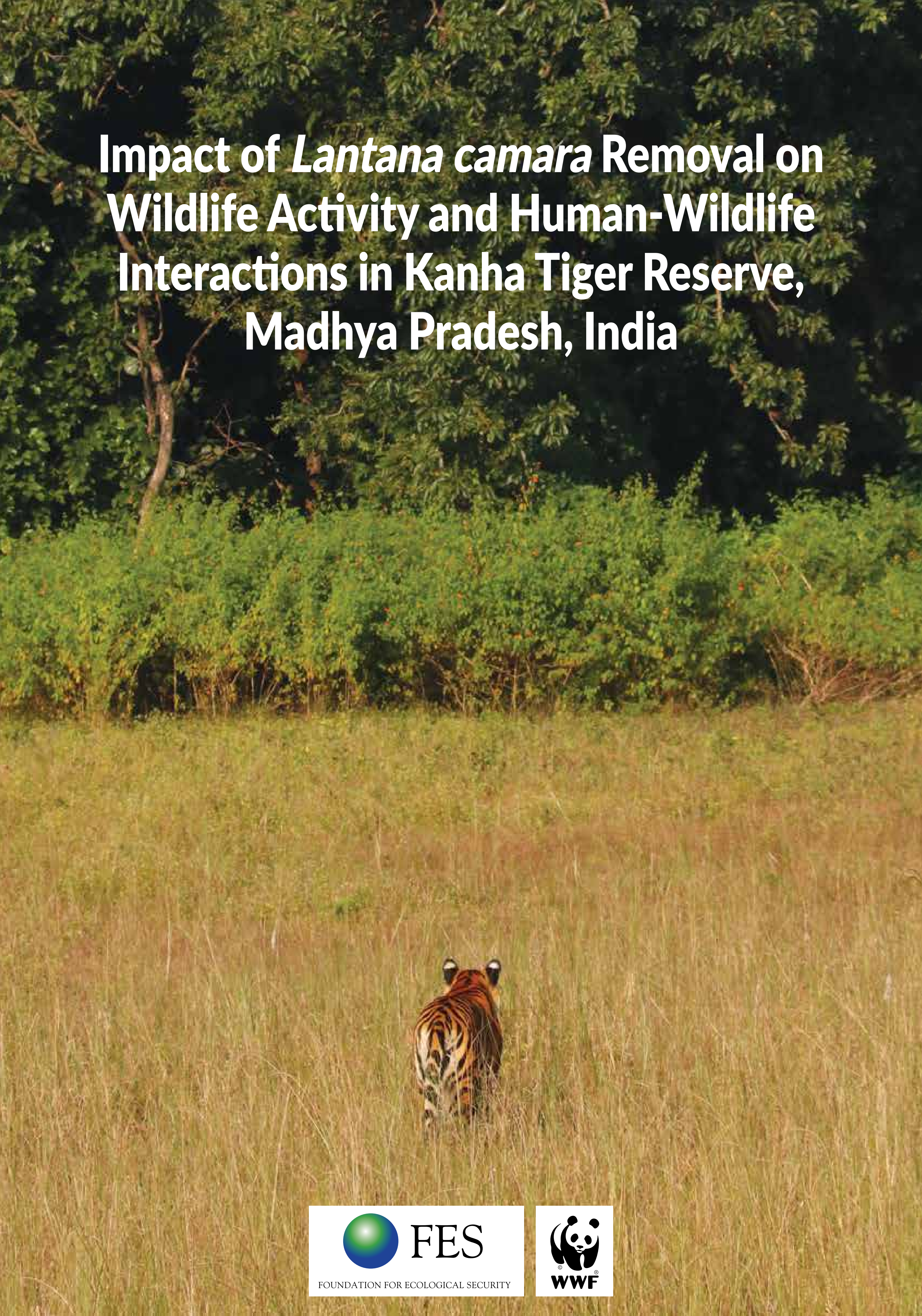
Impact of *Lantana camara* Removal on Wildlife Activity and Human-Wildlife Interactions in Kanha Tiger Reserve, Madhya Pradesh, India



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WWF

Impact of *Lantana camara* Removal on Wildlife Activity and Human-Wildlife Interactions in Kanha Tiger Reserve, Madhya Pradesh, India

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Registered under the Societies Registration Act XXI 1860, the Foundation for Ecological Security was set up in 2001 to reinforce the massive and critical task of ecological restoration in the country.

The crux of our efforts lies in locating forests and other natural resources within the prevailing economic, social, and ecological dynamics in rural landscapes and intertwining principles of conservation and local self-governance for the protection of natural surroundings and improvement in the living conditions of the poor. By working on systemic issues that can bring about a multiplier change, we strive for a future where local communities determine and move towards desirable land use that is based on principles of conservation and social justice.

Contents

Acknowledgements

Aniruddha Dhamorikar/WWF-India

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We thank the presidents of village committees and the members, Community Resource Persons, and volunteers for their continued support and engagement. Our gratitude extends to the local community members and conservation partners who provided valuable insights into lantana removal and for their collaborative efforts. We acknowledge the importance of community awareness in creating sustainable strategies that consider and respect the needs of sharing these spaces.

Impact of *Lantana camara* Removal on Wildlife Activity and Human-Wildlife Interactions in Kanha Tiger Reserve, Madhya Pradesh, India

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Executive summary

PIXCOM

Carrying dry wood for domestic use along lantana-infested forests

Lantana camara poses significant threats to biodiversity and ecosystem health in India, as it disrupts native plant growth, changes habitat structure, and alters soil properties. Several mitigation measures have been undertaken to eradicate lantana*,* including physical uprooting and burning. Since 2015, the Foundation for Ecological Security (FES) has been actively involved in removing Lantana from the buffer zone of the Kanha Tiger Reserve.

Farmers have reported decreased crop raiding by wildlife in areas where lantana has been removed in addition to other benefits, such as an increase in the area available for livestock grazing. To understand the effect of lantana removal on wildlife activity vis-a-vis the perceived benefits, FES and WWF-India collaborated on a study by deploying camera traps in treatment (where lantana was removed) and control (with lantana intact) sites, in 1 ×1 km grids.

The study revealed a shift in the activity patterns of mammals across seasons following lantana removal. Animals were seen to be more active at night in the treatment sites during summer, which may be attributed to the increased availability of open space. In contrast, in winter, foraging activity was observed during the daytime in treatment sites, likely due to the enhanced availability of edible plant biomass.

Manohar Pawar/FES

Asian rock honey bee (*Apis dorsata*) species feeding on lantana flower

Our findings corroborated with people's perceptions regarding lantana removal: among the reported benefits included availability of fodder and reduced visits to forests for grazing and a decrease in incidents of livestock depredation by wild carnivores. Although there was no statistically significant difference in livestock depredation events between the treatment and control sites, a minor shift was observed, with a 30% reduction in depredation in treatment sites between 2017 and 2022. Farmers also highlighted reduced crop damage by wild ungulates as a major benefit of lantana removal, with 76% identifying it as one of the top three perceived benefits. We found an overall reduction in wildlife activity in treatment sites close to farmlands due to loss of hiding sites, which may be linked to reduced crop raiding.

We demonstrate that lantana-removal initiatives in shared, multiple-use spaces have tangible benefits for both wildlife conservation and human wellbeing. Continued monitoring and adaptive management strategies are essential to further understand the long-term impacts of lantana removal to ensure the sustainability of conservation efforts such as invasive species eradication in shared spaces.

SECTION 1

INTRODUCTION AND OBJECTIVES

1.1. Introduction

Invasive plant species are considered a threat to biodiversity and ecosystems (Bhatt et al., 2011); they alter the growth of native plant species in their vicinity (Sharma et al., 2005; Barahukwa et al., 2023) and disrupt the regeneration of native species (Gooden et al., 2009; Sundaram et al., 2012). Invasive species also affect the chemical and biological properties of soil and alter the nutrient cycle (Funk and Vitousek, 2007; Sharma and Raghubanshi, 2009; Zhang et al., 2019). They negatively affect the composition and structure of the invaded habitat (Kennard et al., 2002; Gooden et al., 2009) as well as the ecological integrity (Mack et al., 2000; Pimentel et al., 2005) of natural ecosystems, reducing the variety, extent, and primary productivity of lands (Rishi, 2009). Invasive species alter major biological processes, such as the nitrogen cycle, plant-pollinator mutualism and the mycorrhizae mutualism of native plants, and the hydrology of the local environment (Ashton et al., 2005; Strayer et al., 2006). They promote changes in the community structure of native vegetation (Strayer et al., 2006) by altering the abundance and diversity of native species and inhibiting the spread of native species through their allelopathic effects, which leads to loss of diversity in the native vegetation composition (Clavero et al., 2009; Gooden et al., 2009; Hejda et al., 2009; Sanders et al., 2003; Hillebrand et al., 2008). Further, most invasive species are unpalatable and have high concentrations of toxins that can adversely impact or even kill wild and domestic herbivores that consume them (Day et al., 2003, Rastogi et al., 2023).

The past two centuries have witnessed a proliferation and spread of alien species within and between continents, often mirroring the movement of people and animals as well as human ingression into natural habitats (Wilson et al., 2013; Hiremath and Sundaram, 2013). Sometimes invasives have been deliberately introduced to novel areas for various reasons: as garden ornamentals, commercial cultivation, provision fuelwood and fodder, expansion of green cover in arid areas, and even to provide camouflage cover during World War II (Hiremath and Sundaram, 2013). Invasive species may also be spread inadvertently by the movement of animals and people, or dispersed by wind and water, or exploit suitable conditions created by disturbance and by climate change and global warming, often at the expense of native species (Day et al., 2003; Vardien et al., 2012). Such alien species show significant genetic and morphological modifications to adapt themselves to the introduced environment (Negi et al., 2019), enabling them to outcompete native species and often cause significant negative impacts on the ecosystems and the services they provide to the communities (Sundaram et al., 2012).

India's forest ecosystem is under the pressure of many anthropogenic influences, which facilitate the growth of many non-native invasive species (Diwakar, 2003; Mungi et al., 2018) such as lantana (*Lantana camara*), thoroughwort (*Chromolaena sp.*), tropical whiteweed (*Ageratnm conyzoides*), Santa Maria feverfew (*Parthenium hysterophorus*), and pignut (*Mesosphaerum suaveolens*). Among all, lantana is the most successful invader in India and is often seen as the most challenging weed and a threat to native biodiversity (Mungi et al., 2020: Bhatt et al., 2011, Isbell et.al. 2009).

Lantana camara, L. (Verbenaceae), is native to Central and South America. It was introduced outside its native geographic range as a garden ornamental or a hedge plant, now spread around 60 countries (Walton, 2006; Babu et al., 2009). It is a low, erect or sub-scandent woody perennial shrub with stout recurved prickles and a strong odour of black currants (Negi et al., 2019). It is a fast-growing species,


Manohar Pawar/FES

Lantana camara flower throughout the year, hence are locally called baramasi

drought and salt-resistant, seldom bothered by pests or diseases and adapted to most soil types. Lantana has a history of multiple introductions in India. It was introduced in 1809 as an ornamental and hedge plant in Calcutta (Negi et al., 2019) and is now the widest spatially distributed species across the country, covering various habitat types (Khuroo et al., 2012). It extends from the tropical forest type of peninsular India to the sub-tropical and lower temperate forest type of the Himalayas in the north up to 2000 m (Hiremath and Sundaram, 2013; Izhar et al., 2023). It is widely distributed across landscapes in India and has invaded more than 40% of forest areas (Mungi et al., 2020). The worst-affected areas are the Shivalik Hills in the North, the Southern Western Ghats and the fragmented deciduous forests of central India (*ibid*). It has also invaded the tropical and subtropical zones of the Himalayan ecosystem, including parts of the northeastern states (Hakimuddin, 1929; Negi et al., 2019).

The disturbance caused by fires, landslides and floods stressed the growth of native plants and allowed lantana to spread (Hiremath and Sundaram, 2013; Raghubanshi and Tripathi, 2009; Mungi et al., 2018). Their unpalatable nature (Hiremath and Sundaram 2013), efficiency in up-taking and using natural nutrients compare to native plants (Bhatt et al., 1994), and ability to bear an abundance of fruits year-round, which attracts a large number of frugivorous birds – in addition to wild pigs (*Sus scrofa*) and sloth bears (*Melursus ursinus*) – helping in seed dispersal (Lockwood, et al., 2005; Sundaram, et al., 2015), has made it a successful exotic invasive species.


Manohar Pawar/FES

Lantana removal by pulling it by the roots is recommended during monsoon when the soil is soft

Lantana-invaded areas witness a sharp increase in the density of its spread, and its dense thickets deplete the regeneration of native tree species (Sharma et al., 2005; Upadhyay et al., 2019). This invasion across all forest types is at the expense of native vegetation and the overall ecosystem (Sundaram et al., 2012; Qureshi et al., 2023). Further, denser pockets of lantana may help spread fire along the edges and pose a direct threat to forests and agricultural, pastoral, and grazing lands (Upadhyay et al., 2019). Its presence around human settlements provides shelter to wildlife, which is believed to exacerbate negative human-wildlife interactions. Lantana and other invasive species may also have societal impacts on forest-dependent communities by suppressing plant species that are otherwise consumed or sold (Sundaram et al., 2012), causing immense economic loss. Thus, its spread affects livelihoods, human health, and the ecological integrity of the invaded area (Pimentel et al., 2001; Mungi et al., 2020).

Several mitigation measures have been taken so far by the forest department to eradicate lantana, especially from the Protected Areas (PAs) and become an integral part of forest management (Sundaram et al., 2015). Physical uprooting and burning are among the few strategies that have been identified as effective measures by various studies to control lantana invasion (Day et al., 2003; van Wilgen et al., 2001; Bahuguna and Upadhyay, 2002). Controlled burning can be effective in its management, but is not favoured because it may also damage the native seeds present in the soil seed bank and may have a deleterious impact on native vegetation (Sundaram et al., 2015). Furthermore, although the physical removal has shown positive results, it has been observed that repeated removals are required in subsequent years and native species planted in its place (*ibid*).

State forest departments undertake lantana removal through eco-development committees in Protected Areas (PAs). It provides employment and increases the space available for the growth of native flora as well as for the movement of wildlife. However, the role of lantana in the ecology of wild animals is unclear, although anecdotal reports suggest that it is used as a roost, nursery, or temporary retreat for wild ungulates and carnivores.

The FES has been engaged in lantana removal in the buffer zone of Kanha Tiger Reserve (KTR), Madhya Pradesh, since 2015, preventing the spread of invasive floral species and freeing up crucial areas for wildlife movement and community use in the Kanha-Pench Corridor. Over the last three years (August 2017 to September 2019), 18.4 km^2 of the area including private and common lands was cleared of lantana. Anecdotal information on the impacts of lantana removal is contradictory, with locals reporting both reduced crop-raiding as well as increased crop raiding. Benefits cited include an increased availability of land for grazing, although a clear understanding of the impacts needs to be assessed.

FES and WWF-India jointly studied the impacts and recorded people's perceptions towards lantana removal to ascertain whether (1) *Lantana removal has reduced occurrence of wild ungulates close to villages and farmlands, reducing crop raiding instances*, (2) *Lantana removal has reduced occurrence of wild carnivores close to villages and farmlands, reducing livestock depredation incidents*, (3) *Lantana removal has increased area for grazing for livestock close to villages by opening up the area for the growth of palatable grasses.*

1.2. Objectives

1. To understand the impact of lantana removal on wildlife movement with respect to farmlands.
2. To understand the impact of lantana removal on the frequency of crop raiding and livestock depredation.
3. To understand people's perception towards lantana removal in areas adjacent to farmlands.

Note: The last objective was the focus of the research by Lalai et al. 2023.

Rahul Talegaonkar/FES

Livestock grazing in lantana invaded area

SECTION 2

STUDY AREA

Aniruddha Dhamorikar/WWF-India

2.1. Kanha Tiger Reserve (KTR)

Tiger captured in camera traps of study area

KTR is one of the first nine tiger reserves to be notified under Project Tiger in 1973. The reserve is nestled on the northern slope of the Maikal Hills of the Satpura mountain range in central India. KTR comprises two conservation units: the Kanha National Park with an area of 940 km^2 and the Buffer Zone of 1134 km^2. Besides this, Phen Wildlife Sanctuary (110 km^2) acts as a Satellite Micro Core under the unified control of the Field Director of KTR. The reserve administratively falls in the Mandla and Balaghat districts of Madhya Pradesh. The terrain is mainly characterised by a series of plateaus on the main ridge and major spurs. The slopes are steep in the upper reaches. The reserve has an excellent interspersion of the *dadar* (plateaus), grassy expenses, dense forests and riverine forests (Ghose, 1995). The entire area is a part of the Narmada Catchment and consists of two ecological units formed by the Halon Valley in the east and Banjar Valley in the west. Both rivers are the main drainage of the reserve.

The habitat consists of southern tropical moist deciduous forests with Sal (*Shorea robusta*) on the lower slopes and in the valleys and mixed forest on the upper and top of the hills with 3c/C2- Moist peninsula Sal with low-level Sal (3c/C2 cii) and subgroup high-level Sal (3c/C2 ci) and miscellaneous forests (3A/C2), with subgroups southern tropical moist deciduous forest, southern tropical dry mixed deciduous forest and grassland in the valleys and on plateaus (Champion and Seth, 1968). Invasive plant species such as *Ageratina adenophora*, *Ageratum conyzoides*, *Chromolaena odorata*, *Mesosphaerum suaveolens*, *Mikania micrantha*, *Parthenium hysterophorus*, *Prosopis juliflora*, and *Lantana camara* have been recorded from KTR (Qureshi et al., 2022).

KTR supports a population of 105 tigers with a density of 5.57±0.54 tigers per 100 sq. km². (Qureshi et al., 2022). It is home to more than 43 species of mammals, 300 species of birds and 26 species of reptiles. The floral diversity includes more than 850 species of angiosperms including 50 species of aquatic plants and about 109 species of grasses (NTCA n.d.).

2.2. Site selection for the study

The buffer zone and periphery area of KTR acts as a multiple-use area for local communities. The locals extract forest produce for domestic and agricultural use. A large number of cattle are also reared, which graze in the commons and designated grazing compartments. Overgrazing is linked with reducing the productivity of the land and accelerating the invasion of non-native plant species and weeds (Isbell et al., 2009). The present study was conducted in the buffer zone and peripheri area of KTR, where FES has been doing lantana removal since 2015 in the Sijhora and Khatiya ranges of KTR and the Baihar range of the North Balaghat forest division (Figure 1).

