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Assessing the patterns of human-wildlife conflict and mitigation strategies in and around Nandhaur Wildlife Sanctuary, Uttarakhand, India.

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled **Assessing the pattern of human-wildlife conflict and mitigation strategies in and around Nandhaur Wildlife Sanctuary, Uttarakhand, India** independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 21.04.2022

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Chirag Girdhar

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Abstract

Success stories in Indian conservation also carry opportunity costs in the form of human-wildlife conflicts, especially for people living in close proximity to wildlife. In India, human-wildlife conflict is a serious challenge to wildlife conservation, which needs a much-improved scientific and social understanding. In this study, we assess the patterns of HWC, people's perception of conflict, and compensation which is the key factor in protecting wildlife in the Nandhaur Wildlife Sanctuary using suitable mitigation measures.

Secondary data on HWC that had taken place during the past 7 years across the entire landscape were collated from the records of the Uttarakhand Forest Department. A questionnaire survey was carried out in 2018 by the Wildlife Institute of India to gather information on the HWC and the socio-economic status of communities around NWS.

A total of 799 incidents of livestock depredation and 274 incidents of crop-raiding were recorded from 45 villages in and around NL during the period from January 2013 to April 2019. Most of the incidents of livestock depredation involved leopards (40.8 %) followed by tigers (33.6 %). In the entire landscape, livestock depredation and crop damage incidents are much higher during the monsoon compared to winter and summer. Early warning systems were deployed to protect vulnerable villages adjoining NWS and this resulted in a 90 % decrease in crop depredation by elephants.

The cattle compensation policy of the UKFD is quite effective, and all the compensation in all the cases of human injuries, deaths, and cattle kill cases up to March 2019 has been paid to the individual's beneficiaries in the NL.

Keywords: human-wildlife conflict, crop-raiding, livestock depredation, Tigers, Leopards, Elephants, Nandhaur Landscape

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List of the abbreviations used in the thesis

CFD Champawat Forest Division

EWS Early Warning System

GPS Global Positioning System

HFD Haldwani Forest Division

HEC Human-Elephant Conflict

HTC Human–Tiger Conflict

HWC Human-Wildlife Conflict

MF Managed Forests

NFD Nainital Forest Division

NTFP Non-Timber Forest Produce

NWS Nandhaur Wildlife Sanctuary

NL Nandhaur Landscape

PA Protected Area

RFD Ramnagar Forest Division

SER Shivalik Elephant Reserve

TAL Terai Arc Landscape

TEFD Terai East Forest Division

THB Tiger Habitat Block

UKFD Uttarakhand Forest Department

1. Introduction and Literature Review

Interactions between humans and wildlife are inevitable. The rapid expansion of the human population, coupled with extensive habitat loss and fragmentation, has increased the potential for people and animals to come into contact – often with devastating consequences for all involved. Human lives and livelihoods can be significantly impacted by wildlife through the predation of livestock and game (Hemson et al. 2009; Loveridge et al. 2017), damage to crops and property (Storie & Bell 2017), and direct attacks resulting in human injury or even death (Amarasinghe et al. 2015). Moreover, individuals may experience psychological trauma including fear, extreme stress, and diminished mental well-being (Barua et al. 2013). The consequences for wildlife can also be extensive and severe. Retaliatory killing, hunting, and habitat destruction have contributed to widespread declines in countless species and have driven others to extinction. Such situations – where humans and wildlife have an adverse impact on one another – are known in mainstream conservation as human-wildlife conflicts (Conroy & Beatley 2007).

1.1. Human-Wildlife Conflict

Different forms of human-wildlife conflict (HWC) have been recorded around the world, such as livestock depredation, human death/injury, crop-raiding, and property damage. Carnivores and herbivores (especially wide-ranging animals and those of larger body size) regularly prey upon livestock and raid crops, resulting in significant financial loss (Treves & Karanth 2003; Karanth et al. 2012). Furthermore, damage to property (houses and utilities) is a common cause of conflict between human populations and wildlife species (Ogra 2008; Upma et al. 2016; Hussain et al. 2018). The dominant categories of human-wildlife interactions in India are loss of crops, preying on livestock by wildlife, and human injury/death, usually through sudden and direct contact with wildlife, livestock grazing inside a forest, agricultural activities near forested areas, and direct attacks on humans (Naha et al. 2018). About 70 % of the wildlife population exists within PAs, which serve as source habitats. Contiguous corridors outside PAs enable mammals to disperse toward sink habitats (Bargali & Ahmed 2018). Villages located in the vicinity

of PAs suffer from wildlife attacks mostly in the form of crop damage by wild herbivores, human casualties, and livestock depredation by carnivores. These cause hostility towards wildlife conservation among villagers (Ogra & Badola 2008). Therefore, it is important to understand such losses that impact villagers living near forested areas (Karanth et al. 2012).

Corridors play a vital role in the movement of wild animals from one protected area to another. One of the most important transboundary corridors of India's Nandhaur Wildlife Sanctuary and Nepal's Sukalaphata National Park is the Boom-Bhramdev Corridor of Nandhaur Landscape (NL). This landscape lies between the Haldwani Forest Division (HFD), Champawat Forest Division (CFD), and Terai East Forest Division (TEFD) in the Uttarakhand state of India. There has been an increase in incidences of HWC along these corridors due to the high resource dependency of local people on forests and a growing human population. There are several villages around the Nandhaur Landscape where people are involved in different activities such as grazing livestock and firewood collection. Apart from carnivores such as tigers and leopards, the Nandhaur landscape is a stronghold of the endangered Asiatic elephant and provides connectivity for elephants between India and Nepal through the Boom–Brahmdev corridor and the Kilpura–Khatima–Surai corridor on the easternmost boundary of this landscape (Johnsingh 2006). But the increasing human population and agriculture exert pressure on the wildlife habitat and create barriers in wildlife corridors. The local forest department compensates for the agricultural and life loss due to wildlife, but still, scanty literature is available on this crucial transboundary corridor. Therefore, this thesis aims to study the patterns of HWC, people's perception of conflict, and compensation which is the key factor in protecting wildlife in the Nandhaur Wildlife Sanctuary using suitable mitigation measures.

1.2. Agro-ecological practices in the landscape

The Himalayan region is known to have an extremely active geodynamic condition possessing an enormous wealth of natural resources of land, water, and forest. Its various ecosystems and rich biodiversity not only provide crucial ecosystem services but also provide and support nearly 50 % of livelihoods in the highlands as well as lowlands (Sati & Wei 2018). To fully comprehend the socioeconomics of people living in this region, it is imperative to understand how geodynamics has influenced, impacted,

provided, and also limited the lives of the people settled here. The geophysics of Uttarakhand can be divided into the following zones, first the foothills / outer Himalaya comprising Terai, Bhabar, and Siwalik, secondly, the lesser or middle Himalaya, thirdly the greater Himalaya or Himalayan highlands and lastly the trans-Himalayan or greater Himalayan zones. Since the present study is located in the first zone particularly, I will limit my descriptions to it.

1.2.1. Siwalik hills

The Siwalik hills are known to be the youngest sub-mountainous range of the outer Himalaya and form a distinct ecosystem. They are formed almost parallel to the south of the lesser Himalayan range and are composed of the Siwalik hills and its piedmont plains. A wide expanse of this zone is composed of fluvial and molassic sediments such as compact mudstones, nodular siltstones, and fine to massive, grained sandstones as a result of tectonics and erosion (Kotlia et al. 2008). In Uttarakhand, the Siwalik hills rise to 1200 m and are often 45-50 km wide. The soil in the fluvial valleys is moderately deep, well-drained, and loamy with slight erosion. The soil on the cliffs, on the other hand, is very shallow and excessively drained. The slopes in the southern part are relatively moderate with flat-topped hills. The primary source of groundwater replenishment in the region is precipitation and a considerable part of it flows away as surface run-off. Rivers originating in the Siwaliks are essentially monsoon torrents with very little water flowing for the rest of the year. Springs and groundwater are the main sources of drinking water and irrigation in the region and agriculture are predominantly rainfed. Productivity of crops is considerably low here due to low soil fertility and a high rate of soil erosion (Sati & Wei 2018). Parts of the study area in the southeastern Nainital and southern Champawat district belong to the northwestern Siwaliks and adjacent piedmont alluvial zone. Below 1200 m, the forest areas and pasture lands have been increasingly invaded by the exotic shrub *Lantana camara*.

1.2.2. Bhabar

Below the foothills, towards the south of the Siwalik hills is the Bhabar region. This tract is 8-24 km wide and is composed of coarse sand, shingle, and boulders

Figure 1 The Nandhaur river flows through the western part of the study area, and it is flanked by dense riverine and mixed mountain forests that provide habitats to the keystone

deposited by the rivers that flow from the higher Himalaya through the Siwaliks (Figure 1). This region is highly porous and defines a significant characteristic of the bhabar tract where all rivers, rivulets, and streams disappear here except the permanent streams of Nandhaur, Gola, and Kosi. In the monsoons, however, torrents cut into the ground, and streams and rivulets flow across this region. The porous geology allows for considerable groundwater recharges here, though water availability is restricted because of the deeper groundwater table (Tiwari 2008). The term bhabar means 'porous' and the region derives its name from this geological characteristic. The occurrence of large boulders and unavailability of surface water despite shallow alluvial layers makes the bhabar unfit for cultivation. Parts of the study area which is in Udham Singh Nagar district belong to the Bhabar Zone.

1.2.3. Terai

The Terai lies to the south of Bhabar and is known to cover a width of 80-90 km (Negi 1995). In contrast to the Bhabar, the Terai region is characterized by high water retention capacity, moist loamy soil, deep, marshy, gravel and boulder free, and extremely fertile. The underground streams of Bhabar reappear in the Terai. In the past when the Terai used to be waterlogged alluvial plains, there used to be a mosaic of dense sal (*Shorea robusta*) forest interspersed with wet tall grasslands, shallow seasonal swamps. The water table is very high in this region and despite being predominantly marshy land,

once reclaimed for agriculture, has been considerably altered. Owing to the synchronized pattern of irrigation and agriculture practiced over the years, the Terai belt had gained popularity for having the very high productivity of paddy. In the study area parts of the district, Udham Singh Nagar is defined by the physiographic characteristics of Terai and bhabar. Udham Singh Nagar was carved out of Nainital District in 1995 due to its distinct physiographical characteristics and was known as 'Chawal ki nagri' or the 'food bowl of the state'. Today it is an agro-industrial district. The grasslands of Terai are however severely threatened presently due to water drainage for irrigation purposes, landfilling, rapid industrialization, and urbanization (Chandran 2015).

1.3. The socioeconomics of the human communities in the landscape

According to Census 2011, the population of district Udham Singh Nagar (1,648,902) in Terai and the hill district of Nainital (954,605), is highest after Haridwar (1,890,422) and Dehradun (1,696,694) in comparison to the rest of the districts of the state. The decadal population growth rate of districts Udham Singh Nagar and Nainital is at 33 % and 25 % respectively since the last census of 2001. Udham Singh Nagar is the second most densely populated district in the state with 649 people/km^2 after Haridwar at 801 people/km^2 and Nainital has a density of 225 people/km^2 after Dehradun 11 at 549 people/km^2. Nainital and Udham Singh Nagar are noteworthy primarily due to their geographical location in Kumaon and can be comparable to Haridwar and Dehradun in Garhwal. The third district in the study area, which is Champawat, is located between the districts of Pithoragarh and Udham Singh Nagar. It has witnessed a decadal population growth rate of 15.63 %, a population of 259,648 people (Chandramouli 2011), and a density of 147 people/km^2. Among the three districts, Nainital and Udham Singh Nagar are important locations in terms of over-concentration owing to tourism and industrial development and exhibit conurbation or urban clustering in certain parts of the districts. Apart from those pockets of the districts, the rest of the study area predominantly reflects the socioeconomics of subsistent agrarian communities. However, the trend of Gross District Domestic Product (GDDP) in terms of contribution to the primary, secondary and tertiary sectors of the economy from 1999-2017 in the three districts indicates a thought-provoking pattern of economic growth rate (Figure 2). Notably, there has been a steady

decline in the primary sector of the economy more so in the plain district in comparison to the hill districts. Instead, there is a significant hike in the secondary sector of the economy in the plain district and mostly the tertiary sector in the hill districts.

