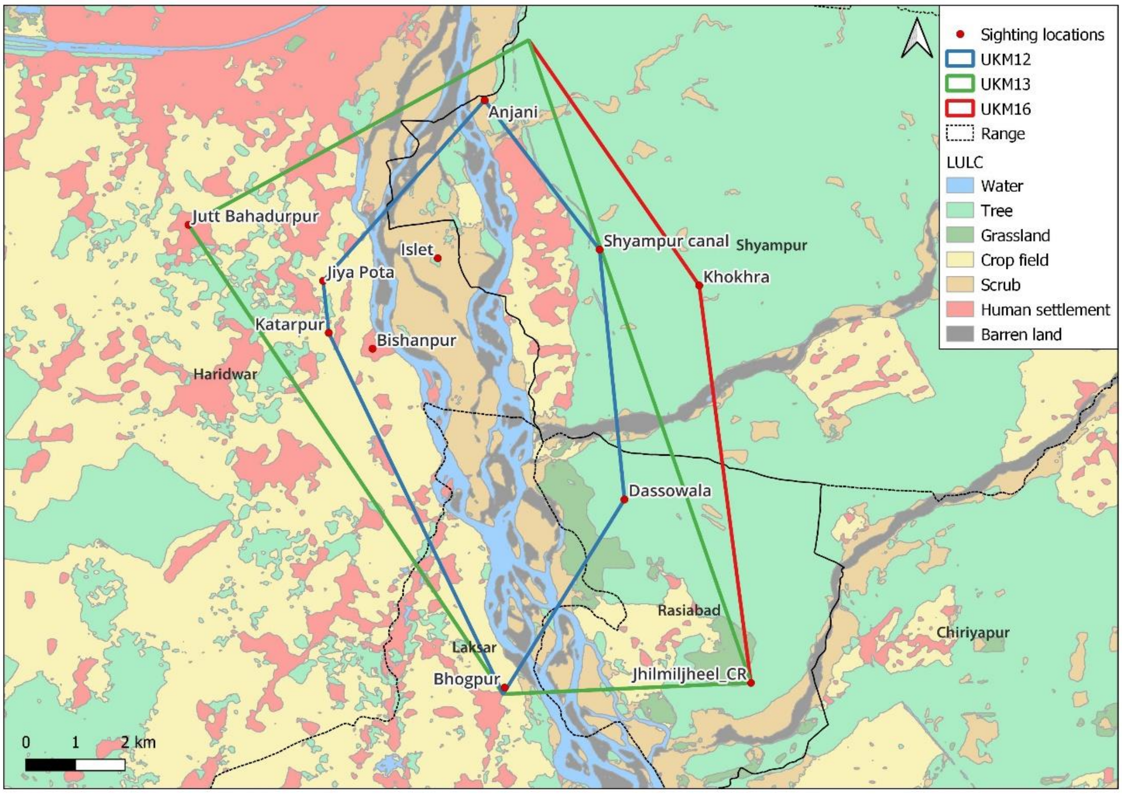


Figure 2.27: Sighting locations for UKM12 (sighting, n = 17), UKM13 (sighting, n = 41) and UKM16 (sighting, n = 42)

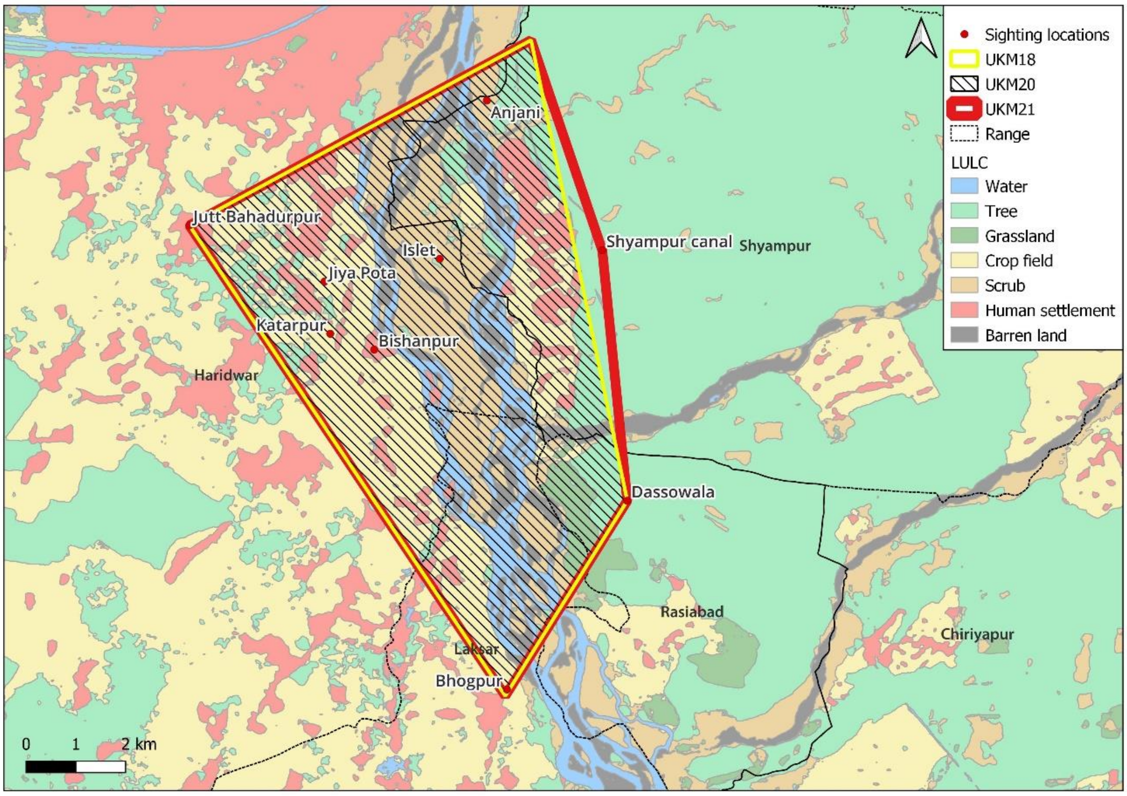


Figure 2.28: Spatial ranging pattern of UKM18 (sighting, n = 53) , UKM20 (sighting, n = 15) and UKM21 (sighting, n = 15)

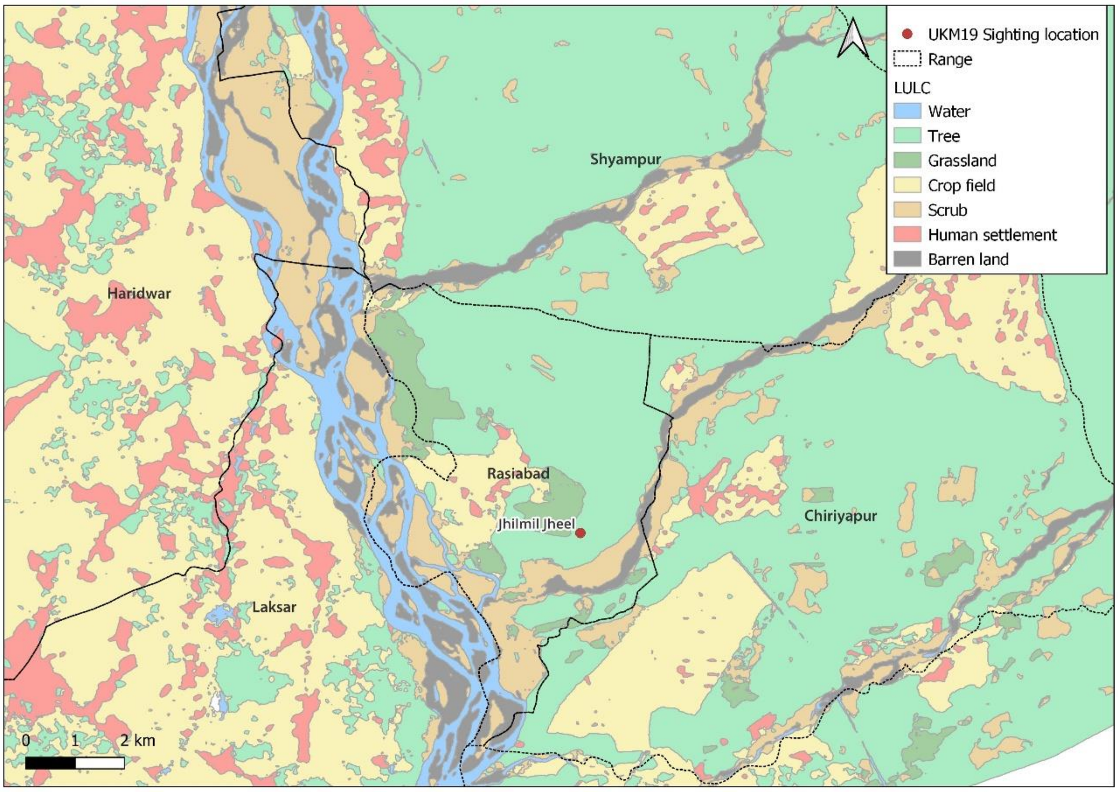


Figure 2.29: Spatial sighting location of UKM19 (sighting, n = 6)

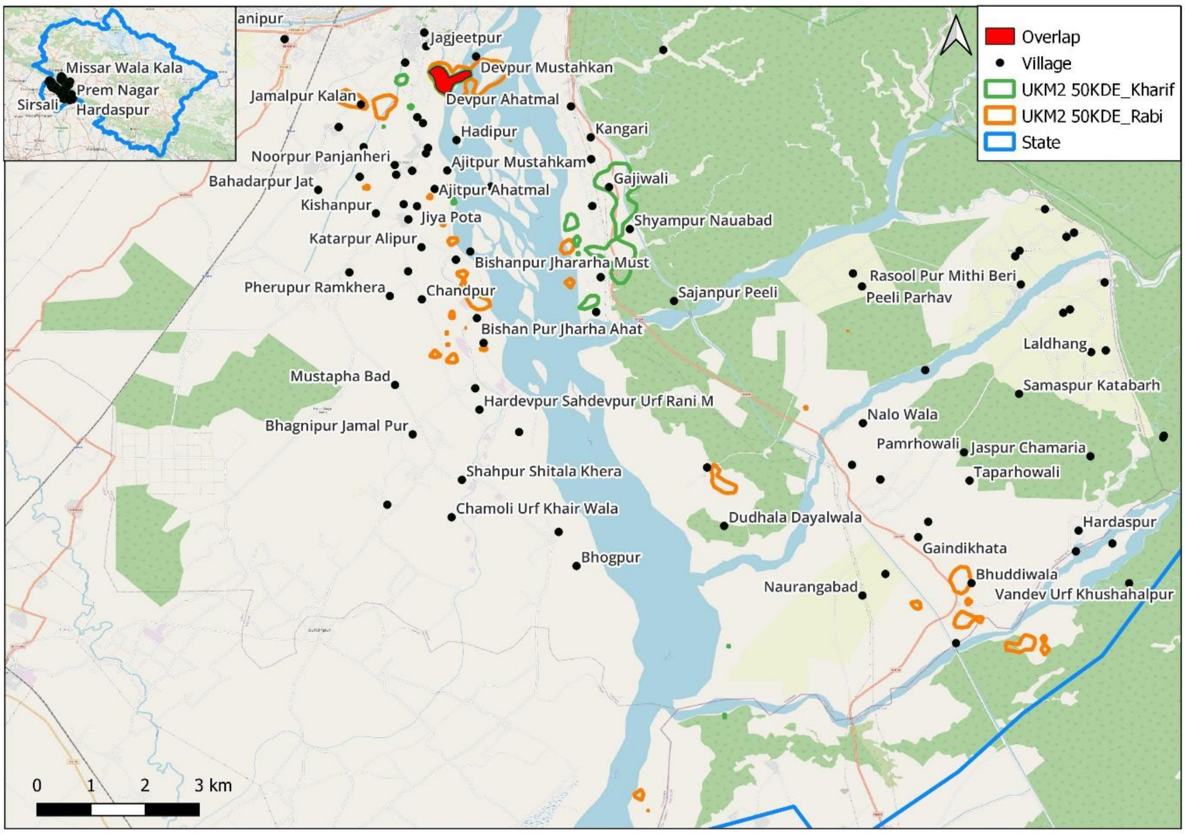


Figure 2.30: Spatial extent of crop damage based on 50% KDE of UKM2 (Brahma) during Rabi (June to mid – November) and Kharif (mid – Novemeber to May) season, with overlap 15.12% area (0.41 sq. km.)

Intensive use area of UKM2, based on 50% Kernel Density Estimation (KDE) suggested that there was a spatial shift in the crop raiding pattern of the animal with an overlap of 15.12% area (0.41 sq. km), near Devpura Athmal area of Haridwar range, Haridwar Forest Division (Figure 2.30).

***Musth* and the ranging pattern:** Six bull elephants were observed to come into *musth* during the study period (Table 2.6).

Table 2.6: Identified individuals and period of *musth*.

Individual ID	UKM2	UKM4	UKM4	UKM7	UKM8	UKM9		UKM10
Year	2021	2020	2021	2020	2021	2020	2021	2021
Months	Jan	Jan	Jan	Jan	Jan	Jan	Jan	Jan
	Feb	Feb	Feb	Feb	Feb	Feb	Feb	Feb
	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar
	Apr	Apr	Apr	Apr	Apr	Apr*	Apr	Apr
	May	May	May	May	May	May*	May	May
	Jun	Jun	Jun	Jun	Jun	Jun	Jun	Jun
	Jul	Jul	Jul	Jul	Jul	Jul	Jul	Jul
	Aug	Aug	Aug	Aug	Aug	Aug	Aug	Aug
	Sep	Sep	Sep	Sep	Sep	Sep	Sep	Sep
	Oct	Oct	Oct	Oct	Oct	Oct	Oct	Oct
	Nov	Nov	Nov	Nov	Nov	Nov	Nov	Nov
	Dec	Dec	Dec	Dec	Dec	Dec	Dec	Dec

* could not observe due to CoVID19 restrictions

Discussion

Space use pattern of collared bulls: Elephant home ranges vary widely (Fernando et al., 2008b), based on their population and ecological conditions. Home range of UKM2 was estimated to be 331 sq. km, based on 100% MCP. The home range of UKM2 is within the range of the findings from earlier studies on bull elephants in Rajaji landscape (Williams et al., 2008). Home range estimates of bull elephants from different elephant landscapes of India were compared. Home range of elephants in relatively intact habitats of the Nilgiris were estimated to be around 400 sq. km (Baskaran et al., 2018a, 2018b), whereas in relatively fragmented habitats, elephant home ranges were found to be inflated. This is highlighted by peaks in the home range of bull elephants in West Bengal and Chhattisgarh, where the habitats are relatively more fragmented when compared to home range estimates of elephants in Nilgiris and Terai landscapes (Figure 2.31).

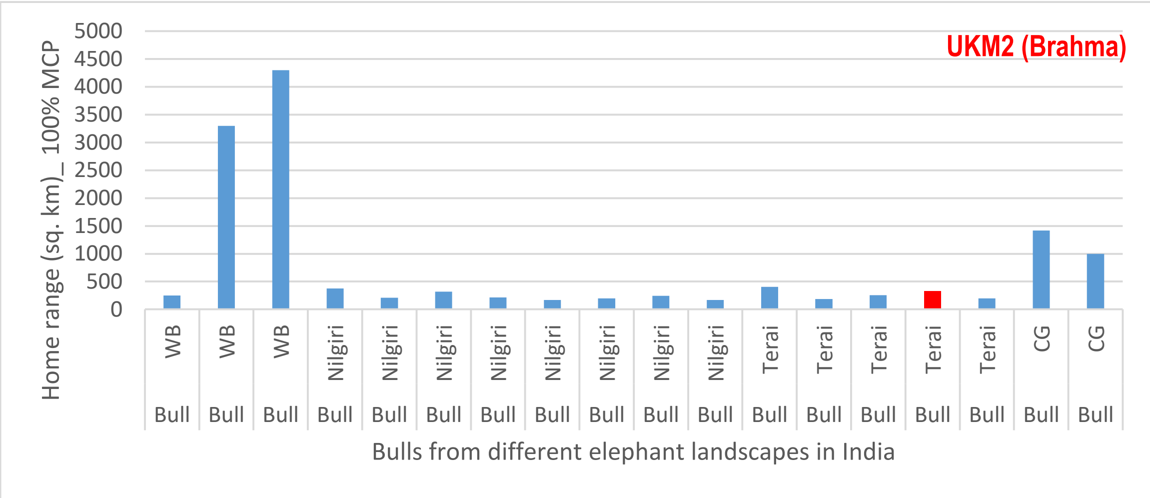


Figure 2.31: Comparison of home range estimates of collared elephants (bulls) from elephant in other landscapes

Space-use pattern (based on MCP and KDE) of collared bull elephants with respect to their behavioral and physiological states: The proportion of 100% MCP falling under "habitat", during non-*musth*, crop raiding state (NMCR) ranged from 0.59 (UKM4) to 0.79 (UKM17), indicating variability in the available area under different classes. For UKM2, there was an increase in the proportion of area under "habitat" class from non-*musth* crop raiding (NMCR) – 0.70, to *musth*-crop raiding (MCR) state – 0.77, to non-*musth*, non-crop raiding state (NMNCR) – 0.89.

The proportion of time spent by all the collared bulls during NMCR state within their habitat ranged from 0.7 (UKM7) to 0.76 (UKM2). While the proportion of time spent within the habitat across behavioral and physiological states of UKM2 increased from 0.76 (NMCR) to 0.84 (MCR) to 0.99 (NMNCR). The increase in the time spent and proportion of area covered within the habitat class from NMCR to NMNCR states by UKM2 may be a response to the changes within the system of the animal (physiological/hormonal) and simultaneously, the ongoing changes in its immediate environment – low availability of crops from late April to mid – July 2021 (NMNCR state). UKM2 was observed to use roving strategy during MCR state, where the animal explored the relatively undisturbed areas in search of potential mates in family groups. The spatial organization of female groups in the forest patches adjoining the forest-crop field interface resulted in the animal raiding crops on the crop fields along the interface areas at night and associating with female groups in the forest patches during the daytime. Similar ranging pattern was observed for non-collared bull elephants. During *musth*, they were not seen in all-male groups but associating with female groups in the forests of Shyampur, Chiriyapur and Rasiabad range of Haridwar Forest Division. The findings are consistent with observation made in the past by (Fernando et al., 2008b; Sukumar, 2003; Williams et al., 2008).

Monthly space use patterns of collared bulls: The monthly proportion of time spent by collared elephants in "human-use areas" varied between 0.01 (~7.2 hr) to 0.35 (~252 hr) across the year. The dips in the time spent in human-use areas corresponded with low availability of crops in the crop fields within the study area. Similar observations of seasonality of crop raids based on availability of crops were also reported in different parts of Africa and Asia (Branco et al., 2019; Osborn, 2004; Sukumar, 2003)

Diel movement and space-use pattern of collared bull elephants: Diel space-use and movement pattern of all the collared bulls during NMCR state showed a crepuscular behavior with most of the daylight hours spent inside habitat and speed of movement peaking during dawn and dusk hours. These peaks in speed corresponded to the forays of movement while returning from human-use areas (crop fields) to habitats (during dawn hours) and going to raid crops from habitat to human-use areas (during dusk hours). The movement pattern for UKM2 was similar during MCR and NMNCR states with relatively low variance in the speed between the hours of the day. There were differences in the diel pattern in space use of UKM2 between NMNCR and MCR/NMCR state. During MCR and NMCR state, the animal showed similar behavior of using the habitats during daylight hours while transitioning to human-use areas (crop fields) between dusk to dawn hours, while for NMNCR state, throughout the 24-hour cycle, the animal stayed mostly within the habitat. The pattern of movement reflects their crepuscular behavior and are consistent with the observations made by Hoare, (1999); Mills et al., (2018); Naha et al, (2020). Observations from previous studies suggest that the elephants have become behaviorally adapted to avoid humans, in response to the high incidence of human–elephant conflict across their range (Fernando et al., 2008b).

Pattern of crop-raiding incidents around the year: The dip during the months from April to July 2021 in the proportion of crop raid nights can be attributed to low availability of crops during that time of the year. Most of the sugarcane in the fields were harvested from February to April, while March and April witnessed harvesting of wheat. The crop fields during the time period from late April till mid-July are primarily used for certain fodder species for livestock (e.g. “chari”, millets) and have smaller remnants of the sugarcane stems. The paddy fields are sown in tandem with the onset of monsoon, between the late June and mid-July. The dip in the crop raiding behaviour by the elephants around this time may be explained by the non-availability of the quantum of crops (nutrition) in the fields for them to take the risks involved in raiding crops. The spatial organization of crop fields on the western bank of the Ganges is such that vast stretches of sugarcane, wheat and paddy fields start from the immediate edge of the western bank of the Ganges. The anthropogenic pressure (human settlements, linear intrusions) increases with west-ward movement from the edge of the river. These conditions may explain the average distance covered by the collared bulls from the edge of the western bank of the Ganges, into the human-use areas to be 1058.22 (±794.6) m.

Spatial ranging pattern (MCP) of non-collared elephants based on direct sighing and re-sighting: The annual home range of the bull elephants monitored in the forest-crop field interface areas showed high spatial overlaps. The spatial overlaps can be attributed to the life-history strategy of bull elephants (Sukumar, 2003). All the studied bull elephants engaged in raiding crops throughout the year, except for the seasons when most of the crops were harvested. The bulls were observed to form all-male groups (AMG), possibly to diminish the threat arising from exposure into the human-use areas while raiding crops and to benefit from social learning by associating with older bulls in the area. Consistent with the findings from the previous study in this landscape (Williams et al., 2008), the females were found to trade food for safety as they showed less tolerance to anthropogenic disturbances. They were mostly observed range in relatively undisturbed areas, with the only exception of them extensively using the human-use areas being the canal-road in the Shyampur-Rasiabad range of Haridwar Forest Division, especially during the dry season. During the study period, the family groups were never observed to cross the Ganges to raid crops on the other side of the river.

Through this study, field tracking, coupled with telemetry data showed the ranging and space use pattern of collared and non-collared bull elephants. A total of 21 bull elephants were observed to raid crops along the crop fields on the western bank of the Ganges. It was interesting to observe the space use pattern of bull elephants in forest-crop field interface areas. Most of the bull elephants using the interface areas were between sub-adult to young-adult age classes. High number of young bull elephants using the interface areas may be explained by the adult sex ratio of elephants in the study area. Previous study (Williams, 2002) had reported the adult male to female ratio as 1 male : 1.87 females, which may result in high-competition for potential mates, resulting in older bull elephants of higher social strata occupying the relatively less disturbed parts of the study area (female ranging areas) and pushing the young bull elephants in the interface areas. For long-term conservation of elephants in the landscape, it is imperative to look beyond just the habitat quality. Habitat degradation in the context of resources such as food, water and shelter and threats faced by elephants due to anthropogenic pressures in the adjoining areas needs serious attention. One of the collared bull elephant was electrocuted on the islet (one of its daytime refugia) between the banks of the Ganges on 23rd November 2020. The linear intrusions inside the elephant ranging areas need to be monitored regularly to avoid any such incidents. In light of the increase in the density of elephants inside the Rajaji Tiger Reserve, it would also be prudent to study and understand the demographics of the elephant population in the area. This is imperative to understand the health of the population in the area and explain the space-use pattern of the elephants in the region. As proposed in the earlier study, habitat degradation within the protected area, increase in elephant density and developmental activities in the adjoining area may escalate HEC in the years to come. Therefore, it is imperative to device a management plan for this elephant range that takes into account all the above factors and addresses them for long-term co-existence.

CHAPTER 3: LANDSCAPE-LEVEL ASSESSMENT OF HUMAN–ELEPHANT CONFLICT AND ITS DRIVERS TO SUGGEST IMPLEMENTABLE STRATEGIES TO MITIGATE CONFLICT

INTRODUCTION

Over the years, the Rajaji landscape has experienced change in the land-use, land-cover (LULC) pattern inside and outside the elephant habitats. As in other Asian elephant range states, factors such as LULC change and elephants' response to it may govern Human – Elephant Conflict (HEC) in this context. HEC is multifaceted and evidence-based approach to address conflict is critical. As a part of the project objective, assessment of HEC was attempted with the following objectives.

1. Landscape-level assessment of crop losses due to elephants to understand the spatial spread and intensity based on the secondary records collated from the Uttarakhand Forest Department (UKFD)

2. Fine-scale assessment of patterns of crop losses by elephants in the select villages

Most of the elephant population in this study area resides within the Rajaji Tiger Reserve, with few elephants (primarily bulls) using the forest-crop field interface along the boundary of Rajaji Tiger Reserve to raid crops, constituting major share of HEC cases. The northern and southern boundaries of western Rajaji Tiger Reserve is bounded by crop fields, especially mango orchards, sugarcane, wheat, paddy and maize are main crops cultivated during Kharif and Rabi seasons. While the stem of sugarcane stands on the crop fields throughout the year, it is primarily harvested from January to March. Other crops damaged by elephants include millets, barley, sesame, pumpkin, mango and other fruits and vegetables.

METHODS

Data collection

Secondary data

To understand the long term spatio-temporal pattern of Human – Elephant Conflict in the study area, secondary data was collected from UKFD. The data comprises of past records of Human-Elephant Conflict documented in a systematic manner by the Forest Department. The database was generated following the reporting of HEC cases by affected villagers to their respective range offices. The records are maintained to help enable the respective ranges to disburse compensation amount for respective cases.

Secondary data comprised of crop damage, human casualty, property damage and compensation records.)Secondary data for Haridwar Forest Division, Dehradun Forest Division and Narendranagar Forest Division were collected from 2015-2020. For Lansdowne Forest Division, it was from 2016-2020, while for Mussoorie Forest Division, it was from 2000-2020.

Primary data

Primary data pertaining to crop damage were collected from select villages across the study area. To assess the cases and pattern of crop damage in the landscape, the team followed a combination of a) standardized data collection protocol was developed for primary data collection. Based on the distance covered by the crop raiding elephants in the landscape which extended till 4500 meters from their habitat/daytime refuges (Chapter 1), a buffer of 5 km was demarcated from the edge of the elephant habitat, into the human-use areas (crop fields, settlements/villages). For daily monitoring of the villages in the study area along the boundary of elephant habitats and to enhance the spatial coverage, field team were stationed in 4 different zones in the study area (figure 1). From all the villages falling inside the buffer, 77.96 % villages from zone A and B and 66.66 % villages from zone C and zone D were randomly selected (using "random selection" tool in QGIS) for daily monitoring (Table 1). Villages in zone A, C and D were part of Haridwar Forest Division, while those of zone B were part of Dehradun Forest Division.

Table 3.1: Villages monitored for primary data on crop damage

S.No.	Zone	Feasible villages	Selected for monitoring	Coverage %	Monitoring period
1	A and B	59	46	77.96	July – December 2021
2	C and D	60	40	66.66	February – December 2021

Primary data collection was carried out in zone C and D from February 2021 to December 2021 (Rabi and Kharif season), while in zone A and zone B, the work was carried out between July 2021 to December 2021 (Kharif season).

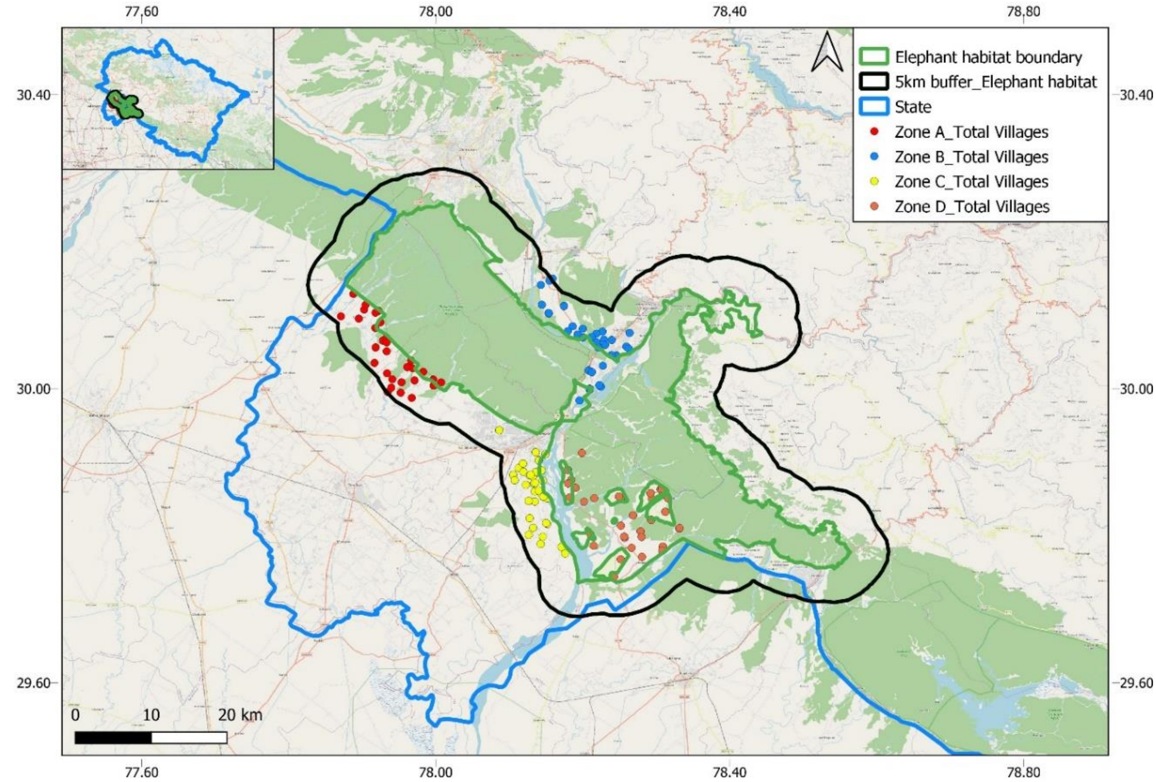


Figure 3.1: Study area for primary data collection pertaining to crop damage, highlighting zone-wise locations of villages feasible for monitoring crop damage by elephants

Analysis

Secondary data

Analysis on secondary data were performed in the following step-wise manner:

a) Collation of data from respective forest divisions
b) Translation of data to English, for analysis
c) Cleaning of data
d) Arranging data for meaningful comparisons across the divisions

Trends pertaining to a) year-wise change in conflict hotspots (beat-level) across the study area was observed by performing the analysis with crop damage and property damage data (because of limited data on conflict as beat-level), b) The year-wise change in percent of damage types, total cases and villages affected across the forest divisions were analyzed using all the HEC data and c) year-wise change in seasonality of crop damage was analyzed using only the crop damage data.

Primary data

Analysis on primary data were performed to understand the following:

a) Village-level conflict hotspots:
   Village-level conflict hotspots were generated to visualize the extent and intensity of crop damage in the study area
b) Pattern of crop damage across the zones (percent of damages and seasonality):
   To understand the key crop types affected damaged by elephants and the seasonality of crop damage
c) Demographic pattern of elephants involved in raiding crops:
   To understand the elephant group types and sexes involved in crop damage
d) Phenophase of crops damaged by elephants:

To understand extent of crop damage across the states of growth for respective crop types

e) Response of humans and elephants during the interaction (crop raids):
To understand how humans and elephants respond to each other while they encounter one another during crop raids

f) Crop guarding measures used by the villagers:
To understand the commonly used measures deployed by farmers/villagers to protect their crop fields from elephant raids

g) Driving measures used by villagers during crop raids:
To understand the methods used by the farmers/villagers to drive the crop raiding elephants

All the analysis were performed using MS excel, R and QGIS.

Results

Secondary data

Between 2016 to 2020, 66 beats out of 286 beats in Haridwar, Dehradun and Lansdowne forest divisions were affected by HEC.

