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Research Article

Efficacy of different human-elephant conflict prevention and mitigation techniques practiced in West Bengal, India

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Abstract

Human-elephant conflicts (HEC) have become an ever-increasing threat to wildlife management in recent years around the world. In India, West Bengal has been one of the worst sufferers of these conflicts. With 2.89 % of the entire elephant population in India, the state records a high mortality rate, both human and pachyderm every year. Although several mitigation techniques, traditional as well as modern, have been used for many years, however, the conflict cases have not shown any steady decline. It seems that the measures practiced in the region focus on short-term alleviation rather than a long-lasting solution ensuring peaceful coexistence of the two species. The study discusses the mitigation and preventive measures of human-elephant conflicts practiced in the state, their efficacy and shortcomings. The study revealed a single "universal model" is not successful to mitigate the concerns; rather a combination of measures is required. An amalgamation of traditional and modern techniques is also suggested. An efficacious operative mitigation plan should be site-specific and based on several local factors including conflict, physiographical, habitat, anthropogenic and other such variables. Thus, a hypothetical model for designing an effective mitigation strategy has been proposed for future researchers and competent authorities to look into. This could be helpful for policy makers to plan effective management practices not only in the region but also elsewhere.

Keywords: human elephant conflict (HEC); human wildlife conflict (HWC); mitigation techniques; mitigation measures; wildlife management; wildlife conservation; West Bengal, India

Introduction

The Indian elephant (*Elephas maximus indicus*) is recognized as one of the three extant subspecies of the Asian elephant, native to mainland Asia, covering India, Nepal, Bangladesh, Bhutan, Myanmar, Thailand, Malay Archipelago, Laos, China, Cambodia and Vietnam (Santiapillai, 1987). Out of the global population of around 44,000-56,000 Asian elephants (Doyle *et al.*, 2010), India holds a major share, estimated at 29,964 (about 60% of the global population), of pachyderms (2017 census) (Panda *et al.*, 2020).

Habitat loss, degradation and fragmentation, illegal killing and severe HEC cases have hampered their conservation process for long (Treves *et al.*, 2009; Shaffer *et al.*, 2019). The Asian elephant has been listed as 'Endangered' on the IUCN Red List since 1986. It is also included in Schedule I of the Indian Wildlife (Protection) Act, 1972 as well as in Appendix I of the Convention on International Trade in Endangered

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Species of Flora and Fauna (CITES) (Williams *et al*., 2020). Recently, in February 2020, the Asian elephant was enlisted in Appendix I in the Convention of Migratory Species (CMS, COP 13, India), giving it the highest protection status (MoEF and CC, 2020).

In India, a population of 27,312 wild elephants is present within a habitat of 109500 sq. km spread out into four geographical zones: northern, north-eastern, east-central and southern (Lenin and Sukumar, 2011; MoEF and CC, 2017). About 70% of the pachyderm population resides in patchy forest fragments near human settlements with human density above 500 individuals/sq. km at certain sites (Naha *et al*., 2019). Thus, the close proximity of elephant and humans has magnified the cases of conflicts and consequent mortality on both sides (Chakraborty, 2015).

According to elephant census 2017, out of 27,312 tuskers present in India, around 682 (2.49%) are reported from the state of West Bengal (MoEF and CC, 2017; WBAFR, 2019). In terms of elephant population, West Bengal stands 9th among all Indian states, Karnataka being the highest (6049 individuals) (Figure 1) (MoEF and CC, 2017). The wild elephants in the state are scattered over two distinct geographical regions: the northern part of the state (comprising Alipurduar, Jalpaiguri and Darjeeling districts, with 488 elephants) and the southern part of West Bengal (including West Midnapore, Bankura and Purulia districts, with 194 elephants) (MoEF and CC, 2017; WBAFR, 2019). West Bengal also receives seasonal visits of 100-150 elephants from adjoining states of Assam, Jharkhand, Odisha and also from neighbouring country Nepal (WBAFR, 2018).

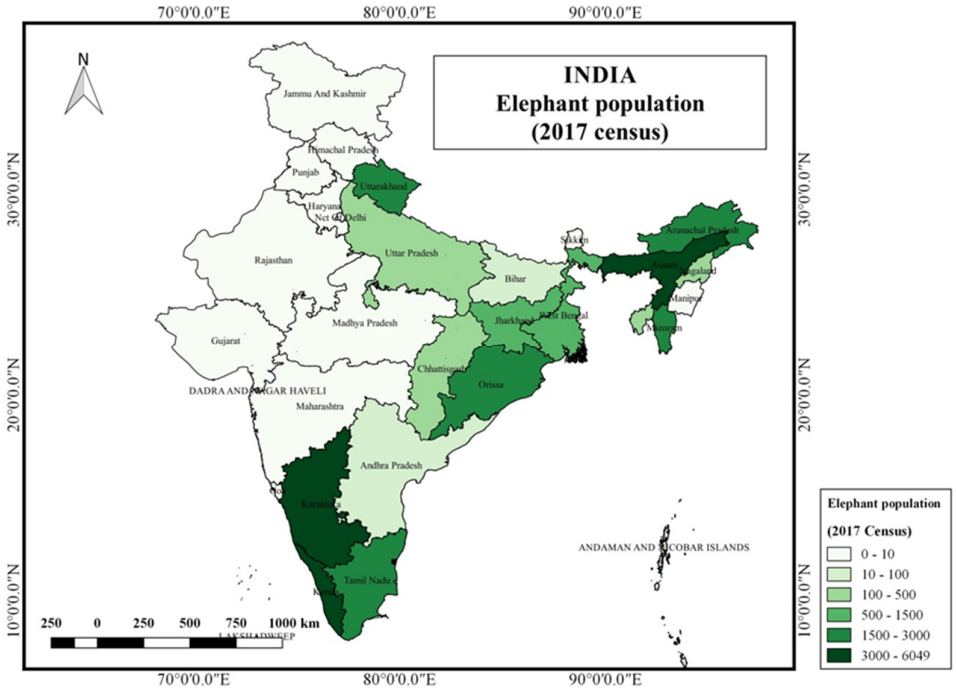


Figure 1. Distribution of elephant population in different states of India (According to Elephant Census, 2017) (Map generated by QGIS ver., 2.18.2, Las Palmas)