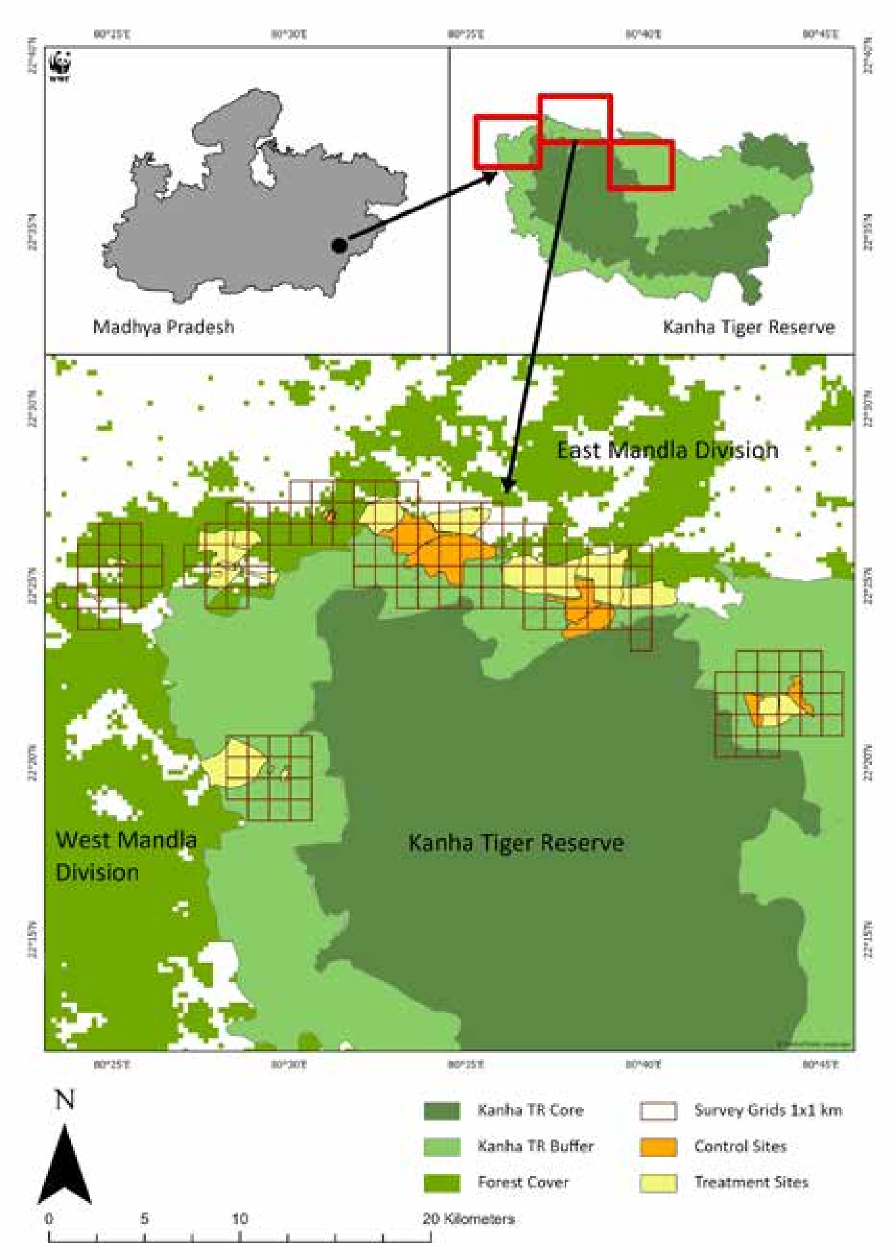

Figure 1. Map showing the location of the study area and the study grids in the treatment (lantana removed) and control (lantana existing) sites.


Sandeep Chouksey/WWF-India

Lantana eradicated area

Between 2015 and 2018, lantana was removed from a total of 18.4 km^2 of area from 110 villages. These villages are dependent on the surrounding forests to fulfil their resource requirements. Lantana removal was undertaken in the commons* (10.8 km^2) and private land (7.6 km^2) as well as along the periphery of the surrounding forest compartments. This region is important for wildlife movement (Jena et al., 2014) and experiences a high prevalence of crop raiding (Figure 1; Table 1). Twelve of these villages were selected for this study.

*Commons refers to resource or land categories that are considered village resources or revenue lands shared by the community.

Table 1. List of treatment sites where camera traps were deployed

Sr. No.	Location (village/beat)	Area (km^2)	Year of removal
1	Magdha beat	1.32	2017
2	Mohgaon beat	1.96	2017
3	Khapa beat	0.04	2018
4	Baihar-Dhanwar Theka	0.93	2019
5	Baihar-Kumadehi	0.21	2019
6	Malara	0.27	2018
7	Manikpur Mal	0.1	2018
8	Tatuawa-Bandhatola	0.20	2017
9	Taktauwa-Gourikasa	0.10	2017
10	Taktuawa-Kukarikhol	0.46	2017
11	Manikpur Ryt	0.2	2018
12	Soutiya	0.2	2017
	Total area (approximately)	6.0	

SECTION 3
METHODS

Manohar Pawar/FES

3.1. Survey design

In the KTR buffer zone and periphery area, sites where lantana was removed for three years (August 2017 to September 2019), were compared with the sites where lantana exists within the same region. The lantana removal sites were marked as a "treatment site" and the sites with the existing lantana were marked as "control sites" (Table 1 & 2). Each treatment site was mapped using GPS Etrex 20 by walking along the edge of all lantana patches. Virtual grids of 1x1 km were laid out using ArcGIS 10.0 in the study sites since the area of the lantana removal site was small (Figure 2).

Treatment sites were characterised by low tree cover and openness, with bare to low ground cover with herbs, shrubs and tree saplings. Control sites had moderate tree cover, where the lantana shrub was spread over the forest understory with small breaks and animal trails in between.

Manohar Pawar/FES

Lantana infestation in one of the control site

Manohar Pawar/FES

A treatment site after the lantana removal

Table 2. List of control sites (areas adjacent to treatment sites with existing lantana cover)

Sr. No.	Location (village/beat and compartment)	Area (km^2)
1	Sarhi 1538	2.33
2	Sarhi 1540	2.36
3	Magdha 351	6.25
4	Magdha 350	3.68
5	Sijhora 1436	1
6	Atariya 1439	1
7	Amjhar 155, 268, 266, 95	0.35
	Total area (approximately)	16.97*

*Control site area in terms of the number of grids equivalent to the study site area was surveyed.

3.2. Activity pattern of ungulates

Animal activity rhythms are known to match sun/moon-related cycles, referred to as circadian rhythms. Activity patterns synchronise with daylight and night-time hours (Kronfeld-Schor and Dayan, 2003). As a result, animals can be broadly categorised as either nocturnal (active at night) or diurnal (active during daylight hours). Some species are active at dawn and dusk, exhibiting bimodal activity peaks, a pattern known as crepuscular activity. Researchers (e.g., Weckel et al., 2006; Harmsen et al., 2011; Gerber et al., 2010; Ross et al., 2013) have arbitrarily defined the crepuscular time range, typically ranging from 1 to 1.5 hours before and after the local sunrise and sunset times, respectively. This categorisation allows for a deeper understanding of how various species adapt their behaviours to specific times of the day and night, shedding light on the ecological and physiological strategies they use.

Manohar Pawar/FES

The field team deploying a camera trap

Manohar Pawar/FES

Field team deploying camera traps in control and treatment sites

3.2.1. Camera trapping sessions

A total of 74 camera traps (Cuddeback Ambush and Cuddeback Attack) were placed in 41 grids. At least 2 camera traps were installed in a grid of 1 km^2 in the control and treatment sites after a transect survey to determine wild ungulate presence in the grids. In 7 grids only one camera trap was installed to avoid camera trap theft and other unprecedented events. Based on the animal signs, camera traps were placed along animal trails or areas they frequented. The camera traps were deployed in the grids for a duration ranging from 18 to 21 days, across summer, winter, and the monsoon, between 2021 and 2022. The season-wise camera trapping sessions corresponded with cropping patterns, viz. paddy in monsoon, wheat in winter, and fallow or being used for vegetable cultivation in the summer. The villagers and landowners were informed about the camera trapping exercise prior to the trapping sessions. Subsequent analyses and results are based on the seasonality of animal movements in the study area (Table 3).

Table 3. Camera trapping sessions

Season	Number of grids	Mean inter-trap spacing (km)	Camera-trap period for the first session	Trap nights	Camera trap period for the second session	Trap nights
Summer	41	1	10 April 2021 to 30 April 2021	861	20 May 2022 to 7 June 2022	779
Monsoon	41	1	12 September 2021 to 29 September 2021	738	22 August 2022 to 10 September 2022	820
Winter	41	1	11 February 2022 to 28 February 2022	738	13 December 2022 to 30 December 2022	738

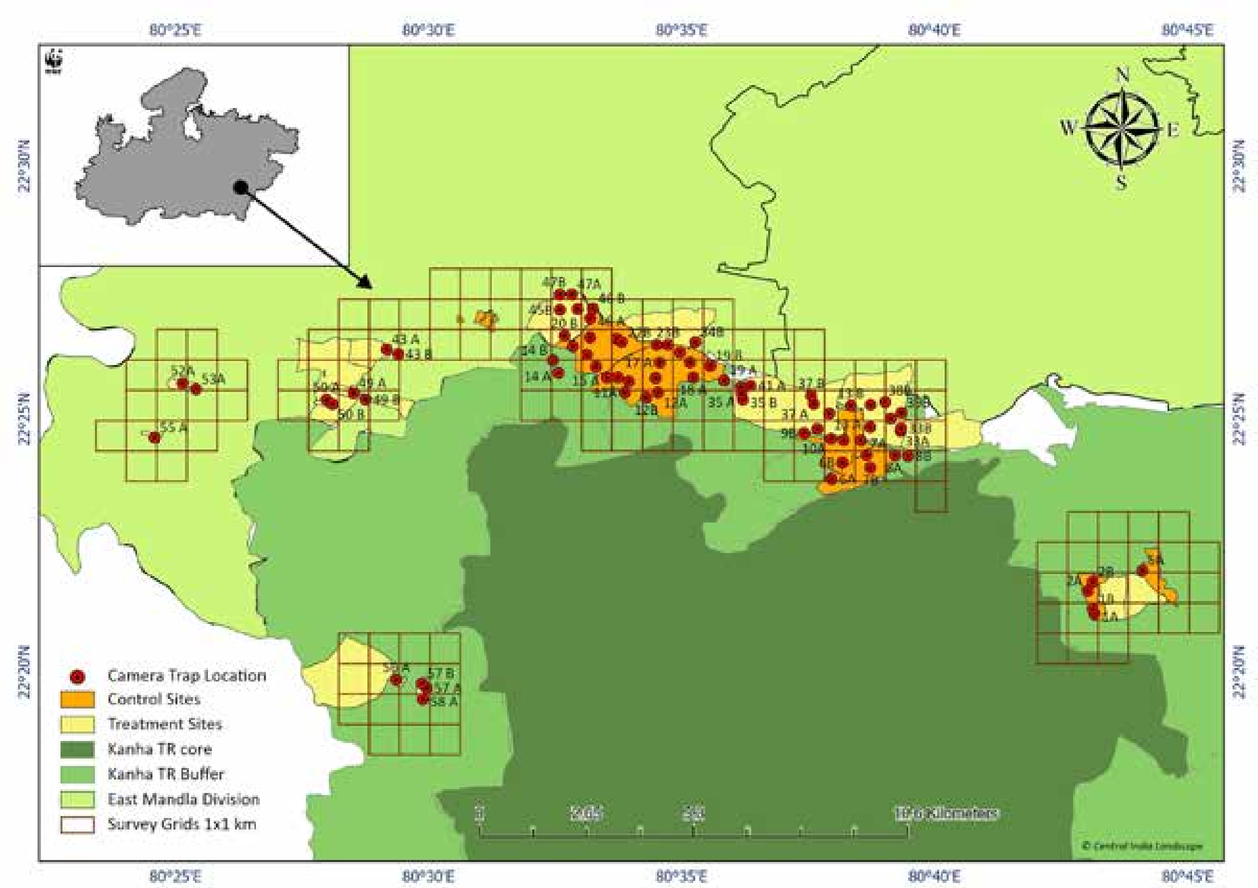

Fig 2. Map showing camera-trap locations in study grids of 1x1 km.

3.3. Human-wildlife interaction

Concerning this study, we treated livestock depredation by carnivores as human-wildlife interaction. Since we did not quantify crop damage relative to both sites, we focus on this only in the context of people's perceptions. WWF-India with The Corbett Foundation (TCF) has implemented an interim relief scheme (IRS) as a timely compensatory mechanism on the event of livestock depredation by carnivores in the buffer zone of KTR. Since 2016, an interim relief amount has been provided to the cattle owner whenever a livestock kill incident occured.

Livestock kill incidents by carnivores were considered to quantify the intensity and frequency of kills in treatment and control sites. Livestock depredation data from January 2017 to December 2022 was accessed to analyse the impact of lantana removal on changes in the kill patterns. In the event of livestock kill, the location of the carcass was recorded. This geotagged location enabled identifying the site in treatment and control sites. A chi-square goodness of fit test was performed to test whether there was a significant difference in livestock depredation events following lantana removal.

3.4. People's perceptions

Participatory learning methodologies were used to understand people's perceptions on the impacts of lantana, both after removal and in its standing state, as well as its perceived effects on human-wildlife interactions such as crop raiding and livestock depredation. The survey was conducted in the study site villages from September 2020 to February 2021. A total of 18 villages were randomly selected for the

Manohar Pawar/FES

Use of lantana branches weaved to be used as farm fences

social survey from among the 123 villages in Niwas, Bichhiya, and Baihar block, as well as a few villages in the periphery and buffer zone of the KTR where lantana removal had taken place. These villages were divided into 6 categories depending on the intervention area, as indicated in Table 4. The methodology and results related toward objective three are covered in detail in Lalai et al. 2023.

Table 4. Treatment area, number of villages in each category, and names of the sampled villages

Treatment area (in hectares)	Total number of villages in each category	Names of sampled villages*
0–20	44	Bharweli, Khalodi, Singpur
20–50	39	Dhutka, Chhapri, Bharadwara
50–80	24	Umardehi, Tatri ryt, Khamariya Mal
80–110	7	Rajma, Dudgaon
110–150	6	Malara, Pakrtitola (Taktaua)
>150	3	Kamta Mal, Mohgaon

* In addition, Chichhari, Silwani, and Bamhni were also included among the selected villages.

The assessment team surveyed 10% of the farmers from the intervention villages to assess the impact of lantana removal on crop depredation. A total of 191 farmers were interviewed randomly (10% from an intervention group of 1,818 farmers). Farmers whose farmlands bordered the lantana treatment sites were selected for the survey. In addition to basic details related to farming, the survey questionnaire captured the perceived impact of lantana removal on crop depredation. The data were collected using the Open Data Kit (ODK) platform. The respondents were asked to choose the top 3 most important benefits of lantana removal through focus group discussions (FGDs) in the intervention villages. Weightage of 3, 2 and 1 were assigned to the most important, second and third most important benefit, respectively (Table 5).

Table 5. Top 3 of the 8 perceived benefits of lantana removal in the intervention villages

Benefits (from the topmost)	A	B	C	D	E	F	G
	Top benefit	Weighted score (A × 3)	Second benefit	Weighted score (C × 2)	Third benefit	Weighted score (E × 1)	Weighted average (B + D + F)
Reduction in crop raiding	28	84	57	114	60	60	258
Increased fodder availability	36	108	39	78	53	53	239
Paddy cultivation	36	108	15	30	8	8	146
Millet cultivation	34	102	8	16	9	9	127
Cultivation of other crops	10	30	8	16	2	2	48
Increased mahua collection	22	66	24	48	13	13	127
Increased tendu leaves collection	6	18	16	32	6	6	56
Other benefits	1	3	5	10	8	8	21

3.5. Data analysis

To understand temporal patterns in animal movements, the date and time metadata from camera trap images were converted to solar time to minimise any bias associated with local times. The transformation to solar time was carried out using the 'Activity' package (Rowcliffe et al., 2011). For each species, detections were considered independent if they were taken at intervals exceeding 1 hour. This criterion ensured that the observations were sufficiently spaced apart. To extract a dataset with observations separated by one hour, we utilised the assess temporal independence function in the R package 'camtrapR' (Niedballa et al., 2016). This function facilitated the extraction of data points that met the temporal independence criteria. Overall, these steps were taken to ensure an accurate and unbiased analysis of the data while considering the temporal aspects and potential dependencies between observations. Activity patterns were segregated and plotted to compare data from treatment and control sites, with activity intensity presented as kernel densities. Overlap of activity patterns was determined by Dhat1 values. The statistical analyses were performed using R software version 4.0.2 (R Core Team, 2021).

SECTION 4
RESULTS

Manohar Pawar/WWF-India

Rosy starling (*Pastor roseus*),
a migratory bird from south-east Europe

4.1. Understanding seasonal animal activity patterns

A total of 25 mammalian species (Annexure 5) were photo-captured during the monitoring period. These recordings provided crucial insights into site use by wild ungulates. Since chital (*Axis axis*), sambar (*Rusa unicolor*), and wild pig (*Sus scrofa*) were the top three crop raiders in the study area as per perception surveys, a comprehensive analysis of their activity patterns for the three seasons is presented.

4.1.1. Chital (*Axis axis*)

Chital are often seen in herds of 10 to more than 30 and are found in almost all kinds of forested habitats – grasslands to deciduous forests, from the foothills of the Himalaya to peninsular India (Menon, 2014). They are inclined to be diurnal and are mainly active from morning to late noon (Prater, 1971). In the summer, their activity peaks as dusk approaches. On colder days, they begin foraging before sunrise, and activity peaks in the early morning and the late afternoon and continues till midnight (Schaller, 1984).

During summer, a marked difference in movement was found between the treatment and control sites, with activity at treatment sites peaking at night-time (post-18:00 to 06:00 hours) and at control sites in the daytime (post-06:00 to 12:00 hours) (Figure 3a, Table 6). The activity overlap between the two sites was 51%. This may be due to lantana removal, which opened-up space enabling better predator avoidance during dark hours, whereas the presence of lantana in the control sites acted as cover during the daytime.