1.3.1. Villages in the Siwaliks

Nearly 70 % of the hill population in the state depends on agriculture as their primary source of livelihood and most of it is rainfed except in the Doon/Dun areas (flat longitudinal structural valleys to the north of the Siwaliks). Not only is there a climate-dependent high crop diversity, but there are also various agro-climatic zones where production and productivity decrease with increasing altitude. The Siwalik doon regions belong to the moist-dry climate zone. Besides Siwalik having a low productive potential it is also frequently ravaged by vagaries of soil erosion, landslides, forest fires, and flash floods. Most of the agriculture here is at a subsistence level and nearly 90 % of them are

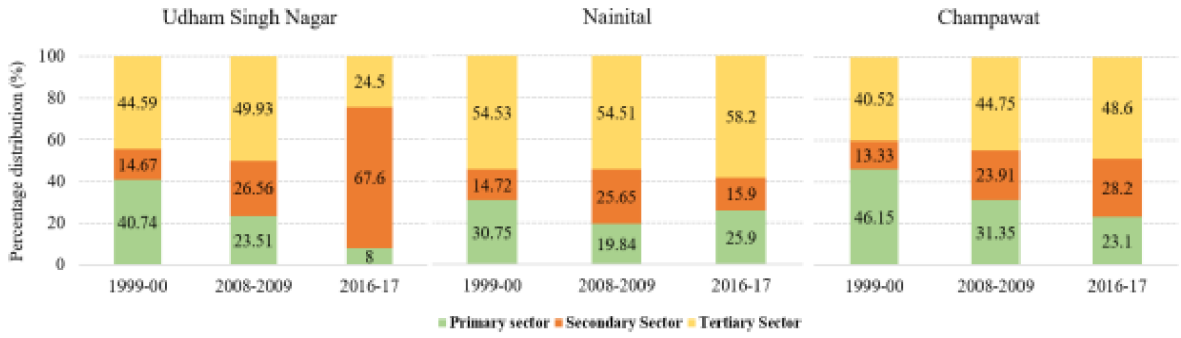

Figure 2 A comparison of sector-wise Gross District Domestic Product contribution from 1999 to 2017 of districts Udham Singh Nagar, Nainital and Champawat (current prices) (Source-Chandramouli 2011)

marginal farmers with less than 1 hectare of land where mostly traditional cereals are grown (Watershed Management Directorate). The average landholding in the hills is 0.68 hectares usually scattered and fragmented. The major crops grown in the region are paddy, soya bean, maize in Kharif and wheat, potato, barley, lentil, mustard, grams, and peas in Rabi.

1.3.2. Khattas of Bhabar

As mentioned before the absence of surface water due to porous substratum is the main characteristic feature of bhabar. Water unavailability thus has been a conditioning factor for population concentration and economic activities in this region. However

historically poor residents of the middle and higher hills have been known to migrate to bhabar during winters along with their cattle when fodder would be scarce in the hills. Since the Terai and bhabar provided excellent grazing grounds for the cattle these people lived here in temporary settlements called khattas or goths during the winter and returned to their homes in the hills in spring. They sold clarified butter and condensed milk (Rawat 1993) and have also been known to work as agricultural or forest labourers to earn a livelihood during the British period. Over time, the vested interests of both the British administrators and the settlers were instrumental to assume permanency for some of the khattas or goths. Accordingly, they were documented as permanent or temporary by the forest department. The British provided the local's facilities for cattle breeding and grazing rights in the nearby grasslands of Terai and bhabar where fodder was available all-round the year. In the bargain, the settled population made it possible for the British administrators to keep a vigil and have firm control over the valuable and dense forests that were known to be hideouts for dacoits and criminals. It is believed that this was a selfish move of the British administration since there were no formal facilities were provided to the khattas in terms of grazing or cattle breeding schemes or connecting roads to carry produce to the markets. Uncontrolled and overgrazing at that time presumably destroyed the better fodder grasses and rich grasslands. Without any planned breeding schemes epidemics followed and the cattle wealth deteriorated. With large forest tracts of Terai and bhabar coming under cultivation after independence to meet food scarcity, many khattas became extinct but a few stayed put.

Around the 1960s with the beginning of the third five-year plan large-scale plantations began in the erstwhile Nainital Terai, now Udhham Singh Nagar where near about 6000 hectares of land was brought under plantation. Today the khattas and goths are located within these plantations and as mandated grazing was prohibited in the plantations at least for five years. Subsequently, the khattas dwellers came in conflict with forest conservation projects as the khattas had not been regularised but instead made quite clear that the inhabitants of the khattas dwellers have no claim over forest land.

Presently the settlements inside the forest area are in the buffer of NWS and residents comprise Paharis and Gujjars. Till the formation of the NWS, cattle were allowed to graze in the sanctuary area against a nominal amount of grazing revenue. However, with the formation of the sanctuary, the grazing revenue has been excused and

herdsmen are prohibited from grazing livestock in the sanctuary area. Most of the Paharis cultivate less than 1 hectare of land surrounding the khattas and occasionally find employment as wage labours in the sanctuary. Before the formation of the sanctuary employment in the forest was quite regular in Uttarakhand Forest Division Corporation (UAFDC) works but many have become unemployed since most of the activities of UAFDC in the sanctuary such as repair of roads after the monsoon have been stopped. Since the khattas dwellers are in the buffer of the sanctuary they are also not entitled to ex gratia compensations when they lose their crop or livestock to predators. The inhabitants of this region cannot go back to their villages in the hills because they cannot cultivate there and cannot go away from the forest buffer since they cannot afford the expenses of relocation by themselves. Despite being cut off from the mainland during monsoons and negligible amenities the dwellers of the khattas are unable to relocate even if they wish for better housing and living conditions.

1.3.3. Settlements in Terai

The Terai region of Uttarakhand is primarily defined by agriculture. Unlike the hills where it is mostly at a subsistence level, the Terai plains are known for their high productivity of crops because of the alluvial soil brought by the perennial rivers. Additionally, irrigated agriculture is possible here. The average landholding in the Terai plains is 1.77 hectares and instead of the usual two cropping seasons, farmers here cultivate Rabi, Kharif, and Zaid crops (a short season between Rabi and Kharif during March and July which is not monsoon dependent). Major rabi crops are wheat peas and mustard, paddy in Zaid, and paddy as well as sugarcane in Kharif.

Some of the ethnic groups that inhabit this region are:

- The particularly vulnerable tribal group (PVTG) of ban rawat/ van rawat/ van rajis. They are the smallest tribe in the state with a population of 690 people according to the Census of India 2011. Most of their population (80 %) is settled in Pithoragarh district and only a few families live in Khridwari village of district Champawat and Bilhari (Julianala) village of Khatima tehsil in district Udham Singh Nagar in the landscape. Traditionally the Rajis were forest-dwelling hunters and food gatherers. They depended on forest produce and bartered handmade wooden articles of domestic use for food grains with local villages. Their

settlements are mostly away from main habitations as they prefer to live aloof from other communities (Pandey 2016). To date, they are one of the most socially and economically underdeveloped tribal community in the central Himalayan region of Uttarakhand (Pandey & Pandey 2010).

- The scheduled tribes of Tharu are the largest tribal group in the State constituting 33 % of the total tribal population in the state. They live close to the Nepal border in Khatima and Sitarganj Tehsils of district Udham Singh Nagar. The origin of the Tharus is contested but it is believed that they are predominantly mongoloid people and have successfully assimilated non-mongoloid features as well (Pant & Pal 2017). Presently agriculture is the main occupation of the Tharu, but traditionally they were engaged in hunting, fishing, and collecting forests fruits, and roots. The Tharus like the Bhoksas inhabiting the jungle tracts of Terai-Bhabar of yore were exploited because of their backwardness during the early days of the clearing of Terai forests, by enterprising Sikh farmers from the neighbouring state of Punjab, well to do class of Uttar Pradesh feudal castes, retired ex-servicemen belonging to Almora and Nainital districts. In addition to the vulnerable social condition, their unfortunate habit of consuming alcohol further enhanced their plight and often rendered them landless. There seems to have developed a lot of awareness among the Tharus and are seen to take an active interest in the constitutional and political posts reserved for tribal communities. The Khatima seat of the legislative assembly of Uttarakhand is reserved for the tribal community, so a Tharu has been elected as representative of this area. While some other Tharus have been elected chairmanship of the Block Development Committee, the youth are active workers of political parties and consequently are emerging as a politically strong community today (Verma 2011).

- The Bhoksa are a particularly vulnerable tribe and constitute nearly 20 % of the tribal population in the state. They mainly inhabit the terai and bhabar areas in the districts of Udham Singh Nagar and Nainital. The Bhoksas have been known to live in Terai since ancient times, claiming ancestral connection with king Jagatdeo of Rajasthan who fled to Terai after suffering defeat by the Mughals. The Bhoksas consider themselves descendants of Nandhaur. Their first intrusion into Terai was attempted during colonial times even though Terai was then known to be an

uninhabitable, harsh, malaria-infested territory of marshy lands and dense forests with tigers in it. With the retreat of the Britishers, as shifting cultivators the Bhoksas were free to occupy and cultivate the land as they pleased. However, the Bhoksa were displaced from land with India's independence when the Central Government embarked on a strategic plan to meet food scarcity post-second world war, by increasing the production of staple food grains in the well-known fertile soils of Terai. In a strategic plan, Uttar Pradesh Government negotiated with Punjab Government to encourage peasants, landless farmers, and refugees from Pakistan to settle in Terai, as it was well known that Punjabis were good agriculturists. By early 1948 dense forests of Terai were cleared to make roads and eradicate malaria from the region and large tracts of land were apportioned to settlers for cultivation. The initiative brought in Pakistani refugees, the Rai Sikhs, and Hindu Punjabis into the region. The Rai Sikhs went beyond what was allotted to them by usurping Bhoksa land and emerged as political elites in Terai land using their aggression and power. The Bhoksas were relegated to undeveloped villages unfit for agriculture. Additionally, alcohol was introduced to the Bhoksas as a strategic tool to curb any potential rise of militant aspirations among the dispossessed by the Rai Sikhs. Furthermore, the Bhoksas inability to repay debts after borrowing money from the Rai Sikhs for life cycle rituals and keeping their land as collateral led to rapid dispossession of their land. The processual deceit has over the years rendered the bhoksas as landless laborers for the very people that usurped their land (Ranjan 2008).

