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Interactions between Habitats of Asian Elephants and Socioeconomic Factors in the Teknaf Wildlife Sanctuary (TWS), Bangladesh

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Abstract

We conducted a one-year study in TWS, Bangladesh, to test socioeconomic-related impacts on the sanctuary caused by three performers marked as forest-endorsed settlers, illegal settlers, and forest-nearest villagers. The performer's activities were marked as cattle ranching, gardening, paddy cultivation, vegetable growing, betel-leaf growing, and forest resource collection. These factors had a marked impact on the elephant's use of fodder species, water bodies, feeding trails and resting places, as well as soil types. We revealed that 8% of the intruders were engaged in cattle ranching, 17% in gardening, 32% in paddy cultivation, 25% in vegetable growing, 6% in betel-leaf growing and 12% were forest resource collectors. These numbers were taken out of a recorded total of 26,937 incidences of forest intrusions, including forest endorse settlers (4%), illegal settlers (35%) and nearest forest villagers (61%). The disturbance rate differed statistically significantly across 6 study sites on the east coast and 4 study sites on the west coast in response to socioeconomic-related activities. Almost 2827 hectares of forestland was replaced by paddy cultivation (575 ha), vegetable growing (529 ha), betel-leaf growing (480 ha), gardening (448 ha), and illegal settlement (795 ha). Thus, a total of 11615 hectares of the sanctuary was permanently damaged, posing challenges to elephant survival.

Keywords: ecological factors, forest endorsed settler, forest nearest villager, illegal settler, socioeconomic factors

1. Introduction

Habitat selection by elephants is governed by several ecological factors. However, human-induced socioeconomic factors are frequently major threats to good-quality elephant habitats (Lin et al., 2008; Viljoen, 1989b). Ecological factors account for crucial components of an ecosystem but are occasionally curbed by climatic and socioeconomic factors (Hillman-Smith, de Merode, Nicholas, Buls, & Ndey, 1995). Ecological factors are a large part of environmental factors that are disturbed by many anthropomorphic factors, such as society, economy, culture and politics. Such factors act along with biological and physiological components, e.g., lithosphere, hydrosphere, and atmosphere (Adams & Hutton, 2007; Oliver, 1978). Climatic factors, such as rainfall, temperature, humidity, light, and wind, are also parts of the environment that have a great influence on ecological factors (Owen-Smith, 1982). Climatic factors frequently restrict food quality, water bodies, and resting shade quality for elephants, which directly or indirectly suppresses several ecological factors in a habitat (Leuthold, 1977; Buss, 1961). Therefore, there is great concern regarding how such socioeconomic factors, frequently referred to as anthropogenic activities, continue to abolish and handicap the primary features of climatic and ecological factors (Sukumar, 1989; McNaughton, Oesterheld, Frank, & Williams, 1989). The life of living organisms in a forest ecosystem becomes suffocated by the adverse impact of both climatic and socioeconomic factors, which are extremely harmful to the true features of a habitat (Leggett, 2006b). The main characteristics of major ecological factors are fading and terminating due to mounting pressure from socioeconomic factors (Eltingham, 1977; Caughley & Goddard, 1975).

Asian (*Elephas maximus*) and African (*Loxodanta africana*) elephants are well adapted to live in diverse habitats where they exploit a wide spectrum of fodder species, as well as resting and movement facilities (Baskaran, 1998; Laws, Parker & Johnstone, 1975). A good-quality habitat means that the condition of ecological factors is of high

quality, which again means that the availability of fodder species, water bodies and feeding, resting, and roaming conditions are high quality (Baskaran, 1998; Daniel et al., 1995). It is therefore challenging to protect the biogeographical resources of elephants over a wide range of countries to favour and ensure the presence of elephants knotting with ecological factors (Hoare, 2000). The increase in human populations and reduction in forest cover are correlated with and deplete the quality of ecological features of the elephants' habitat (Sukumar & Santiapillai, 1996). Elephants frequently move outside their home ranges, mostly due to inadequate conditions of the ecological factors (Hoare, 1999; Leuthold & Sale, 1973). According to Desi (1991), different patches of the elephants' home range are consistently used year after year if the ecological factors remain unchanged with negligible influence from socioeconomic factor-related activities. The use of fodder species and bodies of water is frequently predicted by several ecological factors to ensure the survival of elephants in both African and Asian habitats (Sukumar, 1990; Sikes, 1971). The daily requirement of African elephants is in the range of 160 to 250 kg vegetation and 160 litres of water (Sikes, 1971). The Asian elephant's daily demand, on the other hand, is approximately 150 kg vegetation and 100 litter waters (Sukumar, 1990; Baskaran, 1998). The activities associated with water oscillate with seasonal variation (Wyatt & Eltringham, 1974; Kabigumila, 1993). The proper performance of daily activities, such as feeding, watering, resting and movements by forest and desert elephants, is mostly desired by the congenial condition of ecological factors and climatic parameters (Baskaran, 1998; Leggett, 2006b). Spatial and temporal changes in major ecological factors greatly change the daily activities of elephants in different habitats (Daniel et al., 1995). The elephant's social activities entail aggregation, playing, fighting and communication, which are pursued by a proliferated mode of ecological factors beyond seasonal variation and the intense impact of socioeconomic factors (Moss, 1983; Kabigumila, 1993). The success rate of elephants' reproductive outcomes, offspring raising, and social organization are primarily determined by the qualities of major ecological factors (Poole, 1987; Sukumar, 2003; Weir, 1973). The availability of water and fodder resources will therefore affect the breeding rate of African and Asian elephants (Sukumar, Bhattacharya, & Krishnamurthy, 1987; Western, 1975).

The daily activity patterns of elephants have been interrupted by a set of anthropogenetic socioeconomic factors in different habitats (Baskaran, Anbarasan, & Agoramoorthy, 2012). Elephants inherently use such habitats, but currently, they are forced to share these habitats with humans under the pressure of a cohabit framework (Ogutu, 1997). Elephant habitats are frequently being transformed into agriculture and monocultures with human settlements with multifarious development activities with respect to globalization, urbanization and modernization (Fletcher et al., 2018). Annexation of human activities in forests results in a serious element of chance with respect to elephant survivability in Africa and Asia (Hoare & du Toit, 1999; Sukumar, 1990). Declining and fragmenting habitats in different ecosystems caused by human expansion into natural habitats of elephants are causing a high rate of destruction (Hoare & du Toit, 1999). The rate of overwhelming socioeconomic factors and practices is causing depletion of the quality and quantity of ecological factors in the elephants' habitat (Thouless, 1994; Hoare, 1999; Barnes, 1996; Naughton-Treves, 1996). In Asia, elephant habitats are invaded into forestland, overexploiting forest resources and outermost practices of relevant activities along with gardening and mining (Sukumar, 1991; Sarker, Hossen & Røskaft, 2015; Mckay, 1973). As discussed by Leimgruber et al. (2003), increases in the human population are the most important factor responsible for the degradation and fragmentation of pristine wildlife habitats over time. Habitats in 13 Asian range countries are relentlessly fragmented, degraded, isolated, and becoming sparse due to the increasing number of anthropogenic factors (Santiapillia & Jackson, 1990; Leimgruber et al., 2003). Approximately 51% of Asian elephants' rangelands occur in wilderness areas, while all other range areas are occupied by agricultural practices, settlements, roads, and infrastructure development (Leimgruber et al., 2003). The burden of socioeconomic activities imposed by forest-dependent people forcibly limits the forest's productivity rate (Sukumar & Santiapillai, 1996; Kumar, 1994). Humans modify forest landscapes, which drive elephants into alternative habitats in search of food, water, and other resources. However, such new environments hinder elephant breeding, feeding and moving (McNamar & Houston, 1985). Boundless mosaic formation and reshaping of forestland have led to a new arena of conflict between humans and elephants in response to forest resource utilization (Graham, Douglas-Hamilton, Adams, & Lee, 2009). The conflict rate between elephants and humans escalated after the increase in crop cultivation, forest resource collection, and settlement into forestland (Sukumar, 1989). The upsurge in socioeconomic activities in the periphery of the elephant roaming range have concurrently accelerated the peak number of conflict-related incidents (Desi, 1991; Oliver, 1978).

