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A COMPARATIVE REVIEW ON HUMANITY CASUALITY PATTERNS DUE TO ASIAN ELEPHANTS ELPHAS MAXIMUS

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Abstract.

Human casualties caused due to human-elephant conflicts are a major problem in the modern world where conservation is often pitted against development. This review paper is an attempt to study cases where human casualties have occurred due to human-elephant conflicts involving Asian elephants (Elephas maximus) by using peer-reviewed articles and verified news reports from various national and international dailies. The main aim of this study is to understand monthly, seasonal, spatial, and temporal patterns of human casualties and our study reveals that most human casualties due to Asian elephants occur during the dry season (winter) mostly in December and January with very few exceptions and occur in higher frequency in farmlands located near fringe areas or boundaries of protected zones. Temporal patterns indicate that most of these casualties have occurred in the nighttime. The patterns are supported with relevant statistical data and analysis for better understanding of the problem. Mitigating this problem is a challenge which is discussed in this article with potential solutions suggested as per proven and tested methods and is also based on our understanding of these patterns.

Keywords: *human casualties due to Asian elephants, protected areas, seasonality, human-elephant conflict, human casualty patterns, and spatio-temporal pattern.*

Introduction

Elephants are the largest terrestrial mammals. Elephants are found in their natural habitat on only two continents – Asia and Africa. Elephants of the species *Elephas maximus* which is the only living species of the genus *Elephas* are found majorly in South and South-east Asian countries like India, Bangladesh, Nepal, Bhutan, Sri Lanka, Myanmar, Thailand, Cambodia, Laos, Indonesia, Malaysia, and China (Sukumar, 2006; Olivier, 1978). In Africa, there are two species of elephants living – African Savanna Elephant (*Loxodonta africana*) and African Forest Elephant (*Loxodonta cyclotis*) which are found in almost entire African continent apart from some northern African nations (Thouless et al., 2016; Douglas-Hamilton, 1987).

Every year, there are several instances of human-elephant conflicts (HECs) occurring by destroying crops, livestock and causing human casualties, sometimes even death (Shaffer et al., 2019; Sukumar, 1991). This has become a major longstanding issue in conservation of elephants (Sukumar, 2006). Human casualty occurrence due to elephants is one of the grave results of HECs where hundreds are killed every year in Asia and Africa. It is especially important to study these incidents and produce effective and feasible prevention techniques and wildlife management strategies to reduce both human and elephant casualties.

Most of the human casualties have occurred in the areas inside or near the protected areas where elephants live or migrate. This is seen in all the cases studied in this paper with no exceptions. The foremost cause of human casualties due to elephants is the provocation of elephants by farmers in farmlands located in fringe areas of protected areas to drive away the elephants where they enter to forage for food. Night-time HECs are more casualty-prone because of sudden and unprecedented attacks on humans by elephants which is reflected not only in farmlands but also on roads located near the protected areas. Apart from

the areas around the protected areas, there have been cases of human casualties inside these protected areas as people go to collect wood, fruits and leaves from these forests and end up encountering elephants. Seasonal influence of elephant attacks on humans is also seen mostly during the dry season (winter) with little exceptions to this pattern. Also, natural causes of driving the elephants out from their natural habitats like floods or drought-like conditions play a significant role in HECs resulting in casualties on both sides.

All these casualties have a negative impact not only on the daily lives of the people residing in these areas but also pose a problem to the purpose of conservation of elephants as local people often tend to differ from the cause of conservation. So, the problem of human casualties induced by elephants needs to be studied to prevent such incidences and create a better place for both sides to sustain their lives easily.

Despite rising importance to wildlife management of elephants and implementation of several measures and incentives to reduce HECs, human casualties are still common in the context of HECs, especially in Asia. Most of the elephant population share their natural habitats with humans or use forest corridors close to or through the human settlements which increase HEC instances. Moreover, rapid urbanization, habitat destruction and human encroachment especially in South and South-east Asian countries where most of the wild Asian elephants reside have witnessed most HECs and resultant human as well as elephant casualties. Therefore, addressing the pressing issue of conservation of *Elephas maximus* along with the goal of human development and casualty reduction is an utmost need and has gained importance over the last few years.

Human casualty cases caused by *Elephas maximus* (Asian elephants) have been studied in this review from various parts of Asia to understand the nature of elephant attacks and understanding the causes of their attacks on humans. Many diverse types of patterns of these casualties in the form of injuries as well as deaths have been noticed and studied. It is also noticed that more detailed studies about HECs pointing out the casualty patterns of both humans and elephants are required in several places where the Asian elephants are found in the wild. Some of the major patterns have been taken up in this paper and studied considering cases from various places to understand if there is any uniform correlation in elephant-induced human casualties in Asia. The human casualty patterns studied in this paper are monthly pattern, seasonal pattern, spatial pattern (outside/inside reserved areas) and temporal pattern (diurnal variation).

Methodology

General Overview

The initial aim of the review paper is to discern the reasons of Asian elephant attacks on humans which eventually caused human casualty in the form of physical injury or death. A comparative analysis is done to see if these elephants are disturbed or provoked by humans before their attack or if they attack humans due to other reasons. These reasons might be linked to their daily survival and the survival of their kin, like food foraging in farmlands, protection of elephant cubs from passers-by or sudden events like natural disasters which unleashes a lot of mayhem among wildlife. The latter case of elephant attacks is more violent than the former case and it has resulted in a higher number of casualties among humans. This is because in such cases, humans are more likely to be less armed (less defensed condition) and in small numbers (at times, solitary) where human casualty is more prone to occur. We have studied several cases where human casualties have occurred to better understand the nature of elephant attacks as well as their causes.

After understanding the nature and causes of attacks by Asian elephants on humans, a relative review of different patterns of human casualties due to Asian elephants have been conducted. The following variables were decided upon to demarcate the pattern of human casualties due to elephant attacks –

a. Monthly Variation
b. Seasonality influence
c. Spatial Pattern – Inside or outside protected areas
d. Temporal Pattern

The human casualty patterns are finally correlated with the previous analysis of nature of elephant attacks to understand the overall problem of human casualties due to elephants. The nature of elephant attacks on humans and the patterns studied in this paper are then elaborated to understand their correlation in the *Discussion* section of this paper.

This review paper also tries to find and recommend solutions to the grave problem of human injury and death due to Asian elephants by suggesting methods to reduce human casualties (steps to be taken individually as a person as well as collectively in a group, in case a group of people is exposed to elephant attack). An attempt is also made to advocate effective wildlife management techniques to reduce such incidents due to these elephants.

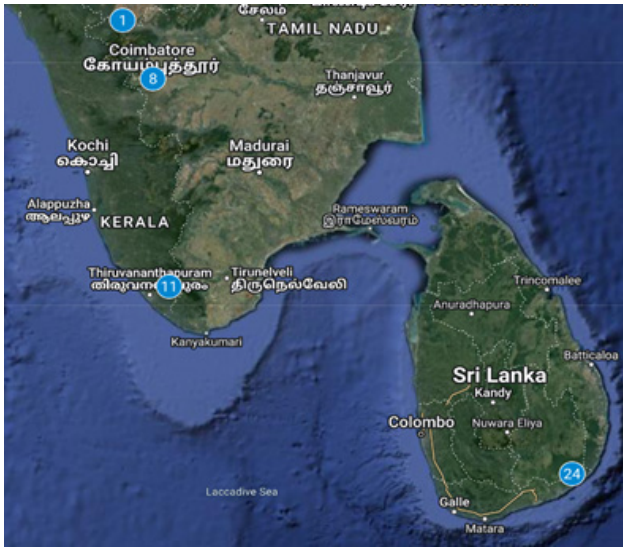
Data Collection and Analysis

This review paper only considers human casualties due to Asian elephants (*Elephas maximus*). General HECs involving damage to crops or other properties are not accounted for in this article. The scientific name of the species of these elephants are correctly mentioned in this paper.