Although, with strict conservation measures, the population of elephant has increased in the state of West Bengal steadily (327 numbers in 2000 to 682 numbers in 2017), however, the extent of HECs has increased many folds (Das, 2015; Chakraborty, 2015). Wild Elephants moving through the matrix of forests, tea gardens, croplands, and human settlements have to face severe conflicts bringing about crop-raiding, property loss, human casualty and death at both ends (Rangarajan *et al*., 2010; Chakraborty, 2015). Between 2014 and 2019, 403 human deaths and 63 elephant deaths have been recorded in West Bengal (Kaggere, 2020).

The presence of a broad-gauge railway line through the elephant habitats has significantly added to the potential for HEC (Roy *et al*., 2009; Dasgupta and Ghosh, 2015; Mitra, 2017). A large number of elephant deaths have been witnessed in the 168 km long Siliguri- Alipurduar jumbo "killer track" (Tiwari *et al*., 2017) in northern West Bengal. The death toll rose from 27, recorded between 1974 and 2002, to 65 between 2004 and 2015. Thus, in recent times, on an average six elephants were killed in railway accidents every year in northern West Bengal (Roy *et al*., 2009; Dasgupta and Ghosh, 2015; Roy and Sukumar, 2017). In the past few decades, research on spatial patterns of human-elephant conflicts shows changing land cover in northern districts, leading to both the elephant and human population increment with large tracts of forests converted to commercial tea plantations, army camps and human settlements in Siliguri and adjoining area (Naha *et al*., 2019). Northern habitats of West Bengal, comprising just 1.8% of the entire elephant population of India, witnessed 12% of the human deaths (in terms of national annual record), confirming the heightened level of conflict cases in the region (Tiwari *et al*., 2017). The problem in southern West Bengal started in 1987 when elephant herds from Dalma Wildlife Sanctuary, situated in the State of Jharkhand started migrating to Jhargram Division in the state of West Bengal. The chief etiology of conflicts in the southern part of West Bengal is the movement patterns of migratory elephants (mainly from Dalma range) throughout the year (Singh *et al*., 2002; Santra *et al*., 2007; Chatterjee, 2016).

Several researches have been conducted on the patterns, levels, reasons and effects of HECs, perceptions of locals towards HECs, and corridors of elephant movement in West Bengal (Singh *et al*., 2002; Chakraborty and Mondal, 2013; Chakraborty, 2015; Roy and Sukumar, 2017; Chakraborty, 2018; Naha *et al*., 2019; Kshettry *et al*., 2020). Studies have been conducted regarding various techniques for mitigation of these as well (Venkataraman *et al*., 2005; Santra *et al*., 2007). However, a thorough study on the types, effectivity and application status of different mitigation measures in the conflict zones of the state has not been elaborately done yet. Thus, a study was conducted to highlight the mitigation measures practiced in different human elephant conflict zones of West Bengal, their mechanism and effectivity (including advantage, disadvantage) in addressing the conflict cases. A hypothetical model for successful mitigation of the conflicts is also suggested. This study will help future researchers in analysing the presently applied preventive and mitigation techniques and devising better management practices, not only in the human- elephant conflict prone zones of the state but also elsewhere.

Materials and Methods

Study site

The study was concentrated in the elephant habitats spread over the state of West Bengal, India including the districts of Alipurduar, Jalpaiguri and Darjeeling in northern West Bengal and West Midnapore, Bankura and Purulia districts in southern West Bengal (Figure 2). Major HEC conflict prone zones within the elephant habitats, in the above-mentioned districts, were emphasized for study.

Data collection

The study was based on both primary and secondary data sources. Primary data were collected from different government forest offices, local non-governmental organisations (NGO), forest fringe villagers and local people. For recording unbiased, spontaneous responses and for open ended, elaborate discussions, unstructured (or non-directed) interviews were conducted regarding the types and effectiveness of the existing mitigation measures. The information from the conversation were recorded and compiled with prior consent from the interviewee.

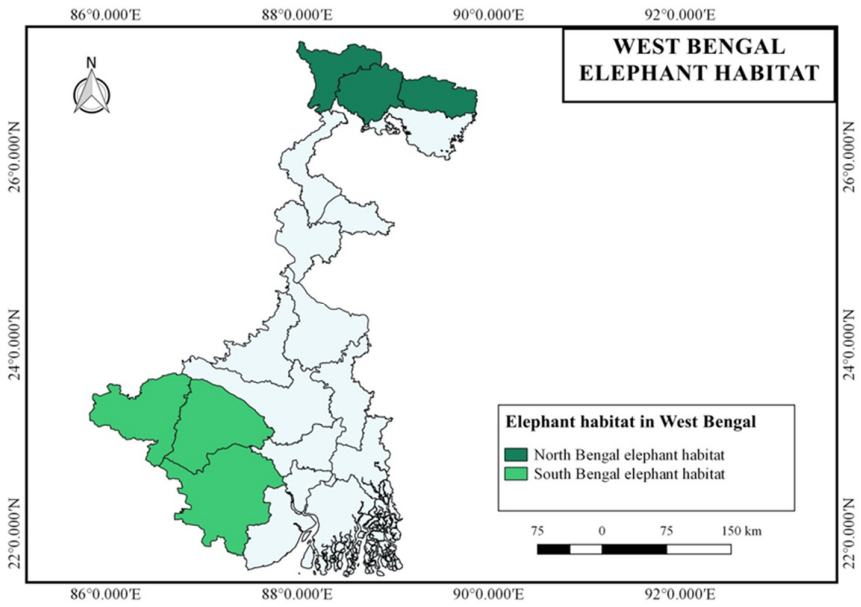


Figure 2. Location of elephant habitats in different districts of West Bengal (Map generated by QGIS ver., 2.18.2, Las Palmas)

Secondary data sources for the study include published papers, forest department reports, newspaper reports, news portals and official websites of government and NGOs. Online data repositories including, Google Scholar, Science Direct, Elsevier, Plos One and others were browsed for all available published articles on the topic during the study period (July, 2020 to June, 2021). The search was done using the keywords: "human-elephant conflict", "mitigation measures of human- elephant conflict", "human- elephant conflicts in West Bengal", "elephant conservation", "elephant corridors" and so on. Articles were then screened according to the focal theme of the research. Cross-references of the papers were also studied for an exhaustive literature survey.