Table 3.2: Beats affected between 2016 – 2020 in Haridwar, Dehradun and Lansdowne forest divisions.

S.No.	Beat	Years affected_2016-2020	Years affected				
1	Lalpani	5	2016	2017	2018	2019	2020
2	Katewad_East	5	2016	2017	2018	2019	2020
3	GandIkhata-I	5	2016	2017	2018	2019	2020
4	Devpura_Ahatmal	5	2016	2017	2018	2019	2020
5	Gular_Ghati	5	2016	2017	2018	2019	2020
6	Kaluwala	5	2016	2017	2018	2019	2020
7	Gandikhata-II	5	2016	2017	2018	2019	2020
8	Manuvas_South	5	2016	2017	2018	2019	2020
9	Bishanpur_South	5	2016	2017	2018	2019	2020
10	Aurangabad	5	2016	2017	2018	2019	2020
11	Peeli-I	5	2016	2017	2018	2019	2020
12	Majri	5	2016	2017	2018	2019	2020
13	Danda	5	2016	2017	2018	2019	2020
14	Semlas	5	2016	2017	2018	2019	2020
15	Birbhadra	5	2016	2017	2018	2019	2020
16	Bishanpur_North	5	2016	2017	2018	2019	2020
17	Mithiberi	5	2016	2017	2018	2019	2020
18	Nalonwala_South-II	5	2016	2017	2018	2019	2020
19	Pathri_East	5	2016	2017	2018	2019	2020
20	Shahmansur	5	2016	2017	2018	2019	2020
21	Ghamandpur-I	5	2016	2017	2018	2019	2020
22	Shyampur	5	2016	2017	2018	2019	2020
23	Gola_East	5	2016	2017	2018	2019	2020
24	Malan	5	2016	2017	2018	2019	2020
25	Rasulpur	5	2016	2017	2018	2019	2020
26	Boxawali	5	2016	2017	2018	2019	2020
27	Jakhan-I	5	2016	2017	2018	2019	2020
28	Thano	5	2016	2017	2018	2019	2020
29	Sajanpur	5	2016	2017	2018	2019	2020
30	RIshikesh	5	2016	2017	2018	2019	2020
31	Gularjhala	5	2016	2017	2018	2019	2020

S.No.	Beat	Years affected_2016-2020	Years affected				
32	Hazara	4	2016	2017	2018	2019	2020
33	Bhogpur_South	4	2016	2017	2018	2019	2020
34	Sneh-II	4	2016	2017	2018	2019	2020
35	Bhogpur_North	4	2016	2017	2018	2019	2020
36	Khattapani	4	2016	2017	2018	2019	2020
37	SaInkot-I	4	2016	2017	2018	2019	2020
38	Joli-I	4	2016	2017	2018	2019	2020
39	Amsot	4	2016	2017	2018	2019	2020
40	Budhwashahid_East	4	2016	2017	2018	2019	2020
41	Haridwar	4	2016	2017	2018	2019	2020
42	Banbaha	3	2016	2017	2018	2019	2020
43	Bhopalpani	3	2016	2017	2018	2019	2020
44	Koh	3	2016	2017	2018	2019	2020
45	Pulinda	3	2016	2017	2018	2019	2020
46	Sukhrao	3	2016	2017	2018	2019	2020
47	Jhawanu	3	2016	2017	2018	2019	2020
48	Rasulpur_Papri	3	2016	2017	2018	2019	2020
49	LachhIwala_North	3	2016	2017	2018	2019	2020
50	Gwalgarh	3	2016	2017	2018	2019	2020
51	Bhogpur	2	2016	2017	2018	2019	2020
52	Budhwashahid_West	2	2016	2017	2018	2019	2020
53	Fatehpur	2	2016	2017	2018	2019	2020
54	South_Papidanda-II	2	2016	2017	2018	2019	2020
55	Palasi	2	2016	2017	2018	2019	2020
56	Golatappar_West-I	2	2016	2017	2018	2019	2020
57	Sainkot-II	1	2016	2017	2018	2019	2020
58	Feduwa	1	2016	2017	2018	2019	2020
59	Gadakot-II	1	2016	2017	2018	2019	2020
60	Tigri	1	2016	2017	2018	2019	2020
61	Nawada	1	2016	2017	2018	2019	2020
62	Bagnala-II	1	2016	2017	2018	2019	2020
63	Gadakot-I	1	2016	2017	2018	2019	2020
64	Bahadrabad	1	2016	2017	2018	2019	2020
65	Khanpur_West	1	2016	2017	2018	2019	2020
66	Katewad_West	1	2016	2017	2018	2019	2020

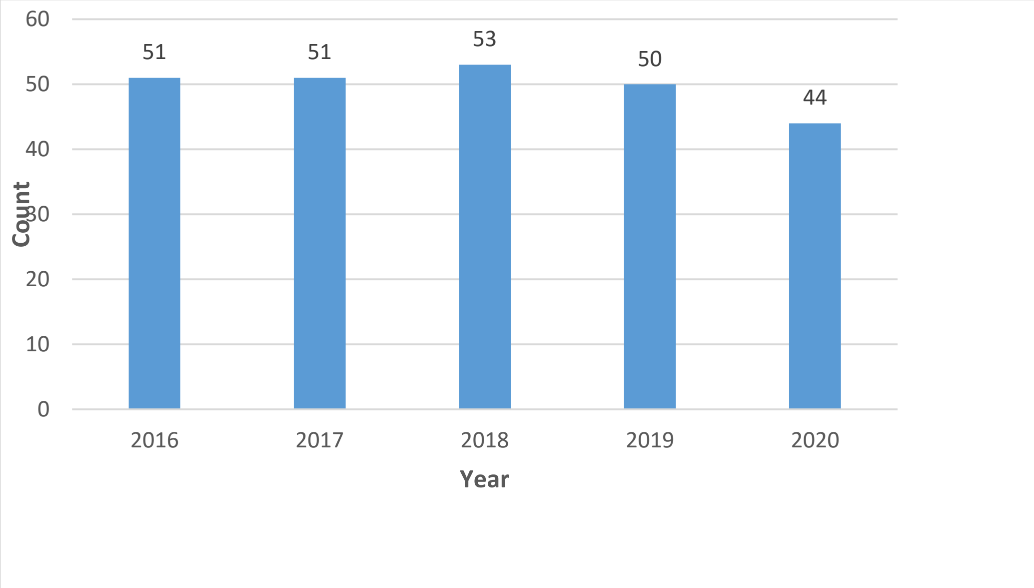


Figure 3.2 Number of beats affected in Haridwar, Dehradun and Lansdowne forest divisions between 2016 to 2020.

Year-wise change in conflict hotspots (beat-level) across the study area

1) Most affected beat in the landscape during 2015 were Gularghati, Lacchiwala range (15.37% cases), Majri, Barkote range (10.58% cases) and Kaluwala, Thano range (9.57% cases) of Dehradun Forest Division (Figure 3.3; Table 3.2).

2) Most affected beat in the landscape during 2016 were Katevad East (12.99% cases) and Gaindikhata 1, Chiriyapur range (12.09% cases) and Devpura athmal, Haridwar range (9.25% cases) of Haridwar Forest Division (Figure 3.4; Table 3.2).

3) Most affected beat in the landscape during 2017 were Gularghati, Lacchiwala range (6.85% cases), Bhogpur North, Laksar range (6.67% cases) and Boxowali, Chiriyapur range (6.67% cases) Figure 3.5; Table 3.2).

4) Most affected beat in the landscape during 2018 were Katevad East 10.65% cases) and Gaindikhat 1, Chiriyapur range (9.91% cases) and Devpura athmal, Haridwar range (6.36% cases) of Haridwar Forest Division) (Figure 3.6; Table 3.2).

5) Most affected beat in the landscape during 2019 were Bhogpur South, Laksar range (10.26% cases), Katevad East, Chiriyapur range (8.94% cases) and Devpura athmal, Haridwar range (8.11% cases) of Haridwar Forest Division (Figure 3.7; Table 3.2).

6) Most affected beat in the landscape during 2020 were Katevad East (10.8% cases) and Gaindikhata 1, Chiriyapur range (9.43% cases) and Danda, Thano range (9.2% cases) belonging to Haridwar Forest Division and Dehradun Forest Division respectively (Figure 3.8; Table 3.2).

7) Most affected beat in the landscape during between 2015 to 2020 were Katevad East (8.96% cases) and Gaindikhata 1 (7.88% cases), Chiriyapur range and Devpura athmal (5.6% cases), Haridwar range belonging to Haridwar Forest Division (Figure 3.9; Table 3.2).

8) Most affected range in Mussoorie Forest Division was Raipur range (91 cases, 100%) between 2000 to 2020 and Kushraila (2 cases, 66.66%) and Ghigud beat (1 case, 33.99%) of Narendranagar Forest Division between 2015 to 2020 (Figure 3.10; Table 3.2).

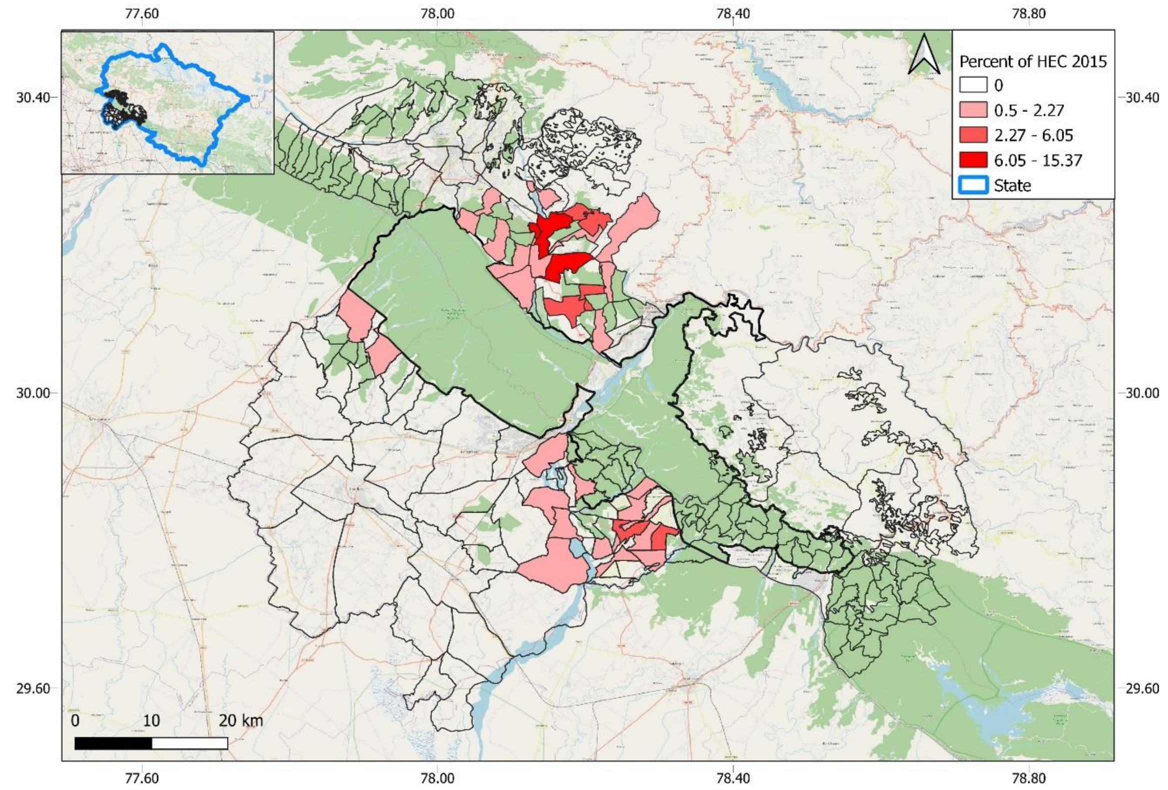


Figure 3.3 Spatial pattern of HEC (beat-wise) in Haridwar and Dehradun Forest Division for 2015

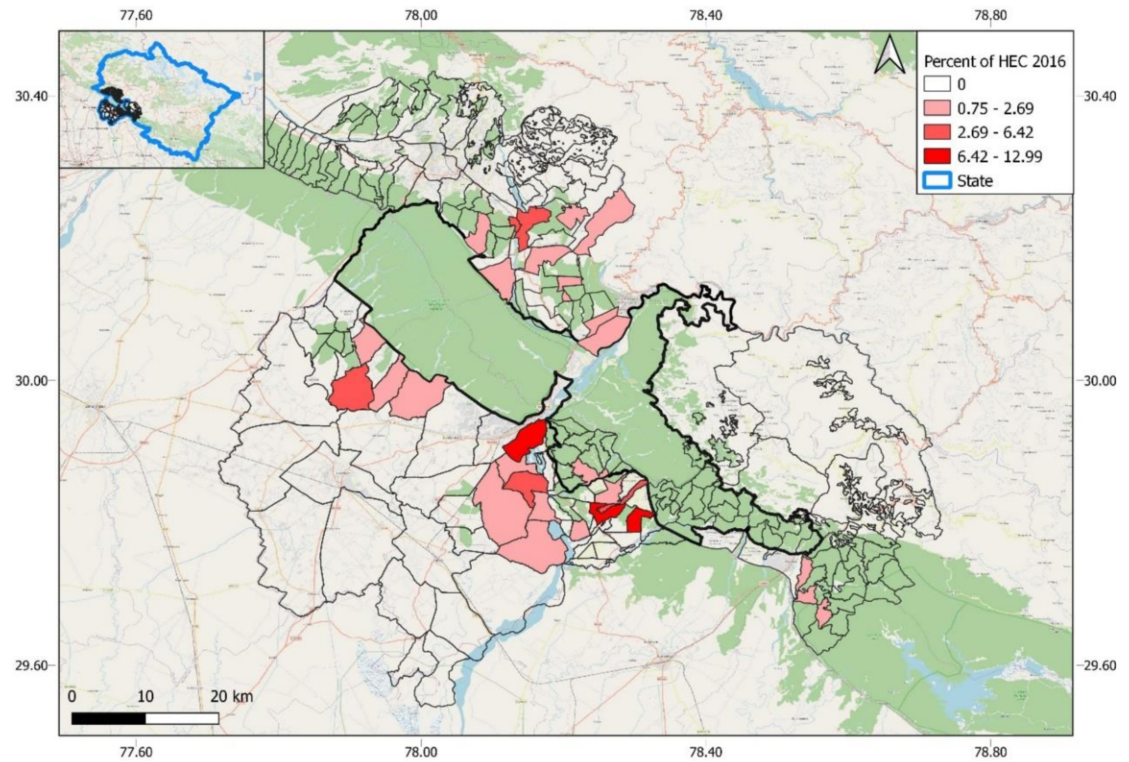


Figure 3.4 Spatial pattern of HEC (beat-wise) in Haridwar, Dehradun and Lansdowne Forest Division for 2016

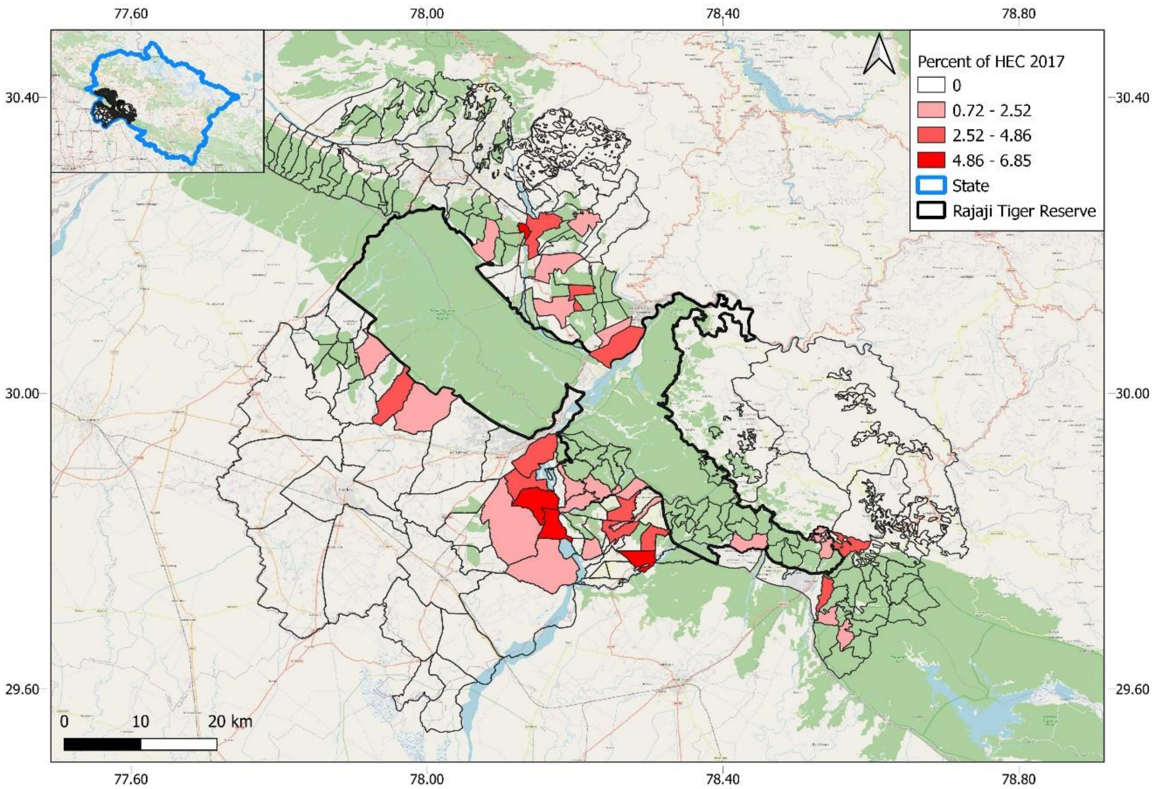


Figure 3.5 Spatial pattern of HEC (beat-wise) in Haridwar, Dehradun and Lansdowne Forest Division for 2017

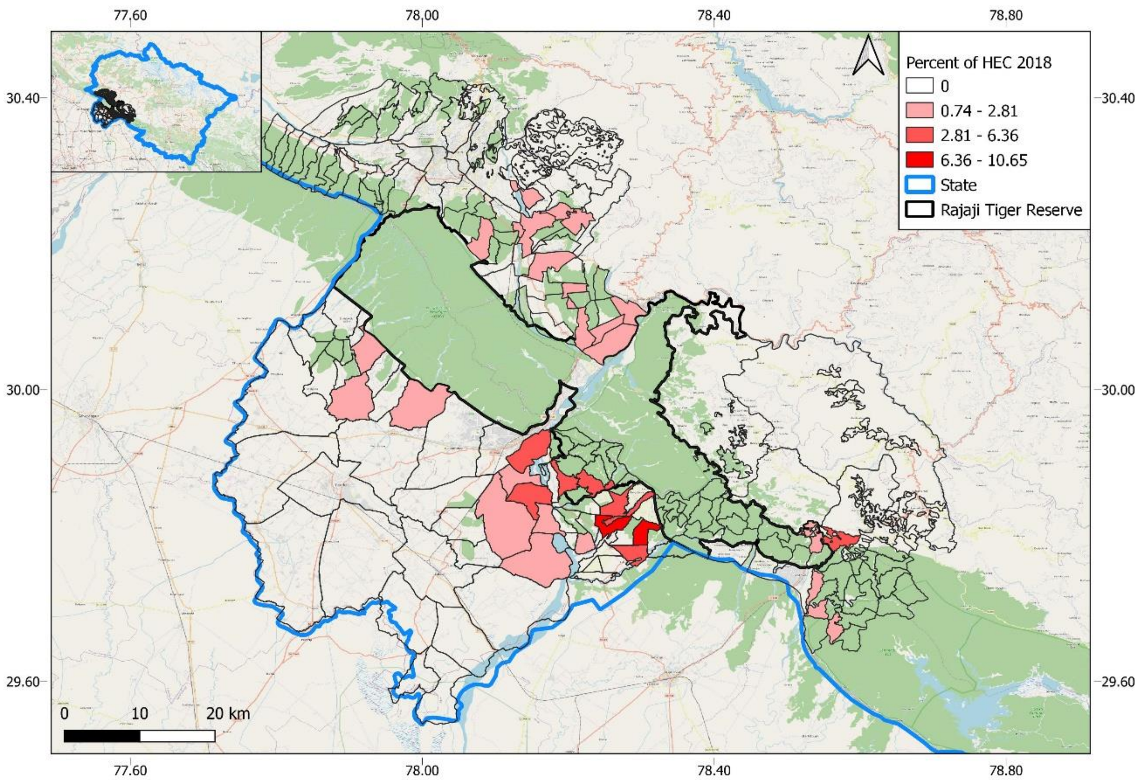


Figure 3.6 Spatial pattern of HEC (beat-wise) in Haridwar, Dehradun and Lansdowne Forest Division for 2018

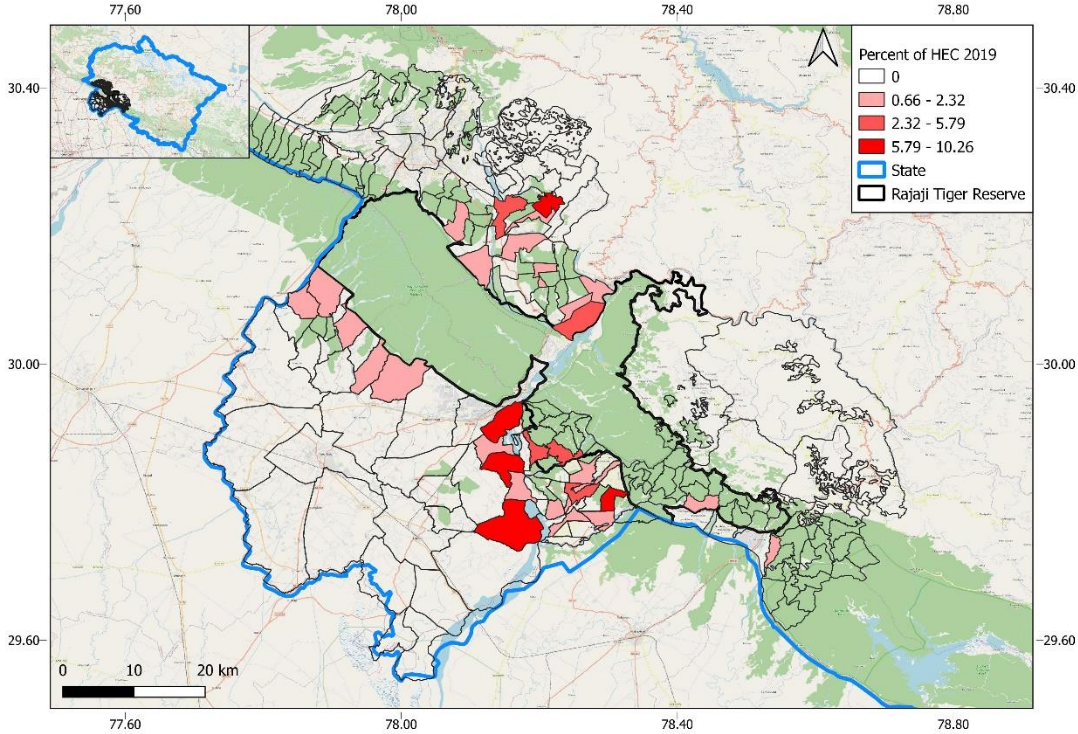


Figure 3.7 Spatial pattern of HEC (beat-wise) in Haridwar, Dehradun and Lansdowne Forest Division for 2019

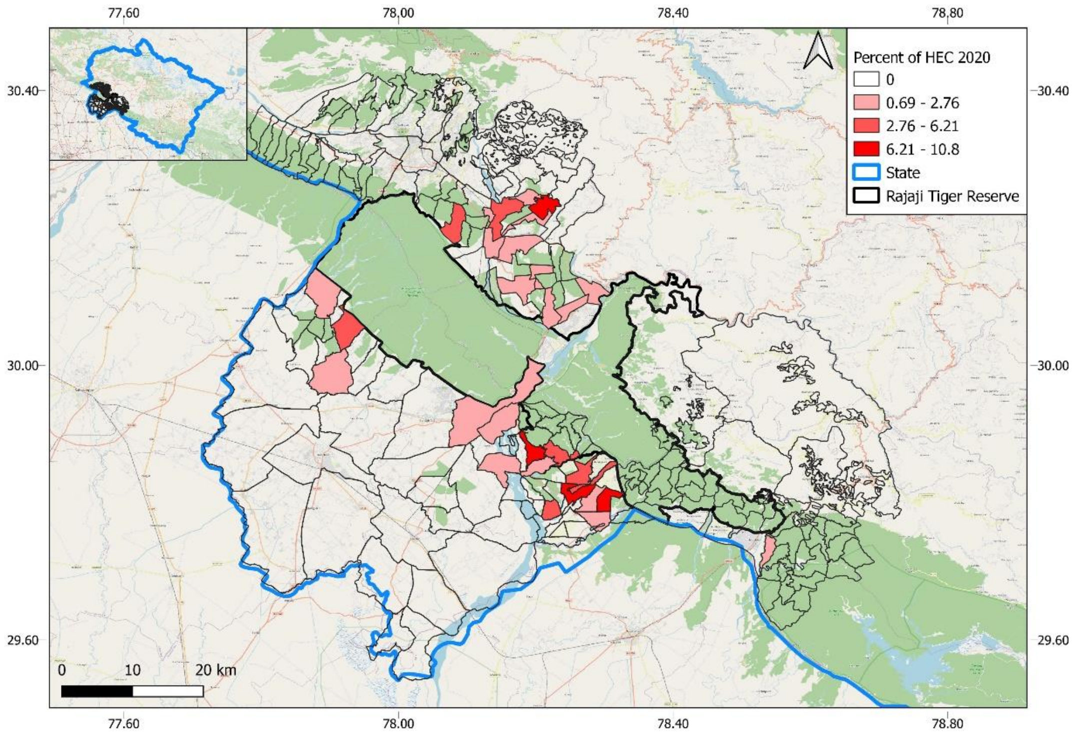


Figure 3.8: Spatial pattern of HEC (beat-wise) in Haridwar, Dehradun and Lansdowne Forest Division for 2020

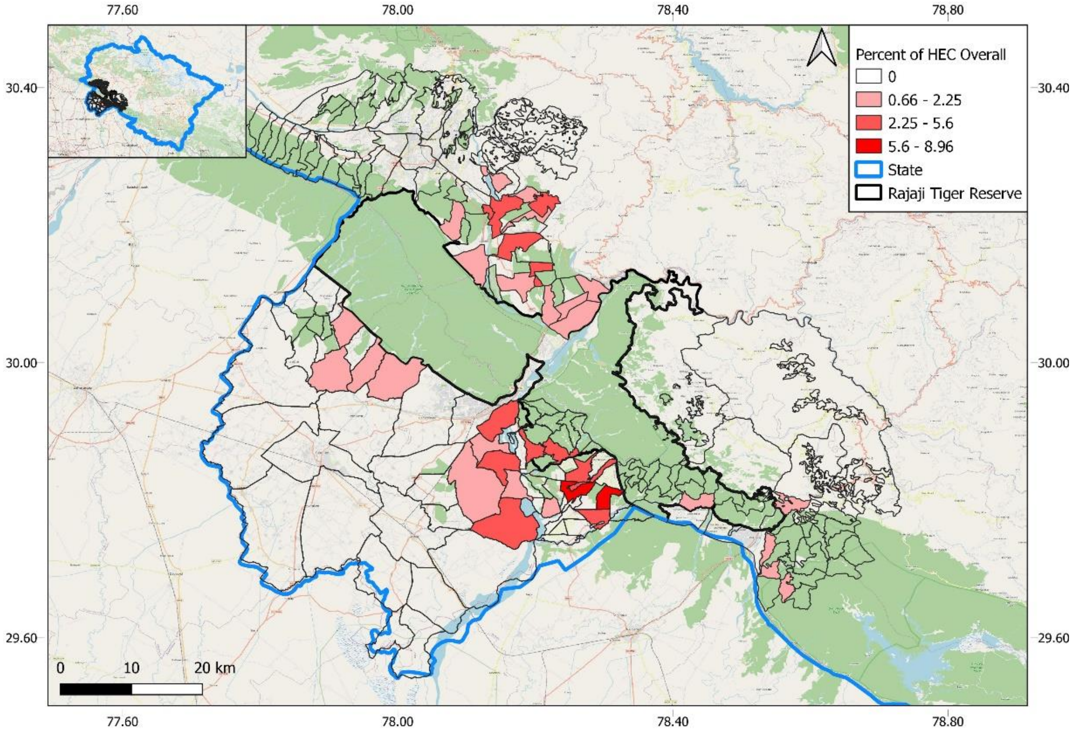


Figure 3.9: Spatial pattern of HEC (beat-wise) in Haridwar, Dehradun and Lansdowne Forest Division from 2015 to 2020.

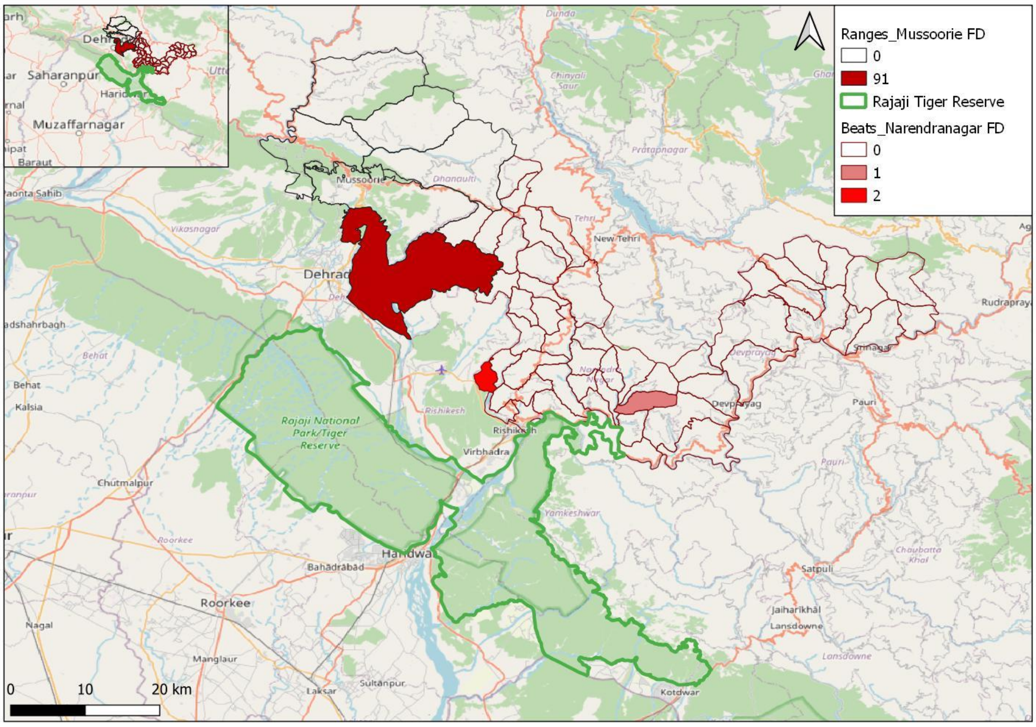


Figure 3.10: Spatial pattern of HEC (beat-wise) in Raipur range of Mussoorie Forest Division (from 2000 to 2020) and Narendranagar Forest Division from 2015 to 2020.

b) Year-wise change in percent of damage types, total cases and villages affected across the forest divisions

Between 2015-2020, Haridwar Forest Division reported 95.6±1.5% cases of HEC due to crop damage. Damage to sugarcane between 2016,2017,2018,2019 and 2020 was 70%, 58%, 64.9%, 59.9%, 68.9% and 60% respectively. HEC affected 44.3±10.9 villages between 2016 to 2020 in Haridwar Forest Division (Figure 3.11).