Data about the nature of these elephant attacks on human which caused casualty in humans have been collected from grey literature available on the internet from English newspaper articles and reports only where the nature of elephant attack has been clearly mentioned which includes disturbance caused to elephants by humans before their attack or other specified reasons (Fig. 1; Table 1). For newspaper articles and reports, the information was collected by searching in the websites of the respective newspa-

Fig. 1: The regions/areas where data has been collected for this review study – A. South India and Sri Lanka; B. North India, East India, and Nepal; C. North-east India and Bangladesh; D. Myanmar. Details of the studied regions/areas are mentioned in Table 1.

A.



C.

B.

D.

pers – the keywords searched include *Human death due to elephants*, *Human injuries due to elephants*, *Elephants*, *Human casualties due to elephants*, *elephant AND human AND death*, *elephant AND human AND injury*, *Elephant conflict* and *Human-elephant conflicts*. The newspaper articles and reports are collected from published national and/or local English newspapers like *New Age Bangladesh* (Bangladesh), *Hindustan Times* (India), *The Times of India* (India), and *The Statesman* (India).

For mapping the places where cases human casualty cases due to Asian elephants have been considered has been conducted using *MyMaps* software, an online tool to incorporate maps directly from *Google Maps* (Fig. 1).

Table 1: Regions/areas considered for this study.

Index No.	Regions/Areas	References
1	Bandipur National Park, Karnataka, India	Lingaraju et al., 2016
2	Chittagong hilly south-eastern region, Bangladesh	Hossen, 2013
3	Sherpur Forest Reserve, Bangladesh	Sarker et al., 2015
4	Rangamati Forest Reserve, Bangladesh	Sarker et al., 2015
5	Banshkhali Forest Reserve, Bangladesh	Sarker et al., 2015
6	Chaunti Wildlife Sanctuary, Bangladesh	Sarker et al., 2015
7	Teknaf Wildlife Sanctuary, Bangladesh	Sarker et al., 2015
8	Coimbatore Forest Division, Tamil Nadu, India	Ramkumar et al., 2014
9	Dhenkanal Forest Division, Odisha, India	Pradhan et al., 2013
10	Jharkhand, India	Khan et al., 2023
11	Peppara Wildlife Sanctuary, Kerala, India	Jayson & Christopher, 2008
12	Manas National Park, Assam, India	Nath et al., 2009
13	Rakhine Yoma Elephant Range, Myanmar	Thant et al., 2021
14	Yangon region, Myanmar	Thant et al., 2021
15	Ayeyawadi region, Myanmar	Thant et al., 2021
16	Nepal	Neupane et al., 2013; Pant et al., 2016; Acharya et al., 2016; Ram et al., 2021
17	Darjeeling Jalpaiguri and Coochbehar districts, West Bengal, India	Naha et al., 2019
18	Midnapore, Bankura and Purulia districts, West Bengal, India	Singh et al., 2002
19	Baksa, Assam, India	Purkhayastha, 2023
20	Lakhipur area, Goalpara district, Assam, India	Kalita, 2022
21	Shahdol district, Madhya Pradesh, India	Naveen, 2022
22	Kotdwar, Pauri district, Uttarakhand, India	Azad, 2022
23	Lalgarh forest, Jhargram, West Bengal, India	Goswami, 2019
24	Ruhuna National Park, Sri Lanka	Santiapillai et al., 1984

Information about the causes and nature of elephant attacks on humans which caused human casualties from peer-reviewed articles have been collected by searching them on *Google Scholar*, *PubMed,* and *Web of Science*. The words used to search the research papers are *Human casualties due to elephants*, *Human deaths due to elephants*, *Human injuries due to elephants*, *Elephant conflict* and *Human-elephant conflict*.

The data for patterns of human casualties due to elephants were collected from cited research articles and review articles on *Google Scholar* and *Web of Science*. The words used for searching the paper were *Human casualty patterns due to elephants*, *Human casualty patterns due to large mammals*, *Variation in elephant attacks on humans*, *Pattern of elephant attacks on humans*, *Human-elephant conflicts,* and *Human-elephant conflict patterns*.

The patterns have been explained by plotting relevant graphs using *Microsoft Excel* and based on these data, an attempt has been made to identify the most probable situation of human casualty due to HECs.

Data Selection Criteria

The data from newspaper articles and research papers have been collected from such sources where human casualties due to elephants have been specified and/or verified.

For nature of human casualties due to elephants, those sources from newspaper articles and peer-reviewed articles have been considered which clearly mention the reasons of elephant attack on humans due to prior provocation of humans, close passers-by or encounter etc.

For patterns of human casualties due to elephants, only those articles have been considered which provides data about variation in elephant attacks due to temporal pattern, seasonality and monthly variations, and spatial pattern (inside or outside protected areas).

Observation and Result

Most elephant-caused human casualties are due to elephants entering farmlands and human settlements near the protected areas mostly in search of food. Many of these attacks occur in the nighttime and mostly in the dry season

when food is scarce in forests. The people who drive the elephants away from the farmlands and the villages are more casualty prone. Also, provocation of elephants either knowingly (hunting/poaching) or unknowingly (trespassing) have also led to human casualties. These causes have been elaborated with the help of peer-reviewed articles along with 6 newspaper reports and articles containing the details of human-caused human casualties. Occurrence of all these cases are recent incidents (2019-2023) and henceforth, exemplify modern problems faced by people due to HECs caused by Asian elephants.

Monthly human casualty pattern indicates greater frequency of human casualties in December, September, October, November, and January with few exceptions.

Seasonal pattern indicates a higher number of human casualties in the dry season (October to May) which goes together with the monthly pattern with little exception.

Spatial pattern study shows that higher number of human casualties have occurred in the farmlands where the farmers who guard their crops from being destroyed/eaten by elephants have been the primary victims. The human settlements located near the protected areas (mostly villages) are also prone to elephant infiltrations causing human casualties due to conflicts arising.

Temporal pattern suggests that higher frequency of human casualties occurred during the night when humans are often unaware of the elephants approaching them or close to when they travel.

Reasons of Human Casualties Due to Asian Elephants

Humans and elephants co-exist in nature in many places located in Asia and Africa. They are bound to face each other when they co-exist in close habitat. Often, humans living near forests where elephants reside or near elephant corridors face HECs. Many a time, encounters between humans and elephants are from a distance and do not cause any harm to either side but at times, these encounters turn out to be unfavorable. These unfavorable encounters here are meant by HECs where there are losses in life and property of humans as well as elephants. Therefore, to study the pattern of human casualties due to elephant attacks, it is a necessity to study and understand the reasons and natures of elephant attacks on humans.