The maps were prepared using QGIS software (ver., 2.18.2, Las Palmas). Graphic illustration was created using *BioRender* software. Charts and tables were prepared using Microsoft Office software (ver., 2010).

Results

Elephant habitats in West Bengal

The forestry area in West Bengal is spread over 16901.5 sq. km, 19.04% of the total geographical area. Among the districts, South 24 Parganas, West Midnapore, Darjeeling, Bankura, Purulia and Alipurduar comprise high forestry areas (Figure 3) (FSI, 2019). The elephant population is distributed among the six districts of the state, viz., Darjeeling, Jalpaiguri, Alipurduar (in the northern part) and Bankura, West Midnapore and Purulia (in the southern part) (Figure 2). The elephant habitat in the state is restricted to about 4200 sq. km, that is, 24.8% of the total forest area (Lahiri Choudhury, 1980; Barua and Bist, 1995; Roy, 2017; WBAFR, 2019). Out of this, about 1933 sq. km is distributed in northern West Bengal and is confined to three distinct geographical zones (Figure 2), namely:

a. The Terai stretch between the River Mechi and the River Teesta, comprising of the forest areas of the Kurseong Division and the Mahananda Wildlife Sanctuary,
b. The western Dooars stretch between the Teesta and Torsa rivers comprises Apalchand range of Baikunthapur Division, Jalpaiguri, Kalimpong and Cooch Behar Forest Divisions, Jaldapara Wildlife Sanctuary, Chapramari Wildlife Sanctuary and Gorumara National Park and
c. The eastern Dooars stretch between River Torsa and River Sankosh that adjoins Assam and Bhutan and comprises the forests of Cooch Behar Forest Division and Buxa Tiger Reserve (BTR) (Tiwari *et al.*, 2017).

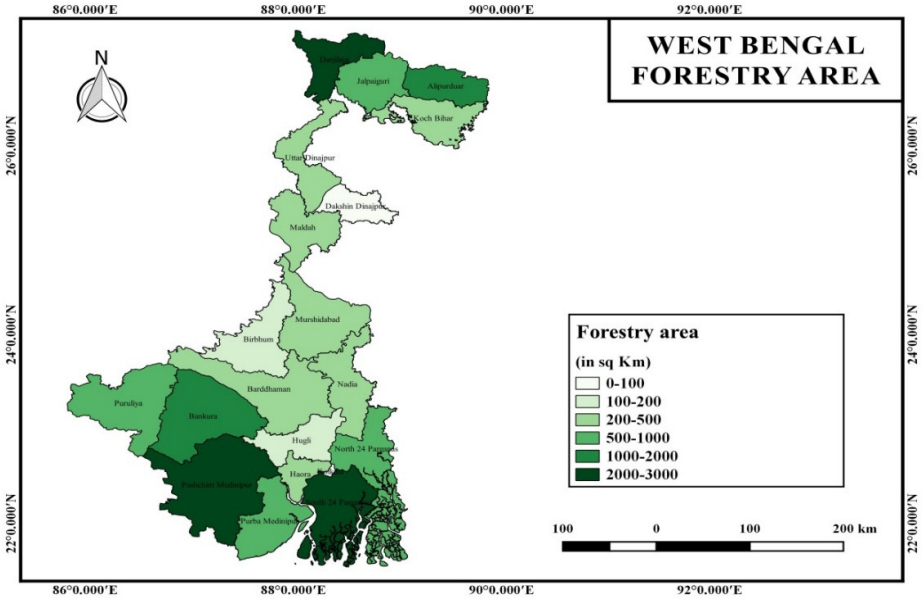


Figure 3. Range of forestry area in different districts of West Bengal (According to FSI, 2019) (Map generated by QGIS ver., 2.18.2, Las Palmas)

The elephant habitats in northern West Bengal are flat or hilly with a maximum elevation of about 1750 m. The average temperature ranges between 8 °C and 32 °C, and, the average rainfall is around 3489 mm. Here, 34% of the elephant habitat is under forest cover, while 27% is under anthropogenic activities. 22% of the elephant habitats are within tea gardens, especially in Terai and Dooars region. Among them, 90% of tea gardens in Jalpaiguri district (including Alipurduar district) and 30% of Darjeeling district are within human-elephant conflict zones. The forest type is of dry deciduous, moist deciduous, semi evergreen and evergreen forests type (Tiwari *et al.*, 2017). The average population density in Terai and Dooars region is 679 individuals/sq. km (2011 census). Among 9 forest ranges, the Gorumara forest range has the highest elephant population density (1.06/sq. km) (MoEF and CC, 2017). As the elephants in this part have larger home ranges, wandering elephants frequently raid human settlements bringing about conflicts.