- The Rai Sikhs living on low-lying riverbanks of Terai are primarily farmers and traders. Their ancestry can be traced to belonging to the Mahtam clan who were low caste Hindus living in the Montogomery district of Punjab during colonial times who were followers of Hinduism, Islam, and Sikhism. They have been refugees from the territory that is now in Pakistan and despite being skilled cultivators, inadequate access to irrigation compelled them to engage in criminal activities. Over time the Rai Sikhs emerged as notorious characters specializing in activities such as distillation of liquor, cattle rustling, dacoity, and murder and were notified as a criminal tribe by the colonial government. After independence, they were denotified in 1952 when the draconian Criminal Tribes Act was replaced by the Habitual Offenders Act. The Rai Sikhs continue to live with the

label of a criminal tribe. Though the Rai Sikhs of Punjab have been conferred the status of a scheduled caste, they have been granted Other Backward Classes status elsewhere (Gandee 2018). They are an economically well-off and politically influential community.

- The Gujjars of Terai and bhabar are a pastoral tribe residing in three forest divisions in the landscape - Terai West, Terai Central, and Terai East. They are known to be followers of different religions such as Hinduism, Islam, and Sikhism. Traditionally the Gujjars were transhumant grazers who practiced buffalo husbandry, considered their animals sacred, and treated them with utmost care and affection (Agrawal 2014). They would migrate to the pastures of Munsyari, Tehri, and Uttarkashi during winters and return to Terai bhabar during summers to graze their animals in the forests following a well-planned transhumance route that allowed the regeneration of vegetation. Though traditionally nomadic cattle breeders, they settled in Terai and bhabar regions in the 1950's given that fodder was abundantly available here. Since then, they have become forest dwellers, known as van gujjars, and depend entirely on their buffaloes for subsistence and sustenance. The dwelling of a gujjar is called a 'dera' and is built on isolated and small cleared patches in the middle of thick forests. Usually, their dera's are near water sources or have hand pumps. Their homes are thatched huts and large in size with a square base and conical roof. These huts are normally multipurpose and besides the residential hut, they have animal sheds with thatched roofs designed in a way to prevent wildlife from entering them at night. Gujjar dera's do not give the impression of a village since they are not clustered together. Not more than six to seven families live in one spot and in this way, they are scattered over a large area so that no one infringes on anyone's grazing land. The gujjars have no tradition of hunting wild animals for meat consumption and do not consume liquor and their diet consists of a lot of milk products (Rawat 1993). Given that their livestock is their only means of livelihood they are particularly careful about their supervision. It is believed that the fearless gujjars living in the middle of forests with wild animals inspired other winter migrants to eventually assume permanency in the khattas of Terai -bhabar.

1.4. Urbanization, industrialization, and employment opportunities for local people in the region.

With the advancement of India's economic deregulation since the 1900s as a BRIC (Brazil, Russia, India, China) country, special industrial policies and subsidies were allotted by the central government to some of the states from disadvantaged areas classified as special category states. The newly formed state of Uttarakhand was one of them, and as an outcome, State Industrial Development Corporation Limited (SIDCUL) was established in 2002. Its primary aim is the promotion of rapid and sustainable industrial development to improve employment opportunities, investments, gross state industrialization, and the development of regional economies. As a result, six industrial parks were developed by SIDCUL in the Terai belt of the state in the districts of Dehradun, Udham Singh Nagar, Haridwar, and Pauri Garhwal. Integrated Industrial Estates (IIE) of Pantnagar and Haridwar were developed as industrial development bases for Kumaon and Garhwal respectively.

Type of industries	Factories	Percentage
1. Transport Equipment	56	14.3
2. Pharmaceutical products	46	11.7
3. Plastic Products	46	11.7
4. Electric/electronic products	44	11.2
5. Machinery equipment	31	7.9
6. Food products	27	6.9
7. Metal products	28	7.1
8. Chemical products	18	4.6
9. Textile products	23	5.9
10. Paper products	14	3.6
11. Cosmetic and hygiene products	10	2.6
12. Other manufacturing	44	11.2

13. Unclassifiable	5	1.3
Total	392	100

Table 1 Number of factory wise industrial organizations in Integrated Industrial Estate of Pantnagar (Source: Kazuo 2014)

Thus, in the district of Udham Singh Nagar on both sides of NWS at a distance of 30 km is IIE Pantnagar and ELDECO – SIDCUL industrial park (a joint venture between the private real estate capital group ELDECO and SIDCUL) in Sitarganj (Kazuo 2014). Table 1 provides a factory-wise percentage break-up of the various industries supported by IIE Pantnagar. Though industrialization in this region has generated quite substantial employment opportunities for the local communities, the hill regions are still left out and widening the economic gap between the hills and the plains. Rapid industrialization in Uttarakhand (though restricted to plain areas) has undoubtedly strengthened the State economy which was primarily dependent on agriculture and tourism by transforming tourism and manufacturing into its main contributors. This overall state of affairs moreover necessitates imploration of the development status of the vulnerable tribal communities in Udham Singh Nagar as it alone has a tribal population of 43.03 % among the other 13 districts of the state.

Since education is perceived as a powerful tool for economic and social change leading to upward social mobility furthering development, we resorted to education status among ethnic communities when employment information was unavailable.

- Insights from a study by Pandey (2016) on education among the Ban Rajis highlight some of the limitations that the tribe encounters in availing employment opportunities despite government-aided ventures for their development. According to the study marriage, among the rajis happens early in life, consequently, young boys are compelled to seek means of earning a livelihood to maintain a family. Furthermore, limited educational institutions in the village have led to persistent illiteracy among them. The Ban Rajis live away from mainstream habitations and to avail school outside the village involves longer routes through the forest of which many parents are wary. Though Government-subsidized schools exist, these are mostly for primary education. The vicious poverty cycle of the Ban Rajis has never allowed them to develop a resource base that is required to pursue higher education for it entails additional expenses of staying away from

the village. Lack of awareness among parents also hinders educational pursuits. Their deep-rooted poverty has led many to believe that a greater number of helping hands in the family will emancipate them from their drudgery. Education of children is looked at as a waste of money since even after education there is no guarantee of employment. Their contact with outsiders while conducting day-to-day business for a livelihood such as selling firewood collected from forests, quarrying, as agricultural labor, or porters in markets is slowly making them realize the significance of education (Pandey & Sharma 2015).

- A study of 116 college-going Tharu youth enrolled in the Government Post Graduate College of Rudrapur, by Verma (2011) highlights the level of awareness in education. However, the desire to dissociate themselves from their traditional occupation and way of life among Tharu youth seems to be a driving factor for increasing dropouts from further education in the hope of being employed. Most of the youth do not like agriculture and related activities and hence are on the verge of foregoing their cultural values to be identified as mainstream and not tribal. This however is not the overarching reality of the entire tribe as there are also a few from among the Tharus such as the Tharu Rana Parishad (Council of Tharu Community) who are trying to uphold their traditions and culture by emphasizing their identity as Tharus. Educated Tharu youths are aware of their political rights and struggling for the freehold of their agricultural land and other properties that have been forcefully usurped by powerful and influential elites of the region for generations.

- According to the findings of a study on Bhoksa youth by Ranjan (2008), many in the newer generations among the Bhoksa seek employment in the neighboring industrial areas as skilled or unskilled workers. A few training centers have also come up in recent times to impart skilled training to the youth and disempowered people in the region. Some of these centers train in cottage industry skills such as spinning, weaving, handloom, apiculture, carpentry, and fruit preservation, and others in industrial training such as electronics, electrical work, watch repairing, automobile repairing, and tailoring. Despite government enterprises towards empowerment through skilled training, the author highlights, the inability of the Bhoksas to live in inorganically structured and institutionalized towns that

alienate them from their own culture as one of the major deterrents to success in finding sustainable employment.

- Several studies on Van Gujjars (Gooch 2004; Harihar et al. 2014; Hussain et al. 2016) of the Terai Arc landscape, highlight their poor literacy levels and lack of formal education that hinders their opportunities to seek mainstream employment even if they are interested to move away from their traditional pastoralist occupation. Being forest dwellers, mostly where access to basic amenities like schools and hospitals are restricted, there is a high proportion of school drop out after primary education since further education implies traveling a greater distance. This has made the Van Gujjars largely an illiterate community unable to adapt to the cash economy to diversify their livelihood options for living off the forests and animal husbandry is all that they know.

These anecdotes reaffirm that poverty has been more acute among scheduled tribes and scheduled castes and people inhabiting backward regions and need direct intervention in the form of targeted and informed programs intended for a much larger set of disadvantaged population groups.

2. Aims of the Thesis

The first aim of the thesis was to assess the pattern of conflict of crop damage, livestock depredation, and human injury/death caused by wildlife in the Nandhaur Landscape.

The second aim was to assess the people's perception of conflict and evaluate the effectiveness of current mitigation strategies and compensation schemes.

3. Methods

3.1. Study Area

The Nandhaur Landscape (NL) is situated along foothills in eastern Uttarakhand harbours the flora and fauna of the Bhabar and Outer–Himalayas ranges. The spectacular landscape harbours a rich terrestrial and aquatic ecosystem and is flanked by human habitations and agricultural land on its southern and northern extremities. NL lies in three districts, viz. Nainital, Udham Singh Nagar, and Champawat districts, of the state of Uttarakhand and is situated between latitudes N 28°45′ and 29°15′ and longitudes E 79°31′ and 80°16′ (Figure 3).

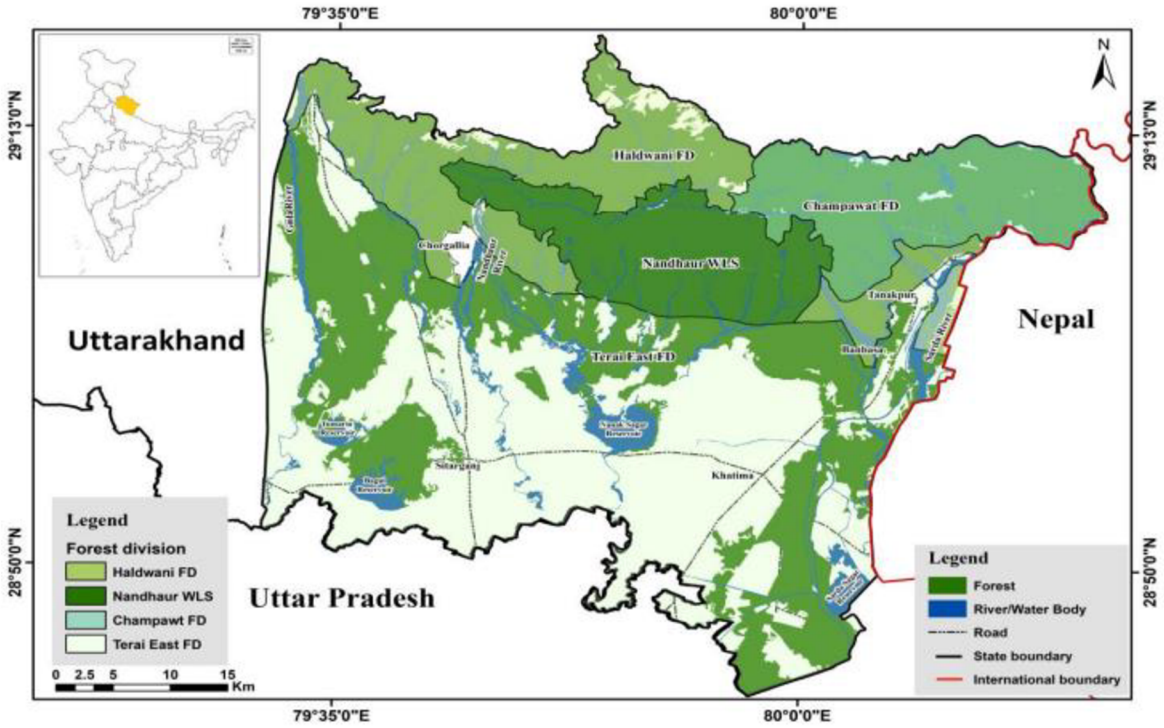

Figure 3 Map of Nandhaur Landscape

The landscape is spatially heterogeneous comprising PAs, including Nandhaur Wildlife Sanctuary (NWS) and managed forests (MFs) of Haldwani Forest Division (HFD), Terai East Forest Division (TEFD), and Champawat Forest Division (CFD), within a matrix of private agricultural lands. The Indo-Nepal border forms much of the eastern border of the NL, particularly HFD, CFD, and TEFD. Forest, grassland, and wetland area in the NL encompasses 1740.66 km^2 which is split into PAs (269.79 km^2) and MFs (1470.87 km^2)

categories. The area of NWS is 269.79 km^2 and HFD is 364.14 km^2. The area of TEFD and CFD is 824.29 km^2 and 282.44 km^2 respectively. NL area including PAs, MFs, and the agricultural matrix covered 2572.38 km^2 area (Table 2).

