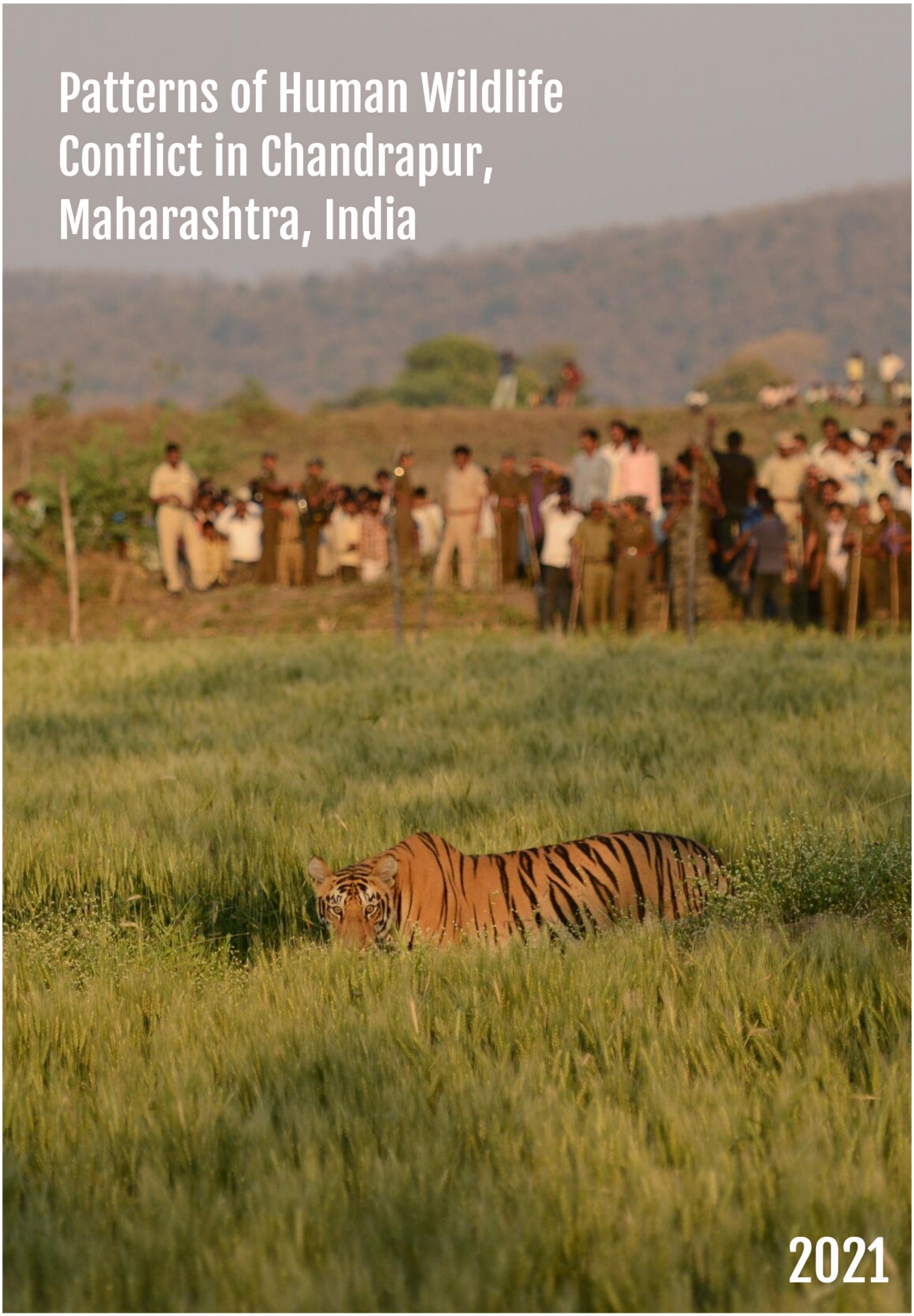
Patterns of Human Wildlife Conflict in Chandrapur, Maharashtra, India



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Report Title:
Patterns of Human-Wildlife Conflict in Chandrapur, Maharashtra, India

Project Title:
Understanding Large Carnivore Conflict Issues in Maharashtra for Suggesting Conflict Reduction Measures

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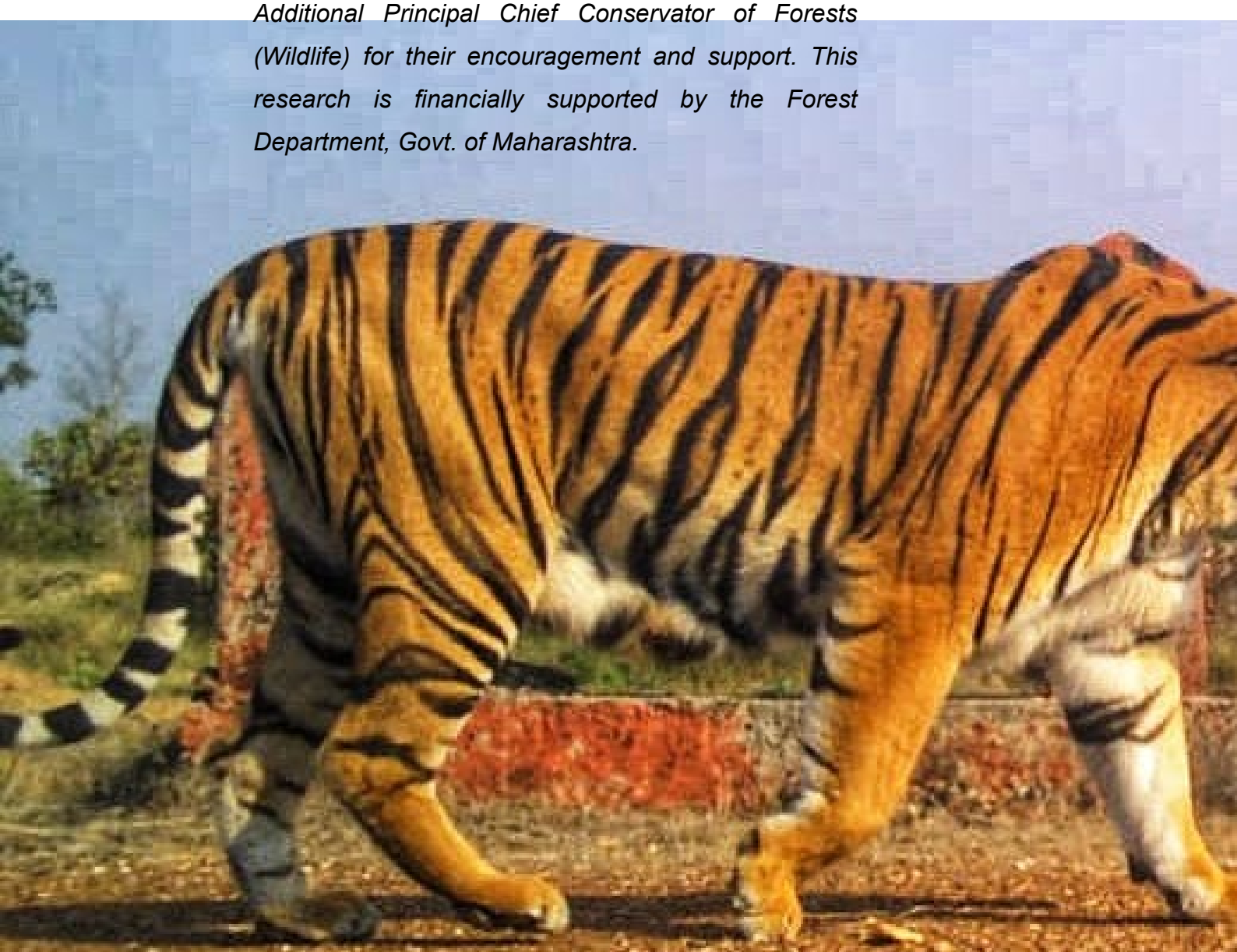

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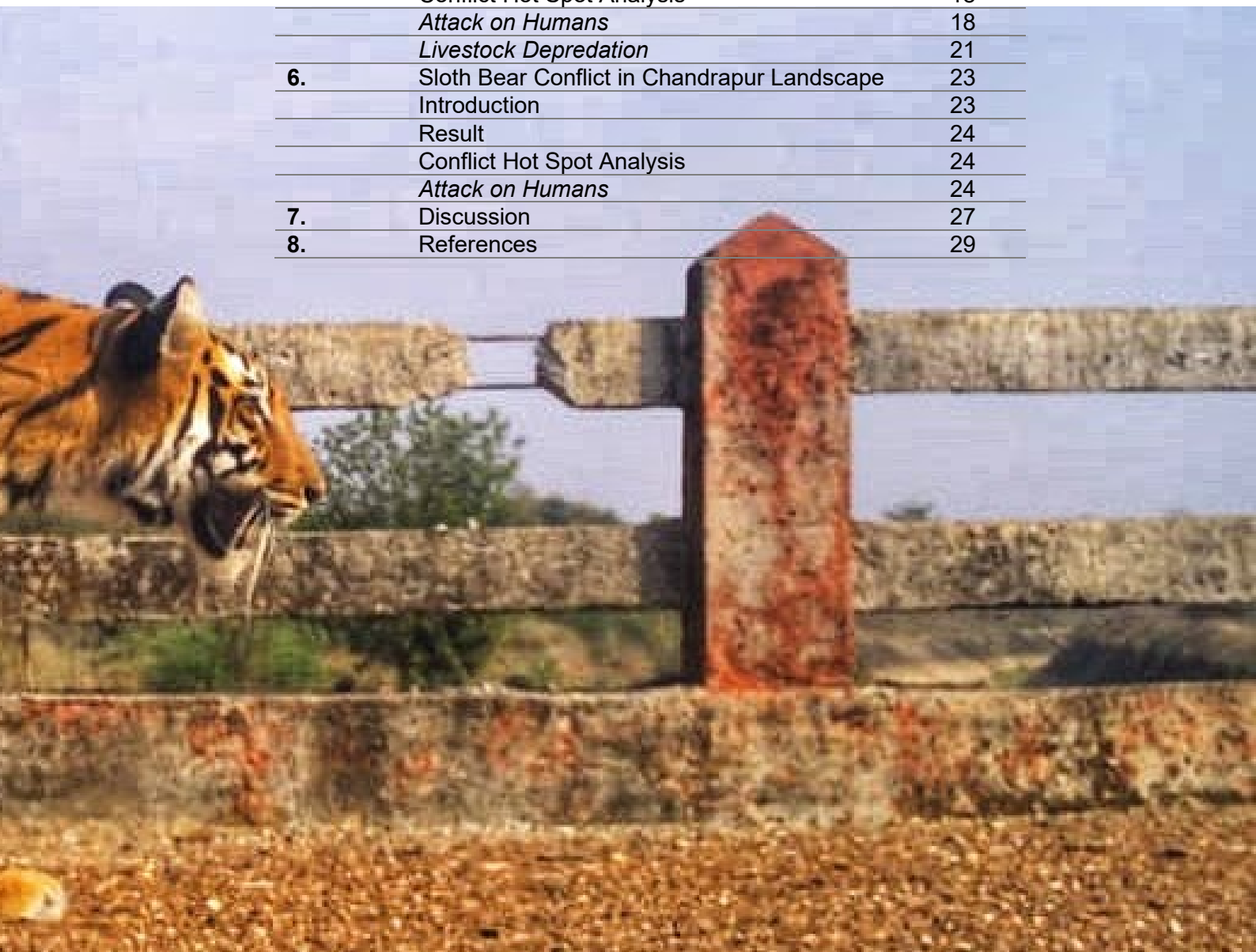

EXECUTIVE SUMMARY

Human-wildlife conflict (HWC) is the negative interaction between human or human property and wildlife and is a growing cause for concern among conservationists and scientists globally. Although HWC is a global phenomenon, there are certain differences in its manifestation as well as magnitude in developed versus developing nations. Developed regions of the world exhibit lower levels of direct dependence on forest ecosystems and their resources, as well as exclusionary management of the wildlife habitats. India, being a developing nation, is witness to an increasing intensity of human-carnivore conflict due to the fast-shrinking percentage of forest cover, that act as natural habitats of many carnivore species, due to a combination of factors including human population explosion, agricultural expansion, and large-scale developmental activities, leading to fragmentation and destruction of forest cover all across the country.

