BIODIVERSITY CONSERVATION IN INDIAN SUNDARBAN IN THE CONTEXT OF ANTHROPOGENIC PRESSURES AND STRATEGIES FOR IMPACT MITIGATION

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SUPERVISOR CERTIFICATE

This is to certify that the thesis entitled "Biodiversity Conservation in Indian Sundarban in the context of Anthropogenic Pressures and Strategies for Impact Mitigation" submitted by Pradeep Vyas for the award of Ph.D (Wildlife Science) degree of SAURASHTRA UNIVERSITY Rajkot, is based upon his own work under the supervision of Dr. Vinod B. Mathur, Wildlife Institute of India and Dr. P.P. Bhojvaid, Ex Vice Chancellor & Dean, TERI University and neither this thesis nor any part of it has been submitted for any degree/diploma or any other academic award anywhere before.

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Dedicated

To

My

Mother and Wife

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SUMMARY

Indian Sundarban, located at the southern fringe of the State of West Bengal is a mangrove dominated unique deltaic ecosystem at the apex of Bay of Bengal. One National Park and three Wildlife Sanctuaries are located in this landscape. The Sundarban National Park is also inscribed on the UNESCO‟s Natural World Heritage List. This highly specialized mangrove ecosystem supports rich biodiversity. Many floral and faunal species are highly endangered. The area is subjected to frequent storms and lacks fresh water, which has made the survival of faunal and floral species a struggle and has resulted in a multitude of adaptations in respect of morphological, anatomical and physiological characteristics. The area has highest mangrove diversity in India. Among fauna, tiger and estuarine crocodile are at the apex of land and aquatic ecosystem respectively. People live in the reclaimed area of Sundarban, which was totally under mangrove forest till 1833. The reclaimed area is now surrounded by earthen embankments of 3500 km, which is erected as a dyke to keep away tidal saline water from running over the habitation area. Frequent storms and cyclones causes heavy damages in the villages and deprive communities from various livelihoods especially agriculture, the main occupation of people. The area has a poor infrastructure and high human density, as a result of which communities heavily depend on natural resources of Sundarban for livelihoods. Next to agriculture, fishing is the main occupation. Honey collection from forests supplements the income of resource dependent populations. Sharing of the same habitat by human beings and wild animals results into frequent man-wildlife conflicts in this ecosystem. In terms of magnitude human-tiger conflict is highest.

Sundarban ecosystem is subjected to various anthropogenic pressures originating locally, regionally and globally. Stakeholder consultations has categorized human-wildlife conflicts (24.35%), change in salinity (19.93%) and the climate change (18.82%) as three major anthropogenic factors adversely affecting the delicate balance of Sundarban ecosystem. This study has attempted to determine the nature and extent of these anthropogenic pressures on Indian Sundarban and to appropriate management interventions and mitigation strategies.

The human-wildlife conflicts in Indian Sundarban may be categorized into three main types *viz.* human-shark conflict, human-crocodile conflict and human-tiger conflict. The present study revealed that human-crocodile conflict is a low key affair whereas the information on human-shark conflict is almost non-existent. The data on human-crocodile conflict from 1999 to 2009 revealed that a total of 29 persons were attacked by crocodiles, in which 12 people were killed and 13 were seriously injured. A total of 13 crocodile straying incidences were recorded during this period. The analysis of result of human-crocodile conflict reveals that it is restricted to the areas where tiger prawn (*Penaeus monodon*) seed collection is carried out. The tiger prawn seeds are collected mainly by women and children, who wade through water and drag fine net and in the process often become victims of crocodile attacks. The prawn seed sale to shrimp farms is always in high demand due to absence of any hatchery in the area. Crocodile straying is predominantly in the month of September and October. The establishment of artificial prawn seed hatchery may decrease the demand of collection of prawn seeds from wild, which will definitely minimize the incidences of human-crocodile conflicts. The shift of prawn seed collection method from „drag-net" to „boat method" will allow people to continue collection of prawn seeds without exposing them to the danger of human-crocodile conflict. Initiation of research on estuarine crocodile including their habitat preferences and providing fresh-water ponds may help in reducing crocodile straying incidences, which occur mainly in post-monsoon season.

The human-shark conflict is a very low key affair and most of the victim escape with injuries and are unable to find out whether the injury has been caused by shark or by some other aquatic animal. The affected people are mainly those involved in tiger prawn (*Penaeus monodon*) seed collection. The establishment of prawn seed hatchery to minimize the demand for collection of prawn seed from wild and use of „boat method‟ instead of „drag-method‟ to collect the prawn seed will help in mitigating human-shark conflict.

The human-tiger conflict in Sundarban is very serious in nature and is known to exist since the entry of humans in Sundarban. The Sundarban tiger has nicely adapted to swampy mangrove conditions. It leads almost an amphibian life and is an excellent swimmer. It drinks saline water and its diet spectrum includes crabs and snakes apart from other animals of Sundarban ecosystem. The human-tiger conflict in Sundarban is of two types, first the killing of human beings by tigers inside the forest areas and secondly the straying of tiger from forest to fringe villages in search of food and for other reasons.

An analyses of human killing data for 25 year period (1985-86 to 2009-10) as part of this study revealed that a total of 410 persons were attacked by tigers inside the forest, of which 95 persons survived *i.e.* only 18.84% were fortunate to escape with injuries only. Both killing and injury of human beings by Sundarban tigers have varied over times. During the period 1985-86 to 2009-10, the maximum number of reported human deaths were 48 in the year 1991-92 whereas it was zero in the year 2006-07. Average human death during the period was 16 persons per year. The analyses also revealed that over the period there is decreasing trend in human killings as well as in human injuries by tigers (R^2=0.422 and R^2=0.99 respectively). Profession-wise, it was fishermen (75%) followed by honey collectors (17%) and wood cutters (6%) who were involved in these conflicts. The human killing by tigers shows a distinct seasonality as premonsoon period witnesses high human killing primarily due to movement of local people for honey collection. Diurnal variation in human killing has been recorded as 71% of tiger attacks have been recorded in morning and evening times. The study revealed that out of 410 of human deaths caused by tiger during the period 1985-86 to 2009-10 (25 years) only one human death took place inside the village and 409 human killings by tigers were inside the mangrove forests. It is revealed that human death by tigers in Sundarban are caused inside the forest and they are almost absent outside the forests. Forest Department is paying Rs. 1.00 lakhs *ex-gratia* compensation to the tiger victim"s dependents but the same is not available to the dependents of victims, who enter the forests without valid permits.

Salinity of Sundarban water has been often attributed to be a cause for tiger aggression and human deaths by tigers. The study has revealed that human killing pattern does not change with the pattern of change of water salinity of Indian Sundarban. Salinity profile of Indian Sundarban and human killing do not show any correlation.

Considering the fact that honey collection in Sundarban is a seasonal activity which lasts for about two months, 17% killing of honey-collector by tigers is very high. Honey collection in Sundarban is the only activity in which people enter in mangrove forest land and it causes serious disturbance to the habitat. It is revealed that traditional honey-collectors are gradually losing interest in this activity. Fishing during honey collection period is stopped by Forest Department, so in absence of any other livelihood option during this period, most of the fishermen opt for honey collection. The honey collection from forests can be done by honey bees from apiary boxes to be kept in fringe villages as well on boats which will allow honey from forest to come out without the entry of honey collectors in the forest. The alternate livelihoods to honey collectors may also help unwilling people to earn livelihood in the village and prevent/minimize human-tiger conflicts. It will minimize human death by tigers and will also prevent harm to tigers often caused by honey collectors as an act of self defense against the aggressive tigers inside the forest and is hardly reported.

The straying of tigers from Sundarban forest to fringe villages has always been a cause of major concern and has witnessed large number of killings of tiger by people. Tiger straying does take place throughout the year but it peaks in winter. Among the primary cause attributed to tiger straying is shortage of food or inability of tiger to hunt. Out of 65 Forest Protection Committees / Eco-development Committees of Indian Sundarban, 40 Forest Protection Committees / Eco-development Committees were affected due to tiger straying. Out of 40 affected Forest Protection Committees / Eco-development Committees, 10 Forest Protection Committees / Eco-development Committees are highly prone to tiger straying and share majority of tiger strayings. So serious is the problem that Sundarban Biosphere Reserve management has become tiger-straying centric.

An innovative tool, „Nylon Net Fence" has been developed by Forest Department to prevent straying of tigers from forest to fringe villages. Nylon net fences have been raised in all the tiger straying sensitive areas of Indian Sundarban and are giving good results. However due to tidal rhythm and creeks, the maintenance of nylon net fences is difficult. Tiger, an intelligent predator is also adapting fast to over-come the barriers. Cases of chewing of nylon-net fence by tigers to create big holes and swimming over the fences during high tides in creeks have been recorded. The efforts of Forest Department to improve the quality and design are ongoing. The „Floater model" development as part of the study may be used to prevent tiger straying from creeks. Nylon-net fence, an important tool should be erected in all remaining sensitive forest-villages interface and local communities should be regularly involved in its maintenance.

Shortage of prey in Indian Sundarban is often attributed to be one of the causes of human – tiger conflict of both forms *i.e.* human killing by tigers inside the forest and tiger straying from forest to fringe villages. Due to difficult terrain no scientific estimation of prey base has ever been carried out in Indian Sundarban. The shortage of prey is often attributed to natural factors (salinity, tidal currents etc.) as well as to anthropogenic factors (poaching). The Forest Department has taken a programme to release acclimatized spotted deer in Sundarban forest to augment the prey base in order to reduce the tiger straying incidences and human killings by tiger attacks. Forest Department has also taken many initiatives to improve the protection of natural resources, which includes new land based camps, floating check-post, floating camps, infrastructure development and partnership with Border Security Force which has improved the protection to a great extent. However, it has not been highly successful in preventing the entry of people for illegal fishing and illegal honey collection due to low infrastructure and imposition of soft penalties on law violators. These penalties are imposed keeping the economic status of accused and other socio-political factors into consideration hence are never stringent. The 37% recorded human deaths in non-fishing and non-honey collect zone reveals that fishermen prefer these areas inspite of being prohibited and inviolate. The human killing by tigers is undoubtedly related to the availability of human beings as prey and hence can be minimized with strict law enforcement. Improvement of infrastructure of Forest department and stringent penalties along with sensitization programmes of all stakeholders may yield positive results. The programme of release of acclimatized spotted deer needs a review. The released spotted deer should be monitored and the impact of the programme in mitigating the human-tiger conflicts should be studied.

Human-tiger conflicts in Indian Sundarban can be minimized, if dependence of local communities on natural resources for livelihood can be reduced. Joint Forest Management is a major success in Indian Sundarban resulting in a healthy Human–Forest Department relationship for biodiversity conservation. Since the year 2001, when extra efforts were initiated with eco-development activities and meetings inspite of 324 tiger straying incidents, people have extended co-operation and no tiger has been harmed. This has also seen capture of 55 tigers and their release back into the wild, a major success story compared to an earlier picture of gruesome killings of tiger by local people. The improved relationship of Forest Department with local communities on the platform of Forest Protection Committees and Eco-development Committees has also resulted in rescue of other biodiversity, a very healthy boost to the efforts of biodiversity conservation in Indian Sundarban. Inspite of great success of JFM programme, the sustainability of the programme is always a question on account of governance, low incentives to people from mangrove forests and uncertainty of fund flow for eco-development activities. The Forest Protection Committees / Eco-development Committees in High Category of tiger straying villages should be given more weightage in eco-development activities to ensure their co-operation in future too. Attention needs to be given to all committees as a number of committees, which do not face the problem of tiger strayings are currently neglected. Non-involvement of people from these committees in Joint Forest Management results in disturbance to forest leading to Human-tiger conflict in various forms. The governance of the Forest Protection Committee / Eco-development Committee needs improvement to develop them as a strong institution. Currently Forest Protection Committees do not receive any share in eco-tourism revenue, where as Eco-development committee get 25% of it. This has resulted in dichotomy and does not match with the objectives of Joint Forest Management. As the management of entire Sundarban is same, all the Forest Protection Committees / Eco-development Committees should get uniform incentives and receive the eco-tourism revenue, which may be considered an increase to 50%.

Inadequate information on ecology of Sundarban tigers has always been an impediment to develop strategy for better human-tiger conflict mitigation. Prey-predator relationship and tiger behaviour are important aspects related to management of human-tiger conflict. The ongoing telemetry studies by Forest Department in collaboration with Wildlife Institute of India and National Tiger Conservation Authority may help in resolving the issues of tiger straying and human killing behaviour. The collaborative study of Forest Department with WWF to develop the prey base estimation methodology for Indian Sundarban may provide vital information on availability of prey in Sundarban. The tiger population estimation with credible methodology of 64-90 tigers is a positive step and needs to be refined with better sampling and covering the 24-Parganas (South) Division forest areas also as this tiger population assessment figures are only for Sundarban Tiger Reserve

The Forest Department personnel involved in tiger immobilization needs to be imparted professional training to improve their skill. Local communities may be involved in forming „Voluntary Tiger Conservation Teams" (VTCT) to help the Forest Department in crisis time as well as to maintain the nylon-net fence and give early warning of possible tiger strayings. Development of „Human-Wildlife Conflict Mitigation Protocol (HWCMP) may help in better and systematic management of the conflicts.

The Reserved Forest of 24-Parganas (South) Division is still managed with traditional Working Plan approach whereas it has similar management as that of Sundarban Tiger Reserve. The management of this unit of Indian Sundarban on the line of „Tiger Conservation Plan" of Sundarban Tiger Reserve will remove the dichotomy and improve the coordination between the two management units of Indian Sundarban. Better management of Reserved Forest of 24-Parganas (South) Division will result in providing sink habitat for surplus tiger population of Sundarban Tiger Reserve and in absorbing biotic pressures from western boundary of Sundarban Tiger Reserve. The synergetic effect of coordinated management of these two units of Indian Sundarban may help in mitigating human-wildlife conflicts.

The Indian Sundarban is about 40% of the complete Sundarban ecosystem, about 60% of which lies in Bangladesh. Both country share similar problems related to biodiversity conservation and needs to know the wise practices of each other. . The better co-operation on the issues between India and Bangladesh will be of immense help in mitigating human-wildlife conflicts and to improve the integrity of the Sundarban ecosystem as a whole.

The biodiversity conservation in Sundarban is threatened due to increasing people‟s need and changing global and regional factors like salinity alteration, climate change etc. The mangrove habitat of tiger is under serious threat due to anthropogenic and natural factors. In deltaic Sundarban region, the growth, development and survival of mangroves are primarily the functions of ambient salinity. The preference range for salinity is highly species-specific. Low saline condition is preferred by species like *Sonneratia apetala*, *Nypa fruticans*, *Hertiera fomes* etc. This is the main reason why the Above Ground Biomass (AGB) of the mangrove species (*Sonneratia apetala*, *Avicennia alba* and *Excoecaria agallocha*) was relatively higher in the stations of the western region compared to the central region. It is observed that combined AGB of the three species in the western region are 355.41, 414.39 and 475.55 tha^{-1} during pre-monsoon 2008, 2009 and 2010 respectively, 408.46, 469.05 and 535.66 tha^{-1} during monsoon 2008, 2009 and 2010 respectively and 452.95, 514.24, and 574.51 tha^{-1} during post-monsoon, 2008, 2009 and 2010 respectively. In the central region, the values are 255.12, 338.58 and 414.38 tha^{-1} during pre-monsoon 2008, 2009 and 2010 respectively, 314.82, 399.59 and 491.47 tha^{-1} during monsoon 2008, 2009 and 2010 respectively and 364.56, 450.47 and 541.55 tha^{-1} during post-monsoon, 2008, 2009 and 2010 respectively. This data set indicates that the AGB in the western sector of the three species (collectively) is 17.63% more than that of the central sector (considering all the seasons for three consecutive years). Similar trend is also observed in Below Ground Biomass (BGB) of the selected species. This may be attributed to high dilution factor in the western Indian Sundarbans on account of Farakka discharge. The central Indian Sundarban does not receive the upstream freshwater discharge on account of Bidyadhari siltation. Thus, the present matrix offers a unique test bed to observe the impact of salinity on the mangrove vegetation. Individual mangrove species responds to salinity with its own identity. It is interesting to note that the salinity has negative impact on the biomass of *Sonneratia apetala*, but positive influence on the biomass of *Avicennia alba* and *Excoecaria agallocha*. On the basis of this background, it is clear that freshwater flow in Sundarban is the primary requisite for the growth and survival of mangroves. This can be achieved through channelization of freshwater in the central sector, rain-water harvesting, salinity based afforestation programme and policy level management through setting up of a State Level Mangrove Wetland Conservation and Management Authority.

There is a great thrust on the issue of climate change induced alteration of aquatic parameters in Indian Sundarbans as these can affect the flora and fauna of this unique mangrove ecosystem by means of salinity tolerance, habitat loss and temperature tolerance. The pulse of climate change is assessed in Indian Sundarban through three distinct signatures: surface water temperature, surface water salinity and geomorphological changes of the islands. In both western and central Indian Sundarban, the surface water temperature exhibited a rising trend, which synchronizes with the earlier records. During the study period, the average temperature in the western sector (comprising of stations Harinbari, Chemaguri, Sagar South, Lothian Island and Prentice Island) has increased 0.04 ^{0}C/year which is 0.34% hike, whereas in the central sector (comprising stations Canning, Sajnekhali, Chotomolllakhali, Satjelia and Pakhiralaya) the increase is 0.14 ^{0}C/year which is a rise of 1.34%.

The surface water salinity exhibited contrasting features between the two sectors of Indian Sundarban, but this parameter is not well correlated with climate change. This is because human interference in the form of barrage construction and geological events in the form of sedimentation, subsidence and siltation have generated considerable noise in the signal of climate change. The stations in the western region showed a significant and continuous decrease in salinity during the study period of 2008-2010 (0.41 psu/ year, which is 7.37% decrease) whereas the central sector showed an increase in salinity level (0.36 psu/ year, which is 6.31% increase). This difference in the rate of change of salinity in both the sectors is due to the difference in their geomorphologic settings. The rivers in the western sector of the Indian Sundarban (Hooghly and Muriganga), being continuation of the river Ganges, receive the snow melt water of the Himalayas after being regulated by several barrages on the way. On contrary, due to siltation of the Bidyadhari River since the late 15th century, the central Indian Sundarban does not receive the fresh water due to which a rising trend in salinity is observed.

The satellite imageries of Sundarban islands reflect significant zonal patterns with respect to erosion and accretion. More erosion is observed in the western part of Indian Sundarban like Jambu Island, Sagar Island etc. The islands of southern Indian Sundarban facing the Bay of Bengal like Gona, Baghmara, Mayadwip and Chulkati are also eroding because of the strong wave action from the Bay of Bengal. The shrinking of the island area due to erosion will result in habitat loss that may increase the magnitude of human-wildlife conflicts. Accretion is observed in several blocks of central Indian Sundarban. The geomorphological changes of the Sundarban islands may be related to factors like natural subsidence of the entire Bengal basin, complete blockage of the head on discharge due to siltation in the central sector or flow of fresh water through Farakka barrage in the Hooghly channel of western Indian Sundarban. The fresh water discharge ranges from a peak value of 4250 m^3 s^{-1} to almost zero in the dry season. The average values of fresh water discharge are 3000 m^3 s^{-1} during SW monsoon season and 1000 m^3 s^{-1} during a dry season. All these factors acting antagonistically or synergistically create a noise in the signal of climate change induced geomorphological changes. In conclusion, it can be advocated that although the impact of salinity is clearly felt in the mangrove floral community in terms of their above ground and below ground biomass, but the reason for such salinity alteration or geomorphological changes in Sundarban mangrove ecosystem cannot be linked linearly with the climate change episode.

The present study is a pathfinder to analyze the causes of human-wildlife conflicts in the landscape of Indian Sundarban, which is also under threat due to climate change and alteration of salinity. The probable causes of anthropogenic disturbances have been interpreted in the light of available data on human-wildlife conflicts, change in salinity, mangrove biomass, surface water temperature and shore line configuration of the islands. These data may serve as benchmark for future researches and development of appropriate management action plans.

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXURES

LIST OF PLATES

LIST OF MAPS

1. Introduction

1. Introduction

1.1 Physiography of Indian Sundarban (Study area)

The Indian Sundarban at the apex of the Bay of Bengal (between $21^0 13^/$ N to $22^0 40^/$ N latitude and $88^0 03^/$ to $89^0 07^/$E longitude) is located on the southern fringe of the State of West Bengal (a maritime State in the northeast coast of India). The area of Indian Sundarban is 9630 sq. km of which the the forest area is about 4200 sq. km. The region is bordered by Bangladesh in the East, the Hooghly River (a continuation of the Ganges River) in the West, Dampier and Hodges line in the North, and the Bay of Bengal in the South. With a considerable degree of marine characteristics in major portion of the ecosystem, the important morphotypes of deltaic Sundarban are beaches, mudflats, coastal dunes, sand flats, estuaries, creeks, inlets and mangrove swamps (Chaudhuri and Choudhury, 1994) (Plate 1). Although the region is situated south of the tropic of Cancer, the temperature is moderate due to its proximity to Bay of Bengal in the south. Average annual maximum temperature is around 35^0C. The summer (pre-monsoon) extends from mid March to June and the winter (post-monsoon) from mid November to February. The monsoon usually sets in around mid June and lasts up to mid October. Rough weather with frequent cyclonic depressions lasts from mid March to mid September. Average annual rainfall is 1920 mm. Average humidity is about 82% and is more or less uniform throughout the year.

The rivers are the live matrix of deltaic complex, on which the unique spectrum of biological diversity is embedded. In Indian Sundarban, approximately 2069 sq. km area is occupied by tidal river system or estuaries, which finally end up in the Bay of

Bengal. The seven main estuaries, from west to east are highlighted in Table 1 along with their salient features.

TABLE 1

Important tidal rivers of Indian Sundarban

Estuary	Description
Hoogly	It forms the western border of Indian Sundarban. It is the main river of West Bengal and is a direct continuation of the River Ganges. Most of the coastal industries of West Bengal are concentrated along the western bank of this river.
Muriganga	It is a branch of the Hooghly River. It flows along the east of Sagar Island, the largest island in the deltaic complex. Unique mangrove vegetation is found along the bank of this river.
Saptamukhi	It has its origin at Sultanpur. It is connected with the Muriganga (Bartala) branch of the Hoogly River through Hatania-Duania canal.
Thakuran	It begins near Jayanagar in South 24 Parganas and has a number of connections with the Saptamukhi. It was connected in the earlier times with the Kolkata canal through the Kultali and the Piyali rivers, which exist today in a dying state.
Matla	This river originates at the confluence of Bidyadhari, Khuratya and the Rampur Khal close to the town of Canning in 24 Parganas (South). Matla is connected to Bidya and ultimately flows to the Bay of Bengal. The fresh water connection and discharge to this river has been lost in the recent times. Salinity of the river water is relatively high (in comparison to Hoogly or Muriganga owing to fresh water cut-off from the upstream region.
Bidyadhari*	This was flourishing branch of the Bhagirathi during the 15th and 16th century, but now serves only as a sewage and excess rainwater outlet from the city of Kolkata. The river bed is completely silted and presently it is almost in dying condition.
Gosaba	The waters of Matla and Harinbhanga (Raimangal) through a large number of canals form the estuary. The estuary and its numerous creeks flow through the reserve forests.
Harinbhanga	It is the extreme easternmost river in the Indian Sunderbans deltaic complex. The Harinbhanga (also known as Ichamati and Raimangal) forms a natural demarcation between India and Bangladesh.

* Presently a dying estuary and not considered within the seven major types

The presence of 34 true mangrove species and some 62 mangrove associate species (Mitra, 2000) in the zone is the only mangrove based home ground of Royal Bengal tiger (*Panthera tigris*) on this planet Earth. The deltaic complex sustains 102 islands, out of which 48 are inhabited and 54 are uninhabited. The flow of Ganges (Bhagirathi) River through Hoogly estuary in the western sector of Indian Sundarban that ends up at Bay of Bengal has made the geographical situation totally different from the eastern sector, where five major rivers have lost their root with Ganga – Bhagirathi system due to heavy siltation. This has perhaps caused changes in the water chemistry of the area.

The geological formation of Sundarban is of comparatively recent origin (Chaudhuri and Choudhury, 1994)). Till a few thousand years back, the whole tract was under the sea. The deposition of debris and formation of Sundarban delta occurred recently with the change of main course of River Ganga from the Bhagirathi to Padma towards the east between the 12th and 15th century A.D. Basically this was the result of Bengal basin suffering from neotectonic movement and an easterly tilt. During the 16th century, the flow of Ganga shifted almost totally eastwards into River Padma (now in Bangladesh) and the Matla / Bidyadhari rivers which had formed innumerable network of creeks in the delta got completely cut off from the sweet water sources.

The deltaic complex of Indian Sundarban is also noted for its seasonality in terms of climatic condition and wind action as highlighted here in brief. Frequent Nor"Westers is also common in the premonsoon season.

1.2. Seasonality and climate

The deltaic lobe of Indian Sundarban experiences a moderate type of climate because of its location adjacent to the Bay of Bengal as well as due to regular tidal flushing in the estuaries. Wave actions, micro and macro tidal cycles, long shore currents are recorded in most of the islands of the ecosystem. Coastal processes are very dynamic and are accelerated by tropical cyclones, which is locally called „Kal Baisakhi" (Nor" Wester). The seasonal climate in study area may be conveniently categorized into premonsoon (March-June), monsoon (July-October) and postmonsoon (November-February). Each season has a characteristic feature of its own, which is very distinct and unique. The oscillations of various physico-chemical variables in different seasons of the year are discussed here in brief.

1.2.1 Wind

The direction and velocity of wind system in the coastal West Bengal are mainly controlled by the north-east and south-west monsoons. The wind from the north and north-east commences at the beginning of October and continues till the end of March. The month of January and February are relatively calm with an average wind speed around 3.5 km/hour. Violent wind speed recommences from the south-west around the middle of March and continues till September. During this period, several low pressure systems occur in this region, a number of which takes the form of depressions and cyclonic storms of varying intensity.

On 25th May, 2009, a type of tropical cyclone named „AILA" hit the Sundarban region. AILA was formed in the central Bay of Bengal as the net output of several factors. Around May 20th 2009 monsoon initiated at Andaman. The moisture - laden south Westerlies accelerated the moisture content in the winds of the Bay of Bengal. The wind speed was also variable in the northern and southern Bay of Bengal. In southern Bay of Bengal the wind speed in the lower troposphere was around 37 km/hr, whereas in northern Bay of Bengal it was about 9 km/hr. These variations led to the curling of winds, which is known as positive relative vorticity. Basically an area of depression developed in the Bay of Bengal on May 20, 2009 which transformed into a cyclone on May 23, 2009 and hit the deltaic complex of Indian Sundarban on May 25, 2009 destroying the lives and properties of island dwellers (Fig. 1, 2 and Plate 2).

A preliminary IMD report said the cyclone retained its intensity for about 15 hours after it hit the landmasses as it was close to the Bay of Bengal. It lay centered over the Gangetic delta for quite some time, ascertaining the availability of moisture. This is peculiar nevertheless because premonsoon storms rarely hit the maritime state of West Bengal with such severity.

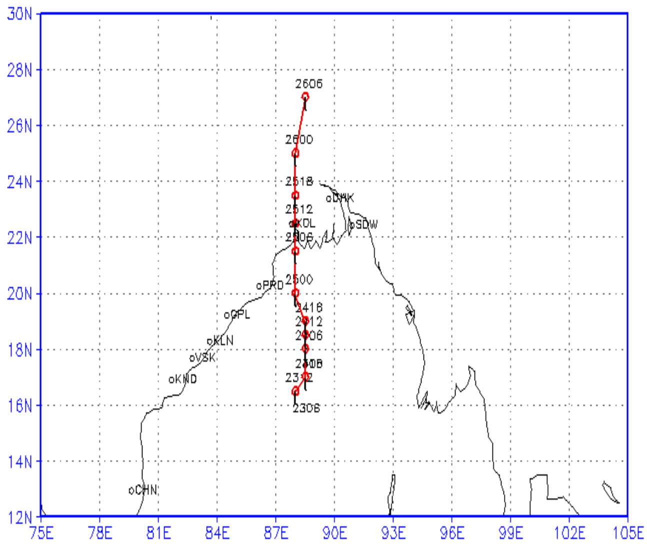
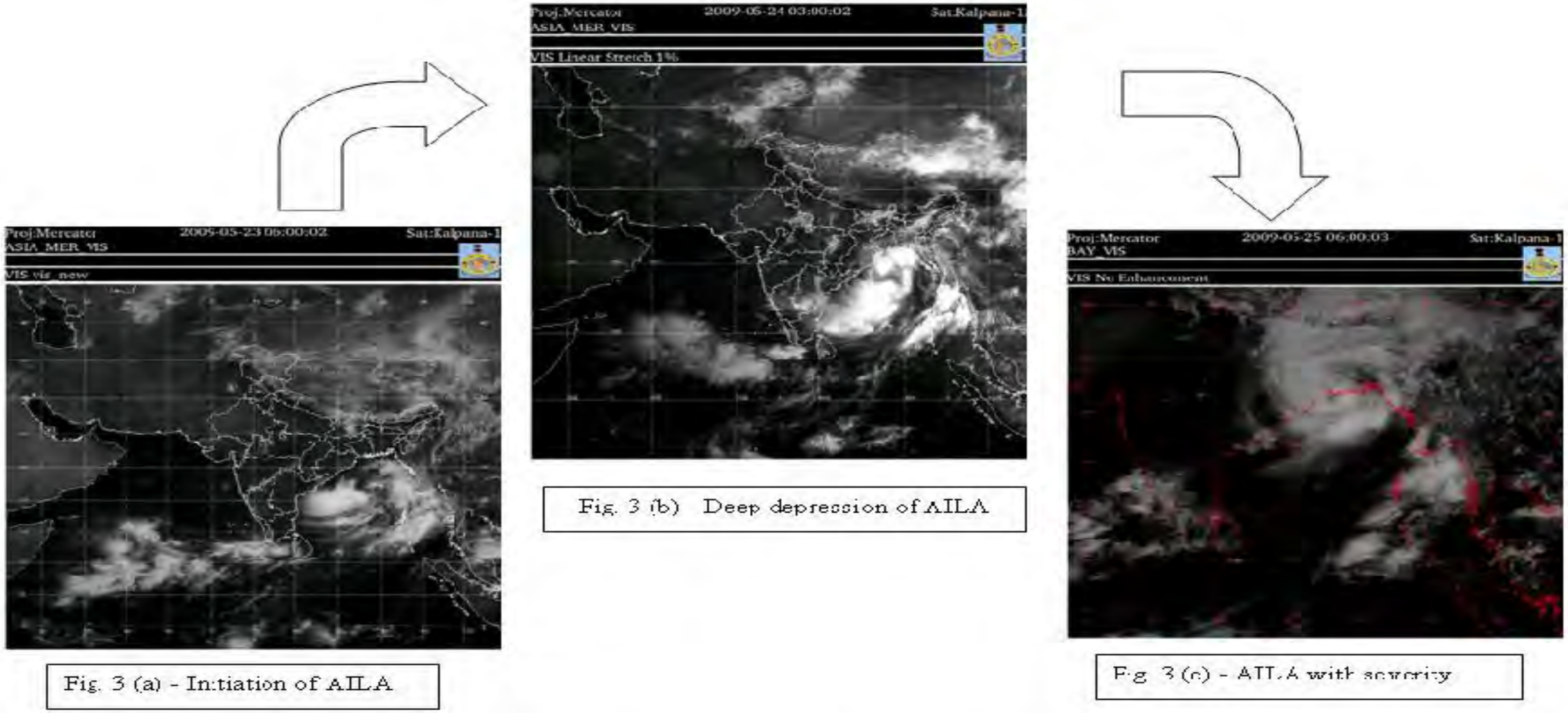


Fig. 1 - Track of AILA during 23rd to 26th May, 2009
(Source: Severe Cyclonic Storm, AILA: A preliminary report of Regional Specialised meterological Centre, IMD, Mausam Bhawan, New Delhi. (Projection: Mercator: Satellite: Kalpana-1; 24th May, 2009)



Source. Regional Specialized Meteorological Center - Tropical Cyclone, New Delhi

Fig. 2- Formation of AILA in Bay of Bengal (23^{rd} May, 2009 to 26^{th} May, 2009)

1.2.2 Waves and Tides

The wind is the basic driving force for generating surface waves in the coastal zone of West Bengal. Sea waves in this region rarely become destructive except during cyclonic storms. During Nor-Westers, the wind speed rises above 100 Km/hour and is usually accompanied by huge tidal waves. When the cyclonic incidences coincide with the spring tides, wave height can rise over 5 m above the mean sea level. Ripple waves appear in the month of October, November and December when wind generated wave height varies approximately between 0.20 to 0.35 m. In the month of April to August, large wavelets are formed in the shelf region and they start breaking when they approach towards the coastal margin. Wave height rises up to 2 m during this period, which causes maximum scouring of land masses. Wave actions, micro and macro-tidal cycles and long shore currents are recorded in most of the islands in this ecosystem. With the change in seasons, tidal pattern in the estuarine systems of coastal West Bengal also changes (Pillay, 1958). During the monsoon month, the effect of flood tide is more or less countered and nullified by freshets and there is a strong predominance of ebb tide. The strength of flood tide over ebb tide is at a minimum during the postmonsoon season. Conversely, during the premonsoon season, the effect of flood tide is considerably stronger than that of the ebb tide.

1.2.3 Surface water temperature

In coastal West Bengal, the seasonal variation of surface water temperature is not so drastic between premonsoon and monsoon seasons. The premonsoon period (March to June) is characterized by a mean surface water temperature around

34^0C. The monsoon period (July to October) shows a surface water temperature around 32^0C (mean) and the postmonsoon period (November to February) is characterized by cold weather with a mean surface water temperature around 23^0C (Mitra, 2000).

1.2.4 Rainfall

The average annual rainfall in deltaic Sundarban region is 1920 mm (STR, 2011). Rainfall is usually maximum during the month of August/September and the monsoon period lasts from July to October. The south-west wind triggers precipitation in the monsoon period with an average rainfall of about 165 mm. The postmonsoon period (November to February) is characterized by negligible rainfall and the premonsoon period (March to June) is basically dry, but occasionally accompanied by rains and thunderstorms.

1.3. Biodiversity of Indian Sundarban

Sundarban is very rich in biodiversity value, which is not yet fully explored. A total of over 96 species of mangroves and its associates have been recorded in Indian Sundarban of which 34 are true mangroves. A total of over 1692 species has been recorded as faunal diversity of Sundarban, of which 481 species belong to vertebrates and 1104 belong to invertebrates.

1.3.1 Fauna of Sundarban

Sundarban is highly specialized mangrove ecosystem supporting a large number of animal communities living either entirely within the mangrove or visiting this zone to feed or to breed. The extreme conditions has resulted in adaptations for survival specially water and salt balance. There are 15 species of mammals, 8 species of birds and 17 species of reptiles which are included in the Schedule I & II of Wildlife (Protection) Act, 1972. Total no. of species, included in Appendix 1 of CITES Regulation is 14. Sundarban Reserve Forest is a rich in floral and faunal biodiversity. A detailed historical account of the wildlife which was once present in the area is given in the Hunter"s Statistical Account of Sundarban (1998), an excerpt of which is reproduced below:

"The large sorts of game found in the district are the tigers, leopards, rhinoceros, buffaloes, spotted deer, hogs deer, bara singhi or large deer, barking deer, porcupines, otters, and monkeys are the principal varieties of wild animals found in the Sundarban. Tigers are numerous, and their ravages form one of the obstacles to the extension of cultivation."

However, over a period of time a number of animals became extinct in Indian Sundarban due to ecological changes, habitat degradation, and related anthropogenic activities. Some of the animals which were once present but have been lost include Javan Rhinoceros (Rhinoceros sondaicus), Wild Buffalo (Bubalus bubalis), Swamp Deer (Cervus duvaucelli), Barking Deer (Muntiacus muntjak) and Indian Rhinoceros (Rhinoceros unicornis).