The elephant habitat in West Midnapore, Bankura and Purulia districts in the southern part of West Bengal is considered as range extensions of the adjoining Dalma Wildlife Sanctuary of Jharkhand. Elephant herds migrate from Dalma Wildlife sanctuary towards the east into Bankura, Purulia and West Midnapore districts shortly after monsoons. The elephant habitats are dominated by dry deciduous and moist deciduous forests. The forestry area here is mostly patchy and chiefly dominated by *Shal* trees (*Shorea robusta*) (Sukumar, 2003; Chatterjee, 2016; Tiwari *et al.*, 2017; Mallick and Chakraborty, 2018; Pandit and Chanda, 2019). The forest cover in different districts of south West Bengal have undergone differential changes over last few years, yet assuring sufficient shelter for the faunae (Mallick, 2018). The land pattern is hilly in the western fringe

while flat plateau in the eastern part. The average elevation ranges between 200-670 m. The average temperature ranges between 8 °C to 43 °C, with an annual rainfall of around 1180-1428 mm (Singh *et al.*, 2002). The population density is around 542 individuals/ sq. km in this region (India, P, 2011).

There are two Elephant Reserves in the state namely, Mayurjharna Elephant Reserve (spread over Bankura, West Midnapore and Purulia districts) with an area of 414.00 sq. km. and Eastern Dooars Elephant Reserve (spread over Jalpaiguri and Alipurduar districts) with an area of 1391.51 sq. km. (WBAFR, 2019).

HEC prone zones in West Bengal

The northern elephant range in West Bengal experiences one of the highest conflicts encounters not only in West Bengal but also in India (Tiwari *et al.*, 2017). In northern districts of West Bengal, the major HEC hotspots are located around eastern and central northern West Bengal belt, covering nine forest ranges viz., Buxa Tiger Reserve (East), Buxa Tiger Reserve (West), Jaldapara Wildlife, Jalpaiguri, Gorumara Wildlife, Kalimpong, Baikunthapur, Darjeeling Wildlife, and Kurseong range (Roy, 2017). The fringe areas around Buxa Tiger Reserve and Jaldapara National Park in the east, Gorumara National Park, Chapramari Wildlife sanctuary in the central part and areas under major tea gardens in northern West Bengal show higher probabilities of conflicts compared to other parts of the region (Naha *et al.*, 2019).

Most conflict zones in southern West Bengal covering West Midnapore, Bankura and Purulia districts of southern West Bengal are not a natural habitat for elephants. These districts attract herds of elephants that migrate during harvest season visit here from Jharkhand. The forest department estimates that at present there are about 194 elephants in southern elephant habitats of West Bengal, out of which 140 are migratory (WBAFR, 2019). Of this, about one-third return to their home in the Dalma hills in Jharkhand but the majority stay back as there is an easy availability of food and water. With each passing year, as the migratory herds kept expanding their numbers, they began entering deeper into south Bengal, even crossing over to Burdwan district. Apart from that herds migrating from Odisha through Mayurjharna Elephant Reserve have created a number of conflict cases in the recent past (Singh *et al.*, 2002; Chatterjee, 2016). The elephant density in southern West Bengal is 0.05 individuals/sq. km (lesser compared to northern districts with 0.25 individuals/sq. km) (MoEF and CC, 2017).

In southern West Bengal, Bankura district, mostly northern and western Bankura belt (including Sonamukhi, Bishnupur, Joypur, Motgora, Taldangra and Sarenga blocks) are one of the most vulnerable zones for HEC (Chakraborty and Mondal, 2013; Panja and Mistri, 2018). In Purulia district the worst affected areas are Jhalda, Kotshila, Matha, Baghmundi and Ajodhya Ranges, whereas, in Midnapore division, Salboni, Gadra, Vatomore, Kalsibhanga, Murakata, Gramal, Chandra, Peechak, Buripala, in the Kharagpur division Chandrakona, Mahespur, Vagabantapur, Vairabpur, Panchhora, Chalogoriand in Rupnarayan division Garhbeta, Raskunda, Mayrakata, Fulberia, Goaltore, Kharikasuli, Bankadaha face the same issue. In the year 2015, 1,598 hectares of crop damage and destruction of 1,677 houses by elephants has been recorded in Bankura district (Banerjee, 2018; Pandit and Chanda, 2019).

Reasons and consequences of HEC in West Bengal

In northern West Bengal between 2001 and 2011, human population has increased by 8.17%, while the elephant population has risen by 38% (Bhadury, 2019). According to a recent census report, the pachyderm density in elephant habitats of northern districts is 0.25 individuals/sq. km (MoEF and CC, 2017). Thus, increase in the human and elephant population has been one of the key factors for increasing HECs in recent times. Pachyderms have a large home range between 100 to 1000 sq. km. Thus, habitat fragmentation and degradation and blockage in their migratory routes are also some of the important reasons responsible for the extensive HECs. A number of corridors for elephant movement have either decreased or have ceased to exist. Most raided areas were also found to have a strong correlation with rice beer (*Haaria*) breweries. Elephants have been found to invade villages with rice beer breweries more than other places in northern districts of West

Bengal. Between 2017 and 2019 around 380 crop-raiding incidents have been recorded, out of which 75% of areas were seen to have *Haaria* breweries (Naha *et al*., 2019).

In elephant habitats of southern districts of West Bengal, most conflicts are created by migratory groups (usually from Jharkhand, Chhattisgarh and Odisha), especially during the harvest period. This is due to illegal felling, encroachments, industrialization and mining in above-mentioned states, the elephant habitat has got compressed, and their traditional migratory routes have been blocked. Consequently, elephant herd does have to take offbeat and disoriented routes in search of food and shelter resulting in conflicts with human.

Although crop damage, human casualties and elephant mortality are the most highlighted consequences of HECs, the other main latent effect is the development of a negative psyche among the victims and local people. This psychic negativity forms a barrier in creating a tolerant and positive mentality for the coexistence of humans and elephants among the local inhabitants. This is a major setback in terms of conservation policies and ecosystem maintenance (Barua *et al*., 2013). This intolerance has brought about ever-increasing conflicts and casualty rates at both ends.