The interaction between biotic and abiotic factors conveys negative or positive consequences to a habitat regarding its ecological dynamics (Yates, Norton, & Hobbs, 2000). Interactions among natural components in a forest, such as assemblage of organisms, types of symbiosis, prey and predator relationships and herbivore and vegetation relationships, maintain the natural balance (Adams & Hutton, 2007; Ogutu, 1997). If interactions between human beings and natural resources become unsustainable, it might cause ecological collapse with perilous impacts on

nature (Sih, Ferrari, & Harris, 2011). Elephants are able to tackle climatic factors that suppress ecological factors through physiological and behavioural adaptations (Moss, 1983; Wittemyer, Douglas-Hamilton, & Getz, 2005). However, elephants fail to maintain their balance with nature if socioeconomic-related activities cause unprecedented damage to ecological factors (Hoare, 2000). Human presence in an elephant habitat brings potential destruction (Parker & Graham, 1989; R. Barnes, K. Barnes, Alers, & Blom, 1991). Even interactions between ecological and socioeconomic factors are imposing great stress on forest keystone species (Western, 1989; Milner-Gulland & Beddington, 1993). Alluded to by Hoare & du Toit (1999), coexistence between people and elephants reflects a threshold between the human population's increase and the elephant populations' decrease. Many setbacks and loopholes persist in elephant habitats, but elephants prefer to utilize such habitats due to their great fidelity to their homeland (Daniel et al., 1995; Desai & Baskaran, 1996). Particular habitats used by elephants 'with forest-dependent people' share a common interest (Kshettry, Vaidyanathan, & Athreya, 2017). The conflict between elephants and humans is flaring up due to an intensified interference on forestland and resources by forest-dependent people (Sukumar, 1989).

Given all of these factors, the interactions between ecological and socioeconomic factors in our research field, TWS, is worth investigating (Hossen, 2013). A poor forest management system, lack of good governance, and flooding corruption have inspired people to extract and claim forestland and resources in an unparalleled way (Sarker et al., 2015; Sarker & Røskaft, 2010). Elephants, as majestic creatures of the forest, are now struggling to survive in Bangladesh (International Union for Conservation of Nature [IUCN], 2015). Forest endorsed and illegal settlers, as well as villagers living nearest forests with Rohingya people (refugees), are the primary actors who are exploiting the most valuable ecological components in this sanctuary (Sarker & Røskaft, 2011, Rahaman, 2018). This is due to a pragmatic reality; Asian elephants in this sanctuary are now confronting troubles with food and shelter in response to an increasing number of people trespassing into their home (Hassan, 2017, Hossen, 2013). Elephant movement trails and resting places are being replaced by gardens and agricultural land, while fodder species are becoming sources of homebuilding materials and fuelwood. Finally, bodies of water are being used for domestic and agricultural purposes (Sarker et al., 2015).

The aim of this study was to determine 1) the kind of ecological features most affected by dominant socioeconomic factors in the study area; 2) who are primarily responsible for generating different socioeconomic-related activities; and 3) the quantity of forestland that has already been converted to agricultural land, gardens, and illegal settlement occupancies. Finally, we will discuss the implications of these activities on the future survival of the elephants.

2. Research Methodology

2.1 Study Area

Our research area, TWS, is an 11,615-ha area in the southern region of Bangladesh, famous for its migratory elephant habitat (Choudhury, 1969; Rosario, 1997). This sanctuary borders Arakan Province in Myanmar and contains several corridors bridging the two countries. The latitude lies between 20^0 52' and 21^0 09' N and longitude 92^0 08' to 92^0 18' E, with a 28 km long and 5 km wide narrow strip through the western and southern parts confined by the Bay of Bengal and the eastern part by the Naf River. The northern part of the sanctuary maintains a corridor connection with the southern reserve forest of Cox's Bazar division in Bangladesh (Bari & Dutta, 2004; Integrated Protected Area Co-Management [IPAC], 2011). The primary characteristics of the sanctuary are a combination of hilly, marine, and estuary features. The topographical features of this sanctuary are characterized by a number of undulating and crisscrossing hills and hillocks with erected elevations and slopes (Green, 1987; IUCN, 2015). The number of narrow valleys and precipitous landforms enhance the diversification of topography with numerous small and large streams (Bari & Dutta, 2004). This sanctuary is encapsulated by surrounding human settlements with 43 villages and many populated dens (Bari & Dutta, 2004). Many forest endorsements and illegal settlers occur in different parts of the country and have scrambled the forestland together with hundreds of thousands of Rohingya settlements (Hassan, 2017). The population density exceeds 1000 humans per $km^{2,}$ and the population size surrounding the sanctuary leaped up after the annexation of more than one million Rohingya people, who are refugees from Myanmar (Hassan, 2017; Rahman, 2018). Some deliberate government activities (road and infrastructure developments) alongside the surplus population pressure on the sanctuary are damaging, along with ongoing abolishing acts. Since the location of the sanctuary is under the tropical regime, the meteorological parameters consisting of temperature, rainfall, and humidity are moderated but somewhat varied by seasonal variation (Sarker et al., 2015). Apart from being the home of Asian migratory elephants, this sanctuary is also recognized as a hub for primates, cats, and ungulates, together with diverse species of amphibians, reptiles and birds (Khan, 2008; Islam, Miah & Habib, 2013).