Mangrove fauna in general, is found to occur in both the terrestrial and the aquatic ecosystems. These areas can be differentiated as littoral or supra-littoral forests, inter-tidal mudflat and estuary. The littoral or supralittoral (i.e. areas beyond the high tide) forest biome is typically a terrestrial environment, which includes both aerial and arboreal forms and the soil inhabitants. The supra-littoral forest habitat includes area where water may or may not reach at all and is essentially densely covered with halophytes. It offers forest floor, roots, stems, branches and leaves of trees as the abode. Mangrove forests here are inhabited by terrestrial animal communities. They may occupy tree or ground or both. The upper canopy of mangrove trees is the home to a variety of of birds, bats, monkeys and insects. The *Rhesus macaque* is the only species of primate occurring in the Sundarban is well distributed in the entire forest. Honey bee (*Apis dorsata*) is responsible for pollination in about 80% of the mangrove species thereby plays a very important ecological role in the mangrove forests. These bees are known to build their honeycomb inside the forest in large numbers.

The intertidal (region between high and low tide) mudflats are essentially semi-terrestrial or semi aquatic habitat supporting mainly the soil forms and the benthos (Plate 3). While the other faunal components in the mudflat and estuary can broadly be divided into zooplankton, nekton and benthos. Several species of crustaceans and larvae of fishes form the main component of the zooplankton in this region. The pattern of distribution of animals in mangrove ecosystem is influenced by the substratum, salinity, tidal amplitude, vegetation, light, temperature etc.

The terrestrial mangrove ecosystem in Sundarban is the domain of the Royal Bengal Tiger (*Panthera tigris*) which is at the apex of the food chain (Plate 4). It leads an almost amphibious life and is an excellent swimmer (Plate 5). It has been seen to cross rivers as wide as 2 km at a stretch. It has adapted itself nicely to this difficult terrain which is characterized by sharp pneumatophores, muddy substratum, innumerable rivers and creeks with tidal rhythm, variable salinity and lack of freshwater source. The principal prey species of the tiger are spotted deer, wild boar, and monkeys. The man-eating trait of Sundarban tigers have become almost a legend. It is considered that man-eating propensity of tiger in this area is an acquired trait over a period of generations given the harsh surrounding conditions (STR, 2000). It has been noticed that in the last 25 years apart from one case where the tiger had accidently killed a girl, all the deaths have occurred inside the forest. Apart from the tiger the secondary predator is mainly the fishing cat (*Felis viverrina*). Among other ground dwelling fauna are spotted deer (*Axis axis*), wild boar, (*Sus scrofa*). The cetaceans like gangetic dolphin (Platinista gangetica) and the irrawady dolphin (*Orcella brevirostris*) are frequently found in the eastern side, particularly in rivers like the Raimongal, Goasaba, Matla and the sea facing areas. The black finless porpoise (*Necmeris phoceanoides*) is also found in rivers near the estuary.

The estuarine crocodile (*Crocodylus porosus*) is the topmost predator in the aquatic ecosystem (Plate 6). It has capacity to overpower swimming tigers and an instance of a tiger killing by estuarine crocodile was reported from Donanki camp of Sundarban Tiger Reserve on 8th August, 2011(SBR Official Records, 2011). The water monitor lizard (*Varanus salvator*) which reaches upto 2.4 m in length can be frequently seen within the Reserve. The sea facing beach of the Reserve forms a nesting ground for olive ridley sea turtle (*Lepidochelys olivacea*) which come to lay eggs on the sandy beaches of the Tiger Reserve. Around 53 species of snakes are found in the area. Prominent among the poisonous are the king cobra, monocellate cobra, banded krait, Russell‟s viper, common krait. The python, chequered keelback, dhaman, green whip snake, ornamental snake, and several other species constitute the non-venomous snakes.

As per the bird surveys conducted in the areas there are over 230 species of birds which have been recorded from the area. These include a large number of migrants from the higher latitudes that visit the area in winter. During the monsoons heronaries develop in eastern part of Sundarban. Common birds found in the area include herons, ergrets, darters, spoonbills, cormorants and storks etc which come out and nest in the area. Other bird species which are most abundant in the Sundarban include the Common Sandpiper, Indian Ringed Dove, Whimbrel, Tailorbird, Black-capped Kingfisher, Jungle Myna, Rose-ringed Parakeet, Large Egret, Bronzed Drongo, White collared Kingfisher, Mag-pie Robin, Pond Heron, Common Lora, Red-vented Bulbul. This mangrove is also known as the Kingfisher‟s paradise having 8 out of 12 species of found throughout the country.

Aquatic habitat has not yet been studied in full details. However, some researches have been done by several workers (Mitra,2000; Mitra etal., 2004). The most interesting are the phytoplankton which gives the various colouration to the water receiving enough sunlight for a luxuriant growth. The phytoplankton are the sources of augmentation of oxygen content in the water. This influx, however, is checked by the zooplankton particularly by the shrimp population which invade mangrove estuary during the semi-larval stage to adult stage. The zoo-plankton consume the phytoplankton, thus diminishes the oxygen content but maintaining the equilibrium of the aquatic ecosystem. Dinoflagellates species like *Noctiluca* produce bioluminescence during winter nights particularly near the sea face and turns the entire atmosphere into a fairy land.

A wide and varied assortment of fishes, molluscs, crabs and prawns inhabit the estuaries. The mangrove leaves litter, which decomposes slowly, detritus offer food and shelter for the larval shrimps that migrate from the sea to the mangrove estuary for attaining maturity. Even the snappers or mullets depend very much on the mangroves. Mullets like Bhetki and Bhangone constitute the main bulk in the catch baskets of the edible fishes in the area. Among the crustaceans the one armed fiddler crab (*Uca Spp.*) often shows off to his mate with the colourful arm. They have diurnal clock inside which regulates their colour change along with tides. Another interesting crab is the *Clibarnius padavensis* (demon) i.e. Hermit crabs occupying gastropod shells of genus *Telescopium, Nerita, Cerithidea* or *Semifusus*. Apart from the edible crab *Scylla serrata* there are 11 species of crabs found within the creek waters. Amongst which ghost crab and patal chingri (*Thalacina anomala*) are important ones. Marine borer like *Teredo* often causes concern to the watercrafts.

There are two species of trilobite *viz. Tachepleurgigus* and *Carcinoscorpius rotundicauda* commonly known as Horse shoe crab or King crab. King crabs are now protected owing to its ability or high sensitivity to bacterial endotoxins. The cell lysates obtained from the blue blood of the species is widely used for estimation of bacterial endotoxin. The species have hardly changed in last 400 million years and are also called "living fossils".

The sharks and rays found in Sundarban include the Ganges shark (*Glyphis gangeticus*), Small toothed saw fish (*Pristis microdon*), Pointed saw fish (*Anoxypristis cuspidate*), and white-spotted shovel nosed guitar fish (*Rhynchobatus djiddensis*) all of which are Schedule I species in the Wildlife

Protection Act 1972. In addition to these the following are also found- *Rhinobatus granulates*, *Himantura alcockii*, *Rhinoptera javanica*, *Sphryna zygaena* etc.

1.3.2 Vegetation of mangrove forests:

Mangroves and mangrove associates constitute the dominant vegetation type of the area. These salt loving plants which are found throughout the tropical and subtropical regions of the world have been variously categorised by different authors. Mac Nae (1968) has designated the total mangrove ecosystem as „mangal" and the intertidal plant assemblage as „mangroves". Tomlinson (1985) has categorised them into i) major elements of mangroves, ii) minor elements of mangroves, iii) back mangroves or mangrove associates.

The Sundarban forests have been variously classified by different authors. These include:

Prain (1903) divided the entire Sundarban into three zones, namely (i) southern coastal strip and south - western part consisting of mangrove species; (ii) central zones of *Heritiera fomes*; and (iii) north - eastern part of Savannah type vegetation. The Indian Sundarban falls in the first category.

Curtis (1933) also divided the Sundarban into three mangrove forest types, these being i) freshwater forest; ii) moderately salt water forest; and iii) salt water forest.

Champion (1936) classified the tidal forests under primary seral type of moist tropical seral formations and did not regard the mangrove as a climax or pre-climax forest types. He divided the forests of the Sundarban region into mangrove forests consisting of i) low mangrove forest; ii) salt water *Heritiera fomes* and iii) freshwater *Heritiera fomes* forest. The Indian Sundarban falls under categories (i) and (ii) while the Sundarban forest in Bangladesh are at large considered to be representative of category (iii).

Champion and Seth (1968) later made one of the most comprehensive assessments of the vegetation communities of the Indian Sundarban. They divided the forest into categories based on broad characteristics of physiognomy and structure. These communities were defined irrespective of physiographic, edaphic or biotic factors. Champion and Seth (1968) were of the opinion that some communities were clearly associated with a definite site factor, which differed appreciably from the surrounding areas. Champion and Seth"s classification sub-group 4B (Tidal Swamp forests) with sub-divisions is mentioned in Table 2.

Naskar and Guha Bakshi (1982) grouped this forest into five major zones as i) sea face of beach forest; ii) formative island flora; iii) flora of reclaimed land and low lying area; iv) flora of river banks; and v) swamp forest. The first category is dominated by xerophytic plants due to the dryness of the soil and numerous sand dunes. The flora of the formative islands consists mainly of *Porteresia coarctata, Salicornia brachiata, Suaeda maritima, S. nudiflora, Phragmites vallatoria* (*P. karka*), *Acanthus ilicifolius* and a few tree species such as Avicennia spp., Sonneratia spp. and Excoecaria spp.. The reclaimed land and low lying areas are dominated by mesophytic flora while the last two zones are dominated by halophytic mangrove species.

As per Naskar and Mondal (1999) there are 40 species of major mangroves, 32 species of minor mangroves and 30 species of back mangroves and associates. These are grouped into 39 families, and 60 genera and 83 species. Among the important mangrove families are Rhizophoraceae, Avicenniaceae, Meliaceae, Sonneratiaceae, Sterculiaceae, Myrsinaceae etc. The list of Mangrove species and other biodiversity of Indian Sundarban has been given in Annexure 18.

TABLE 2

Classification of Mangroves according to Champion and Seth

i.	Mangrove scrub	:	$_4$B/TS$_1$	*Ceriops*, *Avicennia alba*, *Aegialitis rotundifolia*, *Excoecaria agalllocha*, *Phoenix paludosa* (drier ground). Found along the edge of tidal water ways and sheltered muddy coast. Dense forest with average height 3-6 m. Few species are markedly gregarious, all evergreen with leathery leaves. Vivipary seen. Common in western Sundarban.
ii.	Mangrove forest	:	$_4$B/TS$_2$	*Rhizophora*, *Kandelia candel*, *Avicennia alba*, *Excoecaria agallocha*, *Ceriops decandra*, *Ceriops tagal*, *Bruguiera* spp., *Xylocarpus granatum*, *Sonneratia apetala*. Found on mud banks of delta streams and near sea face where accretion is in progress. An evergreen forest of moderate height. Tidal mud flats permanently wet with salt water and submerged with every tide. Stilt roots and vivipary seen.
iii.	Salt water mixed forest	:	$_4$B/TS$_3$	*Heritiera fomes*, *Excoecaria agallocha*, *Ceriops decandra*, *Xylocarpus mekongenesis*, *Avicennia officinalis*, *Aegialitis rotundifolia* (near sea face). *Nypa fruticans* is relatively uncommon. Fairly dense forest, more than the fresh water type but not as high. Rarely over 20 m. Trees do not attain girth. Ground flooded in every tide with brackish water. Less silt deposition than fresh water type. Less humus, soil stiffer, clayey liable to crack extensively when exposed. Bigger river deltas.

iv.	Brackish water mixed forest	:	$_4B/TS_4$	*Heritiera fomes*, *Sonneratia apetala*, *Acanthus ilicifolius*, *Xylocarpus mekongenesis*, *Bruguiera sp*, *Sonneratia caseolaris*, *Excoecaria agallocha*, *Ceriops decandra, Phoenix paludosa* (high land), *Acanthus ilicifolius, Hibiscus tiliaceus, Nypa fruticans* (fringing banks). In the larger deltas, notably of High forests over 33 m., stilt roots rarely met but pneumatophores present. Forest is flooded for some portion each day, the water is never very salty and very fresh during rainy season or slightly brackish. Good amounts of fresh silt deposition.
v	Palm swamp type	:	$_4B/E_1$	*Phoenix paludosa* seen on drier areas within salt water mangrove scrub or forest. Forest area is partly flooded for some part of the day.

The mangrove forest is a very dynamic ecosystem. It is in continuous state of erosion and accretion leading to subsidence or erosion of existing banks and appearance of new lands and mudflats. Mangrove succession starts with the appearance of the pioneer species locally known as dhani ghas or *Porteresia coarctata* on the newly arisen mudflats (Plate 7). With the passage of time this grass species traps the propagules of *Avicennia* and *Sonneratia* spp. which come up well in freshly silted and firm mudflats. Once the land gets consolidated *Goran* or *Ceriops* spp. and *Genwa* or *Excoecaria agallocha* comes and colonises the area. *Phoenix paludosa* is the climax species which comes up on high lands and forms gregarious growth (Plate 8).

However, not all areas of the forest contain plant growth. There are some saline blanks which have been identified with the help of satellite imageries, some of which are saucer and some inverted saucer shaped. These blanks are high lands where water does not reach even during full tides. However, extent of such blanks is very limited. The blanks are generally devoid of any vegetation, but some of these blanks show the signs of primary succession and others contain either scrubby growth of *Ceriops decandra* (Goran) or scanty growth of *Excoecaria agallocha* (Genwa), *Phoenix paludosa* (Hental).

The central section of mangrove patch of the Sundarban delta between rivers Thakuran and Harinbhanga is typified, by the accelerated geomorphic action of ingressing back waters which does not get any upstream resistance of sweet water. This has resulted in movement of plant association within outer, inner and mid estuaries.

In general, the northern boundary and new depositions are characterised by Baen (*Avicennia marina, A. alba*, *A. officinalis*) flanked by foreshore grassland of *Porteresia coarctata*. Baen is gradually replaced by Genwa (*Excoecaria agallocha*) and then Goran (*Ceriops decandra*). About 70% of the area is covered with Genwa-Goran association. There are, however, southern and eastern associations of Garjan (*Rhizophora apiculata, R. mucronata*), Kankra (*Bruguiera sexangula, B. gymnorhiza, B.cylindrica*, and *B. parviflora*) and patches of Sundari (*Heritiera fomes*). Pure Hental (*Phoenix paludosa*) forest exists on relatively high lands. *Xylocarpus granatum* and *X. mekongensis* are distributed throughout the forests. *Nypa* palm swamps are common on central, eastern and southern portions, along side creeks and rivers having soft mud deposition. The sea facing areas have *Excoecaria agallocha, Lumnitzera racemosa, Saccharum, Derris indica, Thespesia populnea, Ipomea pescaprae* etc.

The mangrove distribution depends on the water salinity and flooding. Sundari (Heritiera fomes) is gradually getting off from the central and western sector of

Indian Sundarban owing to hypersalinity of the zone caused by Bidyadhari siltation (Mitra, 2009).

1.4 The people of Indian Sundarban

The population of the area as per 2001 census is over 3.5 million. People live in the reclaimed area of Sundarban, which was under mangrove forest till 1833 and has been colonized only recently. The reclaimed area is surrounded by earthen embankment of 3500 km long, which is erected as a dyke to keep away tidal saline water from over running the habitation area (Plate 9). The habitation is exposed to storms and cyclones, which generally tend to occur in the period from May to December, with the incidence being greatest in May and the post-monsoon months of October and November. Storms and cyclones cause heavy damages in the villages. They also deprive the communities from various livelihoods. Tidal flooding and river embankment breach are the other serious issues which cause damage and livelihood hardships. While often associated with cyclonic storms, tidal flooding can occur with little warning, sweeping people working in or near the waterway and breaching river embankments, with brackish water intrusion into farmland and local flooding (Plate 10).

The area has a poor infrastructure as the whole of Sundarban is composed of around 52 inhabited islands separated by rivers and creeks. There are almost no metalled roads and the only means of travel from one village to another is commonly by country boats. The inaccessibility acts as a serious constraint for development of the region. The surface water in the area is saline and unsuitable for human and agricultural use. The ground (sweet) water is found at great depths generally from 300 to 400 m. from the surface and its exploitation is costly. Health services are extremely poor and are almost nonexistent in most of the islands.

The socio-economic condition of communities living around Sundarban mangrove forest is generally depressed. Human development indices for the 24 Parganas (South) district find the fringe areas of Sundarban forest amongst the poorest (Annexure 9). Majority of the total population (approximately 95%) depends on agriculture supported by other occupation like fishery, forestry and handicrafts. There exists great poverty in the region. Average monthly income varies from Rs. 200 to Rs. 1000 per month. Agriculture is mostly rainfed and 50% of agriculturists are landless labours. The output from agriculture is poor because of saline environment persisting in the locality.

Besides agriculture and fishing activities people subsists on animal husbandry, honey collection. NTFP in the form of honey and wax are collected as a source of income. About 0.5 million fishermen are engaged in fishing in the rivers and creeks of the tract and this is a major economic pursuit.

1.5 Anthropogenic pressures on Indian Sundarban

Nature had destined Sundarban to be untouched by time till human settlements started from 1830"s. Sundarban is highly inhospitable terrain for humans and other life forms. The marshy islands are lashed by tides twice a day. The land is perforated by pneumatophores of mangrove vegetation making it difficult even to walk. Non-saline water or sweet water is highly scarce and almost all the wildlife depends on saline water for most of the time of year. For humans, in inhabited islands, ground water is either not available or is very deep. Tigers of Sundarban are known for their aggression. For all, humans as well as wild animals survival is a daily fight against the elements. Inspite of all the odds the human population of inhabited islands of 24 Parganas (South) district is over 3.5 million and human density is among highest. Records reveal that the population in the deltaic lobe has gradually increased over time (Fig. 3) inspite of hostile natural conditions and lack or resources.

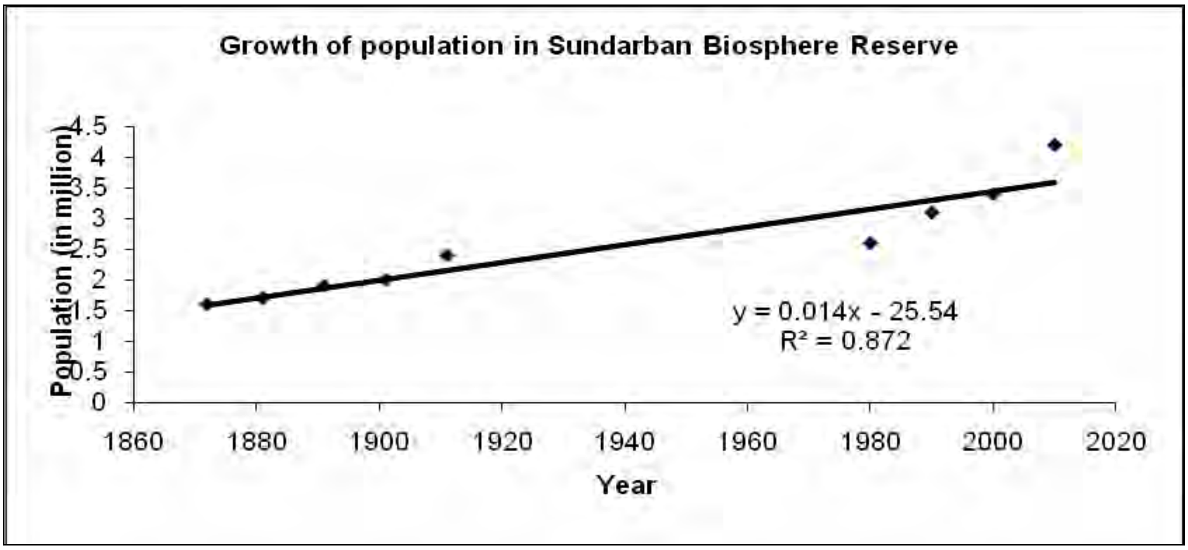


Fig. 3 – Growth of Population in Sundarban Biosphere Reserve

The inhospitable terrain with such high population density has resulted in immense anthropogenic pressure on natural resources of Sundarban, threatening the existence of its biodiversity.

The anthropogenic pressures on Sundarban are mainly from the three broad sources:

The pressure from the local communities due to their livelihood dependence. This pressure is mainly in the form of overfishing, mangrove destruction for small timber and firewood, poaching of wildlife for local consumption or for commercial use, large scale collection of tiger prawn larvae for prawn farms, use of chemical fertilizers and pesticides, urbanization of fringes to name a few.

The second category of anthropogenic pressure originates away from the Sundarban but well within the region mainly within the State of West Bengal. Some examples are the discharge of treated/ untreated pollutants in the water of Sundarban by the industries in and around Kolkata metropolitan city which is a great threat to the biodiversity of Sundarban. The regulated water discharge from Farakka barrage has a direct influence on the salinity of Sundarban water which is a major anthropogenic pressure on mangrove diversity and its distribution and also influences the aquatic life forms.

The third category of anthropogenic pressure is primarily global in nature. The climate change affects is being felt by the people of Sundarban. The people of the area may be affected by a change in rainfall pattern, excessive heat conditions, more storms in Bay of Bengal and decrease in agricultural outputs due to inconsistent rainfall, enhanced pest damage etc. All this in turn shall result in enhanced pressure on natural resources for the livelihood needs. As Sundarban is almost at sea level so any rise in sea level due to global warming might result in habitat loss for wildlife, threatening the biodiversity. The habitat loss and more human pressure may lead to an enhanced human- wildlife conflicts, a threat to long term conservation of biological diversity of this unique ecosystem.

2. Objectives of the study

2. Objectives of the study

On account of a large number of inter-related factors operating at the local, regional and global scales the anthropogenic pressures in Sundarban are increasing. Sundarban is a highly fragile ecosystem and its delicate balance may be adversely affected if these pressures are not dealt with. A sound management policy encompassing threats, conservation and socio-economic conditions is needed to protect this dynamic deltic system. On this background the major objectives of this study are:

1. To identify major anthropogenic pressures on the natural resources of Indian Sundarban.
2. To determine the nature and extent of major anthropogenic pressures and their impact on the biodiversity conservation of Indian Sundarban.
3. To suggest appropriate management interventions, adaptation and mitigation strategies to prevent adverse influence of the anthropogenic pressures on biodiversity of Indian Sundarban.

3. Historical Resume

3. Historical resume

3.1 Historical resume- Human-wildlife conflicts

Oxford dictionary defines "Conflict" as "A situation in which people, groups or countries are involved in a serious disagreement or argument". Human-wildlife conflict refers to the interaction between wild animals and people over the use of common resources and resultant adverse impact on people or wildlife. Human-Wildlife Conflict has also been defined as "Any interaction between humans and wildlife that results in negative impacts on human social, economic or cultural life, on the conservation of wildlife populations or on the environment" (WWF SARPO, 2005). According to the 2003 IUCN World Parks Congress, human-wildlife conflict occurs when wildlife requirements encroach on those of human populations, with costs both to residents and wild animals (IUCN, 2005; FAO, 2009).

Human-Wildlife Conflict has a very old history and was in existence even in ancient times. Forensic evidences show that "Taung skull" which was discovered in South Africa in 1924, belonged to a child who was killed by an eagle two million years ago (Berger and Clarke, 1995; Berger, 2006; FAO, 2009). Egyptian historical records reveal that hippopotamuses fed on cultivated crops and crocodiles ate livestock and occasionally humans even in 2000 BC (FAO, 2009)

In Human-Wildlife conflict, it is wildlife in general which suffers more due to supremacy of human race over other life forms. Human-wildlife conflict is a serious obstacle to conservation across the world. It has become serious with the ever increasing human needs due to population increase, development, global climate change and other human and environmental factors which put people and wildlife in greater direct competition for the shrinking resource base. Such conflict makes the job of wildlife conservation even more difficult as Human-wildlife conflict reduces the local people‟s support to the conservation due to resentment over loses. The Human-wildlife conflict is a world-wide phenomenon across all the continents of the globe. Across the world, right from the small sized wild animals to large animals are in conflict with man over sharing of resources. In Africa small animals like primates i.e. Baboons Vervet monkeys, Antelopes and even smaller carnivores causes major loss to crops and livestock. Birds and bats are also responsible to substantial loss of the crops. However, the major conflict which comes to the notice is the extensive crop damage by large herbivores like elephants, buffalo and hippopotamus. The large carnivores like lion, leopard, cheetah etc. are responsible for extensive live stock predation. Elephants, lions, crocodiles and leopards kill people in substantial numbers. In Europe, species such as wolves that once roamed widely across the continent have been eradicated along with the habitat in which they lived, a small populations now survives in very few remote, sparsely populated areas. In Britain, the last wild wolf is believed to have been killed in 1743. In 2005, the Norwegian government approved the killing of five of the country‟s twenty remaining wolves to protect sheep (Muruthi, 2005; Kirby, 2005).

Conflicts between human and wildlife have been extensively documented in Africa- Samburu (Thoules, 1994; Thoules and Sakwa, 1995; Frank, 1998; Ogada et al., 2003; Ogada and Ogada, 2004), Kilimanjaro (Kangwana, 1993; Kikoti, 2000; Carnivores: Rainy and Worden 2003), Maasai Steppe (elephants: Foley, 2002; Carnivores: Kissui, 2004) and Virunga (Woodford et al., 2002; mountain gorillas: Macfie, 2003; buffalo: MacFie, 2003). In some areas crop damage by wildlife is perceived as a major problem facing farmers; it threatens to undermine conservation and development efforts in the northern districts of Zimbabwe (Mid Zambezi Elephant Project, 2002). Within the Zimbabwe portion of the Zambezi Heartland, elephants are estimated to be responsible for up to three-quarters of all crop damage caused by wildlife (Muruthi, 2005).

In Kilimanjaro Heartland, Muruthi et al. (2000) found that in 1996 and 1997 at least 15 elephants, representing three-quarters of the local population"s mortality, had been killed in conflict situations with local people. Between 1974 and 1990, one third of elephant mortalities (141 of 437 deaths) in the Amboseli ecosystem were caused by people through spearing (Kangwana, 1993). The main problems in the Kilimanjaro Heartland are crop damage, competition for water and grazing, killing of livestock and risk of disease transmission, and human fatalities. In semi-arid areas in general, where livestock production constitutes a major part of local livelihoods, high levels of conflict can occur between livestock owners and wild carnivores due to predation (Muruthi, 2005).

In China Sanjiangyuan National Nature Reserve, one of the largest nature reserves in the world faces the Human-Wildlife Conflict between local herders and large predators. Three wildlife species of this region: snow leopard (*Uncia uncia)*, gray wolf (*Canis lupus),* and Tibetan brown bears *(Ursus arctos pruinosus)* are in conflict with people. They are responsible for livestock predation, home raids for food and even for attack on humans (Worthy and Foggin, 2008).

Studies on Human-Tiger Conflict in Indonesia have recorded that Sumatran tigers (*Panthera tigris sumatrae*) have been responsible for 146 human killings, 30 human injury and 870 live stock predation during the period 1978 to 1997 (Nyhus and Tilson, 2003). In Riau province, Indonesia during the period 1997 to 2009, human-tiger conflict have caused a total 55 human killings by tigers and a total of 49 people were injured. Human-tiger conflict has also resulted in killing of 13 tigers by people and capture and translocation of another 17 tigers. A forty seven live stock predation cases were also recorded (Mahyuddin, 2010). The conflict is mainly being attributed to the logging operations and habitat degradation.

In Virunga habitat destruction and human population growth mean that the mountain gorilla and other forest animals, such as elephant and buffalo, are increasingly coming into contact with people, often leading to conflicts. The impact on local people, many of whom are subsistence farmers, can include economic devastation through destruction of crops, living in a state of fear, inconvenience, and danger to life and limb (Macfie, 2003). For mountain gorillas, interactions with local people are a source of stress that can result in the transmission of human diseases, and can lead to direct physical attacks, disabilities such as loss of limbs from snares, and even death: 18 mountain gorillas were killed between 1996 and 2003 in Virunga and Bwindi (Woodford et al., 2002).

In the Samburu Heartland, Ogada and Ogada (2004) documented the species of wildlife responsible for killing livestock and reported that such deaths were due to: lions (35% of reported deaths), leopard (35%), hyena (18%), baboon (4%), elephants (3%), buffalo (2%), wild dog (2%) and cheetah (1%). Generally, detailed information on economic losses due to human-wildlife conflicts is lacking for the AWF Heartlands.

The level of impact of Human-Wildlife Conflict was studied in Tsavo East national Park by Patterson *et al.* (2004). Two private ranches that lie adjacent to the boundary of the Tsavo East National Park in Kenya with three carnivore species were determined to be responsible for attacks: lions and spotted hyenas, which target large domestic animals such as cows, bulls, steers; and cheetahs, which take only smaller adult stock and young cattle. In a four-year study the ranches have lost an average of 2.4% of the total herd per annum, which represented 2.6% of their economic value and amounted to US$ 8,749. Thus Human-Wildlife Conflict not only affects the vulnerable communities but the commercial ventures too. This situation sometime may become serious if the cost-benefit ratio turns adverse due to Human-Wildlife Conflict and may threaten the entire business itself.

Human-Wildlife Conflict around Chitwan National Park, Nepal has resulted in killing a large number of humans as well as of tigers. A study conducted showed that a total of 88 persons were killed by tigers in and around Chitwan National Park between 1979 to June 2006 (Gurung et al., 2006). Most of the victims were either grass collectors or herders. The study also listed that a total of 37 tigers were involved in killing of these 88 persons. Seventeen tigers were captured or killed and another 8 tigers were removed from the area as they were creating serious threat to the communities (Gurung et al., 2006).

In Australia farmers treat kangaroos as pest as they damage crops and compete with livestock for foraging. The government approves culling of certain numbers of kangaroos without accounting the poaching and killings by farmers.

In Lao People"s Democratic Republic (PDR) effects of Human-Tiger Conflict on tiger population and on local communities has been well documented. Three factors i.e. commercial poaching, livestock grazing followed by prey depletion has resulted in decresed number of wild animals particularly tigers due to poaching and completion with livestock. Tiger abundance was significantly lower where human population and disturbance were greater. The estimated tiger density for the sample area ranged from 0.2 to 0.7 per 100 km^2 (Johnson et. al., 2006). It is clear that competition of wildlife with people though harms both the sides, however, it is wildlife which is a permanent loser in long run.

It is also clear that Human-wildlife conflict is a global phenomenon and persists in almost all parts of world. The nature and extent of Human-wildlife conflict is determined by multiple factors primarily human density and dependence of local communities on the natural resources. The behavioural changes in wildlife species are also responsible for it to a great extent. In South-east Asian countries, one of the attribute responsible for Human-Elephant conflict is elephant"s preference of local crops over naturally growing vegetation inside the forest. Globally Human-wildlife conflict is passing through a serious situation where many wild animal species are struggling for survival and local communities for subsistence.

Human-wildlife conflict in Sundarban is age old and started from the period when people started the efforts to harvest rich natural resources of the Sundarban including the reclamation of the Sundarban land. Human-tiger conflict in Sundarban is an ancient problem and is an example of human-tiger conflict at its most extreme (Barlow, 2009). The stories of human interactions with wildlife have taken epic proportion and has found place in folk tales, music and songs of the region. Primarily, the human conflict is with Sundarban tigers, which are known worldwide for their amphibious life and special adaptations to survive in the harsh conditions; but the conflict with that of estuarine crocodiles is also not uncommon. The conflict of human with that of sharks is rare but do exist. A detailed account of human-tiger interaction is available in old records of Forest Department as well as in other old official documents.

The historical account of human-wildlife conflict is available in both old and current Working Plans of the Forest Department. In addition, reference of the same is also available in old "District Gazetteers" of undivided Sundarban. With the independence of India in the year 1947, Sundarban was divided in two parts. The larger area (about 60%) went to East Pakistan, the newly created country. Since 1971, it is in Bangladesh, as East Pakistan was liberated from Pakistan and became a new sovereign country "Bangladesh". The smaller part of Sundarban became a part of India and is known as Indian Sundarban. So till 1947, the entire Sundarban was managed under single management authority hence all the old records pertain to the undivided Sundarban.

The Sundarban is the southern part of Gangetic delta bordering Bay of Bengal. The undivided Sundarban at one time extended 290 km from East to West and 113 km from North to South, which after the partition of India in 1947 is confined to only about 40% of Sundarban delta. Sundarban since ages is known for the conflict of human with tigers as they were treated as the main obstacle after nature against the reclamation of land for cultivation. The real time reclamation efforts of Sundarban terrain started with the grant of zamindari or landholder's rights of zamindari of Calcutta, to East India company by the Nawab of Bengal, Mir Jafar on the 20th December 1757 (Malley, 1914).

The Sundarban forests occupy a flat deltaic swamp, most of which is under water during the high spring tides of the rains. The area is intersected by a close network of rivers, channels and creeks (vernacular *nadi, gang* and *khal*). The larger of these waterways are the remains of former beds of the Ganges, the main stream of which has gradually shifted eastwards, leaving a number of dead or semi-dead rivers running north and south, and are basically tide-fed in narture. Now in Indian Sundarban, Hooghly River, is closely connected with the Ganges *via* the Julangi and the Bhagirathi, and also receives fresh water from Rupnarayan River, which drains the Midnapore, Bankura and Hooghly districts. In the central part of Indian Sundarban rivers do not receive fresh water and are purely the back water of Bay of Bengal. The present river Matla is in fact saline in nature except during rainy season when the rain water reduces the salinity. Tidal action twice a day brings the salt water of the sea and inundates vast areas of the islands of Sundarban. The tides sweeps over the area twice a day, the tidal current changing its direction after over 6 hours.

The Sundarban forest was sporadically used by small group of peoples who cleared small areas of mangroves in remote islands and settled in small numbers. The remains of buildings, indicate that large areas of forest were cleared probably within the last five or six hundred years. The most extensive ruins within the present forests are found near the Sipsah River in Compartment 39, and include the famous Shekertek Temple; there are also many ruins existing in the recently cleared areas, the best preserved being the Jatar Deul, near the Moni *nodi* in the 24-Parganas (S) district. After the Ganges changed its course there was a gradual influx of salt-water which probably was for the reason that these old cultivated areas were abandoned and allowed to revert back into forest (Malley,1914)

At the advent of British rule *zamindars* on the northern boundaries of Sundarban were allowed to reclaim as much of the jungle bordering on their lands, as they required. During the latter part of the 18th and the beginning of the 19th centuries, colonization was much impeded by the opposition of these old border *zamindars* to any fresh grants of land to the south of their own, to which they considered they had a prescriptive right. It was not until after various surveys and enquiries, that Government definitely assumed the proprietary right to the forests in the Sundarban under Regulation III of 1828; rules for leases under this regulation were published in 1830. The confidence created by this regulation, made the purchase of leases in the Sundarban attractive to capitalists, who were willing to sink capital in clearing and bunding the forest lands, the people then were certain of a secure tenure and many leases were bought by Europeans of Calcutta at that time. Subsequently, the conditions under which Sundarban leases have been granted, have been changed from time to time; but the regular reclamation of the Sundarban may be said to have started in 1830. In the extreme west, the colonization of Sagar Island was much impeded by the continual recurrence of severe cyclones and tidal waves, which swept over the area during the years of 1833, 1842, 1848, 1864 and 1867. These storms caused great loss of life and cattle (Curtis, 1933).

Though the vast tracts of forests were declared reserved and protected in the eastern part of undivided Sundarban but the poor quality forests in the western part of Sundarban was allowed to be colonized and about 932 sq. km of forest was deforested and leased out for cultivation in the early 1800‟s (Curtis, 1933). Due to this reason the human settlement in the extreme western part of Sundarban are right up to the Bay of Bengal.