The Central Indian Landscape (CIL) is one of the regions of high tiger populations and density in India with 6 Tiger Reserves featuring heavily as source populations, including Tadoba Andhari, Pench, Kanha, Satpura, and Melghat Tiger Reserves. But there is a disproportionate decline in forest cover as well as quality, which means that even though the populations of large carnivores are thriving, there isn't enough pristine forest to support their growing numbers. This eventually leads to a spill-over of the carnivores into surrounding human-dominated landscapes (HDL). This acts as one of the major reasons for the burgeoning number of conflict cases between humans and large carnivores.

The Vidarbha Landscape (VL) of the state of Maharashtra is facing a similar decline in forest cover leading to an increase in conflict cases. Records of conflict incidents were collected from the Greater Tadoba Landscape (GTL) which covers the divisions of Brahmapuri, Chandrapur & Central Chanda, along with the Tadoba Andhari Tiger Reserve (TATR), in the Chandrapur Circle. Using these records, hotspots of livestock depredation and attacks on humans were mapped using a hotspot analysis tool in ArcGIS.

Various scientific and non-scientific methods continue to be tested to slow down the increasing rate of HWC across the world. One of the major hurdles in the implementation of a universal mitigation method to curb the number and impact of HWC is the heavy influence of local factors including topography, vegetation, and human demography of the region. This requires an intensive study of the patterns and causes of conflict in a given region.

Studying conflict hotspots and understanding the emerging spatial and temporal patterns is a quintessential step in the process of mitigating the HWC of any landscape. An important step in that direction is the establishment of a comprehensive database, which can be used for trend analysis and predictions.

The hot spot analysis of human-carnivore conflict for tigers, leopards, and sloth bears enables visualization of the spatial distribution of events of attacks on humans as well as livestock depredation by each species, hence aiding in the development of site-specific management strategies to mitigate the effects of human-carnivore conflict.

1. INTRODUCTION

Certain characteristics like large-sized home ranges, high trophic level, specialized niche, and dietary requirements, (Treves and Karanth, 2003) low population densities, and complex social behavior are inherent to large carnivores, making them particularly vulnerable to habitat losses and environmental changes (Terborgh, 1974).

With a shrinking supply of wilderness and growing recognition of the profound impact of top predators on any given ecosystem, the persistence of large carnivores in human-dominated landscapes (HDLs) has emerged as one of the greatest conservation challenges, since their presence in HDLs often sets the stage for negative interactions between them and humans, leading to conflict situations (Lamb et al., 2020).

These conflict situations have intensified over the past few decades due to explosive increase in human population leading to over-exploitation of resources, causing fragmentation and destruction of natural habitats of multitudes of species.

Large carnivores including tigers (*Panthera tigris*), leopards (*Panthera pardus*), pumas (*Puma concolor*), wolves (*Canis lupus*), and bears (*Ursus* sp.) (Jackson and Wangchuk, 1996; Karanth and Madhusudhan, 2002; Treves and Karanth, 2003) are observed to be involved in conflict with humans worldwide, leading to decreased tolerance by the masses (Karanth et al., 2012). Many of these large carnivores, including tigers, leopards, wolves, and bears, are also thought to be the main species tangled in conflict incidents across India.

India as a country is rich in biodiversity, but the richness is limited to small patches of forests dotted across the landmass, which amounts to approximately 5% of the total land available (Athreya et al., 2013). Most of these patches of forests occur inside Protected Areas (PAs) like National Parks (NP) and Wildlife Sanctuaries (WLS), which act as oases of natural habitats for the large carnivores. These PAs act as preserved habitats for a limited number of animals. But due to the increasing populations of both humans and animals, there is high stress on the natural resources in and around these PAs. This causes individuals to spill out into the surrounding HDLs, often causing them to come into contact with humans and their property, which sometimes sets the stage for the conflict to occur.

The Central Indian Landscape is similarly dotted with patches of PAs, which support a substantial amount of biodiversity, including multiple species of large carnivores. The populations of these species are generally seeing an upward trend due to the success of management and conservation strategies applied thus far.

The Central Indian Tiger Landscape (CITL) is considered to have one of the greatest potentials for long-term viable tiger conservation because of the presence of multiple source populations, including TATR, Pench, Kanha, Satpura, and Melghat Tiger

Reserves (Mondal et al., 2018), supports ~40% of the total tiger population in India (Jhala et al., 2015), and has been demarcated as a global priority for tiger conservation (Sanderson et al., 2010). As a result of successful conservation efforts, dispersing individuals from these source populations encounter human habitation and agricultural fields while traversing the landscape. This has led to a spate of conflict incidents involving individuals.

At present, management of conflict situations involves killing or capture of conflict individuals, and monetary compensation to affected humans. The effectiveness of these measures is questionable as there is an apparent rise in conflict cases, which could be a consequence of increased reporting of cases. The fact remains that few attempts have been made to evaluate the success of conflict mitigation strategies.

Thus, gaining a scientific understanding of the underlying factors and drivers associated with HCC in the state of Maharashtra is quintessential towards developing effective and cost-efficient strategies to manage and mitigate the effects of conflict in the state (Dickman, 2010; Karanth et al., 2012; Mateo-Tomas et al., 2012). Information from such a study will be crucial in making necessary changes at the policy level and implementing more effective and efficient management strategies.

Objectives

The project titled “Understanding Large Carnivore Conflict Issues in Maharashtra for Suggesting Conflict Reduction Measures” has been initiated under the aegis of the Maharashtra Forest Department to understand the causes and patterns of HCC, and the development of sustainable mitigation measures for the same, with the objectives:

1. Development of village-level database:
Preliminary data such as population status of humans and livestock, spatial characteristics like forest type, forest cover, location of a village with respect to forest, and different land uses such as agriculture, built-up and linear infrastructure (roads, transmission lines, canals) of the study sites would be collated and synthesized.

2. Assess the present status of large carnivores and prey in the area:
Field data on population status and trends of carnivores, and natural prey and livestock (both village-owned and feral) would be collected. The issue of feral livestock and the factors contributing to the abandonment of livestock would be investigated.

3. Assess diet of large carnivores:
To assess the diet of large carnivores in a human-dominated landscape

4. Assess villages’ vulnerability to conflict:
The vulnerability of villages to the conflict would be assessed based on factors such as the location of villages with respect to forest and corridors, the dependence of local livelihood on natural resources, and past patterns of conflict.

5. Suggest measures for mitigating conflict:
Site-specific conflict prevention, management and mitigation measures with quantifiable outcomes would be suggested based on analysis of the aforementioned factors and data.

6. Develop Early warning systems:
Early warning systems for animal detection and preventing potential conflict situations would be evolved. This would include identifying areas where carnivore coexistence is not possible at all and developing proactive measures to reduce conflict.

2. STUDY AREA

Vidarbha Landscape

The Vidarbha Landscape (VL) (Fig. 1) of Maharashtra lies to the eastern end of the state of Maharashtra, between Melghat Tiger Reserve to the North-west, Yavatmal district to the south-west, Navegaon Nagzira Tiger Reserve to the north-east and Gadchiroli district to the south-east, and lies between 18° 40' 32.45" N to 21° 41' 48.10" N and 77° 15' 39.93" E to 80° 54' 26.11" E (Habib et al., 2018). Vidarbha holds two-thirds of Maharashtra's mineral resources and three-quarters of its forest resources and is a net producer of power. The Vidarbha region of Maharashtra is an agriculturally important area. It also holds pockets of tiger habitats, many of which have been declared tiger reserves. It has a forest cover of 25,546 km^2 (Source: India State of Forest Report, 2019) and a minimum tiger number of 298 (Jhala et al., 2020) despite having a human population of more than 11.7 million (Source: Census of India, 2011).

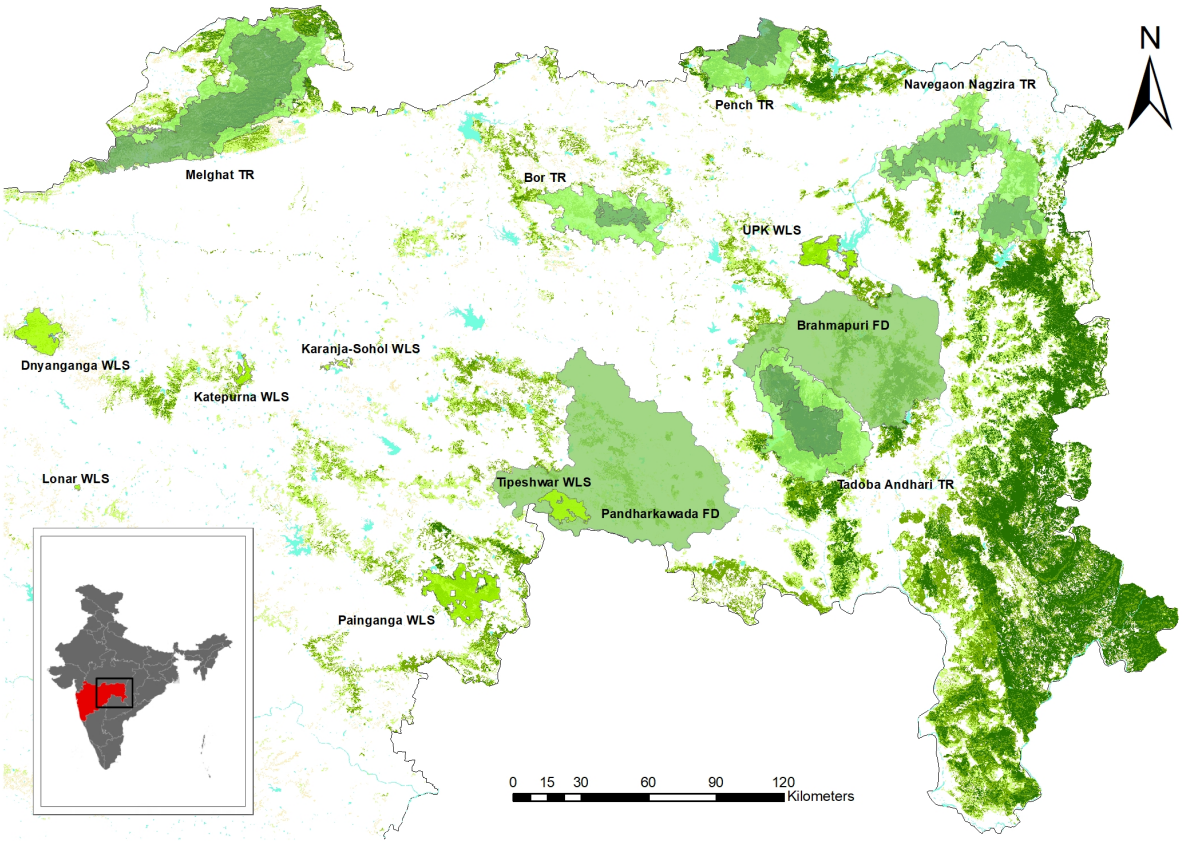

Fig 1: Map of Vidarbha Landscape, Maharashtra highlighting the Tiger Reserves as well as major human habitations

It consists of 8 Easternmost districts of Maharashtra: Amravati, Bhandara, Chandrapur, Gondia, Gadchiroli, Nagpur, Wardha, and Yavatmal. Vidarbha lies within the biogeographic zone of the Deccan Plateau and is mainly fertile, due to the presence of igneous rocks formed from volcanic eruptions more than 66 million years ago, causing the formation of the Deccan Traps in west-central India, making it

ecologically as well as economically important. The region consists of mainly scrubland and deciduous forests, as well as plantations (Champion and Seth, 1968). Wardha and Wainganga are the two main river systems in Vidarbha.

Chandrapur Forest Circle

The Chandrapur forest circle (Chandrapur district) (Fig 2) lies within the administrative division of Nagpur, between 19° 27' to 40° 43' North latitudes and 78° 48' to 80° 00' East longitudes (District Census Handbook, Census of India, 2011). It encompasses an area of about 11,443 km^2, and comprises Tadoba Andhari Tiger Reserve (TATR), Brahmapuri Forest Division, Chandrapur Forest Division, Central Chanda Forest Division. It houses a human population of 2,204,307 people (Source: Census of India, 2011), with a predicted increase to 2,512,910 by 2020 (District Census Handbook, Census of India, 2011). It also has a forest cover of about 4098 km^2 including scrublands (India State of Forest Report, 2019). Chandrapur circle lies within the biogeographic zone of the Deccan Plateau (Rodgers and Panwar, 1988) and the dominant vegetation type is dry deciduous forests (Champion and Seth, 1968). Elevation in the Chandrapur circle ranges from 64 to 930 m.