Wildlife-human conflicts occur when there is a negative impact on either side (Torres et al., 2018). This can be related to HECs too. Due to habitat loss and fragmentation, elephants often come out from forests and venture into croplands to forage for food, sometimes even entering human settlements. Humans, therefore, to protect their crops try to scare the elephants away, sometimes leading to stone and/or stick peltering of the animals. This causes behavioral changes in the elephants resulting in attacking the humans to protect themselves and their younger ones. As a result, there are injuries caused to humans and often, these are fatal causing deaths.

Other causes of human casualties include failed poaching or hunting events, sudden attack on human passers-by in fringe areas of forests or inside forests. These are attributed to the most fatal results of elephant attacks on humans where the humans are either trying to harm the animals (in case of poaching or hunting) or are completely unarmed and/or unalarmed (in case of sudden attack). Provocations caused to elephants through poaching in response to crop protection by farmers or hunting purposes for illegal ivory trades have direct implications of higher HECs in certain studied areas (Compaore et al., 2020).

Some case studies of Asian elephant (*Elephas maximus)* attacks on humans which have been described and elaborated further are hereby pointed to understand the different natures/types of elephant attacks on humans:

- A man was trampled to death by a mother elephant after she turned violent due to its calf's death after the calf fell into a canal and could not be rescue by the mother elephant at Lalgarh forest in Jhargram, West Bengal, India. Moreover, there was provocation by surrounding people as they tried to capture photographs from close range and other elephants of the herd could not come near to help the calf (Goswami, 2019).
- A police constable was chased and trampled to death by an elephant when he went on morning walk in a fringe area of nearby located forest in Pauri district's Kotdwar, Uttarakhand, India (Azad, 2022).
- Two different herds of elephants killed 5 people in 2 days in Shahdol district, Madhya Pradesh, India inside forest areas where they went to collect mahua (Naveen, 2022).
- A herd of wild elephants killed a family of 3 people at night in Lakhipur area, Goalpara district, Assam, India due to floods which pushed the elephants from wetlands to the villages (Kalita, 2022).
- Upon conflict with a herd of elephants entering farmlands in Sherpur, Bangladesh, a man was killed by one of the wild elephants when the man tried to chase the elephants away (United News of Bangladesh, 2023).
- A minor girl was trampled to death in Baksa, Assam by a herd of elephants inside human settlement where the elephants entered, destroyed banana plants and other trees, and tried to trample through the deceased person's house (Purkhayastha, 2023).

Cases 2, 4 and 6 are examples of unarmed and/or unalarmed elephant attacks on humans. The first case occurred as a response to the threat that the elephant sensed due to human presence. Case 4 is an example of habitat loss where the elephant herd was forced to run down over human settlements due to natural disasters in their habitat. Case 6 is the direct attack of elephants on humans outside reserved areas (in fringe area) with probable reason of search of food.

Cases 1, 3 and 5 are examples of elephant attacks of either unknowing or deliberate provocation and/or disturbance of the elephants caused by human beings. In case 1, it was deliberate provocation of elephant by surrounding crowd of humans where the elephant has already undergone loss of its calf. In case 3, the humans unknowingly threatened the elephants as they entered inside forest areas where elephants were present. Case 5 is a typical example of HEC where the farmers tend to provoke the elephants knowingly to protect their crops in the farmlands located near reserved forests or elephant corridors.

Monthly Pattern of Human Casualties

A pattern can be concluded in the number of casualties of humans occurring among humans due to Asian elephants in different months of a year. The monthly variations in HECs are due to behavioral changes of elephants due to changes in food availability in forests and surrounding areas and the climate of the region studied. Moreover, the migration of elephants, which is seen in certain months of the year in various parts of Asia is also a factor which has its direct effects on HECs arising during this period. Migration can occur due to scarcity of water and food resources in a particular region due to which they travel to different lands to regain access to resources as was seen in the case of elephants from Dalma Wildlife Sanctuary in Odisha to West Bengal in India. This migration is a cause for HECs along the migratory route (Guha & Guha, 2014). Another study showed that deforestation along the migratory route from Meghalaya, India to Central Nepal and rapid urbanization of the area caused conflicts during the drier winter months (Acharya et al., 2016). So, studying the monthly variation of human casualties due to elephants can be used to reduce the casualties and avoid unfavorable outcomes.

Most human casualties due to elephants in the form of injuries inflicted and human deaths have been recorded in the months from September to January. Human casualties in the rest of the months were lower in most studied places (Fig. 2).

Seasonality Pattern of Human Casualities

Seasons play a significant role in the frequency of HECs which result in casualties among humans. Studying the number of casualties in different seasons gives an idea about the extent of elephant attacks on humans. The number of elephant attacks on humans have been plotted to conduct a comparative analysis of the effect of seasonality of human casualty pattern due to HECs in Asia.

Most casualties have occurred in the dry season (October-May) when food is scarcely available in the natural habitats of the elephants with little exception than the wet season (June-September) which is the typical monsoon period in South Asia where most wild Asian elephants live in the present day (Fig. 3). As mentioned previously in the monthly pattern section, during the drier months, elephants migrate along a specific route to lands with better resource availability. Deforestation, shrinkage of wildlife habitats, subsistence agriculture along these routes is a major cause for conflicts.

Spatial Pattern of Human Casualities

Elephant attacks on humans have occurred both inside protected or reserved areas like national parks, wildlife sanctuaries etc. and outside the protected areas like farmlands, villages, and towns, mostly located in the fringe areas of the reserved forests. Human casualties due to elephants show a pattern based on these spatial parameters. This paper contributes to the study of spatial patterns of human casualties due to elephants occurring outside or inside protected areas. Human casualties due to elephants are lower inside most protected areas than the nearby farmlands and human settlements located in the fringe areas of the protected zones or outside them (Fig. 4).

Temporal Pattern of Human Casualities

A pattern of elephant attacks on humans at specified time spans which have caused human casualties to have been studied and recorded to understand when the casualties have occurred in higher frequencies. The data considered mentions the human casualties caused by elephant attacks and their specified time of occurrence (day or night) (Fig. 5). By virtue of satellite telemetry, it was observed that elephants mostly foray into cultivated lands and farms during late evenings and nights. This causes aggression in the settlements surrounding the lands leading to conflicts (Venkataraman et al., 2005).

Discussion

Causes of Human Casuality

Assessing the points covered in causes of human casualties due to elephants with the help of peer-reviewed articles and grey literature in the form of verified news reports (articles and newsletters) which clearly specified human casualty due to elephants as cause of injury or death of humans, the reasons and natures of elephant attacks on humans can be broadly classified into two major types:

• Sudden/Unprovoked elephant attack: Unprovoked elephant attack on humans due to natural pressures acting on the elephants which results in HECs resulting in loss of life and property of humans as well as elephants. The natural pressures can be a result of uncalled/unpredicted natural disasters like floods, wildfires, droughts etc. which drives the wild animals to migrate out of their natural habitats in search of food and shelter. These natural pressures can sometimes be a result of anthropogenic activities like climate change which might drive to changing climate conditions leading to droughts or floods in some regions. Also, wildfires might also be caused by humans unknowingly though this is a rarity.