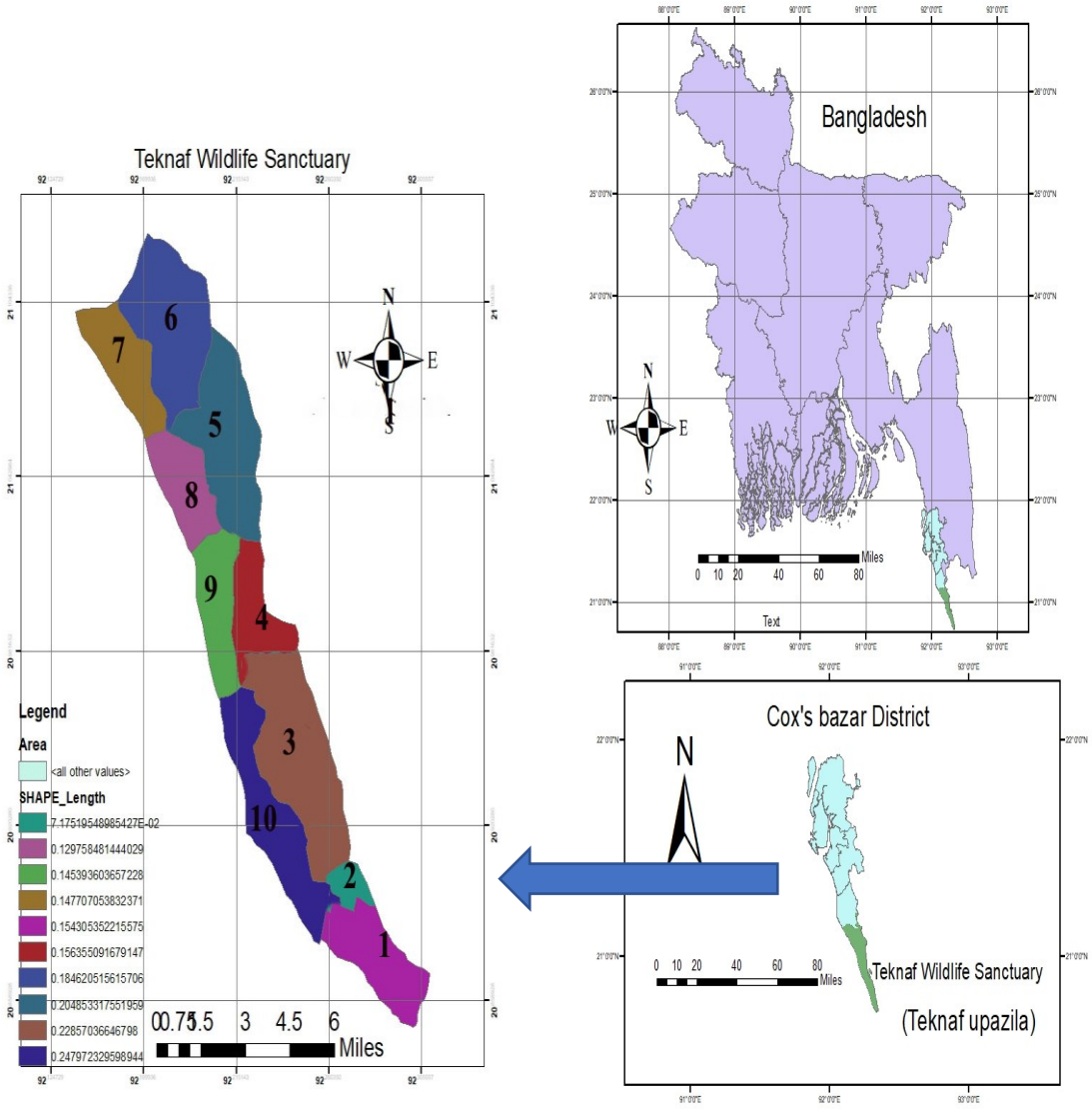

Figure 1. Map of the Teknaf Wildlife Sanctuary in Southern Bangladesh, Consisting of Different Study Sites. 1. (Site-1: Teknaf). 2. (Site-2: Dumdumiya). 3. (Site-3: Ledha). 4. (Site-4: Hnila-south). 5. (Site-5: Hnila-north). 6. (Site-6: Raingkhali). 7. (Site-7: Shaplapur). 8. (Site-8: Shilkhali). 9. (Site-9: Mathabanga). 10. (Site-10: Rajarchara).

2.2 Data Collection

We accomplished one year of research work with a fixed number of working days (5 days) every last week of a month from August 2018 to July 2019. The fieldwork was conducted across ten transect sites in TWS (Figure 1). At each site, we used one research correspondent, adding up to 10 different research assistants among the 10 transect sites. In addition, two research assistants were employed to ensure that the research ran smoothly during the data collection period. We primarily applied a ground-truthing direct observation technique to identify the different observation items and recorded the most affected ecological factors related to several dominant socioeconomic factors executed by forest intruders. We recorded several components in the TWS as ecological factors when they directly influenced the presence of elephants in the sanctuary but also when they were affected by forest intruders. We sorted and categorized the ecological and socioeconomic factors based on importance and value. We selected the following four categorical ecological factors: fodder species, bodies of water, elephant resting places, and movement trails. In addition, we selected soil types that were important for elephants. We observed and counted the number of each ecological factor on every visit across the 10 sites during our fieldwork. We also observed and counted the number of diversified fodder species, the number of bodies of water including

small and large water pools alongside ephemeral and perennial streams, the number of elephants resting places from forest grounds to hilltops, the number of feeding trails by marked footprints, dung-piles, and uprooted trees and broken branches. Soil types were marked as clay, sandy fine, sandy, mixed clay and mixed sandy.

In addition to ecological factors, we identified and categorized the most dominant anthropogenic activities caused by intruders and marked them as socioeconomic factors. Socioeconomic factors consisted of cattle ranching, gardening, paddy cultivation, vegetable growing, betel-leaf growing, and illegal forest resource collections by intruders. We identified three types of intruders, legal forest-endorsed settlers, illegal settlers, and villagers living close to the forest, who were mostly engaged in socioeconomic-related activities. We also classified intruders based on their activities, such as cattle ranchers, gardeners, paddy cultivators, vegetable growers, betel-leaf growers, and forest resource collectors. Cattle ranching activities referred to the number of cows, goats, and buffalos grazing in the forestland. Gardening included planting fruit trees (mango, jackfruit, guava, and betel nut) and nonfruit trees (acacia, mahogany, rubber). Paddy cultivation as a dominant agricultural practice was ranked as the top socioeconomic factor. Vegetable and betel-leaf growth was observed on hilltops, slopes, and on the forest ground. Different types of forest resources, such as fuelwood, homebuilding materials, season-oriented plant parts, and herbs, were collected by several intruders and were recorded as forest resources collected as a part of socioeconomic factors. We recorded the disturbance rate of ecological factors by counting the number of forest intruders and recorded permanent damage to forestland converted to other landforms as a part of socioeconomic factors. We counted the number of ranchers with their herds, number of paddy cultivators, number of vegetable and betel-leaf growers and number of forest resource collectors. We recorded the quantity of forestland transformed for gardening, agricultural practices, including paddy cultivation, vegetables, betel-leaf growing, and illegal occupancy. The transformed landform-related data were converted into percentages along with quantity measurements to compare with real figures. Hectare was the measurement unit.

2.3 Data Analysis

We used SPSS software version 26 (IBM Corp, Chicago, USA), ArcGIS software version 10.7.1 (Esri, California, USA), and Adobe Photoshop software to analyse the data for discrepancies and uniformities and present the data by graphical and tubular outlooks. We performed different descriptive, comparative, and inferential statistical methods using SPSS software. The statistically significant value was set at $P \leq 0.05$.

3. Results

The relationship between different ecological factors (i.e., fodder species, water bodies, resting places, movement trails, and soil types) and socioeconomic factors (i.e., cattle ranching, gardening, paddy cultivation, vegetable growing, betel-leaf growing, and forest resource collection) are specified in Table 1. Most relationships were not significant; however, one socioeconomic factor, paddy cultivation, correlated significantly with most ecological factors, except for the number of soil types (Table 1). In addition, one ecological factor, i.e., the number of fodder species, correlated significantly with most socioeconomic factors (Table 1). Finally, the number of soil types correlated significantly with vegetable growth and betel-leaf growth (Table 1).

