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A case study on conflict intensity between humans and elephants at Teknaf Wildlife Sanctuary, Cox's Bazar, Bangladesh

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Humans' and elephants' conflict is considered a common phenomenon in Bangladesh due to extreme anthropogenic interferences on elephant habitats. Concurrently, the landless people were encouraged to encroach on forest land due to their financial hardship and poor and weak forest management systems. We conducted our research work through frequent field visits, site-oriented positioned research correspondents, and an adopted semistructured questionnaire. We recorded a total of 903 conflict-related cases between humans and elephants, including crop raids (N = 337), house raids (N = 200), homestead garden raids (N = 263), and accidental attacks (N = 103), across sites, during August 2018 to July 2019, in Teknaf Wildlife Sanctuary (TWS). Elephant attack rates varied significantly between traditional forest dwellers (N = 179), illegal settlers (N = 370), villagers nearest forest (N = 212), Rohingya refugees (N = 53), and traditional forest different tribes (N = 89). It also varied along a space gradient, including inside forests (N = 423), buffer zones (N = 297), and outside forest villages (N = 183). The number of conflicts possessed by elephants varied discriminately and was unparalleled among different professions such as cattle ranchers (N = 104), gardeners (N = 112), paddy cultivators (N = 236), vegetable growers (N = 158), betel-leaf growers (N = 163), and forest resources collectors (N = 130). Most conflicts between humans and elephants occurred significantly during the night (N = 592), many during the morning (N = 154), evening (N = 138), and much less during midday (N = 19). The conflict intensity was also higher on the east coast (N = 552) than on the west coast (N = 351). The seasonal variation, including summer (N = 367), monsoon (N = 274), and winter (N = 262), was also significant. The elephant herd size was also an important factor triggering the conflict in TWS. We conclude that conflict intensity between humans and elephants is driven by settlers' location, forest gradient, the profession of forest-dependent people, their household size and income level, attack time, and season.

KEYWORDS

forest intruder, season, elephant herd, crop raid, house raid, homestead garden raid, accidental attack, human–elephant conflict

1 Introduction

Conflict between humans and elephants (HEC) can be viewed as a paradigm of conflict between humans and wildlife. A conflict that includes some wildlife species such as large herbivores, primates, large carnivores, crocodiles, and some birds occurs with humans who usually live with or in the vicinity of such animals, or conflicts occur when humans explore forest resources (Sukumar, 1990; Røskaft et al., 2003). Livestock predation by large carnivores, such as lions (*Panthera leo*), tigers (*Panthera tigris*), leopards (*Panthera fusa*), and wolves (*Canis lupus*), and crop raids and property damage by large herbivores, such as Asian elephants (*Elephant maximus*), hippos (*Hippopotamus amphibius*), Indian rhinos (*Rhinoceros unicornis*), Asian buffalos (*Bubalus bubalus*), and wild boar (*Sus scrofa*), strongly define the conflict between humans and wildlife in many countries in Asia and Africa (Sukumar, 1990; Badola, 1998; Hoare, 2000; Johnsingh et al., 2002). According to Anderson and Pariela (2005), elephants and hippos are the large herbivores that are most engaged in severe conflicts with humans (Mukeka et al., 2018; Mukeka, 2019; Mukeka et al., 2019; Mukeka et al., 2020). The conflict between humans and elephants not only causes negative attitudes but also causes local people to be gripped by fear and resentment due to life-threatening experiences because they share resources and come into contact with these animals (Røskaft et al., 2003; Marshall et al., 2007; Billah et al., 2021). Considering the social context and the importance of biodiversity, human beings can minimize contact with conflict-prone species, such as large herbivores and carnivores that compete with humans for food and space (Peterson et al., 2008). Conflicts between mega-herbivores and humans incur large costs and property damage and threaten human lives more than conflicts with smaller ungulates, other herbivores, or meso-carnivores, as these groups are less life-threatening and cause less property loss and damage (Graham and Ochieng, 2008). The conflict between humans and wildlife not only brings fright, injuries, death, crop damage, and property damage but also the risk of spreading wildlife-transmitted diseases among pets and livestock (Peterson et al., 2008; Mukeka et al., 2020). Human–wildlife conflict in low-income countries in Asia and Africa has adversely affected the wellbeing of communities near forests or protected areas, with both visible and invisible impacts (Barua et al., 2013). The result of such conflicts between humans and wildlife frequently ends up with visible costs of deaths, injuries, or damaged property, as well as invisible costs of reduced livelihood opportunities, physical and mental trauma, and even social insecurity (Woodroffe et al., 2005; Liu et al., 2011; Orga, 2008; Choudhury et al., 2008; Dixon et al., 2009). Opportunity and transaction costs are also partly invisible costs that have a great impact on the victim's family. Humans guarding crops at night is an opportunity cost in Asian and African countries that have elephants. Children and female members of forest-dependent households are forced to engage in extra work, including collection of forest resources, gardening, agriculture practices, cattle ranching, and guarding ripening crops at night. All these activities may traumatize children's bodies and minds and cause poor performance in school (Hill, 2000; Hoare, 2000; Treves et al., 2009; Motaleb and Ahmed, 2016; Haque et al., 2018). The concept of transaction costs focuses on compensation for the victim with an affordable way of rapid verification of the incidents and reliable payment with proper guidelines and management practices (Nyhus et al., 2005).