As the colonization and utilization of the vast tracts of Sundarban and its natural resources continued, man intruded in the territory of swamp tigers, who took upon the chance of hunting man as easy prey in the difficult pneaumatophore laden swamp land of Sundarban. Man treated tigers as pest and administration rewarded the hunting of tigers by people inside as well as outside the forests. The Working Plan of Sundarban Division (1931-1950) by S. J. Curtis gives a detailed account of men and tigers killed from 1912-13 to 1929-30. The number of men killed declined over the years as the number of tigers killed continued to be high. The human –tiger conflict for the period when Sundarban was facing crucial "consumption phase" has been shown in Table 3.

S. J. Curtis (1931) also recorded the imbalance caused to the prey-predator relationship as the population of deer (Spotted Deer and Barking Deer) and wild boar increased due to the fact that a very large proportion of tiger in the Sundarban have been killed off. He recorded that the partial extermination of the tiger has upset the balance of nature, and has allowed an inordinate increase in the number of his natural prey, namely the deer and pig.

TABLE 3
Human-Tiger Conflict in Sundarban (undivided) during the early 19^{th} century
(Source: Working Plan for the Forests of the Sundarbans Division, 1931 to 1951 *by* S. J. Curtis, 1933)

Year	Number of tigers killed or captured in the forests	Number of men killed by tiger in the forests	Year	Number of tigers killed or captured in the forests	Number of men killed by tiger in the forests
1912-13	37	70	1921-22	43	21
1913-14	31	81	1922-23	33	25
1914-15	40	79	1923-24	47	4
1915-16	35	60	1924-25	46	7
1916-17	48	19	1925-26	46	7
1917-18	52	14	1926-27	14	-
1918-19	35	5	1927-28	18	1
1919-20	32	12	1928-29	3	-
1920-21	38	18	1929-30	6	4

Traditionally tigers have come across four categories of people which earned livelihood in Sundarban. The first to arrive were the cultivators who cleared the forests for agriculture and settled in small numbers. The second category of people are the Fishermen who has been traditionally dependent on Sundarban for fishing due to its rich aquatic wealth, Third category of the people are the honey collectors who found tons of honey being produced by migratory honey bees (*Apis dorsata*) which swarms the mangroves in flowering season from April to June every year. The last category of the people was the wood cutters, who arrived on the scene after the start of systematic utilization of forest by way of coupe felling. The coupe felling is comparable to felling of forest by initial settlers who also cleared the forests for land. However in coupe felling after the harvesting of wood, land was allowed to regenerate naturally. S. J. Curtis (1933) observed that "Sundarban tigers are notorious for man-eating, and until a few years fully deserved this notoriety. In the dense jungle, he is extremely difficult to hunt when cases of man-eating occurred on the *sundri* coupes in the past, it was an impossible to shift or kill the offender, with the result that the coupe had to close".

During the early late 1800 and early 1900, tigers were treated as a pest and its hunting was felt necessary to reclaim the Sundarban for revenue generation by Britishers. The reward paid was as high as Rs. 200 and special hunting permits were issued for hunters, who earned livelihood by killing tigers in the difficult terrain of Sundarban. The reward amount can be compared with the fact that for one rupee a total of 10 seers of rice could be purchased in 1903. By this means, the number of men killed by tiger has gradually reduced: so effectively, that during the consecutive three years from 1926-27 to 1928-29, there was only one solitary instance of human killing was recorded. For this reason, in 1927-28, the number of professional tiger shooting permits was substantially reduced. In letter No. T.-R., dated 27th May 1927, the local Government empowered the Divisional Forest Officer to lower the reward of Rs. 200 for killing tiger to such amounts that he thinks fit. He was also provided the powers to increase it, in case tigers again become a real threat to life. The reward system was completely stopped since 1928-29. S. J. Curtis (1933) observed that there was an increase in tiger population which resulted in a small increase in the number of men killed as the same rose to four times in 1929-30.

The forest officers in 1929-30 observed that regeneration of some of the mangrove specially that of commercially important species like Golpata and Sundari was seriously damaged by spotted deer and wild pig as their population increased considerably due to the fact that a very large proportion of numbers of tigers in Sundarban have been killed during that period.

Barlow (2009) estimated 76 human deaths/ year for the entire Sundarban of Bangladesh and India for the period 1881 to 2006. He accounted only those years for which data were available with 33% error in recording efficiency. He also recorded mean number of 6 unnatural tiger deaths/year for Bangladesh Sundarban and 1 death/year for Indian Sundarban for the period of 81 years from 1881 to 2006. He recorded 7833 human deaths from tiger attacks in Sundarban, during the period 1860 to 2006. A total of 4218 (54%) were recorded during the period of six years (1860-1866) with an average of 703 human deaths/year (Blanford 1891). Barlow, 2009 recorded that for the period 1881 to 2006, average human killings by tigers in entire Sundarban were 51/year. He observed that Indian Sundarban had a greater mean number of 30 human deaths/ year as compared to 22 human deaths/ year in Bangladesh Sundarban during this period.

Barlow, 2009 recorded a total of 1259 tiger deaths during the period from 1881 to 2006. No systematic and reliable data for unnatural tiger deaths are available for recent time. 233 tigers deaths were recorded in Bangladesh Sundarban over a period of 42 years, six tiger deaths in Indian Sundarban over six years and 1020 tiger deaths over 33 years, where country was not specified (Curtis 1933; Chaudhuri and Chakraborti 1972; Hendrichs 1975; Jalil 1998; Mukherjee and Tanti 2001; Reza et al. 2002; Bangladesh Forest Department records 2000-2006). According to Barlow (2009) the mean for Bangladesh Sundarban was six tiger deaths/ year (SD = 10.1, range 0 - 57), for Indian Sundarban one tiger death/ year (SD = 1.1, range 0 - 3) and for whole Sundarban it was 16 tiger deaths /year (SD = 21.3, range =2 - 79) (Barlow, 2009).

There is not much information available on the human and estuarine crocodile conflict in Sundarban but old records has a reference of its existence. During the period 1920-1930, when official tiger hunting was on, it was felt that the human killings by tigers have gone down and the major threat to life was from crocodiles. S. J. Curtis (1930) in the Working Plan of Sundarban mentioned that " At the present time, woodcutters incur a greater danger from crocodile *(Crocodylus porosus)* than from tiger. During the last eight years, these reports have been responsible for 60 deaths within the forest. There is no record of number of fatalities due to crocodile amongst fishermen working within the Sundarban except for his occasional man, cattle and carcass eating tendencies, the main food of the crocodile appears to be fish".

No historical account of human-conflict with sharks could be found in old records suggesting that it was too low to be mentioned. The reference of snake bites do exist but it has not been studied and analysed as this conflict exist throughout and is not restricted to natural resource zone. Hence this do not contribute a significant threat to natural resource conservation directly.

3.2 Historical resume-Impact of salinity on mangrove

Mangroves are a taxonomically diverse group of salt-tolerant, mainly arboreal, flowering plants that grow primarily in tropical and subtropical regions (Ellison and Stoddart, 1991). Estimates of mangrove area vary from several million hectares (ha) to 15 million ha worldwide (FAO, 1981). The most recent estimates suggest that mangroves presently occupy about 14,653,000 ha of tropical and subtropical coastline (Wilkie and Fortuna, 2003). The field survey of mangrove biomass and productivity is rather difficult due to muddy saline soil conditions and the heavy weight of the wood. The peculiar tree form of mangroves, especially their unusual roots, has attracted the attention of botanists and ecologists (Tomlinson, 1986). Allometric equations for mangroves have been developed for several decades to estimate biomass and subsequent growth. Most studies have used allometric equations for single stemmed trees, but mangroves sometimes have multi-stemmed tree forms, as often seen in *Rhizophora*, *Avicennia*, and *Excoecaria* species (Clough et al., 1997; Dahdouh and Koedam, 2006) that often create difficulty in developing allometric equations with accuracy. Clough et al. (1997) showed that the allometric relationship can be used for trunks in a multi-stemmed tree. Moreover, for dwarf mangrove trees, allometric relationships have been used to estimate the biomass (Ross et al, 2001). Basically the dwarfness of mangroves is caused due to high salinity. Presence of salt is a critical factor for the development of mangrove ecosystems. At lower intensities it favors the development of mangroves eliminating more vigorous terrestrial plants which other wise could compete with. On the contrary at increased level it might cause overall degradation of mangroves. Salinity is also a controlling factor for mangrove seedling recruitment and the relation is negatively proportional. Siddiqi (2001) noted reduced recruitment of *Heritiera fomes* and *Excoecaria agallocha* seedling in the Sundarban mangrove forest with increased salinity. Ball and Pidsley (1995) observed adverse impact of increased salinity on canopy development, leaf initiation, and leaf area expansion in *Sonneratia alba* and *Sonneratia lanceolata*.

Till date there have been few studies on the effect of salinity on photosynthetic gas exchange in mangroves. Clough (1985) stated in his communication that the rate of light saturated photosynthesis decreases with increasing salinity of ambient media, attributing this to co-limitation of assimilation rate by stomatal conductance and photosynthetic capacity in response to differences in water status induced by the various salinity treatments. Thus, on the evidences available so far it is most likely that salinity exerts its effect on photosynthesis mainly through changes in leaf water status and this study reveals that the photosynthetic process may be affected at high saline condition due to decrease in chlorophyll *a* and *b* concentrations in mangroves. Various studies have shown that a number of mangrove species grow best at salinities between 4 psu and 15 psu (Connor 1969; Clough 1985; Downton 1982; Burchett et al. 1984 and Clough 1984) and for *Heritiera fomes*, the preferred salinity range is much lower (Chaudhuri and Choudhury 1994).

It has been investigated that, at high salinity, the main cause of the decrease in growth is the reduction in the expansion rate of the leaf area caused by the high salt concentrations (Greenway and Munns, 1980; Rawson and Munns, 1984). In fact, the relative leaf expansion and net assimilation rate decrease in mangrove species as salinity increases (Ball and Pidsley, 1995), which adversely affect the biomass of the species. Also under salinity stress, accelerated leaf mortality rate is accompanied by a marked decrease in the leaf production rate, leading frequently to the death of the plant (Greenway and Munns, 1980; Munns and Termaat, 1986). It has been reported that, in several mangrove species, an increase in soil salinity decreases the number of leaves per plant (Clough, 1984; Ball and Pidsley, 1995), which may finally decrease the quantum of glucose production per plant affecting the biomass.

In the maritime State of West Bengal, situated in the northeast coast of India, the adverse impact of salinity on the growth of mangrove species has been documented (Mitra et al., 2004; Mitra et al., 2011). Salinity, therefore, greatly influences the overall growth and productivity of the mangroves (Das and Siddiqi, 1985).

The Indian Sundarban exhibits two significantly different salinity regimes due to siltation that prevent the flow of Ganga-Bhagirathi-Hooghly water to the central region. This has made the ecosystem a unique test bed to observe the impact of salinity on the biomass and allometric trait of the mangrove species.

Not much work is done on the impact of salinity on mangrove biomass/diversity in Indian Sundarban. In a very recent study Banerjee et al (2010) showed that mangrove stem biomass in the western region of Indian Sundarban (22.10 t ha^{-1} for *Excocaria agallocha* to 111.39 t ha^{-1} for *Sonneratia apetala*; averaged over the three seasons) is around values of a *Rhizophora mangle* stand (12.5 t ha^{-1}) in Florida, USA (Coronado-Molina et al., 2004) and of Komiyama et al. (2000) in a secondary mangrove (*Ceriops tagal*) forest in Southern Thailand (92.2 t ha^{-1}). The relatively higher stem biomass of similar aged trees in the western region compared to the central region of Indian Sundarban (22.10 t ha^{-1} for *S. apetala*, 9.79 t ha^{-1} for *E. agallocha* and 16.45 t ha^{-1} for *A. alba*) may be attributed to better hydrological and soil characteristics contributed by the River Ganga–Bhagirathi system. Mangroves, in general, grow better in brackish water and, in extreme saline conditions; growth is stunted (Mitra et al., 2004). The western region of Indian Sundarban provides ideal growing conditions for mangroves due to fresh water input from the Himalayan Glaciers after being regulated by the Farakka dam.

The effect of salinity on mangrove species of Indian Sundarban in terms of above ground biomass (AGB) has been documented by several researchers (Banergee et al, 2010, Mitra et al, 2011).

3.3 Historical Resume-Impact of climate change on Indian Sundarban

Climate change has several components of varied nature and scale that affect the ecosystems of the planet Earth. For mangroves, however, the most relevant components include changes in sea water level, high water events, temperature and atmospheric CO_2 concentration. Of all the outcomes from changes in the atmosphere‟s composition and alterations to land surfaces, relative sea level rise may be the greatest threat to mangroves (Field, 1995; Lovelock and Ellison, 2007). Although, to date, it has likely been a smaller threat than anthropogenic activities such as conversion for aquaculture and land filling (IUCN, 1989; Primavera, 1997; Valiela *et al*., 2001; Alongi, 2002; Duke *et al*., 2007), relative sea level rise is a substantial cause of recent and predicted future reductions in the area and health of mangroves and other tidal wetlands (IUCN, 1989; Ellison and Stoddart, 1991; Nichols *et al*., 1999; Ellison, 2000; Cahoon and Hensel, 2006; McLeod and Salm, 2006; Gilman *et al*., 2006, 2007a,b).

The sea level rise has high possibility to affect the floral and faunal spectrum of coastal and estuarine regions. The mangroves, being the primary coast guard in the estuarine and coastal systems, are the first to bear the effect of sea level rise. According to Field (1995) sea level rise is the greatest climate change challenge that mangrove ecosystems will face. Geological records indicate that previous sea level fluctuations have created both crises and opportunities for mangrove communities, and they have survived or expanded in several refuges (Field, 1995). Researchers have observed that migration of mangroves in a fragile environment (towards sea) often causes mortality due to stresses caused by a rising sea level such as erosion resulting in weakened root structures and falling of trees and increased salinity (Naidoo, 1983; Ellison, 1993, 2000, 2006; Lewis, 2005). Mangroves migrate landward *via* seedling recruitment and vegetative reproduction as new habitat becomes available landward through erosion, inundation, and concomitant change in salinity (Semeniuk, 1994). Depending on the ability of individual mangrove species to colonize newly available habitat at a rate that keeps pace with the rate of relative sea level rise (Field, 1995; Duke *et al*., 1998; Lovelock and Ellison, 2007), slope of adjacent land and presence of obstacles to landward migration of the landward mangrove boundary (seawalls, roads etc.), some mangroves will gradually be reduced in area, may get restricted to a narrow fringe, or face mortality. The mangrove dominated deltaic Sundarban is noted for intense erosion in and around a number of islands and hence mangrove afforestation programmes are undertaken on a regular basis by the Government departments to stabilize the mudflats encircling these islands.

High water event is another major associate of climate change that has significant adverse impact on coastal ecosystems. Projected increases in the frequency of high water events (Church *et al*., 2001, 2004) could affect mangrove health and composition due to changes in salinity, recruitment, inundation, and changes in the wetland sediment budget (Gilman *et al*., 2006). Storm surges can also flood mangroves and, when combined with sea level rise, lead to mangrove destruction. Flooding, caused by increased precipitation, storms, or relative sea level rise may result in decreased productivity, photosynthesis, and survival (Ellison, 2000). Inundation of lenticels in the aerial roots can cause the oxygen concentrations in the mangrove to decrease, resulting in death of the tree (Ellison, 2004). Inundation is also projected to decrease the ability of mangrove leaves to conduct water and to photosynthesize (Naidoo, 1983).

Since 1880, the Earth has warmed 0.6-0.8° C and it is projected to warm 2-6° C by 2100 mostly due to human activity (Houghton *et al*., 2001). Mangroves are not expected to be adversely impacted by the projected increases in sea temperature (Field, 1995). Most mangroves produce maximal shoot density when mean air temperature rises to 25°C and stop producing leaves when the mean air temperature drops below 15°C (Hutchings and Saenger, 1987). At temperatures above 25°C, some species show a declining leaf formation rate (Saenger and Moverly, 1985). Temperatures above 35°C have led to thermal stress affecting mangrove root structures and establishment of mangrove seedlings (UNESCO, 1992). At leaf temperatures of 38-40°C, almost no photosynthesis occurs (Clough *et al*., 1982; Andrews *et al*., 1984). Some scientists have suggested that mangroves will move pole ward with increasing air temperatures (UNEP, 1994; Field 1995;

Ellison, 2005). Although it is possible that some species of mangroves will migrate to higher latitudes where such range extension is limited by temperature. Woodroffe and Grindrod (1991) and Snedaker (1995) suggest that extreme cold events are more likely to limit mangrove expansion into higher latitudes.

The oscillation of temperature also affects the mangrove photosynthesis. An optimum temperature range exists for mangroves in which the glucose synthesis exhibits maximum value, but this range is not strictly uniform for all the mangrove species. Andrews and Muller (1985) have shown that the rate of photosynthesis is much reduced at higher leaf temperatures. In few mangrove species examined so far the rate of photosynthesis appears to be relatively unaffected by leaf temperature over the range 17^0C to 25^0C, but falls sharply at temperatures much above 35^0C and is close to zero at 40^0C. In Florida mangroves, little or no photosynthesis occurred at 40°C and the temperature optima for photosynthesis was below 35°C (Moore *et al*., 1972). There are some views regarding the influence of leaf temperatures on the process and rate of mangrove photosynthesis. According to Andrews *et al*. (1984) high leaf temperatures may influence photosynthesis indirectly through its effect on the vapour pressure deficit between the leaf and its environment. Considering the community structure of mangrove flora, the effect of rising temperature is, however, different in some regions. Increases in temperature are predicted to benefit Pacific Islands Developing Countries (PIDC), because warming is projected to increase the diversity of marginal mangroves at higher latitudes, currently home to only *Avicennia* species (Burns, 2001). In the Pacific Islands, warming is projected to facilitate mangrove expansion into salt-marsh communities (Burns, 2001). Mangrove species in China have demonstrated varying thermal tolerances. Li and Lee (1997) divided the mangrove species in China into three classes based on thermal tolerance: 1) cold-resistant eurytopic species (*e.g.*, *Kandelia candel*, *Avicennia marina* and *Aegiceras corniculatum*); 2) cold-intolerant (thermophilic) stenotopic species (*e.g.*, *Rhizophora mucronata*, *R. apiculata*, *Lumnitzera littorea*, *Nypa fruticans* and *Pemphis acidula*); and 3) thermophilic eurytopic species, (*e.g.*, *Rizophora stylosa*, *Bruguiera sexangula*, *B. gymnorrhiza*, *Excoecaria agallocha* and *Acrostichum aureum* (Zhang and Lin, 1984).

Atmospheric CO_2 has increased from 280 parts per million by volume (ppmv) in the year 1880 to nearly 370 ppmv in the year 2000 (Houghton *et al*., 2001) and this trend will continue due to intense industrialization and urbanization through out the globe. Researchers, however, state that most atmospheric CO_2 resulting from burning of fossil fuels will be absorbed into the ocean affecting ocean chemistry. According to UNEP (1994), the efficiency of mangrove water use will be enhanced, and there will be specific species variation in response to elevated CO_2. Due to the increase in water use efficiency, mangroves in arid regions may benefit because decreased water loss *via* transpiration will accompany CO_2 uptake (Ball and Munns, 1992). Increased salinity may, however, pose hindrance to this benefit. If salinity increases in arid regions, then this advantage may be lost, because increases in CO_2 do not affect mangrove growth when salinity is too high for a species to maintain water uptake (UNEP, 1994). Increases in CO_2 are not likely to cause mangrove canopy photosynthesis to increase significantly (UNEP, 1994). Several scientists, however, documented the positive influence of rising CO_2 on mangrove vegetation. In an experiment aimed to test the effects of humidity, salinity, and increased CO_2 on two Australian mangrove species, *Rhizophora stylosa* and *Rhizophora apiculata*, the rate of photosynthesis showed significant increase with increased levels of CO_2 (Ball *et al.*, 1997). In this experiment, the mangroves were grown in glasshouses for 14 weeks with different combinations of atmospheric CO_2 (340 and 700 ppm), relative humidity (43% and 86%), and salinity (25% and 75% of seawater) to determine the effects of these variables on their development and growth (Ball *et al.*, 1997). Although *Rhizophora stylosa* has a slower relative growth rate and greater salt tolerance than *Rhizophora apiculata*, the scientists concluded that elevated CO_2 significantly increased rates of net photosynthesis in both mangrove species, but only when grown at the lower salinity level. In addition, while increased CO_2 levels did not significantly affect the relative growth rate of either species, the average growth rates of both species increased with atmospheric CO_2 enrichment in the lower salt environment (Ball *et al.*, 1997). These scientists postulated that increased levels of CO_2 might allow these two mangrove species to expand into areas of greater aridity, thus increasing species diversity in those regions. Farnsworth *et al.* (1996) analyzed the effects of doubled levels of CO_2 on *Rhizophora mangle* seedlings. The seedlings demonstrated significant increases in biomass, total stem length, branching activity, and total leaf area compared to seedlings grown in normal levels of CO_2.

4. Current Management Practices

4. Current management practices

4.1 Human-wildlife conflict

4.1.1 Current management practices to mitigate human-crocodile conflicts:

The management practices adopted by Forest Department, West Bengal to mitigate human-crocodile conflicts are:

1. The information of crocodile straying to village is promply attended by the Forest Department staff. The strayed crocodiles are captured primarily with the help of nets and are released back in wild (Annexure 3).
2. Most of the crocodile attacks on people take place outside the forest areas, mainly near villages, where crocodiles take opportunity to attack the people engaged in fishing or tiger prawn seed collection inside the river water or near the river banks. Forest Department provides an ex-gratia of Rs. one lakh to the dependents of victim.

4.1.2 Current management practices to mitigate human-shark conflicts:

The human-shark conflicts in Sundarban is little known and currently there no management intervention of Forest Department to mitigate human-shark conflictiss.

4.1.3 Current management practices to mitigate human-tiger conflict:

Human-wildlife conflict is age old in Sundarban and is the biggest challenge to the Forest Department. The organizational structure of Forest Department in Sundarban and the management practices being used to mitigate human-wildlife conflict are given below.

Organizational structure of Forest Department in Indian Sundarban:

The administration of Indian Sundarban is headed by Director, Sundarban Biosphere Reserve, an officer of the Chief Conservator of Forest (CCF) rank. The entire Sundarban Biosphere Reserve forest is divided in two management units namely, Sundarban Tiger Reserve in the eastern part and 24 Parganas (South) Division in the western part of Indian Sundarban. Following figure shows the organizational structure of Indian Sundarban management (Figure 4):-

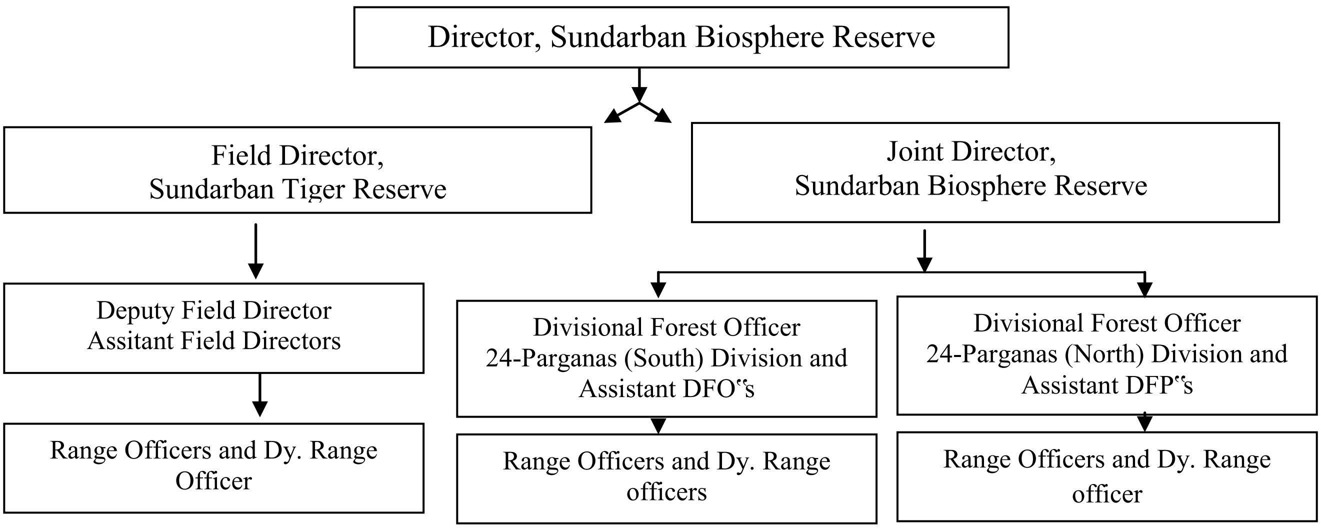


Fig. 4- Organizational structure of Sundarban Biosphere Reserve

The management interventions to mitigate human-wildlife conflict currently in vogue are:

4.1.3. (A) Management interventions to mitigate tiger attacks on human, inside the Sundarban forest:

1. Regulation of people‟s entry or Protection of Sundarban forest

The Core Zone of Sundarban Tiger Reserve as well as the three sanctuaries of Sundarban namely Saznekhali, Lothian and Haliday Wildlife Sanctuary are "no fishing and no honey collection zones". A large number of tiger attacks do take place in Core Zone and Saznekhali Wildlife Sanctuary of Sundarban Tiger Reserve as fishermen and honey collectors illegally enter in these areas and become victim of tiger attacks. There are no tigers in Lothian and Haliday Wildlife Sanctuaries. Forest Department, Government of West Bengal has given special attention to the protection of Sundarban and a large number of new protection camps have been established in last decade. Some of the major management interventions to effectively patrol the area are:

I. Patrolling is performed by using boats and speed boats to cover various water channels and creeks in search of intruders.

II. In last 10 years, six new protection camps have been established at Burirdabri, Katuajhuri, Chamta, Baghmara, Bonnie and at Kalash. Two new protection camps at Mayadwip and Harinbhangha are under construction.

III. "Floating Check posts" and "Floating Camps" have been established to prevent illegal entry of people in protected areas of Sundarban.

IV. Forest Protection Committees (FPC) and Eco-Development Committees (EDC) have been formed for participatory management.

V. Joint Patrolling with BSF and Special Armed Police (SAP) Battalions are made regularly.

2. Regulation of fishing and honey- collection

Fishing is the second most important livelihood in Sundarban after agriculture. The entry of fisherman in Sundarban is regulated against a permit issued by Forest Department called "Boat License Certificate" (BLC) which is non-transferable and renewed annually. Fishing is closed for a period of 3 months from April – June, which is the spawning time of the fishes. This also coincides with the honey collection period. Fishing activities also includes the crab catching. A typical fishing party consists of the BLC owner and 6-8 co-fishermen or 2-3 persons in case of crab collectors. A permit is given for entry into the area (multiple use area only) against a token fee for a specified time period. The core area (which includes National Park also) and three wildlife sanctuaries are out of bound zones for fishing and honey collection. Fishermen, in spite of having knowledge about the non-fishing zone enter there for the lure of high fish catch. The total fishing "BLC" in the Sundarban are given in Annexure 6.

Honey Collection is a seasonal activity which starts from the end of March to beginning of June. Rock bees from the Himalayas visit the Sundarban forest every year and make bee-hives in the mangrove plants. Most of the mangrove flowers are highly nectar bearing. This attracts the rock bee (*Apis dorsata*) to visit Sundarban during summer months which is the main flowering season. Flowering starts with the bloom of *Aegiceras corniculatum* during end of March and is followed by the flowering of *Acanthus ilicifolius*, *Sonneratia apetala*, *Rhizophora* spp and *Avicennia* spp. etc. The traditional honey collectors are known as 'Moulis" but other people also join the honey collection parties for the quick money in short time as well as for the reason that there is no fishing during this period. The West Bengal Forest Development Corporation (WBFDC) is the main buyer of honey. The WBFDC in consultation with the Forest Department fixes the yearly targets of honey collection and price for honey purchase. Based on these targets, the permits (Boat License certificates or BLC) are given by Forest Department to Moulis with individual targets. In each permit 6 - 10 people are allowed to enter the forest areas. Honey collection involves serious risk to honey collector as well as to wildlife as this is the only activity in which people enter the forest land on foot (Plate 13).

3. Fresh water ponds

Sundarban has no fresh water and all its wildlife depends on saline water to meet its water requirement. It was generally believed that Sundarban tiger is aggressive in nature due to drinking saline water

(Hendrichs, 1975: Chakrabarty, 1979). Based on this observation fresh water ponds were dug up in various places in Sundarban (Plate 48). A list of fresh water ponds of Sundarban is given as (Annexure 10) These ponds are now primarily used for ecological monitoring.

4. Human face mask and electrified human dummies

In the 1980‟s‟‟s experiment to put human mask on the back side of human face were started with a belief that tiger which generally attack human when they are not alert will refrain from attacking them due to staring eyes of the mask. The human face mask became very popular due to its uniqueness and the pictorial impression it created. However, no scientific study could prove conclusively that the fisherman wearing the mask could be actually benefitted. The fact that fisherman and honey collectors also do not wear the human mask on their own in spite of free availability from Forest Department indicating that the user do not find them effective. Currently the face mask practice has been reduced to a ritual, when the honey collectors are provided the masks once in a year but they wear the same only when being watched by forest officials. Fishermen do not wear these masks at all. The electrified human dummies have also lost their relevance as the wood cutting operations of Forest Department has been discontinued since 2001.

5. Compensation (Ex-gratia payment) to the tiger victims dependents

The practice of grant of compensation goes back to 1996 when Government of West Bengal vide Order No. 5862-FOR, 11B-32/88 dated 20.09.1996 approved an *ex-gratia* grant of Rs. 7500.00 to the victims or to the legal heirs of the victims of the depredation caused by wild animals. The *ex-gratia* has been revised from time to time and now Rs. 1.00 lakh is provided to the dependents of the tiger victims. However this compensation is not provided to the dependents of persons killed by tiger inside the non-fishing and non-honey collection zones including the core area of Sundarban tiger reserve. The people injured are provided free medical treatment and compensation depending upon the nature of injury.

4.1.3. (B) Management interventions to mitigate tiger straying from Sundarban forest to fringe villages

Tiger straying has been treated as the most important management activity by Forest Department as in every village the dependents of tiger victims treat it as an opportunity for revenge. The strayed tiger in Pakhiralaya village under Saznekhali Range of Sundarban Tiger Reserve in July 2001 and at Kishorimohanpur village in Raidighi Range of 24 Parganas (South) Division in October, 2001 were killed mercilessly by villagers (Annual Reports Sundarban Tiger Reserve and 24 Parganas (South) Division, 2001 (Plate 14a and Plate 14b). Currently some of the methods adopted in Sundarban to mitigate the problem of tiger straying are discussed below in detail.

1. Nylon Net Fencing

In order to prevent tigers to stray out of forest, a newly designed “Nylon Net Fences” have been raised along the forest – village interface (Plate 15). This Nylon Net fence is made of 4 mm polypropylene rope, knitted with 6 inch square mesh and is of 7 ft. height on ground. These nets are raised by using local fencing post and galvanized iron wire runners. The Nylon Net Fences acts both as a psychological and physical barrier. Earlier a vegetative fence of *Ceriops decandra* sticks, locally known as “Chitta Garan” was used for the same purpose but it was not effective due to short life and extreme maintenance difficulties. The entire 63 km long forest–village interface of Sundarban Tiger Reserve has been divided in very high and high priority areas with about 50 km in high priority category. A 52 km nylon net fence has been raised since 2001 in Sundarban Tiger Reserve. In 24 Parganas (South) Division also 30 km nylon net fences have been raised. Thus a total of 82 km nylon net fence has been raised in Sundarban to prevent straying by tiger. The nylon net fence maintenance is a serious problem as the numerous creeks in mangrove forest with about 6 hours diurnal tidal cycle poses problems.

2. Immobilization Teams

In contrast to the situation about a decade back when there was only one immobilization team with just one expert to carry out the immobilization operations, the Forest Department now has five such teams (Plate 16). These teams are equipped with speed boats and immobilization equipments. In addition, the trap and translocation cages are also used to deal with the situation. However, these teams do not function as dedicated teams and are required to perform various other jobs as well.

3. People"s Participation for human-tiger conflict mitigation

The government resolution to involve the local communities in the management of reserve forest of Sundarban by forming Forest Protection Committee (FPC) was issued by the Government of West Bengal in the year 1991. Another government resolution was issued by Government of West Bengal in 1996 to involve the people living in the fringes of protected areas in Sundarban by forming Eco-Development committees (EDC). In the year 2008, another government resolution was issued which has re-designated all the Forest Protection Committee and Eco-Development Committees as Joint Forest Management Committees (JFMC). Since the issuance of these resolutions a total of 14 Eco-Development Committees and 51 Forest Protection Committees or 65 JFMC"s have been registered involving a large section of fringe population (Annexure 16). An eco-development programme to facilitate and provide alternate livelihood to the committee members has also been taken up by Forest Department (Plate 17). These eco-development activities include rainwater harvesting for irrigation, ponds, deep tube wells, brick roads, plantations for fuel-wood and fodder, smokeless ovens, solar lights, jetties, pisciculture, piggery, goatery, poultry etc. (Annexure 14)

4. Prey-base enrichment

It is generally believed that the shortage of prey in forest results in tiger straying as the hungry tigers not only kills human beings inside the Sundarban but also stray to villages to kill and eat the cattle (Sanyal, 2001). A wild boar farm was set up for periodic release of pigs in such periphery during peak straying period which showed salutary effects (Sanyal, 2001). Based on the recommendations of the West Bengal Wildlife Advisory Board, Forest Department has started acclimatization of captive bred medically fit spotted deer of various deer parks of state with an intention to release the next generation in mangrove forests. In the year 2010 a herd of 72 deer was released in Sundarban Tiger Reserve at Dobanki under the Saznekhali Range of Sundarban Tiger Reserve. Similarly acclimatized spotted deer has been released in Herobhanga and Ajmalmari forests of 24 Parganas (South) Division in the year 2010.

5. Behavioral studies of Sundarban tiger

In the year 2004, in order to address the tiger straying problem scientifically, a project to study the behavior and ecology of Sundarban tiger was initiated under the title "A Study on the Behaviour, Home Range and Ecology of the tiger in the Sundarban of India", which was approved by Director Project Tiger vide letter No. 1-3/93-PT (Part) dated 21-06-2004. Later, to provide a solution to the information gap for the population monitoring under the "All India Tigers, Co-Predators, Prey and Habitat Monitoring" organized by Project Tiger (now NTCA), Wildlife Institute of India also joined the project. Since then a total of 6 tigers have been radio collared with satellite based and GPS collars. Of these 6 tigers two were strayed tigers. The outcome of this scientific study might help in providing the valuable inputs for the mitigation of the human-tiger conflict in Sundarban (Plate 17).

6. Development of methodology for the estimation of prey base in Sundarban

Currently there exists no scientific methodology for the estimation of prey base in Sundarban. The existing methods cannot be applied on Sundarban due to its marshy terrain with highly aggressive tigers. As there is always a belief that shortage of prey base is the primary cause of tiger straying, it is important to have a scientific estimation of prey base. Forest Department has undertaken a study with WWF, India (Sundarban Programme) to develop the prey base estimation methodology.

4.2 Current management practices to regulate the salinity-mangrove interaction

4.2.1 Management practices to reduce salinity

In order to minimize saltwater migration, river basin commissions provide low-flow augmentation and water conservation requirements during periods of low flow. Freshwater from rainfall is stored in large surface reservoirs and released continuously during droughts to maintain a flow that helps repel the saltwater from migrating upstream. These planning agencies recognize the need to sustain stream flows to protect freshwater intakes, instream uses (including fish migration and fish production), and shellfish beds, as well as treated-waste assimilation, recreation, and salinity repulsion. An economic justification is usually necessary, showing that the cost of the mitigation is less than the anticipated benefits.

Rising sea level increases the salinity of both surface water and ground water through salt water intrusion. The island dwellers of Sundarban obtain mostly their resources (like fishes, crabs, prawn seeds etc.) from estuarine waters, where the salinity may increase due to salt water intrusion from Bay of Bengal. Salinity increases in estuaries also can harm aquatic plants and animals that do not tolerate high salinity.