Between 2015-2020, Dehradun Forest Division reported 87.9±3.8% cases of HEC due to crop damage. In 2015 38% HEC cases were due to sugarcane, in 2016 29.3% cases of HEC were due to wheat. In 2017, 2018, 2019 and 2020, 28.4%, 29.3%, 42.1% and 29.1% reported cases of HEC were due to paddy. 43.5±9 villages were affected between 2015 to 2020 (Figure 3.12).

Table 3.3: List of year-wise HEC hotspots (beat-level) across the years (2015-2020) in the study area (Haridwar, Dehradun and Lansdowne Forest Division)

S.No.	Division	Range	Beat	Cases_2015 %
1	Dehradun	Lachhiwala	Gularghati	15.37
2	Dehradun	Badkot	Majri	10.58
3	Dehradun	Thano	Kaluwala	9.57
S.No.	**Division**	**Range**	**Beat**	**Cases_2016 %**
1	Haridwar	Chidyapur	Katevad East	12.99
2	Haridwar	Chidyapur	Gaindikhata 1	12.09
3	Haridwar	Haridwar	Devpura athmal	9.25
S.No.	**Division**	**Range**	**Beat**	**Cases_2017 %**
1	Dehradun	Lacchiwala	Gularghati	6.85
2	Haridwar	Laksar	Bhogpur north	6.67
3	Haridwar	Chiriyapur	Boxowali	6.67
S.No.	**Division**	**Range**	**Beat**	**Cases_2018 %**
1	Haridwar	Chidyapur	Katevad East	10.65
2	Haridwar	Chidyapur	Gaindikhata 1	9.91
3	Haridwar	Haridwar	Devpura athmal	6.36
S.No.	**Division**	**Range**	**Beat**	**Cases_2019 %**
1	Haridwar	Laksar	Bhogpur south	10.26
2	Haridwar	Chiriyapur	Katevad east	8.94
3	Haridwar	Haridwar	Devpura athmal	8.11
S.No.	**Division**	**Range**	**Beat**	**Cases_2020 %**
1	Haridwar	Chiriyapur	Katevad east	10.8
2	Haridwar	Chiriyapur	Gaindikhata 1	9.43
3	Dehradun	Thano	Danda	9.2
S.No.	**Division**	**Range**	**Beat**	**Cases_overall %**
1	Haridwar	Chiriyapur	Katevad east	8.96
2	Haridwar	Chiriyapur	Gaindikhata 1	7.88
3	Haridwar	Haridwar	Devpura athmal	5.6

Between 2016-2020, Lansdowne Forest Division reported 85±8.8% cases of HEC due to crop damage. In 2016 64% HEC cases were due to Kharif crops, in 2017, 2018, 2019 and 2020, 75%, 87.1%, 46.8% and 35.29% reported cases of HEC were due to Rabi crops. 14.2±4.4 villages were affected between 2015 to 2020 (Figure 3.13).

Between 2015-2020, in Narendranagar Forest Division two villages were affected and reported three cases of HEC, all due to crop damage (Figure 3.13). Between 2000-2020, Raipur range of Mussoorie Forest Division reported 91 total cases of HEC. 59.34 cases were attributed to crop damage affecting 10 villages (Figure 3.14).

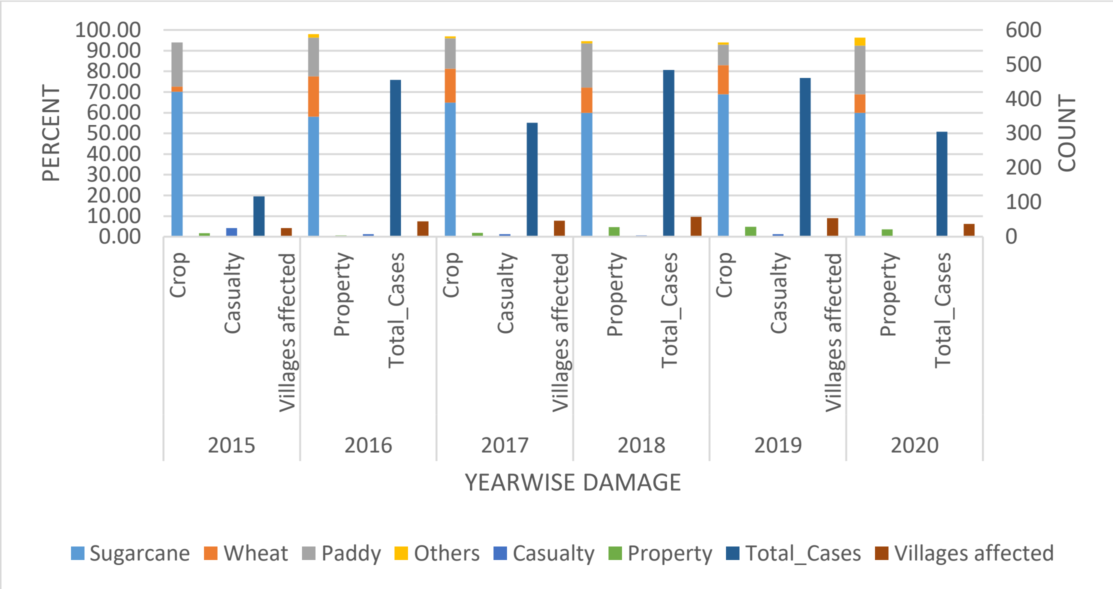


Figure 3.11 Year-wise cases of HEC in Haridwar Forest Division (percent), with cumulative number of cases and villages affected per year.

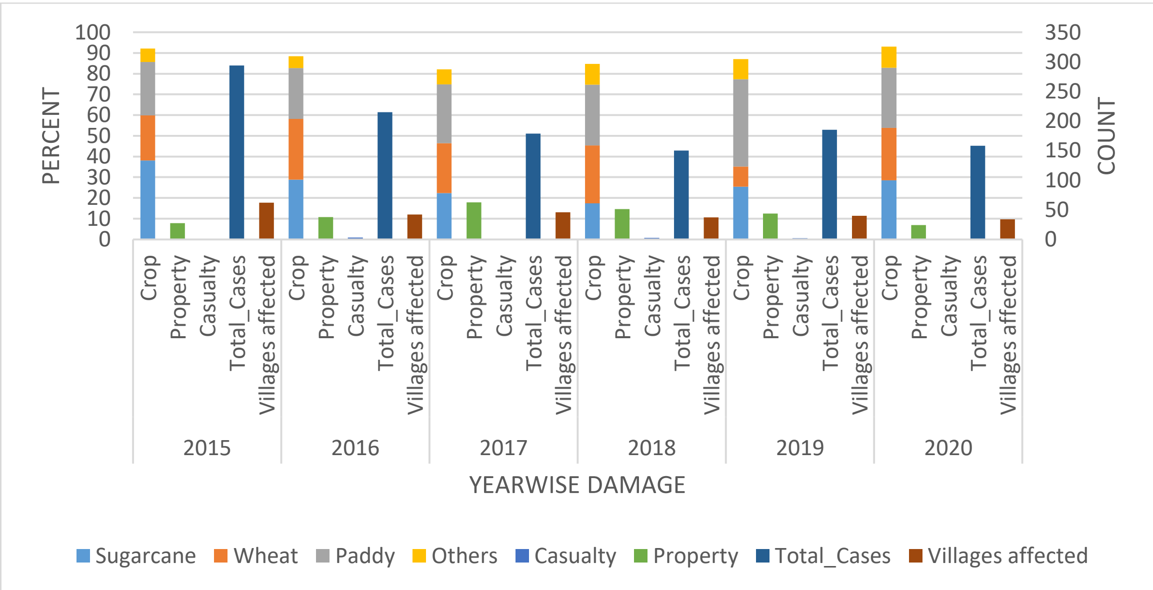


Figure 3.12 Year-wise cases of HEC in Dehradun Forest Division (percent), with cumulative number of cases and villages affected per year.

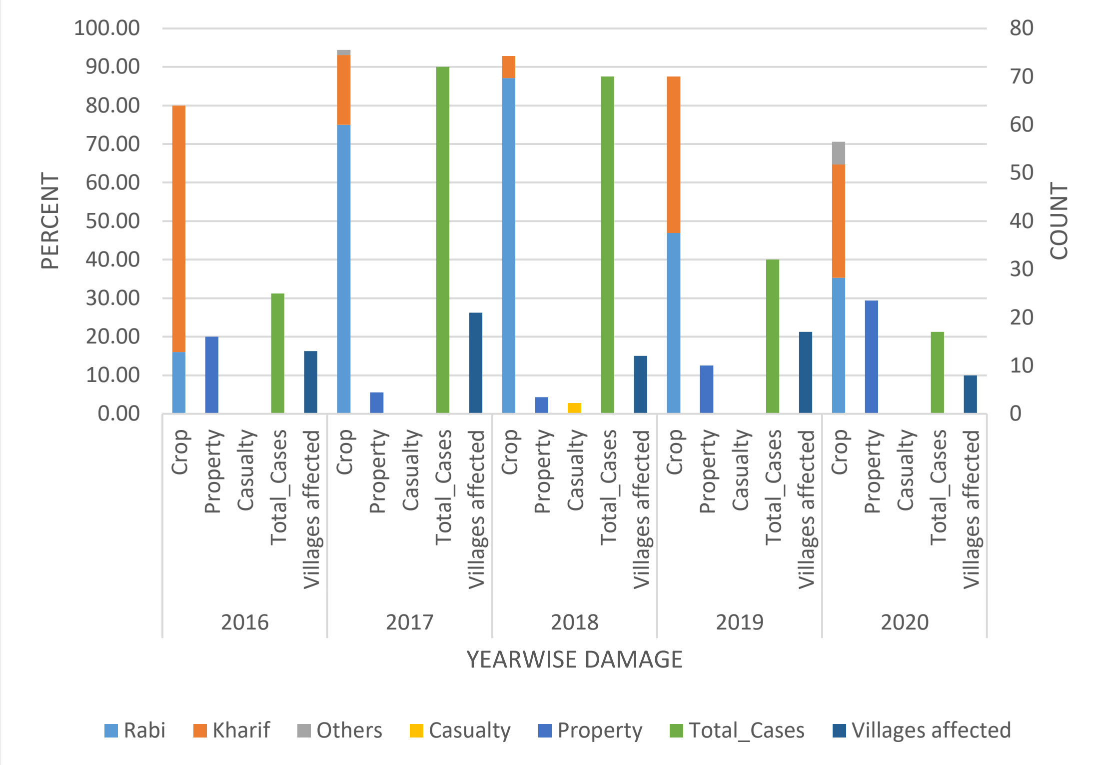


Figure 3.13 Year-wise cases of HEC in Lansdowne Forest Division (percent), with cumulative number of cases and villages affected per year

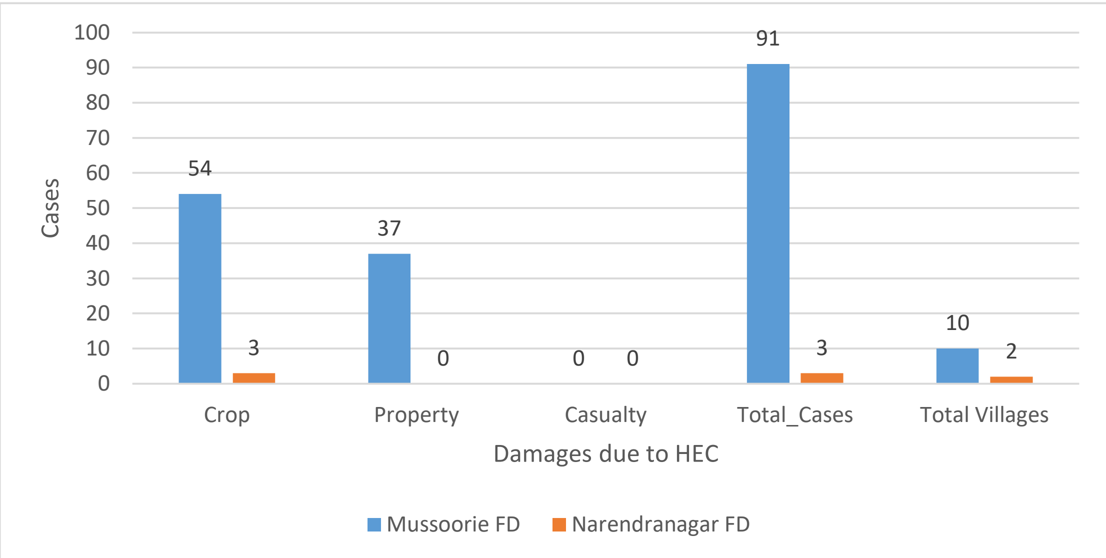


Figure 3.14: Overall cases of HEC in Raipur range of Mussoorie Forest Division between 2000 – 2020 and Narendranagar Forest Division (2015, total)

a) Year-wise change in seasonality of crop damage were analyzed.
In Haridwar Forest Division, between 2015 to 2020, month of October was the most affected month with 46.1 ± 22.2 cases of crop damage (Figure 3.15).
In Lansdowne Forest Division, between 2016 to 2020, month of March was the most affected month with 10 ± 8.3 cases of crop damage (Figure 3.16).

In Dehradun Forest Division, between 2015 to 2020, month of August was the most affected month with 50 ± 24.6 cases of crop damage (Figure 3.17).

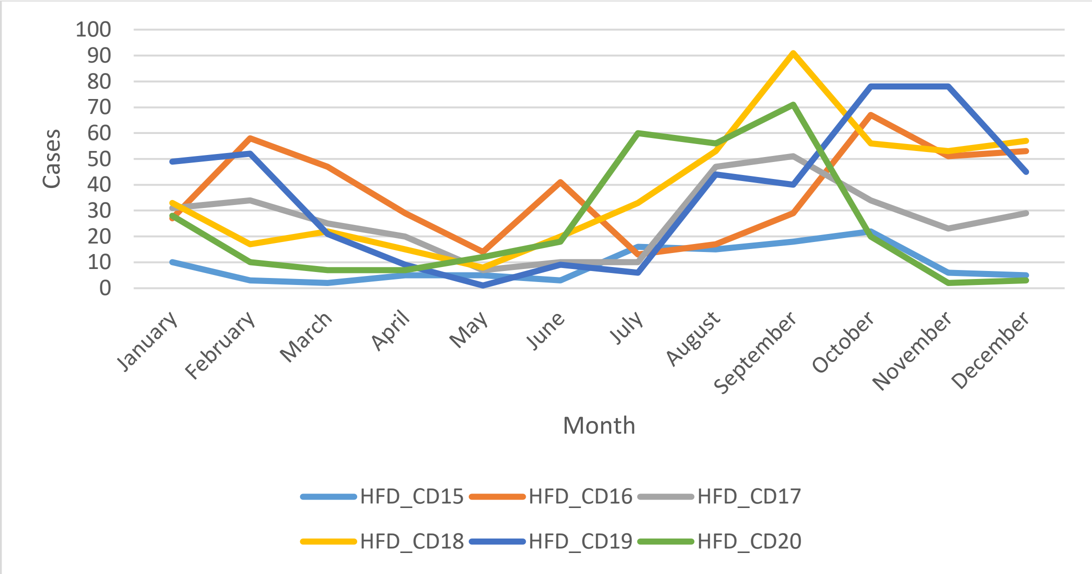


Figure 3.15: Seasonal pattern of crop damage by elephants in Haridwar Forest Division, across the years (2015 - 2020)

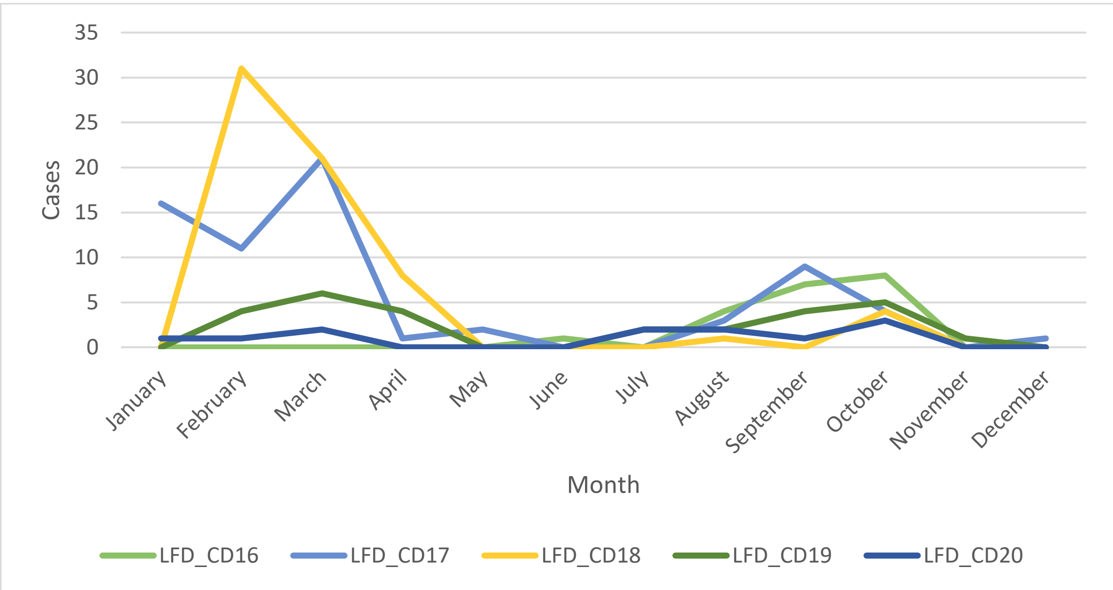


Figure 3.16: Seasonal pattern of crop damage by elephants in Lansdowne Forest Division, across the years (2016 - 2020)

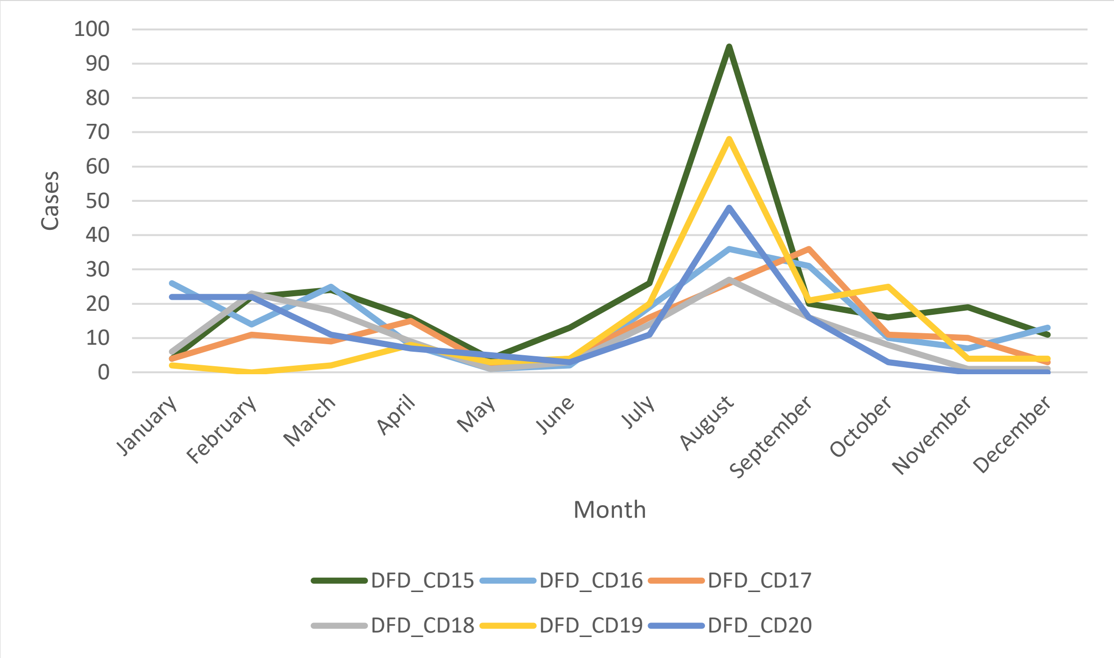


Figure 3.17: Seasonal pattern of crop damage by elephants in Dehradun Forest Division, across the years (2015 - 2020)

Primary data

a) Village-level conflict hotspots

Top three HEC affected villages in respective zones were Bandarjur (16.38%), Shahidwala grant (12.54%), Kudkawala (11.15%) – zone A, Haripur kalan (8.01%), Chandi (6.62%) and Balkumari (4.88%) – zone B, Bishanpur (7.12%), Bishanpur kundi (3.38%) and Ajitpur (2.85%) – zone C and Peeli padav (14.43%), Gaindikhata (8.64%) and Tantwala (8.01%) – zone D.

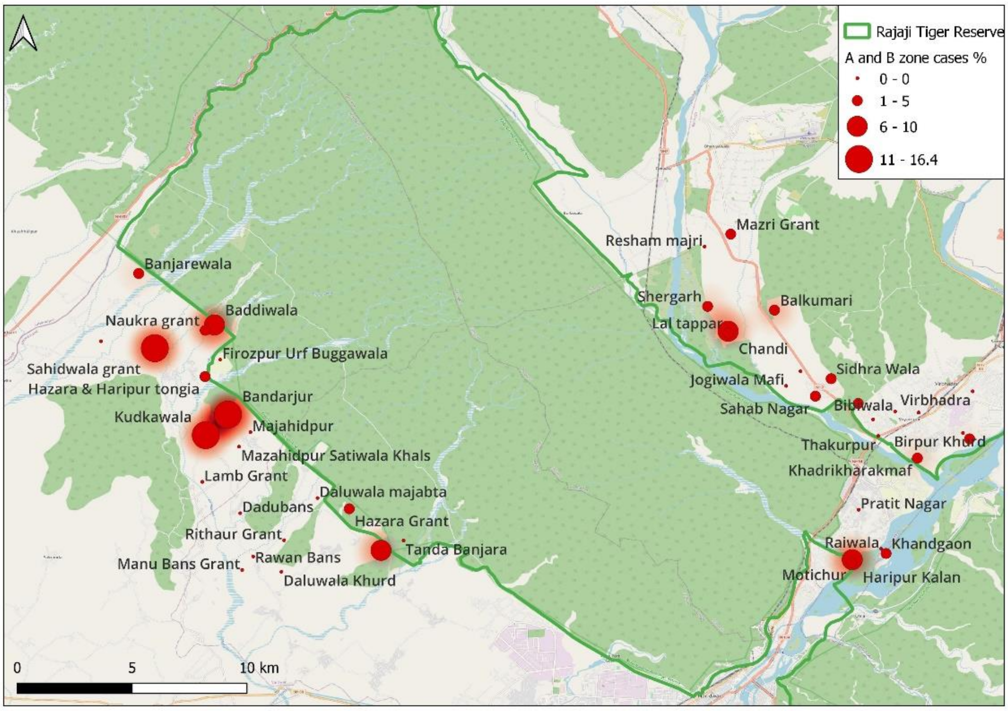


Figure 3.18: Crop damage hotspots (from within the monitored villages) in A and B zones

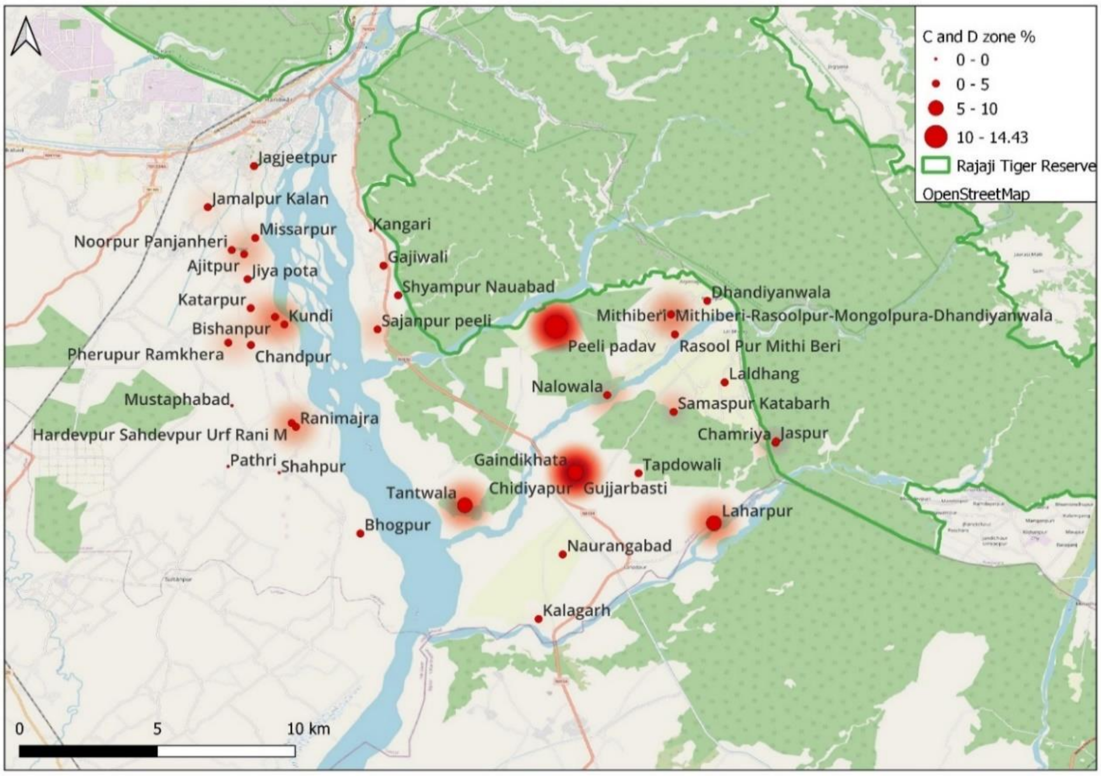


Figure 3.19: Crop damage hotspots (from within the monitored villages) in C and D zones

b) Pattern of crop damage across the zones (percent of damages and seasonality)

Table 3.4: Monthly reporting of crop damage incidents for major crop types in the landscape

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sugarcane												
Paddy												
Wheat												
Maize												

While sugarcane was damaged throughout the year (barring the month of May), paddy and maize being Kharif crops were raided between June to November. Wheat being a Rabi crop was damaged from November to April.

From July to December 2021, most damaged crop in zone A (40.5%), C (40.7%) and D (38.6%) was sugarcane, while paddy was the most damaged crop in zone B (48.5%) (Figure 3.20). Between February 2021 to December 2021, most damaged crop in zone C (36.3%), and D (32.2%) was sugarcane (Figure 3.21). Other than paddy, sugarcane, wheat and maize, crop damage included millet, mustard, mango, barley, marigold flower, pumpkin and bottle gourd.

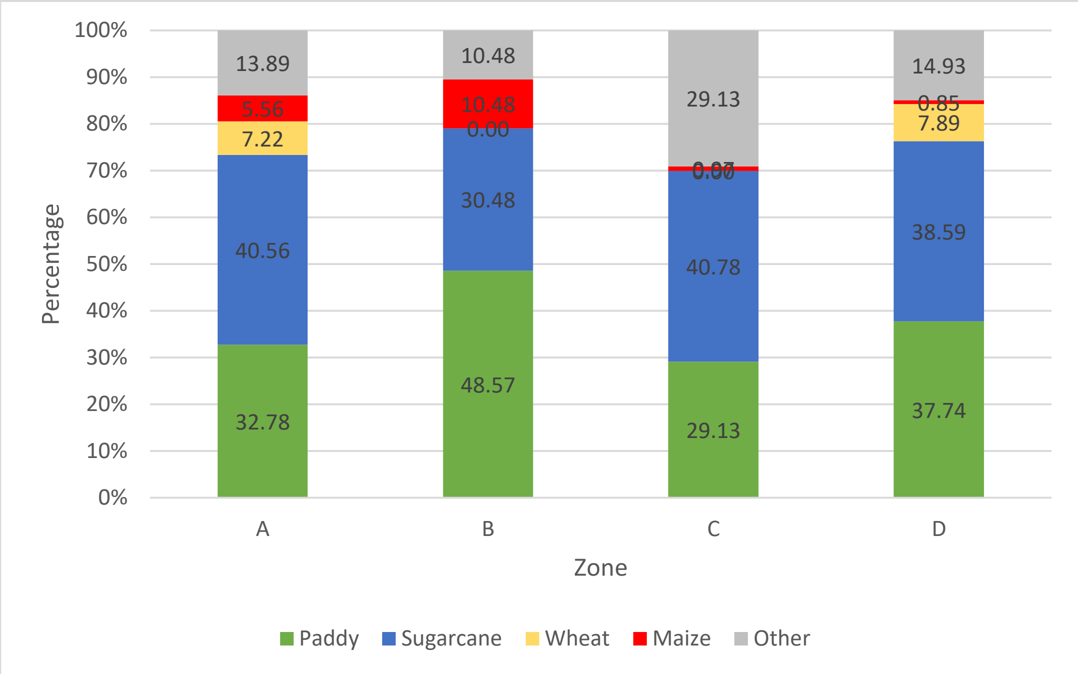


Figure 3.20: Percentage of crop types damages across different zones between July 2021 to December 2021. Number of cases in zone A – 181, numbers of cases in zone B – 105, number of cases in zone C – 103, number of cases in zone D – 469.

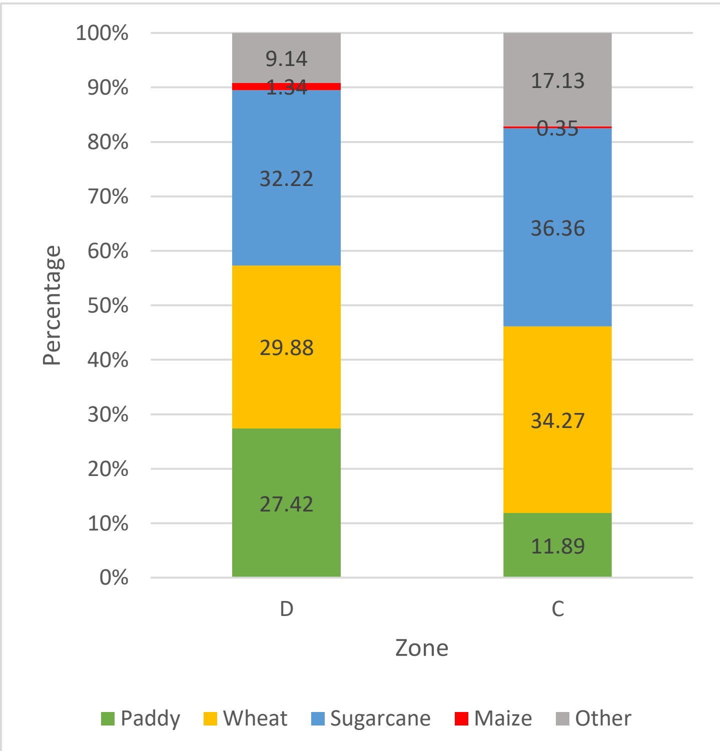


Figure 3.21: Percentage of crop types damages across zone C and D between February 2021 to December 2021. Number of cases in zone C – 286, numbers of cases in zone D – 897.

Proportion of crop damages were least in the month of May for zone C (0.13) and D (0.03), while for zone A it was in the month of October (0.42) and for zone A it was in the month of July (0.16) (Figure 3.22). Proportion of crop damages showed a pattern of peaks in zone C and D that corresponded to Rabi and Kharif cropping seasons.