Elephants are large terrestrial herbivores, and they frequently engage in crop raiding, house raiding, and property damage and cause deaths and injuries in communities near forests or protected areas (Sukumar, 1989; Hoare, 1995; Sarker and Røskaft, 2011). Traditional agricultural practices on the edge and buffer zones of such areas, as well as the sustainable extraction of forest resources, maintain a harmonious balance between humans and nature, but permanent agricultural practices and settlements along with aggressive extraction of natural resources drastically disrupt the coexistence between humans and elephants (Sukumar, 1989; Barnes et al., 1995; Tchamba, 1996; Bist, 1998; Nyhus and Sumianto, 2000; Hossen and Røskaft, 2022). High international market demand and economic growth rates consistently expand agricultural practices in areas and buffer zones near forests and protected areas. Forestland is frequently replaced with agricultural land, which intensifies the conflict between humans and wildlife. In both Asia and Africa, the response to the scarcity of food and shelter affects this conflict with elephants (Santiapillai and Jackson, 1990; Blake and Hedges, 2004; Mukeka et al., 2020). Human–elephant conflict is escalating due to expanding human population density near their habitats, causing increasing encroachment on forests and land discriminately (Hoare and du Toit, 1999). The intensification of the conflict between humans and elephants is not only promulgated by socioeconomic factors but is also affected by climatic factors (Barnes et al., 1995; Hoare, 1995). Such intensified conflict takes place between humans and elephants in the currently shrinking range of this megaherbivore both in Asia and Africa, in isolated pockets where there are shortages of food and space for elephants (Bell, 1984; Sukumar, 1991; Hoare, 1995; Barnes, 1996). The conflict between humans and elephants is considered a serious issue for conservation and social security in communities surrounding such areas (Gubbi, 2009; Ogra, 2009). Elephants are considered agricultural pests (Lahm, 1996; Wunder, 1997) and cause huge losses to various crops (Sukumar, 1990; Hoare, 2000). In both Asia and Africa, approximately 10% to 15% of all agricultural loss at the community level is caused by elephants (Sukumar, 1990; Lamarque et al., 2009). According to Sarker and Røskaft (2014), approximately 20% of crops are lost adjacent to elephant habitats in Bangladesh. Both African and Asian elephants prefer the most nutritious and palatable crops with negligible physical and chemical defense (Laws et al., 1975; Sukumar, 1990; Osborn, 1998). Frequent conflicts between humans and elephants have increased attitudes of resentment and retaliation against killing in elephant-affected people (Sukumar, 1990; Daniel et al., 2008). Conflict intensity between humans and elephants triggers negative attitudes among local people in forest-dependent communities, which is currently considered a major concern in promoting and implementing conservation approaches for such species (Dublin, 1994; Kangwana, 1995; Sarker and Røskaft, 2010; Sarker and Røskaft, 2014; Aziz et al., 2016). Settlements and expanding agricultural practice thresholds will shrink the elephant range (Bell, 1984; Hoare, 1995). The size and type of elephant groups are also

responsible for the escalation of conflict intensity; for instance, solitary males and male groups are involved in more conflicts than female groups (Hoare, 1997; Stokke, 1999; Sarker et al., 2015). According to Hoare (1999), 79% of raids are committed by solitary males or male groups, whereas only 9% are committed by mixed herds and 12% by female herds. Sarker et al. (2015) also discussed the fact that solitary males or temporary male groups are more frequently engaged in attacks than female-controlled groups. Male elephants are risk-takers with a higher degree of tolerance for human disturbances than females during crop maturation (Moss and Poole, 1983; Osborn, 1998). Bull elephants are more aggressive and tend to do more crop and property damage during the breeding season because they are driven to promote their reproductive fitness by gaining more energy, and at the same time, they are inclined to engage in high-risk behavior (Stokke, 1999; Parker et al., 2007). More than 80% of the African elephants' range is outside of protected areas, and they engage in high amounts of crop raiding (Blanc et al., 2003). Crop-raiding elephant group sizes vary from two to 40 individuals due to the opportunity and availability of green and ripe crops (Sitati et al., 2003). In Bangladesh, elephant herd size was found to fluctuate between two and 60 individuals during the paddy maturing time (Sarker et al., 2015). Elephants usually encounter humans at night, early morning, or late evening when they are involved in crop, house, or homestead garden raids (Sukumar, 1990; Hoare, 1999; Chiyo et al., 2005).

The aim of this paper is to identify the characteristics of four attack types, namely, crop raids, house raids, homestead garden raids, and accidental attacks, which are considered byproducts of human–elephant conflict. We tested the following research questions:

1. How is the timing of elephant attack types related to the profession, household size, and income level of the attacked person or location?
2. How do attack frequencies and types vary among sites between the east and west coasts of the TWS?
3. How do the different attack types vary between seasons and elephant group size?