The NL forests are under different management regimes that fall into different administrative units. The entire forests of NL are under the Siwalik Elephant Reserve (SER) to strengthen elephant conservation in the region. The total area of the NL is 2572.38 km^2 and the forested tract is 1740.66 km^2 which constitutes forests of NWS, HFD, TEFD, and CFD, and agriculture areas are 816.72 km^2. The main forest types are moist deciduous and subtropical broadleaf forests. Highly disturbed temperate forests composed of pine, oak and Rhododendron may be found in the upper reaches along with the northern extent.

Serial Number	Category	Area (Km^2)
A.	Nandhaur landscape	
A.1	Protected areas (PAs) (a) Nandhaur Wildlife Sanctuary (NWS) Sub_total	269.79
A.2	Managed forests (MFs) (a) Haldwani Forest Division (HFD) (b) Terai East Forest Division (TEFD) (c) Champawat Forest Division (CFD) Sub-total	364.14 824.29 282.44 1470.87
A.3	The total extent of the Nandhaur landscape	2557.38
B	Agricultural area	816.72
C	Total Landscape Assessment Area	2557.38

Table 2 Area Statistics for the Nandhaur Landscape

Occupying a central position within the TAL, the NL forms a disjunct tiger habitat block (THB), with little connectivity with other THBs to the west and east (Johnsingh et al. 2004). The study area is bounded by the river Gola, in the west, and the river Sharda, in the east.

The Ladhya Valley forms the northern limit, beyond which lie steep Himalayan Mountain ranges dotted with numerous villages. Interspersed amid these villages are the temperate forests of Nainital and Champawat. In the south, the forests give way to agricultural fields and fast urbanizing settlements. Central to this site, and from where it derives its name, is the Nandhaur river valley (Figure 4). The forests in the landscape are managed for multiple uses and fall under three administrative forest divisions namely, the CFD, HFD, and TEFD. To the west of the study area, across the Gola River, lie Ramnagar Forest Division (RFD) and Terai Central Forest Division. To the northeast, across the Sharda River, the forests of Nandhaur are contiguous with those of Nepal along the Bramhadev corridor. The south-eastern tail of the study area has a tenuous connection with Pilibhit Tiger Reserve. The NL encompasses two physiographic zones: the Siwalik and Terai–bhabar zone, characterized by hilly terrain with a loose substratum made up of coarse sediments and bisected by numerous seasonal and a few perennial streams. Parts of CFD and HFD lie within this zone, while TEFD lies entirely in the terai zone, with characteristic flat topography and fine alluvial soil deposits.

Figure 4 The Nandhaur river, just west of the sanctuary boundary. The mountains in the background are the source of the river

The NL is a spatially heterogeneous landscape (2557.38 km^2) of forests within a matrix of sparsely distributed habitations and their extensive agricultural lands. NL presents a rich and diverse forest ecosystem (Figure 5).

On the basis of the physiognomy and floristic composition, the permanent vegetation of the landscape may be classified broadly into seven different types of forest,

Figure 5 *Saccharum spontaneum* flowering along the flooded banks of the Nandhaur river, in the western part of the sanctuary

including plantations (Figure 6). Six non-forest categories (scrub, waterbody, river, riverbed, settlement, and agriculture) were identified based on visual interpretation of satellite data (Sentinel 2A), using a widely used interpretation technique, and ground validation. Two different sal (*Shorea robusta*) forest types were discerned among the forest types, viz. Moist Siwalik Sal and Moist Terai Sal. Western Gangetic Moist Mixed Deciduous, Upper or Himalayan Chir pine, khair, and sissoo (*Acacia catechu* and *Dalbergia sissoo*), riverine, and plantations were among the other dominant forest types. The forest land in NWS, HFD, TEFD, and CFD covered 1740.66 km^2 or 68.06 % of the

landscape. The landscape matrix, including several small towns and villages, along with their agricultural areas, occupied 861.72 km^2 or 31.94 %. While considering the forest land that was under the control of UKFD, different forest types occupied 92.0 % of the forest areas. The Terai Sal, Moist Siwalik Sal, West Gangetic Moist Mixed Deciduous, and Upper or Himalayan Chir Pine forests and plantations occupy 14.37 %, 22.15 %, 33.26 %, 3.43 %, and 8.62 %, respectively. A general survey of the forests reveals some important plant associations, such as the *Shorea–Mallotus–Adina* community, *Shorea–Terminalia–Bridelia* community, *Dalbergia–Acacia* community, and *Syzygium–Phoebe–Drypetes* community (Mehra 2015)**.** The tropical forest ecosystems of the sanctuary have

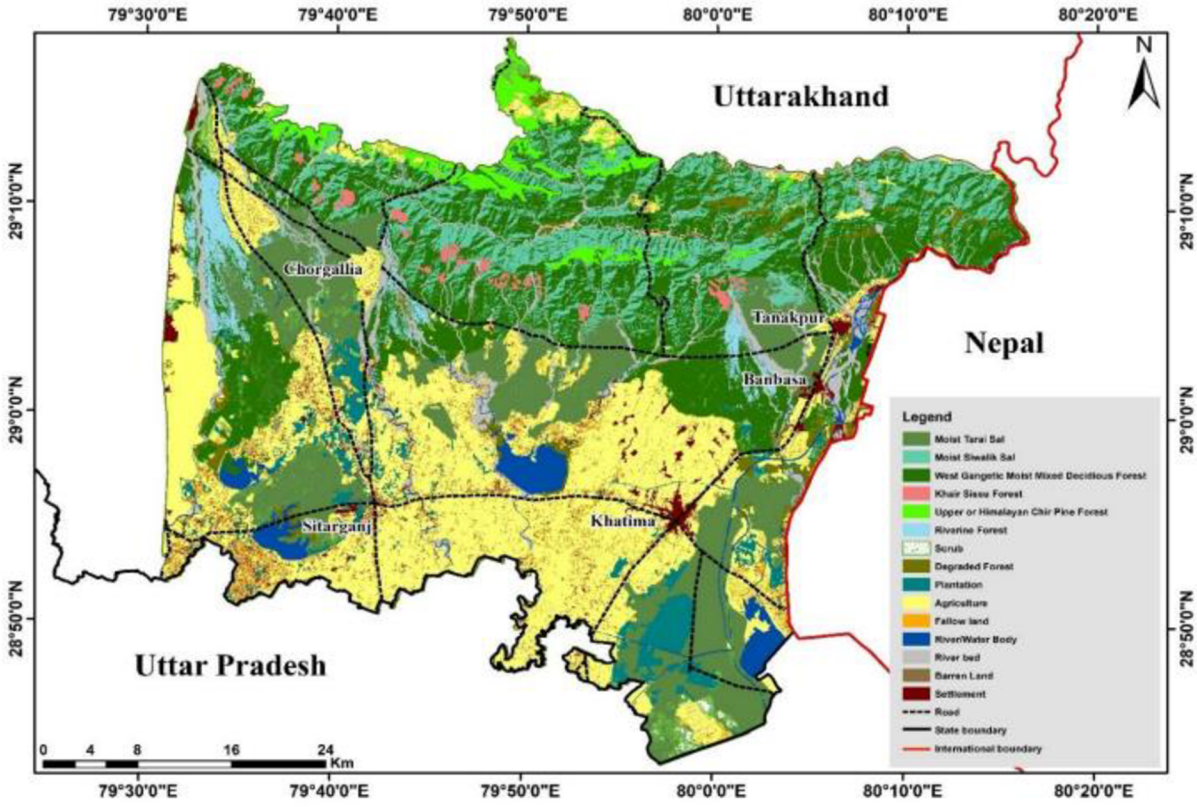

Figure 6 Land use land cover types in Nandhaur Landscape

many unique characteristics that have high scientific significance.

3.1.1. Biophysical Features

The NL is broadly divisible into two physiographic zones viz., Terai - Bhabar and hill ranges. The terai is characterized by fine alluvium and clay-rich swamps, which support a mosaic of tall grasslands, wetlands, and mixed deciduous forests dominated by sal. These habitats lie in the floodplains of several important river systems that originate in the Himalayas. The terai is one of the 200 globally important eco-regions because of

its unique terai–duar savannas and grasslands (Olson & Dinerstein 1998). These alluvial floodplain grasslands are probably the world's tallest grasslands, with some grass species growing higher than 13 feet. The Bhabar belt is characterized by a low-gradient terrain with coarse alluvium and boulders and by the very porous nature of the soil. This makes the area devoid of water most of the year as the water percolates down through the porous soil. Sal (*Shorea robusta*) and mixed deciduous vegetation communities are dominant here. Because of the lack of permanent water sources and large patches of grasslands, the bhabar has a low density of the tiger and its prey species. Nevertheless, it forms an important part of the tiger's habitat today as much of the bhabar is now included in the protected areas of Nepal and India.

The hilly part of NL comprises the outer or lesser Himalaya and a narrow belt of Siwalik that emerges towards the eastern flank of the landscape. The Siwalik ranges are the geologically youngest formations in the Indian sub-continent characterized by sandstone and conglomerate rock formations. These are quite fragile yet serve as safe havens for wildlife, especially during times of flooding and fire.

The Siwalik ranges in NL merge closely with the outer Himalaya. However, they form distinct habitats west of Nandhaur and in Western Nepal, which is locally called Churia hills. The Outer Himalayas in NL covers the lower hills of the Nainital and Champawat districts. These ranges vary between 900 m to 1200 m in altitude. These ranges are composed of sedimentary rocks including schists and gneisses.

The NL provides a diverse array of ecosystem services, providing food, water, and natural resources such as firewood and medicinal plants, as well as wider benefits such as climate regulation and carbon sequestration. The continuing loss of forests and grasslands in the Indian TAL poses daunting challenges to wildlife conservation efforts. There is an urgent need to arrest the loss of these vital habitats through concerted conservation measures, policy interventions, and supportive communities that share this landscape with tigers. In particular, there is a need for government support to restore and maintain habitat connectivity by protecting fragile corridors and to protect remnant forest and grassland patches in the TAL from the impacts of rapid ongoing and proposed infrastructure development and encroachment.