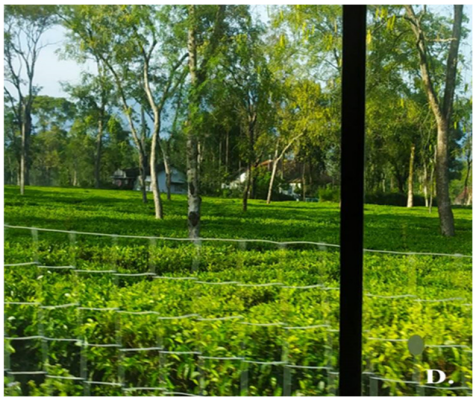
Prevention and mitigation techniques of HECs

Mitigating the HEC is one of the most important conservation priorities as local people are facing serious problems due to loss of crops, damage to houses and even to lives (Vibha *et al*., 2021). Mitigation becomes a huge challenge when life and property loss are extreme (Treves *et al*., 2009). Although, multiple methods have been devised for a long time to manage, prevent and reduce HECs in conflict-prone zones, however, most of the techniques focus on segregating elephants from humans (Shaffer *et al*., 2019). Some of them are traditional methods that are easy to apply at a small scale, while newer ones are sophisticated, technology-based and costly with wider applications. However, none of the methods work single-handedly in any situation. Thus, mitigation measures are circumspective and need to be applied in combinations. In West Bengal, several mitigation measures have been utilized since long. The different techniques according to their success and disadvantages are listed in Table 1, Figure 4.


A


B


C.


D.


E.


F.

Figure 4. Glimpses of mitigation measures practiced in West Bengal; A. Concrete watch tower at Peardoba, Bishnupur, Bankura; B. Iron watchtower at Arabari, Salboni,West Midnapore; C. Electric fence erected to guard crops at a village household at Bankadaha, Bishnupur, Bankura; D. Netted electric fence at Washabarie tea estate,Malbazar, Jalpaiguri; E,F. Railway iron fence near Bagrakote railway station (BRQ) between Siliguri and Alipurduar railway track, North East frontier railways; G. Crop guarding iron fence at Samuktala, Alipurduar; H,I. Elephant proof trench at Jiabandi, Bishnupur, Bankura; J,K,L. Mass awareness programmes by Airavata Foundation (NGO) at Nakshalbari, Darjeeling.

Table 1. Mitigation and preventive techniques practiced in HEC zones in West Bengal, India (Figure 4) (Sukumar, 1991; Lenin, 2011; Venkataraman *et al.*, 2005; Santra *et al.*, 2007; Fernando *et al.*, 2008; Sarkar *et al.*, 2016; Chatterjee, 2016; Basu, 2017; Banerjee, 2018; WBAFR, 2019; Pandit and Chanda, 2019; Mondal and Pahari, 2019; Bhadury, 2020; Gubbi, 2020; Panda *et al.*, 2020; Saha, 2020)

Mitigation techniques used	Procedure/ Methodology	Efficacy (Advantage/Disadvantage)	Location
1. Traditional Methods 1.1. Elephant drive 1.2. Scaring by noise and throwing things 1.3. Crop guarding 1.4. Fire 1.5. Chilli fencing and curtains	i.Driving away elephants physically by locals with the help of wildlife officials is routinely used (Elephant drive). ii.Locals generate noise (shouting, beating drums, burning bamboo, bursting firecrackers and so on), light (fire at entry points to fields, powerful spotlights). iii.*Hullah* is a fire-lit rod, used to frighten tuskers. iv.Farmers at times prepare huts around the cropland and make a sound to guard their crops. v.Chilli as a repellent is used in the form of chilli smoke, chilli rope and chilli bricks. The cost-effective use of 'chilli bombs', where dried chillies are combined with combustible material and burnt, producing a noxious irritating smoke has also been found.	i.These traditional methods have become inefficient more with increased and repeated use. ii.Electric torch, kerosene torch is moderately effective when done systematically. iii.The effectiveness of all these activities decreases as elephants become habituated with increased exposure to them. iv.Males appear to habituate to traditional methods of crop protection more readily than females in herds. v.Crowd management becomes the biggest challenge as people endanger their lives by getting too close to elephants which leads to injury to people in congested areas as well as Elephants. vi.Activities such as noise-making, shouting and throwing objects are more reactive and aggressive. Such activities also indicate to elephants that their presence is detected and that they have to contend with aggressive humans. ii.At times scaring elephants make them split into smaller groups resulting in more rampages of croplands. viii.Chilli ropes were found to be more effective against elephant family groups than bulls, and in drier regions as compared to high rainfall regions.	*Hullah* party is extensively used in all elephant human conflict zones in West Bengal. Chilli smoke is regularly practiced in northern elephant habitats of West Bengal. Elephant drives, crop guarding is practiced in both northern and southern elephant belts.
2. Alert System 2.1. Bulk SMS/Whatsapp and broadcasting of elephant movement 2.2. Trip Alarm 2.3. Sensory based Alarm	i.In places with high elephants-human encounter, advanced warning systems via SMS alerts/WhatsApp Group have been used for prior intimation. ii.The Trip alarm rings when elephants cross a string-trip and gives sufficient warning to the community. iii.Sensory-based alarm system detects elephants in or near village/agriculture land or railway tracks. These are solar-powered infrared systems and are at times fitted with a camera and can alert villagers/ driving squads when elephants are detected close to human settlement through SMS / light/ sound and others.	i.Early warning system through WhatsApp/SMS and regular broadcasting of herd locations has been found to be useful. ii.Technology-based systems are more effective in preventing conflicts compared to traditional methods. iii.However, due to poor network and other technical faults in most forestry areas, conveying a message at times gets delayed or interrupted.	The bulk SMS system has been 60% operational in forests of northern West Bengal and 100% operational in forests of southern West Bengal, since 2016. (WBAFR 2019). In Bankura, a dedicated mobile number (+919015181881) has been made public by the forest department for locating the positions of a wild elephants.