2 Materials and methods

2.1 Study area

Our year-round research work was performed at TWS in Bangladesh. The location of TWS is in southern Bangladesh, under Cox's Bazar South Forest Division, and it is a famous refuge for migratory elephants in the region (Figure 1) (Sarker et al., 2015). This sanctuary maintains a close border with Arakan Province in Myanmar alongside numerous transboundary migratory corridors between Myanmar and Bangladesh (Sarker et al., 2015). The western and southern parts of the sanctuary are enclosed by the Bay of Bengal; the eastern part is bordered by the Naf River; and only the northern part currently contains paved routes that elephants use (along the north forest division of the Cox's Bazar Region) (Bari and Dutta, 2004). TWS is quite narrow, stretching from 20° 52′ to 21° 09′ N in latitude and 92° 08′ to 92° 08′ E in longitude, and the altitude varies by no more than 200 m across the sanctuary (Green, 1987). The estimated length from north to south is 28 km, and the breadth from east to west is not beyond 3.5 km. The total area of this sanctuary is 11,615 ha, but it is constantly shrinking due to extreme human interference (IUCN Bangladesh, 2015). The sanctuary is encapsulated by human settlements: community settlements, forest-dependent settlements, and newly encumbered Rohingya people. Since 2017, more than one million Rohingya have settled in this area, joining the local people as well as another half a million other people because they have been driven out by the Myanmar military government. The total landmass of the region where the Rohingya people currently live covers a range of 300 km^2 (Rahman, 2018). This human population pressure and extreme interference with TWS have jeopardized the lives of approximately 50 to 70 elephants that frequently visit and take shelter in this sanctuary (Sarker et al., 2015). The topographical feature of this sanctuary is similar to that of the Indo-Chinese subregion because they emerged during the same time epoch of the Pliocene and Miocene (Choudhury, 1969). Evergreen and semievergreen hilly crisscross landforms developed this sanctuary into an extraordinary ecosystem suitable for flourishing biodiversity. Most elevated hills and hillocks are situated on the west coast of the southern and western parts, which is where the movements of elephants are becoming limited. Elephants prefer to follow the valleys and slopes as foraging and migration trails, and the area is even used as a resting place. The central part and eastern coast are more suitable for elephant movements due to the presence of small hills and hillocks, which have evergreen and semievergreen environments. This sanctuary is deemed to be an appropriate habitat for elephants due to water bodies that are full year-round, including ephemeral and perennial streams and borehole water deposits, with numerous water depressions alongside a year-round steady source of food. The physiological and ecological features of this sanctuary are proliferated by the presence of a riverine and marine atmosphere. As this region has a tropical climate, the seasonal variation is dynamic and vibrant. Three seasons, the summer, monsoon, and winter, are predominant out of a total of six seasons (e.g., summer, monsoon, autumn, late autumn, winter, and spring). The temperature remains between 20°C and 35°C, humidity remains between 27% and 98%, and rainfall is consistently above 1,000 mm, which occurs around the year (Bari and Dutta, 2004; USAID, 2015; BMD, 2019; BFD, 2020). This sanctuary contains a higher abundance of biodiversity than any other hilly ecosystem in Bangladesh (Sarker et al., 2015). Presently, this sanctuary is a refuge for 535 angiosperms (Uddin et al., 2012), along with 27 amphibian, 54 reptilian, 243 avian, and 43 mammalian species (Khan, 2008; IUCN Bangladesh, 2015).

2.2 Data collection procedures

We conducted comprehensive research work with a fixed number of intensive working days (5 days) in the last week of