Table 1. Pearson Correlations between the Number of Dominant Ecological and Socioeconomic Factors in the Different Transects (N = 10; statistically significant correlations are shown in bold)

Ecological factors►	Number of fodder species		Number of waterbodies		Number of resting places		Number of movement trails		Number of soil-types	
Socio-economic factors▼	r	p≤	r	p≤	r	p≤	r	p≤	r	p≤
Number of cattle ranches	-0.124	0.177	- 0.053	0.567	- 0.198	0.030	- 0.171	0.061	0.023	0.801
Number of gardeners	0.189	0.039	0.074	0.420	0.028	0.759	0.066	0.475	0.106	0.251
Number of paddy cultivators	-0.201	0.028	- 0.298	0.001	- 0.297	0.001	- 0.393	0.0001	0.156	0.088
Number of vegetable growers	-0.216	0.018	- 0.096	0.297	- 0.057	0.536	- 0.141	0.124	0.182	0.047
Number of betel-leaf growers	0.134	0.146	- 0.005	0.961	- 0.053	0.566	0.041	0.659	0.205	0.025
Number of forest resources collectors	0.005	0.552	- 0.229	0.012	- 0.097	0.291	- 0.023	0.803	- 0.130	0.158

Significantly positive correlations were found between illegal settlers and cattle ranchers, paddy cultivators, vegetable growers, and forest resource collectors. In addition, positive correlations were found between the number of paddy cultivators and forest-endorsed settlers, as well as between the number of vegetable growers and the number of villages near forests (Table 2). All other relationships were nonsignificant (Table 2).

Table 2. Pearson Correlations between Illegal and Forest-endorsed Settlers as well as between Villagers near Forests and Different Socioeconomic Factors, including the Number of Cattle Ranchers, Gardeners, Paddy Cultivators, Vegetable Growers, Betel-leaf Growers and Forest Resource Collectors (N = 10; statistically significant correlations are in bold)

	Illegal settlers		Forest endorsed settlers		Forest nearest villagers	
Socio-economic factors	r	p ≤	r	p ≤	r	p ≤
Number of cattle ranchers	0.258	0.004	-0.033	0.721	-0.151	0.100
Number of gardeners	0.077	0.401	0.062	0.504	-0.031	0.735
Number of paddy Cultivators	0.492	0.0001	0.259	0.004	-0.109	0.236
Number of vegetable Growers	0.244	0.007	-0.025	0.790	-0.196	0.032
Number of betel-leaf Growers	-0.143	0.122	-0.078	0.400	-0.072	0.437
Number of forest resources collectors	0.271	0.003	0.064	0.488	-0.097	0.290

Binary logistic regression analyses showed that there were statistically significant differences between the east and west coasts in the numbers of gardeners, vegetable growers, betel-leaf growers and forest resource collectors (Table 3), while the numbers of cattle ranchers and paddy cultivators were not significantly different (Table 3).

In addition, significant differences between the east and west coasts were found between a few ecological factors, such as the number of bodies of water ($\chi^2 = 10.711$, df = 3, P = 0.013), number of elephant movement trials ($\chi^2 = 11.053$, df = 5, P = 0.005) and number of soil types ($\chi^2 = 27.74$, df = 3, P < 0.0001). However, no significant differences were observed between the number of fodder species ($\chi^2 = 10.323$, df = 10, P = 0.413) or the number of elephants resting places ($\chi^2 = 2.307$, df = 3, P = 0.511).

Table 3. Binary Logistic Regression Analyses with the East and West Coasts as the Dependent Variables against Six Independent Socioeconomic Variables (statistically significant correlations are in bold)

Independent variables	B	S. E	Wald	df	p ≤	Exp (B)
Number of cattle Ranchers	0.027	0.035	0.568	1	0.451	1.027
Number of Gardeners	0.096	0.021	20.280	1	0.0001	1.100
Number of paddy Cultivators	-0.010	0.013	0.601	1	0.438	0.990
Number of vegetable growers	-0.033	0.017	3.886	1	0.049	0.967
Number of betel-leaf Growers	0.187	0.055	11.501	1	0.001	1.206
Number of forest resources Collectors	-0.123	0.045	7.560	1	0.006	0.884
Constant	-1.951	1.545	1.595	1	0.207	0.142

Note: *Cox & Snell $R^2 = .577$ *Nagelkerke $R^2 = .781$

Statistically significant differences were found between the 10 different sites and the number of gardeners, number of paddy cultivators and numbers of betel-leaf growers (Table 4). In addition, statistically significant differences were observed between the number of forest intruders and the number of entry roads ($\chi^2 = 69.057$, df = 18, P < 0.0001).

Table 4. The Percentages of Different Socioeconomic Variables across Observation Sites (χ^2 tests)

Variables	1.Site (%)	2.Site (%)	3.Site (%)	4.Site (%)	5.Site (%)	6.Site (%)	7.Site (%)	8.Site (%)	9.Site (%)	10.Site (%)	X^2	df	p ≤
Number of cattle ranchers	20	3	5	14	10	5	12	11	13	7	332.7	306	0.141
Number of Gardeners	15	1	6	4	5	6	16	7	21	19	579.6	522	**0.041**
Number of paddy cultivators	13	3	15	14	15	12	4	8	10	6	695.3	648	**0.05**
Number of vegetable growers	12	3	8	14	14	11	13	7	12	6	589.0	585	0.446
Number of betel-leaf growers	9	4	5	6	7	11	12	17	14	15	305.3	261	**0.031**
Number of forest resources collectors	14	9	13	10	11	8	7	7	9	12	307.6	342	0.909

Statistically significant differences were observed between forestland cover changes and the rate of disturbances by socioeconomic factor-related activities across sites ($\chi^2 = 360$, df = 27, $P < 0.0001$) in response to engulfed forestland converting to paddy land (Mean = 57.54 ± 41.39**),** vegetable land (Mean = 53 ± 31.34), betel-leaf land (Mean = 47.80 ± 36.62), gardening land (Mean = 44.80 ± 17.30) and illegal settlement (Mean = 79.50 ± 53.09) (Table 5). The relationship between site-specific belonging areas and forest intruder activities in terms of permanent damage, such as paddy cultivation ($\chi^2 = 190.5$, df = 153, P = 0.021), betel-leaf growing ($\chi^2 = 176.4$, df = 135, P = 0.010) and illegal settlement ($\chi^2 = 225.5$, df = 189, P = 0.036), were significantly different. However, in relation to vegetable growth ($\chi^2 = 156.5$, df = 135, P = 0.099) and gardening ($\chi^2 = 113.4$, df = 108, P = 0.340), they did not vary significantly (Table 5).