3. Watchtower	i. Watchtowers erected by Forest Department/local people help in keeping track of the movement of elephants and aids in warning the villagers of elephants moving into human habitation. During crop season, villagers use it to protect their crops. ii. Apart from concrete watchtowers, villagers build wooden *Machan* and *Tongs* for vigilance during crop season.	i. Though, it is useful for monitoring but at the time of mitigation, watchtower makes the situation stagnant. People standing on watch tower cannot corner the elephant.	Seen in most elephant habitats of both northern and southern belts. Recently, 23 watchtowers have been constructed in southern elephant habitats of West Bengal.
4. Barriers 4.1. Wire Fence 4.2. Electric/energized and Hanging Fence 4.3. Biological Fence 4.4. Rail Fence 4.5. Elephant Proof trench (EPT) 4.6. Razor-blade fencing in tea-estates	i. Barrier forms a boundary between areas where elephants occur and where they should not move. ii. Fences are built with regular materials like wire, concrete or wooden posts. Electric fences carry high voltage at low amperage as a pulsed current. They are not intended to cause physical harm to elephants but give a powerful and unpleasant electric shock upon contact. iii. Some fences are maintained on a duty cycle of 12 hours, from 6 PM to 6 AM, with the current switched off during daytime as elephants during daylight are less likely to challenge it and to conserve batteries. Electric fences vary widely in their construction. iv. Forest Departments are adopting bio fences as a biological elephant barricade which is made of thorny plant varieties or unpalatable crops. v. Elephant Proof Trenches (EPT) are used around small forest blocks but moderately useful around large forest blocks. vi. Razor blade fences are used in tea gardens, especially in Dooars belt. The fencing material comprises of sharp objects.	i. Barriers are one of the most preferred mitigation technics used in the region with good effect. ii. Injudicious and unplanned use of electric fences, razor blade fences, and electric proof trenches can be extremely detrimental to elephant conservation and likely to result in the death of large numbers of elephants. iii. Involvement of the local community or the stakeholder is most important for the effectiveness of the barriers. The stakeholders must be actively involved in the installation and the maintenance of the barrier iv. However, in a largely agricultural landscape, it becomes difficult to create effective barriers. v. Some elephants eventually adapt with prolonged exposure. The fence becomes useless against the particular individual, once an elephant learns to breach the electric fence. vi. Elephants breach electric fences by using tusks (male) that do not conduct electricity, pushing or kicking down fence posts and stepping over the fence using the thick soles of their feet to depress the wires. vii. Some elephants also learn that an electric shock does not harm them and simply passes through the wires. viii. In situations where a barrier is constructed across elephant home ranges, inaccessibility and loss of resources can greatly jeopardize their survival. ix. Rail fencing though expensive is eco-friendly and more effective than solar electric fences, elephant proof trenches, which are partially successful. x. Elephants and calves at times fall into trenches and get stuck or drown. Trenches with concrete side walls are dangerous because if elephants fall in it then they are unable to climb out. Thus, it is important to construct points in the trenches where elephants can climb out to the side they are to be restricted to in case of falls.	In West Midnapore, Bankura and Purulia districts of southern West Bengal electric fences have been effectively used to separate elephants migrating from Dalma range. Bio fence has been successfully implemented at Jaldapara National Park. Recently, the forest department has dug 108km of elephant proof trench and 103 km of elephant-proof electric fencing in the entire West Bengal.

		xi. Elephant trenches are costly and need to be maintained throughout the year. xii. The elephant herds are often forced to divert their routes for movement, across the tea estates due to randomly installed razor fencing which results in negative encounters between elephants and humans. To deter elephants from entering tea estates, the owners have started using the razor-sharp barbed wires which cause serious injuries to elephants and other wildlife, many of which die.	
5. Alternate livelihood	i. As a mitigation measure, people in conflict zones have started to switch their source of income to alternative forms such as, poultry, dairy farming and others as the source of income.	i. Switching to alternate crops and livelihood may require adopting farming practices different from the traditional practices and people are found too reluctant to do so.	Few farmers of Darjeeling, Jalpaiguri, Bankura, and West Midnapore have shifted their livelihood to avoid life threats from elephants.
6. Alternate crop harvesting	i. Alternate cropping with non-edible crops like chilli, citrus, ginger, onion not consumed by elephants are grown in forest fringes as well as areas near settlements in forest fringes. This deters elephants from reaching and raiding the crop fields.	i. Growing unpalatable crops over large areas will result in loss of habitat and ranging areas, threatening to the survival of elephants that used to range in such areas. ii. Change of crop pattern from traditional livelihood farming to alternate crops by farmers does not seem to be practical and is unacceptable to cultivators in many areas.	Few farmers of Darjeeling, Jalpaiguri, Bankura, and West Midnapore districts of West Bengal use this technique.
7. Deployment of combat teams 7.1. Anti-Depredation Squads (ADS) 7.2. Early/Rapid Response Squad (ERS or RRS) 7.3. EMCC (Elephant movement coordination committee)	i. Anti-Depredation Squads (ADS) have been set up with trained officials and untrained locals. They reach out to conflict spots and help in rescue work. ii. Early Response Squads (ERS) have been created involving community participation in forest fringe villages. iii. Since 2016, a special vehicle called "*Airawat*" has been deployed in the forests of Bankura, Jalpaiguri and Alipurduar for rapid combat. The vehicle has all modern amenities including tranquilizing guns, net, generator and others. iv. EMCC has been formed in southern West Bengal, headed by the chief conservator of forests, coordinating forest officials for prompt action.	i. ADS squad members need to be equipped with vehicles, torches, sirens, firecrackers and even with double-barrel guns and should be trained regularly to address HEC situations systematically. ADS should be composed of trained staff and local volunteers too. ii. ERS members are not always trained enough to tackle all circumstances.	ADS and ERS have been deployed in both northern and southern West Bengal forests. EMCC has been functioning in southern West Bengal districts.
8. Habitat development and improvement	i. Improving the quality of forest areas by growing fodder plants, salt licks, and the water source is a practical method of alleviation.	i. It helps in restricting elephants in their wild habitat. However, the application is made on a small scale. Large-scale effort is required to make it successful.	This method has been applied successfully in forest ranges of Bankura district.
9. Awareness Programmes	i. Multiple stakeholders like governmental agencies, NGOs, and local people are working coherently in some areas. Regular mass awareness camps are organized at local levels to	i. More coordination between all the stakeholders and the local people is required for effective mitigation measures	Practiced throughout the HEC zones in West Bengal by government and non-