NWS, with an extent of 270 km^2, is located in the north Indian state of Uttarakhand (Figure 7). NWS comprises four ranges, namely the Nandhaur, Jaulasal, Danda, and Sharda ranges. The sanctuary falls under the HFD of the TAL, which is largely a Siwalik–bhabar tract. Siwalik merges very closely with the outer Himalayas in NWS and it reappears at Boom and Poornagiri of NL. NWS was declared a wildlife sanctuary in the year 2012 and is named after the river Nandhaur, which runs for approximately 30 km through it. NWS lies between 79° 40′ 31.49″ E, 29° 11′ 2.79″ N and 80° 0′ 33.36″ E, 29° 8′ 20.35″ N. The NL is a promising habitat for tiger and elephant conservation, having large areas devoid of human habitations. The entire PA is part of the SER and has the potential to be declared a tiger reserve. According to the biogeographic classification of Rodgers & Panwar (1988), NWS falls under the Upper Gangetic Plains biotic province

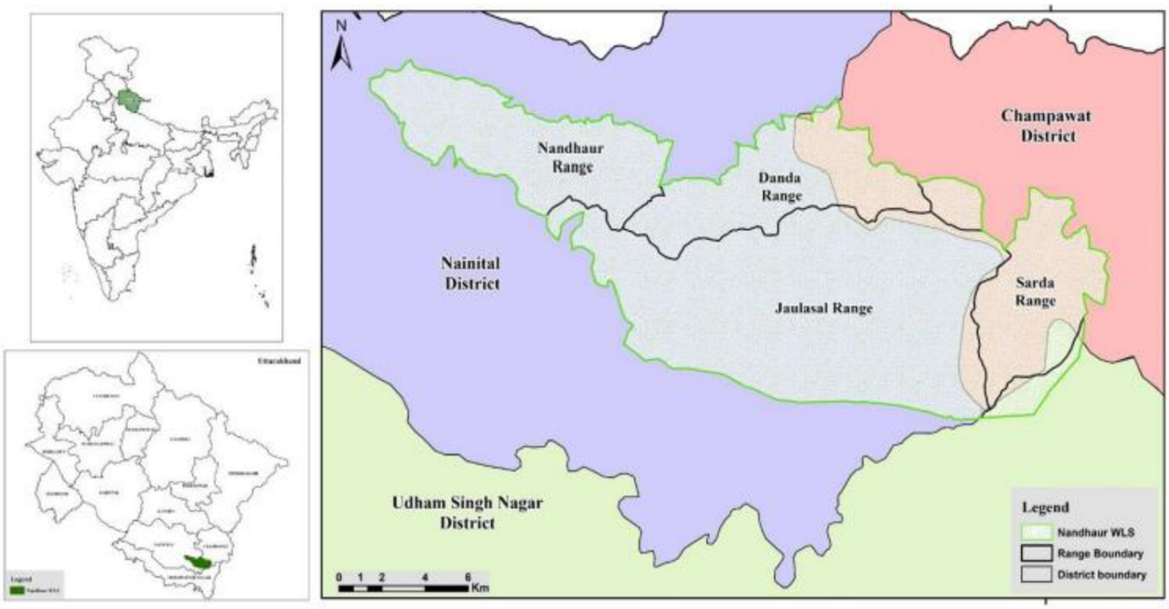

Figure 7 Map showing Nandhaur Wildlife Sanctuary

of the Gangetic Plain biogeographic zone. The major forest type, according to Champion & Seth's Forest classification (1968), is a tropical moist deciduous forest dominated by sal (*Shorea robusta*) and associated species such as *Terminalia tomentosa, Adina cordifolia,* and *Syzygium cumini* (Figure 8). Towards higher altitudes, these forests are gradually replaced by sub-tropical mixed deciduous forests.

NWS is an integral part of the TAL, which spreads across three Indian states, namely Uttarakhand, Uttar Pradesh, Bihar, and Nepal. TAL was once a haven for wildlife, but it is in peril due to habitat fragmentation, as underscored by evidence of local extinctions of the one-horned rhino (*Rhinocornis unicornis*) and hispid hare (*Caprolagus hispidus*)

and the near extinction of the swamp deer (*Rucervus duvaucelli*) and Indian hog deer (*Axis porcinus*) (Johnsingh et al. 2004) in Uttarakhand. However, there is great potential for biodiversity recovery in TAL. It has been identified as one of the three most important regions for tiger conservation in India by WWF-International (Chanchani et al. 2014) TAL is a transboundary landscape in India and Nepal, with an area of 42,500 km^2 on the Indian side, with an estimated forest cover of an extent of 15,000 km^2.

Figure 8 View of a mixed forest patch dominated by *Shorea robusta* from Jaulasal rest house

3.2. Data Collection

Data for this thesis was provided by the Wildlife Institute of India, Dehradun, India under the project Supporting Transboundary Tiger Recovery in India and Nepal by Extending Activities into Nandhaur Wildlife Sanctuary (Phase-1).

3.2.1. Conflict Pattern

To study the pattern of conflict, secondary information on HWC from Uttarakhand Forest Division for all the forest divisions in the Nandhaur Landscape i.e., HFD, CFD, and TEFD from 2013-2018 were collected and analyzed. The total compensation paid to individual households by the forest department for crop and livestock loss from 2013 to April 2019 in the Nandhaur Landscape was also collected. The information also includes incidents of livestock depredation and crop damage within 1 km of the boundaries of NWS (Figure 9).

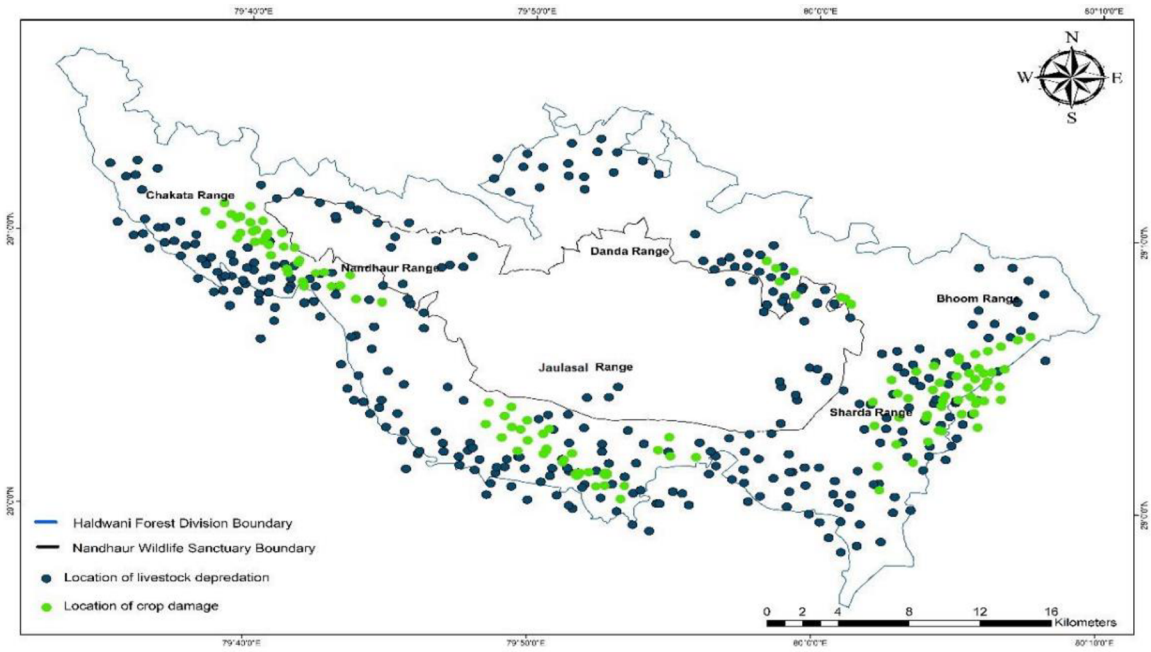

Figure 9 Locations where crops were damaged by elephants and livestock preyed on by tigers and leopards in and around NWS

Locations of livestock depredation and crop damage were visited by forest staff members and data (species, sex, age, crop type, and GPS location) were recorded (Chen et al. 2016; Naha et al. 2018; Bargali & Ahmed 2018). Identification of predators was based on the patterns of carcass consumption in cases of livestock depredation. In case of crop damage,

observation of villagers and footprints and pugmarks were used to identify the animal (Figure 10) (Upma et al. 2016; Hussain et al. 2018).

Figure 10 Crop damage by elephants in Sharda Range

3.2.2. People's perceptions, mitigation strategies and compensation paid

A total of 135 structured and open-ended questionnaire interviews were conducted (Mishra 1997; Ogra & Badola 2008; Hussain et al. 2016, 2018), with households selected from 45 villages around NWS (Figure 11). There are no households inside the sanctuary. The households included ones within the administrative buffer zone of NWS. To enable systematic spatial sampling, a grid-based approach was used to sample the area by placing grid cells (1 × 1 km^2 in size) in a 1-km buffer outside the eco-sensitive zone of NWS (Karanth et al. 2012). The administrative atlas of Uttarakhand and Google Earth were

used to make a digital representation of all the villages 59 around NWS. In each village, the village headman, SHGs, and individual households were approached for discussions. Both male and female respondents were surveyed irrespective of gender. The first respondent meeting in the household was interviewed. They were questioned about the household demography, occupation, education, crops grown, wildlife conflict incidents, mitigation measures, and compensation.

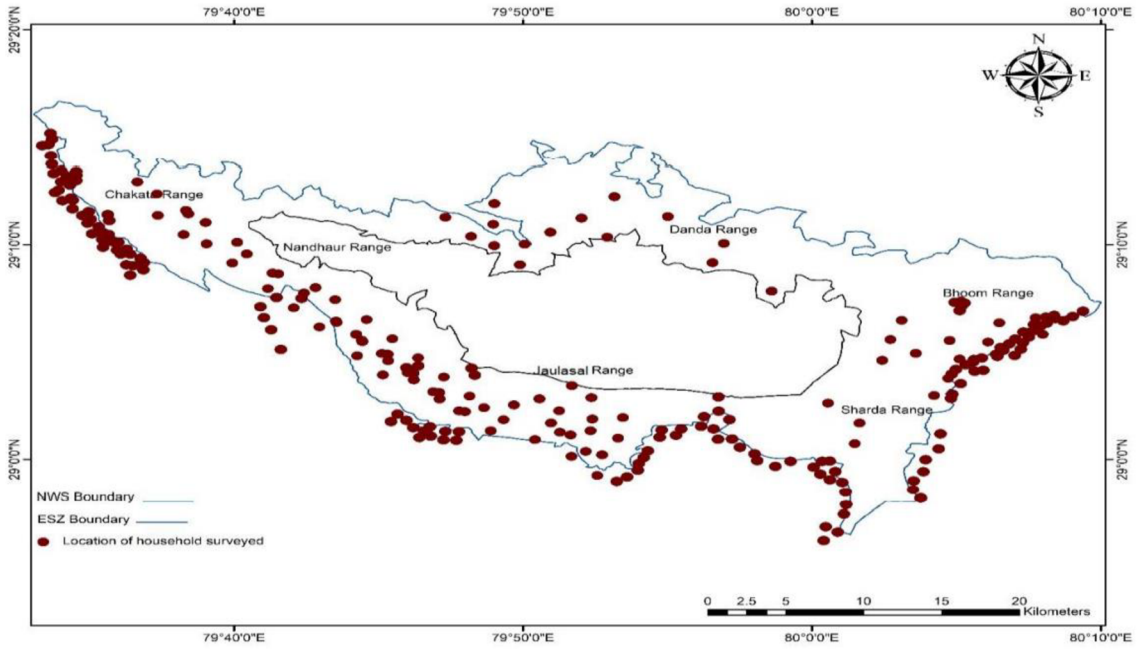

Figure 11 Households of the survey conducted around the NL

4. Results

4.1. Pattern of conflict of crop damage and livestock depredation

A total of 799 incidents of livestock depredation and 274 incidents of crop damage were recorded from 45 villages in and around the NL between 2013 and April 2019. More of the incidents of livestock depredation were by leopards 438 (40.8 %) than by tigers 361 (33.6 %). There were 274 (25.5 %) incidents of crop damage by elephants. The highest number of incidents of livestock depredation (n=242) was in 2015, and the lowest (n=120) was in 2013. Fifty-six incidents were reported until April 2019 (Figure 12).

