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Cover: The critically endangered *Lilium polyphyllum* in watercolour and acrylics. © Aishwarya S Kumar.

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ARTICLE

Patterns of livestock depredation by carnivores: Leopard *Panthera pardus* (Linnaeus, 1758) and Grey Wolf *Canis lupus* (Linnaeus, 1758) in and around Mahuadanr Wolf Sanctuary, Jharkhand, India

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Abstract: Large predator attacks on livestock play a significant role in fuelling conflicts between stakeholders. Effectively managing these conflicts requires a thorough comprehension of locations susceptible to livestock depredation, and the underlying factors influencing such incidents. The recent spread of Grey Wolf *Canis lupus* and Leopard *Panthera pardus* into agriculturally dominated areas in Mahuadanr has resulted in increased proximity between these predators and livestock. We investigated the patterns of livestock depredation in and around Mahuadanr Wolf Sanctuary in the Indian state of Jharkhand using Leopard and Grey Wolf depredation data collected from 2019 to 2021 by the wildlife authorities of the sanctuary. A total of 74 heads of livestock were reportedly killed by Leopard and Grey Wolf in the study area between 2019 and 2021. The Mahuadanr forest beat experienced most of the livestock depredation incidents in 2021, while the maximum depredation incidents happened in Belwar and Lodh sub-beats by Leopard and Grey Wolf, respectively. Livestock depredation incidents varied temporally. Depredation by Leopard occurred more often during evenings (n = 22) and by night (n = 14), but less often during mornings (n = 4). Seasonal livestock depredation by both predators was not statistically significant in our study area. Around Mahuadanr Wolf Sanctuary, hotspots for livestock depredation were identified. The utilization of these findings can facilitate a comprehensive understanding of various aspects related to livestock depredation, while also supporting the design and implementation of effective, long-term conservation strategies for both species.

Keywords: Compensation data, depredation hotspots, financial benefits, large predators, livestock enclosures, poverty, red corridor, temporary relief.

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Author contributions: Concept & Design: SI & OI; Supervision: OI; Data collection: SI; Analysis: SI & OI; Manuscript writing: SI; Manuscript review & comments: SI & OI.

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INTRODUCTION

Livestock depredation by large carnivores and the resulting retaliatory killing represent pressing conservation concerns on a global scale (Madhusudan & Mishra 2003; Thirgood et al. 2005; Treves et al. 2006). Large predators can have significant economic implications at the local level, particularly in impoverished rural areas where households are least equipped to bear such expenses. These costs can hinder the efforts of local communities, particularly traditional pastoralists, to alleviate poverty (Dickman et al. 2011). Negative human-carnivore interactions significantly contribute to large predator reductions, and reducing these interactions is critical to sustain sustainable carnivore populations (LeFlore et al. 2019). Livestock predation is a significant element influencing the effective coexistence of large carnivores and humans from pastoral villages (Decker et al. 2002; Habib et al. 2015).

The Leopard *Panthera pardus* has been assessed as 'Vulnerable' on the IUCN Red List of Threatened Species, and there is evidence for a decline of the global population (Stein et al. 2020). Currently, the Leopard occupies just around 25% of its historical range (Jacobson et al. 2016). Additionally, it demonstrates high adaptability and lives in diverse habitats such as tropical rainforests, deserts, and temperate regions (Kitchener 1991).

The Indian Leopard subspecies *P. p. fusca* exhibits a wide distribution across various habitats throughout India, with the exception of the arid Thar desert and Sundarban mangroves (Prater 1980; Daniel 1996). Within forested landscapes in India, it plays a crucial role as a major predator and coexists with other apex predators such as the Tiger *P. tigris*, Lion *P. leo,* and Dhole *Cuon alpinus* (Jhala et al. 2021). The Leopard is remarkably adaptable when compared to other large carnivores in terms of its habitat preferences and dietary requirements, as it can survive in agro-pastoral landscapes, plantations, and even in close proximity to human settlements, both rural and urban (Nowell & Jackson 1996). In areas where it coexists with humans in a shared landscape, it is likely that some predation on domestic animals occurs (Athreya & Belsare 2007).