Table 5. The Proportion of Areas in Different Sites Used for Paddy Cultivation, Vegetable Growing, Betel-leaf Growing, Gardening, and Illegal Settlement

Site name	Hectare (ha)	Paddy cultivation		Vegetable growing		Betel-leaf growing		Gardening		Illegal settlement		Total (ha)	
		%	ha	%	ha	%	ha	%	ha	%	ha	%	ha
Site-1	1204	4	48.7	5	60.2	2	24.1	4	48.2	8	96.3	23	276.9
Site-2	1032	1	10.3	2	20.6	1	10.3	3	30.9	3	309.6	10	103.2
Site-3	1256	7	87.9	6	75.4	2	25.1	2	25.1	15	188.4	31	401.9
Site-4	836	6	50.7	7	58.5	2	16.7	3	25.1	5	41.8	23	192.3
Site-5	1712	8	137.7	7	120.4	2	34.4	3	51.6	6	103.3	26	447.5
Site-6	1772	6	106.3	4	70.9	3	53.2	4	70.9	5	88.6	22	389.8
Site-7	838	7	58.6	5	41.9	8	67	6	50.3	10	83.8	36	301.7
Site-8	750	2	15	2	15	6	45	7	52.5	2	15	19	142.5
Site-9	854	4	34.2	3	25.6	8	68.3	3	25.6	3	25.6	21	179.3
Site-10	1352	2	27	3	40.6	10	135.2	5	67.6	9	121.7	29	392.1
Total (ha)	11,615		575.4		529.1		479.4		447.8		795.4		2827.2

4. Discussion

Five ecological factors, fodder species abundance, sources of water bodies, resting places, and movement trail facilities as well as soil types, were used in this study as crucial components of elephant habitats. In addition, we identified a number of dominant socioeconomic factors, such as cattle ranchers, gardeners, paddy cultivators, vegetable growers, betel-leaf growers, and forest resource collectors, all of which had adverse effects on ecological factors. Relationships between socioeconomic and ecological factors were mostly negative, except for a few with negligible positive correlations. For example, cattle ranching, gardening, paddy cultivation, vegetable growing, forest resource collection, and forest nearest roadsides all discriminately affect forest ecological factors (Owen-Smith, 1988). Every day, a vast number of cattle ranchers penetrate elephant habitats and indiscriminately execute multiple damaging activities, e.g., cattle feeding on elephant fodder species, use and pollute the water by dung drops, and even intervene in elephant resting places and movement trails (Desi, 1991; Sarker & Røskaft, 2011). Different types of gardening practices, including monocultures, fruit orchards, especially mango and guava, betel-leaf, and nuts accompanied by monoculture woody and rubber plants, are changing the real features of forests, absorbing waterbodies and damaging elephant movement trails (Chowdhury, 1969). Likewise, paddy cultivation occurs twice a year, and vegetables and betel- leaf grown as agricultural practices continually convert forests into

agricultural land and even incur adverse effects on fodder species, bodies of water, resting places, and movement trails (Sarker & Røskaft, 2014, Bari & Dutta, 2004; Baskaran, 1998). Additionally, forest resource collectors cut down trees and disproportionately extract all kinds of forest resources, which are all included as the majority of elephant fodder species (Bari & Dutta, 2004). Forest resource collectors are engaged in all kinds of deteriorating ecological activities (Choudhury, 1969; Sarker et al., 2015). The availability of fodder species and sufficient sources of water in a habitat are the fundamental components of elephants' daily requirements (Eltingham, 1990; Sukumar, 1989). The relationship between elephants and their main fodder species is essential for their survival (Jackman & Bell, 1985). Therefore, the existence of elephants and maintaining the balance in nature primarily involves controlling food access as the vital role of fodder species (Daniel, 1980). There are no more fodder species in a habitat, reflecting the absence of elephants in this habitat (Osborn, 2004). In addition, the large volume of water required for daily drinking and maintaining control of the body temperature of elephants by bathing are necessary (Sikes, 1971; Oliver, 1978). Even the elephants' reproductive success rate depends on the availability of water (Sukumar, 1989, Parkar & Graham, 1989).

Three types of intruders were monitored in this study, including forest endorsed settlers, illegal settlers, and villagers living nearest forest, all of whom were primarily responsible for the depreciation of the Teknaf elephants' habitat. Our year-round research unveiled a total of 26,937 intruders with illegal activities recorded across the different sites in the forest. A common scene everywhere in the Teknaf wildlife sanctuary is that every kind of forest resource is stripped out by intruders (Hassan, 2017). They engulf forestland to create settlements and agricultural land and utilize trees, shrubs, herbs, fuelwood and house building materials and grazing land for cattle (IPAC, 2011, Desi, 1991; Hoffman & Cowling, 1990). The intruders also boundlessly use natural water resources for domestic and agricultural purposes (Baskarn, 1998; Bari & Dutta, 2004). There is no place in a forest untouched by intruders, and eventually, nature becomes captivated and fragmented by their continuous activities (Leimgruber et al., 2005; Sarker et al., 2015). The intruders pave the way for multiple forest entrance passages to augment the connectivity inside and outside of the forest to rapidly wipe out forest resources (Lahm, 1996; Williams, Johnsingh, & Krausman, 2001). They are experts of the articulated newly developed passage to forest roads and routes, where they find easy access with their local vehicles to transport agricultural products and accessories (Desi, 1991). Forest intruders compete with their primary counterpart, the elephant, by sharing a common interest and cutting off the privilege of elephants (Ogutu, 1997). Intruders account for the costs induced on elephants due to various forms of competition and utilization of forest resources (Hoare, 2000; Lahm, 1996).

Our results revealed that the temporal damage and disturbances caused by intruders varied significantly between the east and west coasts. The east coast consisted of six study sites, while the west coast had four study sites. The local human population density was found to be close to 1000 per km^2 nearest the sanctuary border (Bari & Dutta, 2004; Bangladesh Bureau of Statistics [BBS], 2017). Their livelihoods are a circulating base of the forest with a tremendous practice of cattle ranching, gardening, paddy, and betel-leaf cultivation as well as vegetable growing (Sarker et al., 2015). Elephants in both Africa and Asia mostly prefer faster growing and lower concentrations of secondary component fodder species but experience mounting pressure from different types of disturbances by intruders regarding the primary obstruction to remain a suitable habitat for elephants (Oliver, 1978; Guy, 1976; Lin et al, 2008). The number of elephants resting places, locations, and feeding trails where fodder species choice changes rhythmically by seasonal variation are all consonant switches interrupted by the increasing number of forest intruders (Kabigurnila, 1993; Guy, 1976). Elephants occasionally stop their reproductive activities when the disturbance rate increases (Moss, 1983; Poole, 1987; Sukumar, 2003; Wong & Candolin, 2015).

Dwindling forestland and the loss of forest cover are not only exigent problems but are also global issues (Blair, Boon, & Noor, 1979). Globally, forestland is being sharply converted into multipurpose uses for agricultural practices, meadowlands, settlements, various forms of gardening, and infrastructure development, which are all changing green cover into useless vegetation (De Boer & Baquete, 1998; O'Connell-Rodwell, Rodwell, Rival, & Hart, 2000). Our research disclosed grave scenery due to permanent transformation of forestland into agricultural land, vegetables and betel-leaf land, gardening land and illegal settlements. Mallegowda, Rengaian, Krishnan, & Niphadkar (2015) noted that 40,000 livestock were continually grazing, 400 ha were cleaned for settlements, and 1200 ha was cleaned for agricultural practices in a dry tropical forest in India from 1973 to 2014. Our research field was overwhelmed by populace settlements and facing continuous loss of land by forest nearest people's bare enforcement. Illegal settlers and villagers nearest the forest illegally cut hills and cleanse forests to meet their demand and eventually turn a forest into a morbid condition that has lost its identity (Hedges et al., 2005; De Boer, Jordi, Oort, Grover, & Peel, 2015). There is competition among intruders regarding how much forestland will be taken over as soon as possible by managing the forest department and local administration (Wang, Blanchet, & Koper, 2010). Our research field, TWS, has already lost most of its forestland, even though the rate of loss has

decreased over the past 20 years (Molla, Rahman, & Rahman, 2004; Bari & Dutta, 2004). Rohingya flow to TWS is another predominant threat that started around 1960 but has increased successively in 1979, 1991 and the recent 2017 burden with over 1.5 million refugees. Around 4000 acres of sanctuary land have now been cleaned up to erect the makeshift camps (Hassan, 2017). The intensity of temporal and permanent damage in this sanctuary are gradually increasing due to extreme pressure from the abovementioned three types of intruders. Survival is a major concern issue for elephants in this sanctuary with the continually incurring mounting pressure from intruders with their illegal activities. One solution is to curb all types of illegal activities and introduce rehabilitation programs to drive out those who are already residing in this sanctuary.