Shallow coastal aquifers are also at risk (IPCC, 2007). This may pose threat to drinking water budget as the tube wells in Sundarban draw water from these aquifers.

Canals excavated by Forest Department, Sundarban Development Board, Fishery Department and several NGOs store rain water in the midst of saline land for promoting fishery as alternative livelihood. This is, however, a good management practice as the fresh water from these canals percolate vertically and horizontally and thereby decreases salinity.

4.2.2 Management practices to promote mangrove growth

Extensive development of mangroves has occurred in the estuaries of large rivers flowing over shallow continental shelves, such as the Ganges in Bangladesh, Fly River in Papua New Guinea, and the Mekong Delta in Vietnam. The Amazon and Congo, the two largest rivers in the world, do not have extensive stands of mangroves primarily because of the huge outflow of freshwater. The following factors are considered to be the major determinants of mangrove distribution:

A. **Climate:** Mangroves are tropical species and are not tolerant of freezing temperatures. Their latitudinal limits worldwide vary depending on air and water temperatures (Sherrod & McMillan 1985; Tomlinson 1986; Sherrod *et al*. 1986; Waisel 1972;). The abundance of mangroves is also affected by aridity, and development is much greater along coasts that have high inputs of rainfall (Macnae 1968; Golley *et al.* 1975). The present study area receives an average annual rainfall of 1920 mm and is therefore ideal for mangrove growth. The freshwater input of Hooghly-Bhagirathi river system increases the dilution factor of the estuarine system in the western sector, which promotes mangrove growth particularly *Sonneratia apetala*, *Nypa fruticans* and *Brugueira* spp etc.

B. Salinity: Salt is generally not a requirement for growth, since most mangroves can grow in freshwater (Tomlinson 1986; Ball 1988). However, they do not develop in strictly freshwater habitats because of competition from freshwater species. Salinity is thus important in eliminating other vascular plant species that are not adapted for growth in a saline habitat. In Indian Sundarban due to presence of two drastically different ecological units (western zone with relatively low salinity) and central zone (with high saline environment), the growth of mangrove species varies. Species like *Sonneratia apetala*, *Nypa fruticans* and *Brugueira* spp. has preference for low salinity and this salinity preference has been followed in the plantation programme of Nayachar island, just in the northern upstream of Sundarban. The fresh water loving species have exhibited unique growth in this island and the ecological stability has been achieved.

C. Tidal fluctuation: Tidal influence is also not a requirement, but plays an important indirect role:

a. Inundation with saltwater helps exclude most other vascular plants and reduces competition.

b. Tides bring saltwater up estuaries against the outflow of freshwater and extend mangrove development inland.

c. Tides transport sediment, nutrients, and clean water into the mangrove environment and export organic carbon and reduced sulfur compounds.

d. Where evaporation is high, tides help flush soils and decrease salinity.

The tidal influence is observed in every island of Sundarban, and therefore the present geographical locale is mangrove dominated. However the construction of embankments to guard the island villages of Sundarban hinders the natural tidal flow.

D. Sediment and wave energy: Mangroves grow best in a depositional environment with low wave energy. High waves prevent propagule establishment, expose the shallow root systems, and prevent accumulation of fine sediments. Accordingly Chemaguri island, Thakuran char have yielded good results in terms of mangrove growth.

4.3 Current management practices to reduce the impact of climate change

Mangroves have strong power of resistance against all odds. These halophytes have been able to persist through the quaternary despite substantial disruptions from large sea level fluctuations, demonstrating that mangroves are highly resilient to change over historic time scales. However, over coming decades, mangrove vulnerability and responses to climate change will be highly influenced by anthropogenic disturbances, including direct sources of degradation such as clearing and filling, and human responses to climate change that adversely affect mangroves. Many of these threats are extremely localized (*e.g.*, the tiger prawn seed catch in Sundarban that destroys millions of fish juveniles of other species) and can only be tackled through local level awareness. The dragging of nets along the shore for trapping tiger prawn seeds uproots the mangrove seedlings on the mudflats.

To reduce the risk of adverse outcomes from predicted mangrove responses to projected climate change, adaptation activities can be introduced as an attempt to increase the resistance and resilience of ecosystems to climate change stressors. Some of these approaches are summarized here.

4.3.1 Management of activities in catchments regulating mangrove sediment

In order to accelerate the resistance of mangroves to sea level rise relative to the mangrove sediment surface, activities within the mangrove catchments can be managed to minimize long-term reductions in mangrove sediment elevation, or enhance sediment elevation. For instance, limiting development of impervious surfaces within the mangrove catchments and managing rates and locations of groundwater extraction can reduce alteration to natural groundwater recharge to the mangrove systems, which might be an important control on mangrove elevation. Also, avoiding and limiting human activities that reduce mangrove soil organic matter accumulation, such as the diversion of sediment inputs to mangrove systems, nutrient and pollutant inputs into mangroves, and mangrove timber harvesting can contribute to maintaining relatively natural controls on trends in sediment elevation. Depending on the tree species and nutrient added, nutrient enrichment can affect mangrove productivity by changing root production and organic material inputs thereby changing the rate of change in sediment elevation. Enhancement of mangrove sediment accretion rates, such as through the beneficial use of dredge spoils, could augment mangrove sediment elevation, but would need to avoid excessive or sudden sediment deposition.

Management activities are not similar everywhere, rather they are site specific depending on the pattern of threats and needs of the local inhabitants. In Indian Sundarban region dragging of nets along the shore to trap tiger prawn seeds disturbs the underlying sediment bed and often uproots mangrove seedlings (Fig.5).

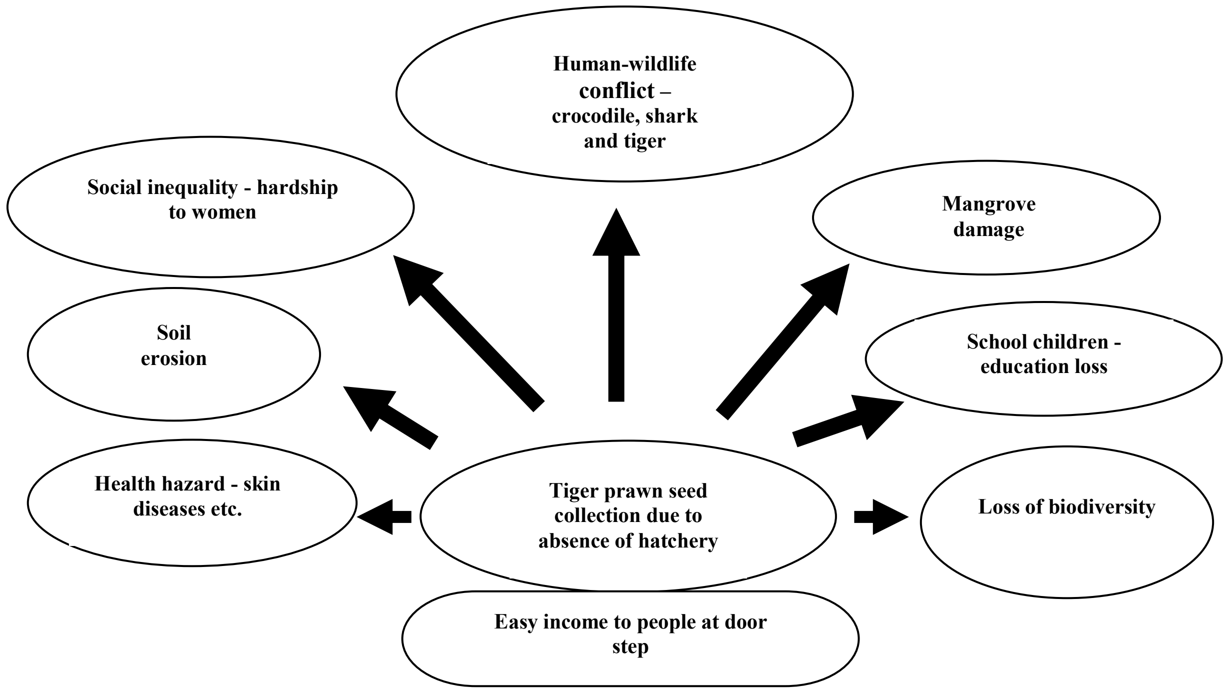


Fig. 5 – Flow chart showing the impact of tiger prawn seed collection

A considerable fraction of the island dwellers are involved in this job as there is great demand of tiger prawn seeds for the local level culture. Such activities have been banned through implementation of laws and providing alternative livelihood to the prawn seed collectors.

Collection of sandy sediments from beach for construction related activities is another major threat witnessed in the lower stretch of Gangetic delta that not only reduces the elevation of the sediment bed, but also changes the pattern of canalization of water in the bed from the adjacent estuary and bay. Such destructive activities need to be stopped through implementation of strict laws involving port authorities, coast guard and local political parties in the loop. However, no specific laws are there to prevent this local level human induced damage.

4.3.2 Management of coastal activities through policy implementation

Site planning for some sections of shoreline containing mangroves, such as areas that are not highly developed, may facilitate long-term retreat with relative sea level rise. "Managed retreat" concept involves implementing land-use planning mechanisms before the effects of rising sea level become apparent, which can be planned carefully with sufficient lead time to enable economically viable, socially acceptable and environmentally sound management measures. Coastal development could remain in use until the eroding coastline becomes a safety hazard or begins to prevent landward migration of mangroves, at which time the development can be abandoned or moved inland. Adoption of legal tools, such as rolling easements, can help make eventual abandonment more acceptable. Zoning rules for building setbacks and permissible types of new development can be used to reserve zones behind current mangroves for future mangrove habitat. Managers can determine adequate setbacks by assessing site-specific rates for landward migration of the mangrove landward margin. Construction codes can plan for mangrove landward migration based on a desired lifetime for coastal development. Any new construction of minor coastal development structures such as sidewalks and boardwalks, could be required to be expendable with a lifetime based on the assessed sites‟ erosion rate and selected setback. Rules could prohibit construction of coastal engineering structures, which obstruct natural inland migration of mangroves. This managed coastal retreat will allow mangroves to migrate and retain their natural functional processes. Coastal zones and water fronts are extremely delicate systems in terms of vulnerability to sea level rise. These zones also need a congenial environment for the mangroves to grow, thrive and act as effective bioshield.

Keeping in view the degradation of the coastal environment and rampant construction activities along the coastal areas of Indian sub-continent, the Ministry of Environment and Forests (MoEF), Government of India issued a draft Coastal Regulation Zone (CRZ) notification twice inviting suggestions and objections from the public on the 27th June, 1990 and 18th December, 1990. Based on the suggestions and objections received, the MoEF issued the CRZ notification declaring coastal stretches as CRZ and regulating activities in the CRZ. As per this, the CRZ area is defined as coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side). As per the notification, 500 meters on the landward side from the High Tide Line (HTL) and the land area between the Low Tide Line (LTL) and HTL including 500 meters along the tidal influenced water bodies subject to a minimum of 100m on the width of the water body, whichever is less is declared as CRZ area. Based on the ecological sensitivity, geomorphological feature and demographic distribution, the CRZ area has been classified into four categories namely, CRZ-I (sensitive and inter-tidal), CRZ II (urban or developed), CRZ-III (Rural or undeveloped), CRZ-IV (Andaman & Nicobar and Lakshadweep Island).

The notification regulates developmental activities in the CRZ area by prohibiting certain activities and permitting the essential activities. The prohibited activities include setting up of new industries and expansion of existing industries, manufacture or handling or storage and handling of hazardous substances (except specified petroleum products in port areas), fish processing units, disposal of wastes and effluents, mining of sands, rocks and other rare minerals and mechanized withdrawal of ground water. The permissible activities include those activities that require water front and foreshore facilities such as construction activities related to defense requirements for which foreshore facilities are essential (e.g. Slipways, jetties, etc.), operational construction for ports and harbours and construction of hotels and resorts in specified areas.

After the issue of the CRZ notification with the aim to protect and preserve the coastal ecosystems, many of the developmental activities were hindered in several of the maritime states. The Ministry of Environment and Forests has been receiving series of proposals from coastal States/Central Ministries, industry associations, local communities and NGOs requesting for amendment to CRZ notification on certain specific issues. The Ministry, after examining the proposals, had constituted committees to examine the specific issues. Based on the recommendations of the committee/ request made by the various agencies, the Ministry had amended the CRZ Notification, 1991 as per the provisions laid down in the Environment (Protection) Act, 1986. Some of the amendments constituted to look into specific issues are:

- SO 595(E), dated August 18th 1994- Relaxed Coastal Regulation Zone area to 50 meters along the tidal influenced water bodies. This was based on the BB Vohra Committee‟s report. However, the Supreme Court of India in the Writ Petition 664 of 1993 quashed the above amendment.
- SO 73(E), dated 4th August, 2000- Permitted storage of LNG in the inter-tidal area and exploration and extraction of oil and gas in Coastal Regulation Zone areas.

- SO 550 (E), dated 21st May, 2002- Permitted non-polluting industries in the Coastal Regulation Zone area of special economic zones. Housing schemes of State Urban Development Authorities initiated prior to 19.2.1991 was also permitted.
- SO 110(E), dated 19th October, 2002- Permitted non-conventional energy facilities, desalination plants, air strips in Coastal Regulation Zone of Andaman and Nicobar and also of Lakshadweep islands. Storage of non-hazardous cargo such as edible oil, fertilizer and food grain was also permitted.
- SO 460 (E), dated 22nd April, 2003- Project costing more than Rs. 5 crores requires clearance from Ministry of Environment and Forests.
- SO 636(E), dated 30th May, 2003- Permitted construction of embarkation facilities for Lakshadweep in Coastal Regulation Zone- I areas.

5. Methodology

5. Methodology

Sundarban ecosystem is subjected to various anthropogenic pressures affecting its natural resources and the fine balance between various components of ecosystem. As it is not possible to study all categories of threats to Sundarban ecosystem within this study, a survey was done to identify the dominant threats. “Opinion Forms” were given to the three diverse interest groups of people linked to Sundarban which are the (1) Forest Protection Committee and Eco-Development Committee members in the fringes of Sundarban forest and part of local community (Plate 11) (2) Members of some Non-government organizations (NGO) working in Sundarban and (3) The research scholars and post graduate students of Calcutta University. The “Sample Opinion Form” is attached as “Annexure 1”. The study revealed “human-wildlife conflict” (24.35%), “change in salinity” (19.93%) and “climate change” (18.82%) were the first three major threats to Sundarban (Table 31 and Fig. 29). In addition “pressure on natural resources” (16.61%), “prawn seed collection” (11.44%), and “environmental and water pollution” (8.86%) were also mentioned as threats to Sundarban. The prawn seed collections as well as pressure on natural resources are also linked to the major three threats identified through this opinion survey. Accordingly “human-wildlife conflict”, “change in salinity” and “climate change” have been chosen for the purpose of this study. The study area of the current study is the Indian Sundarban forest areas and its fringes. The detailed methodology for all the three major threats identified has been discussed in respective chapters.

5.1 Human-wildlife conflict

The methods adopted to evaluate the human wildlife conflict in the framework of Indian Sundarban are highlighted below:

5.1.1 Study of old and current records

The old records on human-wildlife conflict were consulted by studying the working plans / management plans of Forest Department, district gazetteers and other related research papers. The current management practices and records of human-wildlife conflicts have also been reviewed to find the ongoing management practices to mitigate the human-wildlife conflict.

5.1.2 Primary and secondary data collection

In order to collect primary data on human-wildlife conflict issue, FPC"s and EDC"s were randomly pooled and administered the questionnaire. The past experiences of the island dwellers on human killing (profession-wise) by wild animals were also documented to analyse the spatial and temporal variations of the conflict.

Tiger straying in Sundarban is not only a human-wildlife problem, but also a most serious issue to be handled by the Forest Department. Secondary data on tiger straying was collected since 1986 to 2009 through months, seasons and zones.

5.1.3 Statistical analysis

Correlation coefficient (r) was computed to investigate the inter-relationship between human death and injury during the event of human-wildlife conflict. Acase study of tiger has been included because of the severity and magnitude of tiger attack compared to other wild animals. The data sets on human-tiger conflict (which encompasses death, injury and straying) have been subjected to ANOVA to find spatial (zone-wise) and temporal variations of the tiger attack.

5.1.4 Analysis of management practices and recommendations

The current management practices to mitigate human-wildlife conflicts have been addressed keeping all factors (like seasonal, temporal, spatial and hourly variations) and statistical results into considerations.

5.2 Impact of salinity on mangroves

Salinity has a crucial role on the distribution pattern and growth of mangroves. With this background the biomass and relative abundance of dominant mangrove species were studied in the deltaic complex. On the basis of relative abundance three dominant mangrove floral species namely *Sonneratia apetala, Avicennia alba* and *Excoecaria agallocha* were identified for the study. The methods that were adopted for studying this section are discussed in brief.

5.2.1 Selection of study area

The mighty River Ganga emerges from the Himalayas and flows down to the Bay of Bengal covering a distance of 2525 km. At the apex of the Bay of Bengal a delta has been formed which is recognized as one of the most diversified and productive ecosystems of the tropics and is referred to as Indian Sundarban. The deltaic complex has a Biosphere Reserve area of 9630 sq. km and houses 102 islands. The western sector of the deltaic lobe receives the snowmelt water of mighty Himalayan glaciers after being regulated through several barrages on the way. The central sector on the other hand, is fully deprived from such supply due to heavy siltation and clogging of the Bidyadhari channel in the late 15th century (Chaudhuri and Choudhury 1994). Such variation caused sharp difference in salinity between the two sectors (Mitra et al. 2009). Ten sampling sites were selected in this geographical locale (Table 22). The stations in the western part (stations 1 to 5) lie at the confluence of the River Hooghly (a continuation of Ganga-Bhagirathi system) and Bay of Bengal. In the central sector, the sampling stations (stations 6 to 10) were selected adjacent to tide fed Matla River. Study was undertaken in both these sectors during low tide period through three seasons (pre-monsoon, monsoon and post-monsoon) from 2008 to 2010.

In each sector, plot size of 10m × 10m was selected and the average readings were documented from 15 such plots. The mean relative density of the selected species was evaluated for relative abundance of the species.

5.2.2 Monitoring surface water salinity

The surface water salinity was recorded through seasons by means of an optical refractometer (Atago, Japan) in the field (Plate 12) and cross-checked in laboratory by employing Mohr- Knudsen method. The correction factor was found out by titrating the silver nitrate solution against standard seawater (IAPO standard seawater service Charlottenlund, Slot Denmark, chlorinity = 19.376 ‰). This method was applied to estimate the salinity of standard seawater procured from NIO and a standard deviation of 0.02% was obtained for salinity.

5.2.3 Tree biomass

Mangrove tree biomass is the sum total of above-ground biomass (AGB) and below-ground biomass (BGB). Compartment wise biomass was evaluated for the year 2008 – 2010 as per the procedure described below.

a. Above ground biomass estimation

The above ground biomass of the dominant mangrove species was estimated by summing up the biomass of stem, branches and leaves as per the method outlined in details by Mitra *et al* (2011).

b. Below - ground root biomass estimation

An excavation method (Bledsoe et al. 1999) was used to estimate root biomass of the same trees that were selected for above-ground biomass (AGB). According to the observation, very few roots in the sampling plots were distributed deeper than 1 m in sediments. Canopy diameter of these trees was usually smaller than 2 m. Most roots of the selected species were distributed within the projected canopy zone. Therefore, for below-ground biomass (BGB, referring to root biomass in this study), roots were excavated (of 2 trees/species) in 1 m depth within the radius of 1 m from the tree center. All the sediments within the sampling cylinder (2 m in diameter × 1 m in height) were excavated and washed with a fine screen to collect all roots. The roots were sorted into four size classes: extreme fine roots (diameter <0.2 cm), fine roots (diameter 0.2–0.5 cm), small roots (diameter 0.5–1.0 cm), and coarse roots (diameter >1 cm). Separation of live or dead roots was not done. The roots after thorough washing were oven dried to a constant weight at 80 ± 5^{0}C and biomass was estimated for each species.

5.2.4 Statistical analysis

The above - and below-ground biomasses were added to get the total biomass of the tree and finally correlation coefficients were performed to find the inter-relationship between biomass and salinity for each of the three species. ANOVA was performed to know the spatial and seasonal variations of mangrove biomass. All statistical calculations were performed with SPSS 9.0 for Windows.

5.3 Impact of climate change on Indian Sundarban

The phenomenon of climate change is a function of natural forces and anthropogenic activities. The later has increased greatly in recent times. The signature of climate change is felt even in the marine and estuarine sectors. Three very relevant indicators of climate change in context to deltaic Sundarban are aquatic salinity, water temperature and erosion pattern due to changes in sea level or current pattern. Data sets on these three indicators are basically secondary in nature, except the salinity and water temperature data during 2008 to 2010 that have been analysed in the present study (primary data). The methods that were adopted to evaluate these three indicators are discussed here in brief.

5.3.1. Surface water salinity

The surface water salinity was recorded in 10 selected stations by means of an optical refractometer (Atago, Japan) in the field and cross-checked in laboratory by employing Mohr- Knudsen method. These data were compared with the past data (from 1985 to 2007) as secondary source to evaluate the trend in salinity change. The Farakka discharge data was also collected (1999-2003) to assess the contribution of fresh water in the aquatic sub-system of Indian Sundarban.

5.3.2. Surface water temperature

The surface water temperature of 10 selected stations was measured during 2008 to 2010 by using 0^0 - 100^0 C mercury thermometer. The results were compared with the previous data and relevant literature was analysed to examine the trend in surface water temperature change in the present study area.

5.3.3. Erosion pattern

One of the important effects of climate change is the sea level rise which cause change in the shore line configuration due to erosion. The sea level rise in the present study area is 3.14 mm/year (Hazra, 2002) compared to global average of 2.67 mm/year. This condition has the possibility of eroding the land masses which has been analyzed by comparing the satellite data of 2009 with that of 1986.

The analysis of satellite imageries for the year 2005 and 2009 has been done with the data available in the GIS Cell of Working Plan and GIS Circle, Forest Department, Government of West Bengal.

Digitization of land area for each compartments including water body within one compartment was done from registered satellite imagery of respective years. Finally, for each block (consisting of several compartments), vector map and FCC maps were generated. As the resolution and the data collection period are different for the available data here, there are variations in area calculation. The land area of various years has been compared in order to provide the clear picture of the erosion pattern.

6. Results

6. Results

6.1 Human-wildlife conflict

6.1.1 Human-crocodile conflict

The aquatic phase of Sundarban is the habitat of the estuarine crocodiles (*Crocodylus porosus*) and their presence in the intertidal mudflats and near shore water is very common. These areas are also the zone of intense human activities in terms of fishing, crab collection, prawn seed collection etc. hence incidences of human-crocodile conflict are often reported. The data for human death and injuries by crocodile appears to be an underestimation. Till the year 2007 no compensation was paid to the dependents of crocodile victims in Sundarban Tiger Reserve, so they rarely approached the authorities. Moreover, all the human deaths by crocodile usually take place in the river-village interface outside the forest, hence crocodile victim"s families preferred not to report, as they got nothing in terms of compensation. In addition, at times traces of the victim body are not found and hence it is difficult to accept the death of the missing person due to crocodile attack. Now a compensation of Rs. 1,00,000 is paid to the dependents of the crocodile victim"s as is given to the victims of tiger attacks. It is very natural that now reports of death and injuries by crocodiles are reported to the Forest Department to claim compensation. The results of such conflict are highlighted below:

1. It is observed that human-crocodile conflict in Sundarban is a low key affair which draws less attention as compared to human-tiger conflict, magnitude of which is very high.

2. The data indicates that a majority of the human death and injuries by crocodile were of prawn seed collectors during the period 1999 to 2009. A similar observation has been made by another researcher for a period 1997 to 2000 (Das, 2002).
3. The large scale prawn seed collection and over-fishing are responsible for low availability of fish in Sundarban. The faulty prawn seed collection method results in large scale destruction of larvae and eggs of shell fish and finfish as they are thrown on mud-flats to perish (Plate 18). The rapid increase in human population (a section of which depends on fishing and crab collection), has resulted in over-exploitation of fish wealth, the primary food of crocodiles. The non-availability of food in Sundarban streams encourages crocodiles to attack humans.
4. As a large number of people wade through the water of Sundarban streams, the crocodiles lose the natural fear of man due to increased encounters, thus leading to more human-crocodile conflicts. This conflict in Sundarban exhibits a distict seasonality with high values during monsoon. Out of total 25 attacks on human by crocodile in Sundarban during the period 2000 to 2009 only 4% have taken place in winter, whereas 92% of the attacks have taken place during the six months from May to October. Crocodile stray to villages mainly in the months of September and October, the period of low salinity due to maximum precipitation in these months (Table 4).

Table 4
Human-crocodile conflict in Indian Sundarban from 2000 to 2009
Mean month-wise crocodile attacks and strayings for the period from 2000-2009

Month / Crocodile activity	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Crocodile attacks on people	0	0	1	0	5	4	4	3	2	5	0	1	25
Crocodile straying to village	0	0	1	0	0	0	1	1	5	4	0	1	13

5. The Forest Department data on human-crocodile conflict from 1999 to 2009 shows that a total of 12 humans have been killed by crocodile and a total of 13 people have been seriously injured in Sundarban (Annexure 2).
6. Based on the sources of Forest Department, village survey and Rangabelia comprehensive health project (RCHP), a total of 22 human death by crocodile has been reported for the period of 1997 to 2000. Most of the victims were prawn seed collectors (Das, 2002). The victims belonged to the age group 11 to 50 and were mostly women and children.

6.1.2 Human-shark conflict:

Human-shark conflict in Sundarban is rare and its magnitude is almost negligible. No adverse impact of this conflict on conservation is seen because of low intensity of conflict and confusion about the attack by shark or other creatures inside the water column. In most of the cases people realize it to be their fault as the attack of sharks often takes place in waist-deep water, of people engaged in prawn seed collection. Shark attacks on people are rarely complained and therefore no documentation on attack statistics is available except few cases from 24 Parganas (South) division, where the victims are mainly tiger prawn seed collectors.

6.1.3 Human-tiger conflict:

6.1.3. (A) Human killing by tiger in Indian Sundarban:

1. During a period of 25 years ranging from 1985-86 to 2009-10, a total of 410 persons have been attacked by tigers inside the forest areas of Indian Sundarban of which 95 persons survived with injuries (Table 15 and Figure 6), indicating that only 18.84% persons were lucky to escape with injuries and 81.16% persons lost their lives. The correlation value (r) between death and injury caused by tigers in forest areas of Sundarban is r = 0.4925 ($p<0.05$). The correlation value depicts that injured persons mostly face death due to tiger death.

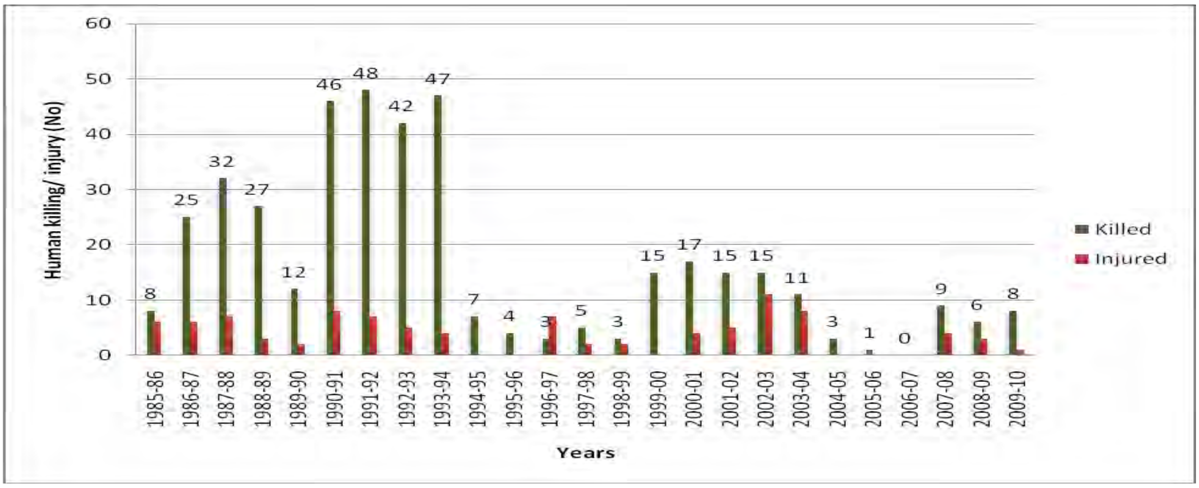


Fig-6 Human death/injury by tiger in Indian Sundarban (1985-86 to 2009-10)

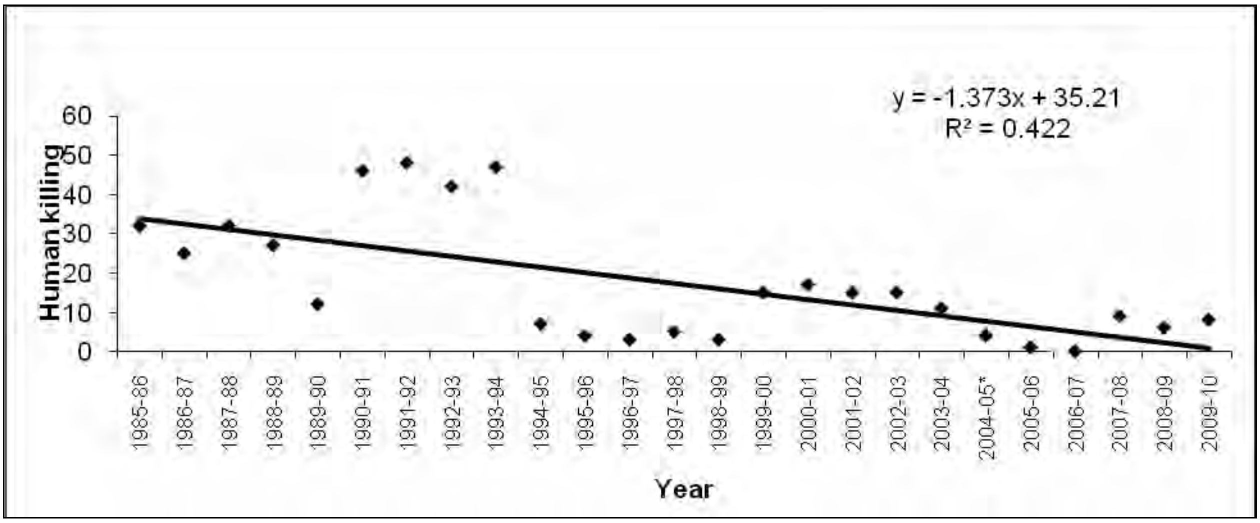


Fig.7- Trend line in human killing by tiger in Indian Sundarban

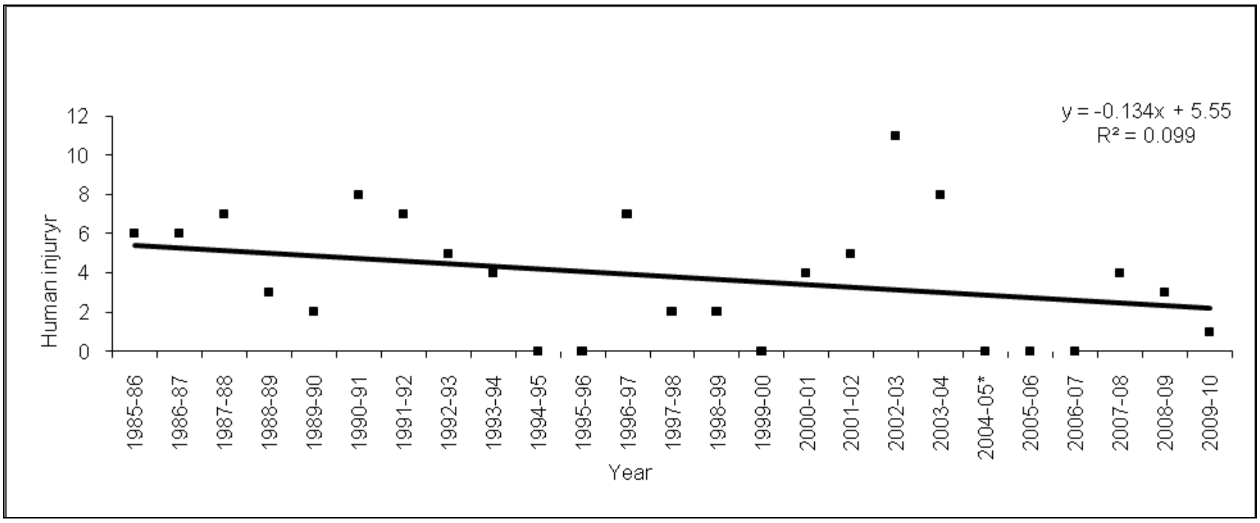


Fig. 8- Trend line in human injury by tiger in Indian Sundarban

2. It is observed that a total of 410 human have been killed by tigers inside the forest areas of Indian Sundarban in last 25 years during the period 1985-86 to 2009-10. Thus an average of 16.36 people has lost their life every year due to tiger attacks inside the forest areas of Sundarban. The maximum death (48) has been recorded in the year 1991-92 and the minimum number recorded is (zero) in the year 2006-07. There is only

one instance of human death by tiger in non-forest areas (Table 14) in the year 2004.

3. Both killing and injury of human beings by Sundarban tigers have varied over times. The decrease in killing is to some extent significant (R^2= 0.422) as seen in Fig. 7, but the injury trend (Fig. 8) with time does not show any trend (R^2= 0.099).
4. It has been observed that profession-wise death occurred maximum in fisherman (75%), followed by honey collectors (17%) and wood cutter (6%). The injury also shows a similar trend (Table 14).

5.1.3. (B) Tiger straying in Indian Sundarban:

1. The data for tiger straying has been collected for both the forest management units of Indian Sundarban (Sundarban Tiger Reserve and 24 Parganas (South) Division) for the period from 1986 to 2009. Sundarban Tiger Reserve has recorded a total of 257 tiger straying whereas 24 Parganas (South) Division has recorded 67 strayings during this period (Table 19 and Fig. 9).

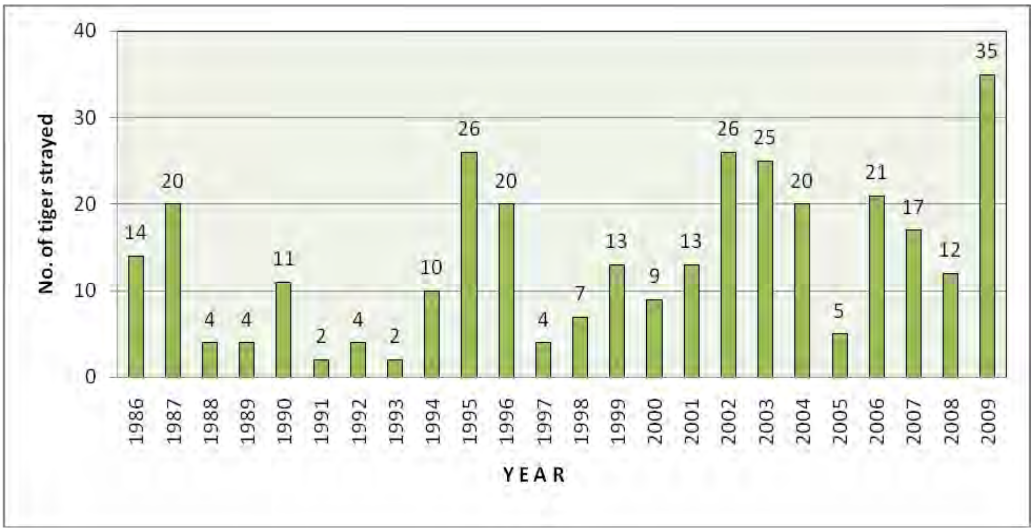


Fig.9- Temporal variation of tiger straying in Indian Sundarban (1986 to 2009)

2. The human-tiger conflict exists in 40 Forest Protection Committees (FPC"s)/ eco-development committee"s (EDC"s), out of total 65 committee"s of Indian Sundarban (Table 20).