	make people aware of the mitigation measures and rescue works. ii. Leaflets, posters, pamphlets, calendars are distributed among fringe villagers mentioning do's and don'ts during a conflict situation.	and to develop a positive psyche about wildlife among local people.	government organizations,
10. Advanced technological measures 10.1. Satellite Telemetry 10.2. Global Positioning System 10.3. Seismic sensors 10.4. Drone 10.5. Automated Early Warning System (AEWS)	i.Satellite-based telemetry has been potentially used for setting up an 'early warning system' ii.Seismic sensors have been utilized for warning systems using movement patterns. iii.Drones are also implemented in certain areas for proper surveillance. iv.Recently, an automated elephant tracking device, based on infrared technology, was installed near fringe villages of Gorumara National Park, Jalpaiguri which could detect the presence of elephants within 200 m distance.	i. Technology based measures are effective at certain locations, however, may be costly. ii. The efficacy of this technology in dense tropical forests may, however, be limited. iii. The range of application is also limited. iv. At the same time, its use in mitigating wildlife–human conflict has not been examined extensively so far.	Applied in small scales at West Midnapore, Bankura and Purulia districts of southern West Bengal and Jalpaiguri in northern West Bengal.
11. Miscellaneous 11.1. Building tube well with toilets 11.2. Creation of solar street light 11.3. Standard Operating Procedure (SOP)	i.Lack of sanitation facility in many forest fringe villages make people victim of elephant attack during open defecation. Thus, building toilets and tube wells at poor households has been a good strategy to reduce human-elephant contact. ii.Illumination conflict-prone zones have been beneficial in reducing conflicts at many interior locations. iii.Standard operating procedures have been issued regularly by the State Forest department on emergencies arising due to straying of wild animals, or due to any human casualty. It is issued by the Principal Chief Conservator of Forests (PCCF) of the department from time to time.	i. As a result of avoiding open defecation confrontation with elephants can be negated. ii. Solar street lights have illuminated several interior places within forest fringes. iii. SOPs communicated at proper timing have reduced casualties to some extent.	Such innovative techniques have been utilized at Jaldapara Wildlife Division in Jalpaiguri and also in Bankura district.

Successful mitigation techniques of HEC in other states of India

Recently in Odisha, the local joint forest management group has utilized the bamboo seed ball technique as an efficient mitigation technique. The fresh bamboo (*Dendrocalamus sp.*) seeds are rolled into balls and thrown into unreachable forest areas. This process has helped in increasing food reserves within the forest area and is expected to do more in the next five years helping in limiting elephants in their wild habitats. Chhattisgarh government is also using the same technique using other fruit-bearing plant seeds. The state forest department has developed a mobile application called "*Sajag*" which intimates to the fringe dwellers the presence of elephants within 2 km (Kumar, 2021). An NGO in Karnataka has implemented the use of digital display boards at strategic locations projecting the locations of elephants to the locals (Aravind, 2019). Since 2018, an NGO, working in collaboration with the state forest department in Chhattisgarh has started radio collaring the matriarch individual of the migratory herd. It has helped in tracing the herd location beforehand, thus helps in making locals aware of elephant raids (Wildlife SOS, 2019). In Chelur village in Karnataka's Kodagu district, the "honey bee fence" has been initiated as a cost-effective mitigation measure, with some success (Arakal, 2021). In a recent study done at foothills of western Himalayan India, an incentive-based mitigation strategy involving the local community has been proposed to be effective in reducing the negative psyche of the inhabitants (Badola *et al.*, 2021). Thus, such effectively successful techniques can be provisionally implemented in major HEC prone zones in West Bengal.

Discussion

The study reveals HEC situation is severe in the state of West Bengal, especially in the northern districts. Several, traditional and modern mitigation techniques have been employed to mitigate conflict situations throughout the conflict zones. While traditional methods have limited effect, barriers of different forms have been found to be comparatively more potent and extensively used method of mitigation technique. In recent times, with use of modern technology-based techniques, alerting, preventing and combating HECs have become more far reaching, prompt and effective to certain extent. However, all these techniques have pros and cons associated with them (Table 1) and thus, are not solely sufficient. As an outcome, successful mitigation and prevention of HECs have not been achieved in the state. Thus, an effective mitigation method seems to be multifaceted and spatio-temporally determined. A hypothetical effective model of mitigating HEC is thus described:

Hypothetical model of mitigating HEC

West Bengal being a state with diverse physiography, biodiversity, socio-economic culture, and demographic variables, an effective mitigation technique needs to be multidimensional and site-specific. Considering previous works an effective conflict management technique is proposed based on multiple variables such as anthropogenic variables, physiographical variables, elephant habitat variables, elephant related variables, conflict variables and so on (Figure 5). For a peaceful long-term coexistence, all these factors have some significance in conflict management and should be given equal importance while formulating a strategy.