5. Conclusion and Final Remarks

The TWS, a hub of Asian migratory elephants, is currently facing tremendous pressures from different socioeconomic factor-related activities. The daily forest intruder entrance rate and their devasting activities have sharply escalated from previous times. The temporary and permanent damage of major ecological factors is increasing the presence on elephants in this sanctuary. The temporal and spatial disturbances and damage were found to vary across sites along the east and west coasts. The intruder number and intensity of socioeconomic factor-related activities were also found to be different among sites. The lack of enforcement by forest personnel from higher authorities to the grassroots level suffers from low capability, knowledge gaps and forest management expertise. Additionally, the illegal flow of money, exercise of power and poor forest management as well as reduced awareness among people living nearest to the forest are the primary reasons for the meagre condition of this sanctuary. Unless the government sets up a well-trained group of forest staff and officers who will develop good service management, it will be impossible to revamp the original features of this sanctuary.

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References

Adams, W. A., & Hutton, J. (2007). People, Parks and Poverty: Political Ecology and Biodiversity Conservation. *Conservation and Society*, *5*(2), 147-183.

Bari, A., & Dutta, U. (2004). Co-management of tropical forest resources in Bangladesh. Secondary data collection for pilot protected area: Teknaf Game Reserve. USAID-Bangladesh and Ministry of Environment and Forest, Govt. of People's Republic of Bangladesh, 01-33.

Barnes, R. F. W. (1996). The conflict between humans and elephants in central African forests. *Mammal Review*, *26*(2-3), 67-80. https://doi.org/10.1111/j.1365-2907.1996.tb00147.x

Barnes, R. F. W., Barnes, K. L., Alers, M. P. T., & Blom, A. (1991). Man determines the distribution of elephants in the rain forest of northeastern Gabon. *African Journal of Ecology, 29*(1), 54-63. https://doi.org/10.1111/j.1365-2028.1991.tb00820.x

Baskaran, N. (1998). *Ranging and Resources Utilization by Asian Elephant (Elephas maximus) in the Nilgiri Biosphere Reserve, South India*. Ph.D. thesis, Bharathidasan University, Thiruchirapalli.

Baskaran, N., Anbarasan, U., & Agoramoorthy, G. (2012). India's biodiversity hotspot under anthropogenic pressure: A case study of Nilgiri Biosphere Reserve. *Journal for Nature Conservation, 20,* 56-61. https://doi.org/10.1016/j.jnc.2011.08.004

BBS (Bangladesh Bureau of Statistics). (2017). Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh (36th ed.).

Blair, J. A. S., Boon, G. G., & Noor, N. M. (1979). Conservation or cultivation: the confrontation between the Asian elephant and land development in peninsular Malaysia. *Land Development Digest, 2,* 27-59.

Buss, I. O. (1961). Some observation of food habits and behaviour of African elephant. *The Journal of Wildlife Management, 25*(2), 131-148. https://doi.org/10.2307/3798671

Caughley, G., & Goddard, J. (1975). Abundance and distribution of elephants in Luangwa Valley. Zambia. *African Journal of Ecology, 13*(1), 39-48. https://doi.org/10.1111/j.1365-2028.1975.tb00122.x

Choudhury, M. U. (1969). *Working plan of Cox's Bazar Forest division 1968-69 to 1977-78*. Forest Department, Government of East Pakistan.

Daniel, J. C. (1980). *The status of the Asian elephants in the Indian Sub-continent IUCN/SSC Report*. Bombay Natural History Society, Bombay.

Daniel, J. C., Desai, A. A., Sivaganesan, N., Datye, H. S., Rameshkumar, S., Baskaran, N., Balasubramanian, M., & Swaminathan, S. (1995). *Ecology of the Asian elephant*. Final Report 1987-1994. Bombay Natural History Society, Bombay.

De Boer, W. F., & Baquete, D. S. (1998). Natural resource use, crop damage and attitudes of rural people in the vicinity of Maputo Elephant Reserve, Mozambique. *Environmental Conservation, 25*(3), 208-218.

De Boer, W. F., Jordi, W. A., Oort, V., Grover, M., & Peel, M. J. S. (2015). Elephant-mediated habitat modifications and changes in herbivore species assemblages in Sabi Sand, South Africa. *European Journal of Wildlife Research, 61,* 491-503. https://doi.org/10.1007/s10344-015-0919-3

Desai, A. A. (1991). The home range of elephants and its implications for the management of Mudumalai Wildlife Sanctuary, Tamil Nadu. *Journal of Bombay Natural History Society, 88*(2), 145-156.

Desai, A. A., & Baskaran, N. (1996). Impact of human activities on the ranging behaviour of elephants in the Nilgiri Biosphere Reserve, South India. *Journal of Bombay Natural History Society, 93*(3), 559-569.

Eltringham, S. K. (1977). Number and distribution of elephant (*Loxodonta africana)* in the Rwenzori National Park and Chambura Game Reserve. Uganda. *African Journal of Wildlife Ecology, 15*(1), 19-39. https://doi.org/10.1111/j.1365-2028.1977.tb00375.x

Eltringham, S. K. (1990). Wildlife carrying capacities in relation to human settlement. *Koedoe, 33*(2), 87-97. https://doi.org/10.4102/koedoe.v33i2.444

Fletcher, R. J. Jr., Didhamb, R. K., Banks-Leited, C., Barlowe, J., Ewersd, R. M., & Rosindell, J. et al. (2018). Is habitat fragmentation good for biodiversity? *Biological Conservation, 226,* 9-15. https://doi.org/10.1016/j.biocon.2018.07.022

Graham, M. D., Douglas-Hamilton, I., Adams, W. M., & Lee P. C. (2009). The movement of African elephants in a human-dominated land-use mosaic. *Animal Conservation, 12*(5), 445-455. https://doi.org/10.1111/j.1469-1795.2009.00272.x

Green, M. J. B. (1987). World Conservation Monitoring Centre IUCN Commission on National Parks and Protected Areas, Teknaf Game Reserve. *IUCN Directory of South Asian Protected Areas,* 38-43.