Furthermore, in India, the Grey Wolf *Canis lupus* inhabits the dry and semi-arid plains and some forested parts of central India and the Terai plains (Jhala 2003; Dey et al. 2010; Sharma et al. 2019). It also occurs in open grasslands, shrub regions, and rocky slopes, as well as moist forested habitats in Odisha, Bihar, Jharkhand, and portions of West Bengal (Shahi 1982). It thrives on somewhat rocky, undulating terrain with minimal foliage cover (Jhala & Giles 1991; Mahajan & Khandal 2021).

The predation on livestock is a primary factor driving human-wolf interaction worldwide, especially concerning the Grey Wolf (Treves et al. 2002; Kaczensky et al. 2008; Ambarlı 2019; Hamid et al. 2019). The interaction between wolves and livestock poses a significant challenge in wildlife management, particularly in Asia, where Grey Wolf populations extensively overlap with livestock husbandry (Reading et al. 1998; Dou et al. 2014; Ekernas et al. 2017; Mahajan et al. 2021). To ensure the conservation of large carnivores, the government has started many compensation schemes for local people for the depredation of their livestock. The majority of large carnivore population lives within protected areas (PAs) (Bargali & Ahmad 2018). PAs act as sources, whereas adjoining forests and corridors outside PAs aid in the spread of large as well as other predators towards sinks (Bargali & Ahmad 2018). As a result, habitat outside protected areas ensures long-term demographic and genetic heterogeneity (Jhala et al. 2015; Bargali & Ahmad 2018).

Communities living near PAs, on the other hand, face restricted historical rights, constraints on traditional livelihoods, and a minor participation in maintaining and safeguarding such protected places (Maikhuri et al. 2002; Negi & Nautiya1 2003; Chan et al. 2007; Miller et al. 2011). Livestock depredation by both Grey Wolf and Leopard in and around the Mahuadanr Wolf Sanctuary can have significant implications for the tribal villagers residing in the area, who heavily depend on their livestock as a major source of livelihood (Mahaling & Kumar 2021). These incidents of predation may result in a negative perception among the villagers, as the loss of livestock not only leads to economic hardships but also generates tensions and conflicts between humans and wildlife (Mekonen 2020). It is imperative to acknowledge the consequences of depredation patterns against the inhabitants in and around the PAs to balance conservation goals (Terborgh & Peres 2002; Naughton-Treves et al. 2005; Bruyere et al. 2009; Karanth & DeFries 2010).

The objective of this study is to understand the livestock depredation patterns by Grey Wolf and Leopard in and around Mahuadanr Wolf Sanctuary. The landscape sustains a substantial population of Grey Wolves, estimated to be 55 individuals in the year 2010 (Mahaling & Kumar 2021). Furthermore, the Leopard population in the landscape was estimated at approximately 36±9 individuals in 2018 (Jhala et al. 2021). Hence, proper carnivore management

initiatives are necessary in and outside Mahuadanr Wolf Sanctuary, and in adjoining territorial forest divisions facilitating large carnivore movement across the landscape. Moreover, wildlife conservation is a difficult challenge in India's red corridor, i.e., the eastern, central, and southern regions of the country where the Naxalite-Maoist insurgency is most active (Prasad 2015). Mahuadanr Wolf Sanctuary falls within the jurisdiction of the Latehar district of Jharkhand, which is also part of the red corridor (Press Information Bureau 2019). The Red Corridor region of India is often perceived as one of the most underdeveloped areas in the country. The socio-economic progress in this region has been highly unsatisfactory since independence, contributing to the Maoists' ability to gain support from the marginalized communities residing there (Mukhopadhyay & Banik 2013). Livestock depredation by the large carnivores contributes to poverty (Dickman et al. 2011). It is critical to understand every detail about the causes of poverty, as this will ultimately aid in wildlife conservation.