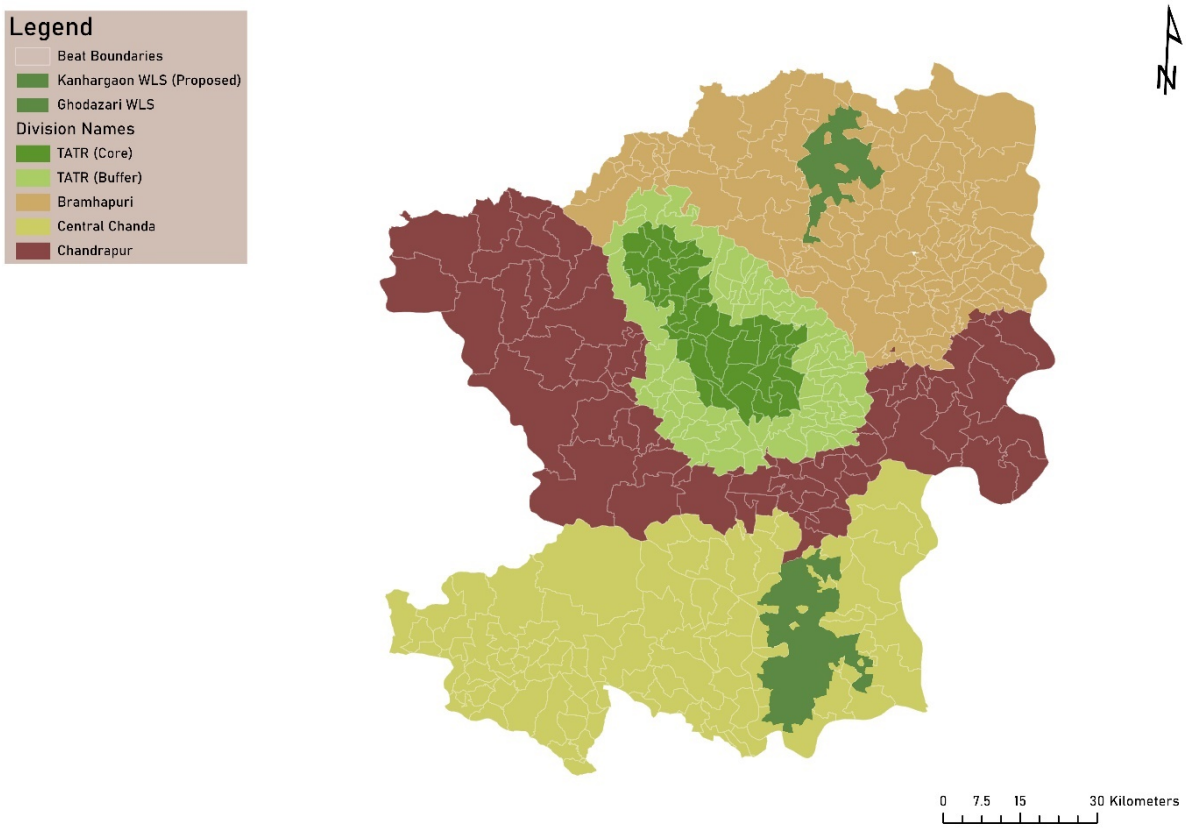

Fig 2: Chandrapur forest circle showing Protected Areas and Territorial Forest Divisions

The major Land Use or Land Cover in the study area are agricultural lands followed by forested areas. Although built-up areas constitute 2% of the total geographical area, human population densities in some of these settlements are 128 km^{-2} (Chandrapur, Census of India, 2011). Most of the forest here is managed by the Maharashtra Forest Department but with different mandates inside and outside PAs. Inside PAs, the mandate is to protect the wildlife and its habitat and to prevent poaching, while outside (territorial forests) it focuses on social forestry, production, and regulated extraction of forest products. In certain pockets, the Forest Development Corporation of Maharashtra (FDCM) manages, maintains, and markets monoculture stands of valuable trees like teak and bamboo.

3. METHODOLOGY

Data collection

The Maharashtra Forest Department financially compensates for livestock depredation, human death, and injury caused by carnivores. The livestock owner or the victim's family should report the kill and locate the carcass to the forest department official within 48hrs of incidence. After verification by Forest Department officials, livestock owners (or immediate family members with respect to human death and injury) receive compensation as per the rules of the scheme. The compensation records from 2005 to March 2020 were used to investigate the patterns of attacks on humans and livestock depredation mainly in the Chandrapur District of the Vidarbha Landscape, including the territorial divisions of Brahmapuri, Chandrapur, and Central Chanda, along with cases recorded in Tadoba Andhari Tiger Reserve. Spatial and temporal details of the incidents which included the GPS location or village name, and date of the incident, the type of incident (livestock depredated or attacks on humans), and the responsible predator were extracted from the records. The records of incidents of human-carnivore conflict collected by the forest department were used for further analysis.

Data Analysis

The livestock depredation (from 2010 to 2020) and human injury/death (from 2005 to 2020) recorded formed the main dataset of this study. Since a portion of the reported incidents did not have GPS location data upon verification, the incidents were assigned to village polygons based on the available location data. The annual frequency of conflict was also calculated for each polygon layer, which helps in gaining a better understanding of the pattern of repetition of conflict in each year. For better visualization of the spatial distribution of conflict incidents, hotspots were mapped.

Mapping Conflict Hot Spot

Annual spatial conflict hotspot mapping was done using the hot spot tool in ArcGIS 10.8 (ESRI 2020). We used livestock depredation and attack on humans for this analysis. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots) using the Getis-Ord Gi* statistic (Ord and Getis, 1995). It aggregates the incidents into weighted features (in our case forest ranges). This was done to get the visual insight of the change of conflict hot spots (the area where conflict incidents tend to occur) and cold spots (the area where conflict incidents tend not to occur) in the study area for the past 15 years.

4. GENERAL RESULTS

The data collected from different Forest Divisions (Wildlife and Territorial) was used for further analysis of human-carnivore conflict. A total of 9434 incidents of conflict were recorded, out of which 8506 were attributed to conflict with the tiger, leopard, and sloth bear. Table 1 shows the data collected from each division. 1124 incidents of carnivore attacks on humans were recorded from the study area, while 7426 incidents of livestock depredation were reported.

Table 1: Number of reports of human-carnivore conflict from study area for tiger, leopard, sloth bear

Division	Reported incidents	Reported years
TATR	1324	2008-2020
Brahmapuri FD	5284	2005-2020
Chandrapur FD	177	2007-2020
Central Chanda FD	1721	2009-2020

Table 2 shows the species-wise distribution of attacks on humans and livestock depredation. The spatial information along with these numbers was used to plot the incident points, wherever possible, to better understand the spatial distribution of occurrence of conflict.

Species	Attacks on humans	Livestock depredation
Tiger	181	5356
Leopard	250	2147
Sloth bear	91	2

The incidents containing GPS locations of attacks on humans and livestock depredation were plotted using ArcGIS (Fig 3 and 4).

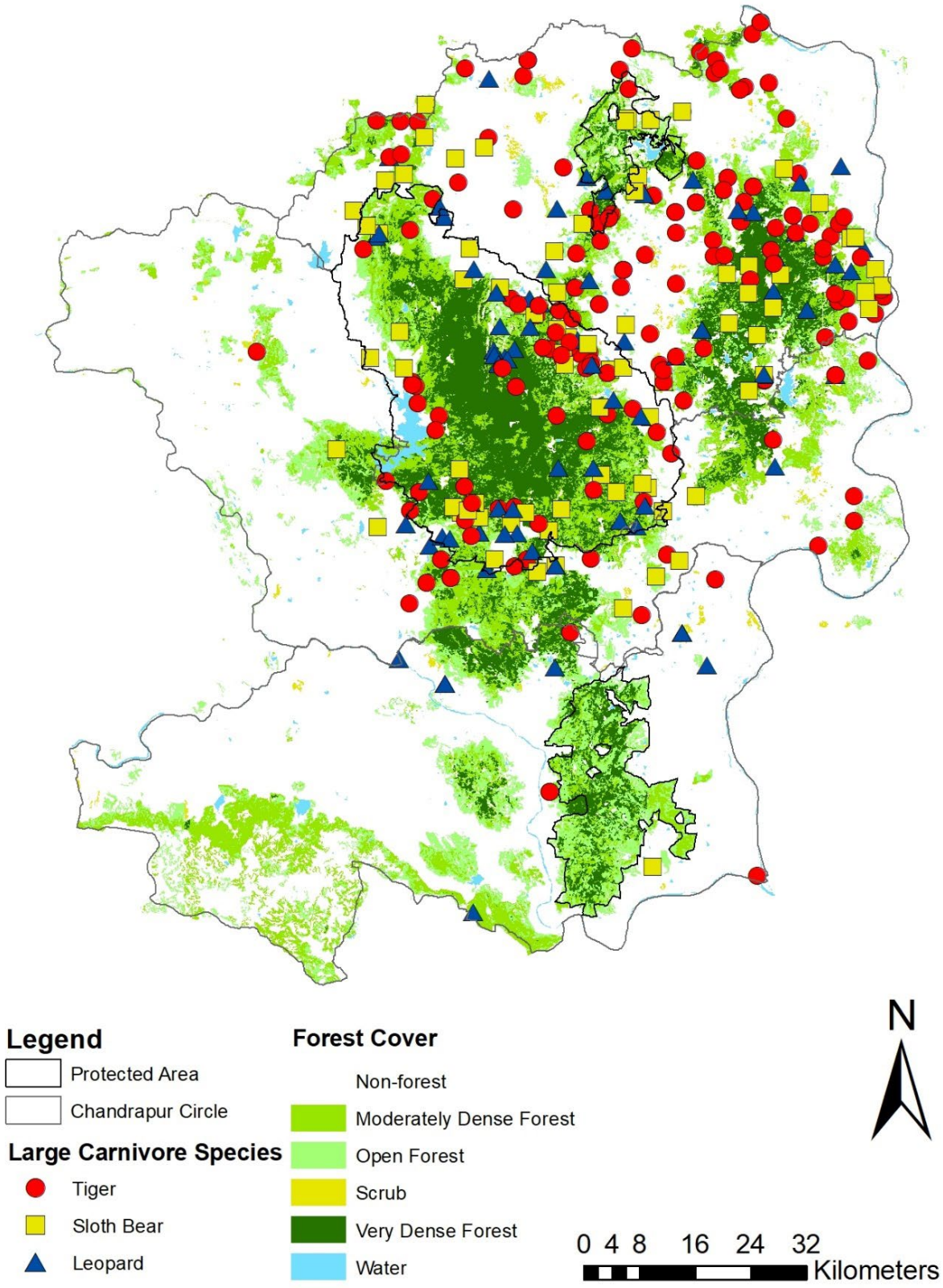

Fig 3: Map of Chandrapur showing incidents of attacks on humans by large carnivores