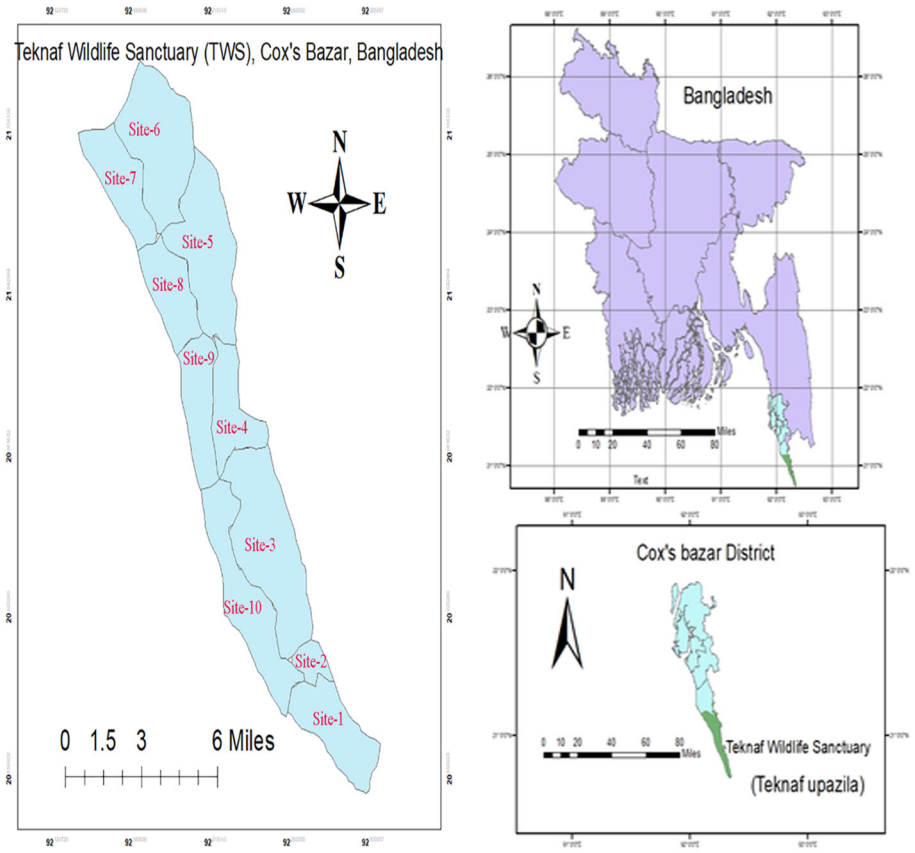

FIGURE 1
Site map of Teknaf Wildlife Sanctuary (TWS) divided into 10 study sites.

every month from August 2018 to July 2019. The fieldwork was accomplished across our demarcated 10 sites in TWS (Figure 1). We divided the study area into 10 sites by following forest administrative delineation and Bari and Dutta (2004), adopting a demarcation line. We formed a research team that included two research assistants, 10 research correspondents, and a researcher. The research correspondents were positioned at each site, as this was the easiest method of data collection. The first research assistant was responsible for communicating with east coast-positioned site correspondents and the second with west coast correspondents, and the researcher oversaw the whole team. Our research target group was forest-dependent people who lived inside the protected forest or just outside it and engaged in illegal activity in the forest. Their livelihood is dependent on forest resources. These people are frequently confronted with elephants because they engage in activity and settlements on protected forest land. They continuously illegally collect house-building materials, fuelwood, and different plant parts as a source of income. They are also illegally engaged in agricultural practices, gardening, and cattle ranching in TWS to earn income to meet their daily household demands. We recorded data through semistructured questionnaires about confrontation cases between forest-dependent peoples and elephants in terms of crop and house raids, homestead garden raids, and accidental attacks over 1 year. A site-oriented research correspondent carried out their duty throughout the year to collect all kinds of human–elephant conflict-related data in addition to our frequent field visits. Our site-specific research correspondent was local and continued being a watchdog at the spot. After getting information about any elephant causing an incident through social media platforms or mobile phone calls, the correspondent immediately went to the spot and interviewed the victim, the victim's family, or even the neighbors about the incident. The collected information was recorded, assisted by our designated questionnaire. During data collection, the priority data collected were on elephant herd size and damage types (crop, property, and humans, as severe or moderate). Our field visits were mainly concentrated on conflict-oriented negative interactions between victims or victims' families and elephants that caused property and homestead garden damage as well as crop loss. During the field visit, we contacted our research correspondents and collected the data from questionnaires. Crop and house raids, homestead garden raids, and accidental attacks in relation to the season were the main contents of our questionnaire. We also included forest-dependent people types, professions, locations, attack times, household sizes, income levels, and elephant herd sizes. The social status of the victimized forest-dependent people was determined by considering their settlement status, including legal or illegal status, their profession and income level, and their settlement location (inside or outside the forest). In addition, we recorded different levels of conflict intensity between humans and

elephants across sites over the year. We identified victims and victims' families by collecting information from our site-based research correspondents who resided close to the victims' families. Four elephant attack types with related information were collected at all sites. We also identified the time of day during which attacks occurred on a 24-h scale. The forest-dependent people were classified into (1) traditional forest dwellers, (2) illegal settlers, (3) forest-adjacent villagers, and (4) Rohingya refugees. In addition, we recorded the traditional forest native tribes who have lived in the forest from generation to generation by maintaining a harmonious relationship with nature. We enumerated the number of villages (35) as well as the community-oriented settlements (that is, settlements that were within 2 km of the forest boundary) as forest-adjacent villagers. The settlement location was separated into inside the forest, buffer zone, and adjacent outside the forest. The forest buffer zone is an interface between the forest boundary and the populous area. Forest outsiders are marked as intruders—people who engaged in at least one out of six types of forest-dependent illegal activities. The forest-dependent livelihood (profession) of forest-dependent people was divided into (1) cattle rancher, (2) gardener, (3) paddy cultivator, (4) vegetable grower, (5) betel-leaf grower, and (6) forest resources collector. The forest valleys and plains are mainly used for paddy cultivation and vegetable and betel-leaf growing; other types of terrain are used for gardening; and forest resource collection activities occurred everywhere. For forest-dependent people, there was no other way of generating money and supporting a family other than these professions due to remoteness and a lack of alternative livelihood opportunities. The elephant attack time was grouped as early in the morning (0400 to 1000 hours Greenwich Mean Time (GMT)), midday (1000 to 1600 hours), late evening (1600 to 2000 hours), and night (2000 to 0400 hours) based on GMT. The season (summer March–June, monsoon July–October, and winter November–February) has a great influence on the elephant attack type as well (Rahman, 2019). Elephant herd size was classified as small (less than four individuals), medium (four to eight individuals), and large (more than eight individuals), while attack type was classified as severe (somebody was killed) and moderate (somebody was injured). Moreover, we found that humans often killed elephants by using an electrical boundary fence to protect ripened paddies during the maturation period, traps containing poisoned jackfruit, and sharp weapons.