WWF-India/FES/MPFD

Camera trap image of chital herd foraging in the treatment site

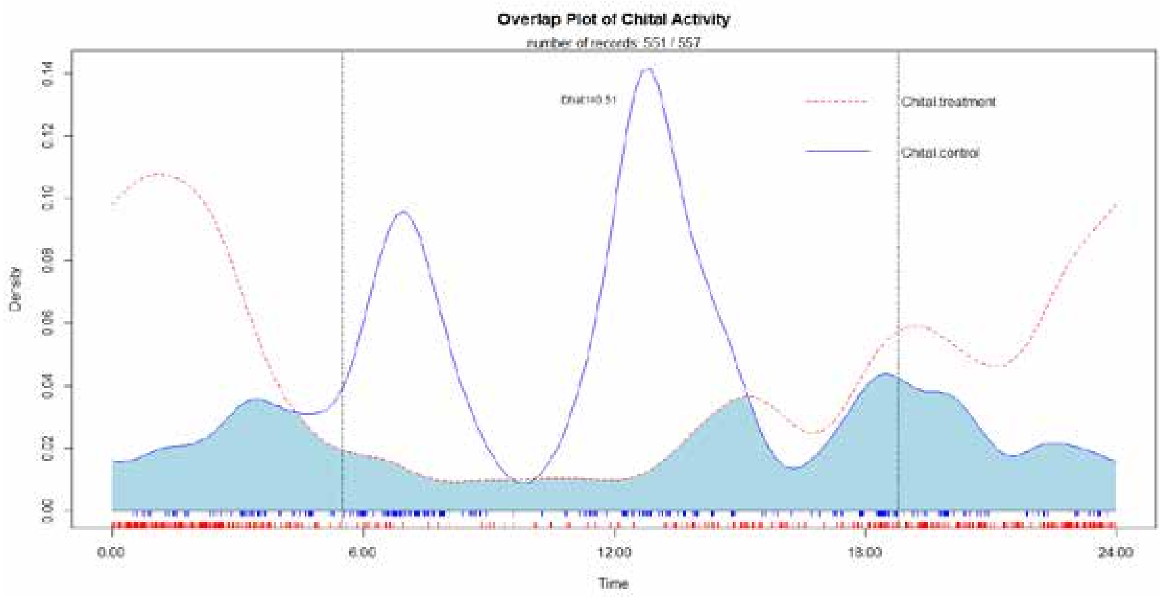

Figure 3a. Summer activity patterns of the chital in the treatment and control sites in 2021 and 2022

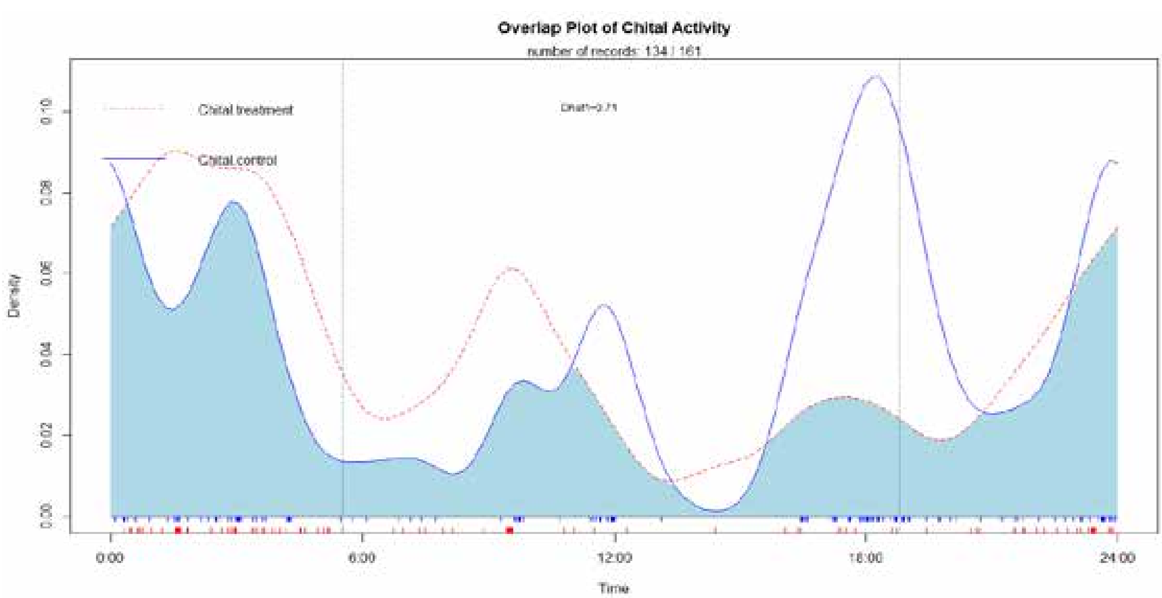

Figure 3b. Monsoon activity patterns of the chital in the treatment and control sites in 2021 and 2022

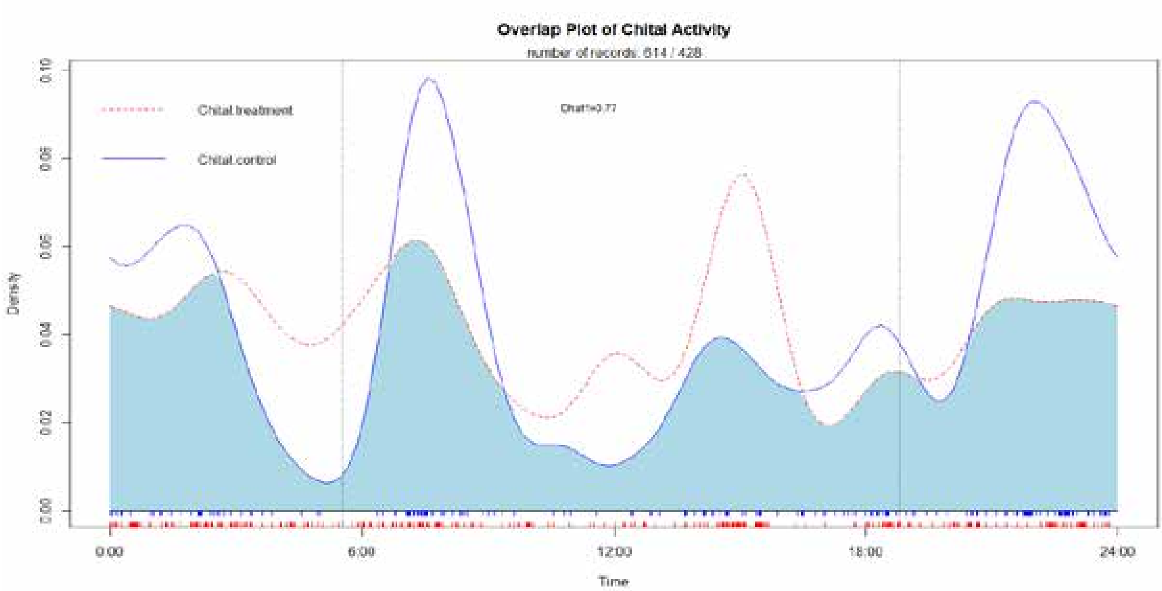

Figure 3c. Winter activity patterns of the chital in the treatment and control sites in 2021 and 2022

During the monsoon, a higher overlap in activity patterns was noted between the treatment and control sites (71%), with a marked decrease in daytime activity compared to night-time. However, daytime activity (between 06:00 and 18:00 hours) was higher in the monsoons than in summers (Figure 3b, Table 6). This may be due to the increased availability of edible plant biomass in the treatment sites, in addition to open space for foraging, even though night-time activity at treatment sites remained similar to that recorded during summers.

During winter, an increased overlap in activity patterns was observed (77%), especially during daytime hours. We also observed that more frequent camera trap images were recorded in the treatment sites than in the control sites (Figure 3c, Table 6). This marked increase in daytime activity compared to night-time activity in the treatment sites relative to control sites may be attributed to the availability of plant growth for foraging after removing lantana. This contrasts with the activity patterns seen in the summer and monsoon seasons. However, the possible presence of standing crops (paddy) on these patterns cannot be ruled out.

4.1.2. Sambar (*Rusa unicolor*)

The sambar prefers dense cover of deciduous shrubs and grasses and is found in forested hillsides throughout India. They feed mainly at night and rest during the day (Prater, 1971) as small herd of three to as many as ten, comprising mostly of does, fawns, young stage, while mature stags roam solitary.

WWF-India/FES/MPFD

A foraging herd of sambar at night in treatment site

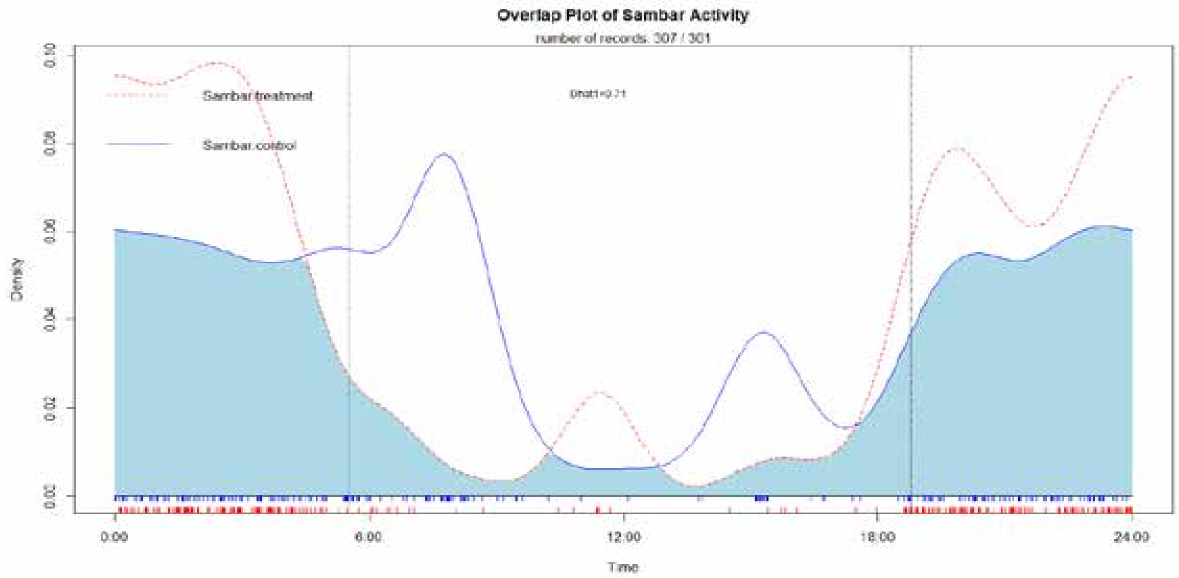

Figure 4a. Summer activity patterns of the sambar in the treatment and control sites in 2021 and 2022

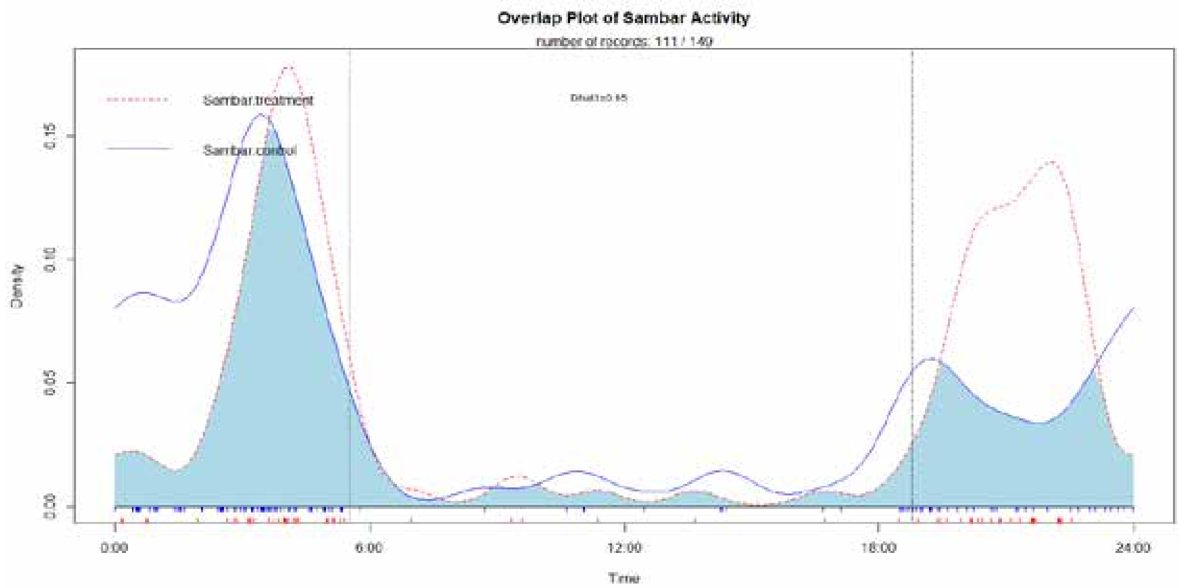

Figure 4b. Monsoon activity patterns of the sambar in the treatment and control sites in 2021 and 2022

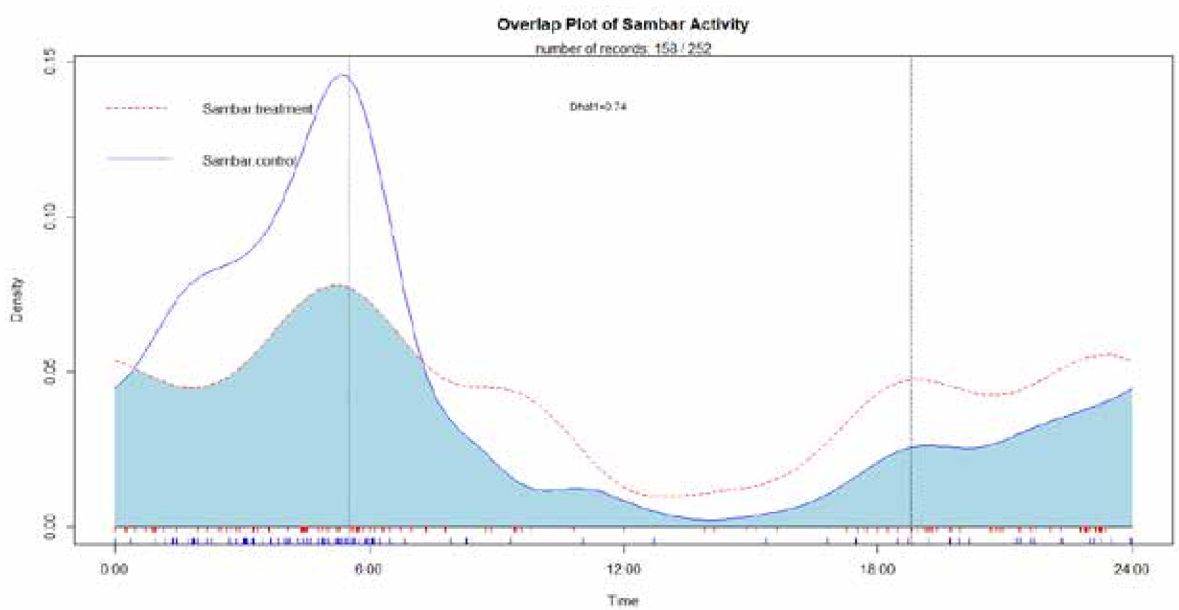

Figure 4c. Winter activity patterns of the sambar in the treatment and control sites in 2021 and 2022

The sambar activity in the study sites presented a distinct pattern compared to the chital. Although peak activity was restricted to night-time in the treatment sites, some activity was captured between 11:00 and 12:00 hours during the summer of 2021 (Figure 4a, Table 6). This may be an artefact of the edge effect, as the sambar may have wandered along the edge of the treatment sites; the same result was not found in the summer of 2022. In the control sites, sambar activity was highest during the morning hours. However, their presence was captured consistently at night, indicating in the lantana-dominated forests.

During the monsoon season, sambar activity was reduced in both the treatment and control sites, with high activity restricted to night-time (Figure 4b, Table 6). This could be because the sambar prefers to forage in wooded areas – a characteristic of the control sites – rather than in the open. The frequency of photo captures was also lowest in the monsoon season, indicative of overall low activity in both sites.

In contrast to the summer and monsoon patterns, the sambar was largely active in the early morning hours during winter in both sites, with relatively higher daytime activity in the treatment sites than in the control sites (Figure 4c, Table 6). However, a markedly higher frequency of photo captures was observed in the control sites. Such patterns are expected for wild foraging species in forested areas, despite the presence of paddy near treatment sites.

4.1.3 Wild pig (*Sus scrofa*)

Wild pigs are present throughout India and are found in almost all kinds of habitats. They feed in the early morning and late in the evening (Prater, 1971); however, they are also reported to be active through the night. A sounder of wild pigs, with as many as 30 individuals, are known to raid paddy, wheat, maize, and vegetable farms throughout their growing stages in all seasons.