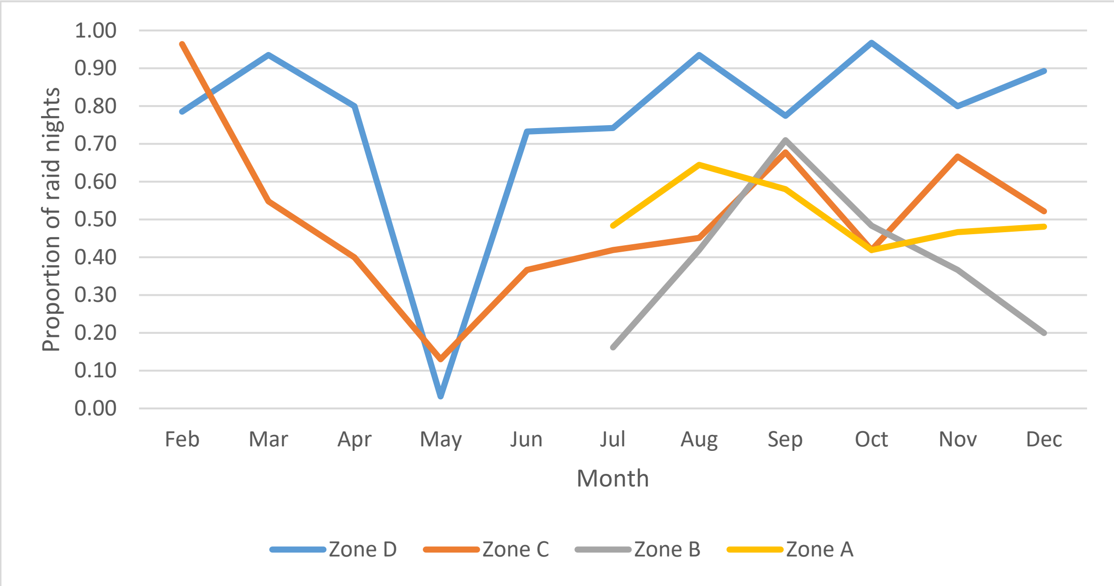


Figure 3.22: Seasonality of crop damages in respective zones

Across zone A, B and D incidents of crop damages were mostly attributed to solitary bulls (A-99 %, B-73%, D-86.3%), while in zone C, most of crop damages incidents (52.5%) were attributed to all-male groups (AMG) (Figure 3.23).

c) Demographic pattern of elephants involved in raiding crops

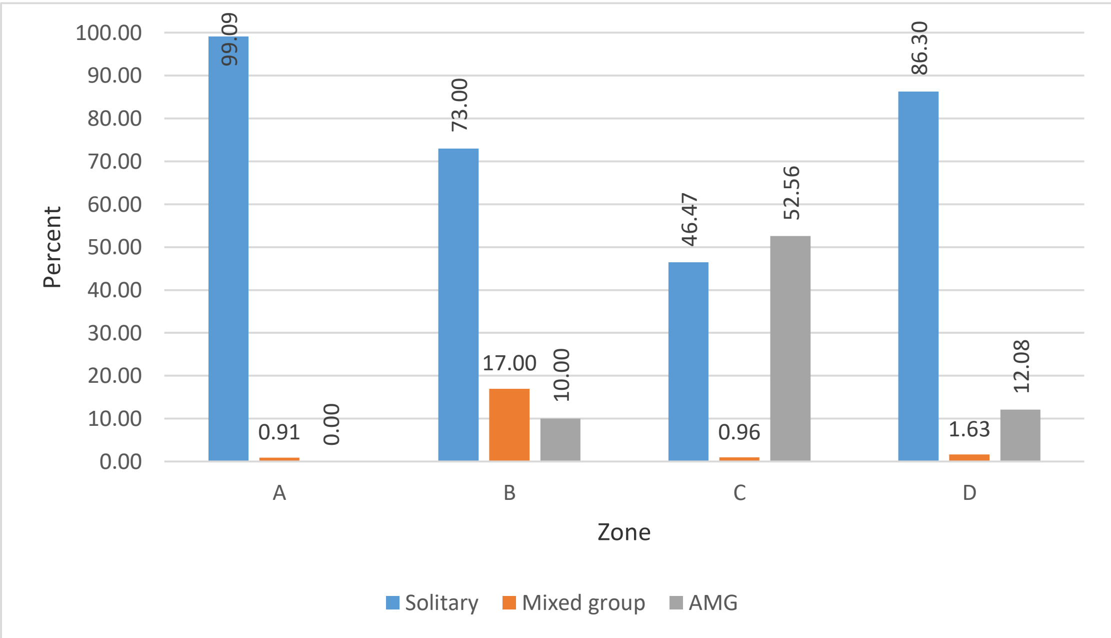


Figure 3.23: Percentage of social groups involved in crop damages across the zones

d) Phenophase of crops

Across the most commonly raided crops in the landscape (sugarcane, paddy, wheat and maize), most of the crop damage incidents occurred when these crops were in their intermediate state (Figure 3.24).

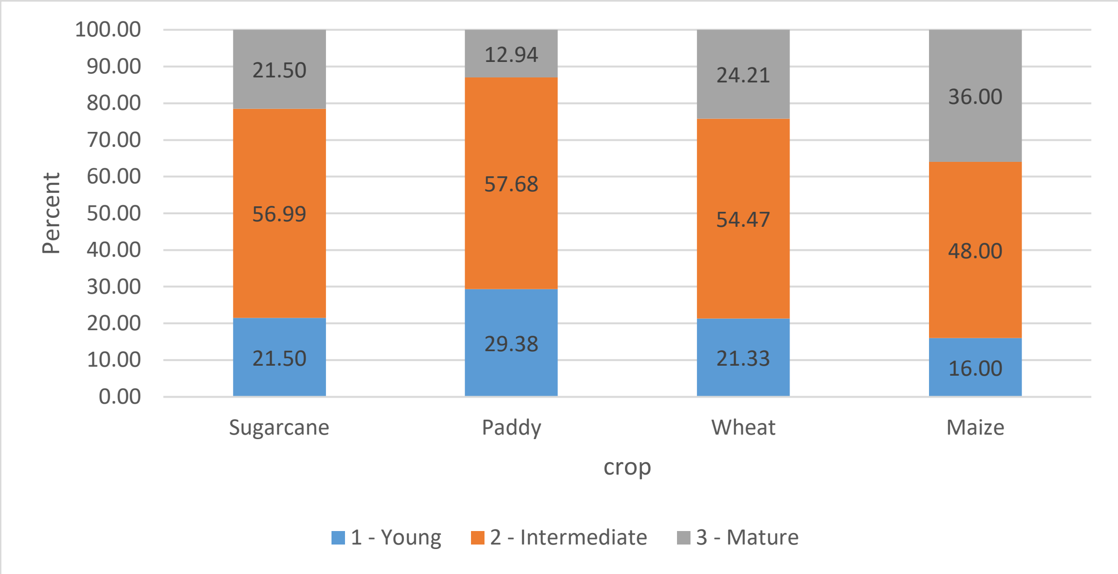


Figure 3.24: Phenophase of damaged crops

e) Area of crop damage

In 2021, overall 39.6 ha of crop field was damaged by elephants in the villages monitored in zone C and D. Crop-wise, most area damaged by elephants were those of sugarcane (24.6 ha), wheat &7.7 ha) and paddy (5.6 ha) fields (Figure 3.25). For all the 3 major crop types damged in the area, the area damaged due to trample was greater than area damaged by consumption (Figure 3.26).

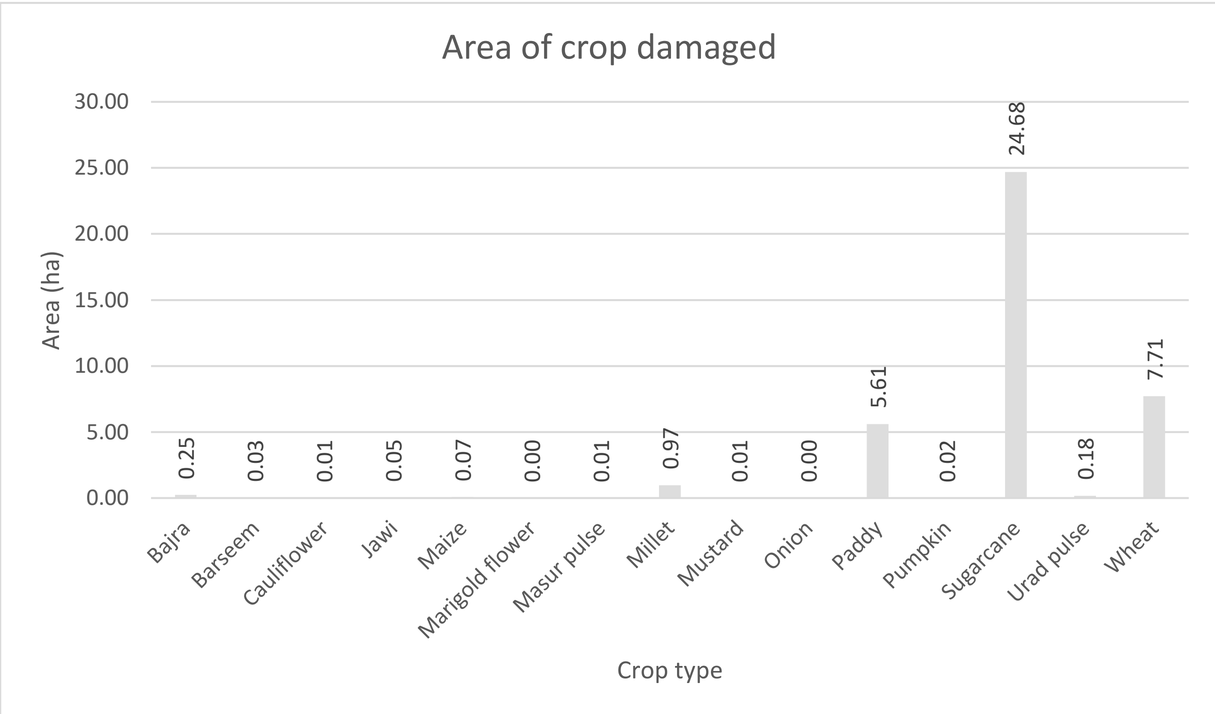


Figure 3.25: Area of crop fields damaged

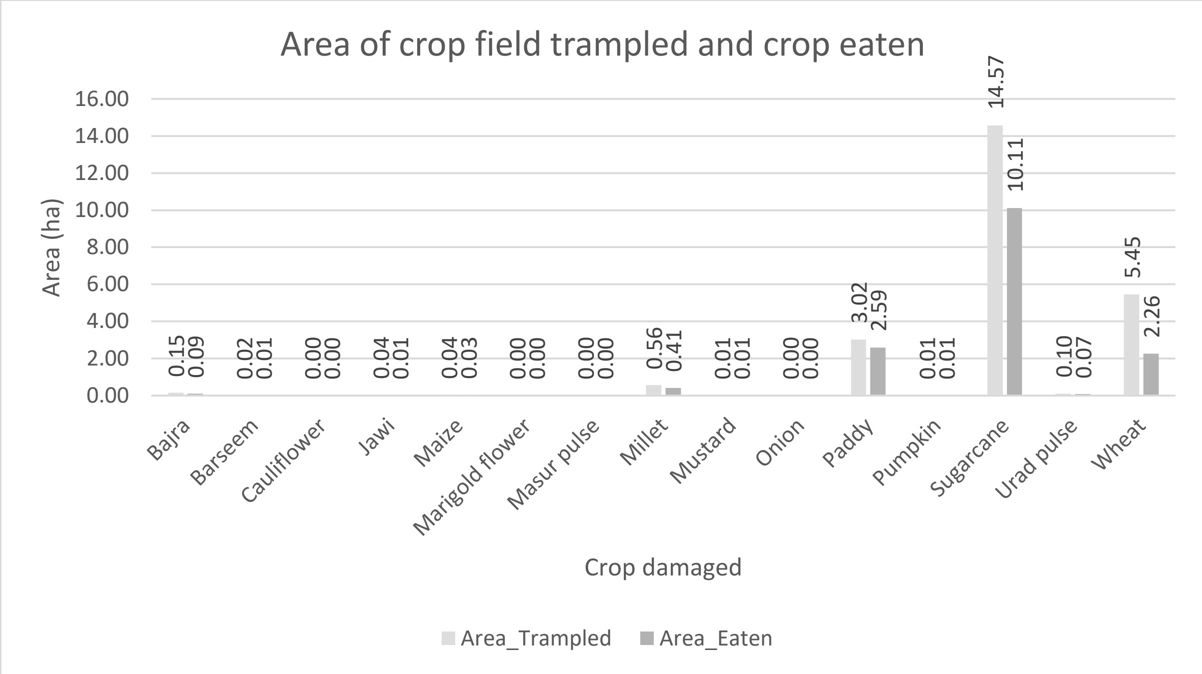


Figure 3.26: Area damaged due to trampling and consumption (eating)

f) Response of humans and elephants during the interaction (crop raids)

In most of the cases (88.3%), humans responded by driving elephants when they encountered each other during crop raiding incidents (Figure 3.27).

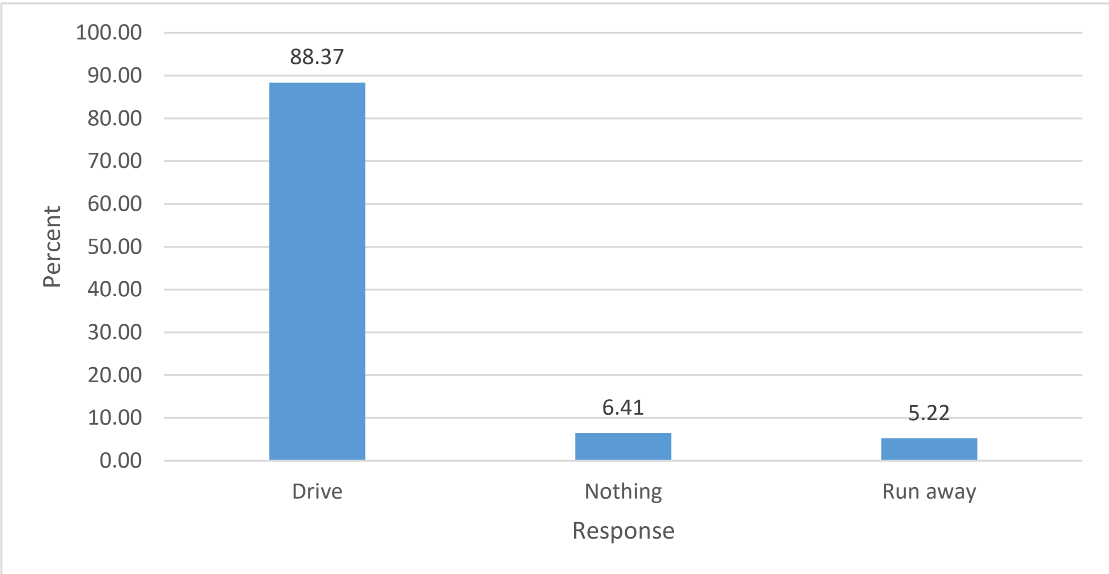


Figure 3.27: Response of humans to elephants during their encounter during crop raids

In most of the cases (41.6%), elephants responded by running away when they encountered humans during crop raiding incidents (Figure 3.28).

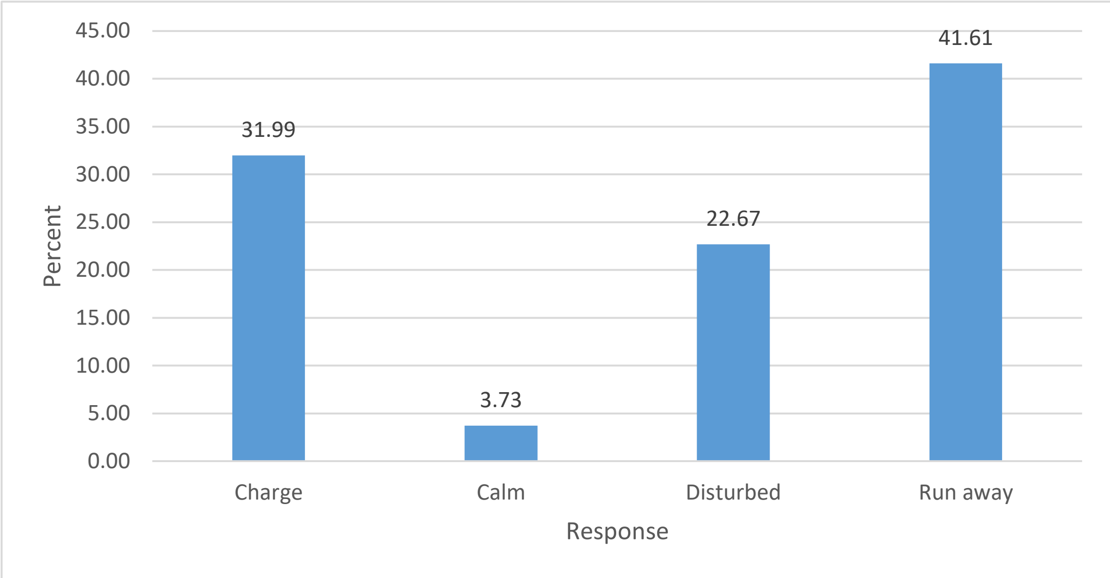


Figure 3.28: Response of elephants to humans upon their interaction during crop raiding incidents

g) Crop guarding measures used by the villagers

Most commonly used crop protection measures were solar fencing (34.3%) and barbed wire (33.2%) (Figure 3.29).

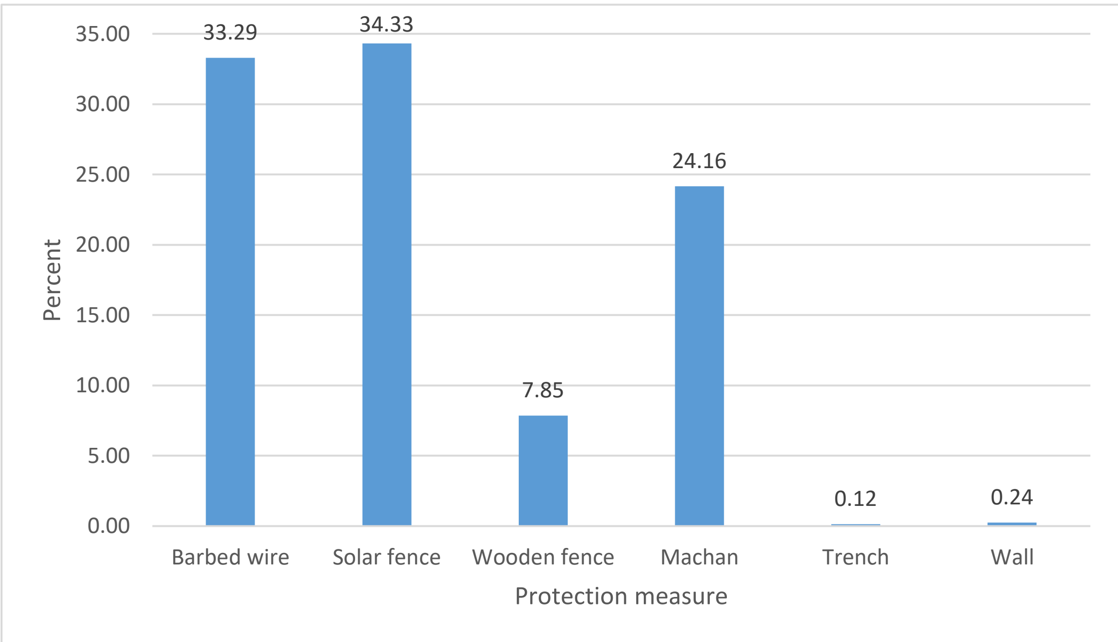


Figure 3.29: Crop protection measures deployed by farmers

h) Driving methods used by villagers during crop raids

During most of the crop raiding incidents (50.2%), villagers used torch to drive away or deter crop raiding elephants from their crop fields (Figure 3.30).

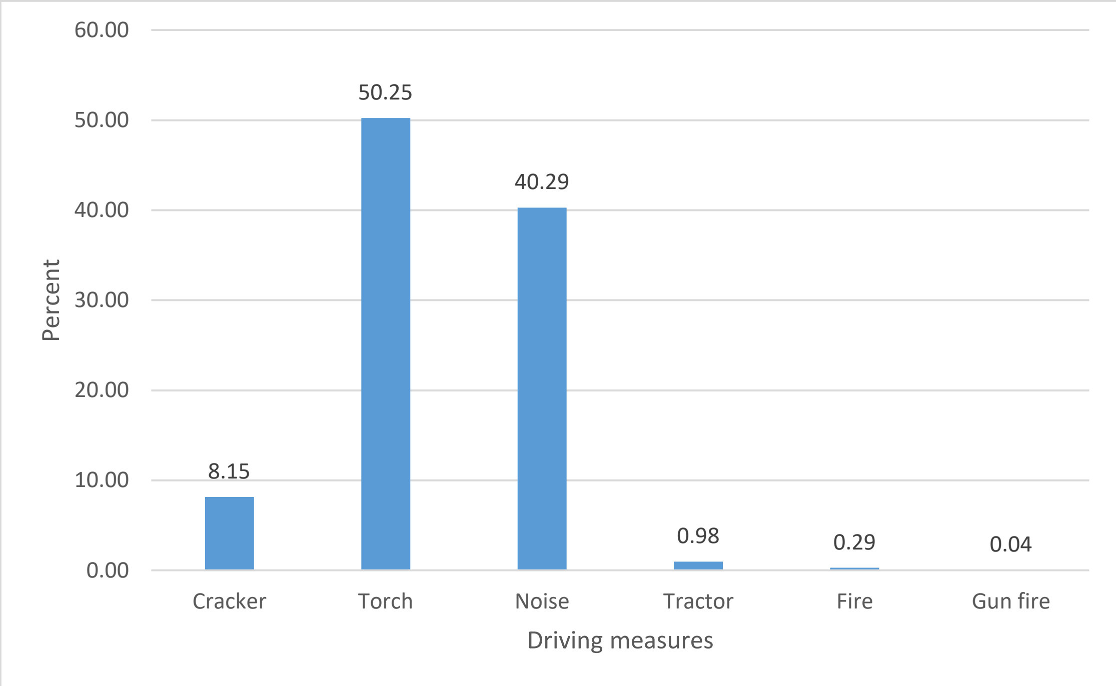


Figure 3.30: Elephant driving methods used by villagers during crop raiding incidents

Discussion

HEC type: Secondary data collated and analyzed from the forest divisions in the study area showed a decline in the number of beats affected in Haridwar, Dehradun and Lansdowne forest division in 2020. The decrease in the number may be attributed to the preparedness of the forest department to manage HEC at the onset of Kumbh 2021. Crop damage was the most pertinent cause of HEC. Unlike in observations made from relatively fragmented, high-conflict areas (Tripathy et al., 2021), human death/injury in this landscape was not an acute problem. Crop damage by wildlife species is one of the most frequently mentioned causes of HWC (Hill & Wallace, 2012). Crop damage were further divided into damage due to consumption or trampling. Foraging of nutrition rich crops by wildlife species has been described as part of an optimal foraging strategy (Sukumar, 1991). The palatability, nutrition content and ease of handling during foraging makes crops highly attractive for consumption (Gross et al., 2018), making crop damage the most frequently mentioned cause of HEC.

Crop type: Based on secondary data, in Lansdowne Forest Division, most of the cases of crop damages can be attributed to Rabi crops such as wheat (except in 2016). Most cases of crop damages in Dehradun Forest Division were of paddy, while sugarcane was the most damaged crop in Haridwar Forest Division. Based on primary data, most damaged crop in total (34.1%), zone A (40.8%), C (37.4%) and D (32.2%) was sugarcane, while paddy was the most damaged crop in zone B (48%). Zone A, C and D falls in Haridwar Forest Division and high incidents of sugarcane damage in these zones is consistent with the finding of crop damage analysis from secondary data as well. This can possibly be due to higher spatio-temporal availability of sugarcane in the area. Similar logic may explain the cases of crop damage pattern for zone B (in Dehradun Forest Division) as well. The type of crop being damaged can be explained by the foraging pattern of elephants based on availability, accessibility, palatability and nutrition value of the forage (Branco et al., 2019; Gross et al., 2018; Osborn, 2004; Sukumar, 2003).

Seasonality: Based on secondary data, in Haridwar Forest Division, between 2015 to 2020, most cases of crop damage occurred in the month of October. In Lansdowne Forest Division, between 2016 to 2020, March was the most affected month. In Dehradun Forest Division, between 2015 to 2020, month of August was the most affected.

To ascertain for the shifts in seasonality of crop damage and year-wise shift in HEC affected beats between 2015 to 2020, focused group discussions and questionnaire surveys need to be conducted. Based on primary data, proportion of crop damages were least in the month of May for zone C (0.13) and D (0.03), while for zone A it was in the month of October (0.42) and for zone A it was in the month of July (0.16). Proportion of crop damages showed a pattern of peaks in zone C and D that corresponded to Rabi and Kharif cropping seasons. Rabi crops were harvested by the end of April and crop fields are left barren or sown with millets and barley. With the beginning of monsoon, by the end of June, crop fields are again sown with paddy (a Kharif crop), which is harvested by end of October. Seasonality has been reported as an imperative factor influencing crop raid by wildlife species, resulting in HEC (Chiyo et al., 2005; Gross et al., 2018; Naughton-Treves, 1998; Webber at al., 2011) and the trend in the seasonality can be explained by the type of crop affected by HEC in the respective area.

Demography of crop raiders: Across zone A, B and D incidents of crop damages were mostly attributed to bull elephants. Solitary bulls were reported to have raided crop fields in most cases across the zones (A-99 %, B-73%, D-86.3%), while in zone C, most crop damage incidents (52.5%) were attributed to all-male groups (AMG). The findings are in line with previous study on HEC in the landscape (Williams et al., 2001). This may be due to the high-risk taking behaviour of bull elephants, driven by their life history strategies, physiological needs and for their biological fitness. Bull elephants associating to form AMGs, especially in human-use areas may help them to negotiate anthropogenic barriers/threats better, enabling them to manage stress and optimize their foraging strategy. Such associations have also been reported in previous studies (Chiyo et al., 2011; Srinivasaiah et al., 2019) and may also enable ecological learning, especially for the younger bulls.

Phenophase: Across the most commonly raided crops in the landscape (sugarcane, paddy, wheat and maize), most of the crop damage incidents occurred when these crops were in their intermediate state. This was an interesting finding and was found to be different from the study conducted by (Gross et al., 2018), where the elephants preferred to consume crops at their mature or harvested state as compared to other states. This can possibly be due to higher spatio-temporal availability of crops in the intermediate state in the study area.

Human and elephant response: In most of the cases, humans responded by driving elephants when they encountered each other during crop raiding incidents. This risk-taking behaviour may be explained by high dependency of the subsistence farmers on the harvest yields for living, and possibly because in most cases, the elephants responded by running away, rather than charging.

Crop protection and elephant driving method: Though an array of crop protection methods ranging from barbed, solar and wooden fence, trench, wall and machan are used to protect crop damage, most commonly used crop protection measures were solar fencing and barbed wire. During most of the crop raiding incidents, villagers used torch to drive away or deter crop raiding elephants from their crop fields.

Similar to the findings from previous study (Williams et al., 2001) in this landscape, most of the cases of HEC were attributed to crop damage. Unlike in situations of HEC in East-Central India (Tripathy et al., 2021), the cases of human casualty (death/injury) is not that high in this landscape. A better understanding of elephant behaviour and why they raid crops will help decide what type of mitigation action is needed in a specific area. Elephants have been reported to raid out of necessity and not as a foraging strategy (Desai & Riddle, 2015). The need to raid crops is a result of loss or degradation of part or most of their home range, to a point where resources may no longer support them. Generally, only clans significantly affected by loss or degradation of their home range will raid crops; those who are not severely affected usually do not raid. Predictably, areas with higher habitat loss or degradation usually see increased HEC (Desai & Riddle, 2015).There is not enough data on spatial requirements of elephants across their Asian range, so conservation needs are best served (at present) when large, intact, and undisturbed habitat patches are conserved so that there is greater possibility that long-term needs are more likely to be addressed (Desai & Riddle, 2015; Madhusudan et al., 2015).

CHAPTER 4: PERCEPTION OF HUMAN – ELEPHANT CONFLICT AND CONSERVATION ATTITUDE OF COMMUNITIES LIVING AROUND THE RAJAJI TIGER RESERVE

Introduction

Conflict between humans and elephants present one of the best examples of two superficially distinct animals sharing common biological needs and competing over these resources whenever they come into contact (Graham, 1973). The interface between wildlife habitat and agricultural lands is a complex and dynamic zone. Elephants are highly social and intelligent animals and their excellent communication and cognitive skills, combined with dietary and behavioral flexibility make them extremely adaptable and effective crop-raiders. In most parts of the country, people perceive wildlife as a public / state property. State institutions that manage protected areas are, therefore, considered responsible for control of 'their' animals. Those affected by HEC may perceive the incidents of HEC as "public" property causing "personal" loss, resulting in gradual erosion of the age-old cultural aspects of conservation associated with the species (Desai & Riddle, 2015). With the change of attitude and perception of communities, wildlife authorities may find it financially and logistically challenging to manage HEC in coming times.

Beyond the visible/direct costs associated with HEC, there are numerous indirect costs, that are difficult to quantify. These indirect costs include (not limited to) expenditures towards torches, *mashaals*, crackers to guard against elephants, loss of school attendance due to fear of HEC, inadequate sleep and the resultant health risks/loss of productivity, exposure to other illnesses (malaria, etc) due to crop guarding in fields at night (Woodroffe, 2005). The combination of such direct and indirect costs associated with HEC makes it imperative to understand the response of communities towards the threat to their lives and livelihoods, and how their response shapes the ecology of the elephant landscape around them.

The study was conducted with the objectives to:

1) Determine major obstacles rural communities face to improving their quality of life, and whether this differs among farming and non-farming households
2) Identify the types and severity of HEC
3) Asses general attitudes toward elephant conservation and
4) Identify which mitigation strategies are most supported by the communities and more likely to be successfully implemented

Methods

To conduct the socio-economic survey around the Rajaji Tiger Reserve, and to cover the spatial extent, the area was divided into 4 zones (figure 3.1, chapter 3). A sampling framework comprising all the 119 feasible villages located within the 5km buffer from the edge of the elephant habitat was developed. The first state involved a rapid assessment of the study area in order to obtain overall information of the villages. Data on parameters such as demography, occupational pattern, distance from forest, religion, education status, past records of HEC and types of houses (cemented/non-cemented) were collected. Out of the 119 feasible villages, 60 villages were randomly selected using "random selection" tool in QGIS. In the second state, hierarchical cluster analysis was performed using Ward's method to identify relatively homogenous groups of villages (Badola et al., 2012).

During the process, clusters were identified. From each cluster, more than 10 percent villages were selected randomly (using "random selection tool" - QGIS). Subsequently, in the third state, 10% of the households from each of the villages were selected randomly for the survey. The questionnaire developed by Elephant Conservation Group and used in Myanmar (Sampson et al., 2019) was modified as per the context of HEC in the present study area. The survey was conducted from December 2021 to January 2022 in the selected villages after obtaining verbal consent from the respondents. Descriptive statistics were used to summarize the data.