6.2 Impact of salinity on mangroves

In the western region of Indian Sundarban the salinity of surface water ranged from 3.65 psu (at station 1 during monsoon, 2010) to 29.10 psu (at station 4 during pre-monsoon, 2008) and the average salinity was 16.97±7.73 psu. In the central region the lowest salinity was recorded at station 6 (3.12 psu during monsoon, 2008) and the highest salinity was recorded at station 9 (30.02 psu during pre-monsoon, 2010) with an average value of 17.95±7.67 psu (Table 22). The relatively lower salinity in the western region may be attributed to Farakka barrage that releases fresh water on regular basis through Ganga – Bhagirathi - Hooghly River system. The central region, on contrary does not receive the riverine discharge due to massive siltation of the Bidyadhari River that blocks the fresh water flow in the region.

It was observed that there was a significant variation in above and below ground biomass between the western and central sectors.

6.2.1 Above-ground biomass (AGB)

The AGB of the mangrove species was relatively higher in the stations of the western region (stations 1 – 5) compared to the central region (stations 6 – 10) (Tables 23, 24 and 25). It is observed that AGB of the three dominant species in the western region are 355.41, 414.39 and 475.55 tha^{-1} during pre-monsoon 2008, 2009 and 2010 respectively, 408.46, 469.05 and 535.66 tha^{-1} during monsoon 2008, 2009 and 2010 respectively and 452.95, 514.24, and 574.51 tha^{-1} during post-monsoon, 2008, 2009 and 2010 respectively. In the central region the values are 255.12, 338.58 and 414.38tha^{-1} during pre-monsoon 2008, 2009 and 2010 respectively, 314.82, 399.59 and 491.47 tha^{-1} during monsoon 2008, 2009 and 2010 respectively and 364.56, 450.47 and 541.55 tha^{-1} during post-monsoon 2008, 2009 and 2010 respectively.

6.2.2 Below-ground biomass (BGB)

Below-ground biomass (BGB) refers to root biomass, which excludes the pneumatophores and stilt roots that are exposed above the soil. The BGB comprising of the root portion of the mangrove was higher in the western region compared to the central region. The total BGB of the three dominant species in the western region are 82.04, 104.42 and 120.94 tha^{-1} during pre-monsoon 2008, 2009 and 2010 respectively, 101.68, 126.63 and 144.25 tha^{-1} during monsoon 2008, 2009 and 2010 respectively and 118.13, 144.98, and 162.20 tha^{-1} during post-monsoon 2008, 2009 an 2010 respectively. In the central region the values are 58.95, 84.4 and 106.50tha^{-1} during pre-monsoon 2008, 2009 and 2010 respectively, 76.51, 104.91 and 131.96 tha^{-1} during monsoon 2008, 2009 and 2010 respectively and 94.74, 125.62 and 154.57 tha^{-1} during post-monsoon 2008, 2009 and 2010 respectively (Tables 23, 24 and 25).

6.2.3. Inter-relationship between salinity and mangrove biomass

Critical analysis of the data on AGB, BGB, total biomass and salinity profile of the study area exhibits the regulatory effect of salinity on the biomass of the selected species. Correlation coefficient values reveal the adverse impact of salinity on *S. apetala*, but positive influence on the biomass of *A. alba* and *E. agallocha* (Tables 26, 27 and 28).

6.3 Impact of climate change on Indian Sundarban

6.3.1. Surface water temperature: a clear signature of climate change

The signal of global warming is already being observed in the mangrove-dominated Indian Sundarban. The surface water temperatures in both the sectors have shown significant rising trends during three seasons from 2008 to 2010 (Table 29). The data has also been compared with the earlier records in this deltaic complex and it is observed that temperatures have risen by 6.14% in the western sector and by 6.12% in the central sector over the past 27 years, at a rate of approximately 0.05°C/year. This rate is, in fact, much higher than the observed and documented warming trends in the tropical Pacific Ocean (0.01– 0.015°C/year), tropical Atlantic Ocean (0.01–0.02°C/year) and the planet itself (0.006°C/year)

(Mitra et al., 2009). The present study also reveals an increasing trend of surface water temperature in the ten different stations of Indian Sundarban (Table 29).

6.3.2. Surface water salinity: contrasting effects of barrage discharge and silting

The observed trends in the salinity are also interesting from two perspectives. First, the salinity decreased in the west, in contrast to the central region (Table 22). This increase in the central Indian Sundarban is probably due to huge siltation and the slow dying of Bidyadhari River since the 16th century that was once a conveyor belt for fresh water from the Himalayas to the eastern Indian Sundarban.

6.3.3. Geomorphological change of Sundarban islands

The islands of Sundarban are in a state of constant erosion and accretion due to sea level rise, current pattern, water discharge from upstream zone (e.g. Farakka discharge), siltation and sedimentation. The satellite imageries reflect significant zonal pattern with respect to erosion and accretion. The islands of western Indian Sundarban exhibit erosional features which may be attributed to current pattern and tidal action from the sea side (Bay of Bengal). The case study of Jambu Island (Fig. 23) is very relevant in this context. The erosion on the southern part of the island is the effect of strong tidal action from the Bay of Bengal. The average tidal amplitude recorded is 4.5 meter along Jambu island. Similar pattern is also observed for Sagar island (Fig. 22).

The root of siltation is linked to dying of river Bidyadhari during 15th century. Because of this dying, the fresh water from the Hooghly- Bhagirathi system does not reach to the central Indian Sundarban. This has decreased the velocity of water flow in this region resulting in sedimentation and subsequent accretion. The islands of southern Indian Sundarban facing Bay of Bengal are gradually eroding because of tidal amplitude. The examples of islands e. g. Gona, Baghmara, Mayadwip and Chulkati are very pertinent in this context (Table 30, Fig. 24, 25, 26 and 27).

7. Discussions

7. Discussions

7.1 Human-wildlife conflict

7.1.1 Human-crocodile conflict:

1. Habit and habitat of crocodiles

Estuarine crocodile or salt water crocodile (*Crocodylus porosus*) is the only crocodile species found in Sundarban out of three species of crocodiles found in India. The other two species fresh water crocodiles (*Crocodylus palustris*) and gharial (*Gavials gangeticus*) are now not found in Sundarban. The fresh water crocodiles and gharial that existed in fresh water streams meeting the delta became locally extinct. A small population of gharial has been rediscovered in lower reaches of Bhagirathi and Jhalangi, the tributaries of Hooghly River in the districts of Nadia and Murshidabad as per Forest Department records, some of which have been rescued and kept in the rescue centre in Bethuadahri Wildlife Sanctuary, Nadia. However, these areas are at a distance from Sundarban and this population cannot be said to belong in Sundarban waters (Plate 19).

Estuarine crocodile or salt water crocodile (*Crocodylus porosus*) is the aquatic animal which rules the saline water of Sundarban estuary. Its conflict with human beings is age old but less talked about as in the case of tigers. The human-crocodile conflict is primarily restricted to the human activities in the water i.e. fishing, crab collection and prawn seed (*Penaeus monodon*) collection. The conflict with crocodiles started when people from far off areas started the fishing activities in the delta. The conflict is even older than that of tigers as the conflict with tigers started when man started its activities in Sundarban forest for reclamation of land and extraction of natural resources i.e. honey, wood.

2. Morphological features of estuarine crocodile (*Crocodylus porosus*)

Salt-water crocodile is probably the largest reptile with some specimens of about 5 metres in length in Sundarban (Daniel, 1983). Its distribution in India is restricted to the tidal estuaries. It looks similar to that of marsh crocodile (*Crocodylus palustris*) but it differs with marsh crocodile in having longer snout, a strong ridge in front of eye nearly half of the length of the snout. It is generally dark olive or brownish olive in colour and young are distinct with black markings above.

3. Behaviour

Thermoregulation is the activity which takes the maximum time of estuarine crocodile. The body temperature is maintained between 30-32 ^{0}C to allow body functions at optimum level. Male take about 16 years whereas females take about 12-14 years to reach sexual maturity. Estuarine crocodiles make the nest in the form of mounds made with mud and leaves of Hental (*Phoenix paludosa*). These nests are protected by females with aggressions against any intruders. About 50 eggs are laid in a clutch and the embryos do not have the sex chromosome hence sex is not determined genetically but by temperature. Males are mostly produced at around 31.6 ^{0}C, and females at a slightly higher or lower temperature (Britton, 1995). Incubation period is about 80 days.

4. Food and prey habit

Estuarine crocodile is a predator and occupies the apex position in the aquatic food web of Sundarban. Its food is mainly the fish occurring in estuarine habitat but it preys upon large animals i.e. spotted deer, wild boar, turtles, monkeys, birds etc. The young prey upon small creatures like crustaceans, arthropods, amphibians, small fish and reptiles. The teeth of the estuarine crocodile are designed for holding rather than cutting but they penetrate in the flesh with force to crush the prey. Larger prey is broken into smaller pieces either by a violent flick of the head or by a twisting/ rolling action of the body (Britton, 1995). The swallowing of prey takes place above the water to avoid water entering in lungs. Estuarine crocodile remains still under water with just nostrils and eyes above water surface and waits for prey to reach close to it and lunge out to take the grip of the prey under its powerful jaws.

5. Conflict

The human-crocodile conflict has always been a low intensity affair for people as well as the government especially because its magnitude is very low as compared to human-tiger conflict. Crocodiles attack primarily people engaged in two professions i.e. fishermen and prawn seed (*Penaeus monodon*) collectors. The fishermen include the crab collectors who venture deep in the forest areas of Sundarban. In contrast to this prawn seed collectors are found almost in all water channels of Sundarban in the non-forest areas and also cover the fringes of forests in pockets. There is an interesting gender aspect related to the people involved in these two professions. Almost all the fishermen and crab collectors in Sundarban

Tiger Reserve are man whereas they comprises both man as well as women in 24 Parganas (South) Division. The majority of people engaged in prawn seed collection are women and children.

In Sundarban water, rivers and creeks thousands of people enter everyday in waist-deep to neck -deep water for prawn seed collection. They wade through the shallow muddy water near to their homes and drag the fine net, which filters almost everything from water. The operation is mainly done to supply tiger prawn seeds in the shrimp farm. Due to lack of hatchery in and around Sundarban, the shrimp farms owners have no alternative but to purchase prawn seeds from local seed collectors. This has initiated the gateway of conflict between crocodile amd human beings.

Occasionaly the crocodiles stray to village pond and are rescued (Annexure 3). People believe that the straying is mainly to eat the fishes of the village ponds. A total of 69.23 % crocodile straying in villages takes place in the month of September and October. This is the time when crocodiles are reported to start making nest to lay egg and are on search of safe nesting sites.

7.1.2 Human- shark conflict

Sharks, locally known as "Kamots" do attack the humans in Sundarban but these attacks are rare. Sharks attack mainly to the people engaged in prawn seed collection in waist-deep water of Sundarban creeks (Plate 18). Over 15 species of Sharks and Rays has been reported in Sundarban waters (Annexure 4). Some of the important species are Tiger sharks (*Galeocerdo cuvier*), Indian dog shark/Yellow dog shark (*Scoliodon laticaudus*), Ganges shark (*Glyphis gangeticus*), Bull shark

(*Carcharhinus limbatus*) etc. Shark attacks in Sundarban have not been reported in old records and are stated to be recent in nature. This has started to be about 15-20 years back with the onset of prawn seed collection (Das, 2002). No human death has been reported due to shark attack. No compensation is paid for injury or death of human by shark so no one has reported to government offices for this purpose. As the attacks take place during the prawn seed collection, the incidences generally occurs outside the forest areas in the forest fringes. As per information available from local people except one incidence of death and injury (of a boy) near an island Mullakhali in eastern Indian Sundarban, no other incidence of human death has been documented in Indian Sundarban in last 10 years.

1. Habit and habitat of sharks

Elasmobranchs (Chondrichythyes) constitute a vital component of marine and estuarine nekton and are of great ecological and commercial importance. More than 350 species of sharks and rays are found in the world (Das, 2002) of which over 65 are found in the Indian waters (Mitra and Banerjee, 2007). Sundarban estuary has recorded 15 Shark and Rays (Mitra and Banerjee, 2007). The size of sharks varies from 20 cm to 14 meter. Sharks have bad eyes sight but detect the prey by picking up electromagnetic currents through the sensors located in the head. Sharks have an unlimited supply of razor-sharp teeth, arranged in rows in the gums. The sharks generally hunt during morning and evening hours and shed as many as 50,000 teeth in its lifetime (Bilson and Bilson, 2000).

2. **Conflict**

Reliable secondary data on human-shark conflict could not be found primarily due to the fact that such conflict is low in intensity and even the victims themselves are not sure that the injury caused to them is due to shark or any other aquatic animal. All such attacks do take place inside the waist deep water and no human deaths are heard due to this human-shark conflict. It has been reported that victims of shark attacks are primarily the prawn seed collectors.

7.1.3 Human-tiger conflict

1. Habit and habitat

Tiger (*Panthera tigris*) the largest existing member of the Felidae is nocturnal and solitary (Schaller, 1967). The average length of the male tiger is about 9 feet to 9 feet 6 inches with females 6 to 12 inches shorter in body (Prater, 1948)). The weight of tiger varies between 180-230 kg. The Sundarban tiger is not so large as his congener along the terai, or in the Central Indian Jungles (Malley, 1914). Its weight is considerably less and some of the specimen weighed 105-120 kg. during 2009-2010 (Plate 20). These variations in length and size are adaptations to Sundarban conditions. Sundarban tigers are great swimmers and an instance of swimming across 8 miles from Sagar island to Rasulpur river has been recorded (Malley, 1914). Sundarban tiger has adapted to the deltaic environment of mangrove in a nice way. Malley (1914) had recorded tigers frequenting the sand dunes at the sea face (covered with tall, brown spear-grass and near the glades, on which deer feed and pigs come out) had almost lost the stripes with less and thinner stripes. One specimen examined by him had barely half a dozen thin dark lines, mostly above the shoulder, and the coat of the animal was of a tawny orange colour, well adapted to the grass or sand dunes. Tigers are present in almost all the island of Indian Sundarban except west of river Thakuran. Records of tigers presence in all the island exists but the colonization in the western most part of Indian Sundarban lead the tigers extinction from these islands (Malley, 1914).

2. Food and Prey

Sundarban tiger is adapted to survive on saline water, has become a great swimmer and developed the hunting skills in pneumatophore laden marshes. The main prey of Sundarban tigers are spotted deer, wild boars, water monitor lizard and monkeys. It supplements its diet with crabs, fish and do not hesitate even to kill men inside the forest. The straying of tigers from forest to fringe villages in search of food is common.

Sundarban is perhaps the only place in the world where tigers influence the culture in a major way. The people of all religion worship the forest deity “Bonbibi” which they believe can save them from the wrath of tigers during fishing, honey collection etc. (Plate 21).

3. Conflict

Human-killing by tiger causes human misery and economic stress, while tigers that enter villages are often killed in return (Gani, 2002). The additional source of mortality of tigers may have a substantial impact on long term viability of the tiger population (Kenney et al 1995; Kerley et al. 2002; Chapron et al., 2008; Goodrich et al. 2008; Barlow et al. 2009).

Sundarban is different from other forests of the world on account of highly inaccessible terrain with islands, criss-crossed by creeks, inundated by saline water with high tide and low tide twice a day. The islands in Sundarban are difficult to be worked due to the presence of the Royal Bengal Tiger (*Panthera tigris*) which is known for their propensity of treating the human beings entering these islands as their prey. Often these tigers stray in the fringe villages and are killed by the irate villagers.

The behaviour of Sundarban tiger is also unique on account of its almost amphibious nature. The inaccessible conditions of the Sundarban forest are real constraints for the management of the eco-system and its people. The poor fishing community are always ready to risk their lives for cyclones, tigers etc.

7.1.3.4 Professional profile of tiger victims in Sundarban

In general, people who enter in Sundarban forest for livelihood can be classified into four categories:

a. The fishermen (Jele)

Fishing was perhaps the first activity that started in Sundarban even before human settlements started in 18th century (Malley, 1914). In the forest areas fishing was allowed in tidal waters in a restricted manner provided that the fishing boats are registered with the Forest Directorate on payment of usual registration fees plus royalty for dry fire wood to be collected and consumed in each fishing trip. Fishing is not allowed in the core area of Sundarban Tiger Reserve, Saznekhali Wildlife Sanctuary, Haliday Wildlife Sanctuary and Lothian Wildlife Sanctuary in the

Sundarban. Buffer zone of Sundarban Tiger Reserve consisting of entire Bashirhat range area and entire 24 Parganas (South) Division areas except Haliday and Lothian Wildlife Sanctuaries are open for fishing to the registered permit-holders (BLC holders). The fishing zones in the Indian Sundarban are given in the Table 5.

TABLE 5

Fishing areas of Indian Sundarban

	Administrative Unit	Management Unit	Total Area (km^2)	Area where fishing is permitted (km^2)
FOREST AREAS	Sundarban Tiger Reserve	Core Area or Critical Tiger Habitat	1699.62	0.0
		Buffer Area (Saznekhali WLS and other Reserve forest)	885.27	522.85
	24 Parganas (South) Division	Areas including Haliday and Lothian WLS	1653.78	1609.78
Sub-total			4238.67	2132.63
NON-FOREST AREAS	Tidal water, rivers in non-forest areas of Indian Sundarban.		5391.33	5391.33
Total fishing area in Indian Sundarban			9630	7523.96

Out of total 9630 Sq. km. of Indian Sundarban, a total of 78.13% is open for fishing, whereas 21.87% area is closed to fishing activities. Within the forest areas, the fishing is permitted in 50.31%.

b. The honey-collectors (Moulis)

The months from March to June are characterized by flowering of mangrove forests. During this time the forest colonized by Honey bees (*Apis dorsata*) (Plate 22). A traditional group of people then enter in Sundarban forest for honey collection. They are called “Moulis.”

Since human activities started in Sundarban, a number of non-timber forest produce (NTFP) were collected by people, of which important are Honey, Bees-wax, Golpata leaves (*Nypa fructicans*), Hental leaves (*Phoenix paludosa*) etc. These NTFP were usually collected by the people coming from outside the Sundarban annually during the short periods for which permit were issued by Forest Department. Golpata collection has however, been stopped since 1978 (Management Plan, Sundarban Tiger Reserve, 2001-2010). Extraction of Hental leaves had also been discontinued since 1991(Management Plan, Sundarban Tiger Reserve, 2001-2010, Forest Department). About 1500, honey collectors were given permits to collect honey for a fix quantity, which was purchased at a pre-declared price in tune with minimum support price (MSP) in turn the honey-collector had to compulsorily sale the honey and wax to Forest Department. The honey so collected was processed and marketed by West Bengal Forest Development Corporation (WBFDC). The honey collection details of last 10 years are given in Annexure 17.

c. The wood-cutters (Kathure)

The Wood-cutters are the people engaged in felling of forest for commercial purpose as per the management prescriptions. In 1863 Dr. Brandis realized the forests as valuable resource for revenue generation and granted toll collection to a private company for forest products (Tiger Conservation Plan, Sundarban Tiger Reserve (Draft), 2011). It was first time in 1893, Heining established Annual Coupes with silviculture practices in the working plan of Sundarban (1893-1903) in the current Bangladesh part of Sundarban to stop indiscriminate felling of Sundarban forest. Since then, under various Working Plans, Sundarban forests were subjected to clear felling operation with natural regeneration and a large work force used to be deployed for the forest felling. The tigers were always a threat to labour and conflict was imminent with tiger as well as people losing their lives (Curtis, 1933). Since inception of Tiger Project in 1973, the core area of Tiger Project has been kept free from all exploitation activities including harvesting of timber, fuel-wood etc. However an area of 2,930 ha. to 2484 ha. was subjected to coupe operations. In addition an area of about 1000 ha. was also clear felled in 24 Parganas (South) Division. The annual coupe working used to be done in two parts - once in rough weather (Rough Weather coupe [RWC]) and the balance in fair weather (Fair Weather Coupe [FWC]). In Sundarban Tiger Reserve since 1991-92 the area of coupe working was reduced to 1000 ha. The Rough Weather Coupe (RWC) working was also discontinued in Sundarban Tiger Reserve since 1992-93. The felling of forests or coupe operations had been totally stopped in Sundarban since 2001, inspite of approved prescription in Management Plan of Sundarban Tiger Reserve (Management Plan, Sundarban Tiger Reserve, 2001-2010).

d. Forest staff and others

The staff of Forest Department has to perform patrolling and various other duties within the forest areas of Sundarban. To execute various development activities inside the forest areas of Sundarban, labour is hired by Forest Department. In spite of best precautions, many accidents had taken place in which tiger has either killed or injured the staff or labour (Plate 23).

Based on the forest and non-forest areas, human-tiger conflict in Sundarban can be broadly classified in two major categories, which are:

7.1.3.5. (A) Human-tiger conflict inside the Sundarban forest – Human killings by tigers

Sundarban tigers are known worldwide for their aggression and tendency to kill fishermen, honey collectors, wood cutters and other people intruding inside the forest (Plate 24). The difficult terrain on one hand provides a safe refuge to the tigers against the advances of human population for land and natural resources. On the other hand, it has also created Sundarban specific survival difficulties for the tigers leading to adaptations. The human killing trait of tigers in Sundarban is age old and has started with the onset of human activities in Sundarban (Malley, 1914). The past records shows that tiger was treated as a pest and main hurdle in advances to grab the land for agriculture and to earn revenue by forest felling.

The human killing incidences by tigers have been meticulously maintained by Forest Department. The human killing data for last 25 years (1985-86 to 2009-10) has been collected from Forest Department records (Table 15). The data are reasonably reliable as they are linked to the payment of compensation to the dependents of victims. The compensation is paid only to the dependents of the victims who venture Sundarban forests with valid Forest Department permit (BLC or Boat License Certificate). There are chances that a number of people, who enter Sundarban forest for livelihood and other reasons, do not have any valid permit from Forest Department. The killings of these people by tigers are not reported to Forest Department for the reasons of not getting any compensation as well as of fear of being on the wrong side of law. There is no possibility of retrieving these data with authenticity, so the data from Forest Department has only been considered for analysis. In a study in Bangladesh Sundarban, it has been recorded that the official figures are an underestimate (Helalsiddiqui, 1998; Jagrata Juba Shangha, 2003; Khan, 2004). The other details of human killings by tigers like location of tiger attacks (forest compartment), date of incidence, profession of victim etc. has also been collected for analysis (Table 14).

7.1.3.5.(B)-Human-tiger conflict outside the Sundarban Forest-tiger straying

The straying of tiger from forest to villages has been a very common phenomenon in Sundarban, in which for various reasons tigers swim across the rivers bordering the forest island in the darkness of night to reach the human settlements in other islands (Plate 25). Most of the times tigers swim back to the forest islands but in many cases they fail to do so, creating fear and panic among the people. In such situations Forest Department inspite of terrain disadvantage has to react very fast to immobilize/ trap the tiger amidst crowd of often thousands of people, a section of which are hostile to both tiger and Forest Department. In fact, tiger straying has always been treated as one of the most difficult challenges to the conservation of tigers in Sundarban for the reasons that the dependents of tiger victims (people killed by tigers inside the forest) are present in all fringe villages and are generally hostile to tigers. People are also scared to be harmed by tiger present in the village. The inaccessible terrain makes it difficult to carry out tiger rescue operations in remote Sundarban islands. About a decade back the relations of the Forest Department were not really cordial with the villages which had resulted in killing of strayed tigers by people in villages. On 29th July, 2001, a tiger was lynched during straying in Pakhiralaya village. It was cut into small pieces, packed in gunny bags and thrown in Gomdi river of Sundarban (Plate 14). In another incidence on 2nd October 2001, a strayed tiger was shot dead in Kishorimohanpur village in Kultali civil block in the fringe of 24 Parganas (South) Forest Division by irate villagers when Forest Department failed to rescue it till the onset of evening (Plate 14). Unfortunately, the rifle used for killing this tiger was also snatched from a forest guard, involved in rescue operations. The tiger straying data for last 24 years have been collected from Forest Department, West Bengal (Annual Reports STR, 2001-02 to 2009-10, SBR Report, 2004) (Table 19).

7.1.3.6 Human killing behaviour of Sundarban tiger and salinity

At times, man-eating behaviour of Sundarban tiger has been attributed to the fact that they live in an ecosystem, where there exist no fresh water for drinking and they depend on tidal water of varying salinity to meet their water requirement (Chakrabarty and Choudhury, 1979: Hendrichs, 1975). With this assumption, in 1975 Sundarban Tiger Reserve management dug up fresh water ponds (as means of rain water harvesting) in several vulnerable forest blocks with an assumption that the consumption of fresh water will help in reducing human casualties due to tiger attacks. However, after 5 years, it was revealed that there was no reduction in human killing in the areas of these fresh water ponds (Sanyal, 2001). Since 2001, Sundarban Tiger Reserve management decided to abandon the maintenance of fresh water ponds located in remote areas as they were found to be used by fisherman and miscreants. Now in Sundarban Tiger Reserve only 12 sweet water ponds, located near the patrolling camps or situated along the patrolling route are maintained out of a total of 41 fresh water ponds dug up over the period of time (Annexure 10). Hendrichs (1975) was the first to draw co-relation between human casualties and salinity in Bangladesh Sundarban and attributed salinity as one possible reason for high human casualties. He later concluded that utilization of forest by men increases from west to east whereas human casualties increase both from east to west and from north to south with the increase in salinity. He opined that inside the high salinity zone the killing of men is co-related with their availability.

Chakrabarty (1992) has analyzed the issue of salinity and its co-relation with human casualty in Indian Sundarban. He classified Sundarban in 12 habitat formations and measured the soil salinity at three depth intervals. Based on human casualties from 1974-75 to 1978-79 data, he observed that a maximum of 20% human casualties were in pure *Ceriops* with 1.2% salt followed by *Excoecaria-Ceriops* formation (18%) with 0.96 % salt, *Heritiera-Excoecaria* (10%) with 0.69 % salt and *Heritiera- Excoecaria-Ceriops* formation (10%) with soil salinity 0.84%. He recorded the percentage frequency of tiger pugmarks were maximum in pure *Phoenix* (20%) followed by *Avicennia-Oryza* (20%) and *Excoecaria-Phoenix* (18%). No corelationship can be established in preferred tiger habitat use and human casualties for the want of occupancy percentage of these 12 habitat formations. The larger the areas of habitat formations more are the chances of human-tiger encounter. The most conclusive cause for highest human casualty in *Ceriops* formations is due to the fact that the sticks of *Ceriops* popularly known as „Garan‟ are collected by fisherman and others for fuel wood and fencing material. Till the year 2001, the *Ceriops* sticks (Chitta Garan) were collected in large quantities for raising „Chitta Garan fence‟ to prevent tiger straying and for protection against tiger in construction activities in Sundarban forest (Management Plan, Sundarban Tiger Reserve, 2000). Since 2001, these “Chitta Garan” fencings have been replaced with Nylon Net Fencing (Sundarban Biosphere Reserve official records, 2010).

Chakrabarty (1992) observed that salinity can never be an isolated factor responsible for man-eating tendency of Sundarban tiger. He observed that although water salinity tends to increase from north zone to central zone and then to southern zone but human casualties pattern do not change in similar pattern, indicating the presence of some habitat formations which are incidentally more in salinity.

The studies in Bangladesh Sundarban for the period 1984 to 2001 have recorded 401 human casualties and 41 tiger killings (Reza et al., 2002). They observed that Burigoalini Range had 45% of human casualties as compared to 24% in Sarankhola Range, 22% in Chandpai Range and 9% in Khulna Range. Salinity is attributed to be another major cause for man-killing as Burigoalini Range is situated in highly saline zone (Siddiqi and Choudhury, 1987). According to the study, vegetation of this forest is different from eastern Bangladesh Sundarban resulting in less healthy population of prey species i.e. spotted deer and wild boars.

Denzau and Denzau (2010) observed for Bangladesh Sundarban that a high level of disturbance by forest resource users may provoke man-eating behaviour among local tigers even in low salinity zone. They observed that the cause of physiological changes of Sundarban tigers due to high salinity which remains without scientific proof till investigated histologically by experts. The possible hypertonicity as a cause for increased activity or aggression can only be determined by measuring the blood pressure of Sundarban tigers and comparing it with that of tigers of other areas.

Under this study, data were collected from specific locations of human casualties by tiger in Sundarban Tiger Reserve for the period 1998-99 to 2009-10. It was observed that maximum human casualties were in Chamta Block (30.95%) followed by Chandkhali (21.4%) and Pirkhali Block (13.09 %). Incidentally the forest blocks of Chotohardi, Mayadwip, Gona and Baghmara at Bay of Bengal recorded no human casualties. In Indian Sundarban, water salinity increases from north to south whereas it is low on eastern & western part and high in central Indian Sundarban, which do not receive any fresh water from rivers (Table 22 and Annexure 8). The human killing pattern does not change in a similar manner as all forest blocks with highest salinity do not record highest comparable human casualties. The Chamta and Pirkhali forest blocks with high salinity recorded very high human killing (average salinity 20.10 psu and 18.6 psu) whereas Gosaba block with highest salinity of 21.71 psu and Matla block with 21.13 psu recorded two human casualties each (Annexure 8). These observations on human casualities by tiger and salinity do not show any direct correlation. However, the impact of salinity as one of the factor for human casualty cannot be ruled out as the observation made by researchers regarding the impact of salinity on mangrove vegetation has a direct relation with prey availability for tiger. This may be the cause for the tigers of high salinity zone to prey upon the available human in the forest.

7.1.3.7 Statistical interpretation of human-tiger conflict (death cases)

1. ANOVA reveals that there is significant difference in human death between "Forest" and "Non-Forest" areas as $F_{obs} = 28.3139 > F_{crit} = 4.2596$. However no considerable difference in death between the years in both the areas was observed. This clearly indicates that though the human killing tag with Sundarban tiger is correct but it cannot be simply put in the categories of traditional man-eater based on the perception of man-eaters of Terai, who once after becoming man-eater always attempt to kill humans for food. Chakrabarty (1992) was of the opinion that problem of man-eating elsewhere can hardly be compared with man-eating incidence in Sundarban and the old age, disease and injury, the attributed reasons for man-eating by Jim Corbett does not seem to be cogent reasons for man-eating in Sundarban. In spite of frequent tiger straying in non-forest areas (Table 19 and 20) the killing of only 1 person in 25 years in non-forest areas and 409 in forest areas indicate that Sundarban tigers are not true man-eaters as per traditional definition of man-eaters but treats human as natural prey within the confine of forest areas or are opportunistic intelligent hunters, who do not miss chance to hunt man

without getting itself in danger which is possible within the confines of mangrove forest and not in villages .

2. Analysis of data during 1985-86 to 2009-10 revealed that, four categories of people have become the victim of tiger attacks i.e. Fisherman (75%), Honey Collectors (17%), Wood Cutters (6%) and Staff and labours (2%) (Fig. 10). The victims profile matches with their professional needs. The fisherman visit Sundarban almost 10 months in the year but spent most of their time in the boats. They are attacked when they go to forest land for fuel wood collection or to use the "Chorapata Jal", a fishing net, which has to be placed on land (Plate 26). The honey collectors visit the forest for about 2 months but have to penetrate deep in the mangrove forest in search of beehives. The wood cutter percentage is low due to the fact that this activity has been discontinued since 2000. The staff and labour work with full precautions so their percentage is also low.

Based on the studies in Indian Sundarban for the period 1964 to 1989, Chakrabarty (1992) has recorded human casualties of fisherman as 57.78%, Honey Collectors as 23.28% and others including Timber Traders as 18.93%. Studies in Bangladesh Sundarban for the period of 1984 to 2000, has recorded that out of eight categories of professionals, it is the Fishermen (44%), Woodcutters (36%) and Honey collectors (18%), which are the most affected (Reza et. al., 2002; IUCN Bangladesh, 2004).

From the discussion, it reveals that in Sundarban though highest human casualties are among fishermen but it is the honey collector‟s category which is most vulnerable and their 17% share among human casualties is very high keeping in mind their small number and shorter time they spent for honey collection. The wood cutters are no longer a profession in Indian Sundarban as this practice has been discontinued.

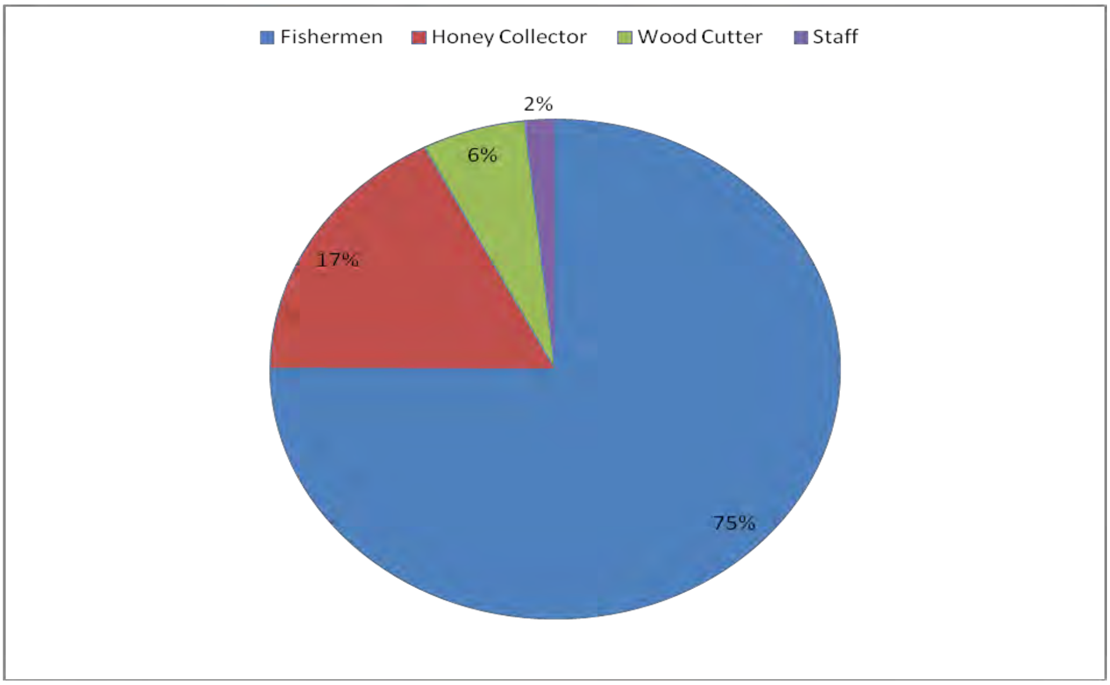


Figure 10- Human death by tigers in Indian Sundarban –Professionwise (1985-86 to 2009-10)

3. The data for Sundarban Tiger Reserve has been analysed for Fishing/ Honey collection zone and Non-fishing/Non-honey collection zones for a period of 12 years (1998-99 to 2009-10). The fishing activities and honey collection are permitted only in Bashirhat Range (fishing zone and honey collection zone) and are not permitted in Core Zone and Saznekhali Wildlife Sanctuary (non-fishing, non-honey collection zone). The core zone of Sundarban Tiger Reserve has witnessed 22 (26.20 %) human deaths as compared to 62 (73.80 %) human deaths in buffer zone (Table 18 and Fig. 13). The human deaths are 31 (37 %) in non-fishing and non-honey collection zone as compared to 53 (63 %) deaths in the fishing and honey collection zone (Fig. 11 and 12).