Study area

Mahuadanr Wolf Sanctuary is located in Mahuadanr Block of Latehar district in the state of Jharkhand and it is administered under Palamau Tiger Reserve Circle (Mahaling & Kumar 2021). The sanctuary was declared in 1976 vide Government of Bihar (Mahaling & Kumar 2021). The smallest administrative unit in the study area is sub-beat (Mahaling & Kumar 2021). The sanctuary falls mainly into two beats, namely Aksi and Mahuadanr of the Mahuadanr range (Mahaling & Kumar 2021). A small forest area of the Baresanr range of Chetna sub-beat is also included in the sanctuary (Rawat 2013). The Aksi beat consists of five sub-beats, namely Sarnadih, Aksi, Lodh, Parewa, and Pakardih, encompassing 18 protected forest areas (Mahaling & Kumar 2021). The Mahuadanr beat consists of three sub-beats covering six protected forest areas. The total forest area in the sanctuary is 63.256 km^2 in size (Mahaling & Kumar 2021). The sanctuary borders hill ranges of various elevations, and the western hilltops are flat with an elevation of 1,170 m (Rawat 2013). The major parts are Chiro Pat, Orsa Pat, and Kukud Pat (Rawat 2013). The isolated hills are also nearer to valleys (Rawat 2013). Burha River is the major river draining the Mahuadanr valley (Mahaling & Kumar 2021). The drainage system follows south to north and forms tributaries of the Son river (Mahaling & Kumar 2021).

There are 25 villages adjacent to the sanctuary, and the remaining 72 villages are in the sanctuary's buffer zone (Mahaling & Kumar 2021) with approximately 14,000 households (Census of India 2011). The population constitutes 78.68% of scheduled tribes and 3.2% of scheduled castes population (Census of India 2011).

The climate in the region is characterized as humid and subtropical, featuring three distinct seasons: a hot and dry summer, a cold winter, and a rainy season (Mahaling & Kumar 2021). The cold season typically spans from November–March, followed by the summer season from April–mid-June, and the rainy season from mid-June–mid-October (Rawat 2013). The topography of the area, a cup-shaped valley surrounded by hills, contributes to high precipitation of 1,300 mm annually, of which about 90% occurs during the monsoon season from June–October (Rawat 2013).

MATERIAL AND METHODS

We examined the Leopard and Grey Wolf depredation data collected from 2019 to 2021 by the wildlife authorities of the Mahuandanr Wolf Sanctuary. Depredations on livestock such as Water Buffalo *Bubalus bubalis*, Cattle *Bos taurus*, Goat *Capra hircus* were included in the data. We examined the Mahuandanr Wolf Sanctuary's wildlife section records on livestock in the sanctuary area. The wildlife section conducts annual wildlife surveys twice in a year on various species (Mahaling & Kumar 2021).

We examined the applications and compensation payments for livestock losses to better understand the Mahuandanr Wolf Sanctuary's wildlife section acceptance and denial trends and cross-check figures. To avoid inflated allegations, the sanctuary's officials went to the depredation scene within 24 hours of the incident to determine whether a Leopard or a Grey Wolf killed the livestock or whether it died naturally. We also checked the maximum number of depredations, both by village and community-wise.

Our data is completely based on records of compensation paid to local people by the wildlife section of Mahuandanr Wolf Sanctuary. Chi-square test was used to determine the seasonal difference in livestock depredation. Statistical analysis was done using SPSS version 24 and MS Excel version 2021. The spatial analyst tool of QGIS (Version 2.18.25- Pisa, QGIS Development Team 2018) was used to map the kill sites in and around Mahuadanr Wolf Sanctuary.