WWF/FES/MPFD

Camera trap image of wild pig in treatment site

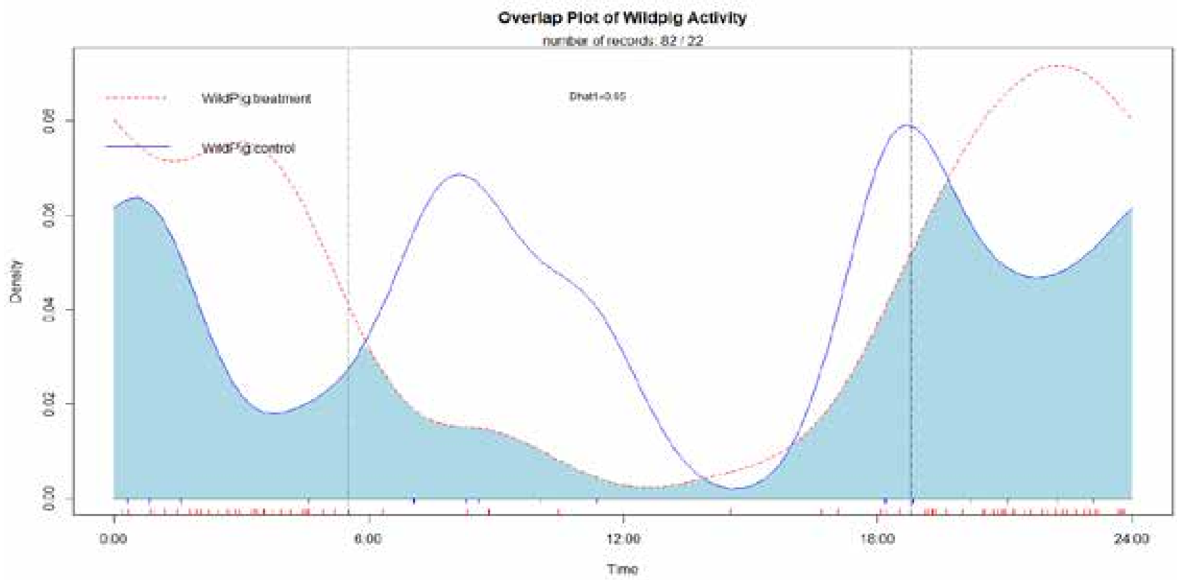

Figure 5a. Summer activity patterns of the wild pig in the treatment and control sites in 2021 and 2022

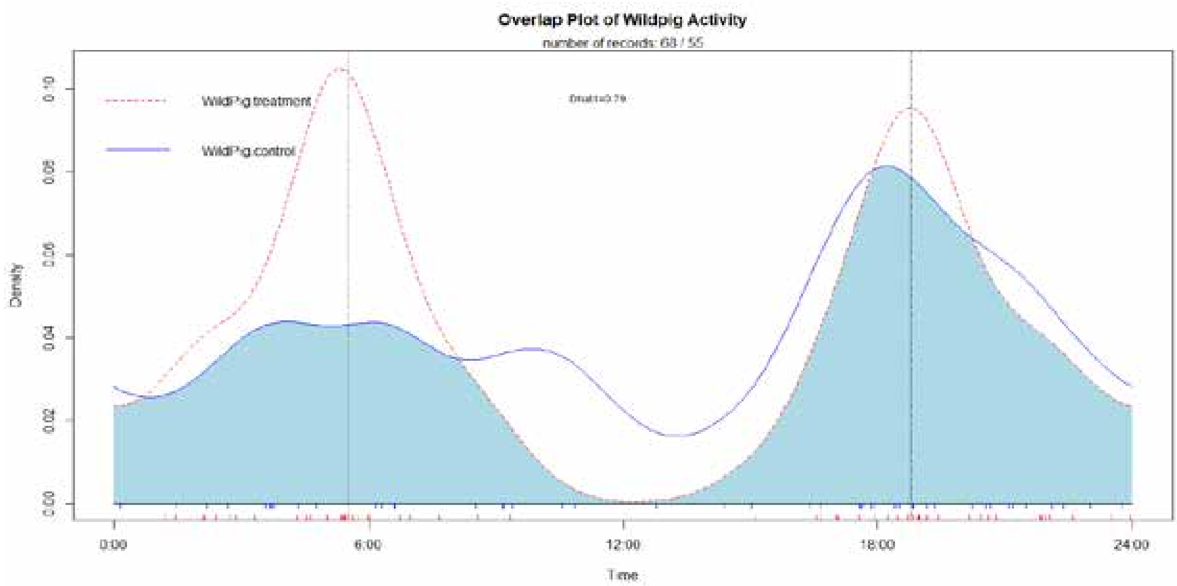

Figure 5b. Monsoon activity patterns of the wild pig in the treatment and control sites in 2021 and 2022

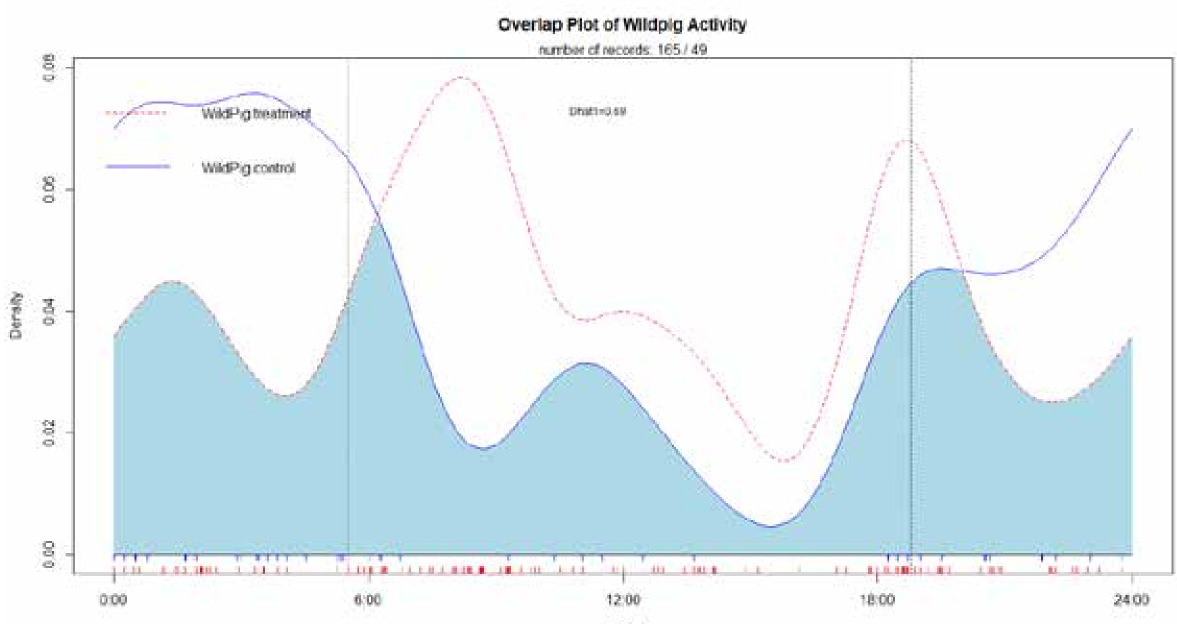

Figure 5c. Winter activity patterns of the wild pig in the treatment and control sites in 2021 and 2022

While the lowest frequency of photo captures was observed for the wild pig, there were distinct activity patterns at the two sites during summer: in the treatment sites, the wild pig were most active at night, whereas in the control sites, they showed a distinct peak in daytime activity (between 06:00 to 12:00 hours) (Figure 5a, Table 6). This distinction indicates the habitat preferences of the species. Wild pigs use lantana as cover during night-time but also during daytime in places where lantana grows.

During monsoon, daytime activity increased at both sites, particularly during early mornings and early evenings in the treatment sites and early evenings in the control sites. While activity patterns in the control sites were like those observed during the summer, the shift to daytime activity in the treatment sites during the monsoons can be associated with the start of paddy planting in the adjacent area. However, the frequency of photo captures was lowest during the monsoon season (Figure 5b).

During winter, markedly higher activity was noted in the treatment sites compared to the control sites. In contrast to summer trends, in the winters of 2021 and 2022, a notable increase was observed in daytime activity irrespective of lantana presence, indicating that lantana removal has had little effect on wild pig activity. The decrease in the frequency of captures in the control sites, and the subsequent increase in the treatment sites, also indicates that lantana removal has had little effect on wild pig activity (Figure 5c).

4.1.4. Overall activity patterns

A distinct diurnal-nocturnal pattern was noted corresponding to the species' known behaviour, with the species showing more avoidance behaviours in the treatment sites than in the control sites during

Sandeep Chouksey/WWF-India

Gaur foraging in lantana invaded area

Sandeep Chouksey/WWF-India

Indian leopard using lantana as cover

daytime hours (06:00–18:00 hours). This may be associated with the presence of open space in the treatment sites, where activity mostly peaked during night-time hours. The overlap in activity patterns was >50% in all seasons – 51% for the chital in summer and 79% for the wild pig in the monsoons – which indicates a partial to small change in behaviour across both sites.

Seasonal variations in the movements of wild ungulate populations are dependent on nutritional requirements for growth, rut, gestation, and lactation, in addition to predation risks (Awasthi et al., 2016). In Panna Tiger Reserve, ungulates such as the chital, sambar, wild pig, and nilgai shift from the valleys, where they stay in summer, to the plateaus in winter (Gupta and Krishnamurthy, 2023). In KTR, the chital show a high preference for grasslands in summer and winter, the sambar for bamboo-mixed forests in summer and miscellaneous forests in winter, and the wild pig for both bamboo-mixed forests and miscellaneous forests in both seasons (Awasthi et al., 2016). This study demonstrates niche-specific differences in movement patterns between a newly created habitat (devoid of the invasive lantana) and lantana-infested forests within the same matrix for a group of wild ungulates in human-use areas.

Table 6. Summary of peak activity patterns of the three species from 2 camera trapping sessions per season

Species	Season	2021		2022	
		Treatment site	Control site	Treatment site	Control site
Chital	Summer	Late evening – midnight – early morning	Morning – Evening	Late evening – early morning	Early morning; noon; and late evening
	Monsoon	Late evening – early morning; morning	Late evening; early morning; noon	Early morning; morning; evening	Evening; early morning
	Winter	Late evening; morning	Morning; late evening; early morning	Late evening; early morning; noon	Early morning; morning
Sambar	Summer	Evening – early morning	Late evening – early morning	Late evening – early morning	Morning; Evening
	Monsoon	Late evening – early morning	Late evening – early morning	Late evening – early morning	Late evening – early morning
	Winter	Late evening – early morning	Late evening – early morning	Morning – noon; evening	Early morning
Wild pig	Summer	Early morning; evening	Morning; late evening; early morning	Late evening – early morning	Late evening; early morning
	Monsoon	Early morning; late evening	Late evening; early morning – morning	Early morning – morning; evening – late evening	Morning – Evening
	Winter	Morning; Evening	Late evening – early morning	Morning; evening; early morning	Late evening; early morning; noon

Note: 18:00–00:00 hours: late evening; 00:00 hours: midnight; 00:00–06:00 hours: early morning; 06:00–12:00 hours: morning; 12:00 hours: noon; 12:00–18:00 hours: evening. Activities with subtle peaks noted as '-' indicate only a minor dip in activity; activities with separate prominent peaks noted as ';' indicate a major dip in activity. See Annexure 2 for activity plots.

4.2. Human–wildlife interactions

A total of 169 cases of livestock depredation were reported from the study area between 2017 and 2022, of which 59% (98 cases) were from control sites and 41% (69 cases) were from treatment sites (Figure 6, Table 7). The average number of livestock depredations in this period was 16.3±2.4 and 11.5±1.9 cases per year for the control and treatment sites, respectively. The maximum number of cases was recorded in 2019; 26 and 19 cases in the control and treatment sites, respectively. No significant difference (χ^2 = 0.27; df = 5; p < 0.99) was noted in livestock depredation between the treatment and control sites. However, a 30% reduction was noted in livestock depredation in the treatment sites during the same period; the highest reduction was recorded in 2017 (44%) and the lowest (23%) in 2020 (Table 7).

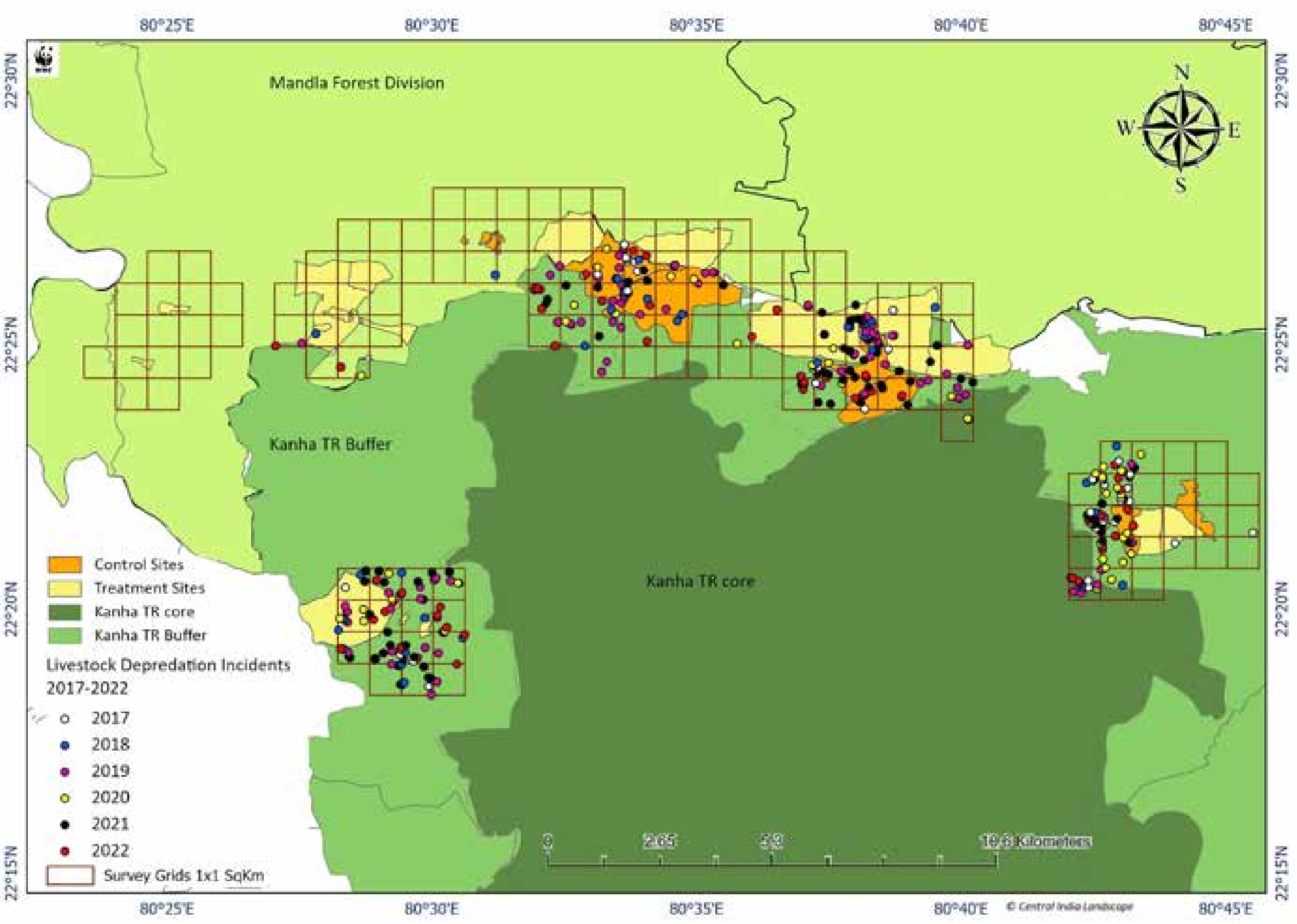

Figure 6. Livestock depredation incidents by carnivores between 2017 and 2022 based on the location of carcasses found

Manohar Pawar/FES

Cattle kill at lantana invaded area by large carnivore


Sandeep Chouksey/WWF-India

Lantana infestation in village commons

Table 7. Livestock depredation cases documented in control and treatment sites for the years 2017–2022

Year	Control	Treatment	Total number of cases	Difference
2017	9	5	14	44%
2018	16	11	27	31%
2019	26	19	45	27%
2020	13	10	23	23%
2021	22	16	38	27%
2022	12	8	20	33%
Total	98	69	167	30%

4.3. People's perceptions

The outcome of the focused group discussion unveiled eight benefits farmers experienced after lantana removal (see Table 5). The foremost among these was decreased crop damage caused by wild ungulates. The survey, which was conducted among 191 farmers from the areas where lantana was removed, showed that 145 of these farmers (76%) identified reduction in crop depredation as one of their top 3 perceived benefits. In contrast, 24% of the respondents did not consider the reduction in crop depredation as the topmost benefit of lantana removal (Figure 7). Among the subset of 145 respondents, 19% ranked this as the top benefit, 39% as the second, and 42% as the third (Figure 7; Annexure 1).

In individual farmer surveys of 191 participants, 37% (n = 70) indicated that crop damage by wildlife was 'much less than before' on their land after lantana removal. Meanwhile, 54% (n = 103) said that crop damage had diminished slightly compared to previous levels and 9% (n = 18) perceived no change in such damage. The survey captured almost similar responses from farmers regarding crop depredation on adjacent plots after lantana removal. 33% (n = 63) felt that crop raiding was much lesser than before, 59% (n = 112) said that it had reduced slightly, and 8% (n = 16) noted no change (Figure 8, Figure 9).

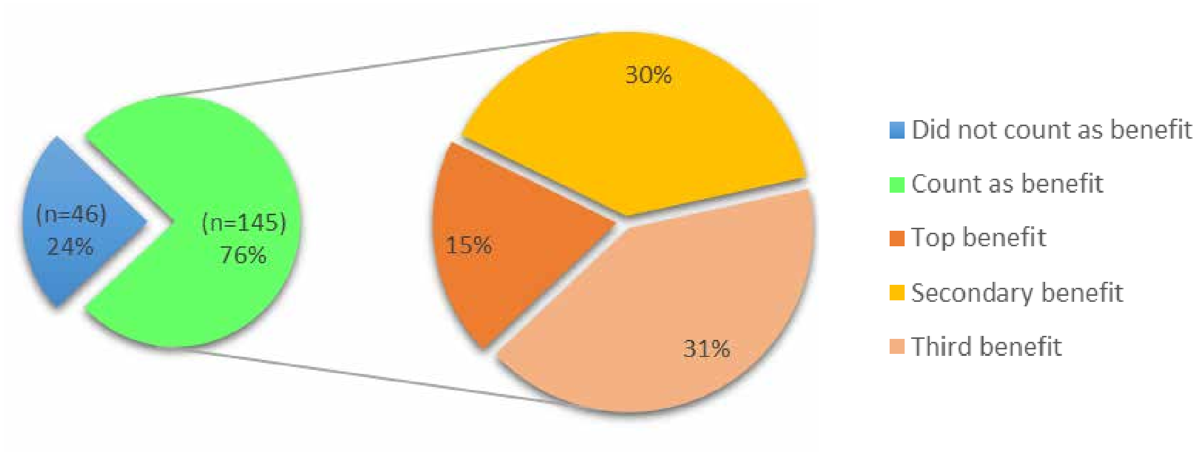

Figure 7. The number/percentage of respondents considering the reduction in crop depredation a benefit; the adjacent chart shows proportion of respondents and ranking

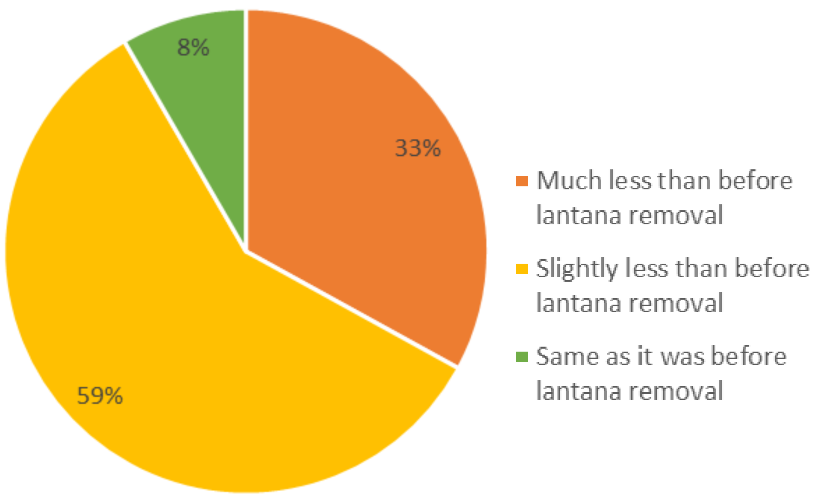

Figure 8. Farmers' perception of reduction in crop raiding by wildlife after lantana removal from farmlands

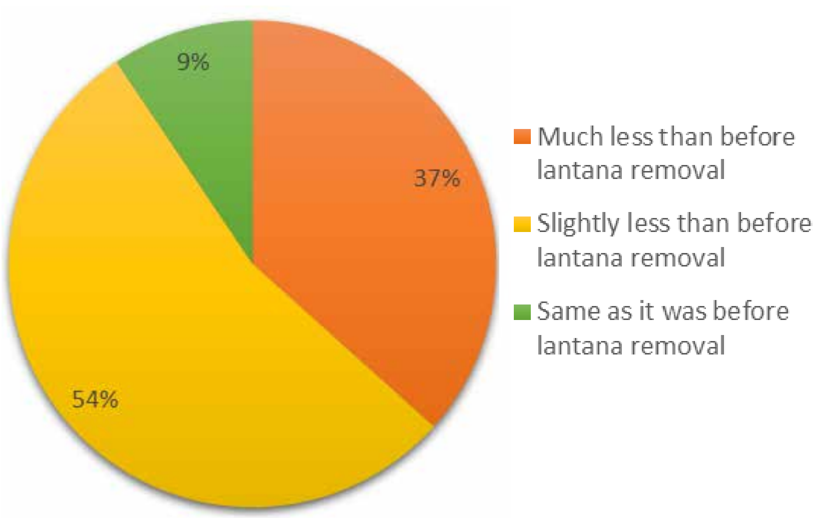

Figure 9. Farmers' perception of reduction in crop raiding by wildlife in adjacent lands after lantana removal

SECTION 5

DISCUSSION

5.1. Animal activity patterns

The study examines the potential effect of lantana removal on the movement patterns of three common wild ungulates – the chital, sambar, and wild pig – concurrent to their behaviours across open (here, treatment sites) and covered (here, control sites) habitats. In the summer, all three species appeared to show avoidance from treatment sites (as measured by their activity) during daytime except during dawn and dusk. During the monsoon, the chital showed increased activity in the treatment sites during daytime, while the sambar showed the least, whereas the wild pig showed increased activity during dawn and dusk. In the winter, chital and wild pig activity in treatment sites increased further, and sambar activity increased around dusk and dawn. The summer camera trapping session was completed when farms were fallow; the monsoon session when saplings were planted in fields or were in their leafy stage; and the winter session when wheat was sown or in early seed setting stage.

