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BEHAVIORAL CHANGE DUE TO CLIMATE CHANGE EFFECTS ACCELERATE TIGER HUMAN CONFLICTS: A STUDY ON SUNDARBANS MANGROVE FORESTS, BANGLADESH

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Abstract

The change in climate has been observed over comparable periods of time. Mangrove ecosystem and its biodiversity are threatened due to climate change. Sundarbans mangrove ecoregion situated in Bangladesh (~62%) and India (~38%) is a bioclimatic zone. Sundarbans is one of the largest reserves for the Bengal tiger (Panthera tigris tigris L) which is the top predator. Therefore, it helps to regulate the number and distribution of prey, which in turn impacts forest structure, composition and regeneration. As climate change affects the flora and fauna in this ecosystem, these may be impaired because of migration of the species. The tigers become stray from forests to human inhabitants and causes tiger human conflicts which often results in retaliatory killings of tiger and human and or livestock. Therefore, the main objective of this study is to identify the effects of climate change towards the salinity intrusion and biodiversity, modification of floral and faunal composition, habitat loss and behavioral change of wildlife, which ultimately identify the factors for accelerating tiger human conflicts. It reviewed related literature through various websites and the secondary data were quoted with necessary modification. The primary data obtained from the office records of Bangladesh Forest Department and a social surveying was conducted on livelihood profile of the people living surrounding the Sundarbans to identify the relations between tiger attacking and their livelihood and living style. We used ArcGIS 9.3 to visualize the tiger habitat and trigger up the causes of root of conflicts between human and tiger. The results reveal the climate change effects in the Sundarbans Mangrove forest through changing its biodiversity composition in terms of loss of wildlife habitats which is responsible for accelerating tiger human conflicts. It suggests, a social and cultural revolution for sustainable alternative livelihood of forest-dependent population i.e., Alternative Income Generation (AIG), modification of the formal legal system, institutional development and in depth research can minimize these issues towards the sustainability of Sundarbans mangrove forest.

Keywords: *Climate change; Sundarbans mangrove forests; tiger human conflicts; wildlife habitat; stray tiger.*

Introduction

The changing climate impacts society and ecosystems in a broad variety of ways. The Intergovernmental panel for climate change (IPCC) defines the climate change as any change in

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climate over time, whether due to the climate variability or as a result of human activity [1]. Human societies have adapted to the relatively stable climate, however, changing climate will bring changes that can affect our water systems, biodiversity, ecosystems, the natural environment, and may change the interaction patterns between flora fauna and their environment [2]. In particular, mangrove ecosystem and its' biodiversity [3] are the unique yet threatened entities that are sensitive to climate change [4]. This ecosystem, due to the slow and fast onset events caused by climate change, has been suffering from many wide-ranging effects. Natural calamities like flood, drought, cyclone, storms, etc., are fast onset events and have been becoming regular disasters on Sundarbans resulting in enormous loss and damages of these ecosystems and their flora and fauna communities [5, 6]. On the other hand, slow onset events such as sea level rise will cause saline water intrusion, coastal erosion, destruction of wildlife habitats, may have more long term damages. Recent assessments of the conservation status of mammals present an alarming picture of ongoing declines due to climate change [7]. Global analyses show that among terrestrial mammals, many carnivores are the most threatened [8].

Bangladesh, especially its mangrove forest is likely to be the worst affected by climate change. The biodiversity of bioclimatic zone- Sundarbans ecoregion, situated in Bangladesh India, is critical to the survival of millions of Bangladeshis and Indians who share the costs and benefits from the ecosystem services like protection from cyclones, food and building materials supplies, fisheries, and carbon sequestration [9, 10]. It is located around the Bay of Bengal and of special interest for many reasons [11]. This coastline receives a major tropical river named Ganges; it has the world's largest mangrove that stands on a single block called the Sundarbans. This worlds' single largest mangrove forest [12] is recognized for its wide biodiversity of mangrove flora and fauna both on land and water [13]. The biodiversity includes about 350 species of vascular plants, 250 fishes and 300 birds, besides numerous species of phytoplankton, fungi, bacteria, zooplankton, benthic invertebrates, mollusks, reptiles, amphibians and mammals. Species composition and community structure vary east to west, and along the hydrological and salinity gradients. Sundarbans is the habitat of many rare and endangered animals (*Batagur baska*, *Pelochelys bibroni*, *Chelonia mydas***),** especially the Bengal tiger (*Panthera tigris tigris*). Javan rhino, wild buffalo, hog deer, and barking deer are already extinct from the area [14]. The Sundarbans is worldwide known for one of the largest reserves for the Bengal tiger (*Panthera tigris tigris*) [15]. Bengal tigers are an integral part of this forest ecosystem [16] and they occur throughout the Sundarbans and their main prey base is spotted deer (*Axis axis*). Nevertheless, there are other occasional prey species like wild boar, barking deer, rhesus monkey and monitor lizard [17]. As the top predator, the tiger may help to regulate the number and distribution of prey, which in turn will impact forest structure, composition, function and regeneration [18].