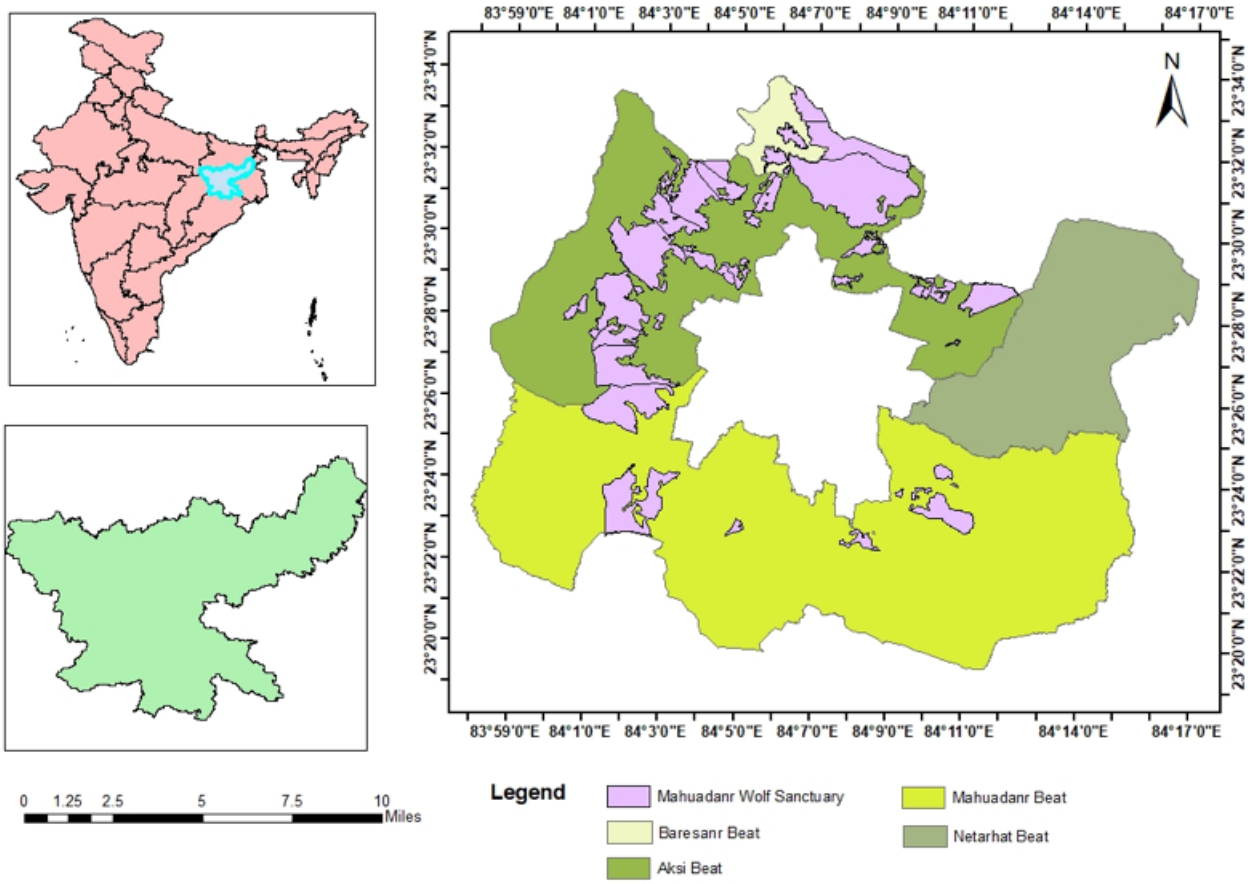

Figure 1. Map of the study area Mahuadanr Wolf Sanctuary and beats of Mahuadanr Range.

RESULTS

Between January 2019 and November 2021, 74 livestock depredation incidents were reported in the villages surrounding Mahuadanr Wolf Sanctuary. These encompassed 21 incidents in 2019, 13 in 2020, and 40 in 2021. The Leopard was responsible for 40 incidents, and the Grey Wolf for 34 incidents.

A higher number of livestock depredation incidents were reported in Mahuandanr beat (n = 49), followed by Netarhat (n = 14) and Aksi (n = 11). At the same time, the Belwar sub beat (n = 25), followed by the Lodh sub beat (n = 19) of the Mahuadanr beat experienced the maximum number of incidents. Livestock depredation incidents around Mahuadanr Wolf Sanctuary indicated that Leopards were the main predator in the Belwar sub-beat (n = 17) and Grey Wolf (n = 16) in the Lodh sub-beat. In contrast, the Aksi sub-beat found a minimum number of incidents. A comparison of livestock depredation incidents across the seasons revealed that depredation by Leopards and Grey Wolves was more during the winter season (n = 57) than the summer season (n = 9), and very few incidents in the monsoon season (n = 8). There was no statistical significance between the predators with respect to seasonal livestock depredation.

Livestock depredation incidents by Leopards and Grey Wolves differed temporally. Leopards preyed on livestock more often during the evenings (n = 22) than by night (n = 14) and in the mornings (n = 4). Grey Wolves preyed on livestock more often in the mornings (n = 14) than during the evenings (n = 11) and at night (n = 9). There was a significant difference in livestock depredation by Leopard and wolf among various temporal durations (χ^2= 9.88, df = 6, P<0.05).