• Provoked elephant attack: When humans end up interfering with wild elephants either knowingly or unknowingly in a negative manner, then the elephants respond by attacking humans for their safety and security. Most of these provocations are caused unintentionally where people living near the forests where elephants reside/conservation sites for elephants go inside the forests to collect materials for their daily use like firewood, leaves, fruits etc. In case of such incidents where elephants attack these people entering forests, often these humans are unalarmed of the presence of nearby elephants and cannot escape in time resulting in casualties. Elephants perceive this intrusion inside forests as a security threat for themselves which multiplies in case there are younger calves of elephants present in the herds. Hunting and poaching threats are also causes of elephant agitation which might welcome human casualties for the people

Fig. 2: Chart showing the monthly pattern of human casualties due to elephants.

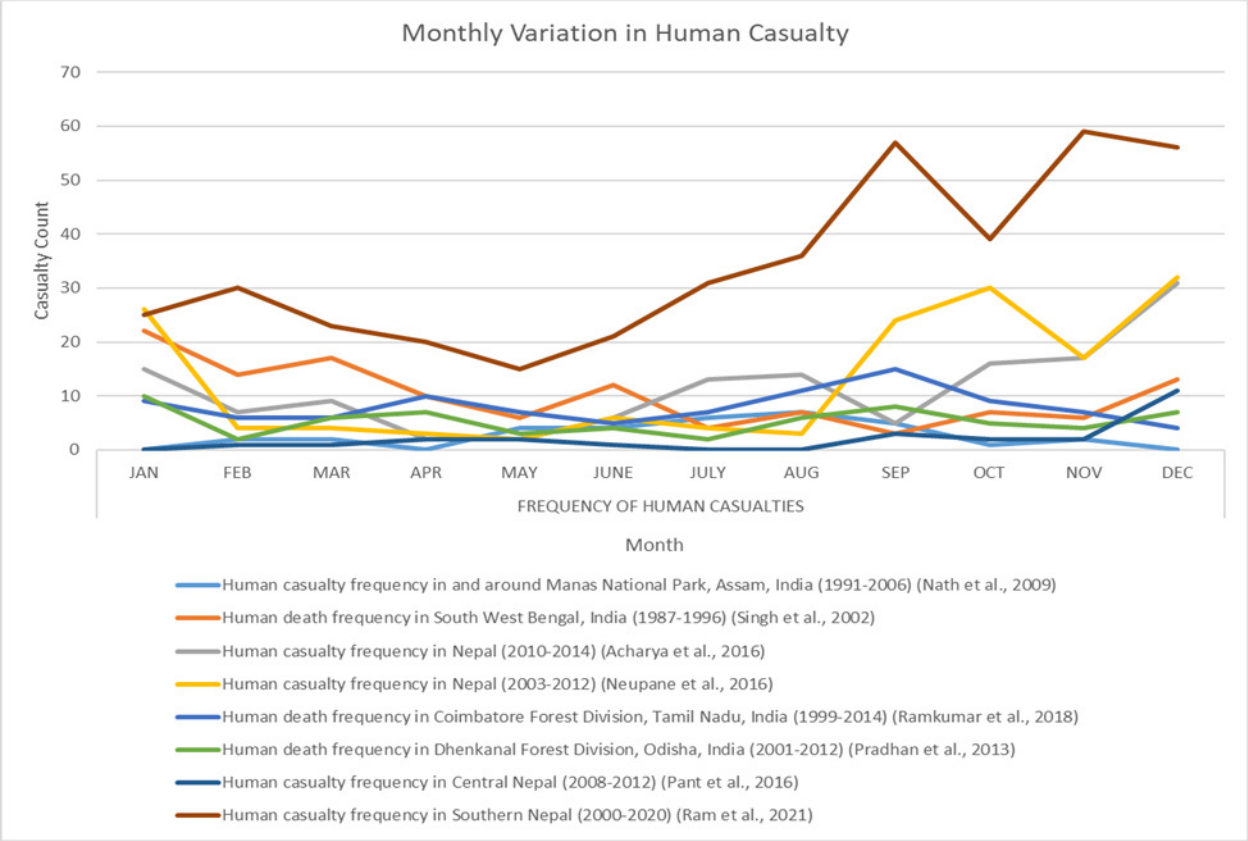


Fig. 3: Seasonality pattern of human casualty occurrence due to elephants.

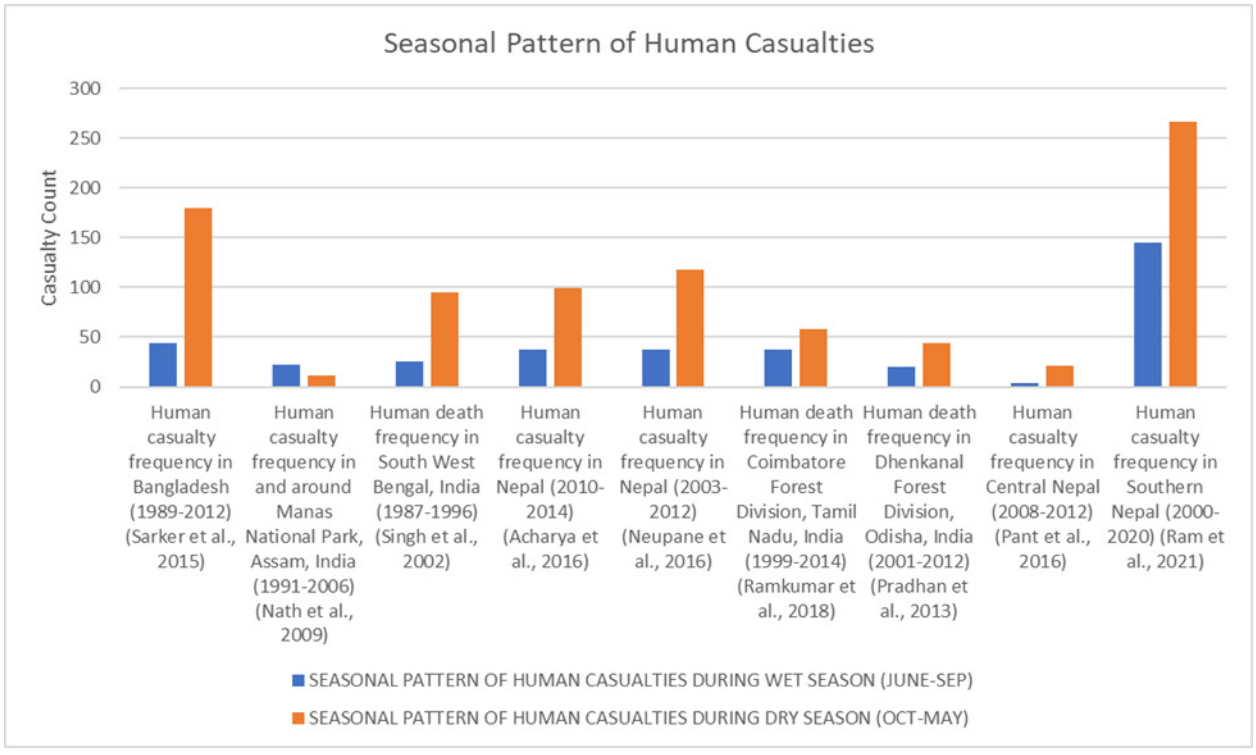


Fig. 4: Spatial pattern of human casualties due to elephants.