The Bengal tiger is an umbrella species because it needs large areas (home range size) of land to live. Saving tigers can help secure the future of the biodiversity that makes up the tigers forest home [19], floristically rich and with historical aspects, different ecological frameworks and distinct evolutionary trends [20]. Climate change affects the habitat of its flora and fauna, which may impair because of migration of the species. A natural food-web becomes changed. As a consequence, tigers leave the forest going closer to human inhabitants, causing tiger-human conflicts that result in often retaliatory killings of both tiger and human and livestock [21, 22]. This is a threat for which we have to protect this large tract of mangrove forest which contributes to the region and to some extent the global climate. It is very difficult to specify the suggestions to solve these issues, but the quick buildup of awareness, avoiding unplanned urbanization, minimizing deforestation and ample research can mitigate this issue which may base on the collaboration among the developed and developing countries.

Therefore, the main objective of this study is to identify the effects of climate change towards the salinity intrusion and biodiversity, modification of floral and faunal composition, habitat loss and behavioral change of wildlife, and ultimately identify the factors for

accelerating tiger human conflicts. Keeping this into consideration, this article reviewed the existing literature and information to identify the root cause of the behavioral changes of tiger and the facts of the conflicts with human. The following section tried to identify the pattern of changes of tiger habitats due to the climate change, and how they may become a causal factor for such conflicts. The trends and facts of the conflicts, and associated functional changes were also discussed. The structural and compositional changes of the mangrove ecosystems and their impact on floral and faunal behaviour are also discussed. Finally, some conclusions and recommendations were made.

Methodology

Study Area

The Sundarbans forest tract, including the Indian part covers an area of 10,263 km^2 of which 66 % are land, the remainder is water. About 62 % of the Sundarbans forests are in Bangladesh and the rest is in India [23]. The deltaic environment on the south west coast of Bangladesh supports extensive mangrove formations due to a gradual intertidal slope and heavy impact on the situation [24]. Sundarbans is the prime example of the estuary of the Ganges and the Brahmaputra river systems in the Bay of Bengal [25]. This biologically and ecologically rich and diverse ecoregion are located within Khulna and Bagerhat districts under Khulna administrative division of Bangladesh [10]. The ecosystem consists of the unique and largest single tract of mangrove forest in the world [26].

The study area in the Bangladesh part of Sundarbans (Fig. 1), lies between the geographical coordinates of 21º 45' to 22° 30' N and 89º 00' to 90º 00' E, covering an area of 5,770 km^2, of which 4,016 km^2 are covered by the forests and the remaining 1,756 km^2 are in the form of rivers, canals and creeks, varying from a few meters to several kilometers [27]. The area experiences a subtropical monsoon climate with an annual rainfall of 1,600–1,800 mm and severe cyclonic storms. Enormous amounts of sediments carried by the rivers contribute to its expansion and dynamics. Salinity gradients change over a wide range of spatial and temporal scales. Nearly 0.5 million people live in the villages adjacent to the forest.

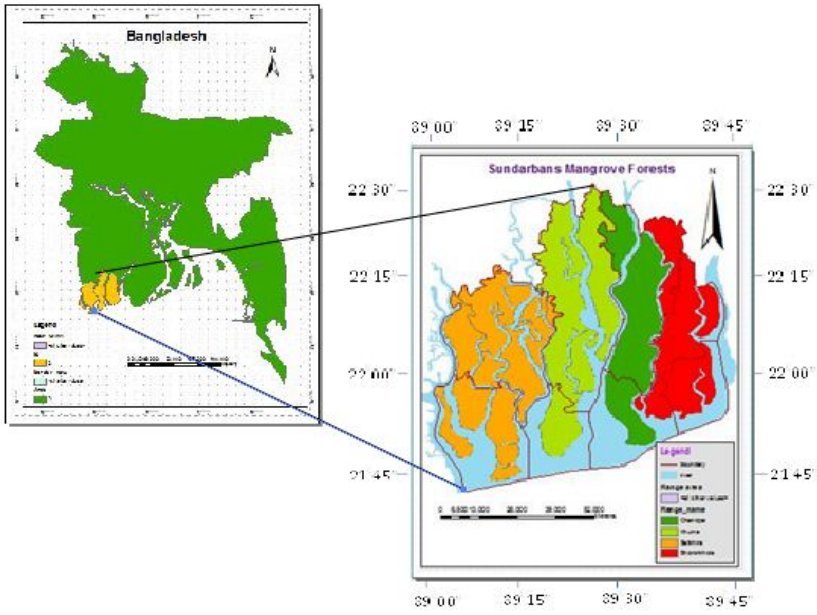

Fig. 1. Sundarbans Mangrove forest (Source: Bangladesh Forest Department)

The Sundarbans was declared as a Reserve Forest (SRF) in 1879, since then it has been directly administered and managed by the Forest Department of Bangladesh. The entire mangrove ecosystem has significant conservation value and has been protected as Sundarbans reserved forests, Sundarbans West Wildlife Sanctuary, Sundarbans East Wildlife sanctuary, Sundarbans South Wildlife sanctuary, Sundarbans Ramsar site and World Heritage site.