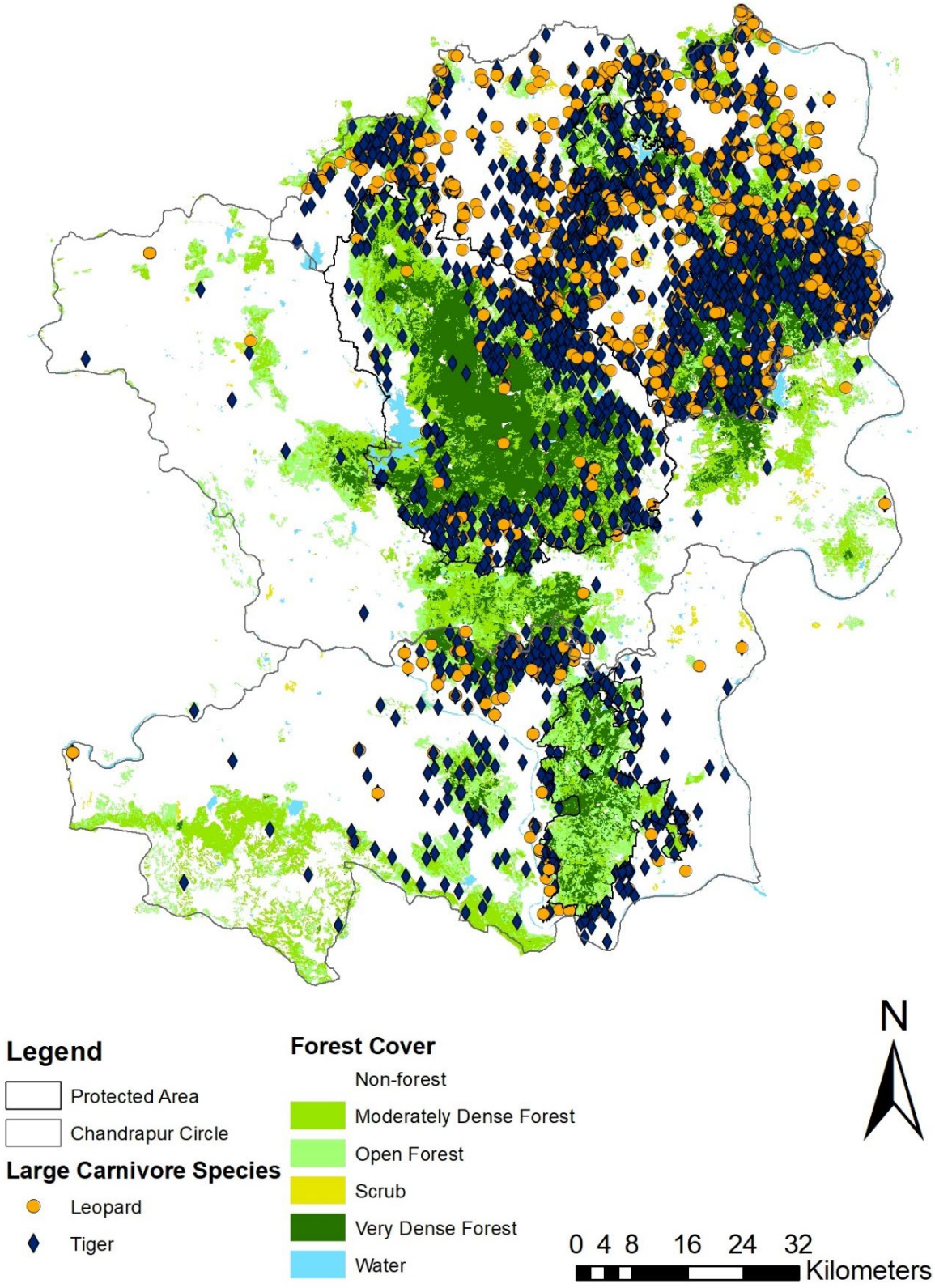

Fig 4: Map of Chandrapur showing incidents of attacks on livestock by large carnivores

5. TIGER CONFLICT IN CHANDRAPUR LANDSCAPE

Introduction

The Indian subcontinent is presently one of the last strongholds of wild tiger populations. However, towards the end of the British Colonial era in India, the wild tiger numbers had been all but decimated due to hunting as well as habitat destruction on a large scale (Mitra, 2019). Due to extensive conservation efforts focused on the tiger, its co-predators, prey, and habitat, under the ambit of the Project Tiger (established in 1973) and the Wildlife (Protection) Act, 1972, India is currently home to more than 60% of the global tiger population (Tiger Action Plan, 2010; Jhala et al., 2021). This population is restricted mostly to a PA network which are isolated patches of habitat in a matrix of ecologically unsustainable land uses (Jhala et al., 2015; Thapa et al., 2017). India has over 980 PAs, out of which 51 are Tiger Reserves (ENVIS, 2020). The Tiger Reserves in India have an average size of 1456 km^2 (492 to 5907 km^2) and while the average home range of an adult male tiger is highly variable, being heavily influenced by various ecological factors, that of an adult female is 40-50 km^2 (Majumder et al., 2012; Jhala et al., 2021). Since a demographically viable tiger population requires a minimum of ~20 breeding females, which amounts to a population of 75-100 tigers, it is safe to say that a large number of the Tiger Reserves in India (~42%) fall short of the area required to host a demographically viable population (Bisht et al., 2019; Jhala et al., 2021). Thus, tiger populations are often confined within small Protected Areas with only a few of them connected via habitat corridors that permit tiger movement (Qureshi et al. 2014). However, since corridor habitats in India are not protected areas, most are in various stages of degradation due to unsustainable human use and developmental projects (Jhala et al., 2020).

The Central Indian Landscape (CIL) has several PAs and Tiger Reserves and shows the most extensive occupancy by tigers (Reddy et al., 2017). It supports about ~35 % of the total tiger population in India and has been demarcated as a global priority landscape for tiger conservation (Wikramanayake et al., 2004; Jhala et al., 2020). The forest patches and corridors in CIL, however, are under high anthropogenic pressure due to encroachment into forest lands, mining and irrigation projects, and various developmental activities (Joshi et al., 2013; Reddy et al., 2017). Tiger populations thus face grave risks of being involved in conflict scenarios while utilizing regions outside PAs.

The Eastern Vidarbha Landscape (EVL) in the state of Maharashtra forms the connecting link between central and southern Indian tiger populations (Habib et al., 2017). EVL also presents a high human-wildlife interface of 37,017.37 km in the form of forest-agriculture edge which forms a breeding ground of human-tiger conflict in the form of cattle depredation, attacks on humans as well as mortality of wild animals (Habib et al., 2017). Of the several Tiger Reserves in CIL, Tadoba Andhari Tiger Reserve (TATR) is one of the largest in the state of Maharashtra and lies in the EVL region. It acts as an important source population of various carnivores, with

connectivity to other PAs in the region (Habib et al., 2019). It has also seen increasing tiger numbers due to focused conservation efforts in the area, which has resulted in the spilling over of individuals into the surrounding HDL (Habib et al., 2021). This has led to the formation of conflict hotspots in and around TATR, as a result of increased human-tiger interaction (Dhanwatey et al., 2013).
Given the importance of conservation of tiger populations in TATR and its surrounding areas within CIL, it is imperative to understand patterns of human-tiger conflict in this region, to be able to minimize damage to human as well as tiger populations (Morehouse and Boyce, 2017).

Result

A total number of 5537 incidents of attacks on humans by tigers were reported from the year 2005 to March 2020 from the Chandrapur Forest Circle, out of which records for attacks on humans may be found from 2005, while livestock depredation cases are found only from 2010. 181 incidents of attacks of humans were reported, along with 5356 incidents of livestock depredation.

Conflict with tigers made up approximately 58% of the total conflict incidents in Vidarbha from 2005 to early 2020 and peaked during the years 2015-18 (Fig. 5).

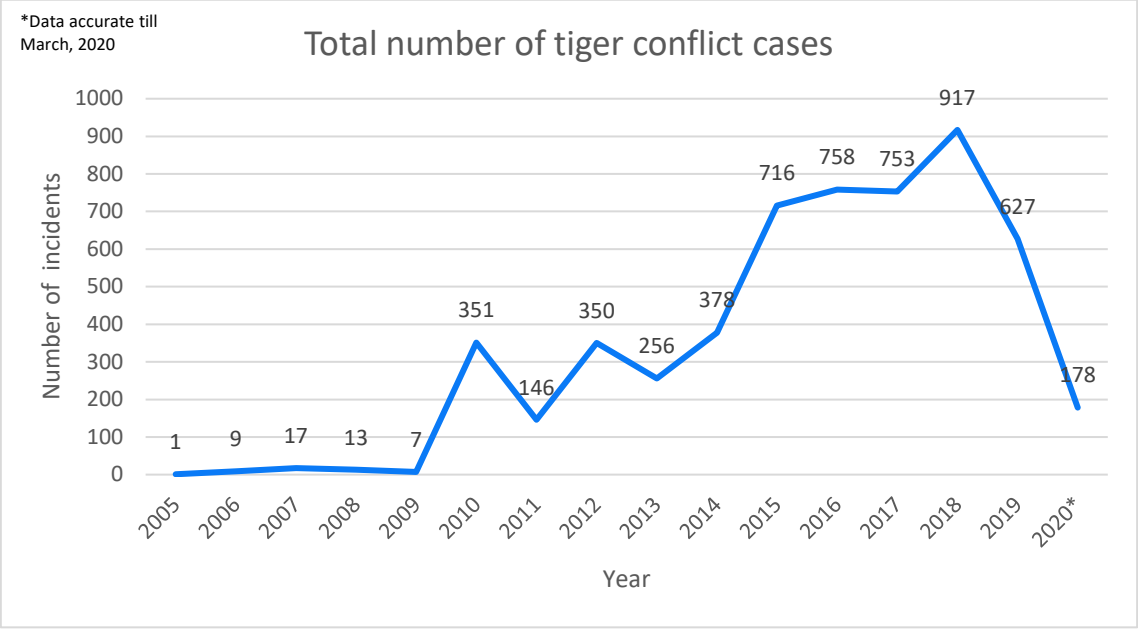

Fig. 5: Year-wise total number of tiger conflict cases (both livestock depredation and attacks on humans) compiled in Vidarbha Landscape from 2005 to 2020

Conflict Hot Spot Analysis

Attack on humans

Hot and cold spots for the incidents and recurrences of attacks on humans from 2005-2020 are given in Figures 6 and 7. Patches of hot spots are concentrated in and around

areas that connect forest patches in Brahmapuri and the buffer region of Tadoba Andhari Tiger Reserve.

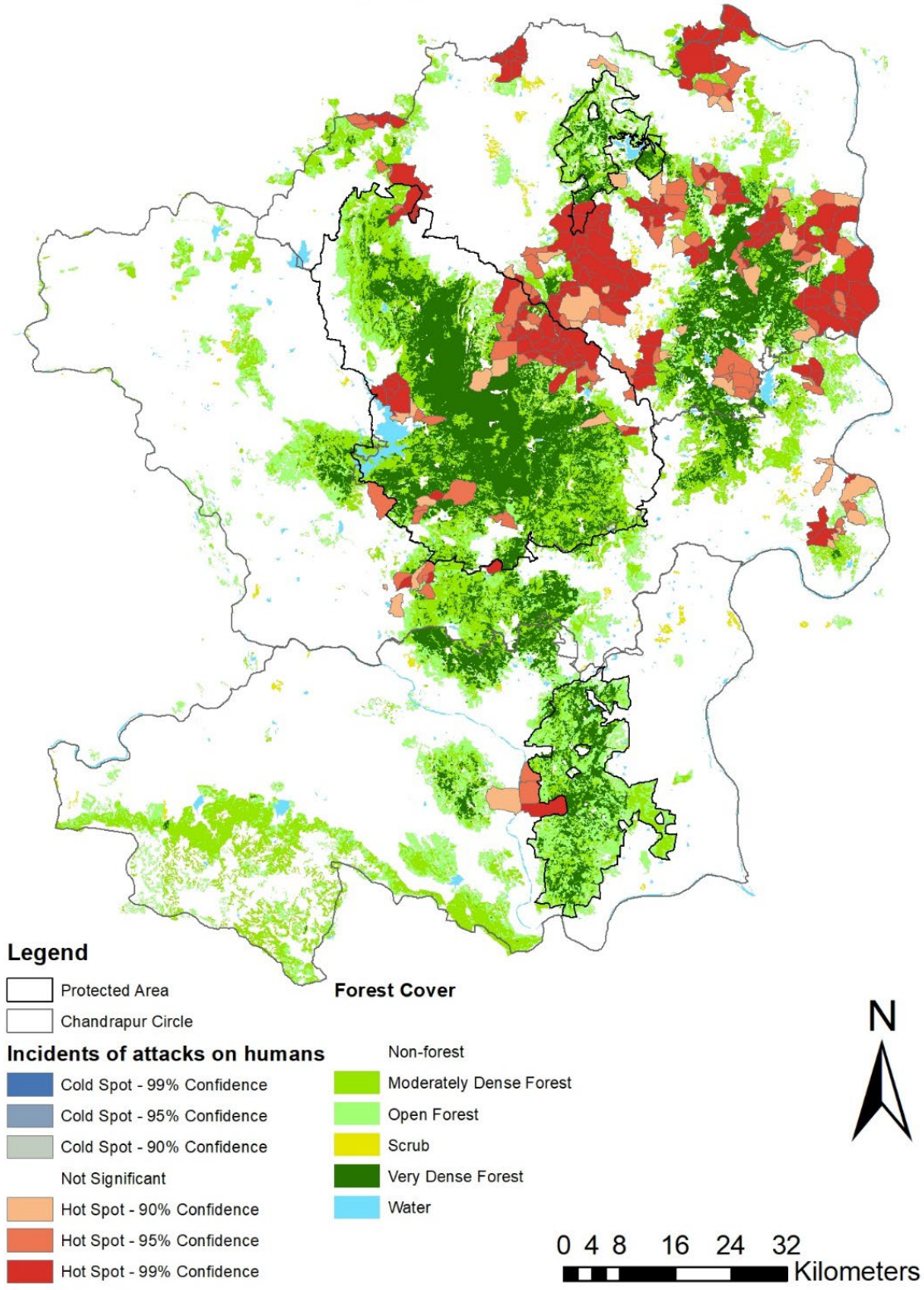

Fig 6: Map of Chandrapur showing hot and cold spots for incidents of attacks on humans by tigers