The high activity patterns in treatment sites during monsoon and winter with presence of crops in neighbouring areas did not corroborate. However, farmers perceived lantana removal as beneficial in reducing crop damage to some extent. Further quantification of crop damage vis-à-vis lantana removal is required to determine the association between removing an invasive species and changes in wildlife behaviour. For instance, wild ungulate habitat use, and not merely activity patterns, in addition to their densities, response to human presence and methods of flushing out animals – such as through the use of fire – requires additional research.

Sandeep Chouksey/WWF-India

A herd of chital in the meadows

Based on their activity patterns, it can be deduced that while perceptible differences exist between treatment and control sites, there are inter-seasonal differences as well. The chital showed a notable shift in activity from evening (12:00–18:00 hours) to late evening (18:00–00:00 hours) between the 2021 and 2022 summers in the control sites; no such change was observed in other seasons, whereas the sambar did not show any perceptible inter-seasonal variations in activity. Wild pig activity patterns showed the highest inter-seasonal variation in both the sites during the summer and winter of 2021 as well as 2022 compared to the monsoon season. The reasons for this could not be determined, but it can be postulated that such differences are an artefact of having a small study area with two sampling seasons; stochastic factors may also have influenced animal behaviour, whether natural, such as presence of a predator, or man-made, such as increased human use.

5.2. Addressing study limitations

The limited number of observations made for each species is a critical limitation of the study, this is a result of a small sample area with restricted sampling duration of two sampling sessions per season. It emphasises the need for more extensive and long-term data collection to draw robust conclusions and understand long-term trends in large mammal behaviour vis-à-vis invasive species in multiple-use lands. We could not assess neighbourhood effect on habitat use of these target species, especially when it comes to roosting (in lantana-invaded forests) and foraging (in farmlands). However, we present a preliminary assessment of how lantana removal affects animal activity in a regional context, especially in relation to people's perceptions towards lantana removal. Lastly, the effect of lantana removal on animals using such sites for giving birth or using it as nursery could not be assessed. Such observations were not made during the study period. Hence, this study might not be relevant to lantana removal undertaken in the inviolate zones of tiger reserves.

5.3. Ecosystem dynamics

The study highlights the interactions between species and their habitats. Changes in vegetation, such as the presence or removal of lantana, can have varying effects on different animal species, and understanding these dynamics is crucial for conservation and habitat management efforts. Observing shifts in animal behaviour in response to environmental changes has implications for conservation efforts. Identifying how wildlife adapts or reacts to habitat modifications can aid in developing more targeted and sustainable conservation and conflict mitigation strategies.

The removal of lantana helps other vegetation recolonise the land and opens it up to native plant species. Grass species – such as *Dichanthium annulatum, Dimeria ornithopoda, Themeda triandra*, and *Bothriochloa pertusa* – and herbaceous plant species – such as *Tridax procumbens, Sida acuta*, and *Sida cordata* – were observed in such sites. Saplings of tree species like *Terminalia elliptica*, *Diospyros melanoxylon* and *Lagerstroemia parviflora* were found to be the most abundant among tree species. It is important to note that the specific plant species that grow after lantana removal depends on factors such as the climate, soil conditions, the natural vegetation structure of the region, and grazing pressures, whether from wild or domestic ungulates. We recognise that the ecological response to lantana removal is complex and can depend on specific regional circumstances. Some challenges may arise, such as the potential for other invasive species to take advantage of disturbed areas left open through lantana removal. A case in point is *Senna tora*, which is observed to grow profusely in the late monsoon season when lantana is removed for the first time.

5.4. Human–wildlife interactions

A perception survey conducted in the villages surrounding the study area revealed 94% of farmers finding expansion of the grazing area beneficial for livestock after the removal of lantana from the commons, and this had reduced their visits to forests (Lalai et al., 2023). They also linked it to a reduction in incidents of livestock depredation by wild carnivores. We tested this hypothesis and found no statistically significant variation in depredation events between the treatment and control sites. Nevertheless, a minor shift (30%) in the spatial distribution of conflict incidents was observed, with a tendency towards lantana-invaded forests than treated areas. We could not test whether there was an overall reduction in depredation for the larger region or attributed to carnivores preferring to hunt more in lantana-infested forests or use these to hide prey, although this indicates that lantana removal geographically isolates depredation incidents from lantana-infested forests. As depicted in Figure 10, compartments highlighted in control areas (orange) exhibited higher livestock depredation locations in comparison to the treatment sites (yellow), potentially due to the utilisation of lantana-removed areas as cover while hunting and concealing prey in lantana-infested forests.

Except for the Mocha treatment site, which reported around 11.24% (19 incidents) between 2017 and 2022, potentially due to the higher density of tigers in the Khatiya Range, most incidents exhibited a shift from treatment to control sites.

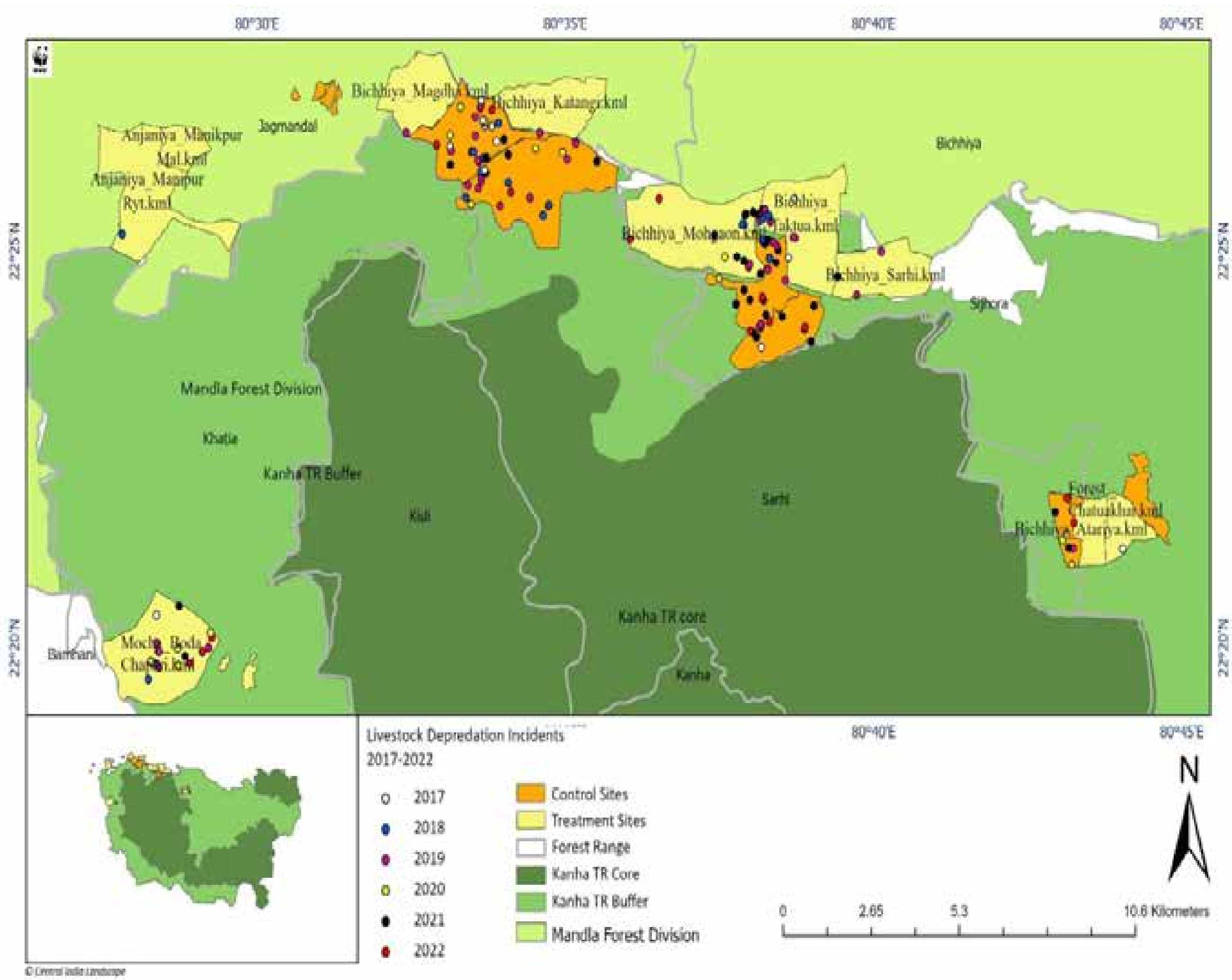

Figure 10. The frequency of livestock depredation by carnivores in control and treatment sites

Manohar Pawar/FES

A day-time foraging sounder of wild pigs alongside lantana shrubs

5.5. People's perceptions

The findings from the FGDs revealed that prior to the removal of lantana, farmers experienced substantial losses in paddy yield, ranging from 80% to 90% due to depredation by wild ungulates. Lantana removal from the commons contributed to a perceptible reduction in crop depredation. One of the farmers interviewed individually from the surveyed villages, who shared similar viewpoints from the FGDs, said, "When our lands were infested with lantana, wildlife would conceal themselves within it and raid our fields during night hours. However, since the removal, the absence of hiding spots has deterred these animals. Even if they enter the fields, they now avoid lingering close to them." (For more information, see Lalai et al. 2023.)

During the FGDs conducted across 10 sample villages, participants indicated that lantana removal has enhanced visibility around their crop fields. Previously, due to wild animals taking refuge in the invasive growth, farmers were compelled to stay in the fields from evening onwards and spend nights there to safeguard the crops. In areas where lantana has become widespread and encroaches on farmlands, it has been claimed that burning lantana is used to clear agricultural land. Some farmers and landowners use burning as a last resort when other methods of lantana management, such as manual removal, become ineffective. In villages such as Kamta Mal and Rajma, the local community experienced comparable relief during daylight hours, while others, such as Dhutka, observed diminished requirements for field protection even through the night. In the villages of Dhutka, Rajma, and Umardehi, there has been a marked reduction in the installation of *maddaiyas* (crop protection huts), for which respondents expressed a sense of ease. Notably, there has been a substantial decrease of over 90% in the number of *maddaiyas* installed on farmlands following lantana removal.

SECTION 6
CONCLUSION

This study highlights the critical need for long-term monitoring of large mammal behaviours and the habitat dynamics associated with invasive floral species such as lantana. The limited number of observations in this study emphasises the fact that short-term data may not provide a comprehensive understanding of the complex interactions between species and their environment. However, we present a unique socio-ecological perspective on the impacts of invasive species in a shared landscape. Long-term monitoring will help track changes in behaviours and habitat use patterns over time, enabling more accurate assessments of the effects of lantana removal and animal responses. Moreover, these issues must be discussed with local communities for better-informed crop protection measures. The observations on the responses of the chital, sambar, and wild pig to changes in vegetation following lantana removal demonstrate the significance of invasive species management in multiple-use areas. Understanding how alterations to vegetation impact animal behaviours can aid in developing effective conservation strategies (including passage for movement), habitat management policies, and conflict-mitigation plans. Regular assessments of habitat quality and its suitability for different species will be crucial for preserving biodiversity and ensuring natural or aided restoration of degraded ecosystems.

This study also demonstrates the potential effects of lantana on wild animal activity through habitat use as well as their interactions with humans in the context of shared spaces. It provides evidence that lantana influences human–wildlife interactions by affecting animal behaviours, with lantana removal leading to shifts in activity patterns in response to environmental changes. It indicates that livestock depredation showed a regional reduction and a shift in depredation incidents from treatment to control sites. The biggest caveat is that the study area is small; thus, our inferences apply strictly to this study and may change if a larger area is considered. However, given that no such large areas have been treated as of now, our investigation indicates that livestock depredation is affected by the presence or absence of lantana. The study's findings have implications for community-based wildlife management initiatives in PAs. Understanding how wildlife responds to habitat modifications can inform local communities about potential changes in animal behaviours and how they might affect human–wildlife interactions. Engaging with local communities and incorporating their perceptions into conservation efforts can foster a sense of ownership and responsibility towards protecting wildlife and shared spaces. To this effect, we recommend combining ecological observations with local perceptions to formulate impactful interventions.

Given the extensive scale of lantana invasion, efforts to remove it in isolated pockets may not provide a sustainable solution. A long-term, programmatic focus is essential for managing invasive species like lantana. These large-scale, labour-intensive eradication initiatives can be effectively supported through programs such as MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) and CAMPA (Compensatory Afforestation Fund Management and Planning Authority). Integrating these efforts with long-term socio-ecological monitoring of the affected sites will provide valuable insights into landscape changes and help mitigate human-wildlife conflicts. This holistic approach will ensure more effective and sustainable management of lantana and other invasive species.

In conclusion, we show that the perceived benefits of lantana removal towards a number of issues, top among them being reduction in crop depredation and opening up grazing space for livestock, are related to the effect of lantana-removed spaces on wild ungulate activities and livestock depredation by wild carnivores; thus, in view of invasive species management and ecological restoration in multiple-use areas, we suggest prioritising removal of lantana from areas fringing farmlands and human settlements.

SECTION 7

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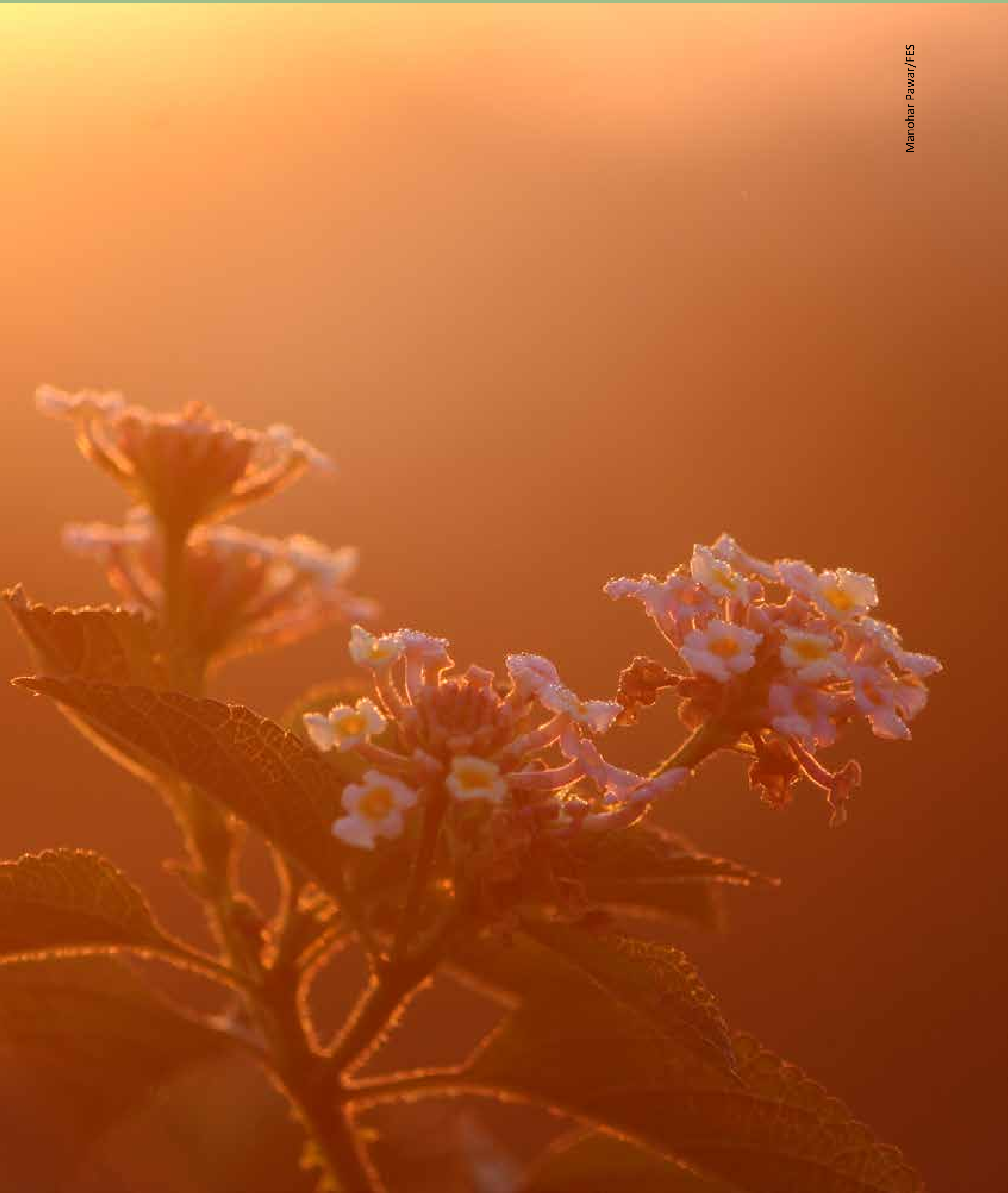
SECTION 8
ANNEXURES



Annexure 1

As part of the farmer surveys mentioned in the Methods section, randomly chosen farmers selected the top 3 benefits they experienced after the removal of Lantana from their lands. Thereafter, they ranked these selected benefits in order of importance to them. To calculate the 'most important' perceived benefits, the survey took count of farmers who chose benefits as the 'most important', the 'second-most important', and the 'third-most important' (refer to columns A, C and E in Table A1). Weights of 3, 2 and 1 were assigned to the most important, second-most important and third-most important benefits, respectively (refer to columns B, D and F in Table A1). This was followed by the calculation of the weighted and total scores (columns F and G in Table A1).