The deltaic mangrove swamps of the Sundarbans are extremely low lying and subjected to regular tidal inundation. The general elevation above mean tide level is between 1.5 and 2 meters. Higher ground extends up to 3.4 meters. The river flow is influenced twice daily by high and low tides at approximately six hourly intervals. The maximum and minimum tide level varies according to lunar days and seasons. Siltation is a common phenomenon in the river systems. Soil erosion is extensive due to heavy thrust of waves of water along the banks of the main rivers in Sundarbans like Raimangal, Bal, Malancha, Hongshoraj, Arpangasia, Sibsa, Passur, Morjat, and Shela Gaang.

Due to the proximity of the Bay of Bengal, the rainfall in the Sundarbans is heavy and humidity is high (80%) and about 80% of the rainfall is obtained in the monsoon. Mean annual rainfall varies from about 1,800 mm in the north of the Sundarbans to 2,790 mm on the coast. There is a six months dry season during which evaporation exceeds precipitation. The most saline conditions prevail between February and April; Temperatures rise from daily minima of 2–4°C in winter to a maximum of about 43°C in March and may exceed 32°C in the monsoon. Storms are common in May and October- November and may develop into a cyclone with tidal waves of up to 7.5 m high [28].

Content Analysis

Related literature was reviewed searching through various websites and secondary data were quoted with modification. In this searching secondary data, information and literature that is available in the public domain, including information available on the official website of the related governmental and non-governmental agencies, scientific data and reports were analyzed thoroughly. The primary data for this paper have been obtained from the office records of Bangladesh Forest Department and a surveying on the livelihood profile of the people living surrounding of the Sundarbans to identify the relation of tigers attacking with their livelihood and living style.

Digitizing soil and geological data layers

Digitization in GIS is a process of "tracing", in a geographic correct way, information from images/maps. The land use map of Sundarbans was obtained from the Bangladesh Forest Department. This map was used as the base maps for the digitizing process (scale 1:200,000) and the part of the thematic paper map [i.e., Soil maps from the Soil Research Development Institute (SRDI), Bangladesh] was scanned in a high performance HP Scanner. The scanned maps were saved in *tiff* form and used in the ArcGIS 9.3 for digitizing process. Prior to the digitizing process, georeferencing the data layers was important. Georeferencing of the data layers relies on the coordination of points on the scanned image (data to be georeferenced) with points on a geographically referenced data map. By "linking" points on the image with those same locations in the geographically referenced data a polynomial transformation was created that converts the location of the entire image to the correct geographic location.

After georeferencing each image, the digitization process was performed using ArcGIS 9.3. Digitizing is the process of converting paper map or image data to vector digital data. In ArcGIS, point, line or polygon of an image can be redrawn following the source data. In this case, redrawing was done through controlling a cursor using a computer mouse and a sample vertex was drawn to define those attributes. The structures of these vertices can be seen in the

images of the data layer at its editable form where those features are assigned additional spatial and non-spatial attributes. Following this process, a digital version of maps were generated which have an attribute table associated with them. The digitizing process was started by creating new layers (vector layer) in ArcCatalog, and then adding features to them in ArcMap (ArcGIS 9.3 Desktop). *Editor* tool bar was used for the digitization of the data layer in the newly created vector layer/shape file. Once all the images were developed, the associated analyses and calculation performed in the GIS.

Results and Discussions

Salinity Intrusion and Threats to Biodiversity

A comparative study has employed based on soil salinity in the Sundarban forest area. The salinity maps obtained from the Soil Research Development Institute (SRDI), Bangladesh for the period of 1973 and 1997 shows salinity intrusion in soil is much higher than the salinity in the water (Fig. 2). Figures 2A and 2B illustrate the degree of salinity of the soil in the examined years. The study revealed that, the high saline area was 2,945.28 km^2, moderate high saline area was 1,780.06 km^2 and the moderate slightly saline area was 257.05 km^2 out of 4,982.39 km^2 of Sundarbans mangrove forests in 1973. While, the high saline area was recorded 4,224.61 km^2 and moderate high saline area was 816.2 km^2 out of 5,040.81 km^2 of total forest in 1997. That is 1279.33 km^2 of land has converted into a high saline area from moderate high and moderate slightly saline area within 24 years. It is noteworthy that moderate slightly saline area that found in 1973 is no more in 1997. This is a clear indication that, flora and fauna that like moderate slightly saline area, are in tremendous threat. A further in depth research may account the rate of extinction or shrinking in population of many flora and fauna. These maps predict that the soil of the Sundarbans mangrove forest has been facing the newly salinized area in 24 years of time expansion [29]. Coastal erosion causes sediment flux and changes in aquifer volume and water quality with increased saline intrusion.