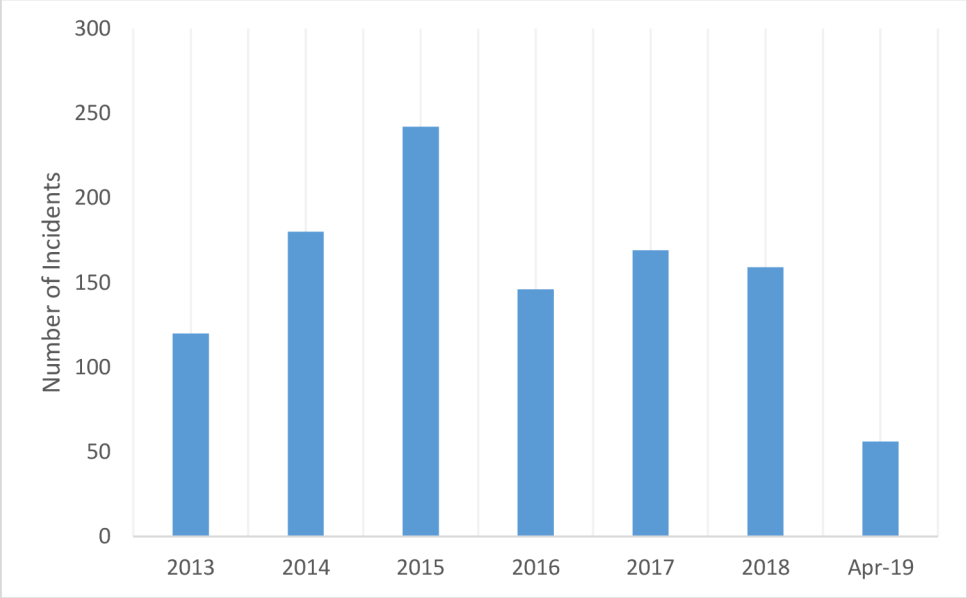

Figure 12 Yearly variation in crop damage caused by elephants and livestock depredation by tigers and leopards in the NL during the period from 2013 to April 2019

The highest number of incidents of livestock depredation was in HFD (n=267), followed by NFD (n=185), CFD (n=176) and TEFD (n=171) (Figure 13). The livestock depredation incidents in and around NWS indicated that the leopard was the main predator in the northern part of the landscape (90.1 ± 7.2) and that the tiger (69.4 ± 8.8) was the main predator in the southern part of the sanctuary. There were many more livestock depredation incidents (n=264) all across the sanctuary during the monsoon

compared with winter (n=162) and summer (n=126). This was probably due to dense vegetation, escape cover for prey, and the easy availability of cattle during the monsoon. Incidents involving crop damage caused by elephants were much more numerous during the monsoon (n=149) than in winter (n=74) and summer (n=50).

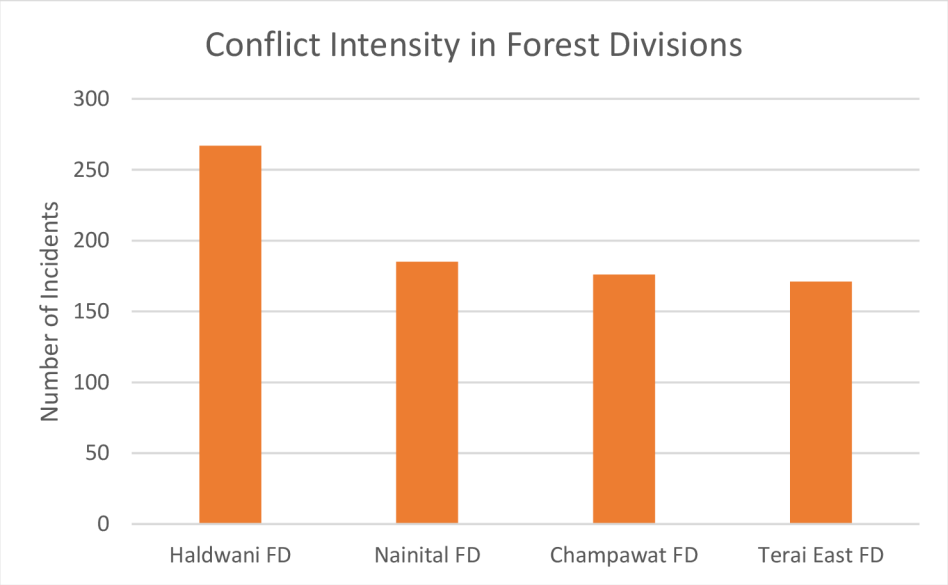

Figure 13 Overall conflict incidences in four forest divisions in and around the NL during the period from 2013 to April 2019

The depredation of livestock by leopards (138 ± 0.68) and tigers (126 ± 0.57) was more during the monsoon than in winter (leopard, 87 ± 0.33; tiger, 63 ± 0.38) and in summer (leopard, 76 ± 0.47; tiger, 34 ± 0.55) (Figure 14). These findings show that there is a significant difference in livestock depredation by leopards and tigers among seasons (KW=17.3, df=2, P<.05).

Overall, cattle (51.53 %) were the major victims of tigers and leopards, followed by buffaloes (30.79 %) and other animals such as goats, horses, mules, sheep, and donkeys (16.71 %). The patterns of livestock depredation by tigers and leopards were different. Tigers mostly prey upon cattle (36 %), followed by other animals (36 %), and buffaloes (28 %), whereas the leopard predation was mainly on cattle (55 %), followed by buffaloes (26.67 %) and other animals (18.33 %).

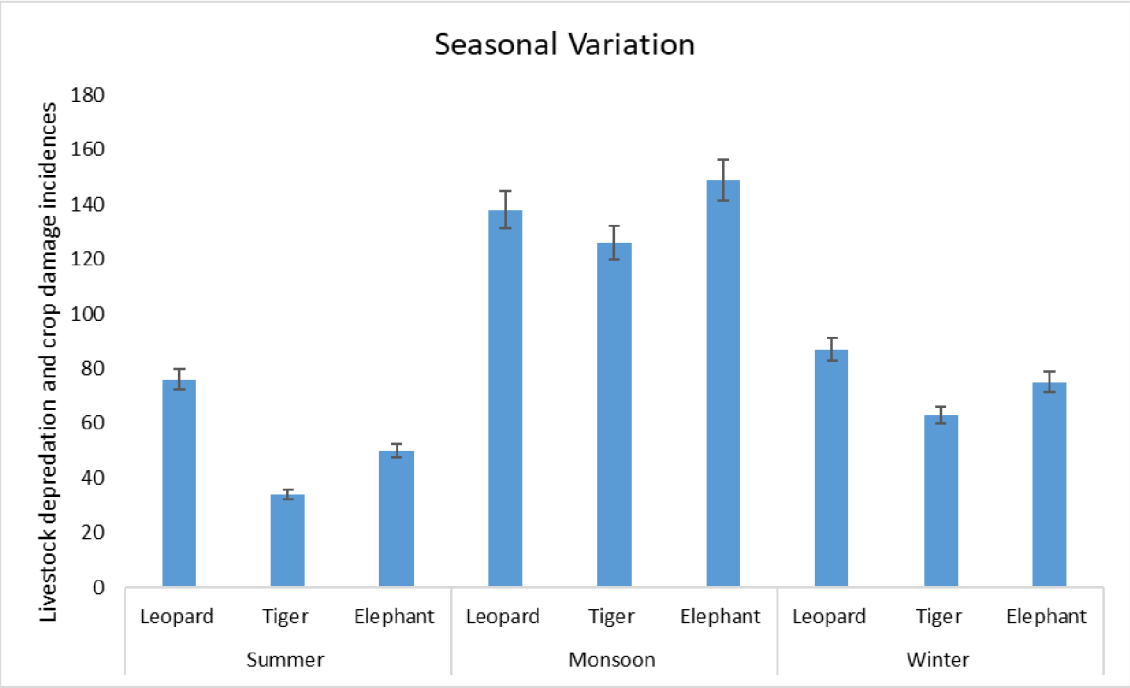

Figure 14 Seasonal variation in crop damage caused by elephants and livestock depredation by tigers and leopards in NL from 2013 to April 2019

4.2. Human Injury/Death and Compensation

There have been records of human killing and injury caused by large carnivores in the NL. During 2013–2018, two cases involving leopards were recorded in Sharda Range, of HFD. In the year 2017–2018, five cases of human killing by tigers were recorded from Sharda Range again. The economic loss to the local community in four forest divisions in terms of livestock depredation by tigers and leopards was calculated to be approximately ₹3,24,238 per year in each division between 2013 and 2018. During the period from 2018 to April 2019, 147 incidents of crop damage caused by elephants were awarded ₹4,76,667 compensation, 19 incidents of property damage caused by elephants got ₹1,48,181 compensation and 62 incidents of livestock depredation caused by carnivores got ₹8,66,875 compensation in HFD (31st March 2019). Most of the people were quite satisfied with the compensation policy in livestock loss, crop damage, and property damage cases as they got fair amounts.

4.3. People's perception

4.3.1. For Carnivores

Sixty-eight of the respondents to the questionnaire survey responded that the main reason for carnivore conflict is low prey availability inside the sanctuary, and they also added that the low prey availability in the sanctuary is because of heavy poaching in the past. Sixty percent of the respondents responded that the prey abundance in the sanctuary is recovering, while 81% of the respondents responded that most of the livestock killing happens during grazing near the fringes of the forest. Around 70% of the respondents believed that tigers kill more livestock than leopards, but the forest department records show that leopards kill more livestock than tigers. All the respondents responded that there is no successful traditional or scientific mitigation measure for carnivores. Forty percent of the villagers who live at the boundary of the sanctuary did not support tiger conservation because of the fear of losing forest rights, such as the collection of fodder, fuelwood, sand, boulders, and non-timber forest products (NTFPs) and livestock grazing, while 60 % supported tiger conservation. Most of the supporters lived outside the sanctuary, and they believe tiger conservation provides livelihoods through wildlife tourism, as in many tiger reserves in the country.