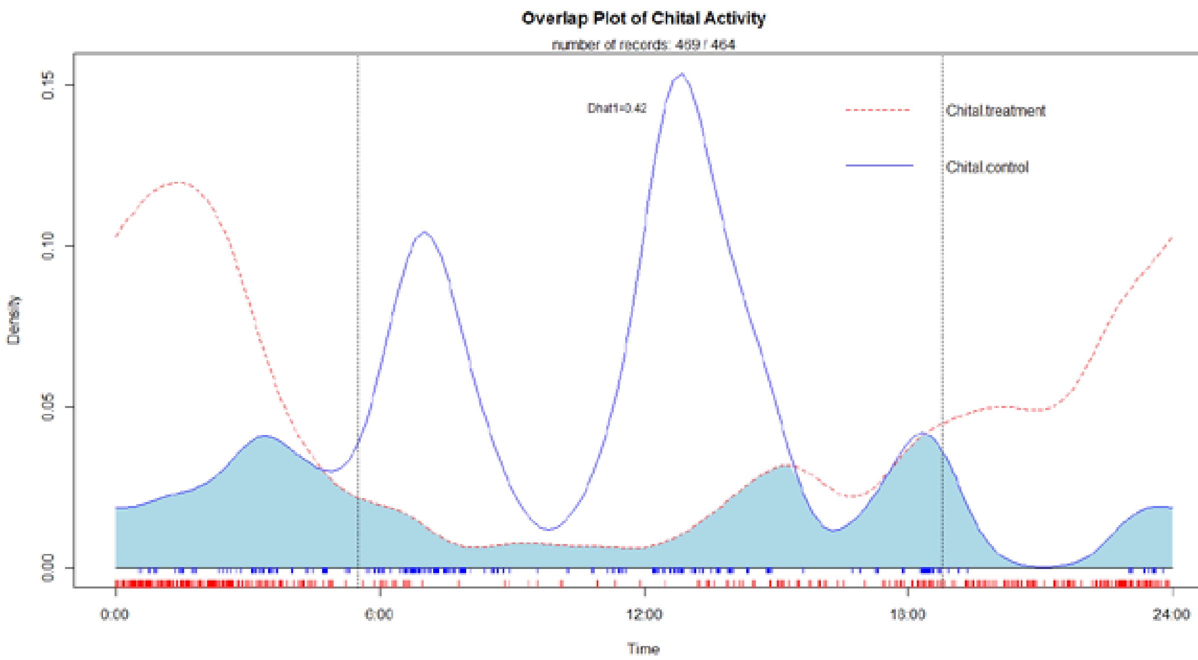
Table A1. Calculation of the perceived top-3 benefits to farmers after *Lantana* removal

Benefits (from the topmost)	A	B	C	D	E	F	G
	Top benefit	Weighted score (A × 3)	Second benefit	Weighted score (C × 2)	Third benefit	Weighted score (E × 1)	Weighted average (B + D + F)
Reduction in crop raiding	28	84	57	114	60	60	258
Increased fodder availability	36	108	39	78	53	53	239
Paddy cultivation	36	108	15	30	8	8	146
Millet cultivation	34	102	8	16	9	9	127
Cultivation of other crops	10	30	8	16	2	2	48
Increased mahua collection	22	66	24	48	13	13	127
Increased tendu leaves collection	6	18	16	32	6	6	56
Other benefits	1	3	5	10	8	8	21

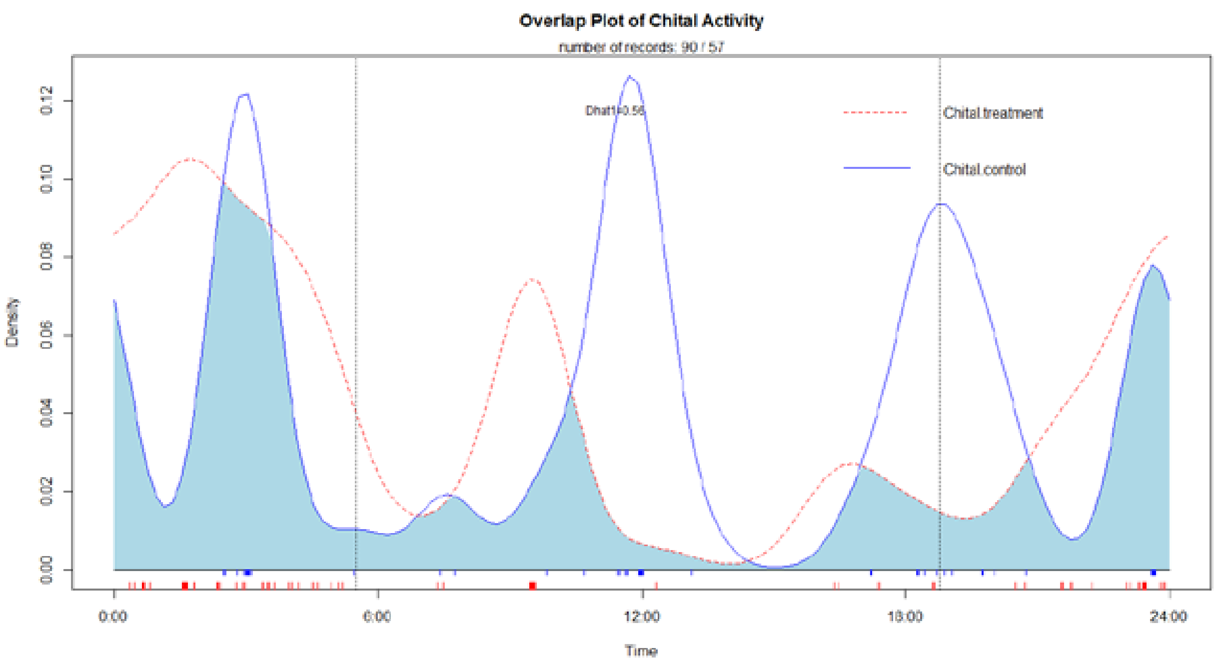
'Increase in fodder availability' was the perceived top benefit of Lantana removal activity followed by 'reduction in crop raiding' and 'paddy cultivation'.

Annexure 2: Graphical representation of the activity patterns of species recorded in camera traps

Figure A2A. Activity patterns of the chital (2021) - Summer



Activity patterns of the chital (2021) - Monsoon



Activity patterns of the chital (2021) - Winter

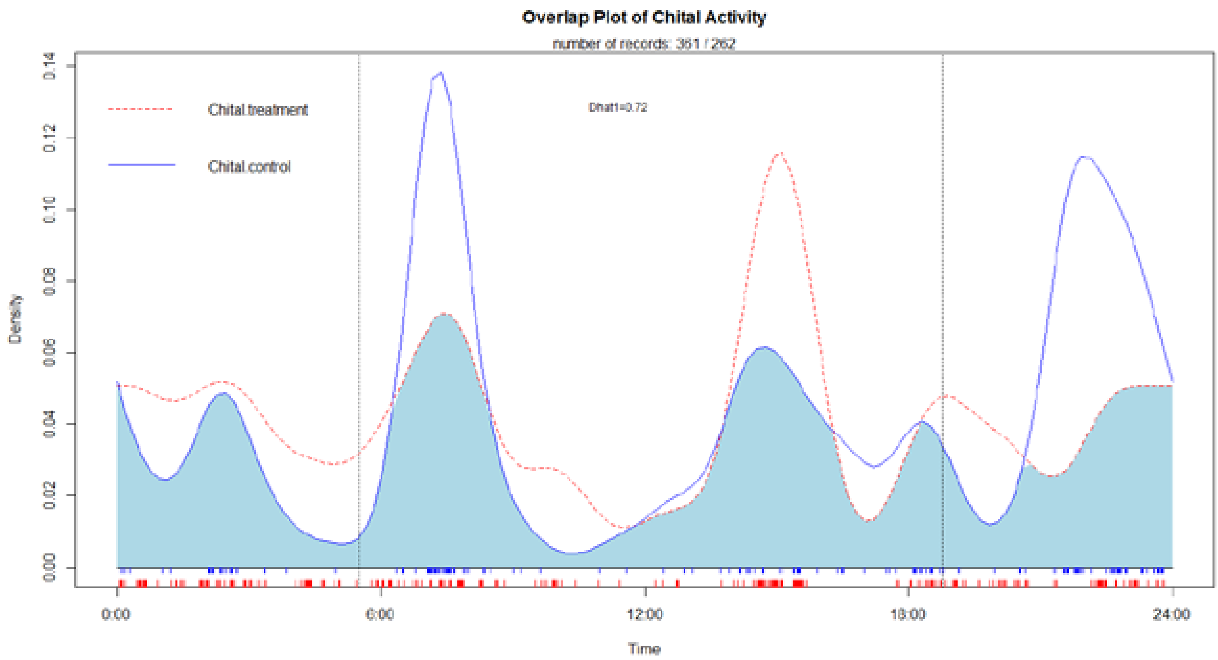
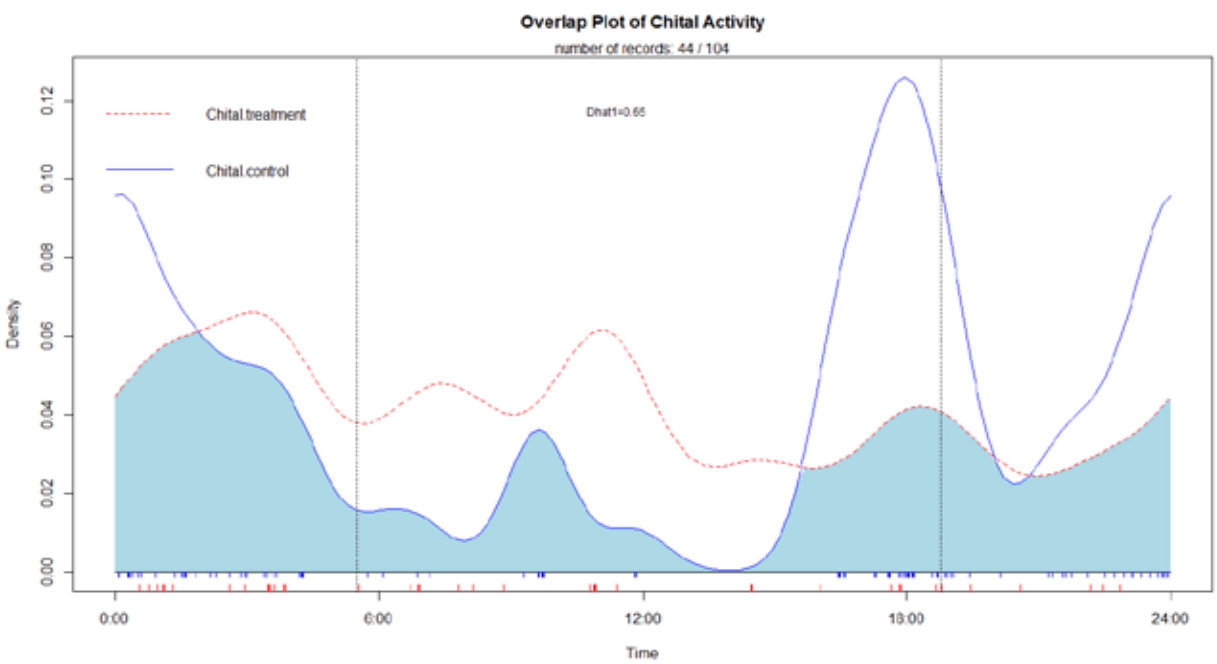
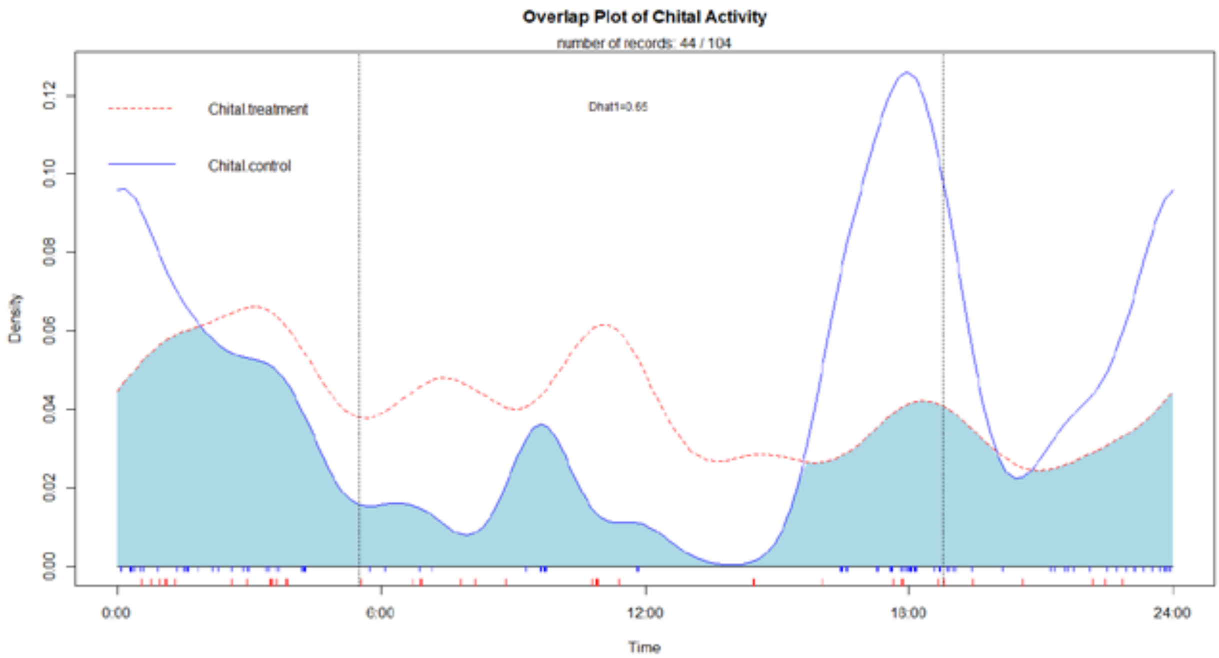