There are various observed effects of climate change in the Sundarbans mangrove ecosystem, such as: sea level rising (SLR) and salinity intrusion. The main impact of sea level rise on water resources is the reduction of fresh water availability by salinity intrusion [30]. It also reduces fresh ground water storage [31]. Both water and soil salinity along the coast have increased with the rise in sea level, changes the normal characteristics of coastal soil and water, mostly in a negative way because salt water has high concentrations of total dissolved solids and certain inorganic constitutes, which is not suitable for wild animals [32]. According to the dimension of coastal plains in Asia, the SLR is likely to become a major challenge to Bangladesh being probably the most drastic example on a national scale and particularly for the Mangrove ecosystems of Bangladesh [33, 34].

Changes of Floral Composition

The diversity of genes, species, communities and ecosystems shapes a balanced and adaptive system of ecological processes [35]. However, due to local extinctions caused by anthropogenic activities and excessive use of natural resources in a given space and time, there is an imbalance in this processes. Declining many flora and fauna species from a particular area like the Sundarbans ecosystem is a great concern for existence of this unique ecosystem [36, 37]. Mangrove species appear to differ in their tolerance to flooding. It is found that tolerance from the most to the least to flooding differed among five species as follows: *Avicennia marina>Aegiceras corniculatum>Rhizo-phora stylosa>Bruguiera gymnorrhiza*. These studies suggest a possibility of changes in the entire extent of forest community composition due to

sea-level rise [38]. Ecological theory predicts several types of species and community responses to changing regional climate in plants and animals. Subsequently, the trend may change the ecosystem structure, function and dynamics [35], including shifts in ranges and distributions; altered phenology; effects on physiology and genetic characteristics and leading to the evolution [39].

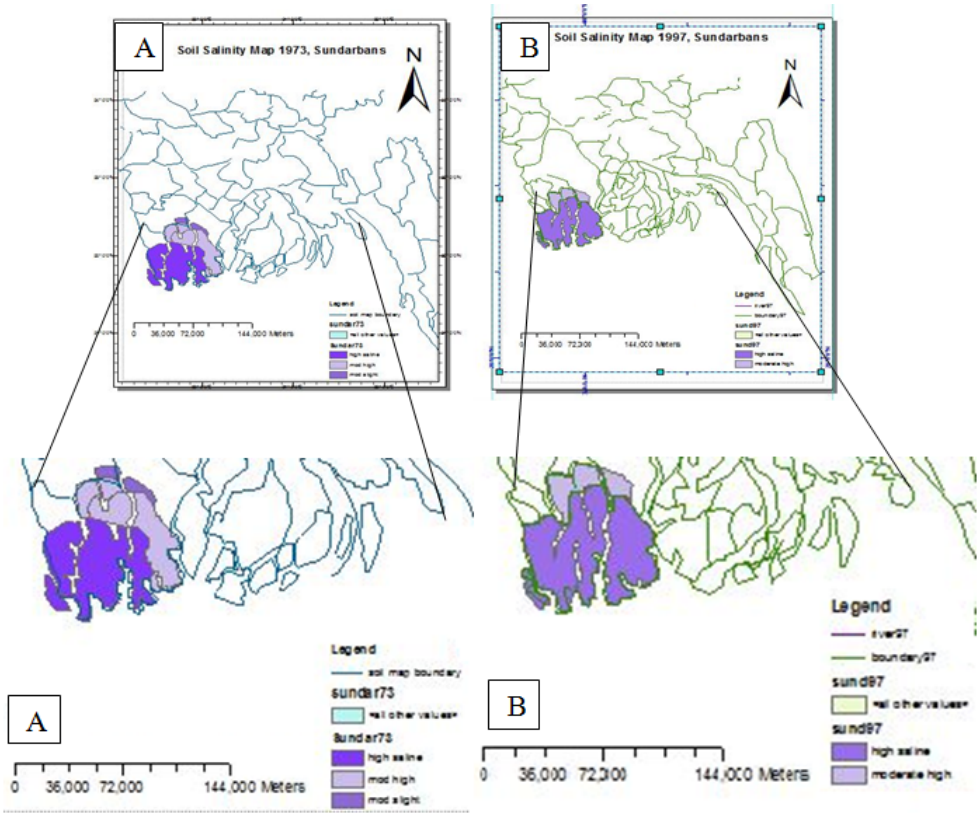

Fig. 2. Soil salinity map of 1973 (A) and 1997
(B) showing absorbed salinity gradients in the soil of Sundarbans