The pattern of livestock depredation differed between the Leopard and Grey Wolf. Leopards mainly preyed upon Cows (n = 23; 57.5% of all), followed by Water Buffalo (n = 9 ; 22.5%), and others (Goat and Ox, n = 8; 20%), whereas Grey Wolf preyed mostly on Goats (n = 34; 100%).

Dujardin and Chutia villages of Belwar sub-beat recorded the maximum cases of Leopard depredation. In contrast, the Lodh, Tewahi, and Mirgi villages of Lodh sub-beat have a maximum of Grey Wolf depredation

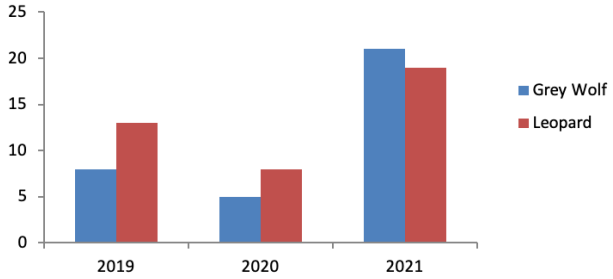

Figure 2. Livestock depredation by Leopard and Grey Wolf between 2019 and 2021.

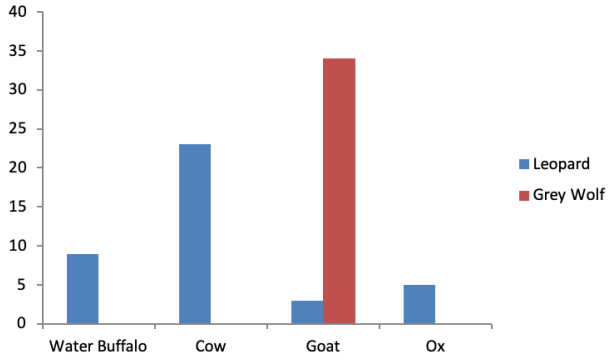

Figure 3 Livestock killed in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

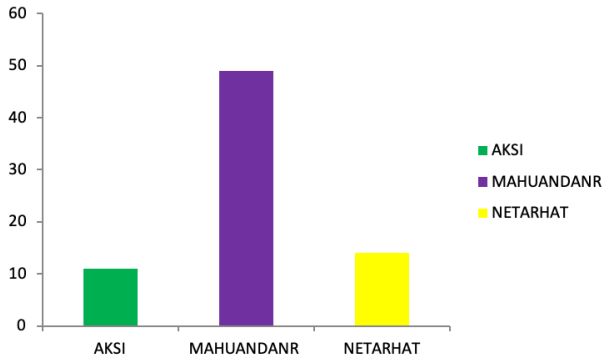

Figure 4. Beat-wise livestock depredation incidents in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

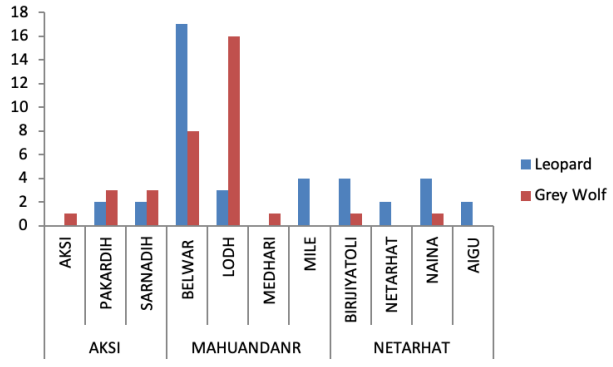

Figure 5. Sub-beat wise livestock depredation incidents in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

incidents.

DISCUSSION

Our results show that livestock loss around Mahuadanr Wolf Sanctuary was more often attributed to the Leopard than to the Grey Wolf. The Leopard is thought to prefer small-sized livestock prey (Patterson et al. 2004). However, in our study area, the majority of compensation for Leopard kills was paid for loss of Cattle and Water Buffalo. On the contrary, the primary cause of Goat kills was attributed to predation by the Grey Wolf, which seems to rely entirely on Goats as a food source. However, it is important to consider that the data available is derived from government compensation schemes, which exclusively focus on livestock and may not encompass wild species. Therefore, conducting further studies is necessary to determine the extent of the Grey Wolves prey dependency within the Mahuadanr Wolf Sanctuary.