Figure A2B. Activity patterns of the chital (2022) - Summer



Activity patterns of the chital (2022) - Monsoon



Activity patterns of the chital (2022) - Winter

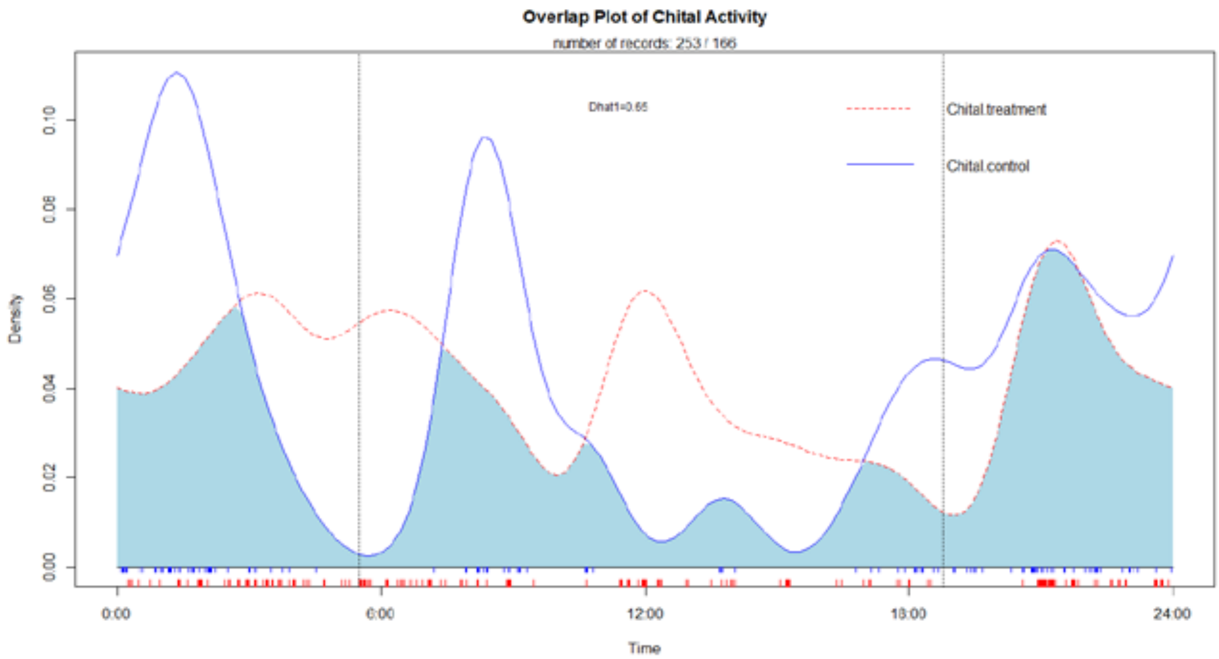
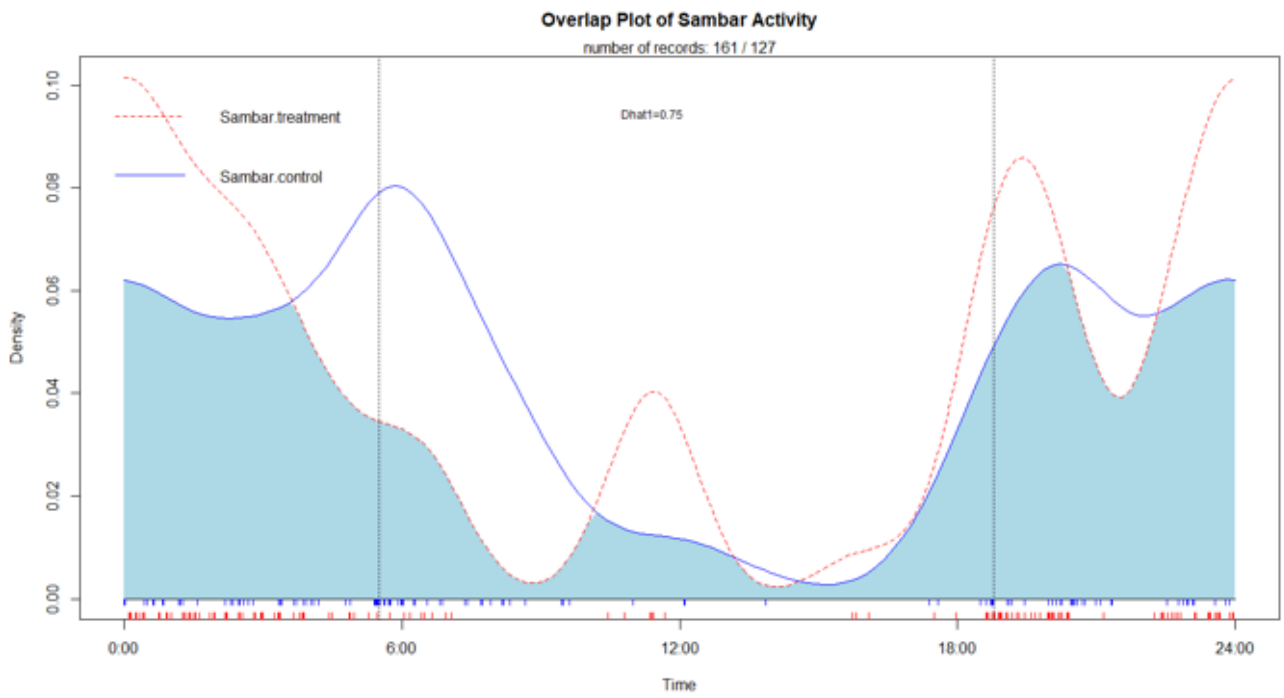
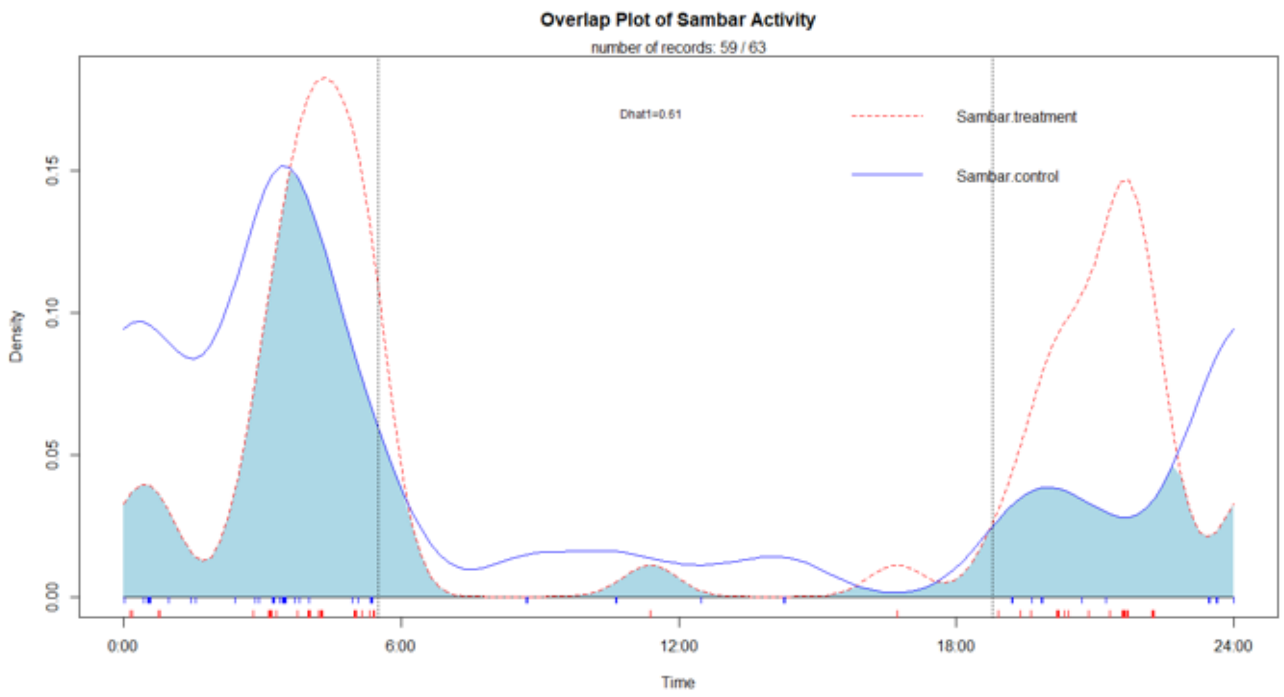


Figure A2C. Activity patterns of the sambar (2021) - Summer



Activity patterns of the sambar (2021) - Monsoon



Activity patterns of the sambar (2021) - Winter

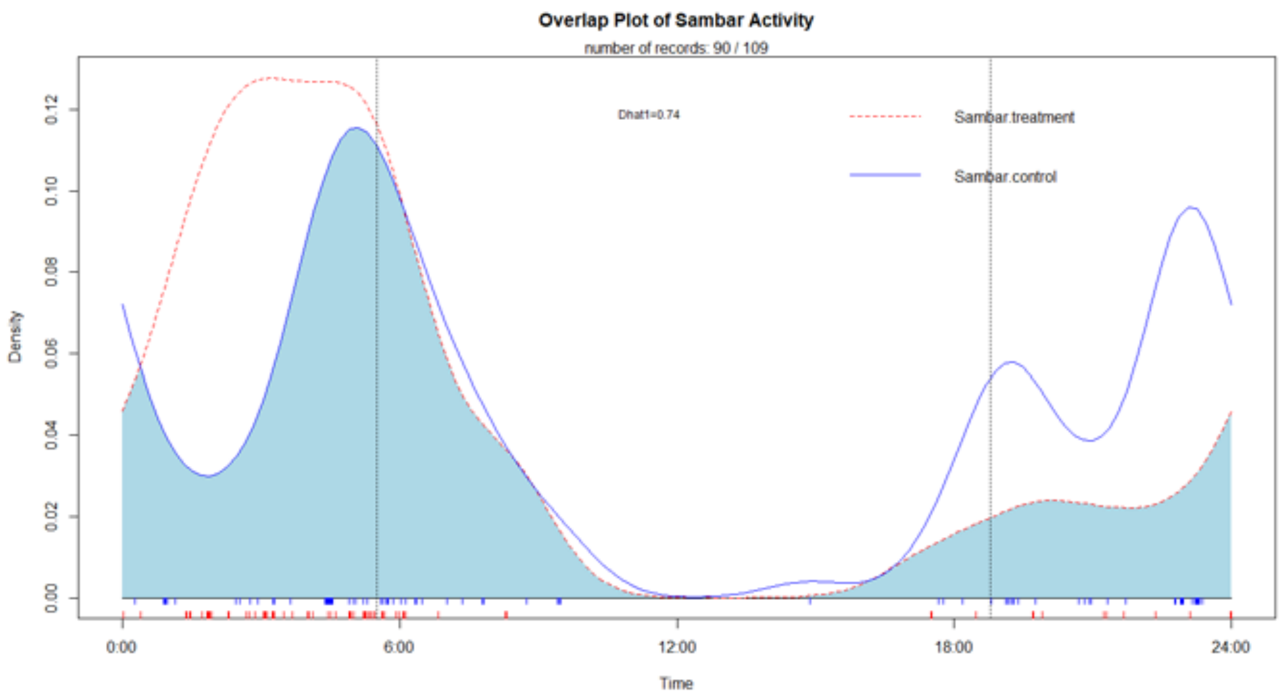
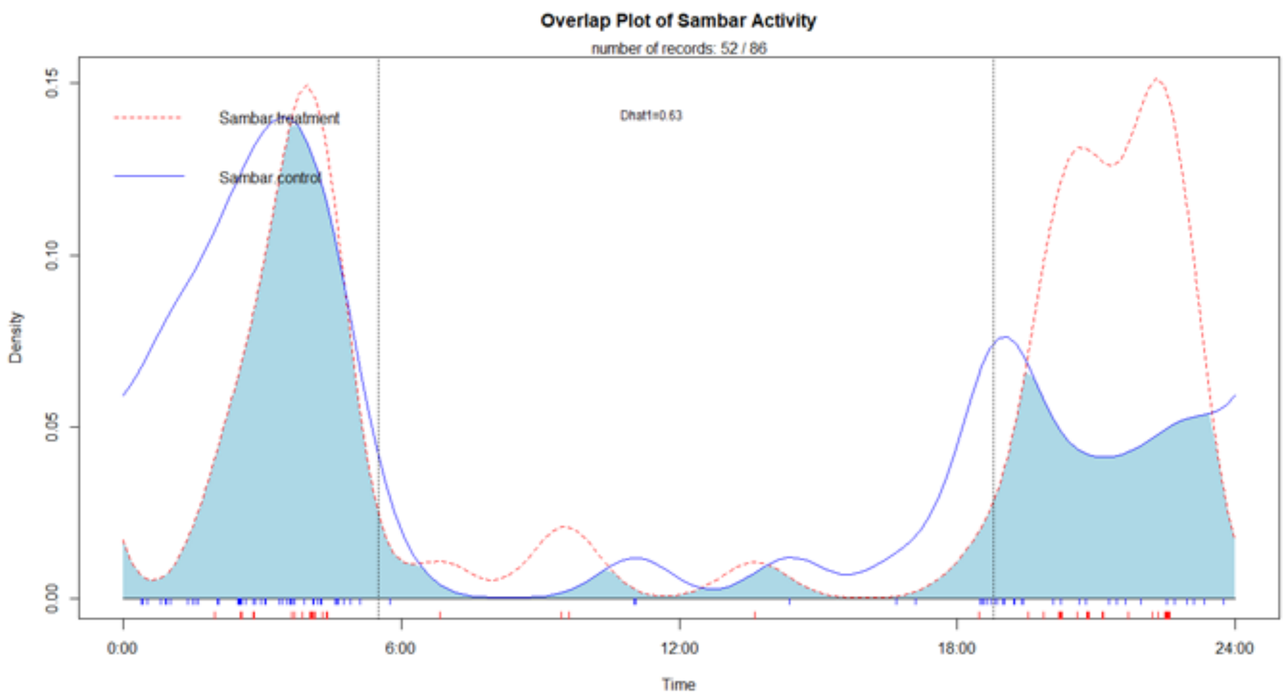
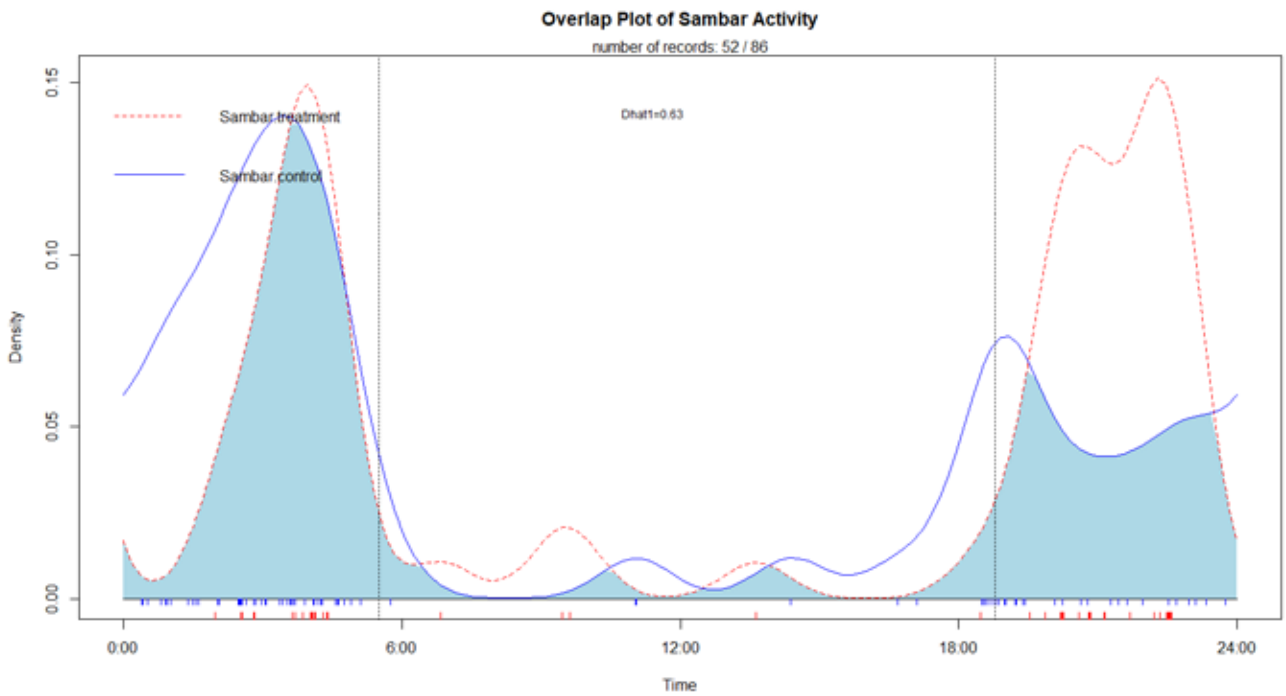


Figure A2D. Activity patterns of the sambar (2022- Summer)



Activity patterns of the sambar (2022)- Monsoon



Activity patterns of the sambar (2022)- Winter

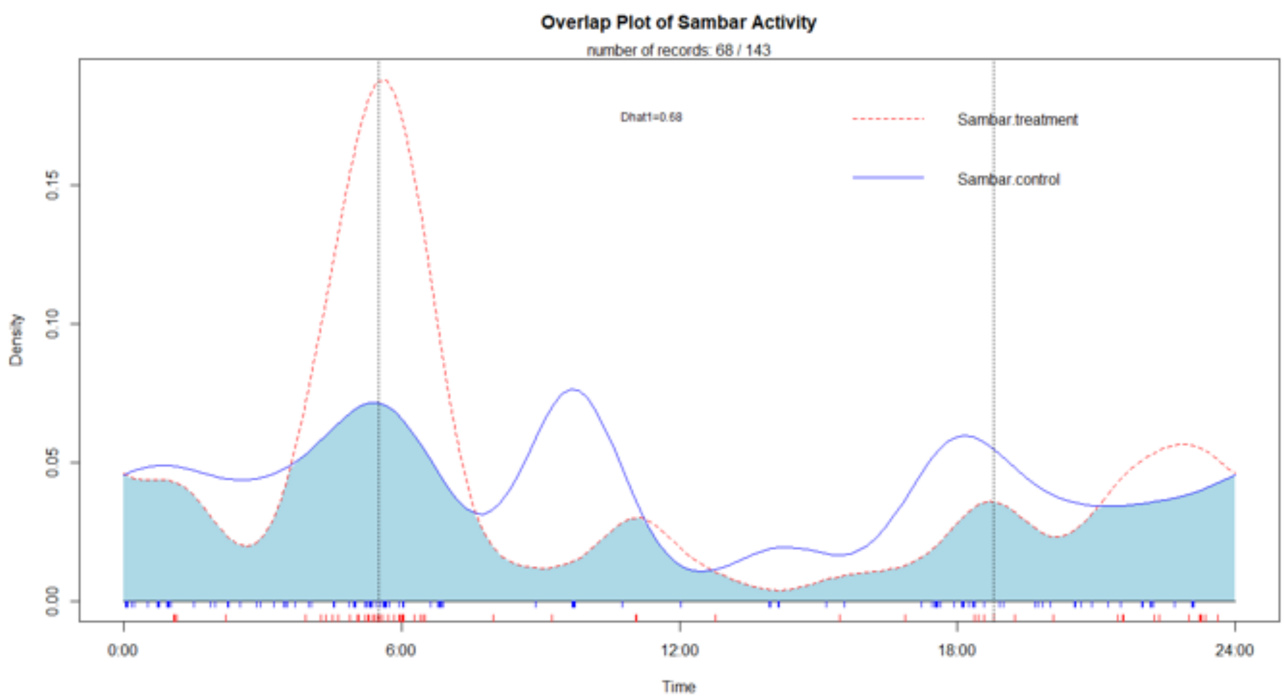
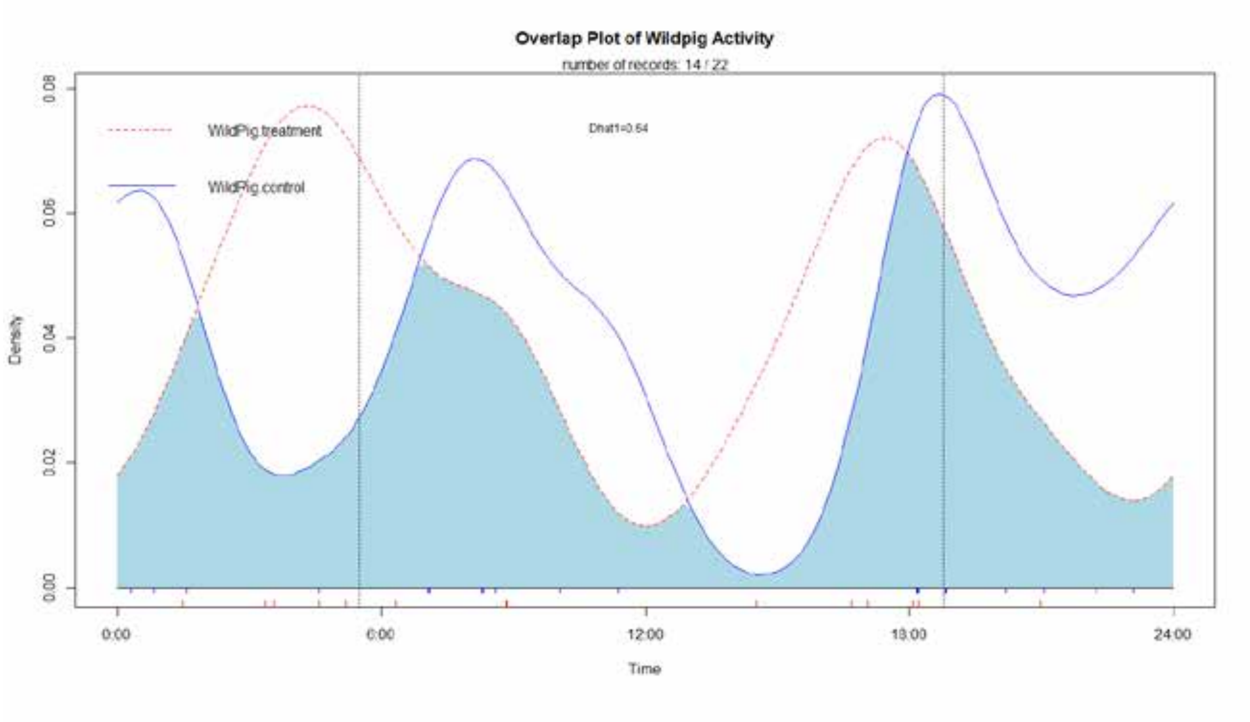
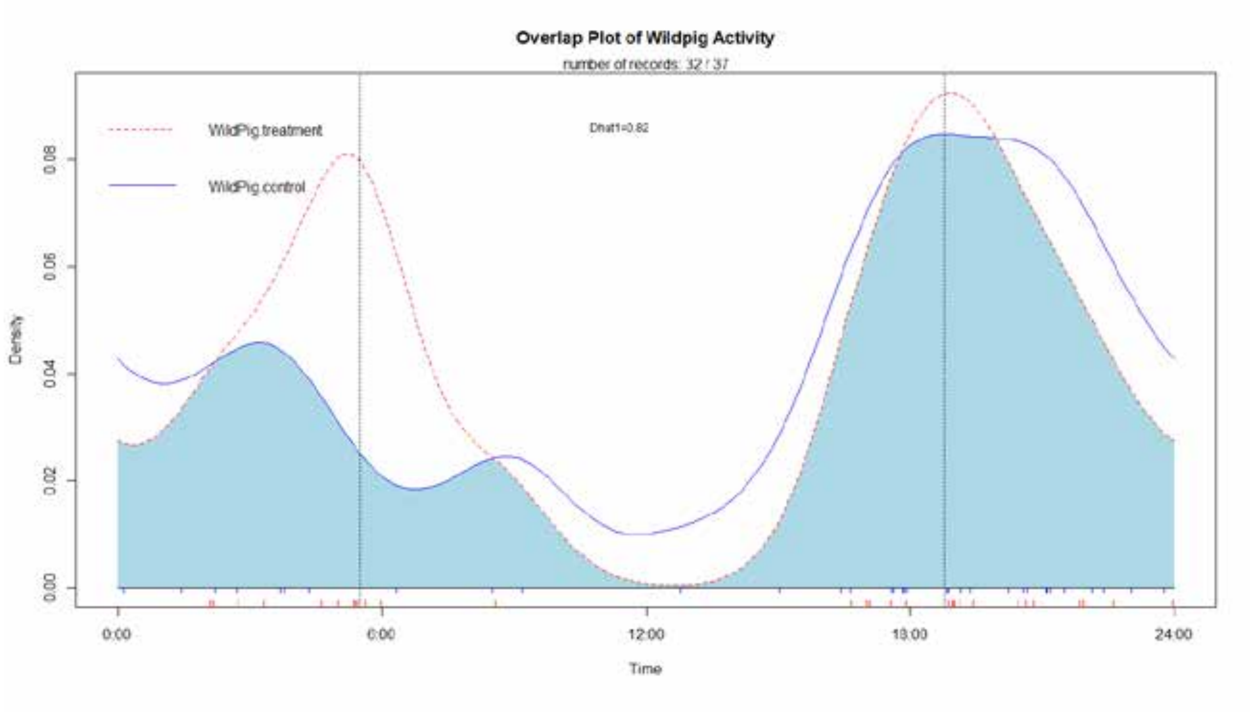