As the impact of climate change may alter the physiographic condition of plants, the supporting services like suitable habitat for plants and animals, nursery ground for fisheries and wildlife of the mangrove will be greatly affected [40]. The changes in the supporting services of the Sundarbans due to climate change and sea level rise would be largely visible on the provisioning services, primarily on the trees and fisheries production. As discussed earlier, sea level rise will change the inundation and salinity pattern in the Sundarbans that will affect the suitable area for the trees. If the Sundarbans is lost, the habitat for several valuable species would also be lost. A 45 cm sea level rise would inundate 75% of the Sundarbans, and 67 cm sea level rise could inundate all of the system [41]. Extrapolating from this information, Smith and co-researchers [42] calculated that a 25 cm sea level rise would result in a 40% mangrove loss. As a result redistribution of species whose habitats will be affected by inundation may be impaired because of migration [43], especially to the north and will be blocked by human settlements and thereby loss of ecosystem, species and productivity of their functions and services [44]. A large reduction in freshwater inflow increasing salinity and changes in sedimentation has seriously affected the biodiversity, such as rapidly declining of ***Heritiera***

fomes (locally called 'Sundari', from which 'Sundarbans' derives its name), ***Nypa fruticans*** and ***Phoenix paludosa*** in this ecosystem complex. During the past three decades, large parts of the remaining Sundarbans have been protected for wildlife, particularly due to tiger, through the creation of several sanctuaries and a biosphere reserve. Parts of the Sundarbans in both Bangladesh and India have been declared World Heritage sites. The future of the Sundarbans will depend upon the management of freshwater resources as much as for the conservation of its biological resources [13].

Changes of Faunal Composition

Temperature change-related effects in animals have been documented within all major taxonomic groups such as amphibians, birds, insects, mammals, reptiles, and invertebrates from all continents. The predominant climate change impact on the Sundarbans and marine area of Bangladesh is the loss of the remaining habitat of Bengal Tiger. Nevertheless, reproductive failure in sea birds, a shift in phenology, i.e., breeding, migration and arrival time of species, flowering of plants, etc. and direct mortality of prey species and birds which are vulnerable to sea level rise, increased sea surface temperature, regional climate change and cyclone respectively (Table 1).

Table 1. Vulnerability of wildlife to climate change in the context with Geographic Area (modified from Smith et al. [4])

Geographic Area	Impact	Vulnerable to
Sundarbans, Bangladesh	Loss of remaining habitats of Royal Bengal Tiger	Sea Level Rise, cyclone
Marine part of Sundarbans, Bangladesh	Reproductive failure in Sea Birds	Increased sea surface temperature
Marine Area, Bangladesh	Shift in Phenology e.g. Breeding, Migratory sp. Arrival time, flowering	Already observed in response to regional climate change
Sundarbans	Habitat Loss – direct mortality of prey sp. and birds	Cyclone.

Habitat loss of wildlife (food, shelter and water)

Due to climate change, habitat fragmentation and habitat destruction are the severe threats to global biodiversity [45]. The interaction between climate change, and these two parameters might be disastrous. During climate extremes, the habitat threshold occurs sooner. Similarly, species suffer more from rapid and intense climatic extreme events in a fragmented habitat [46]. Also, shrinking their home range size due to slow and fast onset of climate change impacts as well as anthropogenic activities will make the habitat less suitable for the tigers [47]. As discussed earlier, due to climate change, wildlife losses many services from its habitat, in terms of food, water and shelter. *Loucks et al*. [48] projected an estimation of adult tiger population associated with increasing sea levels. Using a conservative rate of 4 cm per decade increase, which is consistent with the 4th IPCC report on sea level rise [49] and local tidal gauge records [48], it is predicted that the Sundarbans will realize a 28 cm increase in sea level around 2070. The protected area system, which is located on the seaward side of the Sundarbans, loses habitat at generally the same rate as the rest of the Sundarbans (Fig. 3). Mangroves with its rich biodiversity occur in the intertidal zone, between land and sea, in the (sub) tropics. This intertidal zone is characterized by highly variable environmental factors, such as temperature, sedimentation and tidal currents. The aerial roots of mangroves partly stabilize this environment and provide a substratum on which many species of plants and animals live. Due to the high abundance of food and shelter, and low predation pressure,

mangroves form an ideal habitat for a variety of animal species during part or all of their life cycle [50]. Continued habitat loss and fragmentation are another major cause for declining tigers in the Sundarbans. Many of the remaining fragmented habitats are too small, isolated, or degraded to hold viable populations of tigers and their prey [51].