Results

Table 4.1: Selection of villages for questionnaire survey

S.No.	Total feasible villages	Randomly selected for rapid assessment	% covered	Cluster number	Villages in cluster	Villages for questionnaire survey	% of cluster covered	% of households covered
1	119	60	50.4	1	4	1	25.00	10%
2				2	20	4	20.00	
3				3	37	7	19.00	

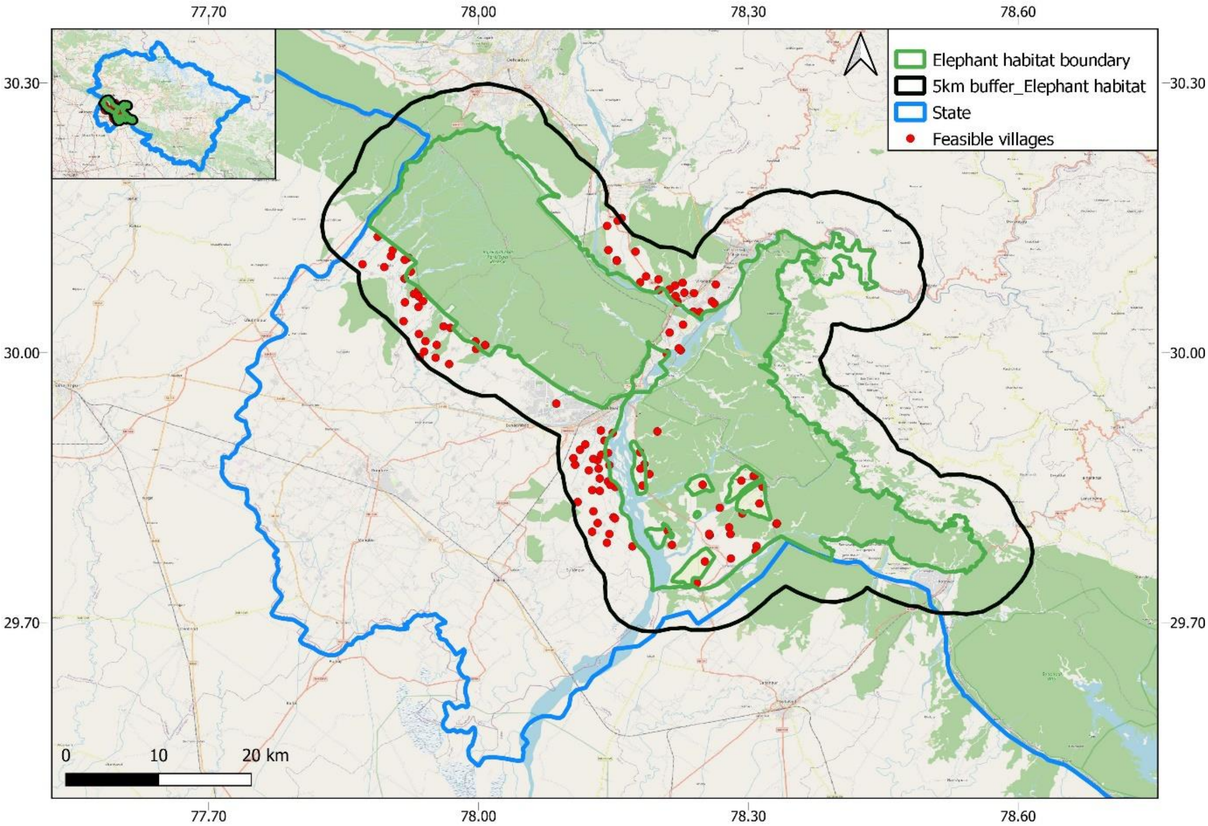


Figure 4.1: Total feasible villages in the study area

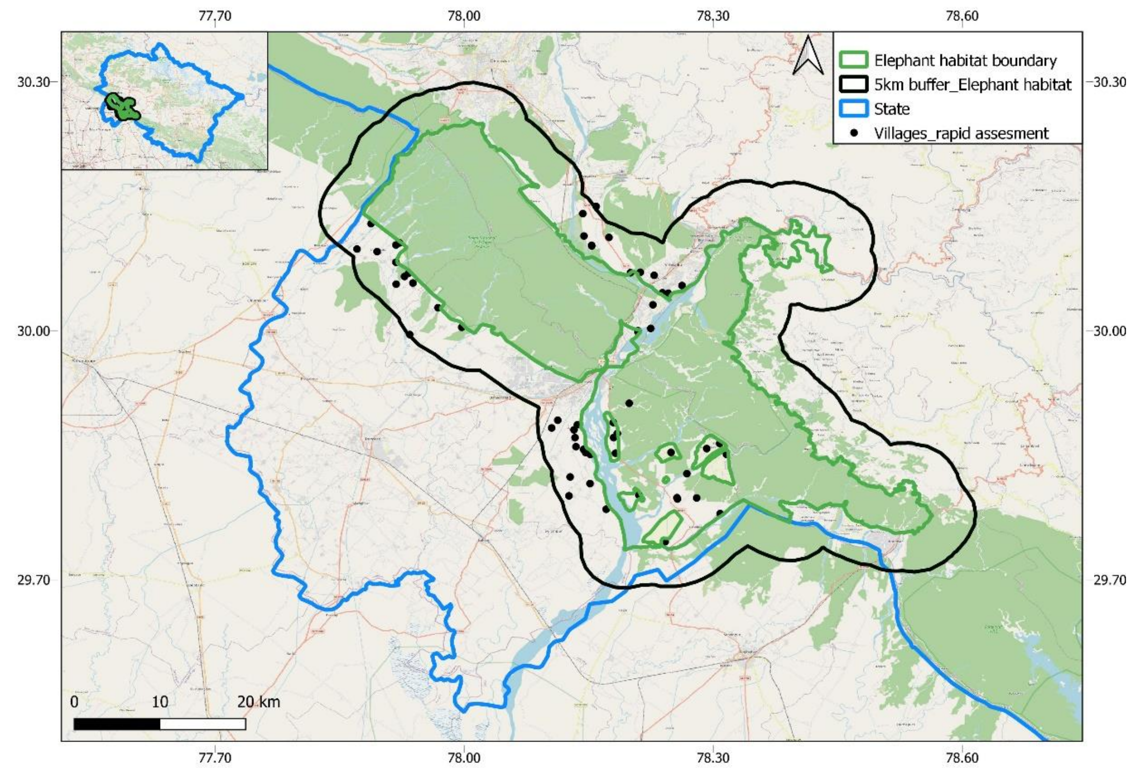


Figure 4.2: Villages selected for rapid assessment

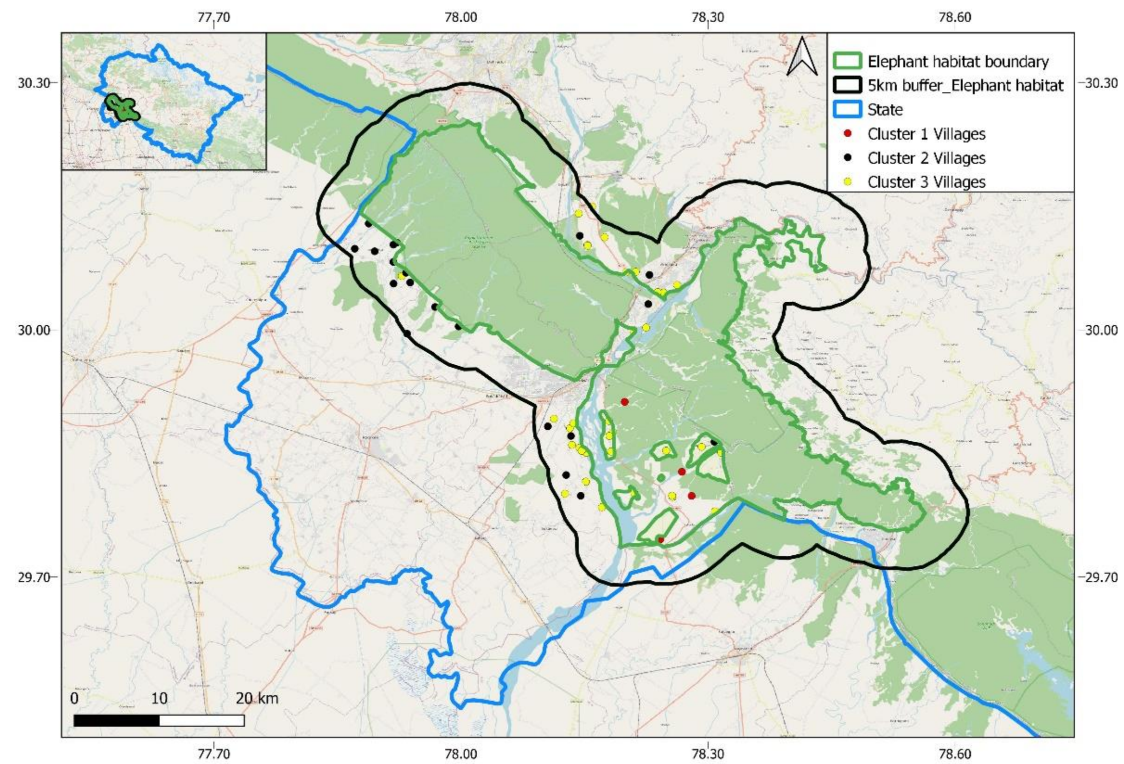


Figure 4.3: Final selection of villages for the survey

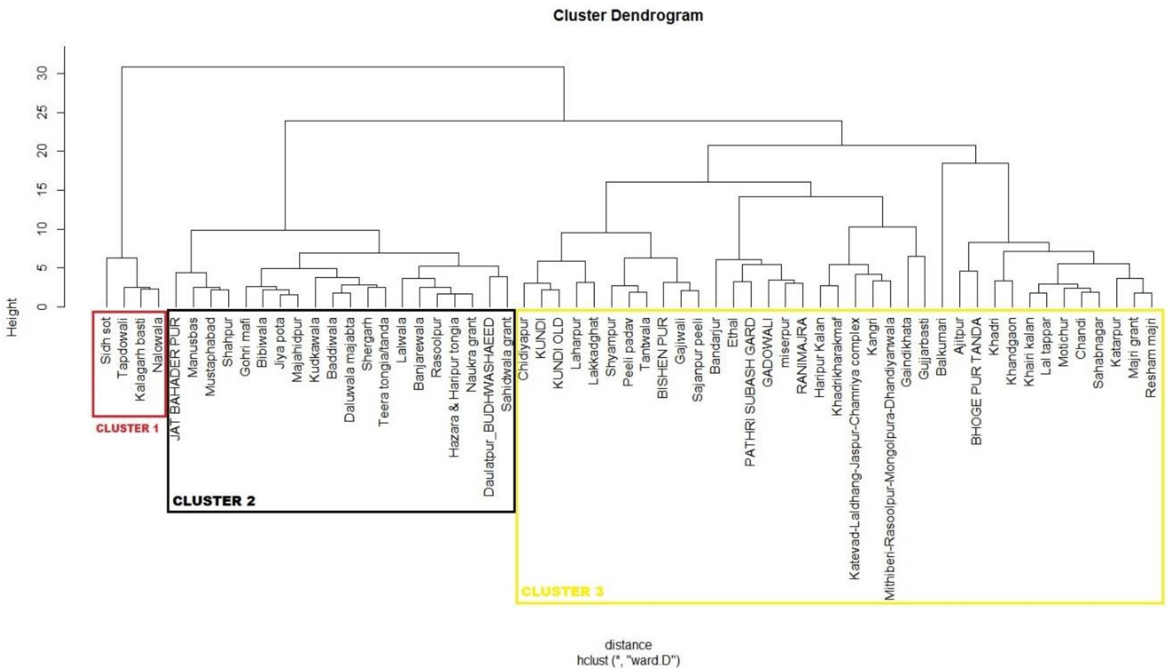


Figure 4.4: Identification of clusters based on hierarchical cluster analysis (Ward's method)

1. **Determining major challenges experienced by rural communities facing HEC**

Among villages facing HEC, a high percentage of farmers (72.5%) said that a lack of capital or funds was an obstacle they faced to improving their quality of life, while availability of land was the major problem faced by the non-farmer respondents (89%) (figure 4.5). The majority of farmers (59.7%) indicated that availability of land was the second greatest obstacle, while for non-famers, lack of capital (70.5%), followed by lack of job opportunity (70%) were the second and third greatest obstacle. More generally, farmers responded that lack of capital (27.8%) was the most prevalent issue for their cultivation, followed by availability of land (25.8%) and water availability (17.2%) and wildlife (17.2%) (figure 4.6).

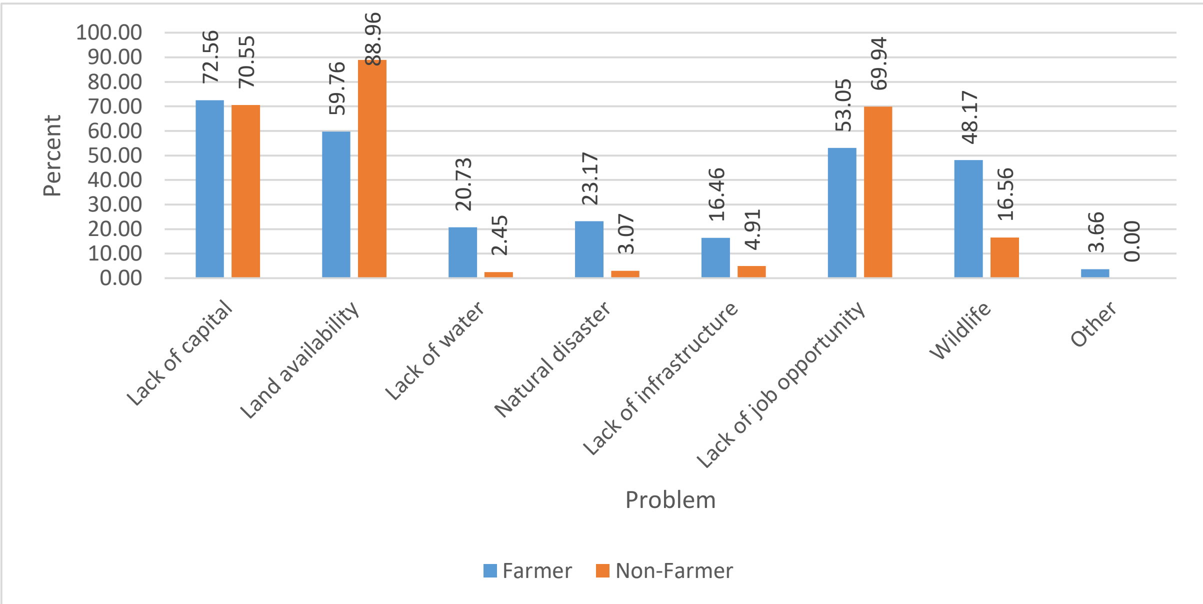


Figure 4.5: Challenges faced by communities in improving the quality of their life

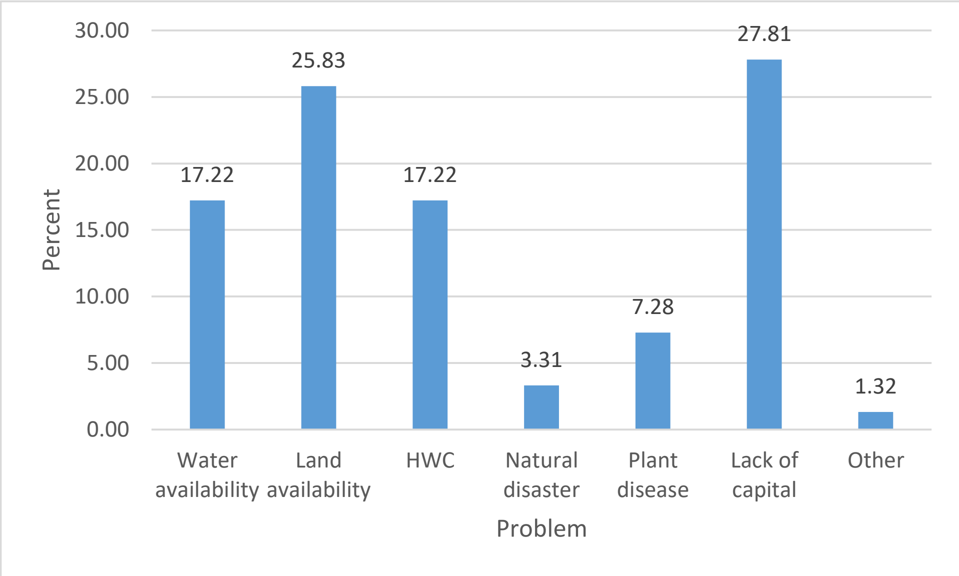


Figure 4.6: Problems faced by farmers in cultivating crops

2. Identifying the intensity and types of HEC

For farmers living the elephant conflict area, 46.7% reported that elephants were a major problem, with an additional 26.6% reporting elephants as a minor problem. For non-farmers in these areas, 55.4% reported elephants were a minor problem with another 21% indicating elephants posed a moderate problem (Figure 4.7). Farmers indicated crop damage (81.5%) as the main concern when living with elephants, while non-farmers in elephant range cited fear (93.5%) as their most prevalent concerns (figure 4.8).

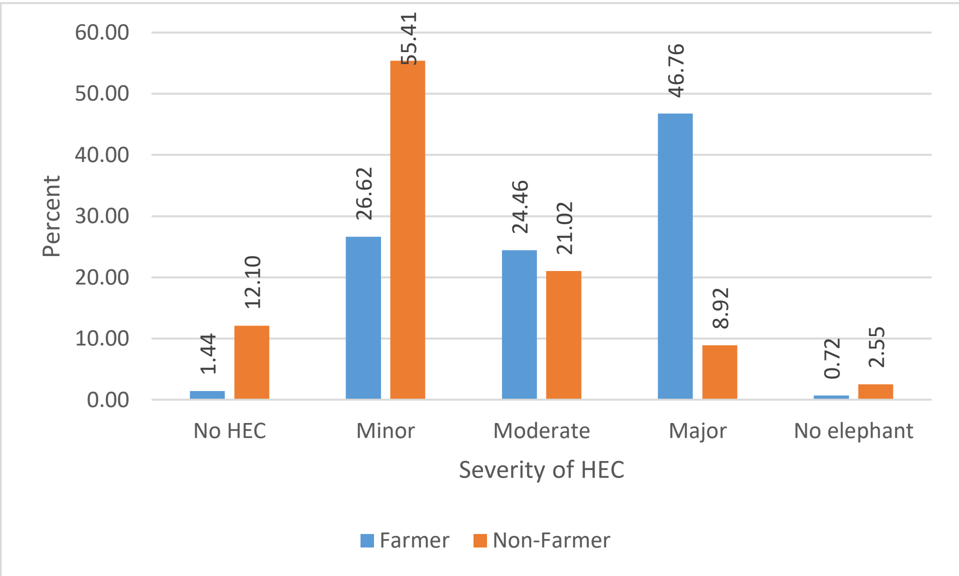


Figure 4.7: Severity of HEC experienced by farmers and non-farmers

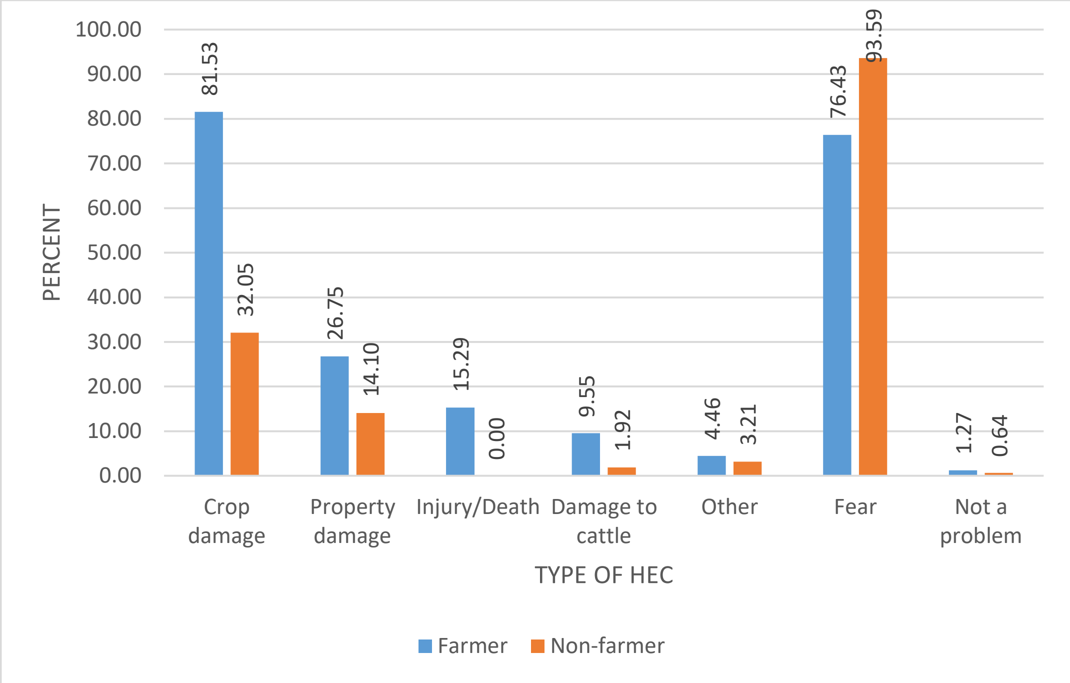


Figure 4.8: Types of HEC experienced by farmers and non-farmers

3. **Assessing how locals perceive the risks from HEC and their general conservation attitudes**

Both farmers and non-farmers indicated support for the conservation of wild elephant population. The reasons they gave for their support included that they were an important of nature (farmer – 85%, non-farmer – 95%) (figure 4.9). Both groups believed that the wild elephants raided crops as they preferred it over wild forage (farmer- 73%, non-farmer – 81.6%) (Figure 4.10). While the farmers mostly believed that the attack on humans were by mistake due to unfortunate encounters during crop raids (50.6%), non-farmers (56%) believed that the attack on humans were deliberate as they guarded the crops against raiding elephants (Figure 4.11).

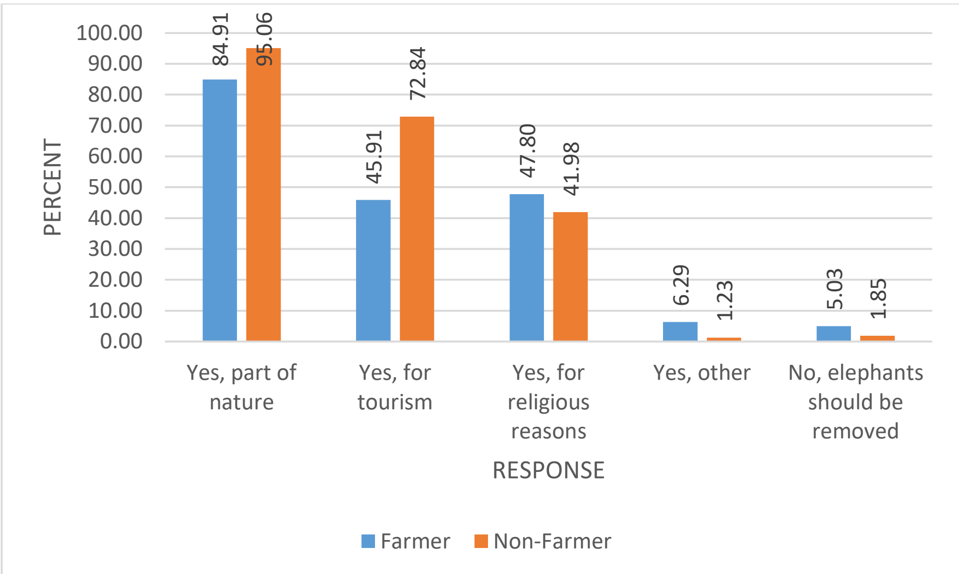


Figure 4.9: Need for conservation of elephants

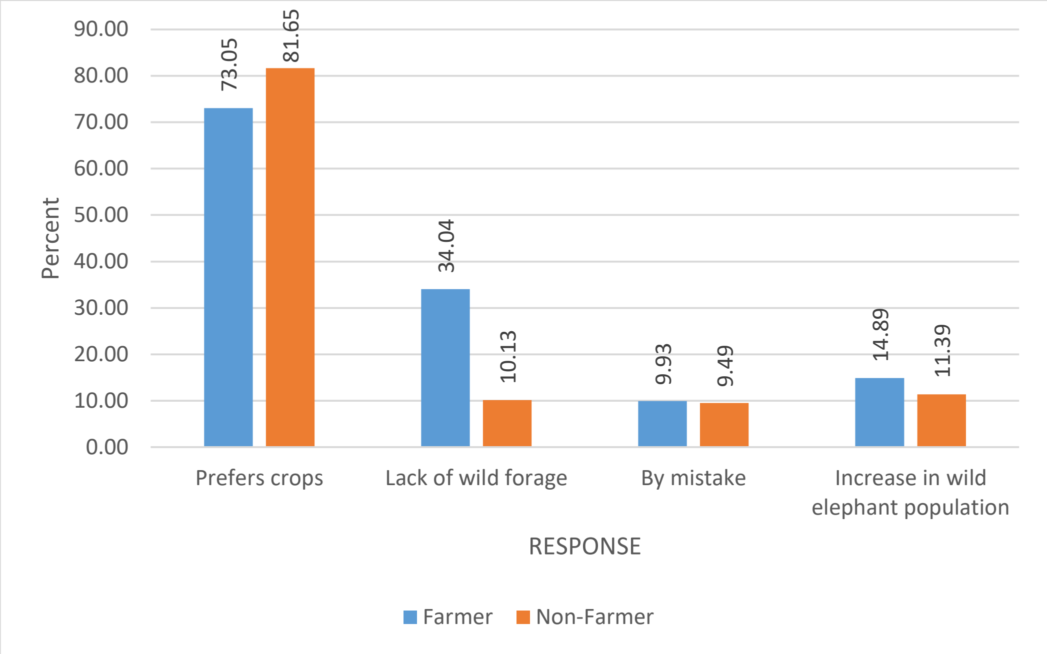


Figure 4.10: Reasons for raiding or damaging crops, perceived by farmers and non-farmers

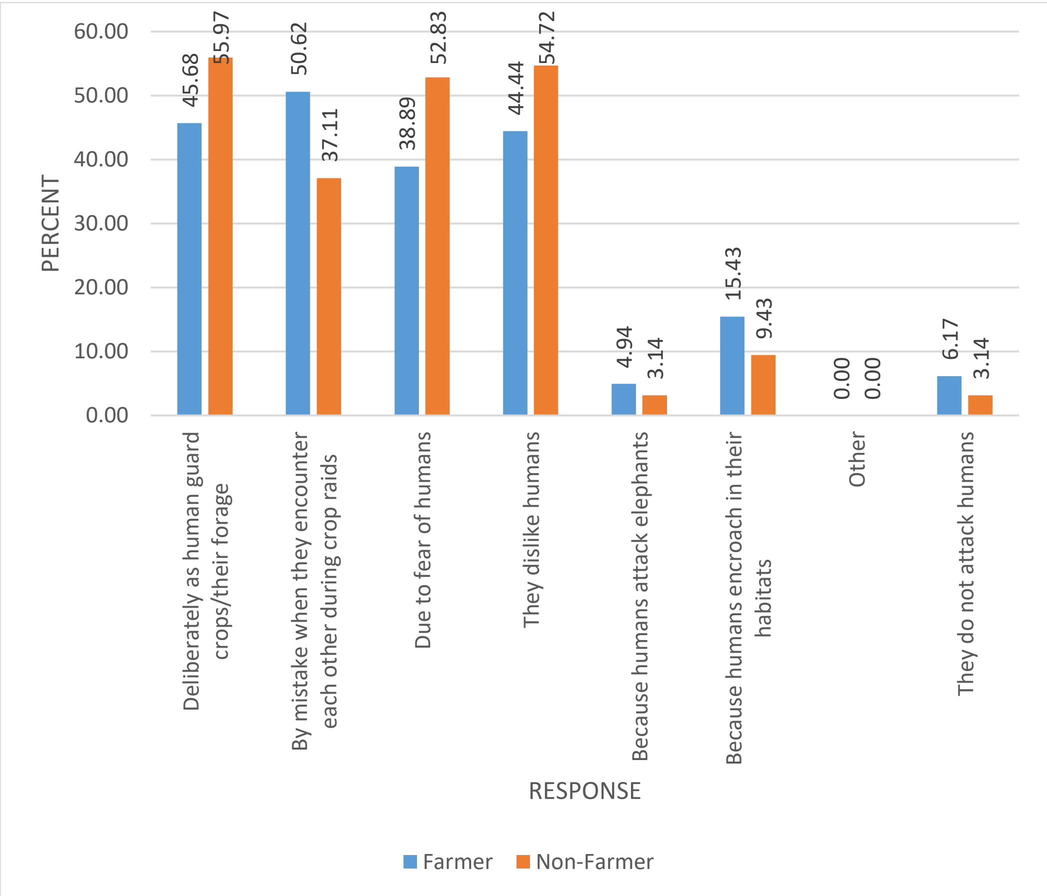


Figure 4.11: Reasons for attack on humans, by elephants, perceived by farmers and non-farmers

4. Identifying mitigation strategies supported by communities

Both farming (98%) and non-farming (98.7%) respondents held government accountable for implementation of HEC mitigation strategy (figure 4.12). For the methods currently being used by the respondents, both farmers (51.9%) and non-farmers (51.7%) reported using crackers as the main method to drive away elephants (figure 4.13). While most farmer (71%) responded by suggesting compensation as a scheme to mitigate HEC, most of the non-farmers (82.8) suggested use of physical barriers (Figure 4.14). Both farming (78.6%) and non-farming (76.4%) respondents responded with agreed to contribute towards HEC mitigation measures, by providing their time towards it (figure 4.15).