Figure A2E. Activity patterns of the wild pig (2021) - Summer



Activity patterns of the wild pig (2021) - Monsoon



Activity patterns of the sambar (2021) - Winter

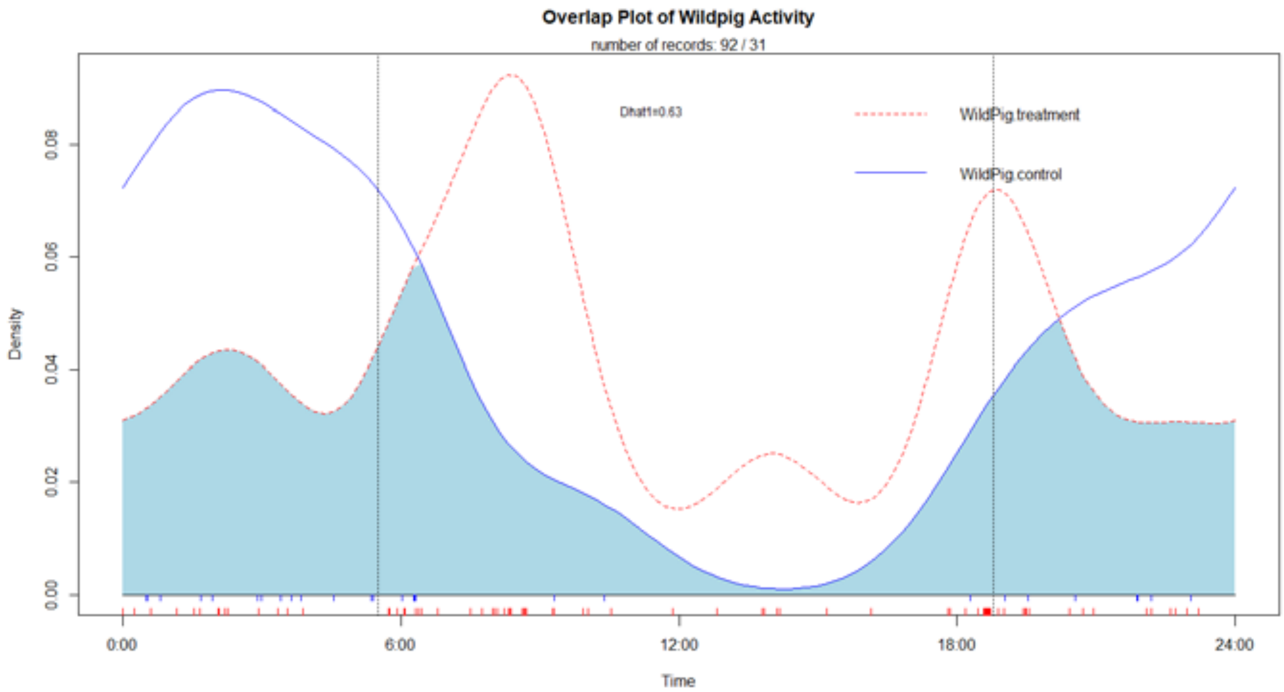
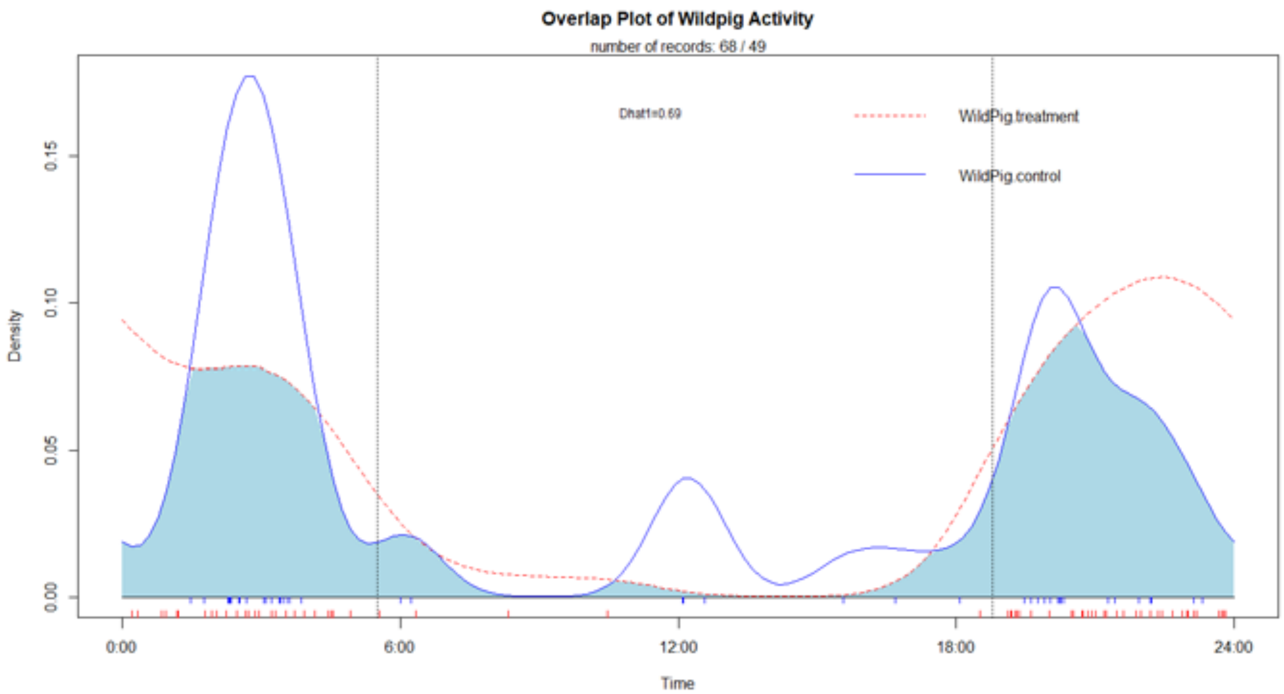
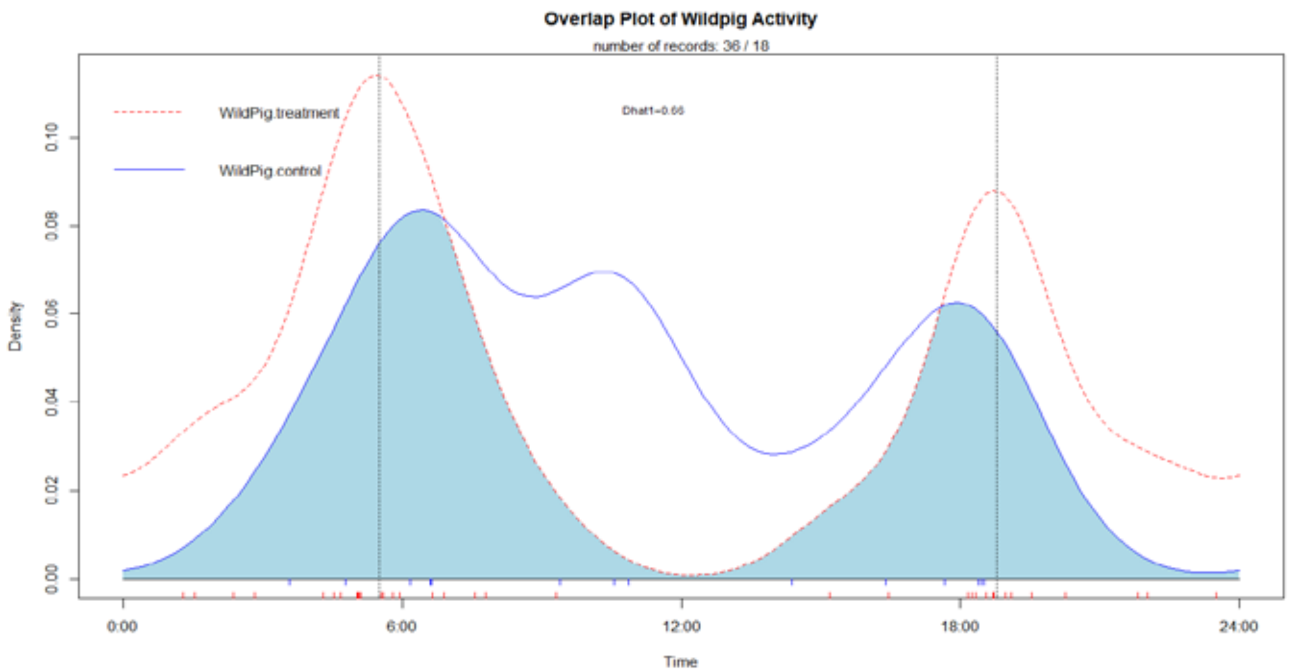


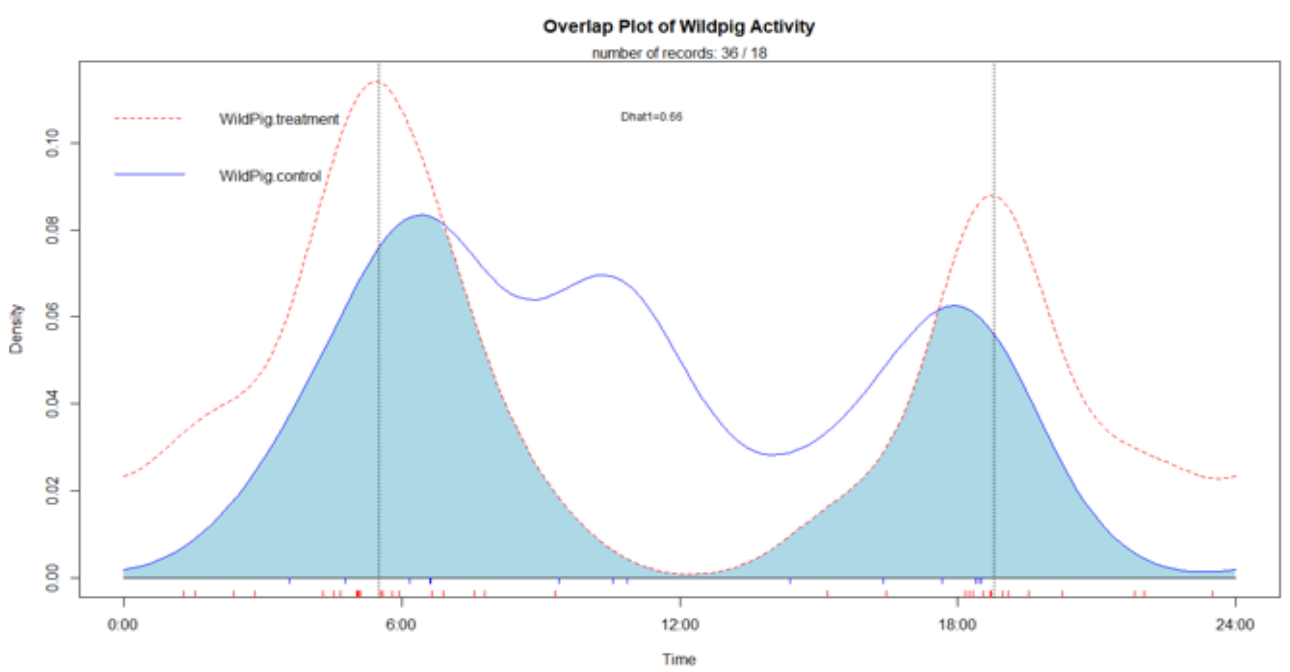
Figure A2F. Activity patterns of the wild pig (2022) - Summer



Activity patterns of the wild pig (2022) - Monsoon



Activity patterns of the wild pig (2022) - Winter



Annexure 3

Table A3. Number of livestock depredation cases recorded in the WWF and TCF interim relief scheme project

Site	Year							Mean	SE*
	2017	2018	2019	2020	2021	2022	Total		
Control	9	16	26	13	22	12	98	16.3	2.4
Treatment	5	11	19	10	16	8	69	11.5	1.9
Total	14	27	45	23	38	20	167		

*SE- Standard error

Annexure 4: Camera trap pictures of different mammal species recorded during study period

Hard-ground Barasingha female (*Rucervus duvaucelii branderi*)

Gaur (*Bos gaurus*)

Wild pig (*Sus scrofa*)

Indian leopard (*Panthera purdus*)

Nilgai (*Boselaphus tragocamelus*)

Indian crested porcupine (*Hystrix indica*)

Tiger (*Panthera tigris*)

Golden jackal (*Canis aureus*)

Livestock

Barking deer (*Muntiacus muntjak*)

Mouse deer (*Moschiola indica*)

Indian pangolin (*Manis crassicaudata*)

Annexure 5: Checklist of mammal species captured during the camera trap exercise

Sr.No	Species	Scientific Name	IUCN Status	WPA 1972 Status
1	Asian palm civet	*Paradoxurus hermaphroditus*	Least Concern	Schedule II
2	Barking deer	*Muntiacus muntjak*	Least Concern	Schedule III
3	Indian tiger	*Panthera tigris tigris*	Endangered	Schedule I
4	Chital	*Axis axis*	Least Concern	Schedule III
5	Domestic dog	*Canis lupus familiaris*	Domestic	Not listed
6	Four-horned antelope	*Tetracerus quadricornis*	Vulnerable	Schedule I
7	Golden jackal	*Canis aureus*	Least Concern	Schedule II
8	Hard-ground barasingha	*Rucervus duvaucelii branderi*	Vulnerable	Schedule I
9	Indian crested porcupine	*Hystrix indica*	Least Concern	Schedule IV
10	Indian fox	*Vulpes bengalensis*	Least Concern	Schedule II
11	Indian gaur	*Bos gaurus*	Vulnerable	Schedule I
12	Indian grey mongoose	*Herpestes edwardsii*	Least Concern	Schedule II
13	Indian hare	*Lepus nigricollis*	Least Concern	Schedule IV
14	Indian leopard	*Panthera pardus fusca*	Vulnerable	Schedule I
15	Indian Pangolin	*Manis crassicaudata*	Endangered	Schedule I
16	Jungle cat	*Felis chaus*	Least Concern	Schedule II
17	Mouse deer	*Tragulus meminna*	Data Deficient	Schedule I
18	Nilgai	*Boselaphus tragocamelus*	Least Concern	Schedule III
19	Northern palm squirrel	*Funambulus pennantii*	Least Concern	Not listed
20	Northern plains gray langur	*Semnopithecus entellus*	Least Concern	Schedule II
21	Rhesus macaque	*Macaca mulatta*	Least Concern	Schedule II
22	Rusty spotted cat	*Prionailurus rubiginosus*	Vulnerable	Schedule I
23	Sambar	*Rusa unicolor*	Vulnerable	Schedule III
24	Sloth bear	*Melursus ursinus*	Vulnerable	Schedule I
25	Small indian civet	*Viverricula indica*	Least Concern	Schedule II
26	Wild dog	*Cuon alpinus*	Endangered	Schedule I
27	Wild pig	*Sus scrofa*	Least Concern	Schedule III

Tarun Bhati

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