2.3 Data analysis

We used SPSS software version 26 (IBM Corp., Chicago, USA) to analyze field-level-collected primary data. We used Chi-square tests to indicate the conflict intensity between humans and elephants in terms of crop and house raids, homestead garden raids, and accidental attacks. We clarified which types of attack and scales of attack the forest-dependent people were involved in, as well as sites, seasons, and elephant herd sizes in these attacks. As most of the variables were categorical, we prioritized the Chi-square test and avoided other types of quantitative tests. The statistically significant value was set at $p \leq 0.05$. Finally, we made a site map with the support of ArcGIS software version 10.7.1 (Esri, California, USA) and Adobe Photoshop software.

3 Results

The elephant attack types, including crop raids, house raids, homestead garden raids, and accidental attacks, differed statistically significantly among traditional forest dwellers (19.8%), illegal settlers (41.0%), forest-adjacent villagers (23.5%), Rohingya (5.9%), and traditional forest tribal people (9.9%; Table 1). Attack type intensity also significantly varied with settlement location, including inside-forest settlers (46.8%), buffer zone settlers (32.9%), outside-forest settlers (20.3%), and even between the east and west coasts ($X^2 = 8.30$, $df = 3$, $p = 0.04$; Table 1). Attack types further varied significantly according to the profession of forest-dependent people's livelihood: cattle rancher (11.5%), gardener (12.4%), paddy cultivator (26.1%), vegetable grower (17.5%), betel-leaf grower (18.0%), and forest resources collector (14.4%; Table 1). The attack type also varied significantly with household size: small households (12.18%), medium (25.47%), large (31.22%), and even extremely large households (31.11%, Table 1). Forest-dependent people were differently affected by elephant attacks in relation to their income level: very poor (16.50%), poor (26.57%), insufficient income (25.80%), and sufficient income (31.11%) across seasons (Table 1). Finally, the attack types varied statistically significantly with the time of day of the attack: night (63.0%), morning (17.0%), evening (15.3%), and midday (4.7%; Table 1).

Elephant attack types varied significantly between the east and west coasts ($X^2 = 120.00$, $df = 9$, $p \leq 0.0001$) but not significantly between different sites (Table 2). The highest number of attacks ($N = 552$, 61.1%) was recorded on the east coast: crop raids ($N = 206$, 22.8%), house raids ($N = 131$, 14.5%), homestead garden raids ($N = 153$, 16.9%), and accidental attacks ($N = 62$, 6.9%; Table 2). The total recorded attacks on the west coast ($N = 351$, 38.9%) were crop raids ($N = 131$, 14.5%), house raids ($N = 69$, 7.6%), homestead garden raids ($N = 110$, 12.2%), and accidental attacks ($N = 41$, 4.5%; Table 2). The attack rates were not significantly different among the 10 sites (Table 2).

The conflict intensity rate varied statistically significantly among the different seasons ($X^2 = 52.50$, $df = 2$, $p < 0.0001$). The number of severe cases ($N = 563$) was higher than the number of moderate cases ($N = 340$) for all attack types (Table 3). Out of a total of 903 cases, the proportions of recorded crop raids were 37.3%, including severe (25.3%) and moderate (12.0%), house raids (22.0%), including severe (15.8%) and moderate (6.2%), homestead garden raids (29.1%), including severe (19.8%) and moderate (9.3%), and accidental attacks (11.5%), including severe (1.4%) and moderate (10.0%) (Table 3). The frequency of severe and moderate crop raids, house raids, and homestead garden raids varied statistically significantly with the season, but the number of accidental attacks did not (Table 3). In summer, the proportions of attack types were crop raids (46.32%), house raids (20.43%), homestead garden raids (22.34%), and accidental attacks (10.89%); these attack types varied significantly (Table 4). During the monsoon season, the proportions of attack types were crop raids (28.83%), house raids (15.69%), homestead garden raids (44.52%),

TABLE 1 Relationships between attack raid types on forest-dependent people and their location, profession, household size, income level, and time of day.

Types	Variables	Crop raids (*N*)	House raids (*N*)	Garden raids (*N*)	Accidental attacks (*N*)	X^2	*df*	*p*≤
Forest-dependent people	Traditional forest dwellers	67	33	59	20	124.90	12	0.0001
	Illegal settlers	154	61	114	41			
	Forest-adjacent villagers	86	39	65	22			
	Rohingya refugees	1	41	0	11			
	Traditional forest local tribal people	29	26	25	9			
Location	Inside forest	148	87	107	81	48.48	6	0.0001
	Buffer zone	118	71	93	15			
	Outside forest	71	42	63	7			
Profession	Cattle rancher	32	21	33	18	62.51	15	0.0001
	Gardener	39	22	36	15			
	Paddy cultivator	115	41	64	16			
	Vegetable grower	66	26	54	12			
	Betel-leaf grower	45	59	45	14			
	Forest resources collector	40	31	31	28			
Household size	Small (> 4 members)	29	22	49	10	56.29	9	0.0001
	Medium (4 to 6)	69	51	88	22			
	Large (6 to 10)	102	79	72	29			
	Extremely large (< 10)	137	48	54	42			
Income level	Very poor (less than 5,000)	26	55	30	38	89.75	9	0.05
	Poor (5,000 to 7,000)	76	67	56	41			
	Insufficient (7,000 to 9,000)	93	42	79	19			
	Sufficient (above 9,000)	142	36	98	5			
Time	Night	225	147	180	40	240.19	9	0.0001
	Morning	58	27	44	25			
	Evening	52	26	39	21			
	Midday	2	0	0	17			

and accidental attacks (10.94%); these attack types varied significantly (Table 4). Even in winter, crop raids (33.58%), house raids (31.29%), homestead garden raids (22.51%), and accidental attacks (12.59%) varied significantly (Table 4).