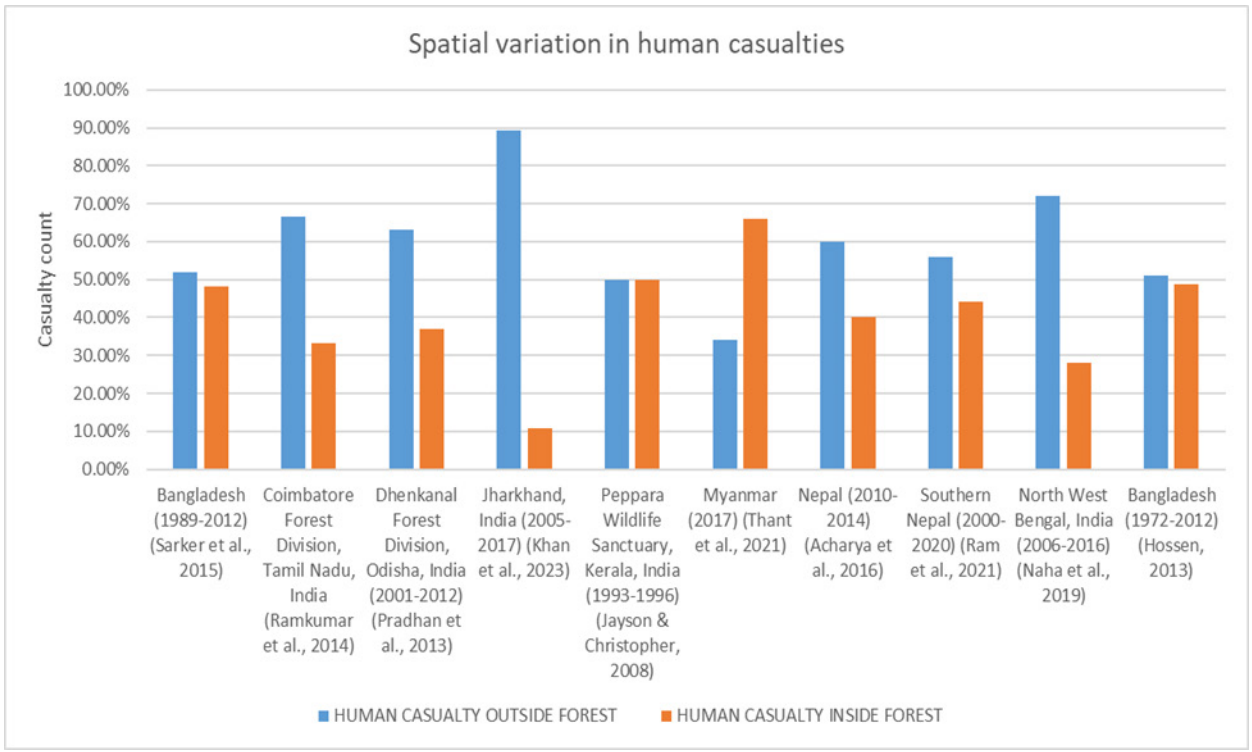


Fig. 5: Temporal Pattern of elephant attacks causing human casualty.

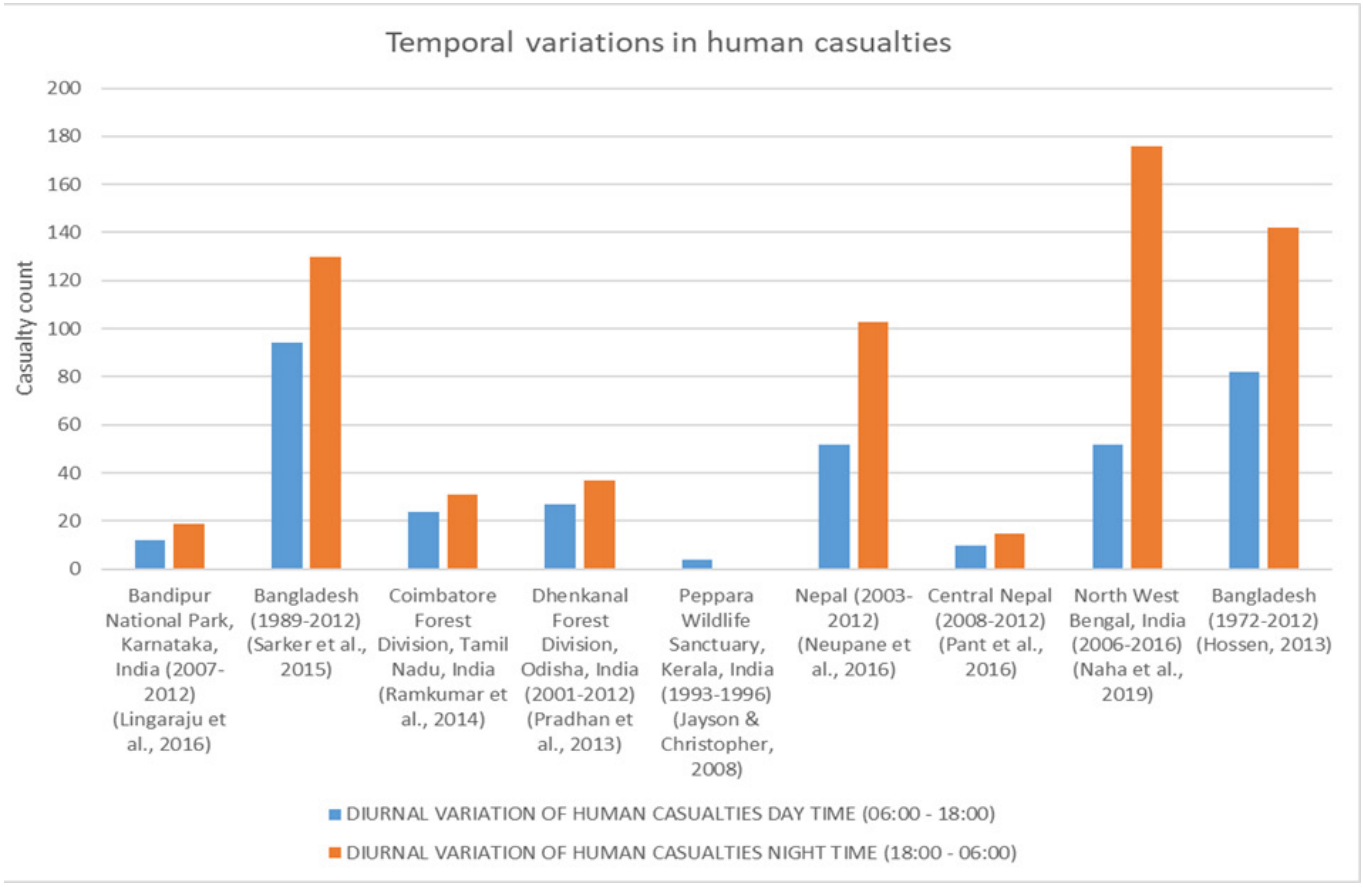
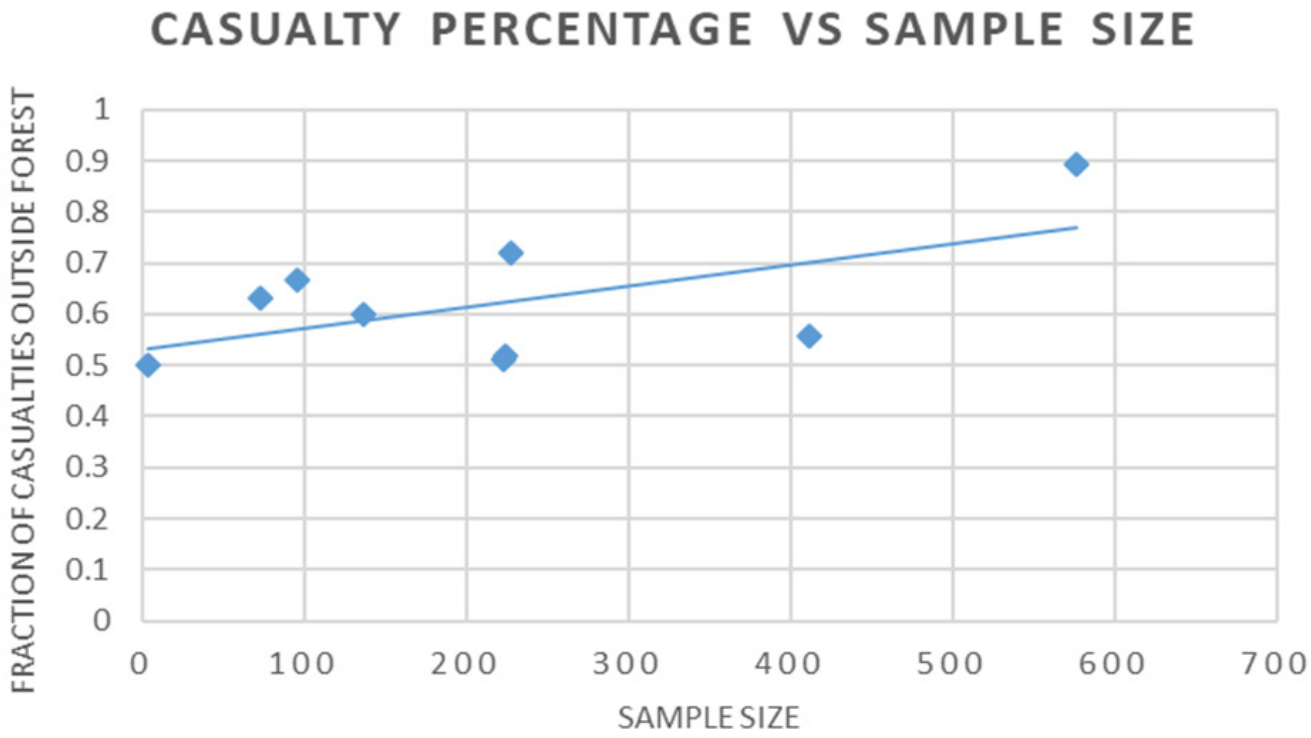