Altogether, livestock depredation was higher in the winter season than in the monsoon and summer seasons. This may be due to the fact that Grey Wolves usually leave the region once their breeding season is over, as well as due to less human mobility in the area during the winter (Mahaling & Kumar 2021). Leopards prey mostly in the evening and night hours, which may be owing to the Leopard's nature as a nocturnal animal that is more active in the latter half of the day (Athreys et al. 2015; Chaudhari et al. 2020). Villagers usually return to their homes in the evening with their livestock from the forest after grazing them, which might lead to the predation by Leopards during the second half of the day (Mahaling & Kumar 2021).

The maximum cases of livestock depredation were reported from the Mahuadanr forest beat. Moreover, the Leopard was the major livestock predator in Belwar sub-beat while the Grey Wolf in the Lodh sub-beat of Mahuadanr forest beat. A relation could be drawn to the topography of Mahuadanr Wolf Sanctuary, Lodh sub-beat is rockier and hillier, which is the most suitable site for Grey Wolf dens (Rajpurohit 1999; Saren et al. 2019).

According to the 20th Livestock Census (Department of Animal Husbandry & Dairying 2019), the density of livestock in the Latehar district is expanding, providing easy prey for predators (Mahaling & Kumar 2021). Carnivores are frequently perceived as hazardous and incongruous within landscapes predominantly influenced by humans (Athreya et al. 2020). In light of the growing instances of livestock depredation by large carnivores in the vicinity of the Mahuadanr Wolf

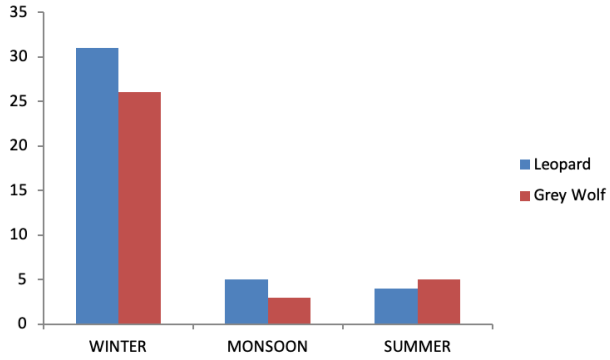

Figure 6. Seasonal variation in livestock depredation incidents in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

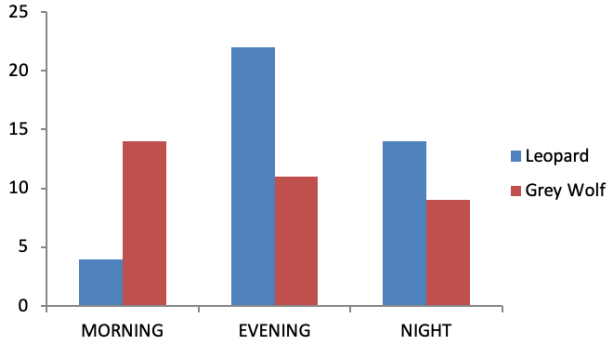

Figure 7. Temporal variation in livestock depredation in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