Elephant attack types (e.g., crop raids, house raids, homestead garden raids, and accidental attacks) varied statistically significantly with the season (X^2 = 93.0, df = 6, p < 0.0001) and herd size (X^2 = 127.2, df = 6, p < 0.0001) (Table 5). The highest number of

TABLE 2 Elephant attack types (crop raids, house raids, homestead garden raids, and accidental attacks) for the 10 different sites.

	East coast						West coast				X^2	*df*	*p*-value
Attack types	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10			
Crop raids	35	18	32	44	40	37	47	28	20	36	16.15	12	.185
House raids	20	25	44	16	14	12	29	13	12	15	3.237	9	0.954
Homestead garden raids	29	15	20	32	27	30	36	22	25	27	5.132	10	0.882
Accidental attacks	10	4	25	7	11	5	15	8	8	10	2.223	4	0.695

TABLE 3 Attack types (crop raids, house raids, homestead garden raids, and accidental attacks) and severity across seasons.

Attack types	Intensity	Summer (*N*)	Monsoon (*N*)	Winter (*N*)	X^2	*df*	$p \leq$
Crop raids	Severe	120	48	60	45.84	24	0.005
	Moderate	50	31	28			
House raids	Severe	55	30	58	28.58	18	0.054
	Moderate	20	13	24			
Homestead garden raids	Severe	64	80	35	36.96	20	0.012
	Moderate	18	42	24			
Accidental attacks	Severe (deaths)	5	6	2	3.91	8	0.865
	Moderate (injuries)	35	24	31			

raids associated with small herds occurred during the summer (N = 128), while attacks with medium-sized (N = 116) and large (N = 122) herds occurred mostly during the winter (Table 5). However, during the monsoon season, the highest number of raids were initiated by large herds (N = 101) rather than small (N = 80) and medium-sized (N = 93) herds (Table 5). In winter, the highest number of raids were carried out by large herds (N = 91), and small (N = 86) and medium-sized (N = 86) herds were similar in number. Large herds mostly engaged in crop raids and homestead garden raids, and small herds mostly engaged in house raids and accidental attacks, whereas medium-sized herds did not show a strong tendency (Table 5). Homestead garden raids varied significantly over seasons, whereas the variation of house raids was close to significant over seasons, but crop raids and accidental attacks did not vary significantly over seasons (Table 5). Most crop raids were carried out by large herds during the summer, although this variation was not statistically significant (Table 5). Furthermore, most house raids and accidental attacks were carried out by small herds during the summer, but the variation among seasons and herd sizes was not statistically significant (Table 5). Finally, most homestead garden raids were carried out by large herds during the monsoon season, and the variation between herd size and season was statistically significant (Table 5).

4 Discussion

4.1 Elephant attack rates in relation to settlement location, profession, household size, income level, and attack time

We recorded six elephant and 13 human mortalities caused by human–elephant conflict. The main reasons for elephant deaths in Bangladesh are revenge encounters and attacks by forest-dependent people with locally made sharp weapons. During the first few days after a revenge attack, elephants suffer from minor injuries, and eventually, these injuries turn into serious injuries that ultimately cause them to die. These causes come in addition to electrocution and poisoning-related deaths (Sarker and Røskaft, 2011). Our research uncovered the intensity of conflict between humans and elephants, resulting in property and homestead garden damage, along with the loss of crops and threats to forest-dependent people. A remarkable number of traditional forest dwellers and illegal settlers suffer from crop raids, while forest-adjacent villagers, Rohingya refugees, and traditional forest tribal people moderately suffer from crop raids (Sarker et al., 2015). Our research work revealed that the number of traditional forest tribal people was not more than 1,000, while the number of traditional forest dwellers was approximately 5,000, and the number of illegal settlers exceeded 100,000 people occupying the forestland of TWS, along with more than one million Rohingya refugees from Myanmar. The number of crop raids was higher than that of house raids, homestead garden raids, and accidental attacks out of the total of 903 recorded cases. The highest number of crop raids was recorded inside the forest and the buffer zone, and the lowest number was recorded outside the forest. On the other hand, cattle ranchers suffered mostly from homestead garden raids, whereas gardeners, paddy cultivators, vegetable growers, and forest resource collectors suffered less from crop raids. Betel-leaf growers suffered mostly from house raids. Large household sizes and higher incomes were associated with suffering more attacks than lower incomes and smaller household sizes. Our research revealed that most attacks occurred during the nighttime, while they were moderate during the early morning and late evening and rare during midday.