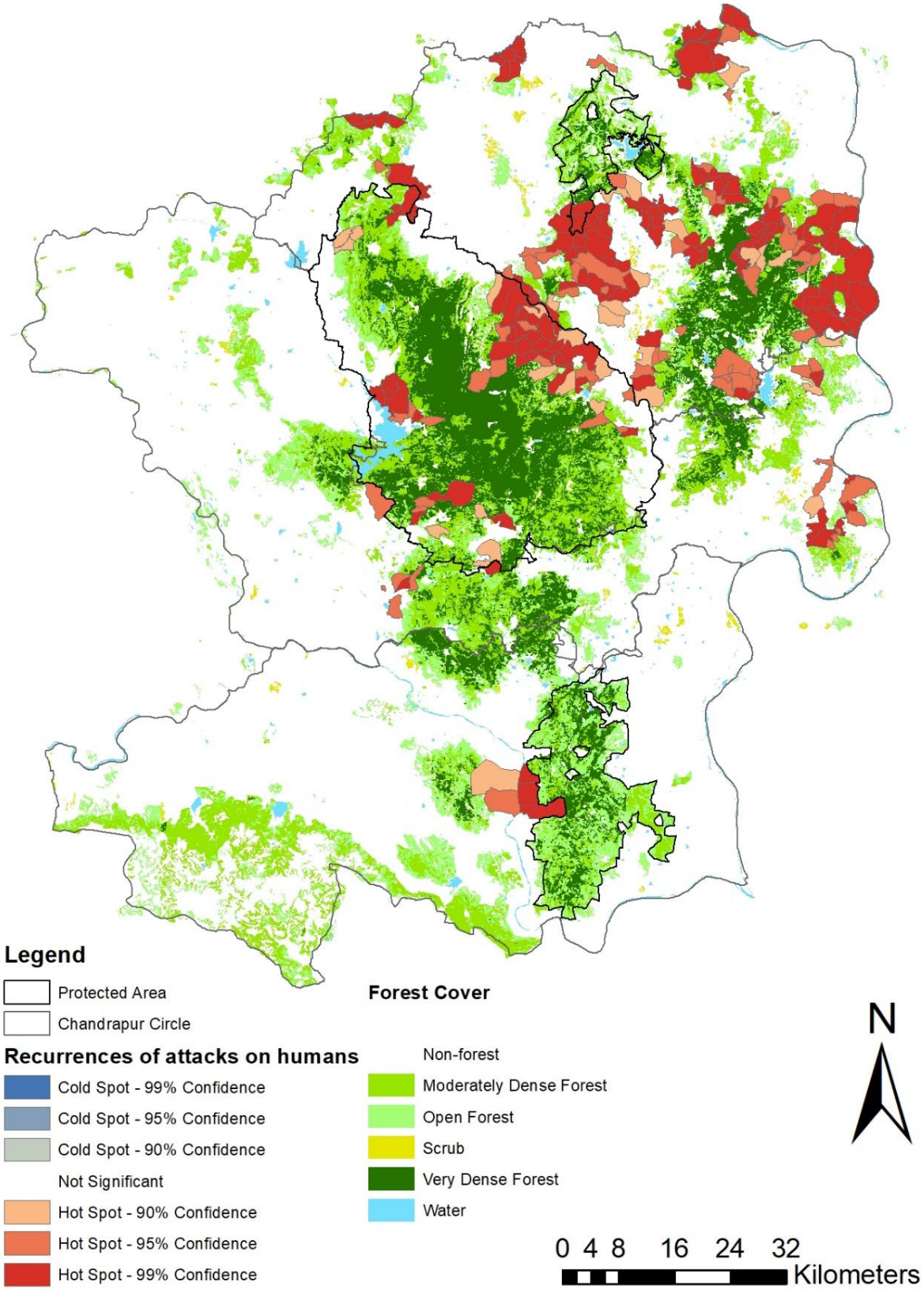

Fig 7: Map of Chandrapur showing hot and cold spots for recurrences of attacks on humans by tigers

Livestock Depredation

We have mapped spatial hot spots of livestock depredation from 2010 to 2020 by tigers in figures 8 and 9, with the maximum number of hot spots concentrated in and around the tiger corridors in the region.

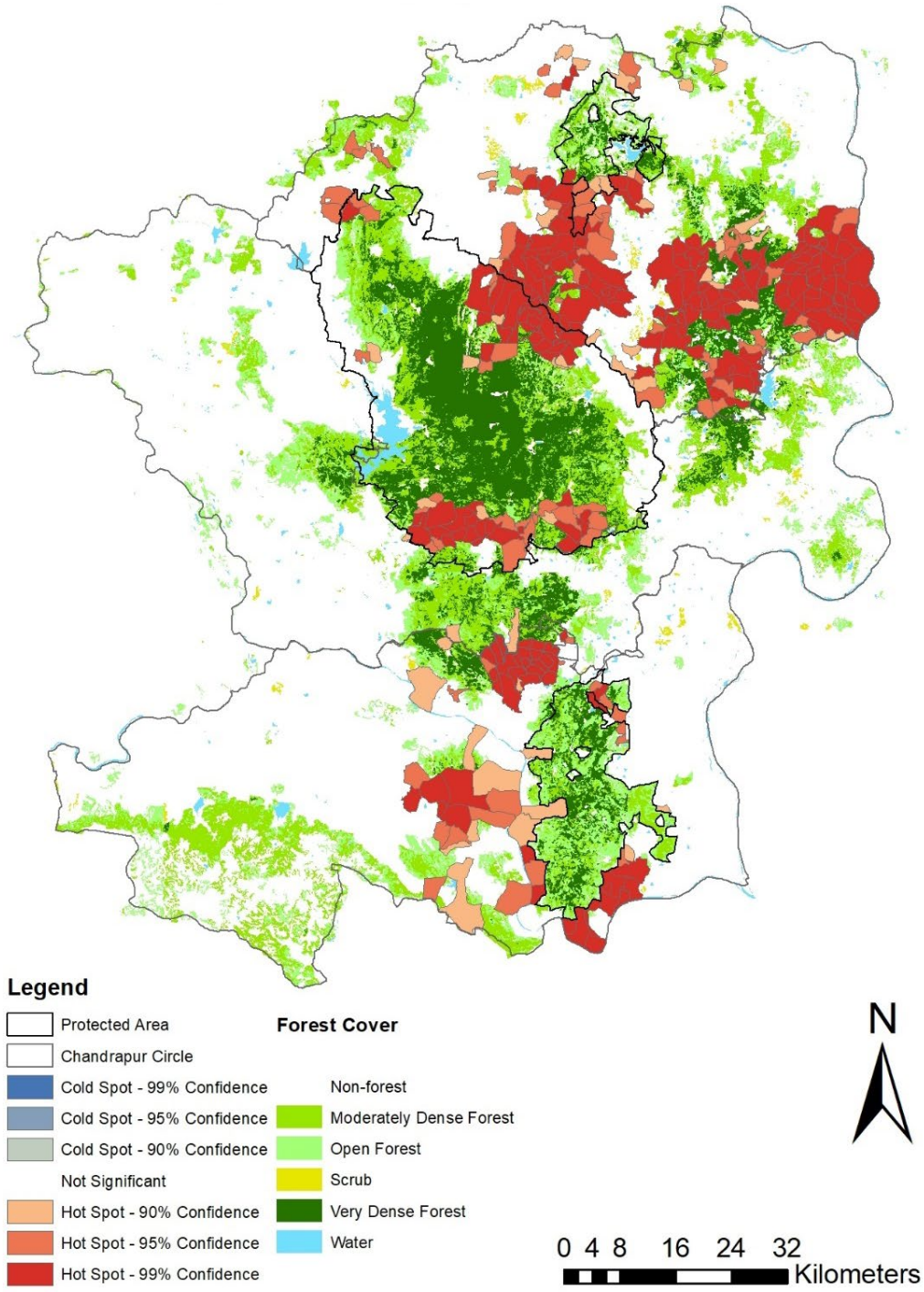

Fig 8: Map of Chandrapur Circle showing the confidence of hot and cold spots of livestock depredation incidents

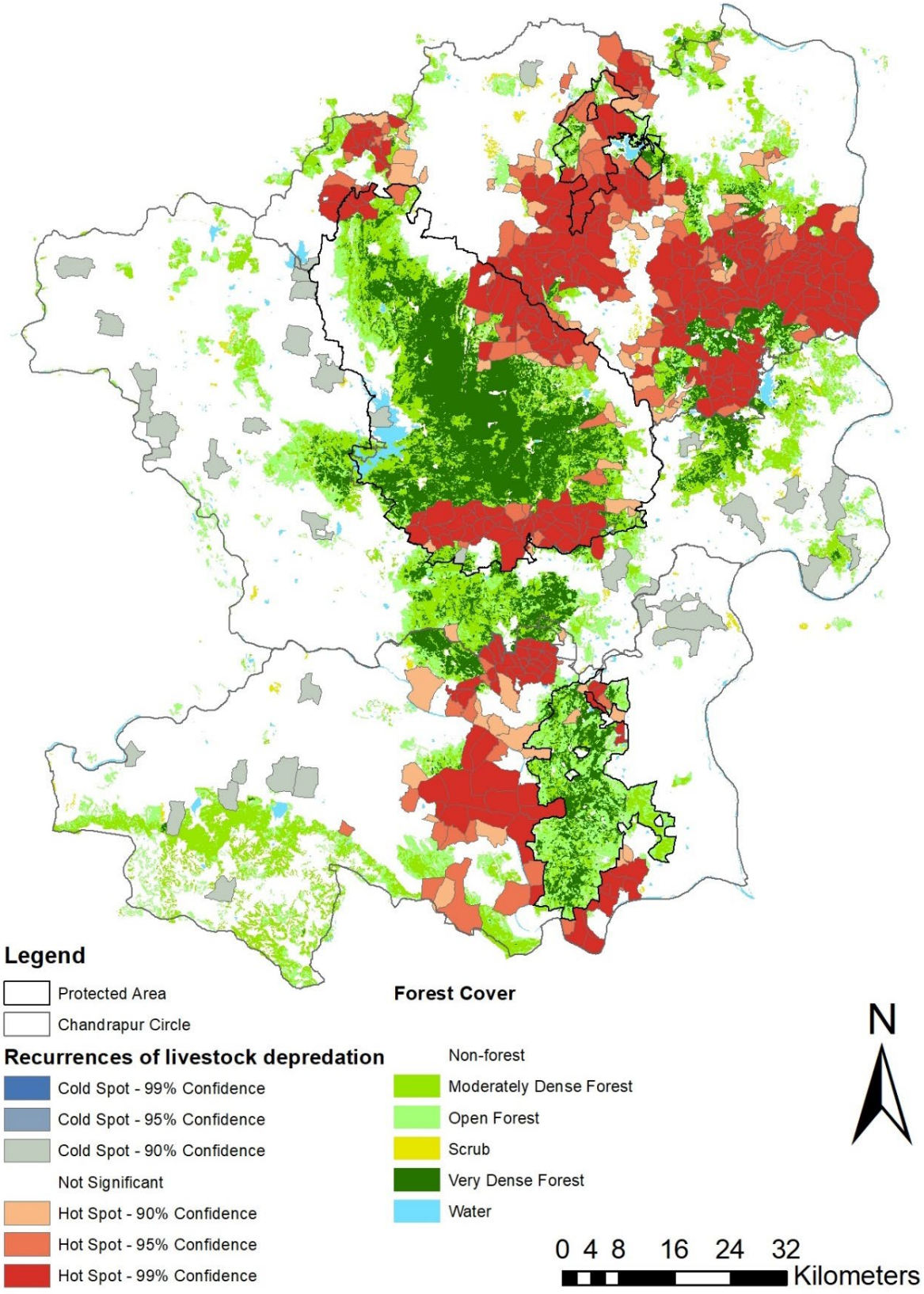

Fig 9: Map of Chandrapur Circle showing the confidence of hot and cold spots of livestock depredation recurrences

6. LEOPARD CONFLICT IN CHANDRAPUR LANDSCAPE

Introduction

Of the four species of large felids in the Indian subcontinent, the leopard (*Panthera pardus fusca*) is one of the most common, versatile, and resilient (Ghosal et al., 2013; Jhala et al., 2020). It has, however, been eradicated from vast tracts of its former range, along with a drastic decline in existing genetically separate subpopulations (Bhatt et al., 2020). Leopards in India are widely distributed except above the tree line in the Himalayas, the desert regions in the West, and the Sundarbans in the East (Jhala et al., 2020). Despite extensive distribution, leopard habitats are being increasingly fragmented, with fragment sizes that cannot sustain a sizeable population of leopards (Jhala et al., 2020). Combined with their versatile and highly adaptable habits, this has increasingly resulted in leopards utilizing HDLs surrounding many PAs (Athreya et al., 2011; Kshettry et al., 2018). Unlike tigers, which prefer forest areas free from human interference, leopards are highly adaptable and are capable of living on the fringes of human habitation, especially in India, where the interface between forests and rural habitations is a continuum (Naha et al., 2018; Yadav et al., 2020).