4.3.2. For Elephants

Field surveys, village interviews, and focal group discussions indicated that the elephant crop depredation is seasonal in the NL. Sixty percent of the respondents responded that most males and female herds with young ones raided crops, while 30 % of the respondents responded that raiding is exclusively done by male elephants. Of 73 elephants' crop raid signs recorded in 20 villages during the field survey, only adult footprints were recorded in 70 % and both adult and juvenile footprints were recorded in 30 %. Elephants in the NL destroyed a variety of crops including maize, rice, wheat, sugarcane, tomato, jackfruit, banana, mango, and lychee. Most of the people grew wheat (November–April) and paddy (July–October) in the southern part of the NL. The maximum loss of paddy caused by elephants was recorded in August and September, and the maximum loss of wheat caused by elephants was recorded during February–March, just before the harvest. Along the boundary of NWS, the majority of the villagers grow

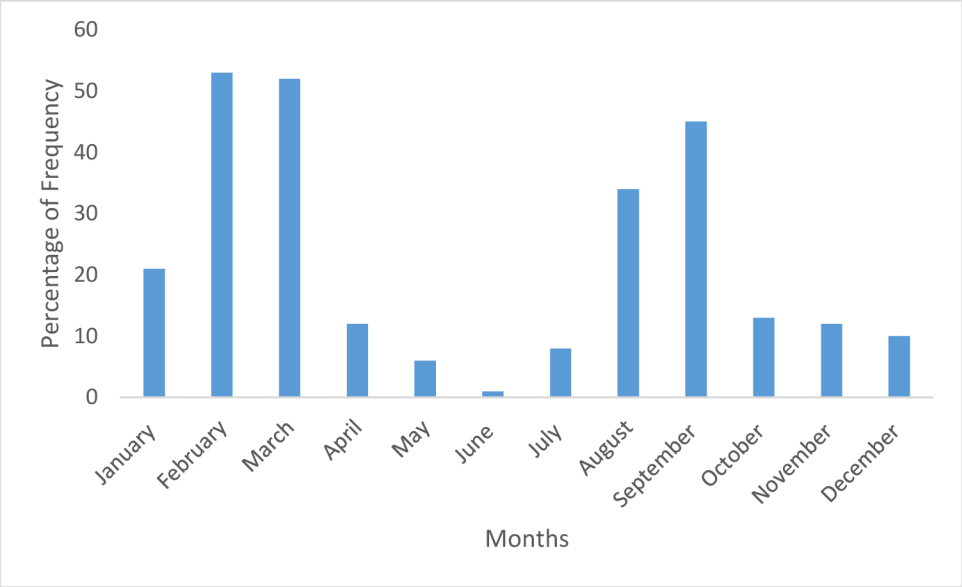

Figure 15 Seasonal pattern of elephant conflict during 2018–19 in the NL

wheat, maize, sugarcane, and paddy, and the duration of the crops is 4–6 months. Paddy planting starts during July–August, during the southwest monsoon, and the crop is harvested during October–November, while wheat sowing starts in October–November, and wheat is harvested during March–April. All the respondents responded that during August–September elephants raid paddy more and during February–March, just before the crop is harvested, elephants raid wheat more (Figure 15). During the interview, 80% responded that crop-raiding occurred exclusively during the hours of darkness, from 16:00 to 06:00 hours, with a peak between 21:00 and 01:00 hours. Thirty-nine percent of the respondents responded that the size of crop-raiding elephant groups ranged from 1 to 9 (median=3), with 80 % of the elephants being in groups of ≤5 animals. Only 12 % of the respondents responded that mostly lone male elephants were involved in crop-raiding incidents. Besides causing crop damage, elephants also attack humans. In 2017, two cases of human killing by elephants were recorded in Chakata Range, of HFD, and two cases of human injury caused by elephants were from Sharda Range, in 2013.

4.4. Mitigation strategies

In the NL, agriculture is the main livelihood (71 % of the 135 sampled families relied on agriculture). 87 % of the families surveyed in HFD considered elephants to be a major threat to personal safety compared with 46 % in the rest of the three forest divisions. Ninety-three percent of the respondents in HFD considered elephants to be the

primary cause of crop losses and property damage, compared with 25 % in the rest of the forest divisions. Therefore, the perception of damage caused by elephants was greater in HFD compared with TEFD, CFD, and NFD. Twelve percent of the families surveyed in HFD considered that blue bulls, sambar, and wild pigs caused more crop damage than did elephants.

Six types of crop protection measures were used by the farmers of the NL. Twenty-six percent of the farmers responded that they mostly shout or raise an alarm whenever elephants enter their fields, while 23 % of the farmers agreed that beating drums helps them keep elephants away from their fields. Fifteen percent of the farmers responded that they chase elephants using Mashal (fire sticks), and 12 % of the farmers used crackers to scare elephants (Figure 16). Ten percent hung colourful and bright metallic colour plastic sheets around their agricultural fields. Central fields were usually not subject to depredation, whereas peripheral fields were at much higher risk.

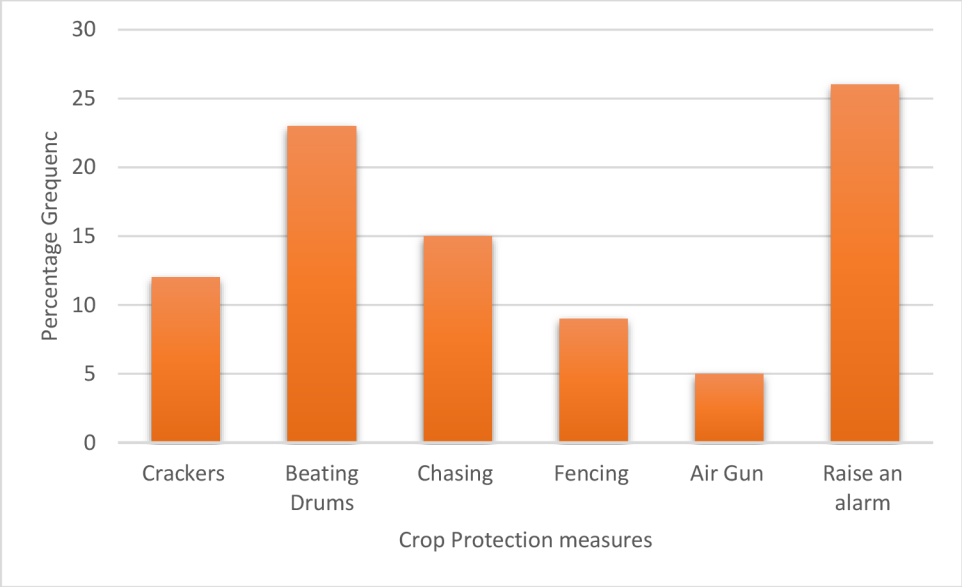

Figure 16 Crop protection techniques adopted by villagers in the NL

4.4.1. Strategy for Mitigating Human-Elephant Conflict

In a bid to mitigate HEC, the early warning system (EWS), an automated thermal detection system that can sense any movement within a 15 m radius, was deployed. Once the system detects a movement, it can play 35 different sounds and emits light, which scares wild animals. A solar panel attached to the top of the system charges the batteries, and the system works through the night (Figure 17). The eight elephant hotspot villages (Aambagh, Thuyal Khera, Gainda Khali, Uchoula Gooth, Nayakgoth, Kishan Nagri, Khera, and Bastiya) in Sharda and Chakata ranges were selected for deploying the early warning system to reduce the elephant conflict. Through interviews and focal group

Figure 17 Early warning system in the NL

discussions with the village heads and forest staff, 20 entry points of elephants in eight villages were identified (Figure 18).

In December 2018 seven EWS with seven infrared camera traps were deployed in four villages in Sharda Range, and three EWS with three infrared camera traps were deployed in two villages of Chakata Range (Figure 20). In March 2019, 10 more EWS were deployed in four villages of Sharda Range. Over a total of 630 trap nights, 1400 images and 230 videos of camera traps were collected from 10 camera trap locations.

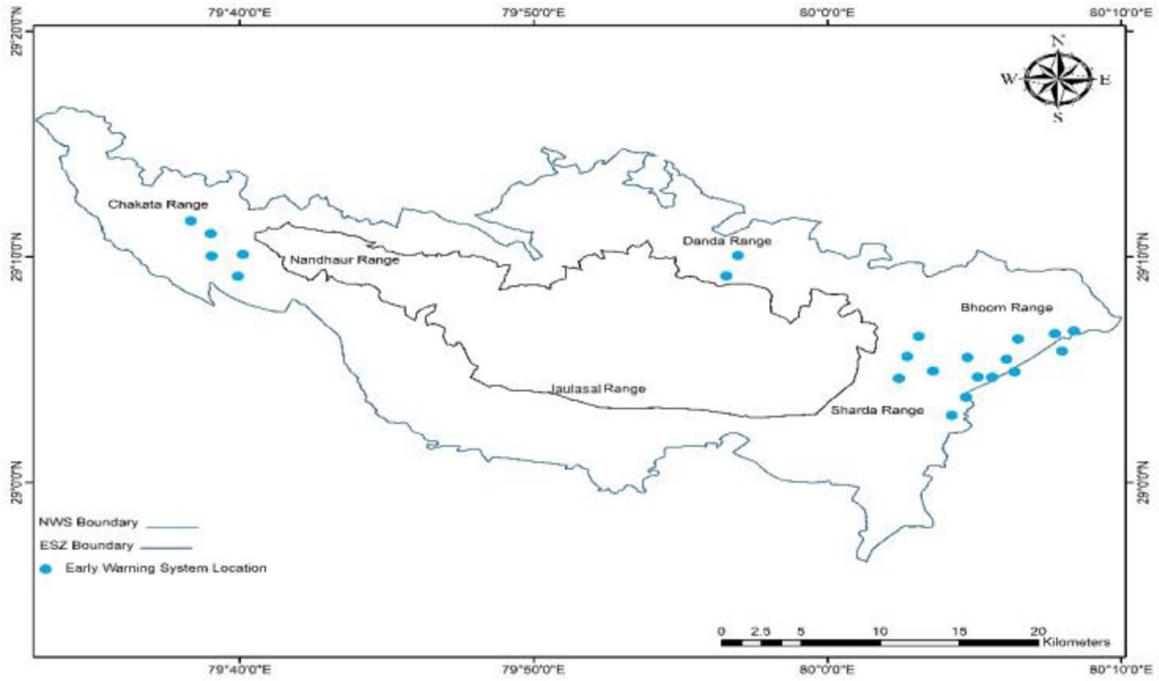

Figure 18 Locations where the early warning system was deployed to reduce human–elephant conflict in the NL

The results show that the frequency of elephant visits to agricultural fields is twice a month. The camera trap data show that the EWS averted elephants effectively in the first 2 months and that this resulted in a 90% decrease in crop depredation by elephants in those villages. But the elephants learned quickly after six or seven encounters with the EWS that there is no danger associated with the sound and light.

After the EWS was installed, a door-to-door questionnaire survey was conducted in 80 households in Sharda and Chakata ranges to understand the effectiveness of the EWS in deterring elephants from entering agricultural fields. Ninety percent of the respondents found that the EWS was effective during the initial months, after which the elephants learned that the sound and light represent no danger. Sixty-five percent of the respondents found that besides elephants, blue bulls, sambar, wild pigs, and feral cattle also avoided the areas where EWS were installed. This was cross-checked against the

camera trap data (Figure 19). As shown in Figure 21, the camera trap data showed that elephants frequently attack agricultural fields at night. Elephants seem to enter agricultural lands or home gardens mostly during the night, between 19:00 and 04:00 hours, and all the respondents also responded that all the raids took place only at night. Therefore, using EWS helps minimize HEC in a few villages but not for a long time.