Sarker et al. (2015) discussed that illegal settlers on forestland along with forest-adjacent villagers experienced frequent attacks by

TABLE 4 The relationship between modes of conflict (crop raids, house raids, homestead garden raids, and accidental attacks) in different seasons.

Seasons	Crop raids	House raids	Homestead garden raids	Accidental attacks	X^2	*df*	*p*-value
Summer	170	75	82	40	115.60	9	0.0001
Monsoon	79	43	122	30	154.12	9	0.0001
Winter	88	82	59	33	147.49	9	0.0001

TABLE 5 Elephant attack types in relation to herd size and different seasons.

Attack types	Summer			Monsoon			Winter			Total (*N*)	X^2	*df*	$p \leq$
Group size ➢	Small (*N*)	Medium (*N*)	Large (*N*)	Small (*N*)	Medium (*N*)	Large (*N*)	Small (*N*)	Medium (*N*)	Large (*N*)				
Crop raids	47	53	70	19	27	33	20	27	41	337	22.90	24	0.525
House raids	41	21	12	17	15	11	37	26	19	199	26.45	18	0.090
Homestead garden raids	22	28	32	29	42	51	10	22	27	263	42.33	20	0.003
Accidental attacks	18	14	8	15	9	6	19	11	4	104	3.73	8	0.881

elephants in Bangladesh. Nontribal people, including legal and illegal settlers in the forest, forest-adjacent villagers, and Rohingya people, were more vulnerable to elephant attacks than traditional forest tribal people due to having less experience and less coping ability regarding living in areas where elephants roam (Sarker et al., 2015). Among people in Sri Lanka who were killed by elephants between 1992 and 2001, 75% were men, 13% were women, and 12% were children (Bandara and Tisdell, 2005), mainly illegal settlers on forestland who were engaged in forest-dependent illegal activities. The highest human–elephant conflict intensity was recorded on forest edges and buffer zones of TWS due to extreme agricultural practices by forest intruders and illegal settlements (Sarker et al., 2015). Sukumar (1989) concluded that out of 123 cases in Tamil Nadu, India, 55% of human deaths occurred inside the forest when people were doing forest-dependent illegal activities. The highest conflict rate occurred in the buffer zones and forest edges, as well as in the villages nearest to the forest, in most Asian countries with elephants (Sukumar, 1990). Several studies suggest that elephant herds roam in the vicinity of forest boundaries (Sukumar, 1989; Kiiru, 1995; Naughton et al., 1999; Nyhus and Sumianto, 2000). Human–elephant conflict takes place outside forests, mainly over crop raiding and homestead garden raiding, as well as raiding houses for stored grains (Sarker and Røskaft, 2011). Annually, elephants cause three million US dollars in crop damage and break down 10,000 to 15,000 houses in India (Bist et al., 2002). According to Sarker and Røskaft (2011), crop and property damage amounted to 5 and 2 lac of US dollars in Bangladesh. In Africa, annual crop damage is worth US$60–150 per farm in Uganda and Cameroon (Naughton et al., 1999). Elephants are the most conflict-inducing wildlife species in India, and every year, they cause large-scale crop and property damage, and approximately 500,000 families are affected by elephant attacks (Sukumar, 1990; Williams et al., 2001; Gubbi, 2009). Forest-dependent people who are engaged in agricultural practices, gardening, and forest resource collection are the ones most vulnerable to elephant attacks (Sarker and Røskaft, 2010; Sarker et al., 2015). In India, approximately 300 people are killed by elephant attacks per year, most of whom are involved in illegal forest activities (Bist et al., 2002). Gubbi (2012) reported 60,939 incidences of crop raids worth US$2.99 million, 91 human deaths, 101 elephant deaths, and 1,078 human injuries in Karnataka state in southern India from April 2008 to March 2011. Lahm (1996) found that 36% of farmers' crops in the West African country of Gabon were destroyed by elephants, and Osborn (1998) found that 85% of open agricultural fields of farmers were destroyed by elephants. Elephant–human conflict occurs mostly after sunset and during the night and less frequently during the daytime (Venkataraman et al., 2005). This is because elephants are mostly active starting in the late evening and are active the whole night to early morning, causing most of the damage and causalities during this timeframe (Sarker et al., 2015). Sukumar (2003) argued that most causalities occur in settlements from dusk to dawn but that they occur during the daytime inside forests where forest intruders are performing illegal activities.