Tigers and leopards are known to have spatially and temporally segregated tactics, in order to reduce interference competition (Miller et al., 2015; Kumar et al., 2019). An inverse relation between tiger and leopard densities was observed in Rajaji National Park and Kaziranga Tiger Reserve, which reflects significant displacement interactions, leading to the leopards being marginalized and often out-competed by tigers. This is believed to have induced a dietary shift in leopards to include domestic livestock, especially in areas with a lack of natural prey (Kala and Kothari, 2013; Malviya and Ramesh, 2015).

Studies claim that local communities perceive leopards to be a bigger threat than tigers due to their intrusive habits and highly adaptive nature. A study based in Northeast India, also discovered a high proportion (>60%) of domestic animals in the diet of local leopards, including cattle and goats, especially in high conflict regions. These studies highlight the behavioral plasticity displayed by leopards which enables them to survive in HDLs (Habib et al., 2021). Today, major human-leopard conflict (HLC) hotspots occur in the Indian states of Uttarakhand, West Bengal, Himachal Pradesh, Gujarat, and Maharashtra (Naha et al., 2018).

Leopards are widely distributed in the Central Indian Landscape (CIL), and these populations of leopards also show the highest genetic diversity, since they are connected to leopard populations in the rest of the country (Jhala et al., 2020). However, due to the availability of a highly fragmented habitat for the leopard populations in CIL, leading to increased utilization of HDLs, high intensity of HLC is also reported from the region.

Tadoba Andhari Tiger Reserve (TATR) is one of the largest tiger reserves (TR) in Maharashtra and is situated in the Eastern Vidarbha Landscape (EVL) of the state. The TR, along with its surrounding Forest Divisions of Chandrapur district, form an integral part of the Central Indian highlands that ensure the integrity and contiguity of populations of large carnivores like leopards throughout the country (Habib et al., 2020a). The surrounding regions outside TATR form a mosaic landscape of human-use landforms (including agricultural lands and built-up area), and forest patches,

which act as refuges for leopards. Leopard populations in these regions have adapted to a diet of domesticated animals, leading to increased instances of HLC.

Result

Out of the 2397 records of conflict by leopards collected from Chandrapur Forest Circle, 250 were attacks on humans and 2147 were livestock depredation incidents. Records of attacks on humans dated from 2009 to 2020, while those of livestock depredation dated from 2010 to 2020.

Conflict with leopards made up approximately 30% of the total conflict incidents in Vidarbha from 2009 to early 2020, and peaked during the years 2015 and again in 2018 (Fig. 10).

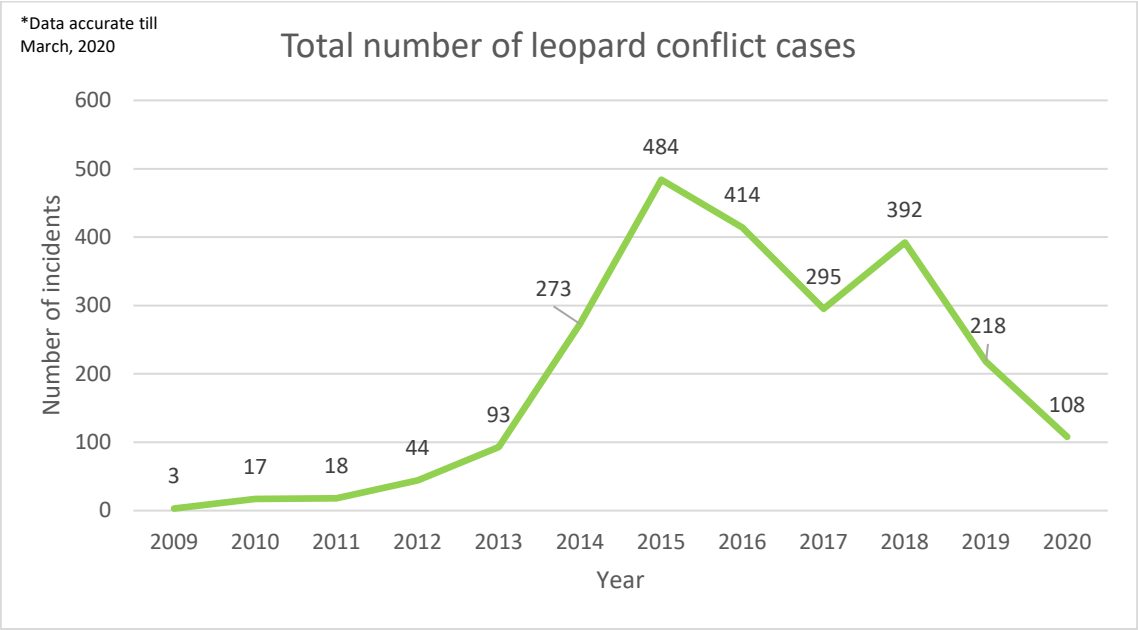

Fig. 10: Year-wise total number of leopard conflict cases (both livestock depredation and attacks on humans) compiled in Vidarbha Landscape from 2009 to 2020

Conflict Hot Spot Analysis

Attack on humans

Hot and cold spots for the incidents and recurrences of attacks on humans from 2009-2020 are given in Figures 11 and 12. Patches of hot spots are scattered across Chandrapur Forest Circle.

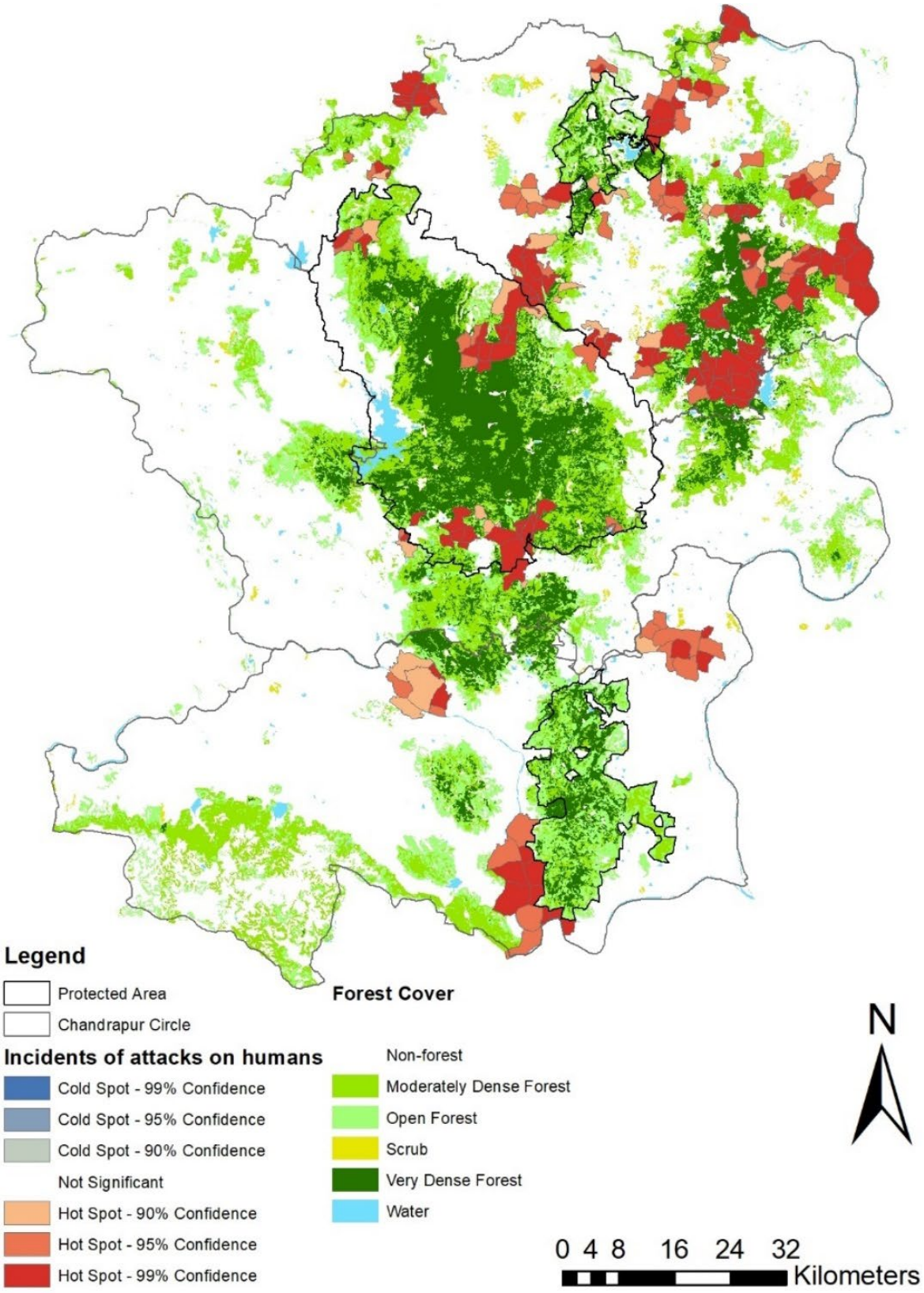

Fig 11: Map of Chandrapur showing hot and cold spots for incidents of attacks on humans by leopards

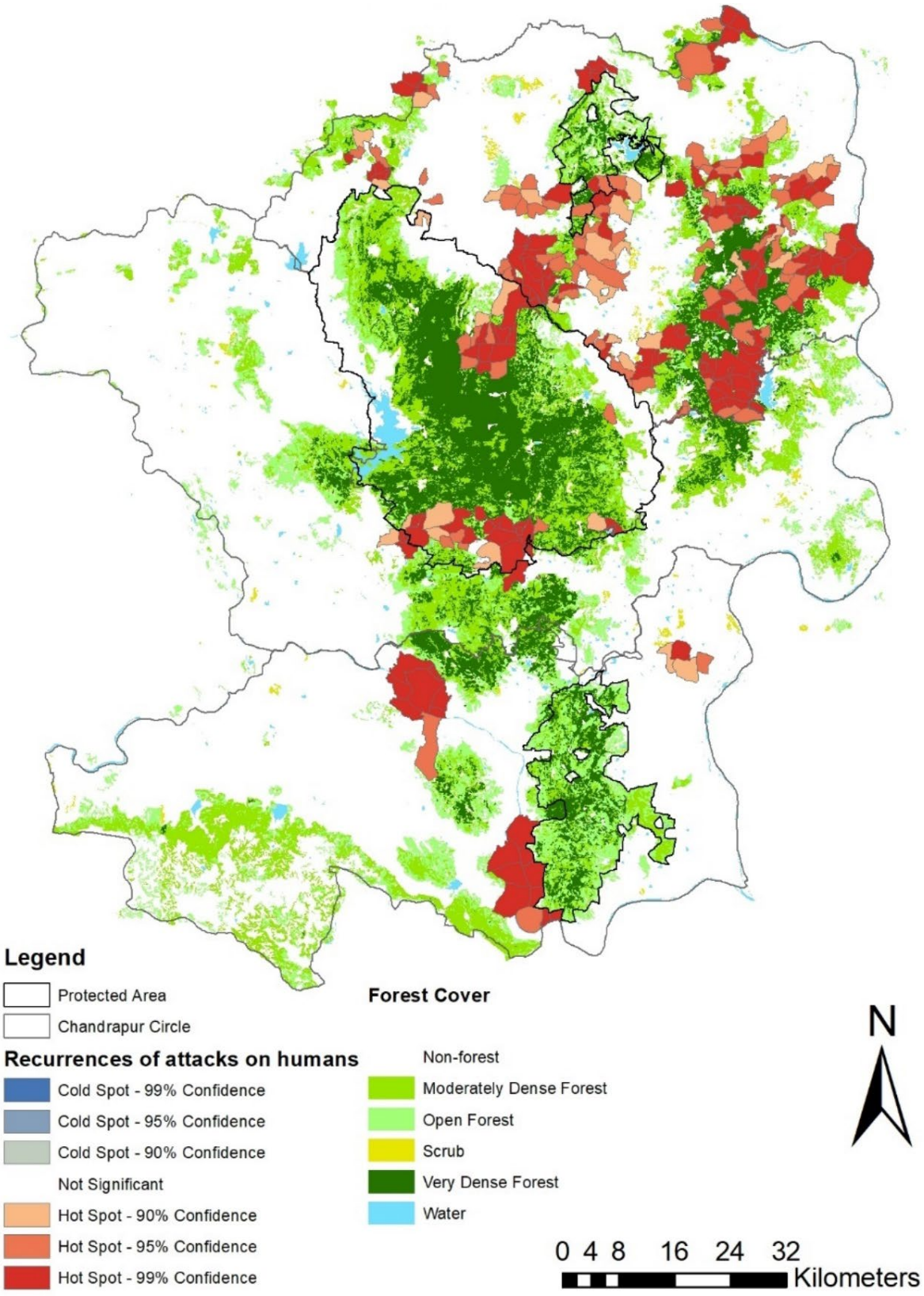

Fig 12: Map of Chandrapur showing hot and cold spots for recurrence of attacks on humans by leopards