Guy, P. R. (1976). Diurnal activity patterns of elephant in the Sengwa Region, Rhodesia. *African Journal of Ecology, 14*(4), 285-295. https://doi.org/10.1111/j.1365-2028.1976.tb00243.x

Hassan, M. M. (2017). Monitoring land use/land cover change, urban growth dynamics and landscape pattern analysis in five fastest urbanized cities in Bangladesh. *Remote Sensing Applications. Society and Environment, 7,* 69-83. https://doi.org/10.1016/j.rsase.2017.07.001

Hedges, S., Tyson, M. J., Sitompul, A. F., Kinnaird, M. F., Gunaryadi, D., & Aslan. (2005). Distribution, status, and conservation of Asian elephants (Elephas maximus) in Lampung Province, Sumatra, Indonesia. *Biological Conservation, 124*(1), 35-48. https://doi.org/10.1016/j.biocon.2005.01.004

Hillman-Smith, A. K. K., de Merode, E., Nicholas, A., Buls, B., & Ndey, A. (1995). Factors affecting elephant distribution at Garamba National Park and surrounding reserves, Zaire, with a focus on human-elephant conflict. *Pachyderm, 19,* 39-48.

Hoare, R. E. (1999). Determinants of human-elephant conflict in a land-use mosaic. *Journal of Applied Ecology, 36*(5), 689-700. https://doi.org/10.1046/j.1365-2664.1999.00437.x

Hoare, R. E. (2000). African elephants and humans in conflict: the outlook for co-existence, *Oryx, 34*(1), 34-38. https://doi.org/10.1046/j.1365-3008.2000.00092.x

Hoare, R. E., & du Toit, J. T. (1999). Coexistence between people and elephants in the African Savannah. *Conservation Biology, 13*(3), 633-639. https://doi.org/10.1046/j.1523-1739.1999.98035.x

Hoffman, M. T., & Cowling, R. M. (1990). Desertification in the lower Sundays River Valley, South Africa. *Journal of Arid Environment, 19*(1), 105-118. https://doi.org/10.1016/S0140-1963(18)30834-6

Hossen, A. (2013). *Human-elephant conflict in Bangladesh; causes and intensity of fatalities*. M.S. thesis, Department of Biology, Natural Resources Management, Norwegian University of Science and Technology, Trondheim, Norway.

IPAC (Integrated Protected Area Co-Management). (2011). *Landuse change trend analysis in seven protected*

areas in Bangladesh under IPAC through application of LANDSAT imageries. UAAID, Bangladesh (pp. 36).

Islam, S., Miah, M., & Habib, M. (2013). Diversity of Fruit and Timber Tree Species in the Coastal Homesteads of Southern Bangladesh. *Journal of the Asiatic Society of Bangladesh, Science*, *39*(1), 83-94. https://doi.org/10.3329/jasbs.v39i1.16037

IUCN (International Union for Conservation of Nature) (2015). *Red List of Bangladesh: A brief on assessment result 2015.* IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, 24.

Jachmann, H., & Bell, R. H. V. (1985). Utilization by elephants of the Brachystegia woodlands of the Kasungu National Park, Malawi. *African Journal of Ecology, 23*(4), 245-258. https://doi.org/10.1111/j.1365-2028.1985.tb00955.x

Kabigumila, J. (1993). Diurnal activity of elephants in Ngorongoro Crater, Tanzania. *African Journal of Ecology, 31*(1), 75-80. https://doi.org/10.1111/j.1365-2028.1993.tb00520.x

Khan, M. M. H. (2008). *Protected Areas of Bangladesh- a guide to wildlife*. Nishorgo Program, Bangladesh Forest Department, Dhaka, 304.

Kshettry, A., Vaidyanathan, S., & Athreya, V. (2017). Leopard in a tea-cup: a study of leopard habitat-use and human-leopard interactions in north-eastern India. *PLoS One, 12*(5), 1-15. https://doi.org/10.1371/journal.pone.0177013

Kumar, S. R. (1994). *Ecology of Asian Elephants, their Habitats and Interactions with People in Hosur and Dharmapuri Forest Division, Tamil Nadu, South Indian* (Ph.D. thesis). Bharathidasan University, Trichirapally, Tamil Nadu, India.

Lahm, S. A. (1996). A nationwide survey of crop-raiding by elephants and other species in Gabon. *Pachyderm, 21,* 69-77.

Laws, R., Parker, I. S. C., & Johnstone, R. C. B. (1975). *Elephants and their Habitats: The Ecology of Elephants in North Bunyore, Uganda*. Oxford: Claredon Press.

Leggett, K. E. A. (2006b). The effect of artificial water points on the movement and behaviour of desert-dwelling elephants of northwestern Namibia. *Pachyderm, 40,* 24-35.

Leimgruber, P., Gagnon, J. B., Wemmer, C., Kelly, D. S., Songer, M. A., & Selig, E. R. (2003). Fragmentation of Asia's remaining wildlands: implications for Asian elephant conservation. *Animal Conservation, 6*(4), 347-359. https://doi.org/10.1017/S1367943003003421

Leimgruber, P., Kelly, D. S., Steininger, M., Brunner, J., Muller, T., & Songer, M. A. (2005). Forest cover change patterns in Myanmar (Burma) 1990–2000. *Environmental Conservation, 32*(4), 356-364.

Leuthold, W., & Sale, J. B. (1973). Movements and patterns of habitat utilization of elephants in Tsavo National Park. Kenya. *African Journal of Ecology, 11*(3-4), 369-384. https://doi.org/10.1111/j.1365-2028.1973.tb00099.x

Leuthold, W. (1977). Spatial organization and strategy of habitat utilization of elephants in Tsavo National Park, Kenya. *Zeitschrift für Saugetierkunde, 42,* 358-379.

Lin, L., Feng, L., & Pan, W. *et al.* (2008). Habitat selection and the change in distribution of Asian elephants in Mengyang Protected Area, Yunnan, China. *Mammal Research, 53,* 365-374. https://doi.org/10.1007/BF03195197

Mallegowda, P., Rengaian, G., Krishnan, J., & Niphadkar, M. (2015). Assessing Habitat Quality of Forest-Corridors through NDVI Analysis in Dry Tropical Forest of South India: Implications for Conservation. *Remote Sensing, 7*(2), 1619-1639. https://doi.org/10.3390/rs70201619

Mckay, G. M. (1973). The ecology and behavior of the Asiatic elephant in southeastern Ceylon. *Smithsonian Contributions to Zoology*, *125,* 1-113.

McNamara, J. M., & Houston, A. I. (1985). Optimal Foraging and Learning. *Journal of Theoretical Biology, 117*(2), 231-249. https://doi.org/10.1016/S0022-5193(85)80219-8

McNaughton, S. J., Oesterheld, M., Frank, D. A., & Williams, K. J. (1989). Ecosystem-level patterns of primary productivity and herbivory in terrestrial habitats. *Nature, 341,* 142-144. https://doi.org/10.1038/341142a0

Milner-Gulland, E. J., & Beddington, J. R. (1993). The exploitation of elephants for the ivory trade: an historical perspective. *Proceedings of the Royal Society B, 252*(1333), 29-37. https://doi.org/10.1098/rspb.1993.0042

Molla, A. R., Rahman, M. M., & Rahman, M. S. (2004). Site-level field appraisal for protected area co-management: Teknaf game reserve. *Nature Conservation Movement* (NACOM), Bangladesh. Prain, D. 1903. *Bengal Plants, 1 & 2*. (Ind. Repr. 1963). Botanical Survey of India, Calcutta.

Moss, C. J. (1983). Oestrous behaviour and female choice in the African elephant. *Behavior, 86*(3-4), 167-196. https://doi.org/10.1163/156853983X00354

Naughton-Treves, L. (1997). Farming the forest edge: Vulnerable places and people around Kibale National Park. *The Geographical Review, 87,* 27-47.