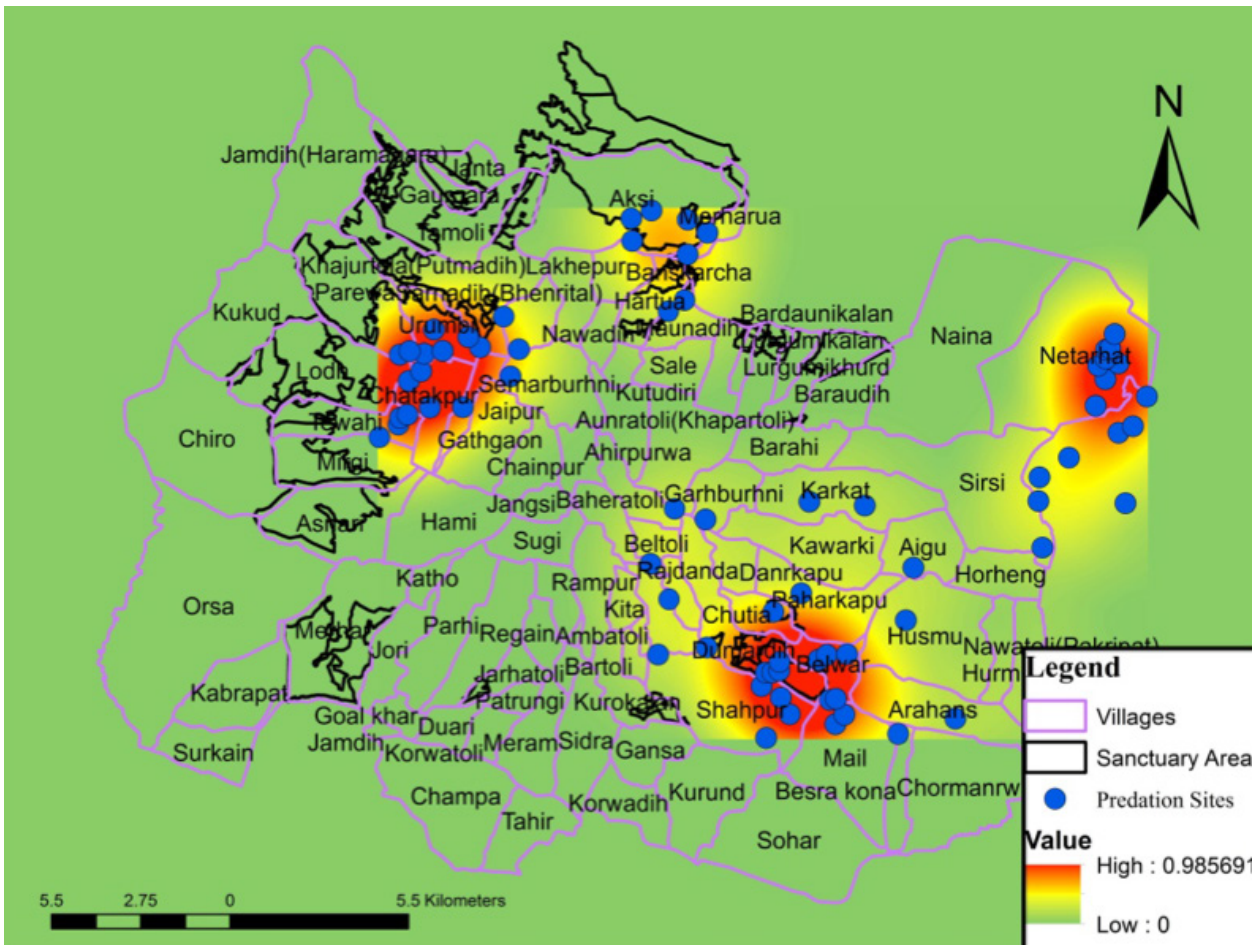

Figure 8. Locations and hotspots of livestock depredation around Mahuadanr Wolf Sanctuary's villages with green colour depicting low interaction and red high interaction areas.

Sanctuary, the impact on the local communities is concerning, potentially leading to economic hardships and an increased risk of poverty among the villagers. In order to formulate practical recommendations aimed at mitigating this situation, it is crucial to thoroughly understand the underlying circumstances surrounding the incidents of predation (Donikar et al. 2011; Mahajan et al. 2022). Through an exploration of circumstantial evidence, it has been revealed that incidents of livestock depredation by both predators are more prevalent during the winter season. Additionally, variations in temporal patterns indicate that Leopards tend to

engage in livestock depredation more frequently during the evening hours, while the Grey Wolf exhibits higher activity in predation during the morning hours. In light of these findings, it is imperative for villagers to enhance their guarding measures while grazing their livestock during these specific seasons and times. Moreover, the Forest Department should exercise heightened vigilance and bolster patrolling efforts during these critical hours.

Sustaining this proactive approach is essential to effectively prevent livestock predation (Suryawanshi et al. 2013). While compensation provides temporary relief, it cannot compensate for the financial benefits that would have been obtained had the livestock remained alive. Therefore, it is crucial for the Forest Department to take proactive measures to establish trust within the community. One potential strategy could involve implementing a program to subsidize the strengthening of livestock enclosures, thereby providing additional support to villagers in protecting their livestock from carnivore predation.

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