Livestock Depredation

We have mapped spatial hot spots of livestock depredation from 2010 to 2020 by leopards in Figures 13 and 14, with the maximum number of hot spots concentrated in and around the forest patches in the Brahmapuri Forest Division.

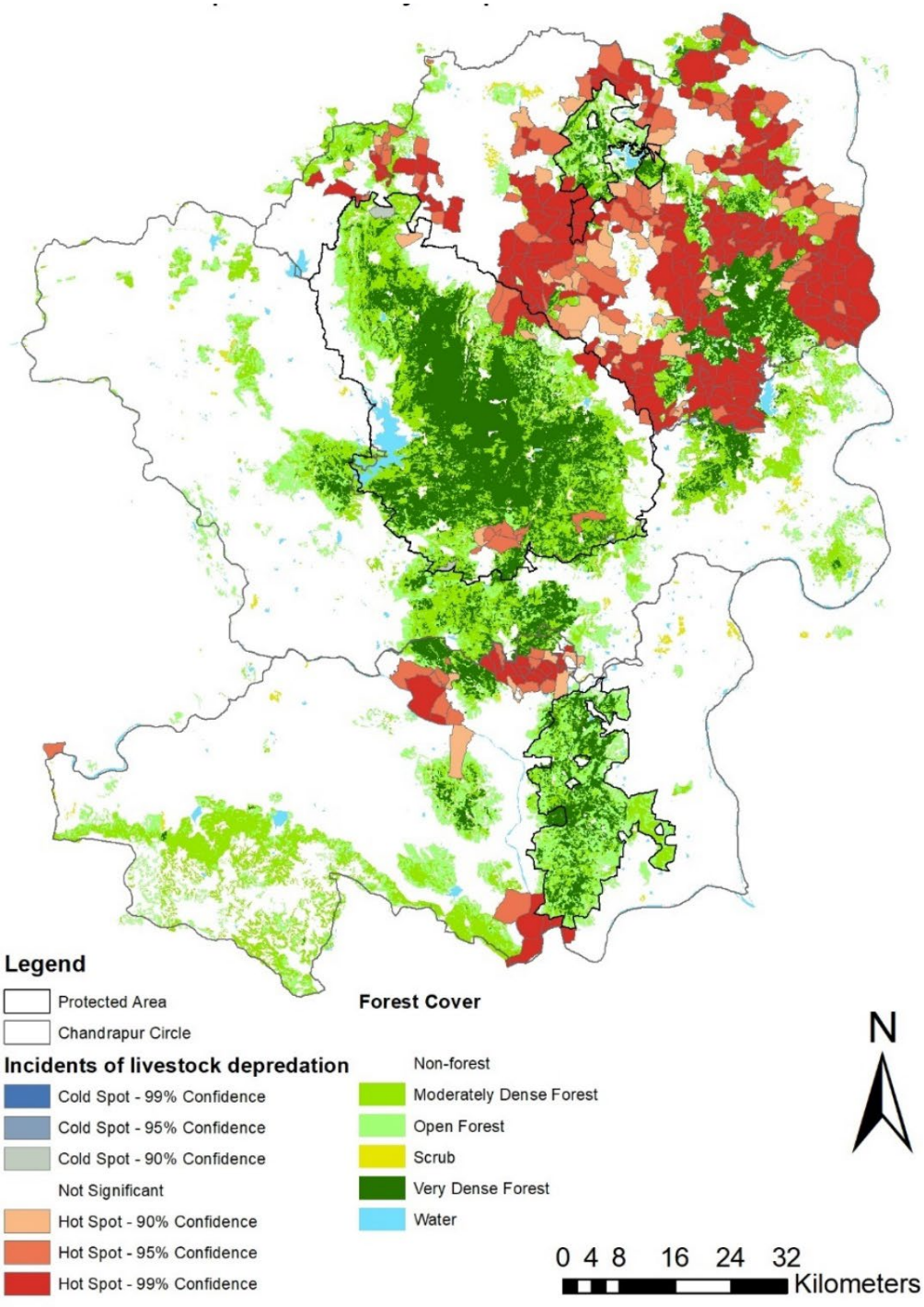

Fig 13: Map of Chandrapur showing hot and cold spots for incidents of livestock depredation by leopards

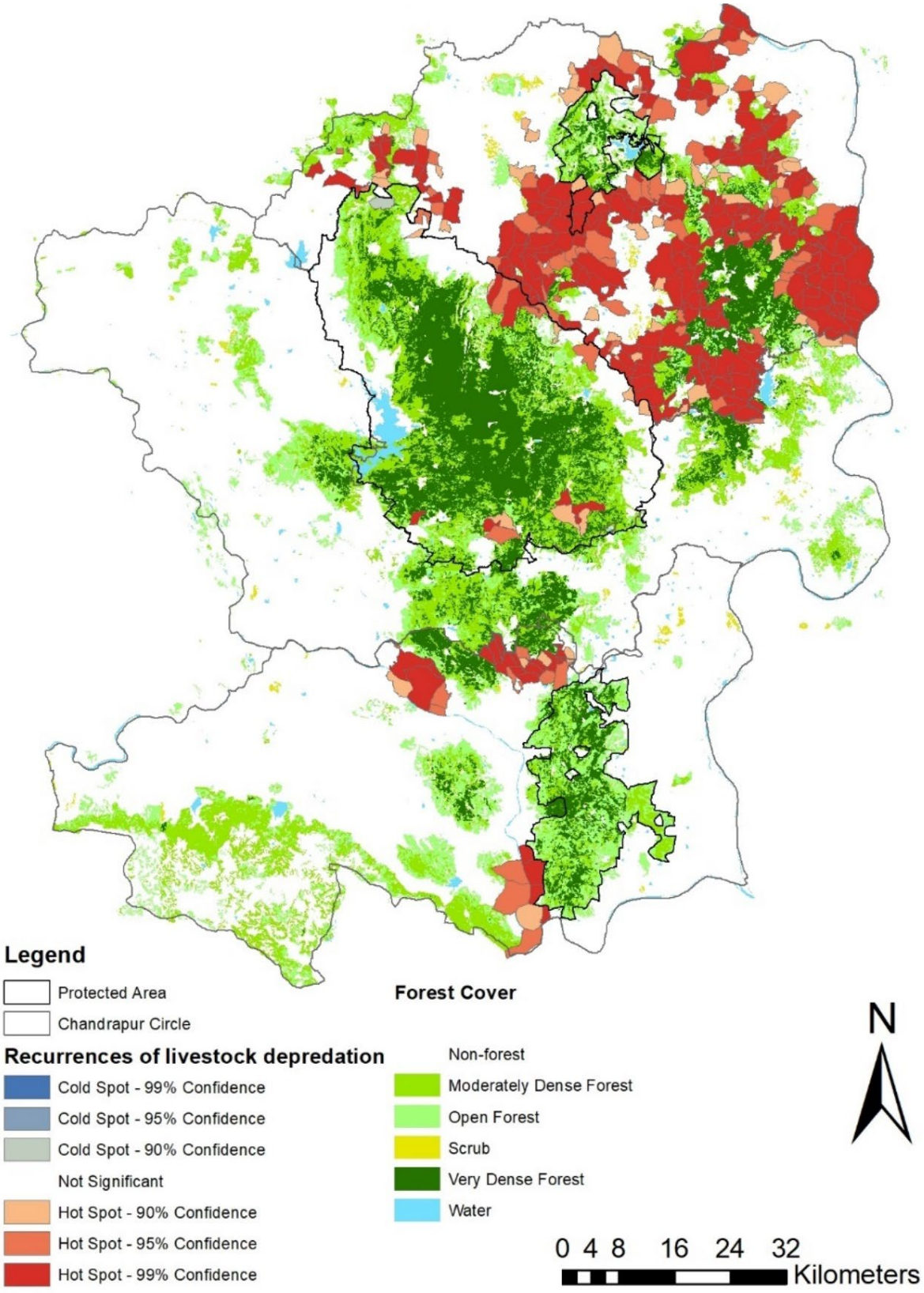

Fig 14: Map of Chandrapur showing hot and cold spots for recurrence of livestock depredation by leopards

7. SLOTH BEAR CONFLICT IN CHANDRAPUR LANDSCAPE

Introduction

Sloth bears (*Melursus ursinus*) are one of the four species of bears found in the Indian subcontinent, and are endemic to the subcontinent, with distributions in India, Nepal, Sri Lanka, and Bhutan (Bargali et al., 2005; Garshelis et al., 2008). Although still widely prevalent in its former range, its habitat is now becoming increasingly fragmented (Dharaiya et al., 2020). As with most large mammals, major threats to sloth bears are anthropogenic habitat loss and fragmentation, along with poaching (Johnsingh, 2003). Throughout its distribution, human population growth causing reforms in land-use regimen is resulting in the shrinking of habitats into islands interspersed within human-dominated landscapes (HDL) (Dharaiya et al., 2016).

Sloth bears occupy a wide range of habitats on the Indian mainland including wet or dry tropical forests, savannas, scrublands, and grasslands (Joshi et al., 1995). Sloth bear populations seem reasonably well-preserved inside Protected Areas (PAs) in India, but face deteriorating habitat conditions outside PAs (Dharaiya et al., 2020). Still, around two-thirds of the sloth bear population in India are estimated to live outside PAs (Dharaiya et al., 2020). Outside PAs, the bears are known to be involved in situations of conflict with humans due to reduced availability of cover and food resources (Akhtar et al., 2004; Bargali et al., 2005).

Being omnivores, sloth bears are often known to raid crops as well as scavenge on livestock carcasses, leading to situations of human-bear conflict (HBC) (Bargali et al., 2005). HBC is known to escalate during different seasons in different regions of the country, depending on the extent of overlap due to common resources. Situations of HBC are escalated in central Indian states of Madhya Pradesh and Maharashtra during the collection of mahua (*Madhuca indica*) flowers before summers (March to early April), while in the eastern states of Odisha and Chattisgarh, the escalation coincides with the monsoon season which is the peak season for agricultural activities (Kumar et al., 2014; Debata et al., 2017).

The Central Indian Landscape (CIL) and the Deccan plateau form the strongholds of sloth bear populations in India (Sathyakumar et al., 2012). The sloth bear is known to have the widest recorded distribution range of any large carnivore in Central India, where it is also feared for its low tolerance towards humans (Pillarisett, 1993; Chauhan and Rajpurohit, 1996). This creates antagonism for the continued conservation of the species, especially in regions with concentrated conflict between local communities and sloth bears (Sathyakumar et al., 2012; Debata et al., 2017).

The Central Indian state of Maharashtra reports a bear habitat that spans over 49,000 km^2, which is a majority of the recorded forested area of the state (Sathyakumar et al., 2012). Over 85% of the Forest Divisions in the state have reported the presence of sloth bears, with 97% of the population of sloth bears reported from the Vidarbha Landscape (VL) (Sathyakumar et al., 2012). Intensifying situations of HBC have been reported from various districts of the VL including Chandrapur, Gondia, Gadchiroli, Akola, and Amravati (Kumar et al., 2014).