O'Connell-Rodwell, C., Rodwell, T., Rival, L., & Hart, L. (2000). Living with modern conservation paradigm: can agricultural communities co-exist with elephants? *Biological Conservation, 93*(3), 381-391. https://doi.org/10.1016/S0006-3207(99)00108-1

Ogutu, Z. A. (1997). Conflicts over resources: Saiwa Swamp National Park (Kenya) and its environs. *GeoJournal, 41,* 25-31. https://doi.org/10.1023/A:1006844031893

Olivier, R. C. D. (1978). *On the ecology of the Asian elephant.* Ph.D. thesis, University of Cambridge, Cambridge.

Osborn, F. V. (2004). Seasonal variation of feeding patterns and food selection by crop raiding elephants in Zimbabwe. *African Journal of Ecology, 42*(4), 322-327. https://doi.org/10.1111/j.1365-2028.2004.00531.x

Owen-Smith, R. N. (1988). *Megaherbivores. The influence of very large body size on ecology*. Cambridge University Press, Cambridge.

Owen-Smith, N. (1982). Factors influencing the consumption of plant products by large herbivores. In Huntley, B. J. & Walker, B. H. (Eds.), *Ecological studies, 42: Ecology of tropical savannas*. Springer-Verlag, Berlin. (pp. 359-404).

Parker, I. S. C., & Graham, A. D. (1989). Men, elephants and competition. *Symposium of the Zoological Society of London,* 241-252.

Poole, J. H. (1987). Rutting behaviour in African elephants: the phenomenon of musth. *Animal Behavior, 102*(3-4), 283-316. https://doi.org/10.1163/156853986X00171

Rahman, M. Z. (2018). *Livelihoods of Rohingyas and Their Impacts on Deforestation.* In Deforestation in the Teknaf Peninsula of Bangladesh; Springer: Singapore.

Rosario, E. A. (1997). *The conservation management plan of the protected areas other than those in Sundarban forest in Bangladesh.* GOB/WB forest resource management project in Bangladesh.

Santiapillai, C., & Jackson, P. (1990). *The Asian elephant: an action plan for its conservation*. Gland, Switzerland: IUCN.

Sarker, A. H. M. R., & Røskaft, E. (2010). Human attitudes towards conservation of Asian elephants (*Elephas maximus*) in Bangladesh. *International Journal of Biodiversity and Conservation, 2*(10), 316-327.

Sarker, A. H. M. R., & Røskaft, E. (2011). Human attitudes towards the conservation of protected areas: a cause study from four protected areas in Bangladesh. *Oryx, 45*(3), 391-400. https://doi.org/10.1017/S0030605310001067

Sarker, A. H. M. R., & Røskaft, E. (2014). Perceptions of Farmers in Bangladesh to Asian Elephants (*Elephas maximus*). *Environment and Natural Resources Research, 4*(2), 23-38. https://doi.org/10.5539/enrr. v4n2p23

Sarker, A. H. M. R., Hossen, A., & Røskaft, E. (2015). Fatal Elephant Encounters on Humans in Bangladesh: Context and Incidences. *Environment and Natural Resources Research, 5*(2), 81-90. https://doi.org/10.5539/enrrv5n2p99

Sih, A., Ferrari, M. C. O., & Harris, D. J. (2011). Evolution and behavioural responses to human-induced rapid environmental change. *Evolutionary Applications, 4*(2), 367-387. https://doi.org/10.1111/j.1752-4571.2010.00166.x

Sikes, S. K. (1971). *Natural History of the African Elephant*. Eidenfeld and Nicholson, London. UK.

Sukumar, R., & Santiapillai, C. (1996). Elephas maximus: status and distribution. In Shoshani, J., & Tassy, P. (Eds.), *In the Proboscidea: evolution and paleoecology of elephants and their relatives*, 327-331. Oxford: Oxford University Press.

Sukumar, R. (1990). Ecology of Asian elephant in south India. II. Feeding habitats and crop raiding patterns. *Journal of Tropical Ecology, 6,* 33-53.

Sukumar, R. (1991). The management of large mammals in relation to male strategies and conflict with people. *Biological Conservation, 55*(1), 93-102. https://doi.org/10.1016/0006-3207(91)90007-V

Sukumar, R. (2003). *The Living Elephants: Evolutionary Ecology, Behavior and Conservation*. New York, USA: Oxford University Press 2003.

Sukumar, R., Bhattacharya, S., & Krishnamurthy, R. (1987). Carbon isotopic evidence for different feeding patterns in an Asian Elephant population. *Current Science, 56*(1), 11-14.

Sukumar, R. (1989). Ecology of the Asian elephant in southern India. I. Movement and habitat utilization patterns. *Journal of Tropical Ecology, 5*(1), 1-18.

Thouless, C. R. (1994). Conflict between humans and elephants in northern Kenya. *Oryx, 28*(2), 119-127. https://doi.org/10.1017/S0030605300028428

Viljoen, P. J. (1989b). Habitat selection and preferred food plants of a desert-dwelling elephant population in the Northern Namib Desert, South West Africa/Namibia. *African Journal of Ecology, 27*(3), 227-240. https://doi.org/10.1111/j.1365-2028.1989.tb01016.x

Wang, X., Blanchet, F. G., & Koper, N. (2010). Measuring habitat fragmentation: An evaluation of landscape pattern metrics. *Methods in Ecology Evol*ution, *5*(7), 634-646. https://doi.org/10.1111/2041-210X.12198

Weir, J. S. (1973). Exploitation of water-soluble soil sodium by elephants in Murchison Falls National Park, Uganda. *African Journal of Ecology, 11*(1), 1-7. https://doi.org/10.1111/j.1365-2028.1973.tb00069.x

Western, D. (1975). Water availability and its influence on the structure and dynamics of a Savannah large mammals' community. *African Journal of Ecology, 13*(3-4), 265-286. https://doi.org/10.1111/j.13652028.1975.tb00139.x

Western, D. (1989). The ecological role of elephants in Africa. *Pachyderm, 12,* 42-45.

Williams, A. C., Johnsingh, A. J. T., & Krausman, P. R. (2001). Elephant–human conflicts in Rajaji National Park, northwestern India. *Wildlife Society Bulletin, 29*, 1097-1104.

Wittemyer, G., Douglas-Hamilton, I., & Getz, W. M. (2005). The socioecology of elephants: analysis of the processes creating multitiered social structures. *Animal Behaviour*, *69*(6), 1357-1371. https://doi.org/10.1016/j.anbehav.2004.08.018

Wong, B. B. M., & Candolin, U. (2015). Behavioral responses to changing environments. *Behaviour Ecology, 26*(3), 665-673. https://doi.org/10.1093/beheco/aru183

Wyatt, J. R., & Eltringham, S. K. (1974). The daily activity of the elephant in the Rwenzori National Park, Uganda. *East African Wildlife Journal, 12*(4), 273-289. https://doi.org/10.1111/j.1365-2028.1974.tb01037.x

Yates, C. J., Norton, D. A., & Hobbs, R. J. (2000). Grazing effects on soil and microclimate in fragmented woodlands in southwestern Australia: Implication for restoration. *Austral Ecology, 25*(1), 36-47. https://doi.org/10.1046/j.1442-9993.2000.01030.x