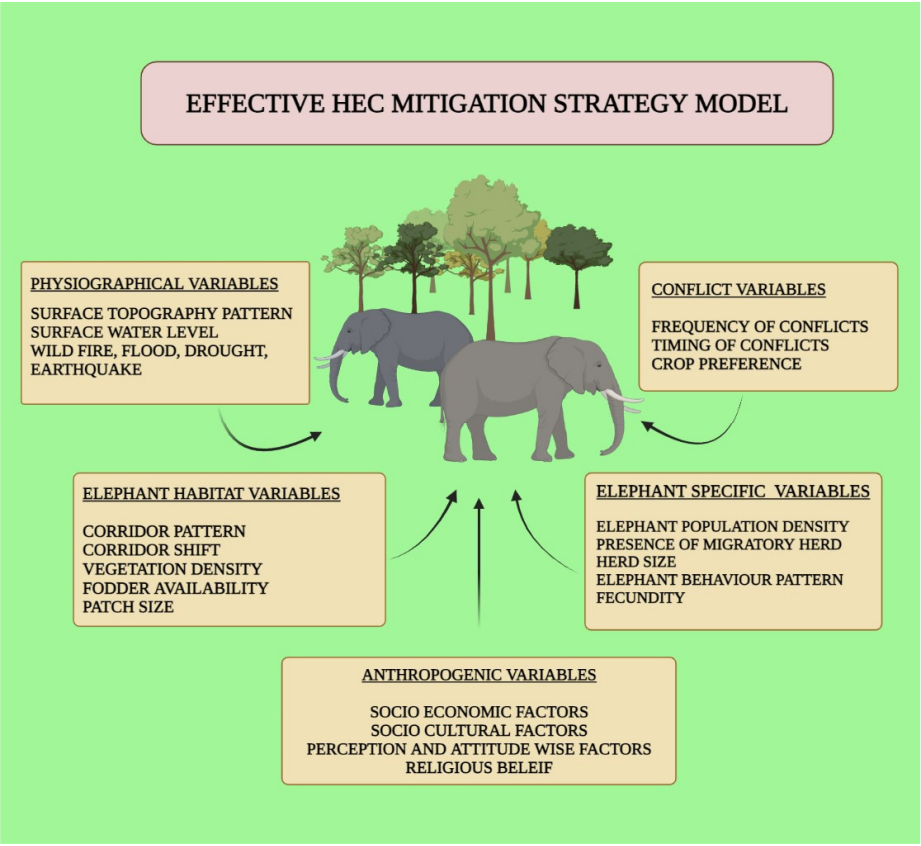


Figure 5. Hypothetical model of effective HEC mitigation strategy (variables are described in the text) (Prepared using *Biorender*)

Anthropogenic variables include factors that are directly related to human aspects, including socio-economic, socio-cultural, perceptions and attitudes factors, religious belief of the local people and so on. Humans, being a main component in the conflicts, these factors need to be carefully analysed site specifically before devising a measure. Human perceptions about the conflicts and attitude towards presence of wild animals are crucial factors in dealing with the situations.

The physiographical features impact elephant movement and human settlement in various ways. The surface topography pattern (namely, slope, soil fertility, soil moisture), surface water level, habitat degradation, the occurrence of wildfire, flood, drought, earthquake and so on are crucial factors for conflict management. These factors regulate elephant movement and migration patterns.

Elephant habitats do have several viabilities such as the corridor pattern (length and width, decreased or intact, presence of human settlement around, blockage and so on), corridor shifting, and vegetation density in forest patches, patch size, fodder availability in the patches and so on. These factors vary according to the region and area and impact conflict situations largely.

Elephant-specific variables include elephant population density, presence of migratory elephants from neighbouring states or countries, herd size, fecundity, elephant behaviour pattern and so on. Thus, understanding the nature of the elephants seems to be very essential for management.

Conflict patterns also show some type of variability in terms of frequency of conflicts, the timing of conflicts, crop preferences and so on. These vary spatially and thus are important for mitigation planning.

Conclusions

Since March 2021, around 11 elephant deaths have been recorded in forests of northern districts of West Bengal out of which 8 have been due to electrocution. According to reports, the deaths have been due to the deliberate erection of high voltage electric wires by the locals. On contrary, four villagers have been killed by the tuskers in the region in the same period. This record summarises the sustained and the ever-increasing magnitude of HECs and the failure of existing mitigation techniques in the region. This unremitting fallout has become an important socio-economic and ecological issue as the villagers in the conflict zone have become intolerant towards the invading elephants. Victimized inhabitants find the forest officials accountable for their inability to resist the elephant raids. As the central and state forest departments have the sole responsibility of policy making and application of wildlife management and mitigation approaches, the accountability seems to be obvious.

Currently used prevention and mitigation techniques mainly focus on the broad approaches including use of deterrents, barriers, compensation, or alarming people. However, it seems the management practices focus more on mitigation rather than prevention. This is because the measures more often address the outcomes of the conflicts rather than reducing the root of the problem. Understandably, there cannot be a universal model of mitigation as the circumstances are different in different regions, even within a single state. Thus, site-specific models of mitigation need to be devised, focussing not only on wildlife management strategies but also taking anthropogenic drivers, including socio-economic and political factors into consideration. An ideal, effective conflict mitigation model (as proposed in the study, Figure 5), thus, should encompass the following consideration: human and elephant etiological aspects, socio-economic and socio-cultural aspects, landscape and geomorphological aspects. As modern technological devices have far-reaching effects, an amalgamation of traditional and modern techniques is also suggestible.

Mitigating the problems has become tougher in recent times for numerous reasons. Increase in human and elephant population, the negative psyche of locals towards elephants, decrease in forest habitats are some of the mains. Although it should be mentioned constant monitoring and surveillance of wild elephants in the forests is neither possible nor desirable from the ecological point of view, however, alternative means of tracing have to be thought of. Participation of local communities, NGOs, the tourism industry, local media is very

essential for spreading awareness and changing the negative perception and attitude of local people. In addition, surging death tolls of elephants due to electrocution from lethal electric fences or saggy electric wires need proper investigation in the specific regions.

The proposed hypothetical model takes into account all the possible factors involved in strategizing an effective mitigation measure. Future researchers can consider the variables mentioned while conceptualizing ideal techniques in the future.

Authors' Contributions

SC conceptualized, collected data, analysed and prepared the manuscript. NP collected data, photographed and added necessary inputs towards finalisation of the manuscript. Both authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Participation by respondents was voluntary and anonymous in the study and done with prior verbal consent.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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