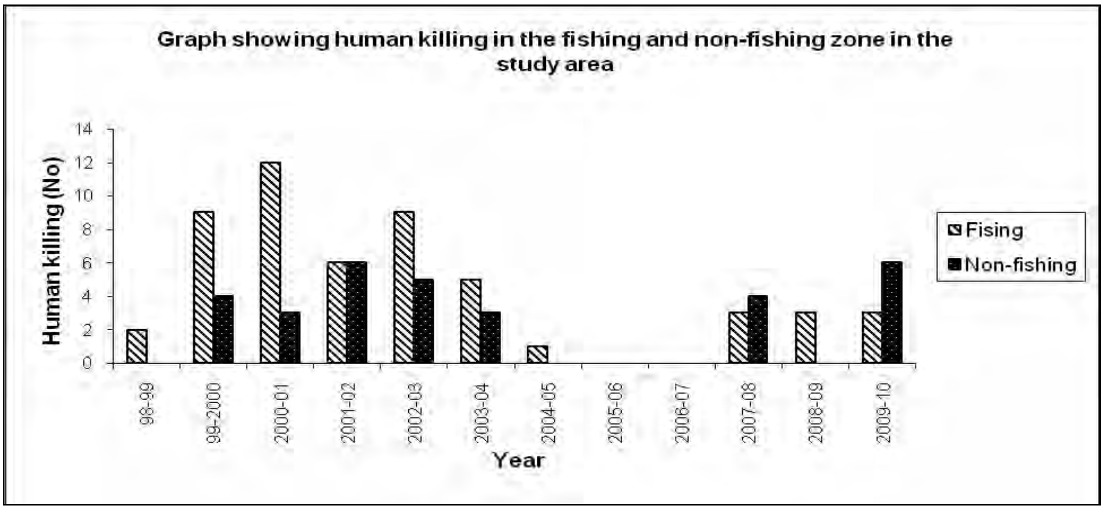


Fig. 11- Graph showing yearwise human killing in the fishing and non-fishing zones of the study area (1998-99 to 2009-10)

ANOVA however depicts no significant variation between these two zones as $F_{obs} = 4.0456 < F_{crit} = 4.8443$, which indicates that parts of the Core Zone and Saznekhali Wildlife Sanctuary is being intruded by fishermen and honey collectors.

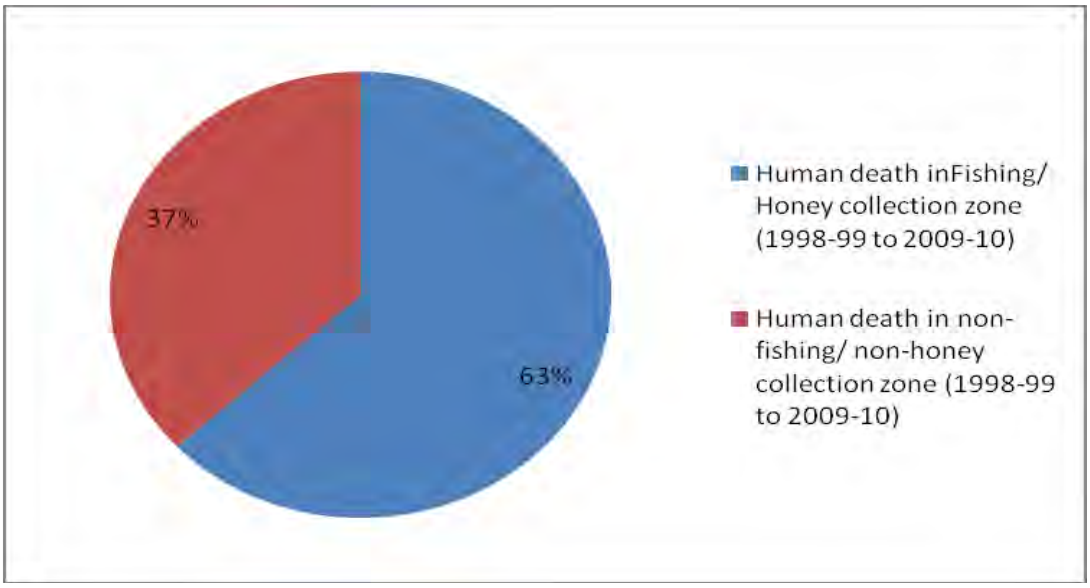


Fig. 12 – Human killing by tigers in Sundarban Tiger Reserve- Fishing/Honey collection zone vs. non-fishing/ non-honey collection zone (1998-99 to 2009-10)

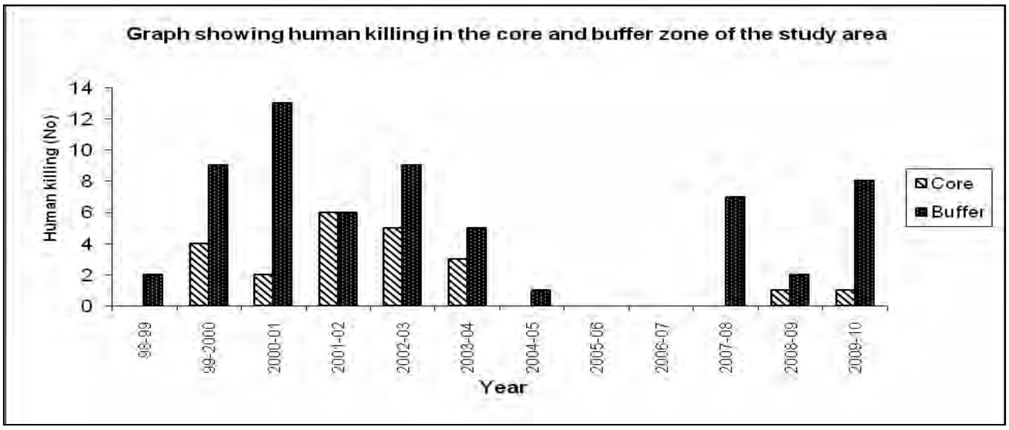


Fig.13- Graph showing yearwise human killing in Core and Buffer Zones of study area

ANOVA depicts significant variation in human death between the Core and Buffer Zones as F_{obs} = 10.7317> F_{crit} = 4.8443. Such variation reveals the behavioral pattern of Sundarban tigers, apparently in Core Zone tigers are not habituated to human presence as compared to the tigers of Buffer Zone, where they often come in contact with human activities and get relatively habituated to human presence hence shows less aggression. The aggression of tigers in Core zone can be reflected by the incidence on 21st April, 2003, when three honey collectors were killed in an attack by a single tiger in the Core Zone (Chamta- 5 compartment).

4. The data from Sundarban Tiger Reserve for a period of 12 years (1998-99 to 2009-10) have been analysed to study the seasonal variation in human killing by tigers (Table 16). Sundarban has three distinct seasons namely pre-monsoon (March to June), monsoon (July to October) and post-monsoon (November to February). The human killing of 38 (during pre-monsoon), 25 (during monsoon) and 23 (during post-monsoon) were documented in these seasons. ANOVA results indicate significant seasonal variation in human death as F_{obs} = 31.6831 > $F_{cri\ t}$ = 7.7086. The high human killing during the pre-monsoon period can be directly correlated

with the honey collection period when honey collectors come face to face with tigers inside the forest during the process of honey collection.

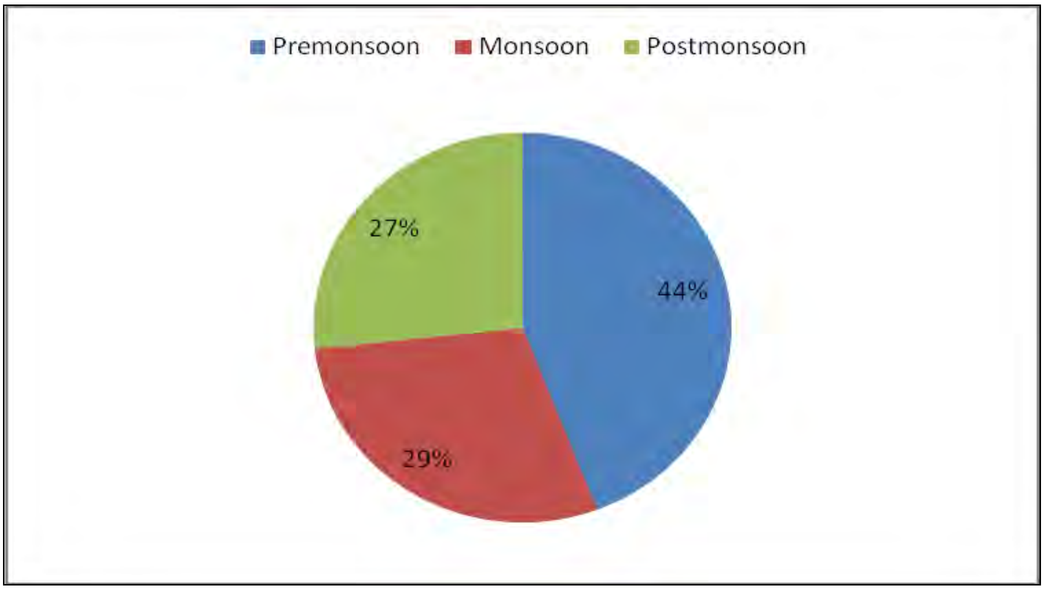


Fig. 14- Human killing by tiger in Sundarban Tiger Reserve- Seasonality (1998-99 to 2009-10)

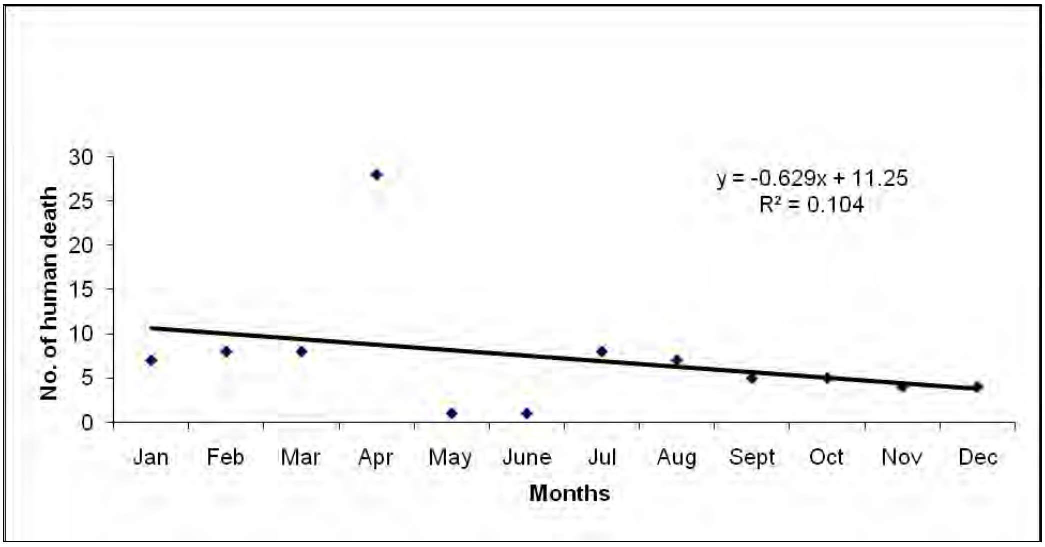


Fig. 15- Trend line showing monthwise human killing by tiger in Indian Sundarban (1985-86 to 2009-10)

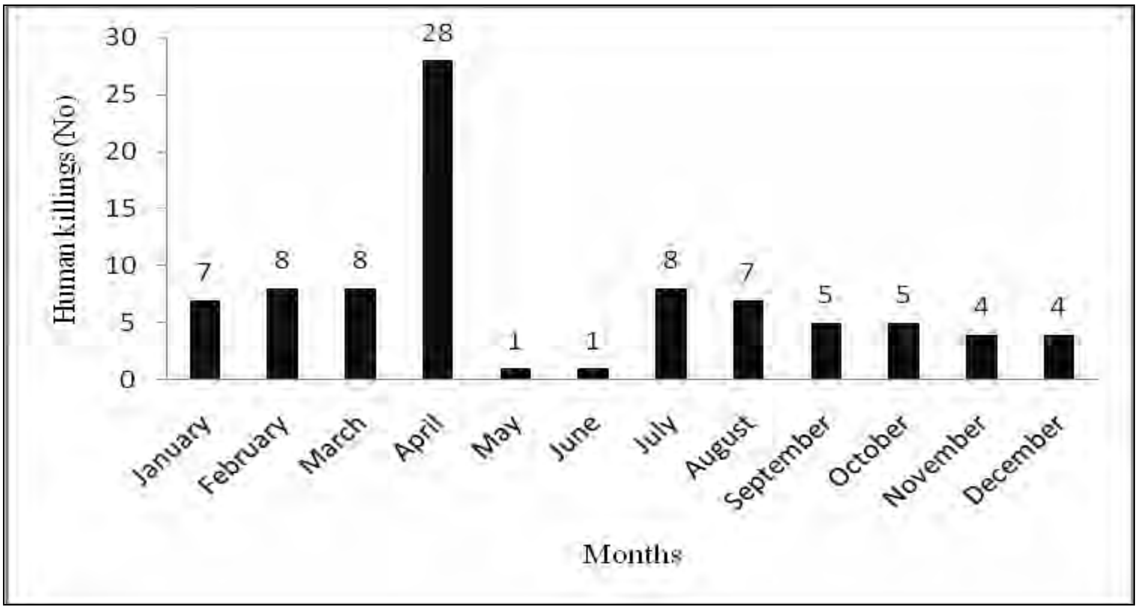


Fig. 16- Human killing by tigers in Sundarban Tiger Reserve- Monthwise distribution (1998-99 to 2009-10)

5. The diurnal variation of tiger attack on human reveals that 46% people have been attacked by tigers in evening (3 pm to 8 pm) whereas 25% people have been attacked in morning hours (5 am to 10 am) followed by 18% in afternoon (10 am to 3 pm) and 11% in night (8 pm to 5 am) (Table 17 and Fig. 17). This shows that maximum killings take place in morning and evening hours (71%) and 29% in afternoon and night (14 hours of day). The trendline equation shows a dreasing trend of human killing by tigers monthwise as shown in Fig. 15.

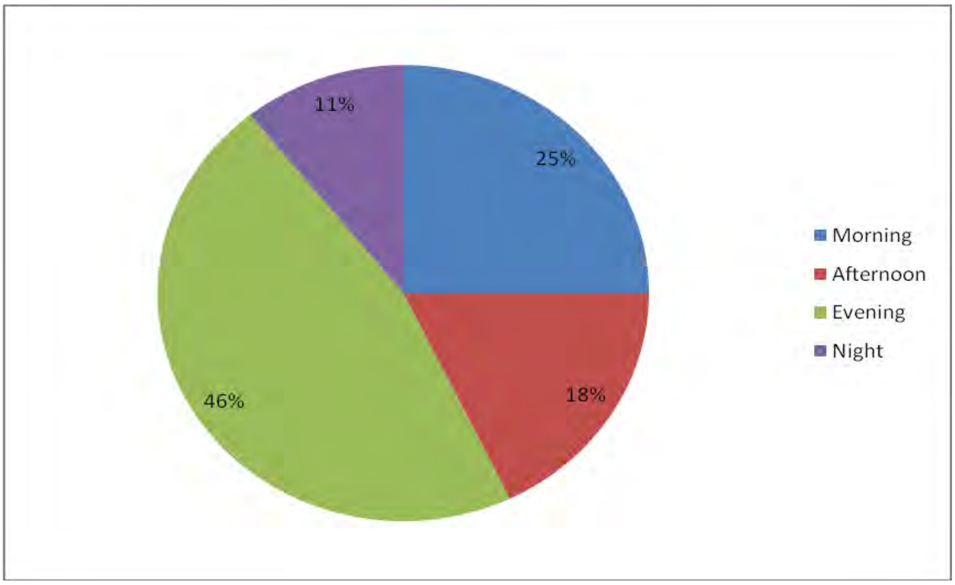


Fig. 17- Human killing by tigers- Diurnal variation (Mean of the year 2003-04, 2007-08, 2008-09 and 2009-10)

7.1.3.8. Statistical interpretation of human-tiger conflict (straying cases)

In Sundarban human death by tiger has been accepted as a professional hazard or lifestyle (IUCN Bangladesh, 2004: Chakrabarty, 1992) but it is the tiger straying which is a most serious management issue. Since the implementation of Wildlife (Protection) Act, 1972 and declaration of large part of Indian Sundarban a "Sundarban Tiger Reserve" the local people has been in conflict with the Forest Department due to the restrictions imposed on fishing and other natural resource extraction. As Forest Department imposes penalties for the illegal entry of people in forest, people have always treated the tiger as the property of Forest Department which has entered in their area. Out of fear, or to take revenge for the relatives killed by tigers inside the forest and to put pressure on Forest Department, people have been very aggressive on tiger and Forest Department during tiger straying. The analysis of data shows that during the last 24 years (1986 to 2009), a total of 40 fringe villages have been affected by the problem of tiger straying. Village wise frequency of tiger straying has been given in Fig. 18.

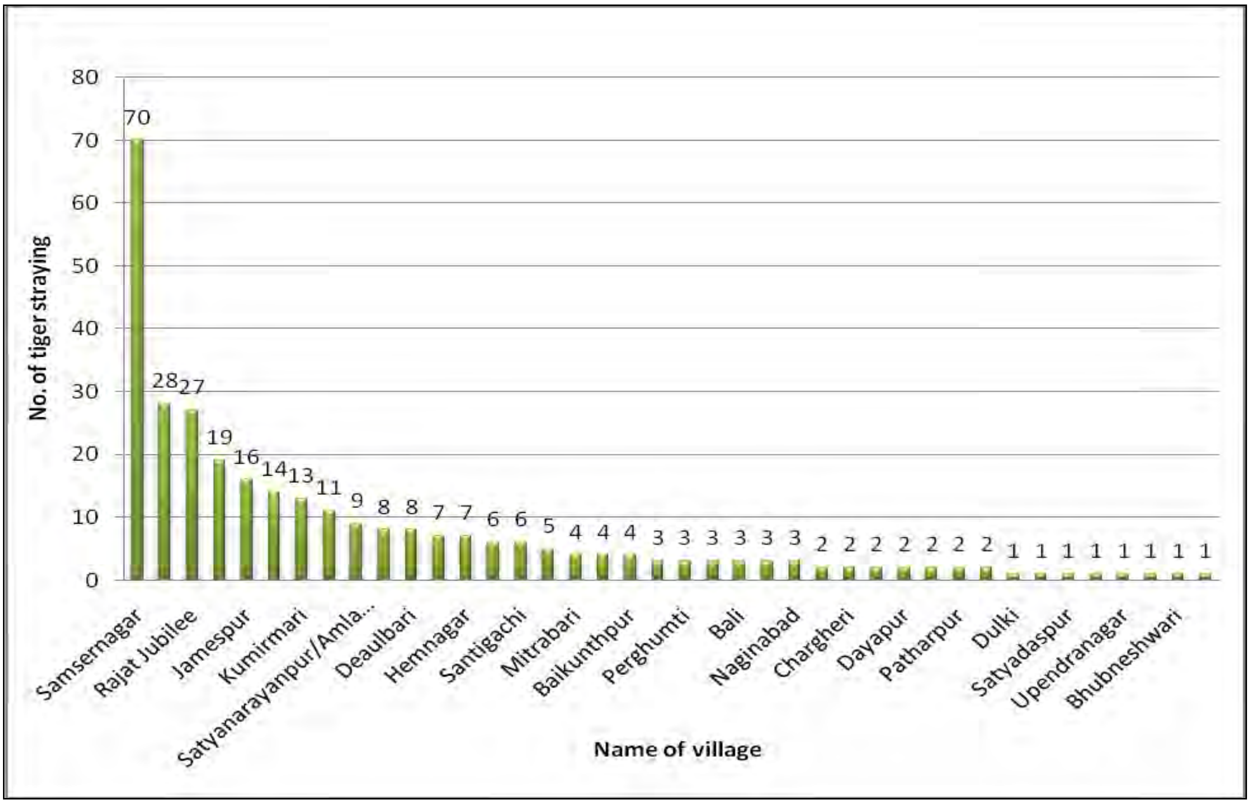


Fig. 18 – Spatial (village wise) frequency of tiger straying in Indian Sundarban (1986-2009)

1. ANOVA reveals significant village wise difference in tiger straying as F_{obs} = 5.7821 > F_{crit} = 4.0068. Such spatial variations in tiger straying are highly important to deal with the issue. Based on the frequency of tiger straying, fringe villages/ Forest Protection Committees and eco-development committeess have been classified in 5 Schedules i.e. Schedule I (Extreamly High tiger straying- > 30 in number), Schedule II (Very High- tiger straying from 21 to 30 in number), Schedule III (High- tiger straying 11 to 20 in number), Schedule IV (Occasionally affected- tiger straying between 1 to 10 in number) and Schedule V (No tiger straying) (Table 20 and Fig. 18).
2. Highly significant variation in tiger straying was also observed between months ($p<0.01$). ANOVA depicts highly significant month wise variation in tiger straying as F_{obs} = 46.9246 > F_{crit} = 4.3009. However ANOVA do not depict any

significant variation in year-wise tiger straying as analysed from the data (Table 21 and Fig. 19).

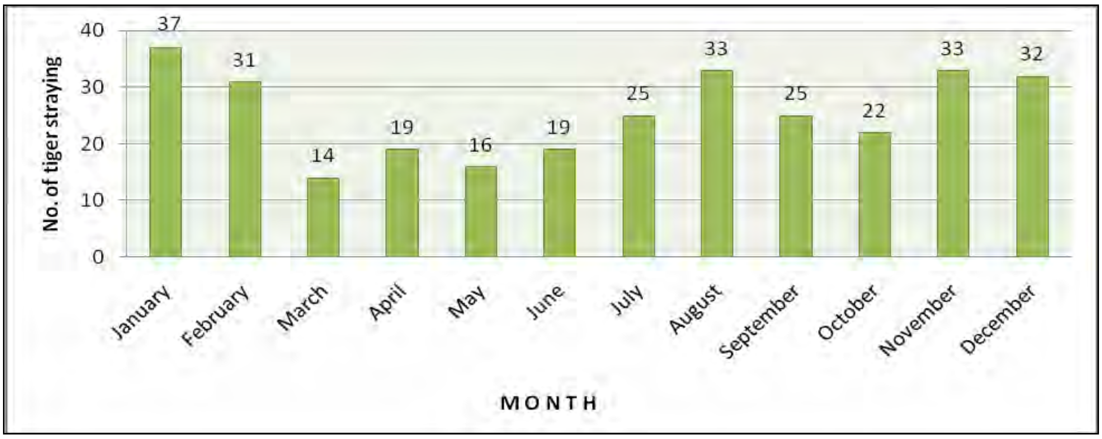


Fig. 19- Monthwise variation of tiger straying in Indian Sundarban (1986 – 2009)

7.1.3.9 Discussions on others causes for tiger straying

Tiger straying from its natural habitat to fringe villages is an abnormal behaviour and many reasons can be attributed for the same. Hunting by tiger in Sundarban is difficult as pneumatophore laden marshes of Sundarban take away the element of surprise, depriving tigers of its stealth up to some extent. Due to low hunting success rate in Sundarban, often tiger stray to villages for easy prey availability. Tigress with cub, old or disabled tiger often find it difficult to resist the "Lure crop" (Cattle, dogs etc.) just across the creeks separating the forest island from human villages. Sundarban is unique as there are no cattle grazing in the reserve depriving the predators of easy cattle availability to compensate the loss of hunting capacity that happens in other protected areas. Hence tigers here stray to village for easy prey.

Young tigers in search of territory and very old tigers are the usual strayers (Chakrabarty, 1992). During mating season the male and female tigers are busy in courtship and at times find it difficult to hunt in Sundarban"s difficult terrain, these restless tigers are often the class which generally stray.

The stakeholder consultation done during this study revealed that 59% of the participants from various Forest Protection Committee and Eco-Development Committee"s attributed lack of food as the main reason for tiger straying. About 22% felt that it is the old age and illness which is the cause whereas 19% attributed other reasons for tiger straying including disturbance caused by miscreants (cattle smugglers etc.), environmental problems, increase in tiger population, trans-border tiger movement etc. One of the major reasons for tiger straying in some of the villages of Schedule I and Schedule II appears to be the siltation of the water channels, which used to provide a clear boundary between mangrove forest and villages. Shamshernagar, Kalitala are such two villages as the Shakun Khal has been silted up gradually in last 20 years (Plate 27). Similarly villages like Nagenabad, Deulbari etc. are facing the same problem as in low tide, water in the channels is less than 4 feet.

The concept of territoriality in tigers in Sundarban has been debated since long time. Some experts feel that territorial markings by tigers in Sundarban get obliterated by the daily tides, as a result of which Sundarban tigers are predominantly non-territorial (Sanyal, 2001). However, capture of a male tiger in Shamshernagar in 2004 and its return to same area twice raises big question on the validity of this assumption (Annexure 13).

Some of the observers state the presence of mangrove plantation on embankment and *Porteresia coarctata* (Dhani grass) covered mud flats around villages confuse tigers with that of forests and this leads to inadvertent straying (Sanyal, 2001).

An observation by researcher has linked the tiger straying to moon phase and its effect on tides. It has been found that tiger trying to cross from one forest island to other forest island near the confluence gets carried away by the high current and struggles to reach the bank. In Sundarban, at places where 2-3 streams meet, different strata of water flows over the other in different direction for short section of length due to difference in density caused by varying salinity. In such places the best swimmers may lose their skills and start strugglling. The volume of water in water channel and its current velocity are maximum in "Kotal Phase" (Four days of pre and post New moon & Full moon) and least in "Morani Phase" (period not covered under Kotal Phase).

7.1.3.10 Nylon net fence- A tool to prevent tiger straying

The Forest Department, West Bengal is now using nylon net fence to prevent tiger straying from forest to village. Nylon net fence is a "maintenance sensitive" tool for mitigating tiger straying and its capacity to prevent tiger straying depends on its quality. Nylon net fence on one hand prevents tiger to stray in villages and on the other hand it also prevents people‟s entry in forest for various purposes, as a result of which, many villagers damage it. Sundarban forest has numerous creeks in which tidal water changes direction every six hours and carry debris hence these creeks cannot be blocked. The Stakeholder Survey-2010 has shown (Fig. 30 a-s) that 53% of the participants viewed nylon net fence as very useful, 43% felt that it is of little use and 4% felt that it is not useful. The 43% participant‟s opinion that fence is of little use indicates that perhaps these fences were not really maintained and needs attention.

Since 1st April, 2010, a new system to investigate all the tiger straying incidences have been started by Forest Department. According to this system every tiger straying is investigated by field officer and the report is submitted to Director, Sundarban Biosphere Reserve. The analysis of these reports indicates that tigers have negotiated the fences primarily by three means viz. (i) by jumping over the fence, (ii) through creeks and (iii) through poorly maintained nylon net fences. Since then it has been decided to raise the height of nylon net fence from 6 feet to 7 feet to prevent jumping over cases. Another fact which has come to light is that the fencing post of Baen (*Avicennia sp.*) has rotted at the base resulting in drooping of fence (Plate 28a, Plate 28b and Plate 28c), making it easier for tigers to jump over. To overcome this problem, a decision has been taken to replace the Baen posts with Bamboo or with Garan (*Ceriops sp.*) (Plate 29). The advantage with Bamboo is that they prevent the use of mangroves thus helps in habitat protection and mangrove conservation. As part of the present study, a new design of the nylon net fence to prevent tiger straying from creeks has been implemented. This new design with "Floaters" has been successful at Jharkhali. The creek part of fence has two strands: one fixed and another with floaters, which moves up and down with tides, ensuring that the creeks are fully fenced even in high tides (Plate 30).

7.1.3.11 Integrity of Indian Sundarban and human-tiger conflict

Integrity of forest is one of the most important factors which influence the human-tiger conflict in Sundarban. Tiger straying is directly related to the entry of people in forest as it causes disturbances, leads to chances of poaching of wildlife and blocks the chance for tiger to use the area as corridor to move from one island to other island in search of prey and other requirements. Hendrichs (1975) initially felt that salinity is the major factor for man-eating. However, he also pointed out the "availability of human prey" who utilize the forest and are caught by the tigers in Sundarban. Later after analysis of data, he claimed that numbers of people engaged in the forestry operations in low salinity areas are not directly correlated with the availability of men but in high salinity zone human killing by tiger is directly correlated to the availability of men. Salter (1984) also opined that frequency of man-killing is highest in areas of high concentration of people, where frequencies of man-killing and man-tiger contacts are directly correlated. JJS (2003) also suggested that a direct relation exists between the number of attacks and number of people accessing the forest. Denzau and Denzau (2010) suggests that "High level of disturbances by forest resource users seem to provoke man-eating behaviour among local tigers, despite all other aspects. Therefore number of tiger victims can only be reduced if less people enter the forest".

In Indian Sundarban, many positive steps have been taken to improve the integrity of forest against the illegal activities. In addition, complete closure of timber harvesting for over a decade has also resulted in less number of people entering the forest as compared to the period up to the year 2000.

The analysis of human-killing data suggests that during the last decade human-killing were minimal in the years 2004-05, 2005-06 and 2006-07 i.e. 3, 1 and nil but has shown a rising trend thereafter. Although human killing by tiger is an outcome of functioning of various factors but the analysis of "Offence Records" and practices followed to deal with the violation of integrity of Core Zone or Critical Wildlife Habitat and Saznekhali Wildlife Sanctuary of Sundarban Tiger Reserve has indicated to a great extent, that it is the very small amount of fine imposed for the fishing offences, that encourages fishermen to enter the Critical Wildlife Habitat and Saznekhali Wildlife Sanctuary, where the large number of people are killed by tigers. There is currently no monitoring system to identify the habitual offenders who enter the critical wildlife habitat and Saznekhali wildlife sanctuary and pay small fine in lieu of rich catch of fish. Following tables show the Compensation Offence Reports (COR cases) booked in Sundarban Tiger Reserve and the compensation amount realized (Table 6 and Fig. 20):

Table 6

Average fine (in Rs.) imposed on fishermen for violation of rules in Sundarban Tiger Reserve (2005-06 to 2009-10)

Particulars	**YEAR**				
	2005-06	**2006-07**	**2007-08**	**2008-09**	**2009-10**
No. of COR* cases (mainly fishing offences)	1462	2427	2086	1490	1684
Compensation (fine) realized (in Rs.)	801914.00	1021420.00	998920.00	684500.00	825834.00
Average Compensation / COR case (in Rs.)	548.50	420.86	478.87	459.40	490.40
*Compensation Offence Reports in Sundarban Tiger Reserve are primarily the offences committed by fishermen in the form of illegal entry in Critical wildlife Habitat (Core Area) and in Saznekhali Wildlife Sanctuary, over stay than permitted as per Boat License Certificate. (Source : Monthly Offence Reports of Sundarban Tiger Reserve).					

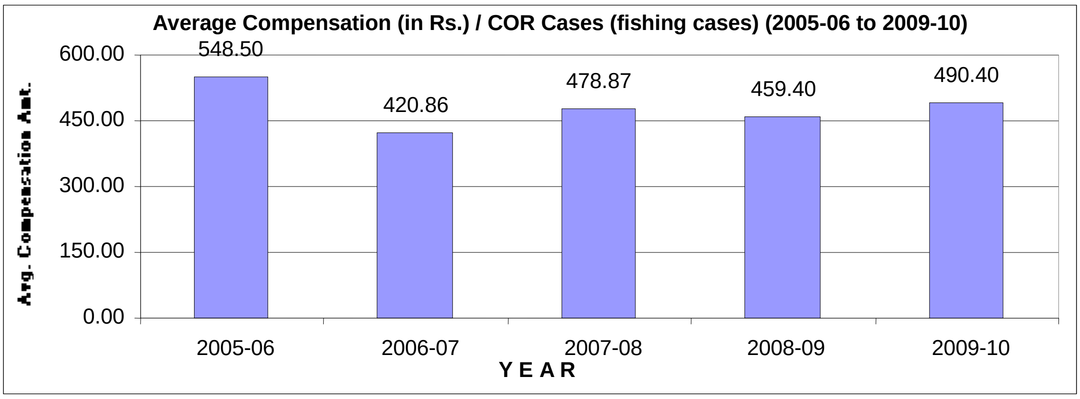


Fig. 20 - Average compensation (Rs.) realized from fishermen for violation of rules.

From the data it is clear that since 2005-06 average compensation (offence penalty) per fishing case has ranged from Rs. 420.86 (2006-07) to Rs. 548.50 (2005-06). It was Rs. 548.50 per case in 2005-06 and was Rs. 490.40 per case in year 2009-10. It is obvious that the „pocket pinch" felt by average fisherman violating the rules is almost half in the year 2009-10 as compared to the year 2005-06 due to inflation. The compensation amount should have been almost doubled in 2009-10 as compared to 2005-06 but in reality it is less than the penalty amount of the year 2005-06. The fish catch in no-fishing zone is very high (due to under-exploitation) as compared to fishing zone (due to over-exploitation). Based on compensation amount COR data for the year 2010-11 were categorized in four categories as given in Table 7 and Fig. 21.

Table 7

COR Cases Sundarban Tiger Reserve – Financial Slabs for the year 2010-11

< Rs. 400	Rs. 400 - 800	Rs. 801 - 1200	> Rs. 1200
1400	202	332	21
Source : Monthly Offence Reports of Sundarban Tiger Reserve, 2010-11			

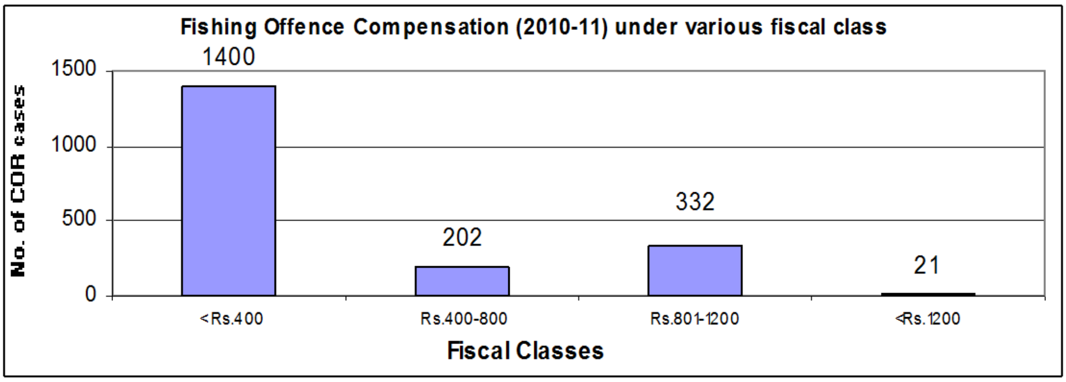


Fig. 21 - Fishing offence compensation (2010-11) under various fiscal class

The COR data for the year 2010-11 has been analyzed and placed in four fiscal categories. It is observed that out of total 1955 COR cases 1400 (71.61%) are in the category with compensation amount less than Rs. 400 per case. There are 202 (10.33%) COR cases (Table 7 and Fig. 21) in fiscal category of Rs. 401-800, 332 (16.98%) COR cases in fiscal category of Rs. 801-1200 and 21 (1.07%) COR cases in fiscal category of Rs. 1201 and above. It is observed that though the number of COR cases, which are mainly for violation of fishing rules, has increased in 2010-11 but the compensation amount of 71.61% cases is Rs. 400.00 or less, which certainly is not a deterrent for a fishermen group of about five persons for carrying fishing operations for about a week or more in Critical Wildlife Habitat or in Saznekhali Wildlife Sanctuary as the fish catch there is very high. It is a clear from the discussions that though patrolling are performed by Forest Department but the punitive action in the form of fines imposed on fishermen is not a deterrent. There is no monitoring mechanism to find out how many times a fisherman has violated the rules and has become a habitual rule breaker.

7.1.3.12 Joint Forest Management and human-tiger conflict

The "Joint Forest Management" (JFM) or "People‟s participation" has been taken up in Reserved Forests of Sundarban since 1991 (Forest Protection Committees or FPC) and in Protected Areas of the Sundarban since 1996 (Eco-Development Committee or EDC) but the real efforts to use this concept as management tool in Sundarban started since 2001 onward after the killing of tigers by mob during the tiger straying incidents in Pakhiralaya and in Kishorimohanpur villages. An analysis of the performance of these Forest Protection Committee‟s and Eco-Development Committee‟s and their relationship with Forest Department has been done with following indicators:

a. The tiger killing during straying by fringe people and co-operation extended by local communities to Forest Department during the operation.