Behavioral change in wildlife

Ecological changes are occurring in the phenology and distribution of marine, freshwater, and terrestrial groups of plants and animals. Predator-prey and plant-insect intersections have been disrupted when interacting species have responded differently to warming. Observed genetic shifts modulate local effects of climate change [52]. The synergistic effects of the rapid temperature rise and other stresses, in particular habitat destruction, could easily disrupt the connectivity among habitat patches as well as among the species. Eventually, it may lead to a reformulation of species, communities, reflecting differential changes in species, and to numerous extirpations and possible extinctions [53].

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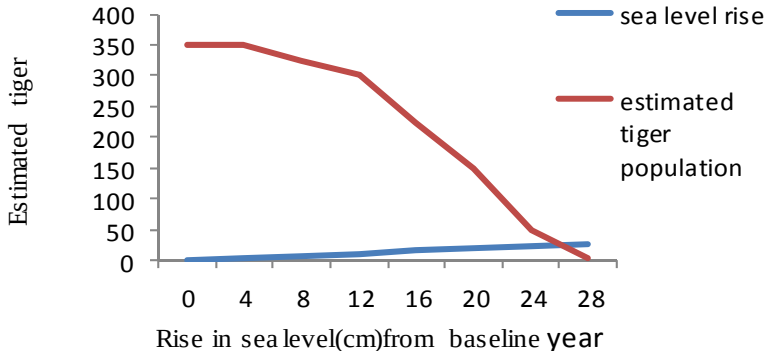

Fig. 3. Declining of tiger population with increasing of sea level rise in Sundarbans Mangrove forests.

Causes of tiger depletion

Cyclones, floods, soil erosion and other climate change, all causes of tiger depletion in the Sundarbans mangrove forests, are exacerbated by poverty-related problems of communities live surrounding of the forest. Interactions between the problems experienced by villagers, including human tiger conflicts (HTC), result in a complex 'risky web' which detrimentally affects lives and livelihoods and ultimately perpetuates poverty levels in the Sundarbans communities [54].

Direct tiger loss: Tiger poaching in Bangladesh is little known [55]. Records are available to the Bangladesh forest department from the seizures or arrests by the authorities deployed in Sundarbans. Tigers are also killed through retribution killings associated with tiger-human conflict. According to the records of the Bangladesh forest department around three tigers are killed in each year [56, 57]. There is always the potential for tigers to die from the disease, but there has been almost no research in this area [58].

Prey depletion: The number of tigers that an area can support is largely dependent upon the number of suitable prey [59, 60]. The main prey for tigers in the Sundarbans is spotted deer (*Axis axis*). The other prey species are wild boar, barking deer, rhesus macaque, monitor lizard etc. [61]. Prey depletion is a serious threat to the tiger population. In recent years, two severe

cyclones named Sidr in 2007 and Ayla in 2009 caused huge mortality of spotted deer and other prey species in Sundarbans.

Causes of stray tiger: Nowadays, in the Sundarbans, the tendency of coming out of tigers from the forest den to adjacent villages has increased remarkably. Several causes can be pointed out for such happenings. In the Sundarbans, tigers have found a small home range which is about 12-16 km^2, the evidence is a probable indicative of a very high density compared to other tiger habitats [62]. Any change due to the effect of climate will enhance its behavioral change which may influence territorial fight for surviving among tigers frequently and the old, weak, injured tiger may have to leave his original habitat migrating towards the adjacent village of the Sundarbans forests. Again, response to the same effect, prey inside forests may be unavailable and in search of food the tigers may enter villages. Thirdly, if there is any disturbance in forest like fresh water deficiency to drink or shelter to ambush, the tiger may move to the villages.

The potential conflicts: If any tiger enters inside a village it reaches to a risk of death or injury of human life by any means. So many a time tigers are killed through retribution killings associated with tiger human conflict. These retribution killings are a result of negative perception of humans towards tigers due to the incidents of human or livestock killing or sometimes simply a tiger appears as a threat when it stays in a village [63]. This conflict creates negative attitudes in local communities towards tigers for its conservation in the long run.

The Bangladesh Sundarbans suffer the highest levels of human killing of tigers in the world and recent surveys suggest that the retaliatory killing of tigers is the acute problems [64]. In this situation, it is essential to save tigers and their habitat inside the Sundarbans, which can be done by reducing this conflict. On the other hand the death of a working member of a family or killing of livestock by a tiger has been a serious economic loss to an already impoverished household. Therefore the program of conserving tigers in the Sundarbans should have one component to help the local suffering people due to the conflict with the tiger. Minimizing tiger human conflict will secure the support for tiger conservation by the local people.