Fig. 6: Correlation (n=1971) between human casuality occurances outside protected areas and total number of human casualities (sample size).



involved in hunting and poaching. Also, provocations caused in human settlements when elephants enter the human settlements in search of food can also lead to sudden maddening of elephants which might turn some of them into rogue ones and end up damaging not only properties but can also cause life-threatening human damage, in extreme cases, even causing major impairments or death.

Monthly and Seasonal Human Casualities

Covering the reasons of elephant attacks on human beings and studying the patterns of elephant attacks which caused human casualties (injuries and death), several HECs can now be better understood.

HECs have been shown to occur more in drier months with increase in conflict frequencies and decrease in rainfall (Gubbi, 2012). Here, we get comparable results while assessing the human casualty pattern monthly where it shows a maximum trend during the dry months of a year, that is, the months which receive lesser rainfall than rest of the year in and around the respective places where the conflicts have occurred. In a study regarding Asiatic elephants in Nepal, this prevalence of human casualties was more evident during the winter months (Neupane et al., 2013).

These months coincide with the winter season with most human casualties occurring in every article which has been studied. This pattern is seen because of shortage of food inside forests during the dry season of winter which drive the elephants to enter farmlands located in the periphery of the forests which again coincides with the harvesting time of several crops which directly implies that increase in human activity in the fringe farmland areas of reserved forests increases the chance of HECs leading to human casualties.

There is no single breeding season of Asian elephants, they reproduce all throughout the year. Yet in most cases, Asian elephants show higher reproductive events (births and mating) in the drier months especially from February to May irrespective of the latitude of our study (Hufenus et al., 2018) except a few studies conducted in Sri Lanka where higher reproduction was observed in the wet season (de Silva et al., 2013; Santiapillai et al., 1984; Ishwaran, 1981). Human casualty occurrence due to elephants, therefore, is influenced by breeding season of Asian elephants which explains the protecting nature of these elephants during this period causing human beings to be vulnerable to elephant attacks upon close encounter with elephant calves.

In some cases, elephants have entered human localities which has led to HECs. Sometimes, these conflicts give rise to fatal outcomes where both sides suffer loss of life and property. Casualties have occurred primarily due to repeated provocations and disturbances of elephants due to stone peltering, burning firecrackers, chasing using sticks or other sharp objects etc. to drive away the elephants from the farmlands or localities to protect the crops and prevent loss of properties like destruction of houses.

In Manas National Park, Assam, India, a 1991-2006 study revealed that most of human casualties occurred during the summer season (months May-September) with peak reaching in August which is also the time of summer

harvesting of crops there (Nath et al., 2009). Also, rainfall increases during these months (monsoon in Northeast India) which also drives the elephants away from forests which get flooded to non-flooded areas of human settlements thus increasing the frequency of HECs.

Spatial Human Casuality Pattern

Spatial patterns show that human casualties have occurred more in fringe areas of protected areas like the farmlands and villages located near protected forests (Fig. 6). Human casualties have been less inside the protected areas because of existing restrictions on the movement of people inside these zones. Contrary to this, elephants have entered farmlands and human settlements around these reserved areas in search of food leading to HECs causing both elephant and human casualties. Most of these attacks were due to elephants entering farmlands in search of food and humans trying to prevent the elephants from eating and destroying the crops. Sometimes, the animals enter human settlements when there are not enough food sources in forests. In Nepal, it was observed that most casualties occurred in the buffer zone surrounding Chitwan and Koshi Tappu National Park in Central and Eastern Terai respectively (Neupane et al., 2013).

There is only one exception out of the 10 studies conducted to see temporal pattern of human casualties. The exception has been observed in Myanmar where most human casualties have occurred in forests (although it is unclear if the forests are protected areas or not) primarily due to lesser agricultural activities in fringe regions of forests and ample supply of food for elephants inside forests, thus resulting in lesser HECs in farmlands. Closer examinations in south-eastern and northern Bangladesh reveal that human casualties inside and outside reserved areas occur in equal frequencies because the farmlands and human settlements in the form of villages are located much closer to the reserved areas which increase the intensity of HECs (Sarker et al., 2015).

The spatial pattern goes together with seasonal pattern of human casualties because the elephant intrusions into human settlements and farmlands increase during the dry season (winter).

Statistical analysis shows that the human casualty occurrences due to Asian elephants outside the reserved forests and the total number of human casualties due to these elephants are moderately positively correlated, $r(1971) = .587$, $p < .05$.

Diurnal Variation of Human Casualties

Temporal pattern of elephant-caused human casualties is strongly inclined to higher frequency of human casualties in the nighttime. This is seen in all the studied areas irrespective of climate, topography or any other geographical or environmental features of the regions. Accidental encounters with elephants in the nighttime due to poor visibility is a major reason for HECs leading to human casualties (Sukumar, 2003).