4.2 Human–elephants' conflict intensity at different sites

Our research showed that the highest number of total crop raids, house raids, homestead garden raids, and accidental attacks occurred on the east coast, while crop raids and homestead garden raids were highest at site 7 on the west coast. The east coast had 1.57-fold higher crop raids, 1.90-fold higher house raids, 1.39-fold higher homestead garden raids, and 1.51-fold higher accidental attacks than the west coast, and the highest number of house raids and accidental attacks was recorded at site 3. Site 7 on the west coast was characterized by more intense attacks and had more gardening and agriculture being practiced at illegal settlements. Site 3 on the east coast had an extreme level of settlement due to the new flow of Rohingyas, and this site experienced the highest-level disturbance-prone patch. The elephant attack rate depends on site quality, which mainly focuses on the availability of food and water sources and less interference by human activities (Sarker et al., 2015; Mukeka et al., 2020). Fodder species, as ecological factors, are considered the core point of the escalating and de-escalating site-specific conflict intensity between humans and elephants in Bangladesh (Hossen and Røskaft, 2021). A remarkable number of conflicts are recorded in various parts of the east coast (more than on the west coast), and the east coast also has various ecological factors that are in worse condition due to being affected by socioeconomic factors (Hossen and Røskaft, 2022). Bandara and Tisdell (2005) recorded a total number of 536 causalities in Sri Lanka between 1992 and 2001, mostly from attacks that were due to a gradual deterioration of the quality of the elephant's habitat by extreme human interference.

Sukumar (2003) discussed that from 1980 to 2000, approximately 200 people lost their lives to elephant attacks, and there were 4,000 nonfatal attacks over two decades. Hossen (2013) recorded 224 severe attacks by elephants, which resulted in death and irreversible severe injuries, in five regions across Bangladesh.

4.3 Conflict intensity fluctuation by season and herd size

The highest number of severe crop raids was recorded in the summer. The status of severe house raids was found to be almost similar both in summer and winter but less in the monsoon season. The highest number of severe homesteaded garden raids was recorded in the monsoon season, more than double that during the winter and much higher than that in the summer. Severe accidental attacks (resulting in death) were found both in the summer and monsoon, but more attacks were moderate (resulting in injuries) in the summer and winter. Large herds (more than eight individuals) were mostly engaged in crop raids and homestead garden raids in all seasons, while small herds (fewer than four individuals) were mostly engaged in house raids and accidental attacks. Medium-sized herds (number of individuals between four and eight) were involved in four types of raids (crops, houses, homestead gardens, and accidental attacks), but these attacks were moderate.

Savanna elephants mostly engage in multiple incidences during the wet season, when most crops are maturing (Hoare, 1995; Kiiru, 1995; Tchamba et al., 1995; Mukeka et al., 2019). In Zimbabwe and Kenya, 75% to 90% of incidents occur during this time, whereas bush elephants in western and central Africa engage in conflict during the early wet season (Bell, 1984; Thouless, 1994; Hillman-Smith et al., 1995). The crop depredation rate escalates during the monsoon season and winter, both of which feature paddy maturation throughout most of India and Bangladesh according to the agricultural calendar in Assam (Lenin and Sukumar, 2011; Sarker and Røskaft, 2011). Seasonal variation has a great impact on elephant herd size and the intensification of conflict between humans and elephants (Parker and Osborn, 2001).

5 Conclusion and recommendation

The conflict between humans and elephants in TWS is dramatically intensifying due to elephant corridor blockage, continual habitat degradation by forest-dependent legal and illegal settlers, and the new burden of Rohingya refugees' illegal activities. Negative attitudes are increasing in communities near forests due to crop depredation, property damage, fear, and life-threatening risks from elephants. Forest-dependent people are those who are engaged in forest-dependent illegal activities. They also consider elephants an obstacle that interrupts their illegal activities with sudden attacks (crop and house raids, homestead garden raids, and accidental attacks). There is an immediate need to stop all kinds of illegal activities by forest-dependent people to de-escalate conflict intensity. A temporary remedy can be implemented by an active elephant response team, watchtower guarding, and paying compensation to victims. Additionally, crop guarding, physical barriers, and deterrents, as well as buffer crops, can be a temporary remedy to dissolve the negative and retaliatory attitudes toward elephants (Choudhury et al., 2008; Dixon et al., 2009; Ogra, 2009; Jadhav and Barua, 2012; Wahed et al., 2016). Relocating Rohingya refugees to a suitable place outside the forest, relocating and rehabilitating illegal forest settlers, and building awareness among forest-adjacent villagers involved in forest-damaging activities can be permanent solutions. Elephant relocation and alteration of their movement pathways are impossible because the elephants of TWS maintained their migratory journey between the southeastern part of Bangladesh and Arakan, Myanmar, by following ancestral corridors and routes. Two types of measurement techniques, active and passive, can be effective in limiting the damage inflicted by elephant attacks (Hoare, 1995; Wunder, 1997; Parker and Osborn, 2001). The passive system consists of restoring the natural environment, and the active system refers to guarding elephants, driving out illegal settlers, and using repellents (such as noise deterrents, olfactory deterrents, chilly greases, and scarecrow techniques). Widespread fatal and nonfatal methods used by forest-adjacent communities to protect crops in African and Asian countries that have elephants have failed to keep elephants outside vulnerable areas due to habituation with new techniques and methods (Bell, 1984; Hoare, 1995; Tchamba, 1996). Strong forest management system involvement with multistakeholder participation can be the pathway to reducing conflict between humans and elephants in TWS. Collaborative research programs and stopping all kinds of forest-dependent illegal activities by forest-dependent people will promote the de-escalation of conflict between humans and elephants.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The ethics committee waived the requirement of written informed consent for participation.

Author contributions

Data were collected by AH. Writing and analyses were shared equally. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/fcosc.2023.1067045/full#supplementary-material

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