Causality to human lives: Data collected from the divisional forest office, Sundarbans west forest division, Bangladesh, revealed that a total of 215 numbers of incidents took place in and nearby forests due to tiger human conflict in the last decade since 2000 to 2010. In these conflicts, 184 people were killed and 31were severely injured including both inside and outside the forests. In recent years, from 2008 to 2010, number of casualties increased significantly because during two severe natural calamities, *Sidr* in 2007 and *Ayla* in 2009, huge prey species were killed, shelter for tigers were destructed and reduced at a great deal and the freshwater source in the forest was severely affected by saline water. In this situation, tigers migrated towards nearby village and caused human killings or increased the rate of attacking on minor forest produce harvesters inside the forests. The victims were mainly fishermen (71%), Golpata collectors (29.44%) and Honey collectors (22.60%). The same incidents happened after the severe cyclone hit in 1991 (Fig. 4).

Categorically, during these accidents, more males than females were killed inside the forests. The males were attacked during honey collection, Golpata collection and fishing. The suitable honey producing trees in the Sundarbans like Kholsi, Baen, Kankra, Goran, Gewa etc., which grow in the interior part of the forest are the tiger risk area (Table 2). Due to scarcity of food in terms of prey species and enough shelter inside the forests, the tigers remain alert. The harvesters are engaged in searching of honeycomb or Golpata stocks which is most critical time for conflicts. 31% of the total harvesters from the 3 villages named Hodda, Baniakhali and Mothbari were found inexperienced in a survey regarding the risk of the tiger attacks during

harvesting time (Table 3). The women are killed more often while pulling fishing nets in the small canal or collecting dry firewood at the boundary of the forest.

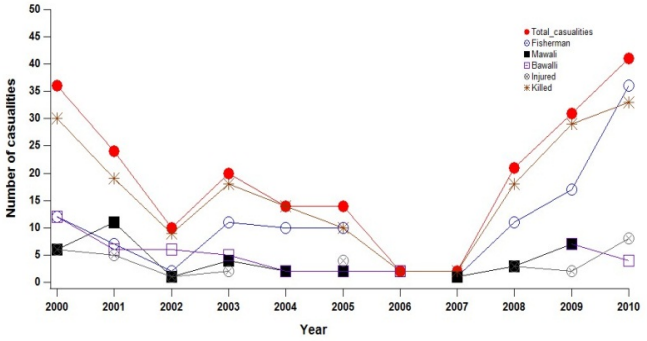

Fig. 4. Year wise human causalities by Tiger

Table 2. The main honey producing trees and its locations in Sundarbans of Bangladesh

Local name	Scientific name	Location (Major compartments)	Honey quality
Kholshi	*Aegiceras corniculatum*	52,51A,51B,43,4916,17,18,19,20,42	Very good
Baen	*Avicennia officinalis*	41,47	good
Kankra	*Bruguiera gymnorrhiza*	48,40,37,35	common
Goran	*Ceriops decandra*	47,16,17,18,19,20,42,8,54,5352,51A,51B,43,49	common
Gewa	*Excoecaria agallocha*	All compartments	Less tasty
Jhana Garjan	*Rhizophora mucronata*	46,50A,50B,45,44,54,53	common
Keora	*Sonneratia apetala*	6,8,7,9,10,11,45,44,35	good
Pasur	*Xylocarpus mekongensis*	55, 46,50A,50B,	common
Singra	*Cynometra ramiflora*	31	common

Retaliating killing of tigers: The conflicts do not always occur only when people enter inside the forest but also for the tigers' stray to the adjacent villages due to its habitat declination. There are many factors which accelerate the retaliating killing of tigers. A livelihood profile of the people living surrounding of the Sundarbans was made based on a survey in 3 villages adjacent to the forest under Khulna Range such as Hodda (Village 1), Baniakhali (Village 2) and Mothbari (Village 3). The survey reveals that these people are poor in economic condition. Their major occupation is fishing and collection of Golpata. People are not well literate; the housing materials they use are mainly of clay, wood and Golpata; Sources of drinking water are limited and Sanitation facilities are not available for every family. According to this survey, 49.33% of the people are literate, 28.33% people can write their names, and 16% and 6.33% people went to the primary and secondary schools respectively. There are 57.33% of the people live in Katcha houses, while 32% people are getting sanitation facilities and 93% people depend on tube well for drinking water outside their houses. These people are mostly dependent on the Sundarbans and the homestead forest for sources of fire-wood (Table 3).