Tadoba Andhari Tiger Reserve (TATR) is one of the largest Protected Areas (PAs) in the state of Maharashtra, which provides suitable habitat to a sizeable population of sloth bears (Sathyakumar et al., 2012). The presence of bears in the forested habitats

around TATR has increasingly led them to share space and resources with the local communities that are heavily dependent on non-timber forest products (NTFP) like tendu leaves (*Diospyros melanoxylon*) and mahua flowers. This has caused an escalation in the HBC in and around the tiger reserve.

Result

A total of 93 sloth bear conflict cases were reported from 2014 to 2020, out of which 91 were attacks on humans and 2 were attacks on livestock. The year-wise conflict incidents remained comparable over the years (Fig 15).

Fig. 15: Year-wise total number of sloth bear conflict cases (both livestock depredation and attacks on humans) compiled in Vidarbha Landscape from 2014 to 2020

Conflict Hot Spot Analysis

Attack on humans

Hot and cold spots for the incidents and recurrences of attacks on humans from 2014-2020 are given in Figures 16 and 17. Patches of hot spots are scattered across the buffer region of Tadoba Andhari Tiger Reserve.

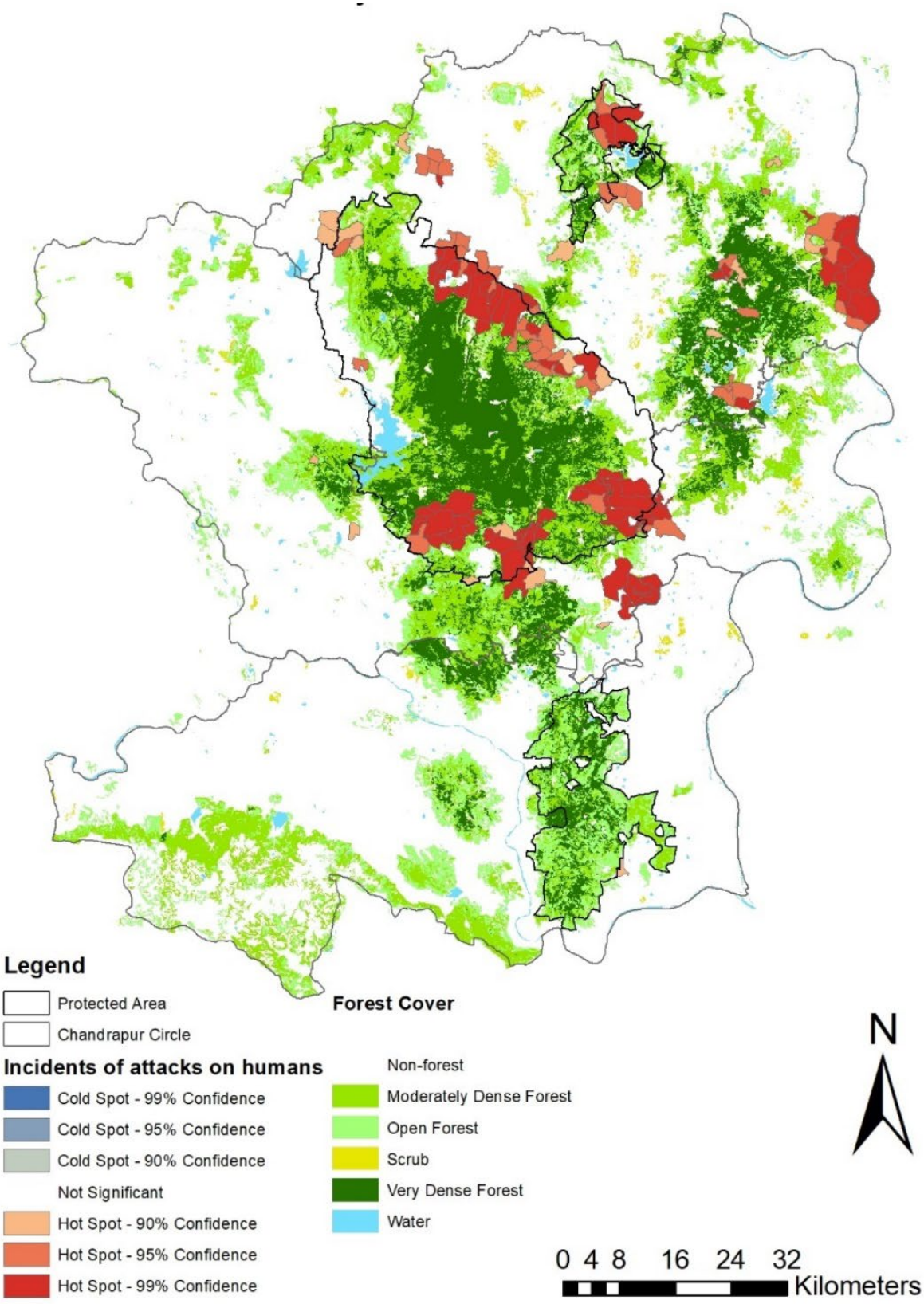

Fig 16: Map of Chandrapur showing hot and cold spots for incidents of attacks on humans by sloth bears

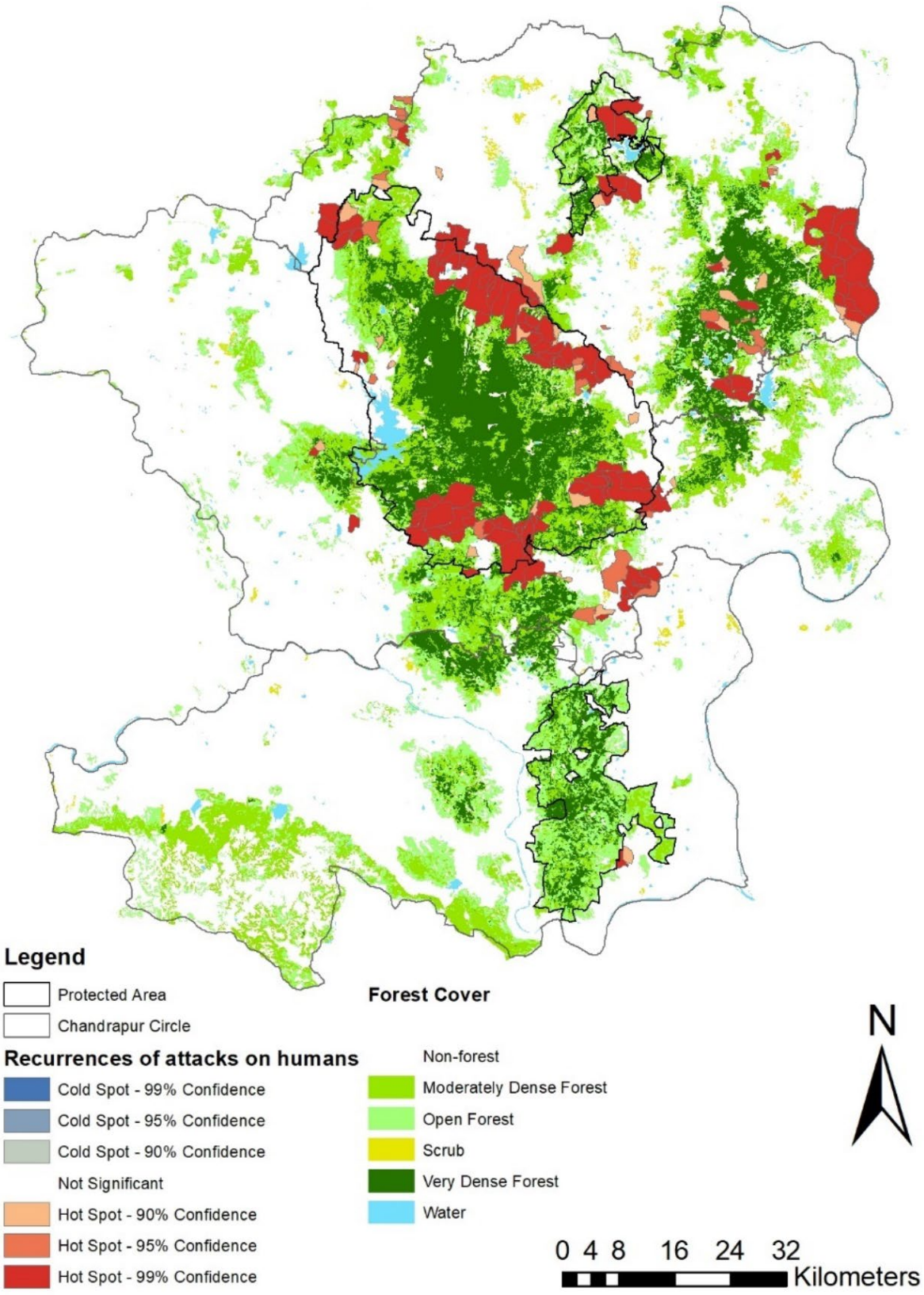

Fig 17: Map of Chandrapur showing hot and cold spots for recurrences of attacks on humans by sloth bears

8. DISCUSSION

Large carnivores are often portrayed as flagship species for conservation (Linnell et al., 2000), and when large carnivore habitat usage spills over to the periphery of human-dominated landscapes, trouble ensues and human-wildlife conflict is not a surprising outcome (Takahata et al., 2014). Carnivore conflict at the local level results in damage to property and loss of human life (Treves, 2009). Several factors can aggravate human-carnivore conflict, (Treves et al. 2004) including population explosion of humans (Census of India, 2011) and carnivores, and habitat fragmentation and destruction. Areas of overlap in human-wildlife habitat often result in linear-shaped boundaries where both habitats are separated by distinct dichotomic geographical features like forest cover and open, flat, and rugged terrain, which plays an important factor in guiding human-wildlife interactions. (Takahata et al., 2014)

On agricultural lands, large carnivores are known to compete with humans for space and resources, resulting in conflict worldwide (Sangay and Vernes, 2002; Ogada et al., 2003). The losses are felt particularly acutely by small-scale households near Protected Areas, which is often challenging for the continued synergy between rural development and biodiversity conservation (Treves and Karanth, 2003; Loveridge et al., 2010; Khorozyan et al., 2015).

A major challenge in carnivore conservation is the identification of priority conflict hotspots where mitigation measures are most required as well as effective (Miller et al., 2015). Mapping hotspots of human-wildlife conflict using locations of past incidents is one of the fundamental steps vital for the formulation of effective mitigation strategies.

Vidarbha Landscape is dotted with fragmented forests outside protected areas. These forest patches contain large carnivore populations which have overflowed from these Protected Areas. There is also a patchwork of human habitations to be found in the middle of these forests. The people residing in these areas are often heavily dependent on the surrounding forests for various aspects of their livelihoods, which causes them to venture into these patches, where there are increased chances of interaction between the carnivores and people or their livestock.

These chance encounters have increased in number and frequency over the years due to the continued destruction of remaining habitats, which can no longer sustain the growing populations of these large carnivores.

Of these, tigers, leopards, and sloth bears have the largest number of chance encounters with humans and human property (livestock), leading to a falling out between the local public sentiment and the conservation goals of the region.

Mapping of human-carnivore conflict hotspots of both livestock depredation and human attack cases suggest that there is a change in the pattern of conflict in the consequent years. The study of these patterns suggests a fluctuating trend in the

number of cases recorded. Further investigation into the causes for the peak years might help shed some light on the factors that might have aggravated the conflict situation in the study area. This clarity is required in order to develop effective and efficient mitigation and management strategies.

The spatial distribution of the conflict incidents suggests the intensive use of forest patches surrounding the protected area both by animals and local communities that are heavily dependent on these forests for natural resources and sustenance of their livelihoods. This pattern is indicative of the need for the removal of overlap between wildlife and humans to reduce potential competition and antagonism wherever possible.

Conflict resolution is not a short-term strategy and requires a long-term understanding of the underlying local environmental and socio-economic contexts (van Eeden et al., 2017). Measurable and quantifiable outcomes of such mitigation interventions are essential for follow-up. A scientific assessment of priority conflict hotspots, the factors contributing to conflict, like the current one, would thus, lead to the evolution of a site-specific socially apt mitigation framework that would equip decision-makers and the conservation community to resolve one of the greatest challenges to conservation in the Anthropocene.

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