The nighttime attacks are more numerous because elephants enter farmlands in search of food more in the night to avoid humans and the farmers who stay awake in the fields to guard the crops end up in HECs which sometimes lead to casualties. The elephants rest during the afternoon and start getting active during evening when the heat reduces (Thapa et al., 2019). This was confirmed through satellite telemetry in a study in Jaldapara National Park, West Bengal (Venkataraman et al., 2015).

Another reason for the higher number of human casualties is due to the movement of people in the dark on roads located in the fringe areas of forests often do not sense the presence of elephants nearby and end up in direct confrontations with them. Sometimes being unable to flee from the confrontations, they end up inflicting some damage in the form of injuries or even death. This is especially seen in regions where human settlements are located close to the reserved areas/forests.

Elephants are known to move around for food foraging and spend considerable amount of time for feeding and walking. During the daytime, the Asian elephants have been observed to spend >60% of their time in walking and feeding to satisfy their nutritional requirements (Ahamed, 2015). Elephants spend lesser amount of time sleeping (Walsh, 2017) and move more in the night; therefore, this percentage will be higher in the nighttime which explains the higher frequency of human casualties due to Asian elephants in the nighttime due to higher HECs.

This article aims to collate human casualty data from various sources to identify a pattern in HECs which help in designing wildlife management techniques for a peaceful coexistence of both species. Finding out the variables on which such attacks depend, and their nature of dependence is rudimentary for conservation practices and forges a common ground for all the species involved.

Reducing Human Casualties by Implementation of Wildlife Management Techniques

Studying the patterns of human casualties inflicted by Asian elephants, several steps can be taken up to reduce human casualties. Some of them are to be implemented individually and some are for society's benefit, which requires proper cooperation of forest officials and wildlife conservation organizations. Efforts to reduce human casualties due to elephants should be collectively made by all the people influenced (Kshettry et al., 2020). Owing to the feasibility and pertinence of human casualty caused by Asian elephants, we propose effective mitigation techniques to reduce HECs leading to casualties –

• Avoiding going alone at night, especially on roads located close to forests/reserved areas. Staying in groups keeps the elephants away and even if confrontations occur, there are ways to flee from the spot or call for immediate help in case any unpredictable mishaps occur.

• Setting up electric fences carrying low voltage electric currents can help in containing the elephants within a particular boundary. This must be implemented properly

to not harm animals living in the forests/reserved areas. This has been successfully used in Manas National Park, Assam, India where HECs were reduced using electric fences were laid in certain places along with regular patrolling, simple driving away of elephants etc. which prevented higher frequencies of human casualties in fringe villages and farmlands (Nath et al., 2009).

• Setting up beehive fences as a means of bio-acoustic methods to control elephant movements have been successful and can be applied in the fringe areas surrounding protected areas. These have restricted elephants from entering villages and croplands and are profitable for the honey-collectors and increased the number of pollinators (Shaffer et al., 2019; King et al., 2011, 2017). This method has also been used in Gorongosa National Park, Mozambique to deter African elephants (Loxodonta africana and Elephas maximus) from crop-raiding (Branco et al., 2020).

• Setting up trenches is yet another method of preventing elephants entering human settlements and farmlands outside the reserved areas and thus help in reducing HECs lowering casualties among humans as well as among elephants (Shaffer et al., 2019). Although trenches help in containing the elephants in reserved areas, they are hard to maintain due to erosion by rainfall and elephant kicking in the periphery of the trenches which eventually fill up the trenches (Perera, 2009). This process thus requires regular maintenance.

• Solar powered fences are eco-friendly option available to prevent HECs which have been reported to be successful primarily in 2016 with the reduction of 96.13% reduction in HECs due to Asian elephants in Nepal which entered Nepal from the Indian side (Neupane et al., 2018). However, regular maintenance is required as the fences are often destroyed by natural means or elephants destroy them.

• Cultivating crops which are unpalatable for the elephants in the farmlands located close to reserved areas/forests like growing tobacco, chili, rubber, timber, and fuelwood consisting of plantations which the elephants do not feed will help in reducing the entry of elephants into farmlands situated in fringe areas of reserved regions. However, there is a requirement of cultivating such plants consisting of large areas so that in the absence of food, the elephants do not enter the fields and move further away from forests into farmlands or human settlements (Fernando et al., 2008).

• Establishment of more protected areas and elephant corridors across between the already existing protected areas can help to contain elephants within a certain range. These allow the elephants to move without facing direct confrontations with humans. Ecologically, it is good for gene flow and helps elephants to forage for food and water (Shaffer et al., 2019).

Other wildlife management techniques from different regions applied for varied species can be implemented after more detailed studies and experimental small-scale studies on select regions which if successful can be implemented on a large scale to mitigate the problem of HECs. Some of them are:

• Mitigation strategies employed on African elephants in the Transmara district, Kenya showed 80% success rate in early warning system (frontline communal guarding from watchtowers), 90% success upon using thunder flashes (powerful touches) and 100% success in using chili rope deterrents (chili-tobacco-engine oil grease applied thrice a week) separating the farmlands from the forests. However, some of them are costly and are not feasible on a large scale (Sitati et al., 2008).

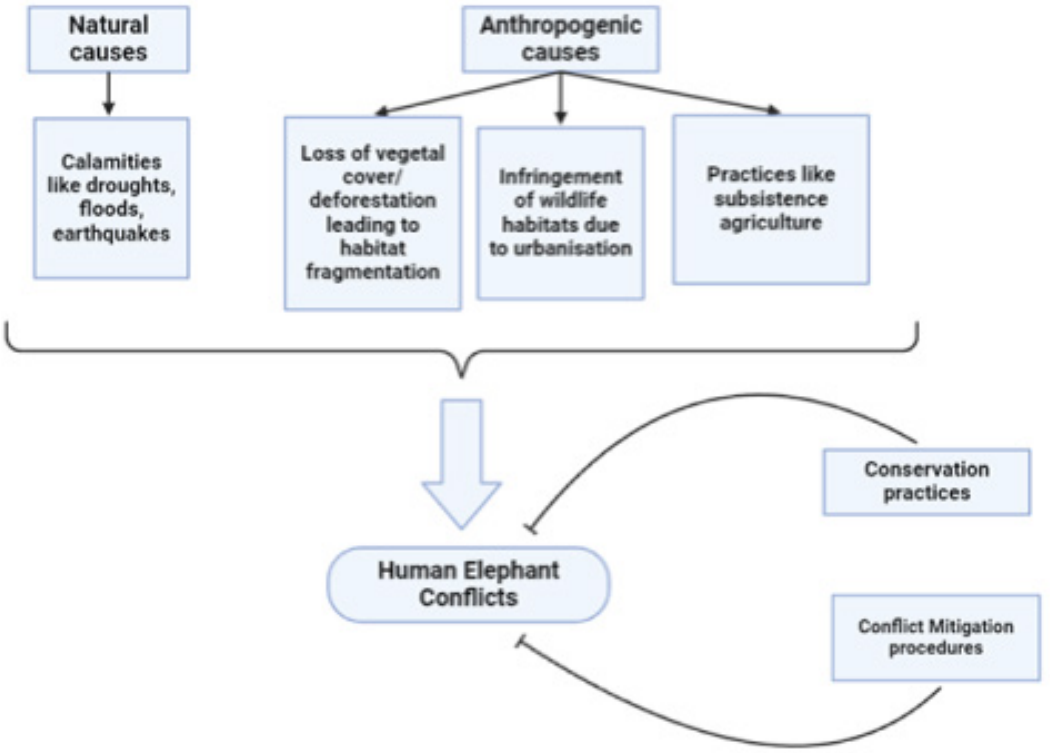
• In Bale Mountains National Park, Southeast Ethiopia, apart from conventional guarding and live fencing, using scarecrows was the second-most successful method used by 22% of the local community to prevent livestock predation by carnivores like leopard, spotted hyena, and common jackals (Mekonen, 2020). It has not yet been reported to be tested against any elephants, however, this method can be improvised upon by making larger sized scarecrows or implementing other improvisations and/or using other mitigation strategies simultaneously to deter elephants from entering human-dwelling areas or farmlands.