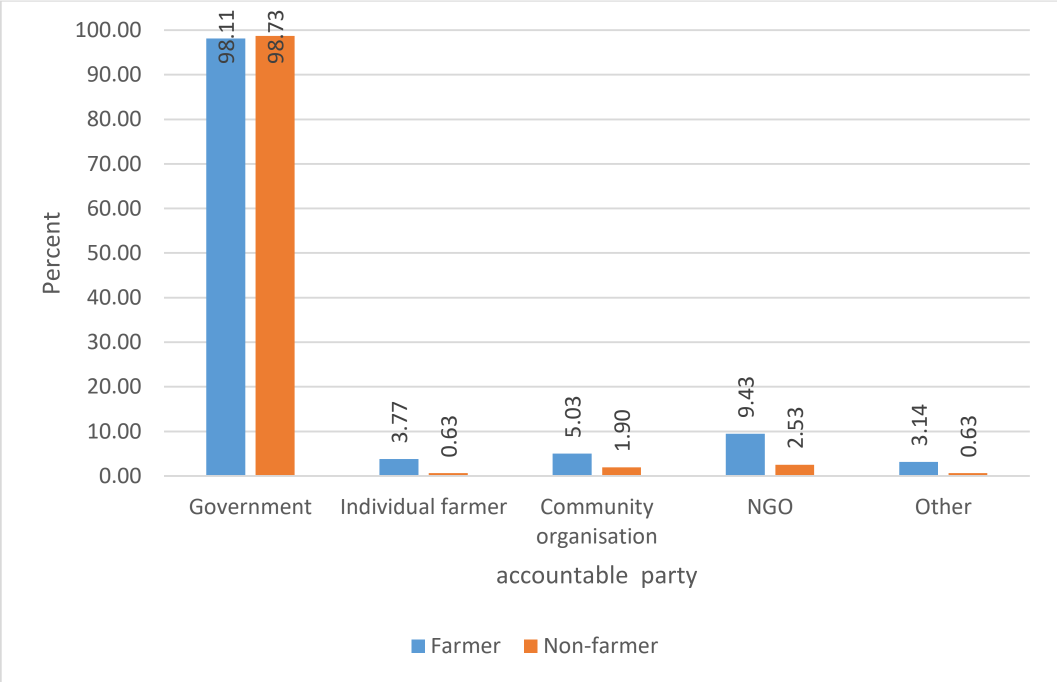


Figure 4.12: Accountability for HEC mitigation, perceived by farmers and non-farmers

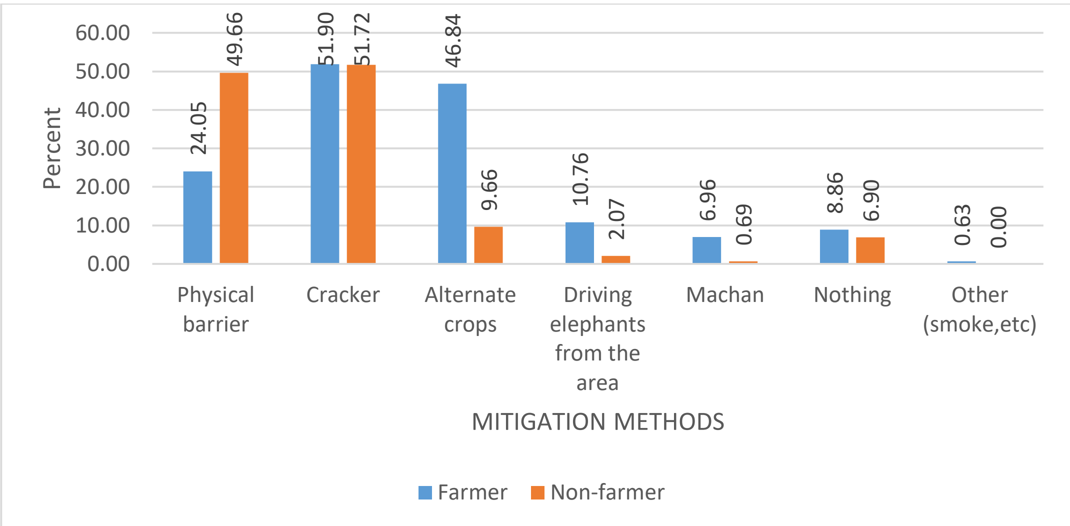


Figure 4.13: Mitigation strategies currently being used by farmers and non-farmers

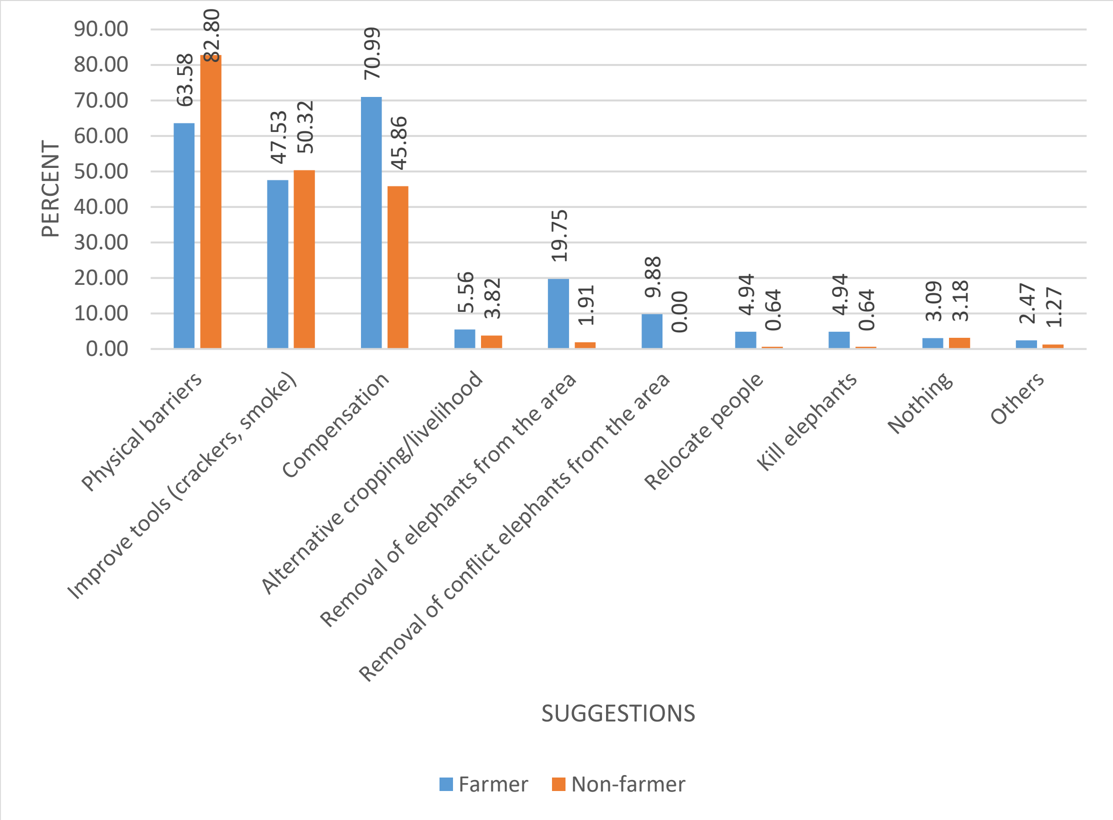


Figure 4.14: Steps that should be taken to reduce HEC, as perceived by farmers and non-farmers

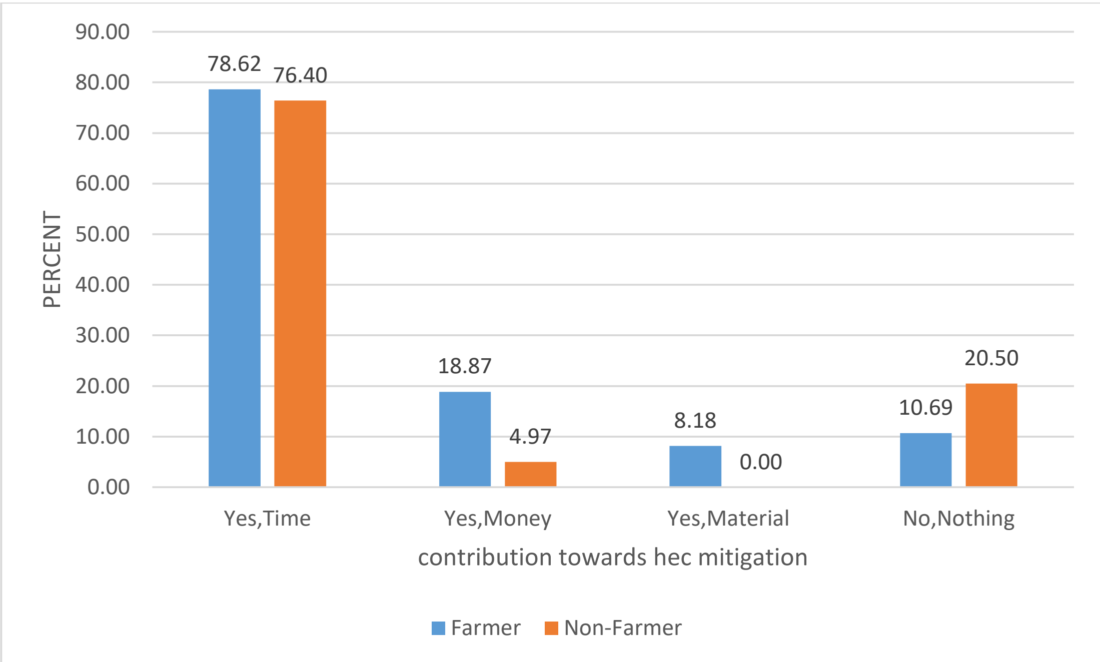


Figure 4.15: Contribution towards HEC mitigation, as responded by farmers and non-farmers

Discussion

Living alongside wildlife can have various consequence (Hoare, 1999). However, assuming that HWC is the only or major challenge for the communities living alongside the wildlife habitats may prevent identification of management strategies that would more effectively cater to alleviate HWC. HWC was found to be one of many, often interconnected challenges facing the people dwelling along-side the wildlife habitat in the study area. Despite these challenges, the participants overwhelmingly supported elephant conservation, in contrast to other studies that have revealed feelings of bitterness towards species involved in HWC (Mwangi et al., 2016). The identification of lack of availability of land and fund with respect to improving the quality of life provides the managers with an opportunity to develop management strategies to try and augment the livelihood strategies of these communities to focus on improving conservation success. Although HWC was not considered the leading cause preventing the communities from improving their lives, farmers identified HEC as a major threat to their cultivation, while for non-farming community, it was a minor problem. The response of farming community can be attributed to their regular exposure to threat and loss of crops (and income) to elephants, as compared to the non-farming community. In terms of the type of HEC experienced by the farming and non-farming communities, the farming communities perceived crop damage as the major challenge while for non-farming communities, it was the overall fear of living alongside elephants. While damage pertaining to the amount of crop consumed may be less, the overall fear instilled due to the size of the animal and perception of damage imprinted, particularly considering the collateral damage from trampling can result in such response by the farmers (Naughton-Treves, 1998; Williams et al., 2001). Eventualities of HEC in the form of human death or injury is relatively very less in this landscape when compared to east-central Indian elephant areas (Tripathy et al., 2021).

Despite the economic losses incurred due to crop damage by the farmers and the constant of anxiety of living alongside elephants in the area, both farming and non-farming communities supported elephant conservation. Both the communities suggested that the elephants raided crops due to their preference towards it. While most of the non-farming communities suggested that the elephant deliberately attacked the humans guarding crops from them, most of the farming community members suggested that the attacks on humans were due to unfortunate encounters during crop raids. It is imperative to understand what the communities favour as effective mitigation strategy for HEC. Identifying it allows local conservationists and stakeholders to address community expectations, the feasibility of the mitigation measure and necessary community inputs expected for its long-term success or effectiveness in important. Such information allows the stakeholders to make adjustments based on what is achievable in a realistic manner. Most of the farming and non-farming community held government accountable to tackle and alleviate HEC in the area. Most of the respondents suggested the use of crackers as a deterrent, to mitigate HEC in the area. This may be based on their past experiences of response of elephants towards crackers and also due to relative ease of acquiring crackers from nearby markets and the use of it. While farming communities have suggested compensation as an effective measure to alleviate HEC, non-farming communities have responded with need for better physical barriers. While compensation in itself is not an effective method to deter on contain elephants from causing physical damage, it serves as a tool to help alleviate the negative perceptions of HEC in the communities. Timely and efficient methods of implementing compensation schemes may lead to decrease in retaliatory measures deployed by the communities, towards elephants and lead to long-term conservation success. Erecting physical barriers and improving deterrents have proven successful in preventing elephants from causing damage in several areas countries (Fernando et al., 2008a; Hoare, 2012) and can be adapted for use by local communities. It should be noted that implementation of any mitigation measure, especially the physical ones need due considerations. Mitigation measures needs to account for the behaviour of elephants, its biological and social needs and responses. Not accounting for these may merely result in short-term success or even worse outcomes where conflict shifts to new area. Since most of the respondents have showed their willingness to provide their time for the mitigation strategies, it may serve as an effective way to manage the mitigation structures e.g. clearing of dry leaves/debri on solar fences or deepening/widening of trenches on a regular basis.

The widespread support for elephant conservation in the study area despite the socio-economic challenges faced by the respondents offer hope for continued and potential collaboration of stakeholders to streamline their efforts for long-term conservation success. However, it is imperative to adapt strategies considering the context of challenges faced by different sections of the society to build stronger connect between conservation success and human well-being. Future studies that assess the effective means of including socioeconomic considerations into conservation planning will prove pivotal for long-term co-existence.

CHAPTER 5: MOVEMENT AND SPACE-USE PATTERN OF ELEPHANTS BEFORE AND AFTER KUMBH 2021

Introduction

Ranging behaviour of elephants has its implications on Human-Elephant Conflict (HEC) in the region. Nagarajan et al. (2018a) showed that the elephant population sub-units (clans and solitary bulls) have different strategies for habitat utilization with well-defined home ranges; this includes the use of seasonal ranges within home ranges, and regular routes or migration paths within these seasonal ranges. The forest-crop field interface of the study area comprising of ranges of Haridwar Forest Division along the bank of the Ganges and the eastern ranges of Rajaji Tiger Reserve creates is one such area where diverse space-use pattern of bull elephants and female groups is observed. While the bull elephants move deep inside the human-use areas to raid crops, female groups have been observed to mostly avoid such ranging behaviour (see Chapter 2 and 3 for more details). The regular movement of bull elephants in the human-use areas along the bank of the Ganges (forest-crop field interface) is a matter of grave concern for the management of HEC in the region. With the proposed camping sites of Kumbh 2021 overlapping with space-use pattern of bull elephants in the area (Figure 5.1), it was decided to document and understand the movement pattern of bull elephants before and after the installation of mitigation structures and measures.

Kumbh, the largest religious gathering in the world, is held every 12 years in rotation at the four holy places of Haridwar, Allahabad, Ujjain and Nasik. The 2021 Kumbh was held in Haridwar. The event was restricted to only the month of April 2021 (instead of starting from January 2021) due to CoVID19 restrictions and witnessed a footfall of 9.1 million people. Such large congregations at the interface areas already used by elephants possess management challenges of grave concern.

Following the formal permission to commence the project on 6th February 2020, the field team of the Wildlife Institute of India (WII) has been intensively monitoring elephants primarily in the ranges of Haridwar Forest Division, where the Kumbh 2021 camping sites are located. The field effort involved tracking elephants between 0500 to 0800 hours and 1500 to 1800 hours on a daily basis. In the process, the team identified 21 bull elephants of various age-class that regularly crossed the Ganges to raid crops and used the islets and other small forest patches along the eastern bank of the Ganges as their day-time refugia (details are given in Chapter 2). Four female groups were also identified but were not followed intensively, as they were mostly restricted inside the forest patches along the eastern side of the Ganges (mostly in Sidhsot, Papri sot, Khohra areas of Shyampur range and some parts of Chiriyapur range of Haridwar Forest Division).

The monitoring started from the month of March, 2020 with the objective to document the elephants using the forest-crop field interface in the landscape and to identify them individually based on the variation in their morphological features. As part of the project first objective 'T*o understand fine-scale spatio-temporal ranging behaviour of these elephants, to help develop effective mitigation strategies for the upcoming Kumbh 2021'*. Four identified adult bull elephants were radio-collared between October to December 2020, before the commencement of the mega event. These individuals were intensively followed by the both the WII and Uttarakhand Forest Department (UKFD) field teams, both before and after their successful collaring. Their regular tracking and hourly GPS updates enabled the manager to device strategies to avoid any untoward incident during the Kumbh 2021.

Due to the CoVID19 related restrictions, Kumbh 2021 did not start with the expected magnitude of footfall. Instead of a multi-month event starting from January 2021 to April, 2021, the event was only limited to the weeks of April with maximum footfall on important occasions (*Shaahi snaans*) of 12th April, 14th April and 27th April, 2021. Hence, the impact of the event on the wildlife was relatively limited.

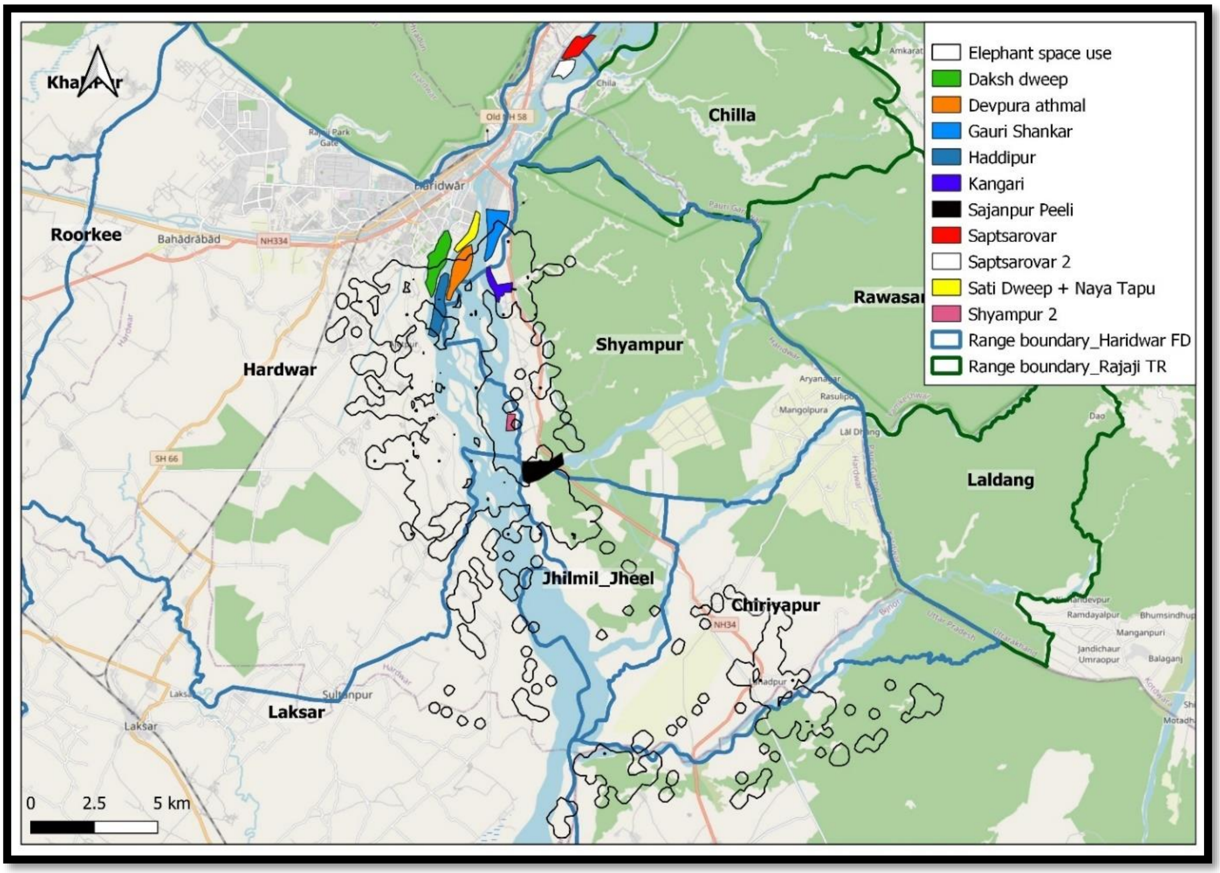


Figure 5.1: Proposed camping sites for Kumbh 2021 with overlap of space-use by collared bull elephants

Efforts by the Forest Department:

Of all the species that are involved in human–wildlife conflict in the Haridwar–Rajaji interface, elephants were of most concern, for the Kumbh 2021. To prevent and manage the potential threat of HEC during the Kumbh 2021, the following steps were taken by the UKFD.

(i) Establishment of Control and Command Centre:

Control and Command Centre was established at Divisional Forest Office, Haridwar. It supervised, monitored and coordinated human-wildlife conflict mitigation activities. Its in-charge was Sub Divisional Officer, Haridwar. It had facilities of telephone, wireless and computer and operated 24x7 during Kumbh 2021.

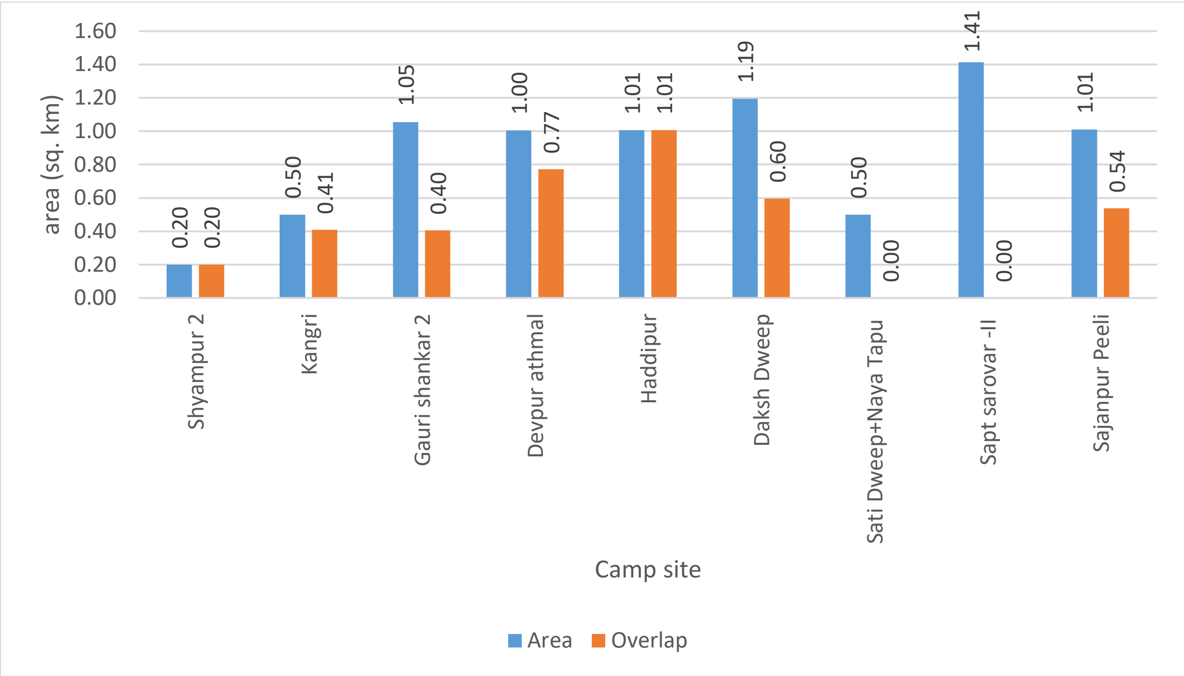


Figure 5.2: Graphical representation of overlap between proposed camp sites and space-use of collared bull elephants

(ii) Day and night monitoring of elephant movements by watchers and trackers:

Deployment of elephant watchers and trackers: The movement of elephants was monitored by following them in the forests by dedicated teams of watchers and trackers. These teams served as a real-time early warning system regarding the possible attempts of elephant(s) towards a particular human area. A total of 41 units were proposed, each comprising of 6-7 forest staff and wildlife watchers.

(iii) Forester Chowkies: These served to lodge the staff deployed to partake in the actions, and also served as information relay center. These were equipped with basic sustenance facilities to operate 24x7.

(iv) Establishment of solar fences: Solar fencing was done at various key areas in Haridwar, Shyampur and Laksar ranges of Haridwar Forest Division. Its main objective was to prevent the entry of elephants in the Kumbh areas and nearby villages to ensure safety of pilgrims in Kumbh as well as safety of human habitations and agricultural crops.

(v) Construction of Gabion structures along western bank of Ganga: The eastern sections of Shyampur forests and all sections of Rasiyabad forests connect to the eastern bank of river Ganga through elephant habitats that are the daytime refuges of bull elephants that raid crops on the western side of the Ganges. It was decided that a physical barrier along the western bank of the Ganges needs to be constructed to discourage further movement of elephants. With this plan in sight, a 17+ km continuous line of solar fencing had been laid along the Western Bank of Ganga from Ajeetpur along the bank of the Ganges. This line had been heavily damaged and disrupted due to various reasons, and was no longer effective. To keep the wildlife, especially elephants from reaching the agricultural fields and human settlements once they cross the Ganges, strengthened gabion structures were constructed along the western bank of Ganges.

(vii) Digging of elephant proof trenches (EPTs): EPTs served as effective physical barrier for elephants to negotiate. These were made near Kumbh camping and parking sites for effective protection of these areas.

(viii) Construction of elephant/wild boar proof concrete wall: In many areas used by elephants to venture in human habitations, the local physical conditions do not permit digging of EPTs. In such identified areas, elephant/wild boar proof wall in form of concrete fencing were constructed.

(ix) Radio-collaring of selected elephants: As an early warning system, selected bull elephants had been radio collared for surveillance and monitoring. A dedicated team of trained staff was deployed to keep a track on the movement of different elephant herds. The satellite tracking team passed information to the rapid response teams regularly for further action.

(x) Rapid Response Teams (RRTs): RRTs were formed in Haridwar, Shyampur Rasiyabad and Laksar ranges of Haridwar Forest Division. Each squad comprised of one Forester as unit leader, two forest frontline staffs experienced in handling elephant conflict cases, six daily wagers with proven record of dealing human-wildlife conflict cases. Each squad was equipped with a vehicle (Mahindra Camper) with driver and flash lights, announcement systems, firecrackers, shotguns, drone for aerial surveillance, night vision binoculars, thermal binoculars, ropes and other paraphernalia necessary to deal with such conflict situations. The squads were mobilized upon report of possible attempts of elephant movements towards human areas from elephant watchers and trackers/ satellite monitoring team, and ensured to prevent the elephants from entering human areas and their safe return to the forest.

Table 5.1: List of key mitigation measures deployed by the UKFD during Kumbh 2021

Sl.No.	Measures	Location	Work/numbers
1	Solar fencing	Different areas in Haridwar, Shyampur and Laksar ranges	42 km
2	Elephant proof trench	Haridwar range	3.2 km
3	Stone concrete wall	Haridwar range	1.5 km
4	Gabion structure	Haridwar range	3 km
5	Watch tower	Bhogpur, Nalowala, Bishanpur, Devpura and Tircchipul	5
6	Forest chowkis	Bishanpur, Bhogpur, Rasiabad, Mithiberi, Devpura and Tircchi pul	6 + 2
7	Watchers and trackers	Kumbh area	41 teams

A

B

Figure 5.3: Active guarding at Anjani chaur - Tircchi pul junction. A) Use of sound and noise to keep the elephants away from crossing the road. B) Use of fire to deter the elephants

Figure 5.4: Mitigation structures along the eastern (A) and western (B) bank of the Ganges to restrict the movement of elephants

Figure 5.5: Breaching of solar fence by elephants

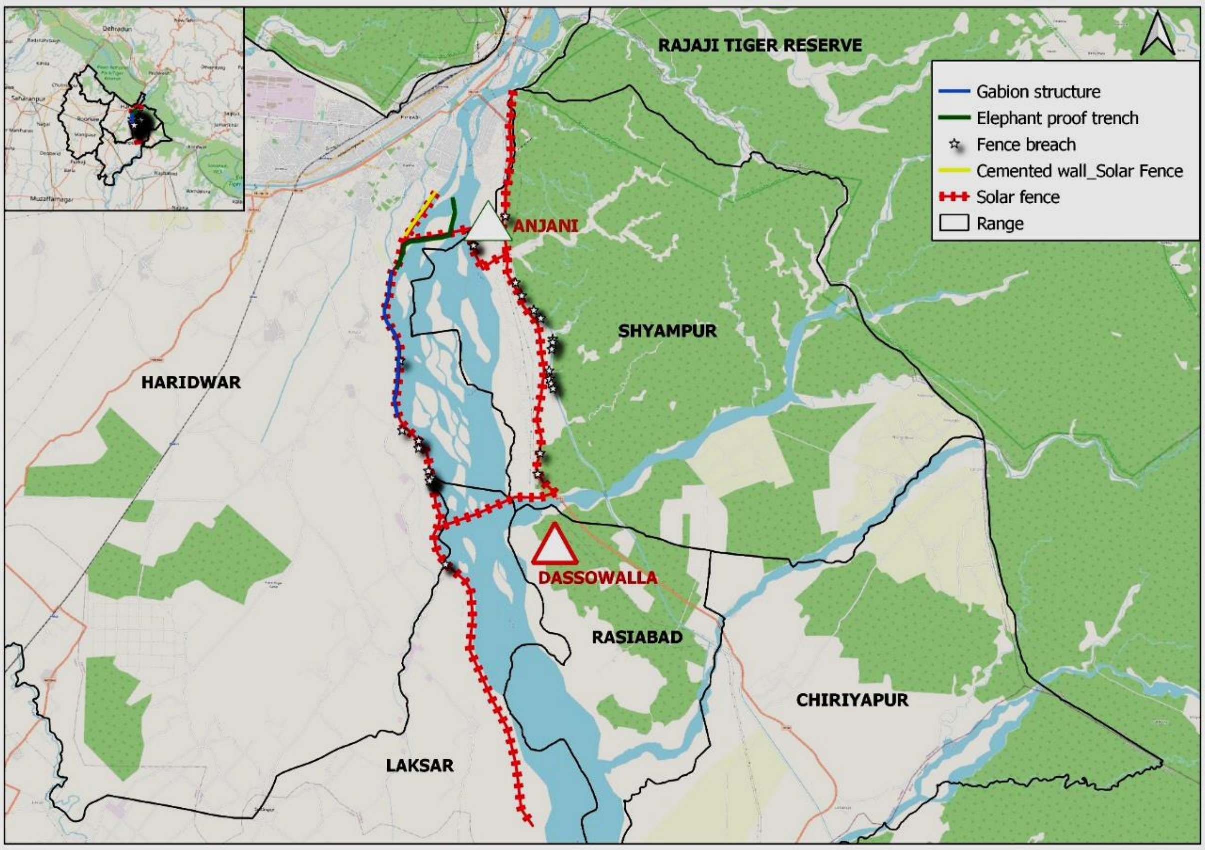


Figure 5.6: Map of the key mitigation measures taken by the forest department to contain movement of elephants from the eastern side of the Ganges

Efforts by the WII field team

Table 5.2: Effort by WII field team

S.No.	Purpose	Months	Tracking Days	Hours	Direct sighting (days)	Direct Sighting (events)
1	Tracking elephants	August, 2020 to July, 2021	334 days	2672 hours 5:00 to 8:00 hour and 15:00 to 20:00 hour	186 (August, 2020 to July, 2021)	376

The WII field team worked towards:

1) Documenting the elephants involved in HEC.
2) Documenting the events of HEC (crop damage, property damage, human and elephant deaths).
3) Documenting the movement of elephants before, during and after the installation of mitigation measures.
4) Provided hands-on training to the front-line forest staff for tracking radio-collared bull elephants and monitoring the non-collared elephants.

Through the process of monitoring the elephants, the team collected information pertaining to ranging behaviour, association and individual identification of elephants involved in regular HEC incidents.

Methods

Analysis of the movement pattern of elephants:

1) **Proportion of crop raids per night (for collared bull elephants)**

   To analyze the proportion of crop raids per night for the collared bull elephants between 15th October 2020 to 22nd September 2021, all the GPS fixes falling inside the "crop-field" class of the ESRI 2020 global land use/land cover (LULC) were extracted for each day of the observation. Number of days the GPS fixes fell inside the "crop-field" class in a particular month were then divided by the number of days the observations were made. i.e. 15 raid nights in 30 days of a month gave us a proportion of 0.5 for that month (Figure 5.7).

2) **Proportion of crop raids on the western and eastern side of the Ganges (for collared bull elephants)**

   Shapefiles for the eastern and western side of the Ganges were produced using QGIS and the proportion of crop raids on either side were then recorded following the same method as mentioned above, to find the proportion of crop raid nights of both side of the Ganges (Figure 5.8).

3) **Extent of area covered by the collared and non-collared elephants. Proportion of time spent in different LULC classes (for collared bull elephants) during pre-guarding, guarding and post-guarding days**

   100% minimum convex polygon (MCP) were created for all the sighting and resighting location of collared and non-collared elephants (identified elephants) in the study area. ESRI 2020 global LULC layer was used to derive the proportion of time spent by the collared elephants in different LULC classes at different seasons (pre-guarding, guarding and post-guarding days) of the year.

4) **Elephant crossing per day from Anjani chaur and Dassowala (for all elephants), during pre-guarding, guarding and post-guarding days**

   To analyze the crossing of elephants from two key day-time refuges along the eastern side of the Ganges – Anjani chaur and Dassowalla, each elephant crossing event were recorded using three different methods:

   a) Crossing of collared bulls were recorded via direct sighting and remotely, using their GPS fixes.
   b) Crossing of non-collared elephants were documented through direct sighting.
   c) Crossing of non-collared elephants were also validated using the information obtained from the forest department frontline staff and their elephant information register maintained in Anjani chaur and Dassowalla anti-poaching chowkis.

Monthly trend of elephant movement was then plotted to highlight their crossing during pre-guarding, guarding and post-guarding days. Proportion of days for the mitigation measures (active guarding – AG, solar-fencing - SF) were also derived. To provide a score/value to the attractants (sugarcane, paddy and wheat) a crop index was developed by multiplying the phenophase of the available crops and multiplying it with their proportion of being damaged, based on the past five years secondary data obtained from the UKFD records.