The data available from Director, Sundarban Biosphere Reserve‟s office revealed that since 2001 no tiger has been killed during straying from forest to villages. It is a major success of the JFM programme. Since 2001, a total of 324 tiger straying have been recorded in Sundarban and due to people‟s cooperation a total of 55 tiger have been captured, 19 by immobilization and 36 by trapping in cages with bait (Annexure 7). It is a major breakthrough especially after two tigers were brutally killed in two separate incidences in the year 2001.

b. The killing of wild animals other than tiger by fringe people during straying from forest to villages.

No data for the rescue of wildlife other than tiger are available for the period prior to 2001 but it is simple to guess that most of them were killed by villagers due to strained relationship with Forest Department. This may be due to their value as food for people (as society in general is non-vegetarian) and also due to lack of awareness. Hardly any information used to reach to the Forest Department about the straying of wild animals other than tiger and estuarine crocodile. The data available for rescue of the strayed wild animals other than tiger since 2001 has indicated a major success of JFM programme in Sundarban as large numbers of wild animals have been saved by people every year. This is an indication of the trust developed between the Forest Department and the Sundarban people in the last decade (Plate31).

c. Governance of the Forest Protection Committees and Eco-Development Committees.

The governance of the Forest Protection Committees and Eco-Development Committees has been analysed with the help of the data gathered on Annual General Meeting"s (AGM"s) held (Annexure 15 and Plate 32). The analysis of these data indicates a direct co-relationship of the governance of Forest Protection Committees and Eco-Development Committees with human-tiger conflicts. Most of the committees which had human-wildlife conflicts especially tiger straying had better governance and AGM"s were held there regularly if not every year in contrast to those committees which did not had the human-wildlife conflicts. The reason for the same is that the committees with human-wildlife conflicts have received maximum attention and inputs from Forest Department whereas other committees have received very less attention resulting in lack of awareness, which has affected its functioning.

In Sundarban Tiger Reserve where tiger straying is a serious problem, it is observed that AGM of each of the committee have been held at least once in last three years as contrast to 24 Parganas (South) Division where AGM"s of many committees have not been held since their formation, as revealed from the official records of Forest Department. This indicates that governance of many committees is not robust and they need improvement. It also indicates that on one hand primarily human-wildlife conflict (mainly tiger straying) centric JFM management has been really a success in Sundarban in mitigating the human-wildlife conflicts but on the other hand those committees which do not share human-wildlife conflicts (mainly tiger straying) issue have remained relatively neglected. The role of these committees in conservation of other bio-resources of Sundarban especially in control of poaching cannot be treated of less value hence their governance needs to be paid attention.

d. Alternate livelihood activities.

It is seen that the funds of the Forest Department have increased steadily in last decade for alternate livelihood programmes (Plate 33 and Plate 34). Prior to 1998, Forest Department hardly had any opportunity in deciding the fate of strayed animals and the animals would either be driven back by the villagers or be killed (SBR, 2010). Since 2002 not a single strayed animal have been killed and all have been safely retuned to wild due to absolute success of the confidence building activities of the Forest Department (SBR, 2010).

The quantum of “Alternate Livelihood Activities” (ALA) taken up in Forest Protection Committee and Eco-Development Committee areas has been analysed for last five years (Annexure 14). It is observed that all the Forest Protection Committees and Eco-Development Committee‟s which have the human-wildlife conflict especially tiger straying have received the maximum quantum of inputs for alternate livelihood activities. The wild animal rescue including that of tigers has a direct linkage with the inputs. The local leadership on one hand helped in the implementation of alternate livelihood programmes and on the other hand has come forward in saving all wildlife and in tiger rescue operations. It was the trust between the local communities and Forest Department, which has ensured that in the year 2004, a strayed tiger was not harmed by the villagers of Shamshernagar Forest Protection Committee, on the eastern border of Sundarban Tiger Reserve though it had killed a young girl inside the village. The analysis of data for investment in various Forest Protection Committee‟s and Eco-Development Committee‟s have shown that the committees with high investment have reciprocated very well and the committees with moderate or low investment has not co-operated to the extent to make it a smooth operation. The Forest Department has faced serious problems in rescuing the tigers in such committees which have received low inputs from the Forest Department in alternate livelihood programmes.

e. The benefit received by Forest Protection Committees and Eco-Development Committees in Sundarban.

Sundarban does not offer much to the local communities except honey and fish. When in 1991 Forest Protection Committees were formed, they were entitled to the

25% of the small wood and firewood coming out of clear felling coupes. Later from 2001 onward no departmental felling has taken place in Sundarban so Forest Protection Committee members have not received any return from the Forest Department till date except free honey collection. Fishing is not allowed to any one until fishermen possesses Boat License Certificate (BLC), which is highly restricted and is generally not given to new people. The Eco-Development Committee members do receive 25% of the share of eco-tourism revenues, which is at present not a very high amount. The quantum of infrastructure development and alternate livelihood programmes undertaken by Forest Department in the Forest Protection Committee and Eco-Development Committee areas is the major benefit for the people. This has resulted in trust building and reciprocal commitment to save the bio-resources of Sundarban.

7.1.3.13 Climate change and human-wildlife conflict in Indian Sundarban

One of the most serious threats to Sundarban ecosystem may be due to climate change. Most of the Sundarban lies at sea level and some of the areas are even below sea level. The impact of climate change on Sundarban will be mainly from sea level rise, rise in water surface temperature leading to increased salinity and increased cyclonic storms etc.

The last cyclone Aila, which devastated Indian Sundarban in May, 2009 has done serious damage to the life and property in Sundarban. A loss of 23% of agricultural land was recorded (Vyas et al., 2011) as the 5 km forest fringe land in the villages could not be cultivated by villagers even after one year as the soil salinity increased considerably due to flooding of sea water. Though the loss of forest and wildlife recorded was very low but the assessment done may not give true picture as the staff teams could visit affected areas only after cyclone was over and the possibilities of carcasses carried away by the mighty tides to sea cannot be ruled out. The loss of livelihood to a large section of fringe population enhanced their dependence on natural resources of Sundarban leading to adverse impact on habitat.

The rise of sea water temperature due to climate change will result in increase in water salinity which has a direct correlation with mangrove vegetation. The rise in salinity will be favourable to some of the mangroves while some other species may become locally extinct (Vyas et al., 2011). This will change the habitat and may result in enhanced human-tiger conflicts.

A study in Bangladesh Sundarban has recorded the impact of sea level rise, due to climate change and concluded that it threatens the long term persistence of the Sundarban forests and its biodiversity (Loucks et al, 2009). Using high resolution elevation data, study estimated that a 28 cm rise above the year 2000 levels, would decline 96% of tiger habitat in Bangladesh Sundarban and number of breeding individuals would be reduced to less than 20.The study predicted that with current level sea rise, this 28 cm sea level rise may occur in the next 50-90 years. This climate change induced habitat loss may endanger the Sundarban tiger survival. Indian Sundarban has almost similar conditions and the impact of sea level rise may have similar impacts in Indian Sundarban too. This study though has not taken many factors into consideration i.e. sediment accretion, erosion, geological processes, drainage etc. but the threat to Sundarban tiger from climate change induced habitat loss is real.

7.1.3.14 Availability of prey, telemetry studies and human-tiger conflicts

The human-tiger conflicts in Sundarban are a complex issue and often rightly linked with the availability of prey. The delta specific conditions i.e. swamp, pneumatophores, saline water, tides, etc. has made the habitat unique and research difficult. There exist no authentic data of prey base for Indian Sundarban. No complete study on Indian Sundarban tiger ecology has been done.

Forest Department started the estimation of tiger population in Indian Sundarban from 1973 onward by using the “Pug Mark Method”. Initially, it was done only in Sundarban Tiger Reserve but from 1983 onward 24 Parganas (South) Division also started the exercise. The estimated tiger population in Indian Sundarban is given in Annexure 12. From the data it is seen that from 1973 to 2006 estimation of tiger population was done with tiger pugmark analysis methodology. The estimated tiger numbers included cubs too. The debate on the low reliability of the pugmark methodology resulted in the development of new methodology jointly by National Tiger Conservation Authority and Wildlife Institute of India in the year 2005. “National Tiger Status and Habitat Monitoring Protocols” a technical publication of Project Tiger, 2005, edited by Rajesh Gopal, Y. Jhala and Qamar Quereshi gave a detailed methodology to be adopted for estimation of tigers. The new methodology is more scientific in approach and has prescribed the process for Monitoring of Tigers, Co-predators, Prey and Habitat, a holistic ecosystem approach away from earlier pugmark method which only focused on tiger numbers. In Sundarban Monitoring of Tigers, Co-predators, Prey and Habitat Exercise was carried out for the first time from 5th to 10th January, 2006 and a large set of data were collected. No tiger estimation figures for the 2006 has been published as the analysis of these data by WII could not be done for the want of information on tiger ecology as the same was not available for Sundarban tigers. It was decided that an already approved project of Forest Department, West Bengal in collaboration with NTCA, titled "A Study on the Behaviour, Home Range and Ecology of Tiger in the Sundarban of India" shall be utilized for the purpose. Later camera trapping also provided valuable data (Plate 35). The analysis of 2010 data has given a range of 64 to 90 tigers with mean of 77 tigers. This is first ever tiger estimation figure received with highly scientific methodology and now forms scientific baseline data. However low sample size for the camera trapping, other surveys and non-availability of prey base data acts as a limiting factor especially when the salinity varies from season to season and from east to west and influences the mangrove vegetation. More sampling by camera traps and collared tigers is required for precise estimation (Jhala et al., 2011). The methodology adopted needs further refinement and long term research on tiger ecology is needed before the tiger estimation figures for Sundarban can be called highly reliable. In the present circumstances they are however the best available estimate.

The Radio-Collaring studies in Indian Sundarban by Forest Department in collaboration with Wildlife Institute of India and National Tiger Conservation Authority has given preliminary findings. Under the project, a total of six tigers were captured and radio-collared (Plate 36). Of these four tigers were resident tigers and captured inside the forest whereas two tigers were the strayed tigers and captured from the villages of Sonagaon and Kalidaspur. Out of these six tigers radio-collared three were male and three female (Annexure 11). Among the two strayed tigers radio-collared one was female and other was male. In general, the resident tigers captured and released at the same place showed sign of territoriality, their movements were normal and within a definite areas in comparison to the strayed tigers (Plate 37). The radio-collared female Sonagaon tigress showed a very high movement before it lost the radio-collar after about two months. The male strayed tiger which was captured in Kalidaspur village of Bashirhat Range and released at Katuajhuri moved to Talpatti forest of Bangladesh after few days (Plate 38). Though it moved considerably but remained confined within this island indicating signs of territoriality. It also confirmed the trans-border movement of tigers, a reason suggested by some participants in Stakeholder Conference-2010. On the basis of these facts it will be inappropriate to say that Sundarban tigers are not territorial. However, this concept needs to be studied further as the territoriality Sundarban tigers may not be as rigid as for the tigers of other areas on account of various reasons including prey availability, tidal rhythm etc.

Seasonality plays a very important role in Sundarban. The data collected from 2006 and that of 2010 exercise were compared. It was observed that though the numbers of days of both the exercise were same but the number of observations made in both the exercise differed considerably. There were a total 2471 number of tiger pugmarks observed in the year 2006 during river transects as compared to only 818 of tiger pugmark observations made in 2010 during river transects. There is sharp decline of 66.89 % in tiger pugmarks in 2010 as compared to 2006. Similarly, the number of signs/ evidences of other wild animals (spotted deer and wild boar) were 18293 in 2006 as compared to only 4267 in 2010 exercise showing a decline of 76.67 %. There may be many reasons for the same but one of the important reasons is that in 2006 exercise was done in first week of January whereas the exercise in 2010 was done in March, when temperature is high in Sundarban.

The prey base estimation has never been done in Sundarban due to difficult terrain and aggressive tigers. The management plan and working plans of Forest Department provide no information on the aspect. The definition of prey base also is very wide in Sundarban as Sundarban tigers prey list includes spotted deer, wild boars, Rhesus macaque, water monitor lizards, otters, snakes, fish, crabs and even birds (Chaudhuri and Choudhuri, 1994). Tiger feeding on marine animal carcass carried by tides to island shores is known to fishermen. One King Cobra and one Monocoellate Cobra were found in semi-digested condition in the stomach, during post-mortem of a tiger found dead in Netidopani-1 compartment of Sundarban Tiger Reserve on 17th July, 2009 (Annual Report Sundarban Tiger Reserve, 2009-10) (Plate 39). A study by Reza et al. (2000) in Bangladesh Sundarban indicated that spotted deer is the principal prey of tigers and accounts for 67% of the prey while wild boar makes up to 12% followed by monkey with 6%. Based on 113 scat samples of tigers in Indian Sundarban, Mukherjee (2004) observed the percent occurrence of various prey species were, spotted deer (53.79%), wild boar (19.31%), monkey (6.89%), water monitor (9.65%), fishing cat (0.68%), fish (4.13%), crabs (4.82%) and turtles (0.68%). He observed that mammalian prey base of the tigers in Indian Sundarban is supplemented by water monitor lizards, fishes, crabs and turtles. He was of the view that medium sized ungulates viz, spotted deer and wild boar forms the main prey as the large size ungulates has become extinct in Sundarban long ago and tigers cannot be said to be under stress because of low availability of food due to the availability of many other species to supplement food.

Reza et al (2004) studied 52 tiger scats during the 15 months study period from January, 1999 to March, 2000 in the Bangladesh Sundarban and observed spotted deer, wild boar and monkey as the main prey species of tigers with 69%, 15% and 5% of total weight. In addition 4% were the unidentified animal parts consisting of scales of fishes, broken hard shells of crabs and even feather of Green- billed Malkoha (*Rhopodytes tristis*). A prey selection study in Bangladesh Sundarban recorded that out of a total of 26 tiger kills, spotted deer kills were the highest with 65%, wild boar kills were 23% followed by monitor lizards with 11% (IUCN, 2004).

Sanyal (2001) observed that there is hardly any food shortage for about 250 tiger of Sundarban and Tiger Reserve has a spotted deer population of nearly 30,000 and 11,000 wild pigs at any point of time. 17.5% of food for tiger comes from aquatic sources like fishes, crabs, turtles, water monitors (Sanyal, 1990). He recorded that in Indian Sundarban wild boar is the most preferred terrestrial prey followed by spotted deer and monkey. The ungulate biomass in Sundarban is 1200 kg/sq. km. (Sunquist, 1981).

It is observed that in Indian Sundarban no long term prey base study has ever been done. There is diverse opinion about the prey base status in Indian Sundarban. Some observed that there is no prey shortage for Sundarban tigers (Mukherjee, 2004; Sanyal, 1990) while others feel that shortage of prey is one of the important reasons for human-tiger conflict in Indian Sundarban. The Stakeholder Survey

2010-11 among the affected fringe dwellers has revealed that 59% of the respondents are of the opinion that shortage of prey is the cause of human-tiger conflict. Forest Department, West Bengal, India had taken the step of a wild boar farming to supplement the food in wild to prevent human-tiger conflict (Sanyal, 1987). In recent time the Forest Department has taken up programme for the release of spotted deer, bought from various deer parks of the State. These spotted deer are medically examined, acclimatized and released in wild to mitigate the human-tiger conflict. Such deer populations have been released at Herobhanga and Bonnie in 24 Parganas (South) Division and Dobanki in Sundarban Tiger Reserve (Plate 40). As there is no strong scientific monitoring mechanism except the observations by local staff, it is difficult to assess the impact of such programmes.

7.1.3.15 Compensation

The Forest Department in Indian Sundarban provides compensation to the dependents of tiger victim and free medical treatment to the injured. This is provided only to those who enter the forest with valid permits. A large section of people mainly the crab-collectors, who enter in Sundarban without permit, do not come in the ambit of this facility. This on one hand is logical as illegal entrants needs to be discouraged but on the other hand results in agony of poor dependents. The enhancement of compensation amount to Rs. 100,000 has helped dependents of victims to cope financial problems and has mitigated chance of retribution (Vyas et al., 2010a). The time taken for payment of compensation amount has improved and 50% of the dependents felt that they have received prompt compensation payment (Vyas et al., 2010a). The human death by tiger generally leads the family to misery and it has been observed that in most of the time the widow of the tiger victim is dependent on relatives and has to work hard for survival (Vyas et al., 2010a).

7.1.3.16 Honey-collection and Boat License Certificates (BLC) for fishermen

Honey collection in Sundarban is an activity which results in maximum human-tiger conflicts. The human-tiger conflicts inside the forest areas primarily occur as tigers gets disturbed and irritated due to human intrusions in its habitat. Honey collectors penetrate deep in the forest areas in search of beehives and burn the leaves of *Nypa palm* and *Phoenix* causing a lot of smoke. Intrusion of large number of people in the forest which otherwise do not receive many intruders causes a massive disturbance to the fragile ecosystem. Vyas at.al (2010b) has analysed the socio-economic aspects of honey collection in Indian Sundarban. It was observed that in the year 2009-10 a total of 154 honey collection BLC (permits) were issued by Forest Department and about 1078 honey collectors entered in Sundarban forest with legal permits. On an average each honey collector earned about Rs. 5800/month from honey collection during April and May as compared to about Rs. 3000/month from earned from fishing activity. This amount is after deducting the expenses. In a sample survey conducted under the study, it was observed that 80% of the honey collectors were traditional, whereas 20% were non-traditional and were new in the profession. All the honey collectors (100%) were fishermen as fishing is closed during this period. The reason for being engaged in the honey collection activity is that some honey collectors opted for honey collection as there were no other job (37%), some opted due to high amount of money earning in short time (10%) whereas 35% respondent opted for both the reasons. Only 18% honey collectors opted for honey collection due to tradition.

The extent of human-tiger conflict with honey collection activity can be correlated with the response of the honey collectors about the threats they face during honey collection. All the honey collector feared tiger as the danger (100%), 70% feared snakes, whereas natural calamity, piracy and sickness were perceived as danger by 30%, 10% and 20% respondents respectively.

The matter of issuance of Boat License Certificate or BLC to the fishermen and others has been analysed. BLC is the license to fishermen for fishing in multiple use zones. Same BLC is issued for honey collection as well as for eco-tourism boats. The BLC is to be renewed every year against a small fee. There are no charges for fishing and no formal permission for fishing is issued. All fishermen with valid BLC approach Forest Department"s "Beat offices or Stations" from where they are issued permission to enter in the forest for 2 to 3 weeks and they pay Rs. 5/fisherman/week for "Dry Fuel-wood Collection" or DFC. In addition, the permit issued to fishermen mentions that certain category of fishing nets cannot be used of which "Chorapata Jal" is the main.

The number of BLC"s in Sundarban has not changed since 1973 and upper limit is 5070 fishing BLC"s. Most of the fishing BLC holders are very old and ownership has been changed within family or in case of death of fisherman by tiger, the ownership is given even to widow, if there is no other adult member in family. In Sundarban Tiger Reserve no women are seen in the fishing business whereas in 24 Parganas (South) Division it is a common sight to see a woman in the fishing party (Plate 41). The fishing boats are open and are subjected to all kind of threats either from wildlife or from the elements of nature. Off late some well off BLC owner has started illegal renting of BLC"s to needy fisherman without BLC. These BLC holders are influential local people and there exist no mechanism to monitor their illegal activities so Forest Department has not yet initiated any action to solve this issue. In recent years, due to the importance of BLC issue, the Bon-O-Bhumi Sthyee Samiti of the district, which is a highest elected district level body on land and forest has started giving advice on issuance of fishing BLC""s. Another interesting aspect of the issue is that though no charges for fishing are levied by Forest Department but fishermen have to pay dry fuel-wood collection charges thus permitting their entry to forest land from boats in search of dry fuel-wood. In the wet Sundarban conditions the dry fuel-wood is unlikely to be available easily so most of the time fishermen go with cutting tools to cut the branches of small trees and are likely to become victim of tiger attack.

7.2 Impact of salinity on mangroves

The development and functioning of mangrove ecosystem is regulated by the dynamics of salinity levels. Salinity affects plant growth in a variety of ways: 1) by limiting the availability of water against the osmotic gradient, 2) by reducing nutrient availability, 3) by causing accumulation of Na^+ and Cl^- in toxic concentrations causing water stress conditions enhancing closure of stomata and reduced photosynthesis. It has been suggested that, at high salinity, the main cause of the decrease in growth is the reduction in the expansion rate of the leaf area caused by the high salt concentrations (Greenway and Munns, 1980; Rawson and Munns, 1984). In fact, the relative leaf expansion and net assimilation rate decreases in mangrove species as salinity increases (Ball, 1988; Ball and Pidsley, 1995).

The impact of increased salinity in the Sundarban is significant since it controls the distribution of species and productivity of the forest considerably (Das and Siddiqi, 1985). Due to increase in salinity, *Heritiera fomes* (Sundari), *Nypa fruticans* (Goalpata) and *Phoenix paludosa* (Hental) are declining rapidly (Gopal and Chauhan, 2006). The primary cause for top-dying of the species is believed to be the increasing level of salinity (Chaffey et al., 1985). Salinity, therefore, greatly influences the overall growth and productivity of the mangroves (Das and Siddiqi, 1985). The present study reveals that the central region of Indian Sundarban (stations 6 to 10) is more saline compared to the western part (stations 1 to 5). The western region of the deltaic lobe receives the snowmelt water of Himalayan glaciers after being regulated through several dams on the way (Mitra et al., 2011). The central region on the other hand, is fully deprived from such supply due to heavy siltation and clogging of the Bidyadhari channel in the late 15th century (Chaudhuri and Choudhury, 1994). The reduced fresh water flows in central region of the Sundarban have resulted in increased salinity of the river waters and has made the rivers shallower over the years. This has had significant effect on the biomass of the selected species thriving along these hypersaline river banks. Interestingly, the effects are species – specific. Increased salinity caused reduced growth in *S. apetala* whereas the positive influence of salinity was observed on *A. alba* and *E. agallocha*. Such differential adaptability of mangrove species to salinity has also been reported from Bangladesh Sundarban (Cintron et al., 1978). Ball (1988) also pointed out the species-specificity in relation to range of salinity tolerance.

Our data on biomass (particularly in the western Indian Sundarban) are higher than most of the published values studied in different mangrove belts of the world (Table 6) which may be attributed to favorable climatic conditions and appropriate dilution of the saline system with fresh water of the mighty River Ganga. The western region continuously receives the fresh water input from the Himalayan Glaciers after being regulated by the Farakka barrage. Five-year surveys (1999 to 2003) on water discharge from Farakka barrage revealed an average discharge of $(3.4 \pm 1.2) \times 10^3$ m^3s^{-1}. Higher discharge values were observed during the monsoon with an average of $(3.2 \pm 1.2) \times 10^3$ m^3s^{-1}, and the maximum of the order 4200 m^3s^{-1} during freshet (September). Considerably lower discharge values were recorded during pre-monsoon with an average of $(1.2 \pm 0.09) \times 10^3$ m^3s^{-1}, and the minimum of the order 860 m^3s^{-1} during May. During post-monsoon discharge values were moderate with an average of $(2.1 \pm 0.98) \times 10^3$ m^3s^{-1}(Mitra et al., 2011). The study area also experiences a subtropical monsoonal climate with an annual rainfall of 1,600 – 1,800 mm (Gopal and Chauhan, 2006) and surface run-off from the 60,000 km^2 catchments areas of Ganga-Bhagirathi-Hooghly system and their tributaries (Mitra et al., 2011). All these factors (barrage discharge + precipitation + runoff) increase the dilution factor of the Hooghly estuary in the western part of Indian Sundarban – a condition for better growth and increase of mangrove biomass. The central Indian Sundarban exhibited lower biomass of the mangrove species as compared to other mangrove zones in the world (Table 8). The high salinity in the central region (7.16% higher than the western region) is the primary cause behind this. Under salinity stress, accelerated leaf mortality rate is accompanied by a marked decrease in the leaf production rate, leading frequently to the death of the plant (Greenway and Munns, 1980; Munns and Termaat, 1986). In fact, in several mangrove species, an increase in soil salinity decreases the number of leaves per plant (Clough, 1984; Ball and Pidsley, 1995).

In mangrove forests, the root biomass is considerable, which could be an adaptation for living on soft sediments (Plate 42). Mangroves may be unable to mechanically support their above-ground weight without a heavy root system. In addition, soil moisture may cause increased allocation of biomass to the roots (Kramer and Kozlowski, 1979), with enhanced cambial activity induced by ethylene production under submerged conditions (Yamamoto et al., 1995). It is interesting to note that the BGB in this study area constituted 26.90% and 26.49% of the AGB in the western and central regions respectively. These values are higher than the usual 15% value of BGB compared to AGB (MacDicken, 1997). The high allocation of biomass in the root compartment of mangroves in the present geographical locale is probably an adaptation to cope with the unstable muddy substratum of the intertidal zone caused by high tidal amplitude (2-6 m), frequent inundation of the mudflats with the tidal waters and location of the region below the mean sea level.

The present study confirms the tolerance of *A. alba* and *E. agallocha* to higher levels of salinity. The significant negative correlation values between *S. apetala* biomass and ambient salinity reflects the sensitivity of the species to high salinity. Several mangrove tree species reach an optimum growth at salinities of 5 – 25% of standard seawater (Downton, 1982; Clough, 1984, Ball, 1988; Burchett et al, 1989; Ball and Pidsley, 1995). The pigments, being the key machinery in regulating the growth and survival of the mangroves require an optimum salinity range between 4 to 15 psu for proper functioning (Downton, 1982; Burchett et al., 1984). *S. apetala*, the fresh water loving mangrove species prefers an optimum salinity between 2 to 10 psu (Mitra et al., 2004). It can be concluded that the future of Sundarban mangroves hinges upon the efficiency of managing the limited freshwater resources coupled with appropriate selection of species for afforestation in the context of rising salinity.

7.3 Impact of climate change on Indian Sundarban

7.3.1. Surface water temperature

An important indicator of climate change is temperature. A critical analysis of temperature fluctuation since 1880 reveals two contrasting trends. Between 1880-1935, the temperature anomaly was consistently negative. However between the period 1980- 2010, a sharp rise is observed, which may be related to rapid industralization, urbanization and deforestation in recent times. The atmospheric temperature directly influences the water surface temperature. The pulse of the temperature fluctuation has also been preceived in the present study area. On the background data of Mitra et al., (2009), the present study also exhibits a surface water temperature rise in both western and central sectors during 2008 to 2010. The average temperature in the western sector (comprising of stations Harinbari, Chemaguri, Sagar South, Lothian Island and Prentice Island) has increased 0.04 ^{0}C/year which is 0.34% hike, whereas in the central sector (comprising stations Canning, Sajnekhali, Chotomolllakhali, Satjelia and Pakhiralaya) the increase is 0.14 ^{0}C/year which is a rise of 1.34%. This rate is, in fact, much higher than the observed and documented warming trends in the tropical Pacific Ocean (0.01–0.015°C/year), tropical Atlantic Ocean (0.01–0.02°C/year) and the planet itself

(0.006°C/year). Although it is hard to discuss with the present data set whether several planetary effects or other geological factors are causing the change, but the trend is a clear indication of change in temperature. In many parts of the world (*e.g*. in Europe), extreme coldness was observed in 2010, but this does not negate the phenomenon of global warming as the summer in the same region experienced extreme heat waves. The point here is that a specific short period such as a cold winter or even a hot summer is not the only proof that global warming has stopped or increased because short term variability can mask long term of trends. Hence, a long term data bank can only give a confirmed answer to climate change phenomenon. The IPCC reviewed relevant published studies of biological systems and concluded that 20–30% of species assessed may be at risk of extinction from climate change impacts within this century, if global mean temperatures rise to 2–3°C (3.6–5.4°F) above pre-industrial levels (Mitra et al., 2009). The observed change of 0.04 - 0.14 ^{0}C/ year presents a clear challenge to the survival of the floral and faunal diversity of this ecosystem in the next three decades.

7.3.2. Surface water salinity

Global warming might impact the salinity of oceanic waters in two very different ways. First, in the open ocean rising temperature would lead to increased evaporation, which in turn would result in increased salinity. In contrast, the salinity of surface water in bays, estuaries and coastal waters is a function of freshwater input from glaciers, precipitation and subsequent runoff, and intrusion of seawater. That the phenomenon of global warming melts glaciers, brings more rain, and transfers more freshwater into estuaries, coasts and bays is a generalization that does not hold uniformly in all the segments of the Indian Sundarban. The stations in the western region showed a significant and continuous decrease in salinity during the study period of 2008-2010 (0.41 psu/ year, which is 7.37% decrease) whereas the central sector showed an increase in salt concentration (0.36 psu/ year, which is 6.31% increase). This difference in the rate of change of salinity in both the sectors is due to the difference between their geographical settings as explained here. The rivers in the western sector of the Indian Sundarban (Hooghly and Muriganga), being continuations of the river Ganges, receive the snow melt water of the Himalayas after being regulated by several barrages on the way. On contrary, due to siltation of the Bidyadhari River since the late 15th century, the central Indian Sundarban does not receive the fresh water due to which a rising trend in salinity is observed (Plate 43). Thus reduction of salinity in the western sector could be a combination of melt water and human intervention (Farakka barrage discharge of freshwater). Increase in salinity in the central Indian Sundarban could be a combination of lack of freshwater and tidal water supply. The present study thus observes a clear *noise* (man- made intervention likeupstream dams) in the climate change signal for the western Indian Sundarban. However in the central sector the rise of salinity due to intrusion of sea water from Bay of Bengal may be a foot print of global warming induced sea level rise although other factors like siltation on the river basin, subsidence of the Sundarban islands are also some causative parameters of sea level rise and subsequent rise in salinity. This rising trend is alarming when compared with other parts of the world. In a study, Curry et al., (1993) found that the increase in salinity over the last 40 years in tropical Atlantic was 0.4–0.5 psu. This was at a rate of

0.125 psu per decade (i.e., ~0.0125 psu/year), which is less in magnitude than that observed in the study area.

Salinity has profound influence on coastal and estuarine biodiversity. Generally mangrove flora can tolerate and withstand higher salinity (Kathiresan, 2004). The mangrove flora develops diverse mechanisms associated with anatomic and physiological characteristics to regulate salt absorption and exclusion (Shan et al., 2008). However, the tolerance limit varies amongst the species, e.g. *Rhizophora mucronata* seedlings do well in 30‰ salinity while *Rhizophora apiculata* are better at 15‰ (Kathiresan and Thangam, 1990). On the other hand, higher salinity would cause a profound impact on animals such as planktons, fungi, benthic forms, shrimps, crabs, fishes, waterbirds and other wild fauna which live in and around the mangroves. For instance, Balasubrahmanyum (1994) reported a notable decrease in gastropods due to increasing salinity in the Pichavaram mangroves, while Nagarajan (1990), Nagarajan, Thiyagesan (1996) and Sandilyan (2009) showed the decline of migratory water birds especially the small and large waders. In addition, Kathiresan (2000) states that higher salinity in mangroves leads to depletion of nutrients. The reduced availability of nutrients in this habitat might influence the population of planktons, benthic organisms and other macro-invertebrates (Ramachandran, 1965). The changes in invertebrate population of any wetland could affect the top level predators such as birds (Sumathi et al., 2008).

In addition to the several species of microorganisms, benthic invertebrates and larval forms which exclusively depend on the mangrove wetlands for their survival are highly sensitive even to a slight change in salinity of this ecosystem (Paula et al., 2001). Obviously several animal species, especially during the larval period, do not possess well-developed salt balancing mechanism like plants. So, larval forms of several animals would get severely affected and most of the time they would fail to withstand increasing salinity. It is needless to say that each and every species has a role to play in an ecosystem. If a particular group or a species is being eliminated from a habitat, it would have a profound impact on the entire ecosystem, most of the time it might be the starting point of the disaster (Odum, 1971). It is the poor nutrients and higher salinity that are two great challenges to invertebrate diversity, which adversely reflects on the untapped biodiversity of the mangrove wetlands of India.

7.3.3. Geomorphological change of Sundarban Island

The deltaic complex of Sundarban encompassing an area of one million ha formed by the depositional activities of the Rivers Ganga, Brahmaputra and Meghna is shared between Bangladesh (62%) and India (38%). It is the last frontier of Bengal flood plains; a sprawling archipelago of 102 island, out of which 54 are inhibited. Evidences of erosion and accretion of islands are scattered throughout the entire deltaic complex (Table 9). It is very difficult to conclude the phenomenon of climate change induced sea level rise and subsequent erosion of islands in the matrix of this dynamic ecosystem as the subsidence rate (2 - 4 mm/yr) is also considerable (WWF, 2011). Several natural and anthropogenic factors are recognized as the key players, which may be divided into various components working in a synergistic or antagonistic way.

Player 1: Vertical delta development due to deposition of sediment

The considerable sediment runoff of the Ganga and Brahmaputra Rivers immediately after the ocean level rise has contributed to rapid development of Holocene delta. It has been reported that the delta development occurred in vertical direction (Mikhailov and Dotsenco, 2007). The comparison of the thickness of deposits ($\Delta H_{deposits}$) on the surface of the southern part of delta over the last 11,000 years (Goodbred and Kuehl, 2000) and the value of the ocean level rise ΔH_{ocean} over the same period (for all the time intervals within the limits of 11,000 years) produced $\Delta H_{deposits} > \Delta H_{ocean}$ or $\Delta H_{deposits} \sim (\Delta H_{ocean} + \Delta H_{subsidence})$, where, $\Delta H_{subsidence}$ was the value of land subsidence over the same period. Over the period of 11,000 – 7000 years ago, the deposited sediment layer on the Bengal basin surface exceeded 50 m; in the last 7000 years, the layer thickness was more than 15 m. The magnitude of $\Delta H_{deposits,}$ ΔH_{ocean} and $\Delta H_{subsidence}$ are the major players in regulating the sea level rise in the Sundarban delta. The sediment load in the central Indian Sundarban is more in comparison to the western zone (Plate 44). This may be attributed to construction of large number of dams and barrages in the upstream region of the Ganga-Bhagirathi-Hooghly channel (in the western region) that tap considerable portion of the silt in to the system. Because of negligible fresh water flow in the central sector, sediments carried during high tide from the Bay of Bengal cause accretion of the islands. The gradual increase of Netidhopani Forest block (trend line equation: Y = 0.701X + 54.51; R^2 = 0.521) in the central Indian Sundarban confirms the hypothesis.

Player 2: Natural subsidence

Slow tectonic sinking of the entire Bengal basin and rather intense land subsidence (more than 15 mm/years in some areas of the delta) caused by compaction of loose deltaic deposits often results in the depletion of the deposited sediment height. The joint impact of the eustatic sea level and more intense subsidence of deltaic deposits results in the so-called relative sea level rise, which reaches 10-20 mm/year in the seaward part of the delta formed by rivers Ganga and Brahmaputra rivers (Allison, 1998; Coleman, 1969).

Player 3: Dam construction in the upstream zone

There are two major dams on the River Ganga. One at Haridwar which diverts much of the Himalayan snow melt into the Upper Ganga Canal, built by the British in 1854 to irrigate the surrounding land. This has caused severe alterations to the water flow in the Ganga, which is a major cause of fluctuation in salinity profile of the lower estuarine region of Indian Sundarban. The other dam is at Farakka, close to the point where the main flow of the river enters Bangladesh, and the tributary Hooghly (also known as Bhagirathi) which continues in West Bengal through Calcutta. This barrage feeds the Hooghly branch of the river by a 26-mile (42 km) long feeder canal. Construction of dams and barrages in the upstream has not only affected the quantum of sediment load but also altered the salinity profile (Mitra 2009, 2011). The velocity of water has also increased which is a powerful agent of erosion. Severe bank erosion is observed both on the northern and southern tips of Sagar Island – the largest of all islands (Fig. 22), located in the western sector of Indian Sundarban. Similar pattern of erosion is also observed for Jambu Island (Fig. 23), an island situated south of Sagar Island in western Indian Sundarban.