• Use of hypothesized “spicy beehive fences” due to 95% reduction of African elephants crossing across beehive fences and significant reduction seen in the case of chili fences in Gorongosa National Park, Mozambique can reduce HECs significantly which needs to be tested (Branco et al., 2020). It is a potential effective intervention to mitigate HECs in Asian elephants too given the fact that similar mitigation techniques in the form of beehive fences and chili farming in the fringe areas are already in practice to deter Asian elephants.

• Zoning is an effective strategy to reduce conflicts between humans and tigers (Panthera tigris) where people and livestock are kept away from tiger habitats through the means of fair and incentives-based relocation programs (Goodrich, 2010). Similar relocation programs can be conducted in areas where Asian elephants reside to reduce the possibilities of human casualties due to these elephants.

Effective elephant conservation strategies and HEC mitigation steps can be taken only when the concerned authorities consider the human social, mental and emotional aspects of the humans concerned with this situation backed with scientific studies and surveys. The regions concerned have great diversity in culture, traditions, religion, and societal relations. Most of these places have certain marginalized communities who face the harshest consequences due to HECs. On top of direct economic and health consequences due to HECs, they often face societal discrimination. For example, some case studies in Jadhav & Barua, 2012 highlight the social discriminations and mental as well as emotional issues faced by widowed women whose husbands have been killed by elephants. It is not only limited to fatalities but also to severe injuries or economic losses incurred due to HECs where it is seen that these individuals suffer from mental and psychiatric issues as well as resort to substance abuse thereby, aggravating the already existing harsh conditions. Therefore, consid-

Fig. 7: Causes of human-elephant conflicts and measures to reduce them.



ering the wellbeing of the vulnerable humans, interdisciplinary aspects based on geography, social demography, conservation science and public health need to be studied and accordingly, new strategies need to be developed to tackle the issue of human casualties as well as maintain the goal of conservation of wildlife (Jadhav & Barua, 2012).

Current strategies and techniques for mitigation of HECs often are human-centric. New strategies should give importance to elephants' sensory perceptions to promote their coexistence with humans. Elephants are known to elicit behavioral flexibility and adaptability which makes many conventional mitigation techniques ineffective eventually where the elephants get habituated with the conventional deterrents. So, innovative approaches should also consider decision-making capability and risk assessments of elephants and at the same time should ensure adequate resource availability specific to the elephants' habitat and landscape. Behavioral studies of elephants based on their multi-modal sensory cues like vision, audition and smell perception should be conducted to better understand and develop effective mitigation strategies (Ball et al., 2022).

Conclusion

Studying the patterns of human casualties occurring due to elephant attacks, different inter-pattern associations have been identified which have been analyzed to understand the human casualties caused by Asian elephants.

From our study, we can conclude that most human casualties have occurred in the fringe areas of protected regions like farmlands during the nighttime, more in the dry season. Seasonal, spatial, and temporal patterns indicate the higher frequencies of human casualties due to Asian elephants based on which we have drawn the conclusion. This is quite a common situation which already has recorded incidents where farmers guarding their farmlands at night near the forests end up in HECs. Also, during winters (dry season), there are more elephants intruding into farmlands in search of food thereby increasing the chances of HECs leading to increased probability of human casualty.

Similarly, studying these inter-related patterns, we identified the situation where there are lower chances of occurrence of human casualties. Human settlements in fringe areas of reserved forests are safer during the daytime during the summer season (wet season), especially during June-August. This can be concluded from studying the monthly, spatial, seasonal, and temporal patterns. This is primarily due to the availability of resources inside the forests. The more the human settlements are farther than the reserved areas, the safer the places are.

Mitigation techniques which have been used for African elephants or other animals which have the potential to reduce the HECs can be implemented in the context of Asian elephants too. Local forest administration and government should financially aid as well as promote the implementation of some of these techniques among the local farmers living in the fringe areas of forests to better tackle HECs. Some of the methods described in this article can be implemented on small scales in various places to assess their feasibility and potential. Successful implementations

can be improvised, and new specific wildlife management techniques can thus be formulated and utilized in the future. Social, ethnic and mental well-being of the people living close to the elephant habitats needs to be prioritized as several cases have been reported where families experi encing daily struggles with elephants for various purposes have developed severe physical, mental and emotional issues like fatigue, stress, anxiety, panic attacks, depression and PTSD to name a few (Jadhav & Barua, 2012). It is the need of the hour as these aspects are often overlooked by the competent authorities while the direct sufferers continue to live in danger and uncertainty. The summary of these conflict causes, and their remediation is illustrated in Fig. 7.

Human casualty patterns along with studies on elephant casualty patterns due to HECs can provide the necessary information to understand the nature of HECs of Asian elephants which can be used to develop new strategies to solve the long-standing issue of HECs and reduce casualties on both sides. The mitigation techniques used elsewhere, even on different animals, can be improvised upon or used as they were to test their effectiveness and solve the problems which will be beneficial for not just controlling human-wildlife conflicts but also maintain the purpose of wildlife conservation. Similar studies on other wild animals with whom human interactions occur frequently causing harm to either or both can be conducted to mitigate those conflicts and develop better conservation and wildlife management strategies.

Article Impact Statement

An analytical and comparative article of human casualty patterns caused by Asian elephants due to HECs is highlighted.

Limitations of this Study

There is a requirement for a greater number of studies on all the patterns covered in this review – monthly, seasonal, and spatio-temporal patterns of elephant attacks on humans. Studies correlating these patterns with other aspects of HECs like elephant casualties, property damage, crop damage etc. are the need of the hour to develop better mitigation techniques and reduce HECs which this review tried to address but to a limited extent primarily due to limited available research.

The patterns examined in this study are limitedly applicable to African elephants as the interactions between humans and elephants are similar in both Asia and Africa, although independent study in case of African elephants will be effective for developing wildlife management techniques and understanding similar patterns of human casualties due to different geography, climate, other environmental factors and socio-economic factors which influence the interactions between human beings and wildlife.

Moreover, the sleep patterns of elephants of the Asian elephants are not well studied and for this limitation, only a daytime study of the sleep pattern of Asian elephants have been used to correlate the data with temporal variation of human casualty pattern.

Scope of this Study

Detailed patterns of human casualties due to Asian elephants can be studied to draw new conclusions and understand the HECs. Our study can be used to correlate with breeding patterns of elephants and other environmental patterns for further conclusion about HECs.

Human casualty patterns due to Asian elephants can be used to develop conservation measures. The patterns studied here can be used to devise several inter-connected patterns to help mitigate HECs which will also reduce casualties on both sides.

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