Table 5.3: Scoring matric for availability and state of crop types

Phenophase	Score
Not available	0
Small	1
Intermediate	2
Ready for harvest	3

Crop index (CI) = {(phenophase of sugarcane)*% damage in the last 5 years}+ {(phenophase of paddy)*% damage in the last 5 years}+{(phenophase of wheat)*% damage in the last 5 years}/ 3.

5) **Response of elephant crossing, to the mitigation measures– active guarding and solar fencing in the two sites a) Anjani chaur and b) Dassowala and crop index**

Generalised linear models (Zuur et al., 2007) were used to quantify the influence of potential explanatory variables on the crossing of elephants. The response variable in the models was the crossing of elephants. Each event of elephant crossing and non-crossing were scored as 1 and 0 respectively for each day. Each event of presence and absence of mitigation measure were also scored in similar fashion (1 and 0). Crop index for each day was documented.

A total of 157 observations were made between 10th January 2021 to 31st May 2021 to document the above-mentioned variables from Anjani chaur and Dassowala. These 157 observations served as sampling units. Three explanatory variables were quantified that could potentially influence the daily crossing of elephants and them using regression. The variables included mitigation measures – solar fence and active guarding and crop index.

Results

1) **Proportion of crop raids per night (for collared bull elephants)**

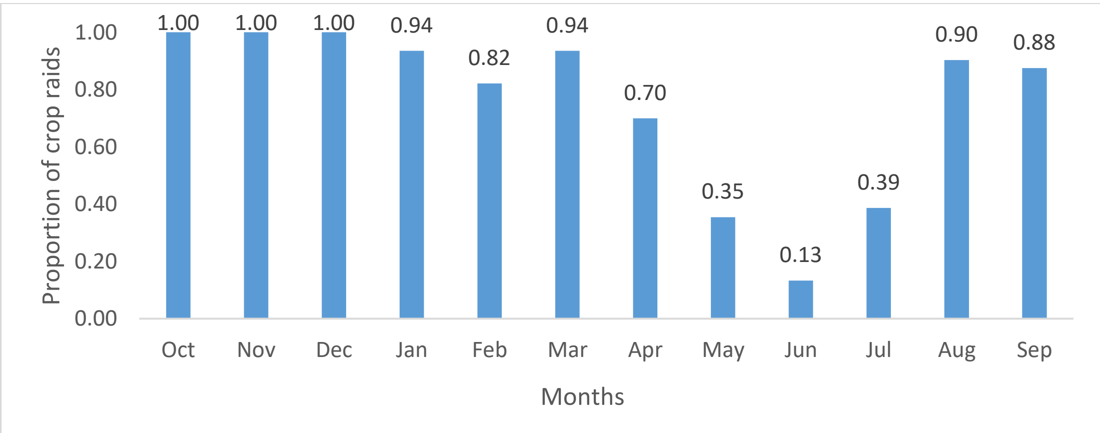


Figure 5.7: Proportion of crop raid nights (from telemetry data of radio-collared elephants UKM2 and UKM7)

A gradual decline in the crop raiding incidents were observed from the month of April, 2021.

2) Proportion of crop raids on the western and eastern side of the Ganges (for collared bull elephants)

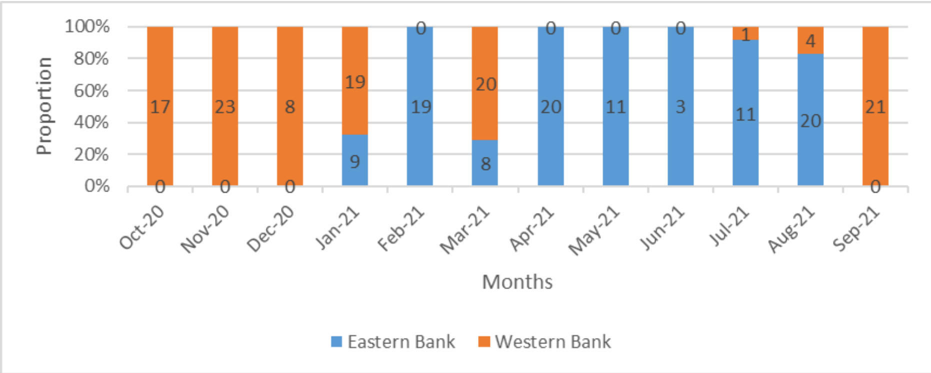


Figure 5.8: Proportion of crop raids in Eastern vs. Western bank

The concerted efforts of the UKFD field team in containing the elephants, especially the collared bull –UKM2 (Brahma) from entering the crop fields along the western bank of the Ganges is evident from the graph. Following March, 2021, in the month of April, May and June, UKM2 has restricted its raiding to the crop fields on the eastern side of the Ganges

2) **Extent of area covered by the collared and non-collared elephants. Proportion of time spent in different LULC classes (for collared bull elephants) during pre-guarding, guarding and post-guarding days.**

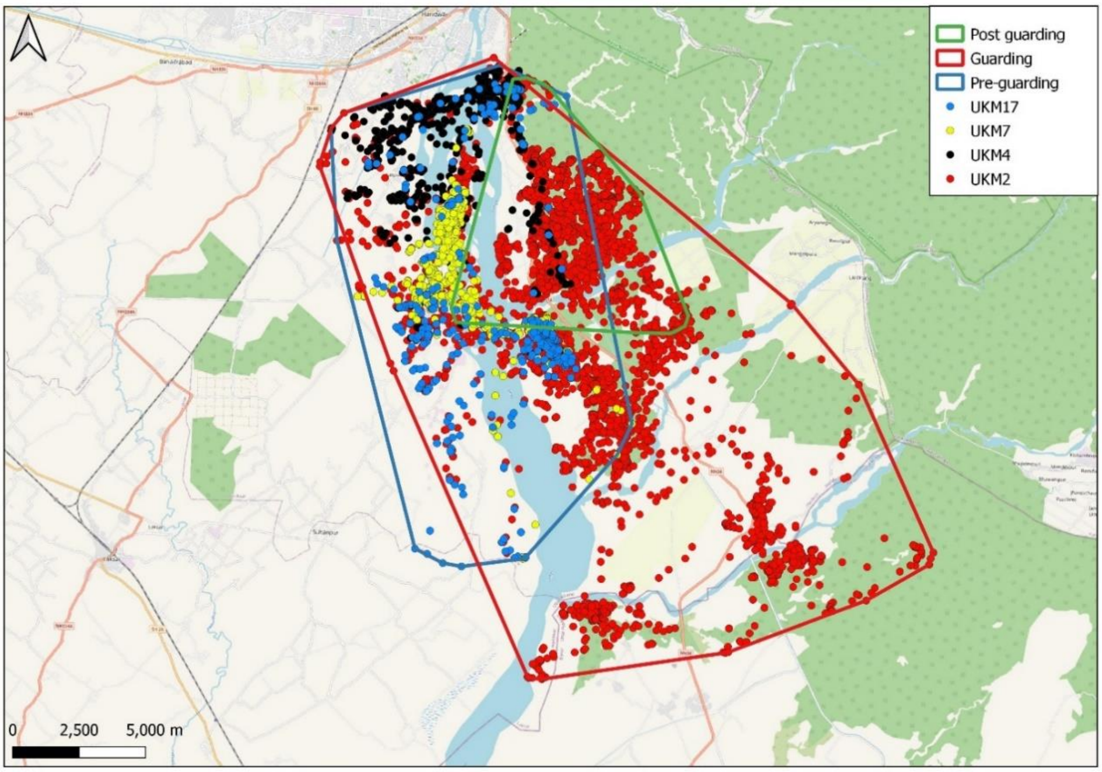


Figure 5.9: MCP highlighting the areas covered by the identified and collared elephants during the pre-guarding, guarding and post-guarding seasons

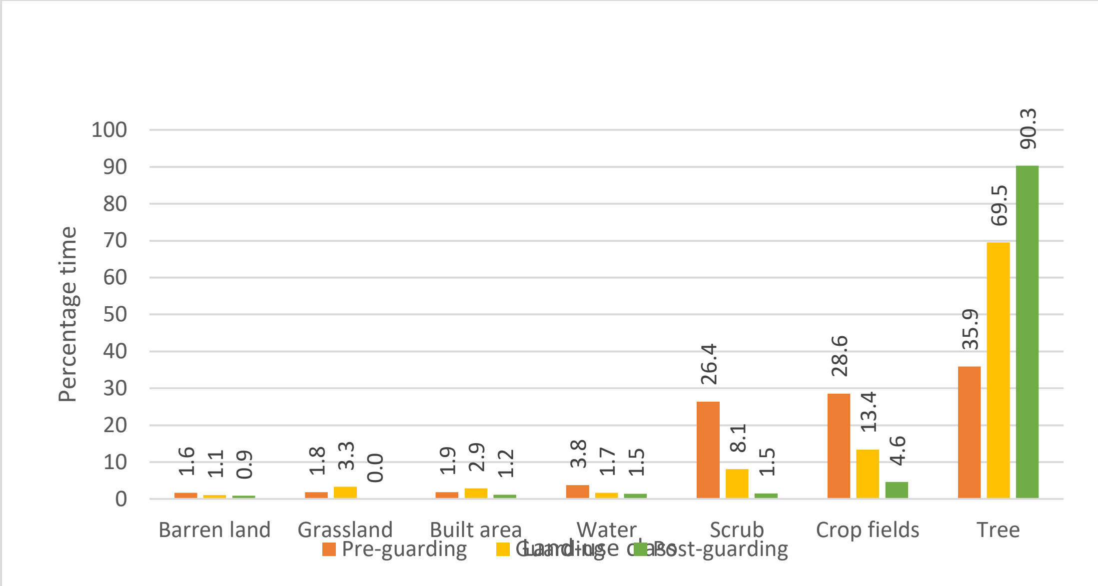


Figure 5.10: Time spent in different LULC classes at different seasons, by the collared elephants

Table 5.4: Period of observations for ranging pattern of collared elephants

S.No.	Condition	Dates	100 % MCP area (sq. km)
1	Pre-guarding	15th October 2020 to 9th January 2021	159.23
2	Guarding	10th January to 31st May 2021	323.46
3	Post-guarding	1st June to 31st July 2021	55.34

In the pre-guarding season, the identified bull elephants used an area of 159.23 sq km, under MCP. This was followed by the guarding season, when the elephants covered an area of 323.46 sq km. During the post-guarding season, the elephants were restricted to small area of 55.34 sq. km.

In all the three seasons – pre-guarding, guarding and post-guarding, the elephants spent most of their time under the tree-cover. Time spent in the crop-fields reduced from 28.6% to 4.6% from pre-guarding to post-guarding seasons.

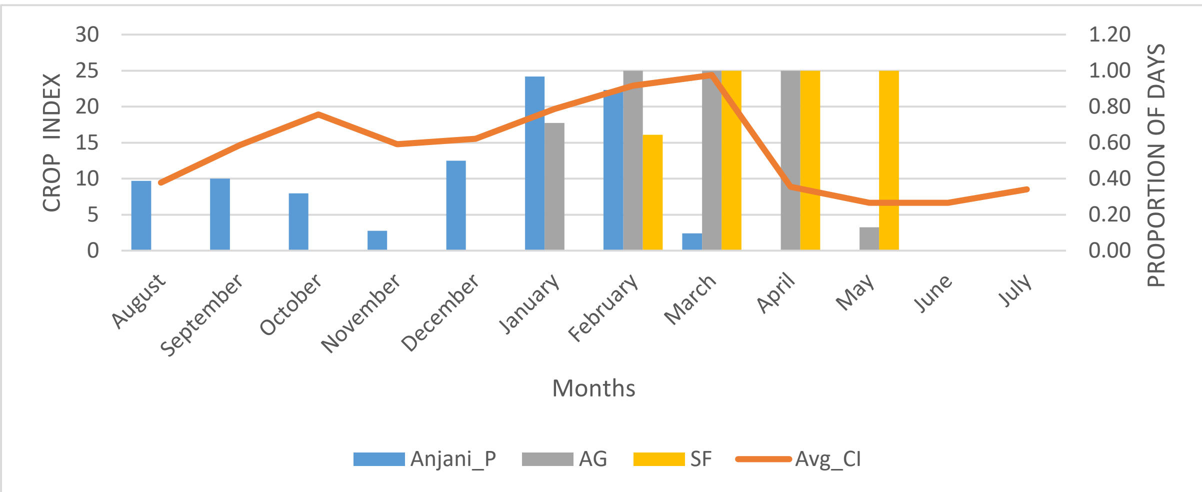


Figure 5.11 Monthly crossing of elephants from Anjani chaur, mitigation measures and crop index

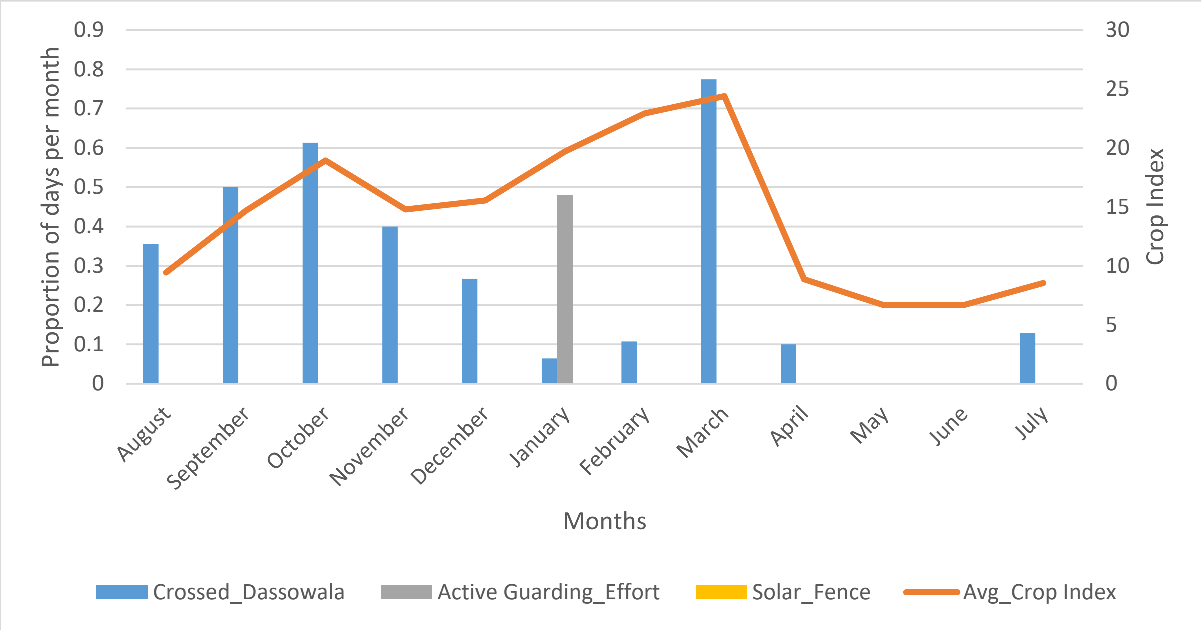


Figure 5.12 Monthly crossing of elephants from Dassowala, mitigation measures and crop index

1) **Elephant crossing per month and per day from Anjani chaur and Dassowala (for all elephants), during pre-guarding, guarding and post-guarding days**
   Anjani chaur
   Number of pre-active guarding or no-active guarding days = 120 (1st August 2020 to 9th January 2021)
   Number of pre-solar fencing days = 152 (1st August 2020 to 10th February 2021)
   Number of active guarding days = 116 (10th January 2021 to 5th May 2021)
   Number of solar fencing days = 109 (11th February 2021 to 31st May 2021)
   Number of overall guarding days = 142 (10th January 2021 to 31st May 2021), of which, exclusively active guarding days = 32 (10th January to 10th February), both active guarding and solar fencing days = 84, 11th February 2021 to 5th May, 2021 and exclusively solar fencing days = 26, 6th May to 31st May 2021).

Crossing of elephants with respect to the corresponding guarding days is shown in figure 5.13

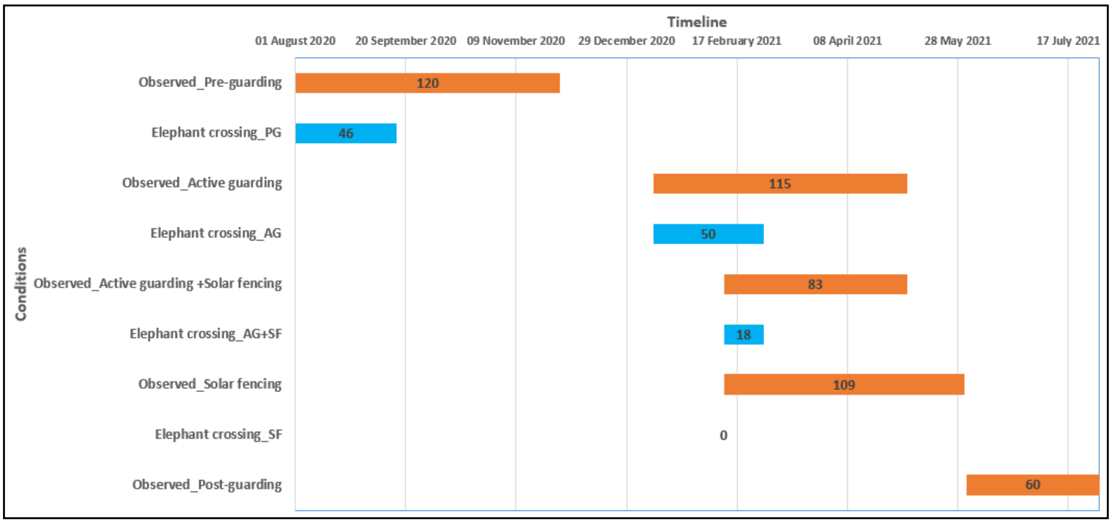


Figure 5.13: Timeline of observations made for Anjani chaur with respect to various mitigation measures by the forest department

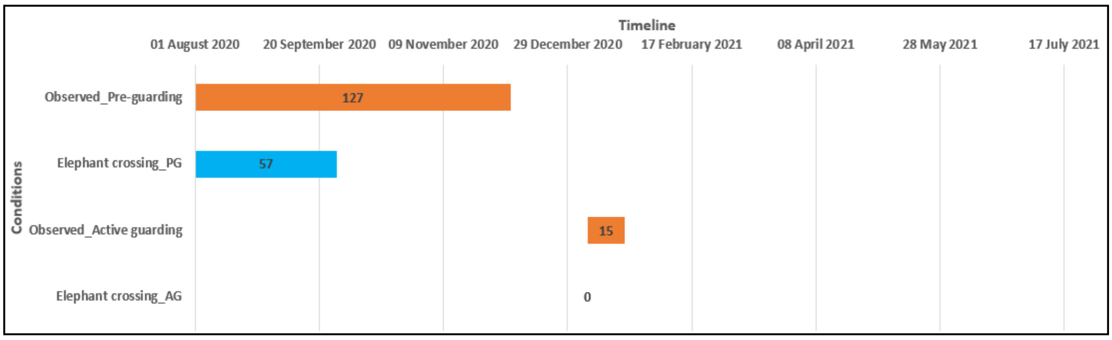


Figure 5.14: Timeline of observations made for Dassowala with respect to various mitigation measures by the forest department

Dassowala

Number of pre-active guarding or no active guarding days: 127 (1st August 2020 to 5th January 2021), Number of guarding days = 15 (6th January 2021 to 20th January 2021)

Crossing of elephants with respect to the corresponding guarding days is shown in Figure 5.14

2) Response of elephant crossing, to the mitigation measures – active guarding and solar fencing in the two sites a) Anjani chaur and b) Dassowala and crop index

Six binomial regression models were evaluated to examine the influence of explanatory variables on the response variable (Table 5). The top model, with least AIC (Burnham & Anderson, 2004) explaining the variation in the elephant crossing included solar fence and crop index as factors.

S.No.	Model	Intercept	SF	AG	CI	family	df	logLik	AICc	delta	weight
1	bm6	-4.578	-2.30	NA	0.26	binomial(logit)	3.00	-60.68	127.52	0.00	0.71
2	bm4	-17.986	-2.24	13.68	0.25	binomial(logit)	4.00	-60.51	129.28	1.76	0.29
3	bm5	-4.736	NA	NA	0.21	binomial(logit)	2.00	-74.22	152.51	25.00	0.00
4	bm2	0.758	-2.39	NA	NA	binomial(logit)	2.00	-78.45	160.99	33.47	0.00
5	bm3	-18.566	NA	18.08	NA	binomial(logit)	2.00	-87.10	178.28	50.76	0.00
6	bm1	-0.761	NA	NA	NA	binomial(logit)	1.00	-98.24	198.50	70.98	0.00

Table 5.5: Summary of model selection results to identify the influence of explanatory variables on crossing of elephants

The model suggests that well-maintained and fully functional solar fences have been successful in deterring the elephants from crossing Anjani chaur, with a marginal effect of crop index serving as attractants for the elephants.

Discussion

As part of the first annual report following analysis were conducted and reported:

a) Average distance covered by collared elephants from Ganges, into the human use areas on the western bank of the river was 1.12 (±0.75) km.

b) Fine-scale diel (24 hour) movement dynamics of collared bulls also suggested their crepuscular behavior, with the bull elephants resting in their refugia during major part of the daylight hours and showing high activity during twilight (dawn/dusk) hours (primarily while going for and returning from crop raids).

c) The earlier reports also highlighted an overlap between space-use pattern of the identified elephants and the proposed Kumbh 2021 camping sites.

These findings suggested high spatio-temporal overlap of elephant space use pattern with the proposed Kumbh 2021 camping sites. It was therefore important to understand the response of elephants towards the HEC mitigation measures taken by the forest department to prevent any untoward incident during the period of the event - Kumbh 2021.

Leveraging the information gained from such fine-scale analysis of elephant behavior was pivotal in developing mitigation or management strategies to avoid any untoward incident, especially in the context of Kumbh 2021. In this report, the movement patterns of collared and non-collared elephants were analyzed in the context of mitigation measures deployed by the forest department prior to and till after the Kumbh 2021.

As documented in the earlier reports (Nigam et al, 2021), it was interesting to note that the elephants ranging the proposed Kumbh 2021 camping sites were exclusively bull elephants. No female or mixed sex group crossed the Ganges to raid crops on the western side. The female groups, almost always comprising of young members like calves/infants preferred the safety of the forest patches along the eastern side of the Ganges, while the bulls associated to form all-male groups to leverage the benefits clumped and nutritious resources (crops), in the process gaining exposure and experiences from "cultural/social learning". The areas of the western ranges of the Haridwar Forest Division along western bank of the Ganges does not offer any cover for the elephants in the daytime. The only patch for their daytime refuge is the scrub vegetation on the islets, between the banks of the Ganges. The sole purpose for the bull elephants to cross the Ganges and enter the crop fields along western ranges of the Haridwar Forest Division is to raid crops, between 1800 to 0500 hours. The strategies deployed by the forest department resulted in gradual decrease in the crop raiding incidents along the western bank of the Ganges as the elephants restricted their efforts to raid crops only along the eastern bank of the Ganges.

Due to the regular raiding bouts in the pre-guarding season, the identified bull elephants restricted their movement to only their day-time refuges on the islet, Anjani chaur and Dassowala, resulting in their movement being restricted within an area of 159.23 sq. km. This was followed by guarding season that experienced a rise in the efforts put by the forest department to constrain the elephants from crossing the Ganges to raid crops. This led to dispersal of elephants resulting in an increase in the area under MCP. In the process of dispersal, the collared bull – UKM2 (Brahma) showed directional movement towards east and crossed Kotawali to enter Uttar Pradesh and raid sugarcane fields at the border of Uttarakhand and Uttar Pradesh.

This pattern also coincided with the wheat and sugarcane harvesting season. Since most of the crop fields in the study area were gradually devoid of the primary attractants for the elephants, the proportion of raid night per month also declined in the months of May, June and July. The sustained effort of the forest department had helped in avoiding any untoward incident during the mega even of Kumbh 2021. Elephants, due to their resource requirements to meet critical life-history strategies, are sensitive to changes in their environment.

Elephants are intelligent social animals with abilities to well-developed cognitive faculties to circumvent physical mitigation measures over time, in most cases. The learnings are also known to get transmitted between individuals. The timely maintenance of the solar fences, especially during the Kumbh period, even after regular breaches at serveral points, played a pivotal role in containing the movement of elephants from Anjani chaur side. The analysis of movement also pattern suggested the effectiveness of well-maintained and functional solar fences as an effective mitigation strategy to contain the daily crossing of elephants from the eastern side of the Ganges to the crop fields on the western side of the Ganges. It is also worth noting that the crop raiding incidents gradually increased over the month of August and September 2021 With availability and gradual ripening of the paddy in the crop fields, it would be interesting to observe how the elephants in the landscape respond to the changes in their environment. The rising incidents of crop raid may provide unique challenges and opportunities to the forest department.

CHAPTER 6: WORKSHOPS, TRAININGS FOR CAPACITY BUILDING OF THE FRONTLINE STAFF AND OTHER ACTIVTIES OF THE PROJECT

One-day workshop and RRT training on elephant behaviour, ecology and conflict management, including field craft on elephant monitoring, tracking, and rescue operation: A one-day workshop and Rapid Response Team (RRT) training was organized on the 11th December 2020 as part of the Uttarakhand Forest Department–Wildlife Institute of India (UKFD–WII) collaborative project titled "*Mitigation of human-elephant conflict in and around Rajaji Tiger Reserve with emphasis on mitigation strategies during Kumbh 2021*". The workshop was aimed at capacity building of the frontline staff of Haridwar and Lansdowne Forest Divisions in Uttarakhand, on dealing with Human - Elephant interface on a day-to-day basis. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through its India project on "*Knowledge Support to Development of Guidelines, Specialized Field Studies and Training on Human Wildlife Conflict mitigation in India*" having similar mandate further supported the training program by joining as partners in organizing the workshop. The workshop was attended by 39 officials including forest officials, veterinary officers and frontline staffs of Haridwar, Shyampur, Rasiyabad, Chidiyapur, Kotdwar, Laksar, and Laldang ranges.

The afternoon session included a demonstration of the radio collar units, its deployment, and tracking by the team of WII scientists and researchers to the frontline staff. The importance of satellite collaring, considerations to be made during the field exercise including animal age and health condition, and terrain issues were explained by the WII team. Besides detailing intricacies of the collars and live tracking methods, the team also clarified various misconceptions regarding collaring exercise.

Open feedback was held with the participants, and they reiterated that such workshops are indeed useful in their routine task of conflict management on the ground, and added that the programme was also timely, considering the forthcoming Kumbh, where human-elephant interface widening and conundrums intensifying is anticipated.

Two half-day workshops on monitoring of elephants through radio-telemetry in the Haridwar Forest Division: Two half-day workshops were organized on the 9th and 12th of January 2021 as part of the Uttarakhand Forest Department–Wildlife Institute of India (UKFD–WII) collaborative project titled "Mitigation of human-elephant conflict in and around Rajaji Tiger Reserve with emphasis on mitigation strategies during Kumbh 2021 in Rajaji Tiger Reserve and adjoining landscapes". The sessions were organized on a telephonic request from Shri. Neeraj Kumar Sharma, IFS, the Divisional Forest Officer, Haridwar Forest Division. The workshops were aimed at capacity building of the frontline staff of Shyampur and Haridwar ranges respectively of Haridwar Forest Division in Uttarakhand, on monitoring of elephants through radio telemetry that extensively use these two ranges on a day-to-day basis. Shri Vinay Rathi and Shri Dinesh Nautiyal, Range Forest Officers of Shyampur and Haridwar ranges coordinated the frontline staff and assembled them at the Anjani Chaur where the exercises were conducted on the afternoons of 9^{th} and 12^{th} January 2021 respectively. WII field team, handled the sessions and trained the officials on assembling the VHF Yagi antenna unit, setting the frequencies on the receiver as per individual collars, and picking signals and explainiung the directionality feature of Yagi antennas.

Physical tracking of one of the collared bulls, UKM04, was possible on both days, the 9^{th} and 12^{th} January 2021, further enabling in aiding the frontline staff in gaining hands-on experience in using the tracking device, and understanding the directionality feature in particular.

The animal was tracked on foot inside the chaur using the tracking device, and following animal tracks, until direct sighting was possible. Multiple trials were done by the staff to ensure that, queries, if any, were all addressed by the field team. Shri Ram Sharan Singh, an experienced field assistant of the WII tracking team also shared his views on difficulties encountered in radio-tracking elephants in dense jungles, and ways to address the same, based on his three-decade long experience working on radio telemetry projects on Asian elephants in the Rajaji-Corbett landscape.

The workshop was attended by four and eight frontline staffs each on 9^{th} and 12^{th} January 2021 respectively, representing Shyampur and Haridwar ranges, including the Range Forest Officers, Foresters and Beat Forest Officers. Following the workshops, the field staff have been using the unit available with the Haridwar Forest Division, for regular tracking of the elephants, especially in the late evening hours when the animals enter crop fields.

Rapid Assessment of Electrocution Threats in Select Areas of Haridwar Forest Division with Special Reference to Elephant Movement in the Landscape

Asian elephants are endangered species that are threatened across range countries by various anthropogenic factors. Amidst growing concerns about their long-term conservation potentials, major conservation efforts are required to ensure the same. Major threat to elephant populations across landscape includes habitat degradation, habitat loss, poaching, trafficking of live animals and retribution killing (an outcome of HEC). HEC and infrastructure-related mortalities are overriding, especially in human–elephant interface areas that are increasing largely owing to extensive forest clearances, habitat degradation and fragmentation. In the context of HEC, electrocution in particular has become a serious threat to elephant conservation. Added to this, electrocution has surfaced as one of the major threat to elephants. Every year, on 50 elephants succumb to this. Between 2009 and 2017-18, 461 elephant have been electrocuted, as per the records of Ministry of Environment, Forests and Climate Change. A closer look at the data reveals that States in the eastern and northeastern region of the country have accounted for most of these deaths — in Odisha, 90 elephants died of electrocution; 70 elephants died of electrocution in Assam; 48 elephants in West Bengal; and 23 elephants in Chhattisgarh.

As part of the project objective, an adult bull was collared on 15th October in Dassowalla, Rasiabad, Haridwar Forest Division to understand the fine-scale spatio-temporal ranging behaviour of elephants. On 23rd Nov' 20, the bull was found to be electrocuted on the islet close to Bishanpur kundi village of Haridwar range. Post this incident, the field team comprising of researchers and field assistants started to actively scan for critical points that posed a similar risk to elephants in the landscape. To understand the vulnerability of elephants, an attempt was made to understand the distribution of "critical points". Identification of critical points were done based on the risk they posed to elephants from being electrocuted. These critical points were transformers and power lines hanging at a height within the reach of an elephant (≤ 20 feet), in the ranging area of elephants.

A survey of critical points in Shyampur, Chriyapur, Rasiabad, Haridwar and Laksar range of Haridwar forest division was carried out. These ranges were scanned for 8 hours every day for 20 consecutive days, from 25/01/21 to 14/01/21 to document and record the GPS coordinate of these critical points. To gain a coarse understanding of the electrocution potential of the elephants ranging in the study area, ranging area of 4 collared bulls (based on Kernel Density Estimation), along with the GPS coordinates of other elephants ranging in the area was overlaid with the GPS coordinates of the critical points.