Figure 20 Deployment of early warning system in Sharda Range

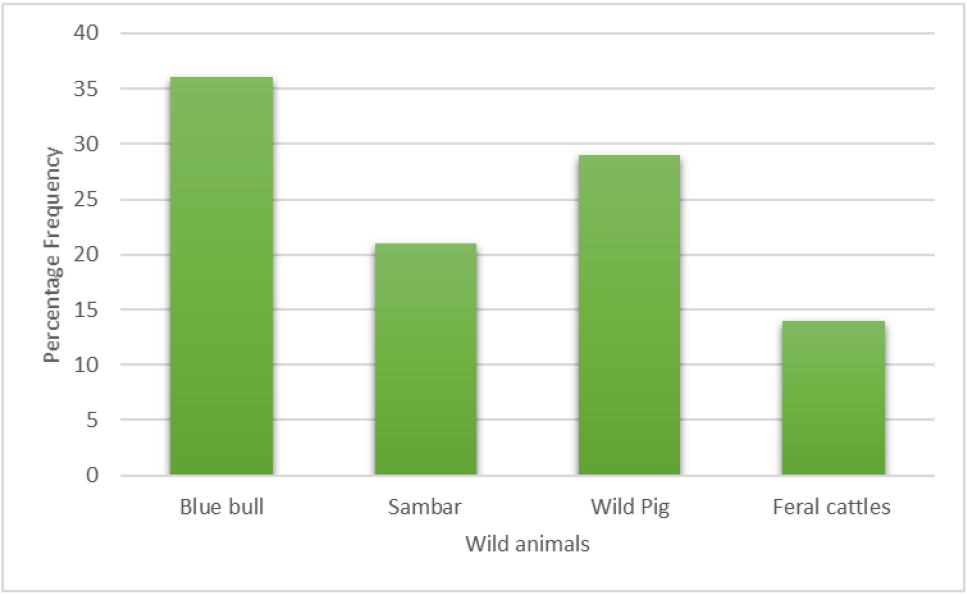

Figure 19 EWS also avert mammals other than elephants

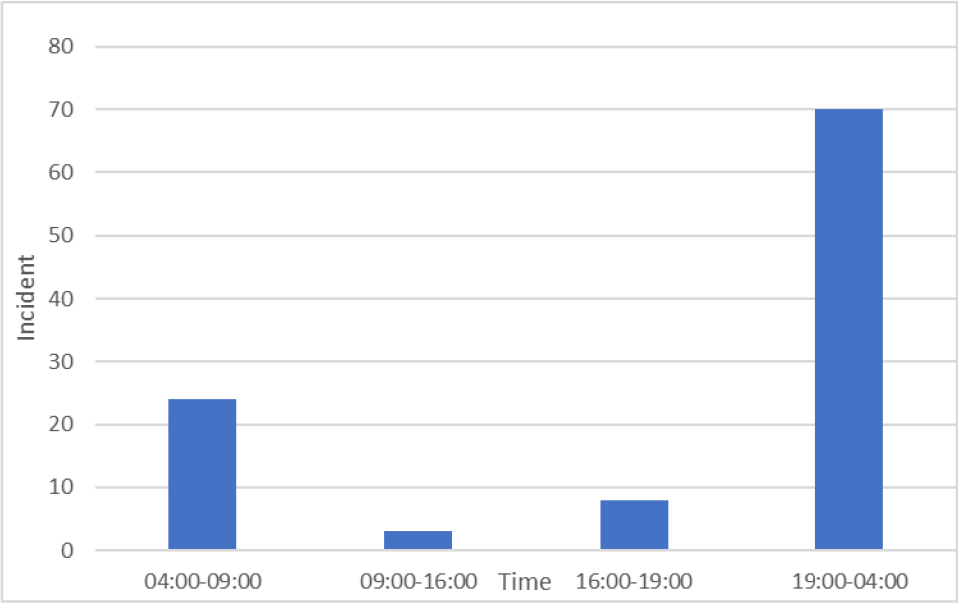

Figure 21 Camera trap data showing frequency of incursions by wild elephants into agricultural areas in the NL

The use of this system benefits both humans and elephants because it does not electrocute wild animals, unlike solar and electric fences. At the same time, the people in the village are notified about an elephant entering the village when the system starts producing the alert signal. Therefore, the EWS was found to be a method that sometimes does not prevent elephants from entering villages but alerts and informs villagers about the presence of elephants in their fields. This system was chosen because it is highly efficient, requires little maintenance, and is cost-effective compared with other mitigating methods.

5. Discussion

5.1. Socio-economics

The Nandhaur landscape is essentially defined by an agrarian economy. Most people living here practice a mixed crop and livestock farming system for their primary subsistence. The terrain complexity of the Siwalik and Terai-bhabar provide commensurate access to varied capabilities in the face of certain advantages and disadvantages. Thus, we classified the data for Siwalik and Terai-bhabar to understand this matrix better.

Employment in the secondary and tertiary sectors is relatively more in the Terai-bhabar region in comparison to the Siwalik region where households are more dependent on the primary sector of agriculture and animal husbandry. Access to certain kinds of employment by virtue of proximity to the place of employment has a significant contribution to this trend. It is evident from the high proportion of local employment availed by those settled in Terai-bhabar vis-à-vis a higher proportion of people from Siwalik engaged in employment outside the state. Those who are employed out of the state are mostly in Gujarat (food-service industry), Delhi (food-service industry and Private jobs), Rajasthan (towel factory), Panipat (food-service industry), Punjab (food-service industry, towel, and garment export factory), Mumbai (food-service industry), Madhya Pradesh (food service industry), Himachal (food-service industry), Lucknow (food-service industry) and Dubai (food-service industry).

Local employment is usually sought in Sitarganj (SIDCUL and food-service industry), Haldwani (wage labor in PWD, dairy cooperative, and drivers), Ramgarh (wage labor in PWD, dairy cooperative, and drivers), Rudrapur (wage labor in PWD, dairy cooperative and drivers), and Chorgaliya (food-service industry). In SIDCUL many people work in the automobile company, soap and mattress manufacturing factory, ironwork factory, and garment sequencing units. Apart from jobs available in companies and factories as carpenters and masons, forest and fire watchers, drivers in Forest Development Corporation (FDC), and enroll as wage laborers in FDC regulated sand mining.

Though there is no significant difference in the annual household incomes of Siwalik and Terai-bhabar, income in Terai-bhabar is relatively more INR 2,07,982.43 (± 15593.91) in comparison to households in Siwalik INR 1,59,872.33 (± 22156.53). It is to be noted that

agriculture in the fertile Terai-bhabar belt is extremely productive and many are small to medium land holding farmers. Apart from the Tharus and Bhoksas, who were dispossessed of their land by late settlers such as the Sikhs and eventually ex-government employees from the hilly regions of the state, most farmers are into commercial farming and have steadily shifted to horticultural cash crops such as mangoes, litchis, sugar cane, etc. This shift in agricultural practices certainly accounts for enhanced annual incomes in the Terai-bhabar region in juxtaposition to that of Siwalik owing to a lack of access to resources and subsequent capabilities. Most of the indigenous communities in the landscape are presently employed as landless labourers with small and medium farmers.

5.2. Human-Wildlife Interaction

Crop loss due to wildlife depredation and wildlife predation of livestock is the most commonly discussed human-wildlife interactions apart from attacks on humans by wildlife. As a preliminary investigation of the nature of human-wildlife interaction in Nandhaur landscape, surveyed sites that are seemingly critical by virtue of their geographical location and consequently heightened chances of human-wildlife interaction. Since these sites and the human-wildlife interactions therein are still defined by the geophysics of Siwalik and Terai but we did not analyze the data separately.

With regards to crop depredation by livestock, it was found that the two major crops of Terai-bhabar, wheat, and Paddy are mostly depredated by wild pigs, elephants, and nilgai in the region. In Terai-bhabar approximately 70 % of loss is incurred per kg of sown wheat and 57 % of loss per kg of sown paddy. In comparison crops such as maize, wheat, paddy, and ragi are mostly destroyed by wild pigs and sambar deer in Siwalik regions. There is an approximate 30 % loss of production per kg of sown maize, 50 % loss of production per kg of wheat and paddy sown, and 40 % loss of production per kg of ragi sown. No compensation is sought for crop loss owing to the long and arduous process of verification and claim.

The study depicts that both large and small livestock predation is quite high in the siwalik region. This might be related largely to the herding practice prevalent, where livestock is usually unsupervised when let out for grazing. Similar unsupervised herding practices can be found among the locals residing in the khattas. The gujjars on the contrary however always supervise the grazing herd. Additionally, as opposed to the practice of abandoning

unproductive cattle in the hills, the gujjars rear the unproductive ones as well for guarding purposes so that even in the event of a predator attack, they lose the unproductive cattle lagging in the herd.

In Terai-bhabar small livestock predations by leopards are reported to be higher in the vicinity of human settlements. Furthermore, in Siwaliks both leopard and tiger predations are higher.

The reason for the high proportion of calves in small livestock predation in Terai can be attributed to the practice of abandoning calves especially male ones after one to two years (or till the milching cow provides milk). Given that there is a shortage of grazing land and fodder for livestock and people in the Terai now rarely use bulls for plowing with the easy availability of tractors, calves usually become a burden and people normally keep only one or two calves (females) and abandon the rest near the vicinity of forests.

6. Conclusions

In the present study, leopards and tigers preyed more on cattle than on buffaloes and rarely preyed on other domestic animals. Overall, more incidents of livestock depredation were recorded in HFD than in the other three forest divisions. This might be due to the contiguous forest patches, which serve as source habitats, with large numbers of predators in and around HFD.

Most of the incidents of livestock depredation were also recorded beyond 3 km from the NWS boundaries of HFD adjoining TEFD and CFD which are contiguous forest habitats of NL. Leopards were found to be the major predator in Nanital, Champawat, and the northernmost areas of HFD, while the tiger was found to be the major predator in TEFD and south of HFD. This could be related to the topography of HFD. The northern part of NWS and HFD is more steep, rugged, and hilly compared with the southern zone, where most of the areas are plain. More images of tigers were captured than of leopards in the southern part of the landscape during the camera trapping survey by the Wildlife Institute of India in 2018 and 2019. This also shows that there are more tigers in the southern part, and thus there are more conflicts involving tigers in the southern part compared with the north zone of the NL. During the monsoon, there were more incidents of livestock depredation by tigers and leopards in the landscape. This could be because it becomes difficult for tigers and leopards to catch the natural prey in the area because of high river flows, increased vegetation cover, and availability of water in the forests.

As mitigation strategies, the villagers used different mitigation measures that were successful in the short term. Raising an alarm and beating drums were the measures most commonly used in the landscape. Besides elephants, wild pigs, blue bulls, and sambar also damaged crops, but elephants were found to be the major species causing crop damage in the landscape. Conflict with elephants increased during August–September, before the paddy harvest, and during February–March, before the wheat harvest. The effect of EWS in minimizing HEC was found to be very successful in the initial months. The villagers also found that besides elephants, EWS helped scare blue bulls, sambar, wild pigs, and feral cattle and stopped them from entering the fields. The camera trap videos showed wild pigs, sambar, blue bulls, and feral cattle running away from the agricultural fields when the EWS started producing sound and light. The camera trap

results, and interviews of villagers revealed that elephants frequently attack the agricultural fields at night. The camera trap images and videos showed that elephants enter agricultural lands or home gardens between 19:00 and 04:00 hours, as noted by the villagers. Using EWS helped minimize HEC in hotspot villages in the initial 70 days of deployment. But this system benefits villagers by alerting them about the presence of elephants in villages through acoustic signals.

There is little tiger conflict around NWS, but with the number of tigers increasing, the conflict will increase due to encroachment and people's activities around Nandhaur. Future activities such as awareness programs for the community in the conflict hotspots should be a priority. Through these activities, the people will be more aware of the importance of NWS and the adjoining landscape. Timely distribution of compensation by the forest department in cases of livestock loss and crop-raiding by elephants in all the villages. The cattle compensation policy of the UKFD is quite effective, and all compensation in all the cases of human injuries, deaths, and cattle kill cases up to March 2019 has been paid to the individual beneficiaries in the NL.

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