Due to lack of proper understanding and awareness of the value of this ecosystems and wildlife, people living around the Sundarbans ecosystem are careless about the integrity of these ecosystems and its valuable flora and fauna. As a consequence, people deeply believe that, tigers are their enemy and a great threat of their existence in that area. Therefore, while they come across to a miss tracked or hungry tiger, the villagers become united and put their utmost effort to kill the tiger. So, the common scenario is that the stray tiger is often killed by villagers. Poisoning, shooting or snaring may also be used in retribution killings. A forest department

official data describe that from the year 2000 to 2011 (shown in Figure 5), a total number of 30 tigers were recorded dead among which 24 tigers were brutally killed by aggressive people and 6 were found dead due to illness or old age etc., inside the forest.

Table 3. Livelihood profile of people living surrounding of the Sundarbans.

Criteria	Description	Village 1 (Hodda)	Village 2 (Baniakhali)	Villlage 3 (Mothbari)	Average/ mean
Average age of respondents	-	37	41	45	41
Average family members	-	6	6	6	6
Traditional occupation	Fishing and Golpata harvesters	94	93	95	94
Literacy %	Literate	50	48	50	49.33
	Can write own name only	18	38	29	28.33
	Primary school	21	10	17	16
	Secondary school	11	4	4	6.33
Housing materials used	Katcha (made of clay, wood and Golpata)	62	60	50	57.33
	Semi Katcha (clay and GI sheet roofed)	30	35	46	37
	Pakka (brick and cement)	8	5	4	5.66
Sanitation facilities	-	30	30	36	32
Sources of drinking water	Tube well	92	95	92	93
	Rainwater	8	5	8	7
Involving inexperienced persons to harvest NTFP	Specially in fishing, and Golpata and honey collection	27	34	32	31
Fuel source	Dependency on forest or homestead trees	100	100	100	100

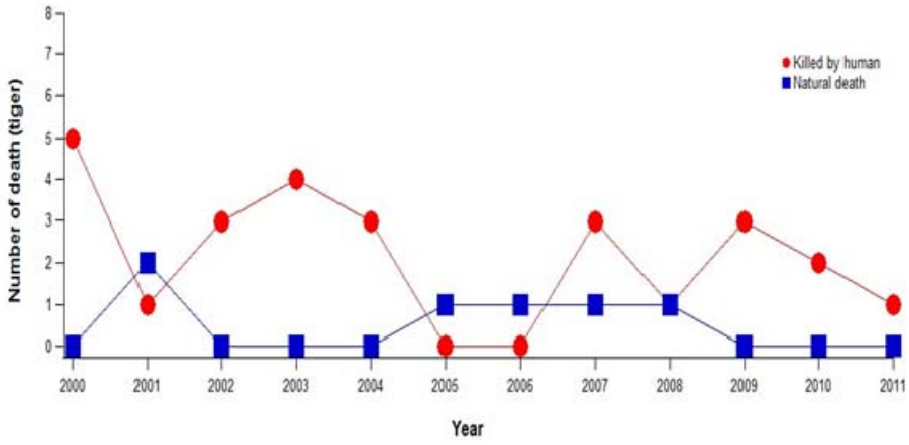

Fig. 5. Year wise Tiger causality (Source: Bangladesh Forest Department)

This present scenario demands primarily a social and cultural revolution for sustainable alternative livelihood for this forest-dependent population by means of the Alternative Income Generation (AIG) and then the modification of the formal legal system, institutional development and in depth research may be the solution for minimizing these issues towards the better conservation of Sundarbans mangrove forest.

Conclusions

Climate change effects on Sundarbans Mangrove forest changes the biodiversity through migration of endemic species. Besides, invasion of unwanted species, loss of wildlife habitat, intrusion of saline water, behavioral change of flora and fauna disrupts the ecological integrity in many folds. Any changes in forest structure, composition and function impact on the species which tends to decline the food stock for tigers in the forests. Thus, tigers become stray to the villages, adopt man-killing behavior and predation on cattle. As a consequence, the retaliatory killing of both human and tigers have been increasing alarmingly. These have become the issues of confrontation, and as a result, the conservation efforts are adversely affected.

It is in turn essential that tigers should be saved for conservation of biodiversity and ecosystem which is very important for sustainable natural resources management. The survival of tigers as well as all human beings living on the periphery of forests should be safe and sustained without any incidents. Therefore, helping the people who suffer for tigers' presence at the boundary of forests should be ensured. It is also essential to ensure tigers' staying in the forest through habitat improvement and safe return of stray tiger to the forest. These will meet the solution to minimize tiger human conflict. Climate change awareness of the human being and sustainable environmental development are a precondition for survival of the ecosystem and the tiger habitat as well.

There are many challenges for the task of minimizing tiger human conflicts and development of an effective tiger conservation effort in Bangladesh. A political commitment to biodiversity conservation, formal legal arrangement, forest protection and law enforcement may help remarkably to reduce these issues. Besides, sustainability education and awareness, research and monitoring, and national and international collaboration may contribute for developing a resilient society for climate change adaptation and for a sustainable Sundarbans mangrove forest.

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