Table 6.1: Critical points in different ranges of Haridwar Forest Divisions

S. No.	Range	Critical points
1	Haridwar	183
2	Laksar	8
3	Shyampur	79
4	Rasiabad	10
5	Chidiyapur	93

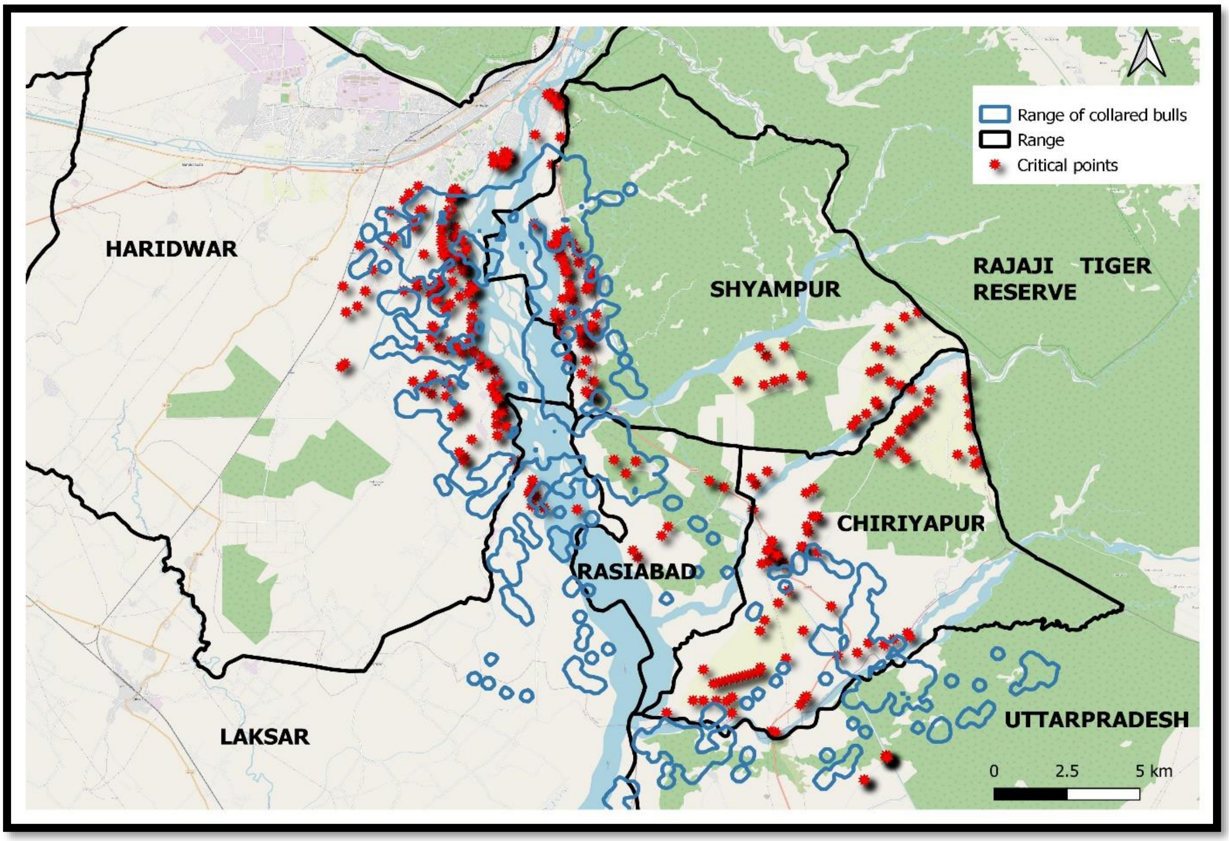


Figure 6.1 Map highlighting the distribution of critical points (low hanging power lines or transformers) in the elephant ranging area

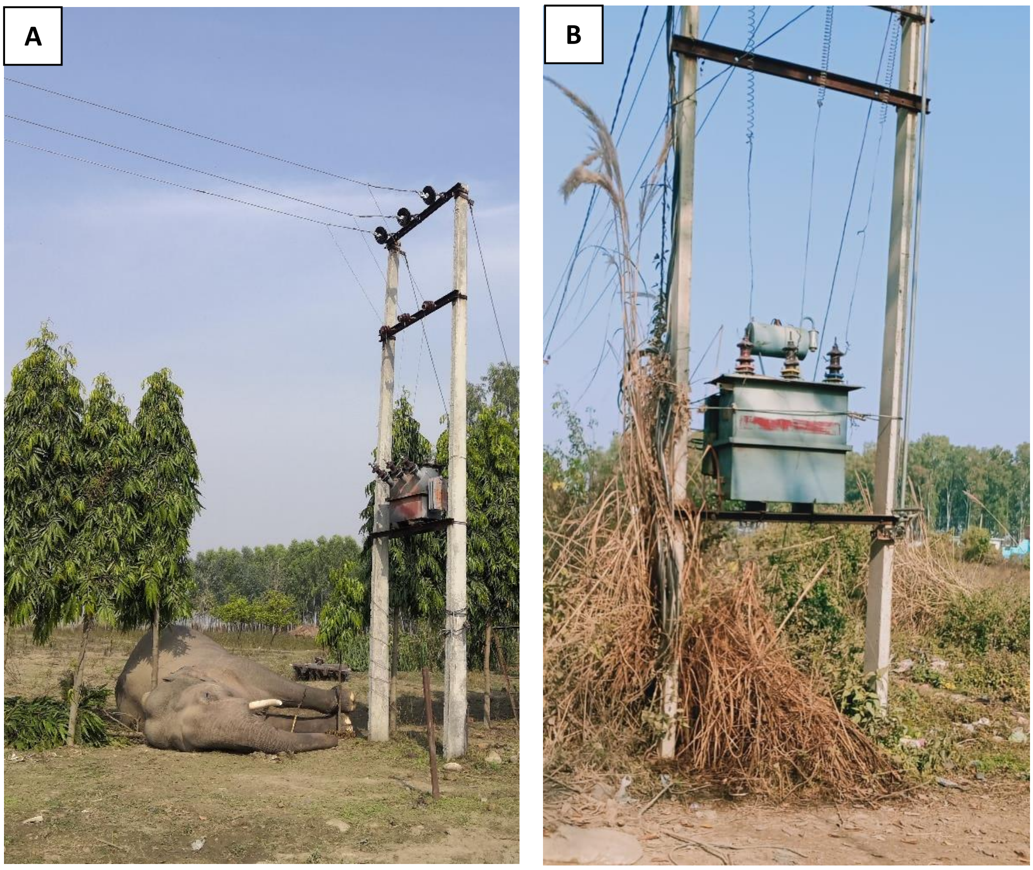


Figure 6.2 A) Electrocuted bull (UKM7) B) Low – hanging powerlines and transformer, close to crop fields.

Evaluation of Animal Crossings through Newly Commissioned Wildlife Underpasses at the Chilla-Motichur and Kansrao-Barkot Corridors in the Rajaji Landscape, Uttarakhand

As a part of Uttarakhand Forest Department (UKFD)-Wildlife Institute of India (WII) collaborative project on 'Mitigation of human-elephant conflict in and around Rajaji Tiger Reserve with emphasis on mitigation strategies during Kumbh, 2021', use by wildlife of the newly commissioned wildlife underpasses namely Motichur and Teen Pani on National Highway (NH) 72 in two of the identified wildlife corridors was assessed. Wildlife use of underpasses was quantified using photographic capture using remotely triggered camera traps that were set up for 94 days.

The study revealed considerable use of underpass by variety of animals thereby establishing the efficacy of these underpasses. The field survey efforts yielded 1,468 images of eight mammalian wildlife species besides 113 images of feral dogs, 2,429 images of livestock, and 32,194 images of people. The eight mammalian wildlife species included leopard (*Panthera pardus*), elephant (*Elephas maximus*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), chital (*Axis axis*), common langur (*Semnopithecus entellus*), porcupine (*Hystrix indica*) and wild pig (*Sus scrofa*). Results showed variability in wildlife use of underpasses between the sections. The sections with presence of trails showed maximum use of the underpasses by wildlife.

Though considerable movement of animals have been recorded in Teen Pani underpass; multiple factors viz. road and railway lines in the Motichur underpass in addition to the highway remain a concern limiting its full use. The assessment further suggests that continued anthropogenic use with associated threats could be a factor limiting a greater use by wildlife of the corridors. The assessment indicates that minimizing the anthropogenic use is of paramount importance for the effective use of the underpasses by wildlife.

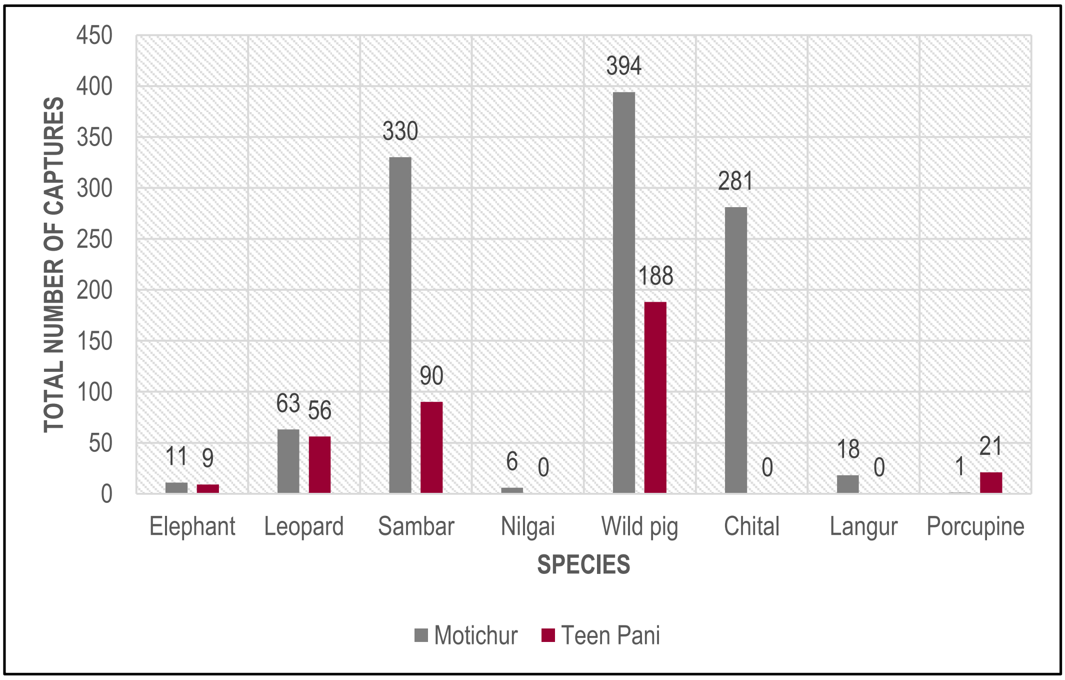


Figure 6.3 Overall capture of wildlife species at both the underpass structures during the study period

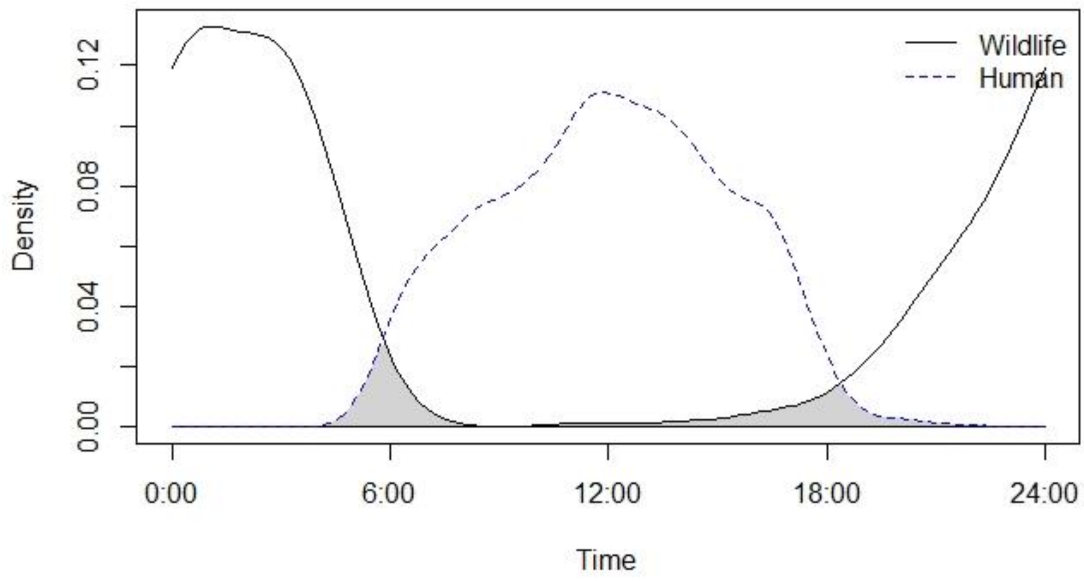


Figure 6.4 Temporal segregation of wildlife and human activity at Motichur underpass

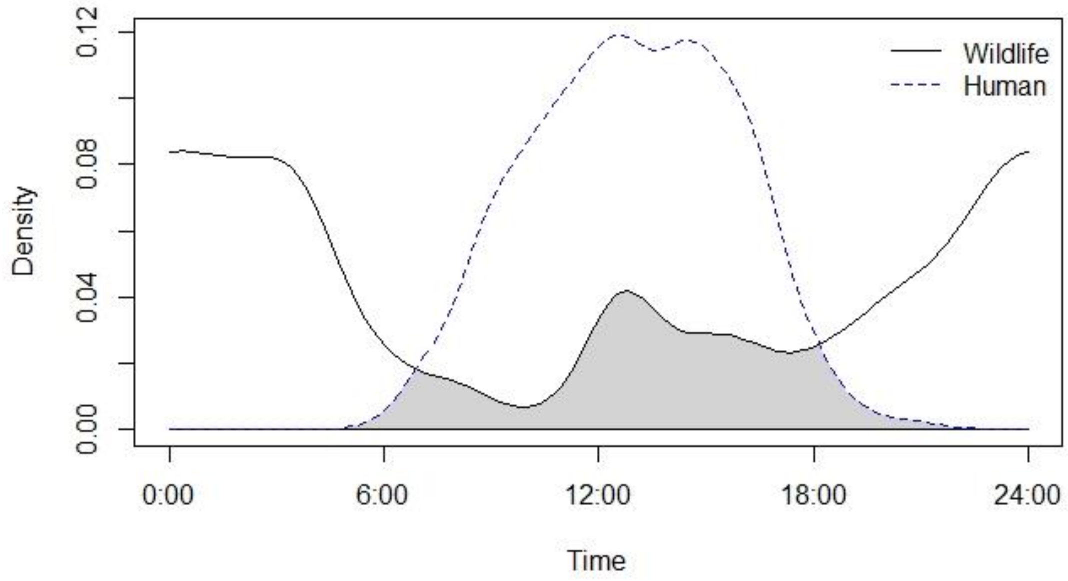


Figure 6.5 Temporal segregation of wildlife and human activity at Teen Pani underpass

Summary

- A total of 1,468 images of eight wildlife species, 113 images of feral dog, 2,429 images of domestic cattle, and 32,194 images of human were captured from a combined effort of 5,778 camera days.
- Total eight wildlife species (leopard, elephant, sambar, nilgai, wild pig, chital, common langur, and porcupine) were captured at both the underpass structures.
- Wild pig had the highest captures, followed by sambar and leopard.
- Not all the areas under the underpass structures were used uniformly by wildlife.
- Underpass with more trails were used more effectively.
- Wild animals avoided using the Motichur range office complex area.
- The photo captures of wildlife were higher at the underpass structures where there were no road and weed.

- The overall capture of elephant was higher at Motichur underpass however; the capture rate was higher at Teen Pani underpass.
- Both, solitary males and female herds with calf have been captured while using the Motichur underpass, however only solitary males used Teen Pani underpass.
- Results of this study highlighted considerable anthropogenic activities at the underpass structures.
- Temporal avoidance to human activity was found by wildlife in both the underpass structures.

OTHER ACTIVITIES

Collection of riverbed-materials (RBMs) in an unregulated manner affects the wildlife using the area. A survey was conducted by the WII team to understand the space-use of animals on the riverbed of Rawasan and its banks. The survey was carried out as per the directions of National Board of Wildlife to ameliorate the negative effects of riverbed-materials (RBMs) collection on wildlife. Fresh signs of elephants, golden jackal, leopard, chital, sambar and nilgai were documented and reported for further action.

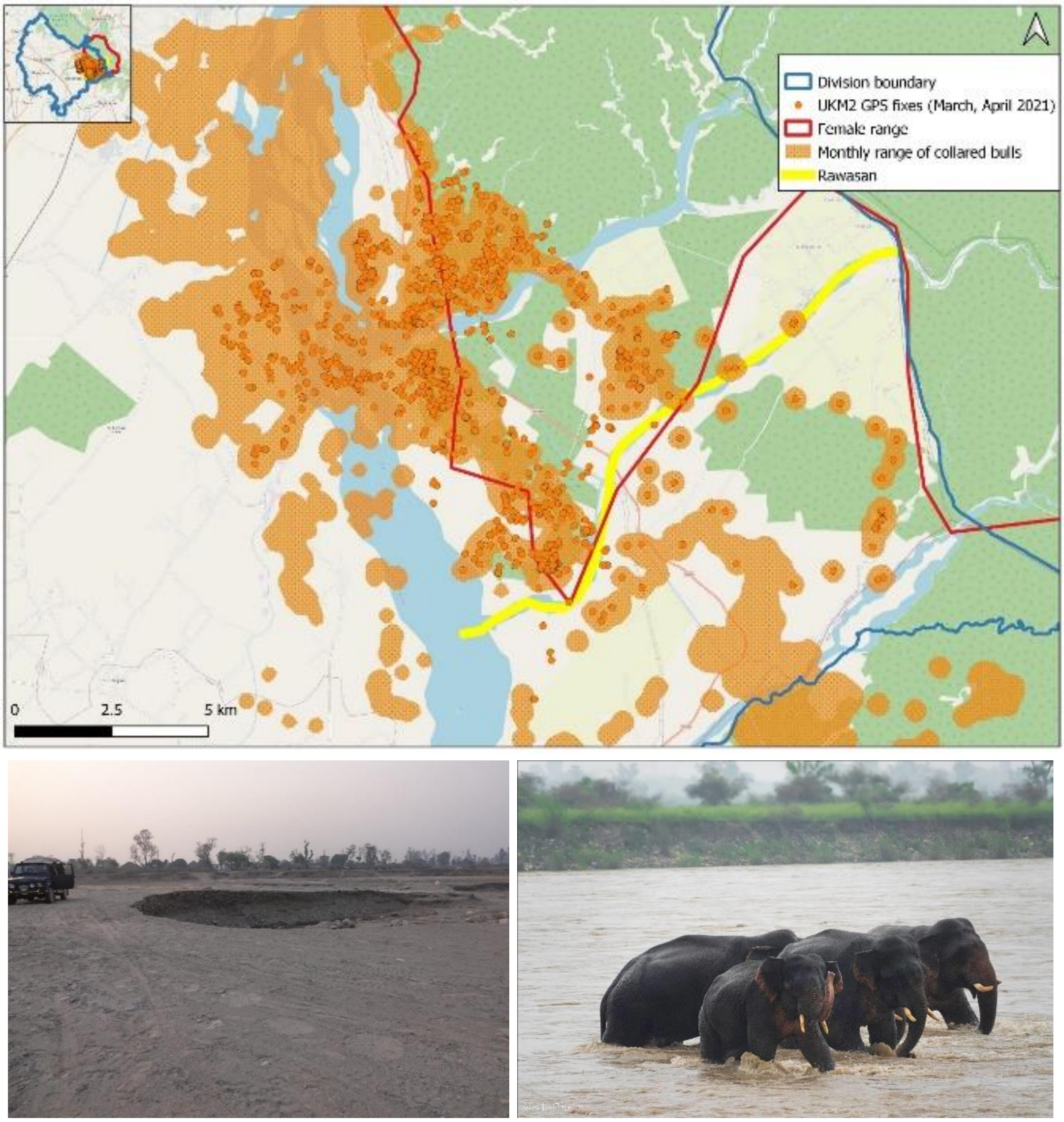


Figure 6.6: Space-use pattern of collared bulls with respect to Rawasan river

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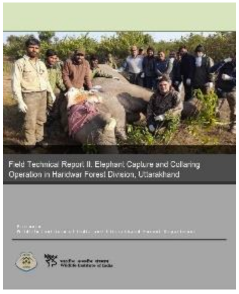
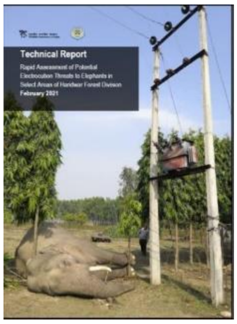
Outcomes from the project:

S.No.	Publications	
1	Nigam, P., Pandav, B, Mondol, S., Lakshminarayanan, N., Das, J.(2020). Field Technical Report 1: Elephant Capture and Collaring Operation in Haridwar Forest Division, Uttarakhand, WII-UKFD Collaborative project. Pp.15	
2	Nigam, P., Pandav, B, Mondol, S., Lakshminarayanan, N., Das, J., Vijaykrishnan, S. (2021). Field Technical Report 2: Elephant Capture and Collaring Operation in Haridwar Forest Division, Uttarakhand, WII-UKFD Collaborative project. Pp.16	
3	Nigam, P., Pandav, B, Mondol, S., Lakshminarayanan, N., Das, J., Vijaykrishnan, S. (2021). Identification manual of select bull elephants of Haridwar Forest Division. Technical manual. WII-UKFD collaborative project	
4	Nigam, P., Pandav, B, Mondol, S., Lakshminarayanan, N., Das, J., Vijaykrishnan, S. (2021). Technical Report: Rapid Assessment of Electrocution Threats in select Areas of Haridwar Forest Division with Special Reference to Elephant Movement in the Landscape, WII-UKFD Collaborative project. WII TR No./2021/07. Pp 35.	

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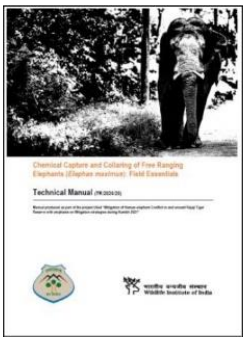

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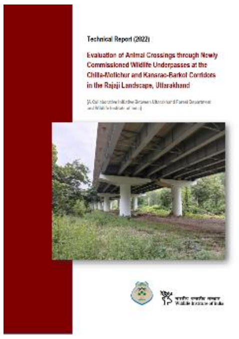

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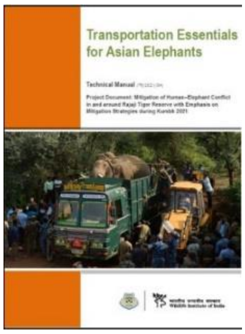

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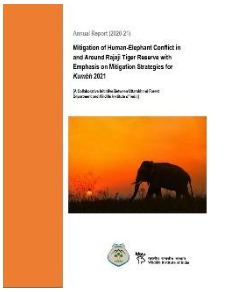


MANAGEMENT RECOMMENDATIONS

1. Among the 34 bulls identified during the study period, 21 bulls were observed crossing over to the west bank of the Ganges between Haridwar city up till the inter-state boundary. The west bank however has minimal elephant habitats and the small and isolated patches of forests in the area do not qualify as viable habitat for elephants. The east to west movement of elephants across Ganges is primarily a crop foraging strategy that needs to be effectively managed through wise-use of physical barriers along the west bank of River Ganges. The foraging and habitat-use strategy of the other bulls that have not been crossing the River Ganges has not been addressed in the present study and may be taken up in future.

2. The physical barriers built along the west bank of River Ganges have been breached by people. The issue needs to be deliberated between Forest Department, District administration and other stakeholders to ensure efficacy of barriers to minimize human-animal interactions. The critical entry-exit points of elephants along the bank of the river needs to be well guarded and monitored.

3. The study demonstrates that the remnant patches of grasslands along the Eastern Bank of the river from Bhimghoda barrage till the inter-state boundary near River Kotawali (extending 6.3 km^2) are extensively used by elephants and other wildlife. These grasslands are under threat from range of biotic pressures. Restoring grasslands can be a long-term conflict mitigation strategy. Additionally, the remnant natural grasslands along Dasowala, Kotawali, Amichand, Anjani and Jhilmil Jheel can be brought under the ambit of Rajaji Tiger Reserve management.

4. The MCP home range of the four satellite collared elephants during non-*musth* crop raiding stage averaged 143.5 km^2 (± 91.2). The annual MCP home range of UKM2 (Brahma) was 331 km^2. The home range estimates were comparable with the previous assessments carried out in the landscape. The KDE estimates were much lesser than MCP estimates indicating high fraction of un-used agricultural areas being included in MCP home ranges.

5. The mitigation structures planned along the National Highway (the stretch between Shyampur to Chidiyapur) need to be commissioned soon as the highway presently poses a major hindrance for elephant movement with a strong barrier effect. There is a possible threat of elephant-related road accidents, which is also a concern for human safety. Considering this, the mitigation measures to restore permeability along the National Highway needs to be expedited and completed in a time-bound manner.

6. One of the findings from the study is the elephant use of islets in River Ganges. The islets in Ganges provide habitats for elephants and other wildlife. Identifying these islets that are frequently used by wildlife and including them in the ambit of Rajaji tiger reserve management would be important.

7. While the average distance moved by the elephants in agricultural areas in the west bank of River Ganges in Haridwar was 1058m (±794.6), there are recorded distances that exceeded 4.5-km. These long-distance movements in human-use areas that probably result from unplanned drives should be monitored and managed effectively.

8. Of the 9 sites designated for Kumbh 2021, *Gauri Shankar* 2, *Devpura Athmal*, *Sapt Sarovar* (1 and 2), *Sati dweep – Naya tapu* complex were exclusively designated for camping while *Kangri, Haddipur, Sajanpur Peeli* and *Shyampur 2* were exclusively designated for parking. *Daksh dweep* was designated as both camping and parking site. During the study, a high intensity of habitat-use by elephants was recorded in *Shyampur 2, Kangri, Gauri Shankar 2, Devpura athmal, Haddipur* and *Dakshdweep*. In future events, from management point of view, these sites should be excluded as far as possible. The sites *Saptsarova 1 and 2, Sati Dweep* and *Naya Tapu* can be considered with effective mitigation measures that are aimed at keeping elephants away from these patches.

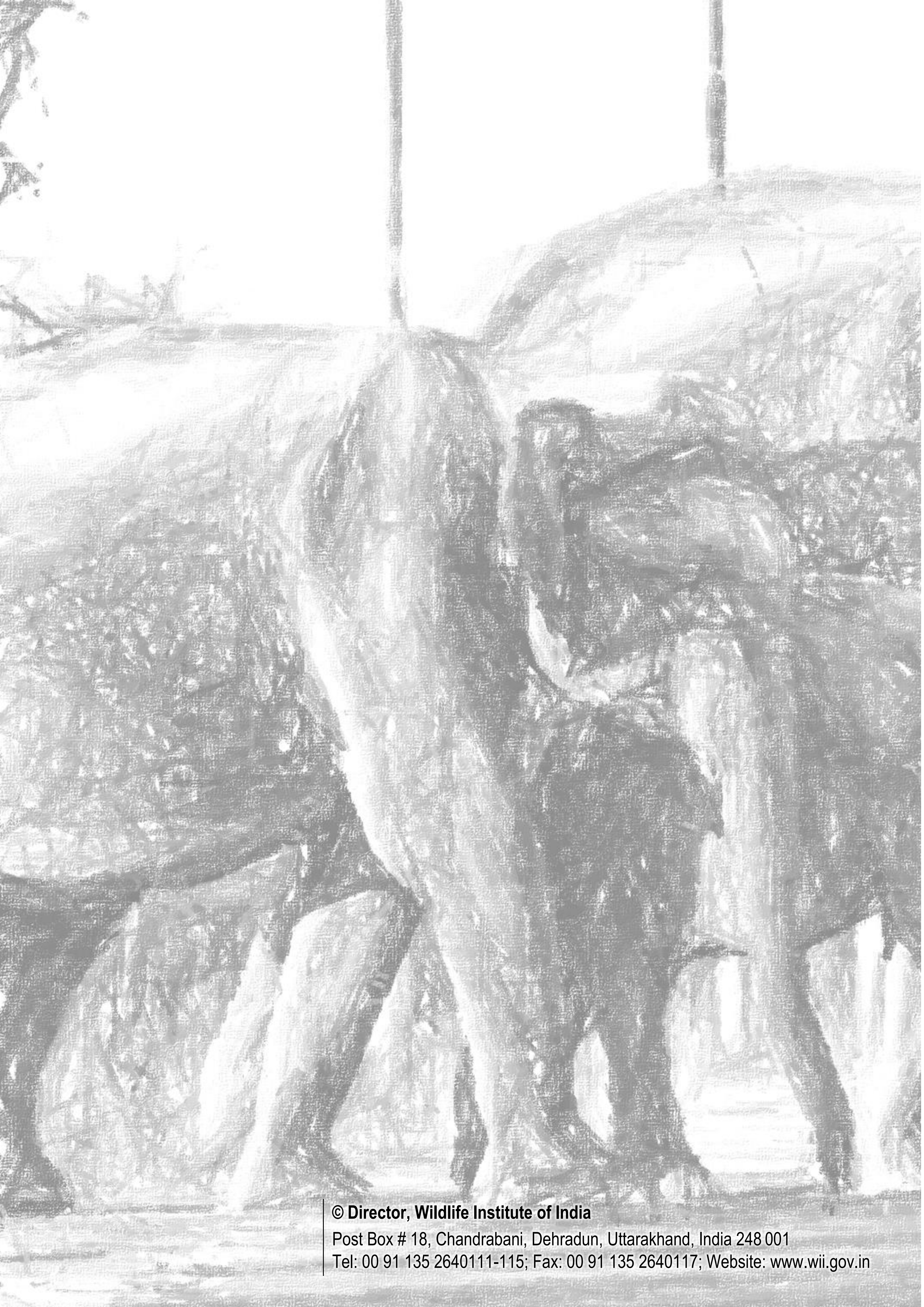
9. The crop raiding patterns by elephants reflect local cultivation cycles. Time-series assessment of elephant crop losses in Rajaji landscape (including forest divisions of Dehradun, Narendra Nagar, and Lansdowne) indicates that there were no major shifts in crop loss hotspots. Thus, prioritizing conflict mitigation strategies in current hotspots would help in reducing the intensity of conflict.

10. Outside of Rajaji National Park, there are isolated forest patches of Anjani chaur, Dassowalla, islets on the Ganges, Chiriyapur, Thano, Barkote and Lacchiwala ranges, that were frequently used by elephants. A few of these patches are used by bull elephants exclusively. Monitoring elephant movement and habitat-use in these isolated forest patches would be crucial. Further to this, intermittently monitoring other forest patches that are currently not used, but can potentially be used by elephants in future is important to detect conflict early and take appropriate measures.

11. The local communities interviewed as part of the study elicit opinions in favour of elephant conservation regardless of the human-elephant conflict. Thus, there is immense potential in engaging villagers in elephant conflict management and ensuring greater participation and ownership that would help in improving the efficacy of mitigation strategies.

12. Analysis of the movement of elephants pre and post-implementation of mitigation measures suggested that well-maintained and fully functional solar fences have been successful in deterring the elephants from crossing Anjani chaur, with a marginal effect of crop index serving as attractants for the elephants. Proper maintenance of the installed solar fences (even after repeated attempts by the elephants to breach them) may prove pivotal in restricting the movement of elephants into the human-use areas if the fences are installed in a planned manner.

13. During the dry season, with the availability of water in the canals, the activity of elephants (both female groups and bull elephants) increases along the East – Ganga canal area. To avoid any untoward incident, it would be prudent to close the canal road (between Anjani post to Rasiabad range office area) for public use and to closely monitor elephant movement, especially during this particular period of the year, primarily during the evening hours.



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