This is due to high flood velocity and meandering nature of the river course. The Muriganga block in the western Indian Sundarban also exhibits the following erosion trend line equation ($Y = -1.122X + 23.36$; $R^2 = 0.610$).

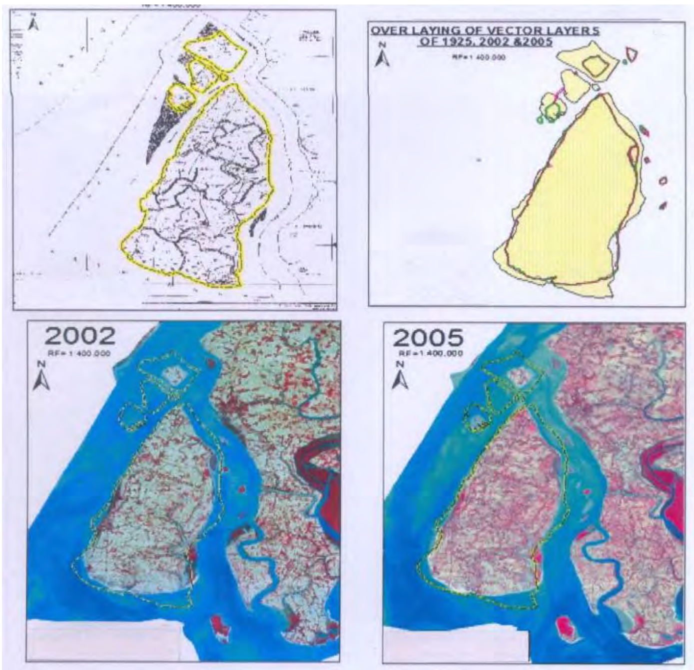


Fig. 22 - Gradual change of Sagar Island

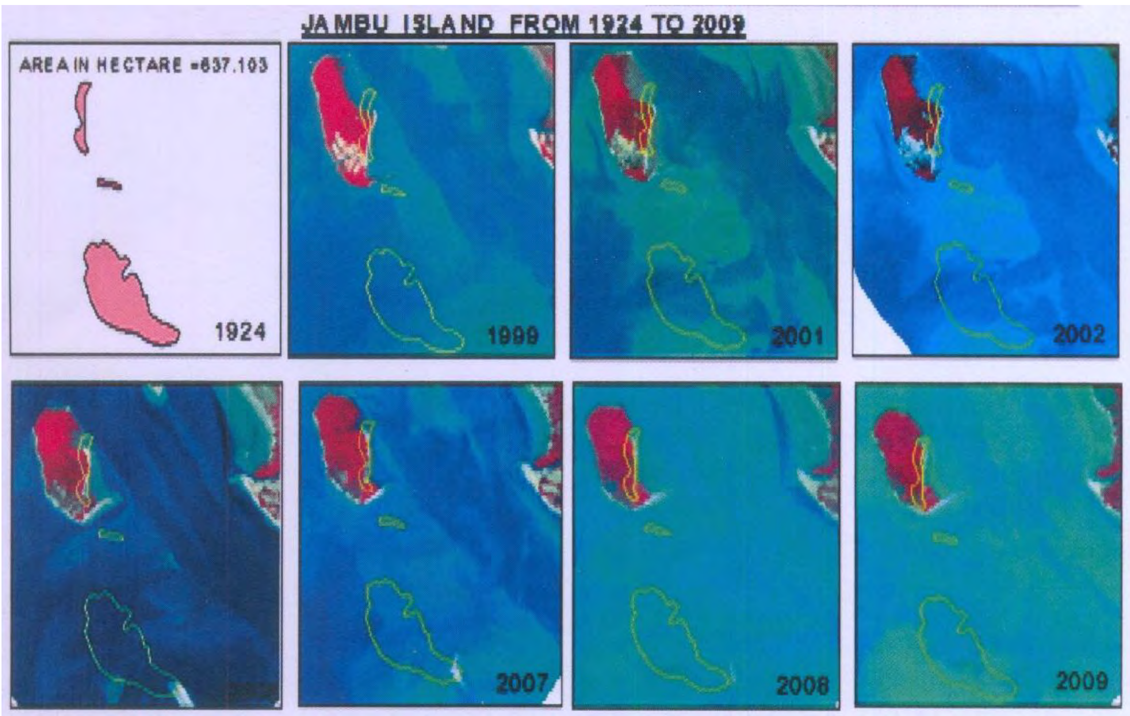


Fig. 23 - Gradual change of Jambu Island

Player 4: Dikes around island villages

The construction of dikes has profound impact on the processes of river sediment accumulation on the delta surface. The construction of earth-full protection dikes began in the middle of the 18^{th} century (Allison, 1998) and large-scale diking began only in the 1960s. Diking resulted in a considerable decrease in the submergence of the protected delta areas and, as a consequence, in cessation of input of sediments onto these lands and vertical accretion of the delta. Man-made diking of channels of the deltaic water courses often aggravates the hazard of floods. This is because the water levels in a diked channel (particularly, after two-sided diking) triggers the phenomenon of flooding of islands. Such processes were previously recorded in the deltas of the Amudarya and Huanghe rivers (Mikhailov, 1998; Mikhailov et al., 2007). In the present study area about 3500 km embankment exists as insurance to protect the low lying islands (Plate 9). This inhibits the natural flow of tidal waters in the islands resulting in the deposition of sediment on the river bed. Finally, the relative water level tends to rise due to apparent rise of the river bed.

Player 5: Tidal currents from the offshore region

In the absence of weak upstream discharge, the tidal currents from the Bay of Bengal cause scouring action on the sea facing islands like Gona (trend line equation: $Y = -0.592X + 80.29$; $R^2 = 0.897$), Baghmara (trend line equation: $Y = -2.110X + 161.9$; $R^2 = 0.859$), Mayadwip (trend line equation: $Y = -4.215X + 99.95$; $R^2 = 0.930$) and Chulkati (trend line equation: $Y = -3.181X + 101.7$; $R^2 = 0.940$) (Fig. 24, 27 , Plate 45 and Plate 46).

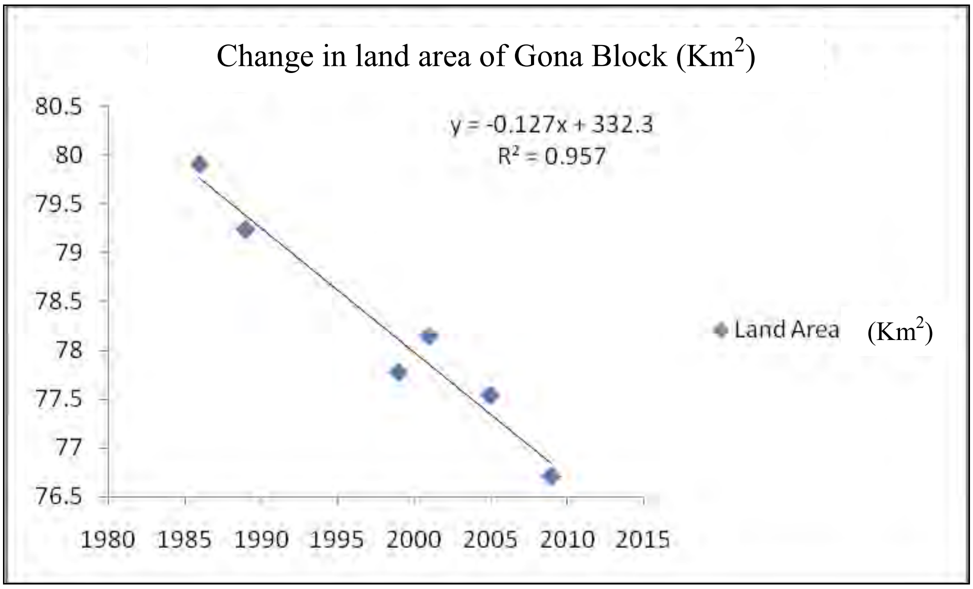


Fig. 24 - Trend line showing change of land area of Gona forest block in Indian Sundarban (1985 – 2010)

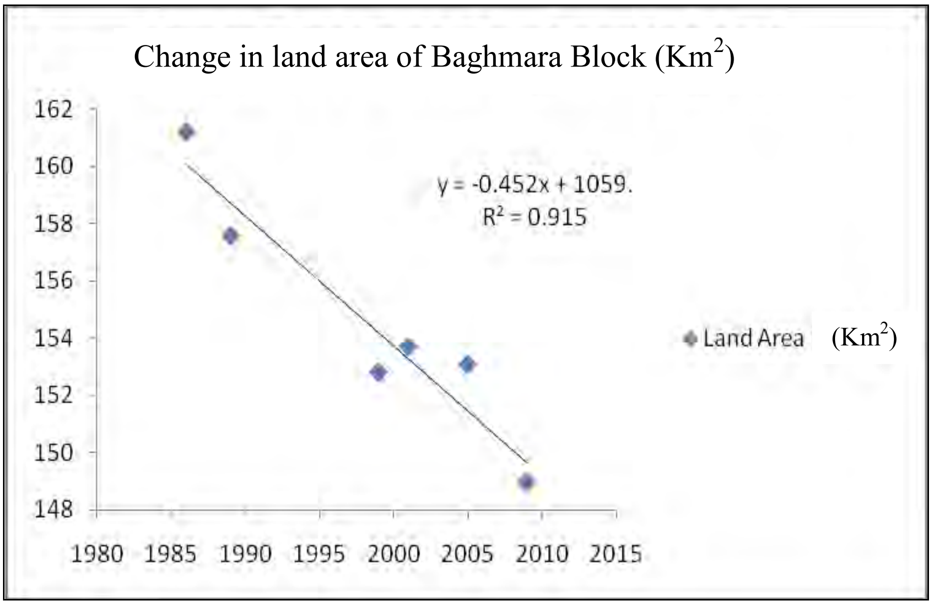


Fig. 25 - Trend line showing change of land area of Baghmara forest block in Indian Sundarban (1985 – 2010)

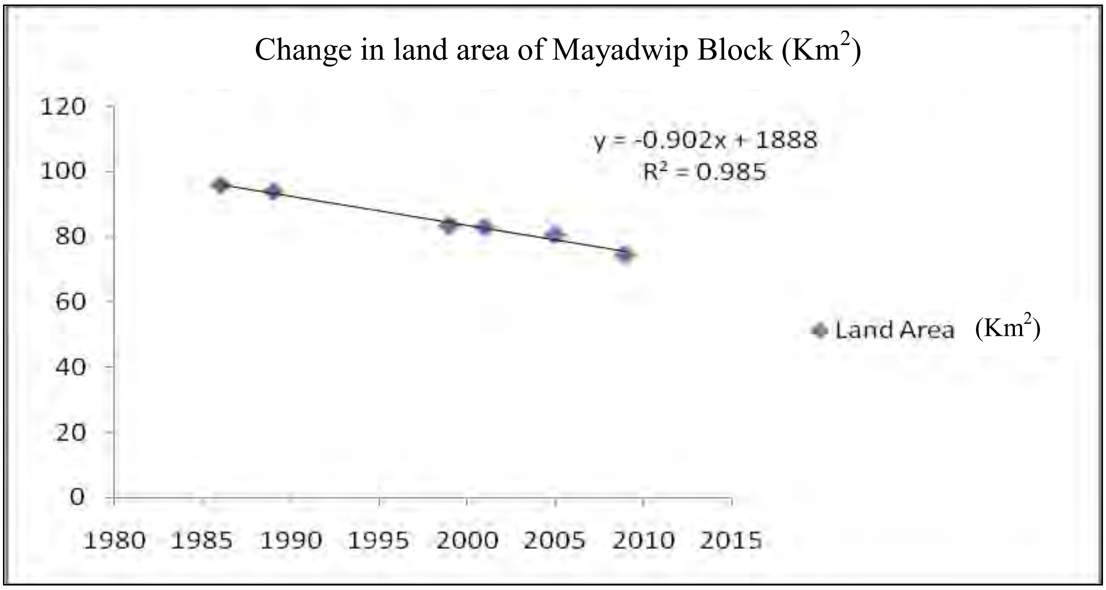


Fig. 26 - Trend line showing change of land area of Mayadwip forest block in Indian Sundarban (1985-2010)

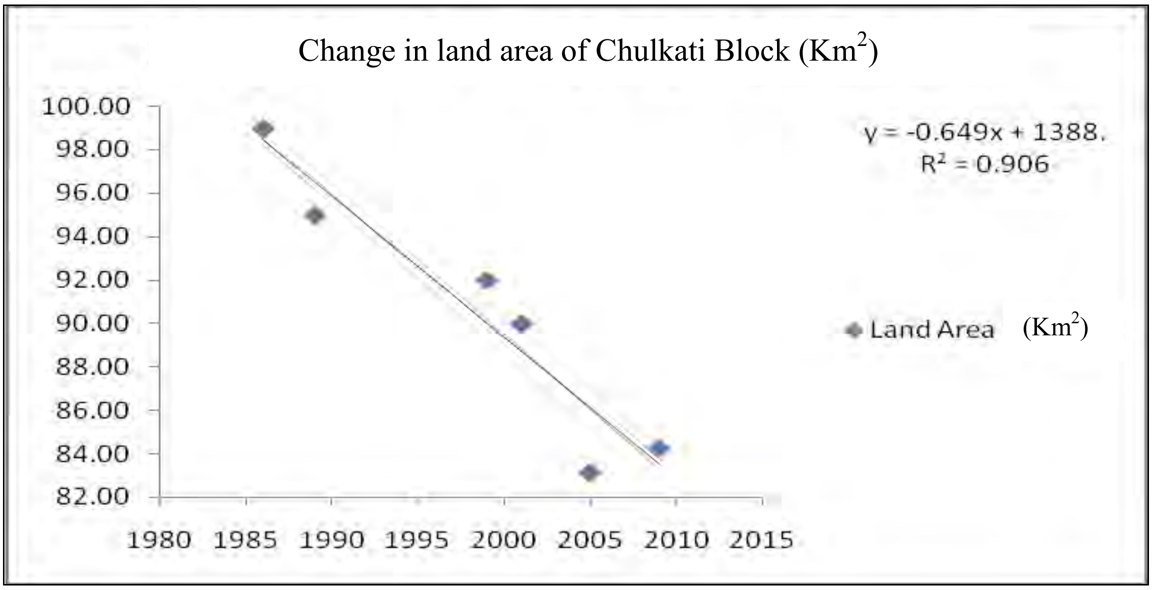


Fig. 27 - Trend line showing change of land area of Chulkati forest block in Indian Sundarban (1985-2010)

8. RECOMMENDATIONS

8. Recommendations

8.1 Human-wildlife conflict

Human-wildlife conflicts in Sundarban are a complex phenomenon and are an outcome of interaction of physical and chemical environment of unique delta, which exists nowhere else in the world. The tides, salinity, island specific mangrove vegetation, availability of prey, compulsive intrusion of poor people in the forest for livelihood and their interaction with wildlife of Sundarban etc., decides to a great extent the nature and extent of human-wildlife conflicts. It is observed that the abundance or scarcities of prey base are not directly related to the human casualty figures by tiger (Chakrabarti, 1992). Following recommendations are suggested to mitigate human-wildlife conflicts in Indian Sundarban:

8.1.1. Human-crocodile conflict:

1. As most of the crocodile attack victims are prawn seed collectors so an artificial prawn seed hatchery should be established to provide tiger prawn seed to the shrimp farms thus reducing the demand for collection of the same from the wild.
2. To reduce human-crocodile conflicts, prawn seed collection by "Dragnet method" in Sundarban should be stopped as it is responsible for most of the conflicts resulting in death and injury to people. Formation of self-help groups to wean away people from prawn seed collection may be an alternative method. Prawn seed collection by "Boat Method" (Plate 47) may continue to provide economic benefits reducing the chances of attack by crocodiles.

3. Awareness generation about crocodile behaviour and negative impact of prawn larvae collection by "dragnet method" may help people to save them from crocodile attacks as well as to save the biodiversity of Sundarban. The simple precaution to observe water for crocodile presence may save many lives.

4. Crocodiles prefer fresh water sources near nesting site hence often they enter in village ponds to lay eggs or to eat the fish in village ponds. A total of 69.23 % crocodile straying in villages has taken place in the months of September and October. Sundarban forest does not have any natural fresh water source in the forests, so it is recommended that fresh water ponds near interior camps with natural vegetation for nesting be created to prevent crocodile straying in to villages. It was observed that one crocodile made a nest in Hental clump near the fresh water pond of "Haldi camp" in the inviolate area (Core zone) of Sundarban Tiger Reserve for many years, which proves the efficacy of the said recommendation (Plate 48).

5. The Fisherman should avoid the nesting sites of crocodiles as they are protected aggressively by mother crocodile.

6. Keeping body parts directly in touch with water should be strictly avoided while fishing or during other human activities in Sundarban.

7. Institutional arrangements from Forest Department and Health Department to provide "Speed Boat Ambulance" may save lives as the medical facilities are almost absent in most of the Sundarban islands.

8.1.2. Human-shark conflict:

Following recommendations are made to mitigate the low intensity human-shark conflict in Indian Sundarban:

1. As most of the conflict is during the tiger prawn collection in the creeks so it is suggested that alternate livelihood should be provided to these people to prevent most of the shark attacks.
2. To avoid being in the water during the morning and evening hours may reduce the attacks as sharks hunt during morning and evening hours.
3. Shark attacks the human legs and other submerged body parts mainly by mistake. This happens mainly during tiger prawn larvae collection by “dragnet method”, which should be replaced with “boat method”.
4. Better medical facilities, first-aid training may help in preventing crucial blood loss due to shark attacks. The improvement in medical facilities may help considerably from such fatal attacks.

8.1.3. Human-tiger conflict:

1. For Indian Sundarban, it is recommended that:
   a. “Human-Wildlife Conflict Mitigation Protocol” (HWCMP) should be developed in activity selection framework as a part of “Tiger Conservation Plan”. It should have well defined activities with priority which will serve as a tool to mitigate human-wildlife conflicts. The linkages among various management activities need to be clearly established to

deliver the best. The existing "Nylon-Net Fence Maintenance Protocol" should be made part of the HWCMP.

b. The Working Plan of 24 Parganas (South) Division should not be traditional forestry working plan as there is hardly any difference in the management of two administrative units of Indian Sundarban i.e. Sundarban Tiger Reserve and 24 Parganas (South) Division. All felling of mangrove has been stopped in 24 Parganas (South) Division since 2001. It is suggested that 24 Parganas (South) Division should also have a "Tiger Conservation Plan/ Management Plan" on the line of plan being developed for Sundarban Tiger Reserve.

c. 24 Parganas (South) Forest Division is an undeclared buffer zone for Sundarban Tiger Reserve and comprises a sizable tiger population and some of the high quality mangroves. There is need for better integration of management activities hence it is suggested to identify the areas of mutual cooperation and institutionalize the same.

2. The integrity of the forest is directly related to the human-wildlife conflict. The large scale illegal entry of fishermen in Critical Wildlife Habitat causes great disturbance to the Core Zone of Sundarban Tiger Reserve. In addition, the entry of people without valid permit for illegal fishing causes disturbances. The poaching of spotted deer and wild boar by noose traps is done by a section of the fishermen leading to prey depletion and consequently adding to human-tiger conflict. The non-

target species like tiger becoming victim to noose trap cannot be ruled out.

Tigers face another problem from the parked fishing boats in their movement from one island to other island though the corridors. These corridors are known to forest staff as the places where tigers crosses the rivers frequently. A parked fishing boat in the river blocks the corridor for a vast stretch, which adversely affect the movement of tigers from one island to other islands. These disturbances affect the overall activities of tigers including hunting and add to human-tiger conflicts.

The spotted deer seldom live under dense cover and prefer the fringes of forests and feed mainly in open expenses of grasslands. In Indian Sundarban, there exist no such grasslands except in the southern coastal stretches. Spotted deer in Sundarban is in general a browser with small herd size and varies from 5-8 in number as compared to 10-30 or more in other parts. In Sundarban spotted deer follow the tidal cycle and during low tide they come out on river banks to browse the leaves of various mangroves, which are left on the mud flats by the tides. This also provides the best hunting opportunities for tigers as not only spotted deer but wild boars too come out on mud flats during low tide in search of food carried over by the tides. Any fishing boat parked in the river with 5-7 fishermen on board deters spotted deer and wild boars to come out on exposed mud flats. Thus an impediment to the normal food activity cycle is caused.

There exists a network of land base protection camps and floating camps to protect the Sundarban and a large number of offences are detected and dealt in accordance to the rules. However, the illegal fishing and intrusion in Core Zone continues. To improve the integrity of the forest in connection to illegal fishing and minimize the disturbances to the wildlife of Sundarban, following measures are suggested:

a. Illegal fishing activity in Critical Wildlife Area and Sanctuaries, which are non-fishing zones, must be stopped with firm hand. There is need to develop a computerized monitoring system for fishing offences to identify habitual offenders. Currently, there is no such system to identify the habitual offenders.
b. Currently 71.61% violations of fishing rules are getting away with fine of less than Rs. 400. It makes a fine of Rs. 7/fisherman/day. If the fishing team of 6 persons does fishing in prohibited area for ten days, the average fine comes to Rs. 490/ offence. This is even less than Rs. 548/offence in the year 2005-06. This is not a deterrent even for a poor fishermen. Hence it is recommended that habitual fishing rules violators must be dealt with firm hand. The first time offenders may be spared with low fine considering their economic condition but any second offence by same permit holder must be imposed maximum fine to make it a deterrent. The permit of habitual offenders with more than three offences must be terminated.

c. In the 24 Parganas (South) Forest Division there is very less vigilance as compared to Sundarban Tiger Reserve. The forest has just two protection camps inside the forest i.e. Bonnie and Kalash, which are insufficient to ensure integrity. There is a need to establish atleast one more Protection Camp to effectively patrol the southern part of mangrove forest, somewhere in Chulkati Forest Block. The Kalash camp which is currently under the charge of Head Forest Guard/ Forest Guard should also be headed by Deputy Range Officer in the line of Sundarban Tiger Reserve Camps.

d. There is pressure on the natural resources in Sundarban Tiger Reserve from across the international border. More BSF Camps (currently there is one land base and two floating camps) should be edstablished to improve integrity of the forest.

e. Sundarban in India and Bangladesh is a single ecosystem in two countries. A co-ordination between the officials of both sides and exchange of information on all issues especially protection will help in preventing poaching of wildlife and habitat thus reducing the human-tiger conflict. The signing of MOU and Protocol on Tiger by India and Bangladesh in September, 2011 will go a long way in conservation of Sundarban. It is recommended that Sundarban should be declared a "Trans- Border Protected Area" (TBPA) to synergize the conservation efforts.

3. Honey collection is the activity which is responsible for the direct confrontation between tiger and man in the mangrove forest leading to possibility of highest human-tiger conflicts. Honey collectors occupy

highest percentage of human casualties during the short period of honey collection. This also results in possibilities of attack on tiger by honey collectors in self defense, which remains unnoticed due to Sundarban conditions. It is also observed that only 18% of the honey collectors are interested in this profession as part of the cultural tradition and rest of them go for honey collection due to compulsion as fishing is closed during this period and also for earning quick money. Honey collection is an important activity for people of Sundarban, which may not constitute a major share of their annual income but is an additional annual income which is important due to high livelihood vulnerability in Sundarban conditions (Anshu Singh et al., 2010). Following measures are recommended to mitigate human-wildlife conflict:

a. Honey collection in Sundarban from the forest areas should be discouraged with a target to stop it gradually. To take care of livelihood of people associated to this profession alternate livelihood should be provided under NREGA and other schemes. This will encourage most of the unwilling people (about 50%) not to opt for this profession.
b. Bee-keeping in the fringes of Sundarban has increased considerably during mangrove flowering. The migratory bee keepers come and set the bee keeping boxes in the villages in lieu of payment to land holders. This has provided good employment to local people hence bee-keeping should be encouraged further. Currently honey-bees flying from bee-keeping boxes in villages to mangrove forest in the village-forest fringes can cover only short distances inside the

forests and most of the mangrove forest remains untapped. It is suggested that these bee-keeping boxes should also be kept on country boats flotilla to be placed inside the forest at specified locations, near protection camps. This will result in tapping of more mangrove forest by honey-bees and shall provide employment to many people especially from among the honey collector groups. This will eliminate human-tiger conflict due to honey collection.

c. Traditional honey collectors should be provided training in bee keeping or any other occupation of choice. They should also be provided financial resources in form of micro-credits from banks to start the livelihood activity. As the number of such traditional honey collectors is small, it is not a difficult task.

4. Fishermen constitute a major stakeholder in Sundarban conservation. They are the people who are present in forest most of the time. Fishermen are the group with valuable information about the integrity of forest and tiger behaviour but there is not much interaction between Forest Department and the fishermen. It is suggested that:

a. The current “Boat License certificate” (BLC) system should be reviewed and BLC should be given only to professional fisherman. Currently, many people who own the BLC are not fisherman and illegally sublet the BLC to needy fishermen. This makes a hole in the pocket of poor fishermen, encouraging them to earn more even by violating rules to meet the end. Non-fishermen should be identified and BLC should be given to right people especially from the fringes.

b. The age old system of Forest Department to charge the fishermen for dry fuel wood collection (DFC) needs to be stopped. This authorizes fishermen to leave the boat and go to forest for fuel wood collection which often leads to human-tiger conflict. The fishermen should be provided fuel wood at highly subsidized rate from the forest office at the time of issuance of permits to ensure that they do not go to forest and remain in the boat. Providing small LPG cylinder at subsidized rate to the law abiding fishermen will go a step further to motivate the fishermen to observe the rules.
c. The fishing boats used by fishermen are open and are of no defense against the tiger attack. Closed canopy boats should be promoted with attractive schemes.
d. Dialogues should be made with Fisheries Department for micro-financing and marketing of product. Currently poor fishermen are forced to take finance for fishing ventures at a very high interest rate and are bound to sell the fish catch to the same money lenders at low price. A check on this explotation will improve the economic conditions of the fishermen.
e. Phase-II of Joint Forest Management (JFM) should be started by Forest Department with an attempt to win the trust of the fishermen and honey collectors on the line which has been nicely done with fringe people by forming Forest Protection Committees and Eco-Development Committees. Medical kits with pure drinking water arrangements during forays, insurance, trainings, etc should be provided to them to win their trust.

5. Currently, nylon net fence is an important tool of the Forest Department to prevent tiger straying. Local communities too have accepted it as an effective tool for mitigation of human-tiger conflict. In order to make it more effective, it is suggested that:

a. The nylon net fence should be erected in the entire forest-village fringe. Currently, 32 km boundary is without nylon net fence.

b. The creeks are the points, which are often used by tigers to come out of the fence. The "Floater" model developed in the present study to plug the creek mouths is working effectively in one of the fence at Jharkhali, which should be replicated to other areas to prevent tiger straying to villages.

c. "Nylon-net Fence Maintenance Protocol" for the maintenance of nylon net fence should include the representatives from Forest Protection Committees and Eco-Development Committees to make it more effective and transparent.

6. The Joint Forest Management has been a great success in Sundarban during last decade as not only all the strayed tigers have been rescued by Forest Department with people"s co-operation but also other wildlife is being saved by Forest Protection Committee and Eco-Development Committee members. To make the programme more effective, following measures are suggested:

a. A clear co-relation has been observed between the alternate livelihood programme implemented in the Forest Protection Committees and Eco-Development Committees where people"s cooperation was received in wildlife rescue operations. Forest

Department has given maximum weightage to the committees in tiger straying sensitive areas which has given excellent results. The importance to such committees should continue. There are some committees of 24 Parganas (South) Forest Division which needs improvement in trust building to assure the safe return of strayed tigers back to the wild. It is suggested that all the Forest Protection Committees and Eco-Development Committees in tiger straying category should receive a minimum quantum of alternate livelihood to ensure a smooth relationship with Forest Department. The 4 Forest Protection Committees and 4 Eco-Development Committee in Very High, High and Medium categories of tiger straying should be paid special attention in JFM programme.

b. The forest management in "Reserved Forest" and in "Protected Areas" of Sundarban is almost same. The Forest Protection Committees have been formed in the fringe villages on the boundary of reserve forest where the fringe villages on the boundary have Eco-Development Committees. The rules allow Eco-Development Committees to receive 25% of eco-tourism revenue sharing whereas Forest Protection Committees do not receive any benefit. This dichotomy is not really good and deprive member of Forest Protection Committees. It is suggested that all the Forest Protection Committee"s and Eco-Development Committees of Sundarban should be governed by same rules and be treated at par.

c. Sundarban forest does not offer any NTFP in substantial quantity to the Forest Protection Committee or Eco-Development Committee members except honey. To strengthen the bonding and reciprocal commitment, Forest Department should consider the enhancement of eco-tourism revenue sharing from current 25% to 50% or more.

d. The governance of Forest Protection Committees and that of Eco-Development Committees needs to be improved. The committees in tiger straying zones are governed nicely. However, those committees which do not fall in tiger straying areas are neglected. The Annual General Body meetings, executive committee elections, meetings, etc. in these committees should be held regularly to improve relationship. The people from these villages regularly visit the forest and improved relationship with them will not only help in integrity of the forest, which in turn will help in mitigation of human-wildlife conflict.

e. The quantum of alternate livelihood activities especially for the landless people needs to be enhanced to reduce their dependence on Sundarban forest. Self help groups with micro-financing arrangements targets the poors so should be encouraged.

7. The size of tiger population and also that of prey in Sundarban has always been a matter of debate. Following recommendations are made on this issue;

a. Current estimate of tiger population in Indian Sundarban is 64-90 tigers. This first ever monitoring with highly scientific methodology has formed a base line figure. This estimation is based on small sample size for telemetry, camera trapping and boat transects. There is need for refinement by having increasing sample size from all representative areas i.e. from estern, Central and Western Sundarban.

b. Prey base estimation has never been carried out in Sundarban mainly due to non-availability of any methodology to address Sundarban specific conditions. Forest Department has taken an initiative to develop the same in collaboration with WWF, Sundarban Programme (Plate 49). This initiative should continue to develop an appropriate methodology for prey base estimation in Indian Sundarban.

c. The current programme of release of spotted deer of various deer parks after acclimatization and medical examination needs a review. The shortage of prey is one of the probable cause of tiger straying but it is not necessarily the only cause for tiger straying. It is more based on observations of people rather on scientific studies. It is suggested that any such future programme should be only after scientific study of various reasons for tiger straying including shortage of prey. It should also look availability of food for the spotted deer to be released and must have a scientific post release monitoring system which currently is lacking.

8. In last decade, Forest Department, West Bengal has developed a strategy to deal with tiger straying. The strayed tiger are either trapped or immobilized during straying or at times preventive capture is also

done to avoid straying. The captured tigers are released in distant forest areas. Following recommendations are made to improve:

a. Though there are more than ten experienced Forest Department staff engaged in immobilization but none of them is professionaly trained in immobilization techniques. The liberal doses of drugs used for immobilization have their own demerits in the form of adverse effect on the health of animal and a long revival time. All the staff engaged in the process should be provided training in immobilization techniques and protocols preferably from Wildlife Institute of India.
b. All the captured tigers are not followed with a systematic post-release monitoring programme. At least on three occasions, it has been confirmed that the captured tigers returned to the same area and strayed again (Annexure 13). There should be a well defined post-release monitoring of captured tigers.
c. Forest Department currently uses heavy iron cages for capture of tigers. The tigers are trapped in "Trap Cage" (Plate 50a) and thereafter transferred in another heavy "Transportation Cage" (Plate 50b). This transfer often results in trauma to captured tigers. The use of two different types of cages results in inconvenience and costs are high. The two different types of cages should be redesigned to be merged to be one cage only so that cost can be reduced and trauma to tigers during transfers can be minimized. The weight of cage should also be reduced as the heavy cages create serious handling problems. The aggressive captured tigers

get themselves injured in the iron cages. The cage bars should be padded to avoid injury.

9. Currently all staff of Forest Department are involved in all type of works which includes human-wildlife conflict mitigation. The execution of various works especially at the end of the financial year results in neglect of routine human-wildlife conflict measures like the maintenance of nylon-net fence, awareness generation, trainings etc. It is recommended that there should be three exclusive "Tiger Response Teams" (TRT) to deal with the issue. These tiger response teams should have modern boats with all related equipments and speed boats. These tiger response teams should have the responsibility for maintenance of nylon-net fence, development of awareness generation material, etc. One of the important activity, these teams can take is to form "Voluntary Tiger Conservation Teams" (VTCT) in the affected villages. These VTCT should involve local youths and provide them with training for initial actions to be taken up during tiger straying including the trainings on First-Aid, mass communication and preliminary monitoring of tiger movement for early detection of the problem. This can develop "Pug Mark Based Early Warning & Control System (PBEW & CS)" to deal with conflict more effectively.

10. Climate Change is a serious threat to Sundarban ecosystem. In spite of being a highly adaptable species, tigers may find it difficult to adapt to the multi-pronged adverse impacts of habitat loss and intrusion of more people in forest due to livelihood loss combined

with other anthopogenic factors leading to rise in human-tiger conflict. The impact of climate change has to be mitigated at global, regional and at local level. It is recommended that to a "Climate Change Adaptation and Mitigation Plan" be developed for people and natural resources. There is need for high quality research on all the components of Sundarban ecosystem to prepare a better strategy to mitigate the impact of climate change in Sundarban.

11. The loss of life and property always creates a sense of animosity. Human-killing by tigers affects the entire family of victim on economic front as well as in social life. It is noted that half of the sum of the Janta Insurance Policy claim as well as a part of the *ex-gratia* given by Forest Department are taken away by unscrupulous middle-men. Following recommendations are made on this aspect:
    a. NGO‟s of repute should be involved in quick processing of compensation claims to avoid middle-men. This may also help in quick fund disbursement.
    b. A programme should be initiated for the exclusive rehabilitation of the families of the tiger victims to make them economically independent. This programme should include the training on some selected livelihood measures along with process of financial inputs.
    c. The children of the victims at times are deprived of education and may carry a ill feeling against tiger for their misery. It is suggested that a scholarship programme for the children of tiger

victims should be started to ensure that no deserving children of tiger victim"s family suffer.

d. There are large numbers of people who are killed by tiger during their illegal entry in forests. These cases hardly come to the notice of the Forest Department. Though Forest Department should adopt all measures to prevent their illegal entry but an *ex-gratia* should be provided to these victim families also to stop the retribution. This *ex-gratia* amount may differ from that of tiger victims with legal permits. All injured persons should be extended free treatment irrespective of the legality of their entry in forest. This will also help in assessing the correct status of human-tiger conflicts in Sundarban.

12. The information on tiger ecology, prey-predator relationship, problem tiger behaviour and other related issues is very limited for Indian Sundarban. The scientific research with radio- telemetry should continue to understand the behaviour of Sundarban tiger.

The human-wildlife conflict in Sundarban is a complex issue and is an outcome of various natural and anthropogenic factors. The poor population, an integral part of the ecosystem struggles with the elements everyday for survival. The people in spite of loss of life and property have shown a remarkable character in saving the wildlife specially the tiger. In order to support local population to save the species and ecosystem, there is need to address the basic needs of people. The Sundarban tiger is an indicator of health of this ecosystem and rise in human-tiger conflict due to anthropogenic factors may threaten its existence. This may be disastrous to the

Sundarban ecosystem as a whole and hence must be stopped by better strategies and promoting better understandings among stakeholders.

8.2. Impact of salinity on mangroves

The normal functioning and dynamics of mangrove ecosystem is regulated by salinity. Salinity affects plant growth by limiting the availability of water against the osmotic gradient, by reducing nutrient availability and by causing accumulation of Na^+ and Cl^- in toxic concentration causing water stress conditions enhancing closure of stomata and reduced photosynthesis. High salinity also affects the chlorophyll concentrations of certain species like Sundari (*Heritiera fomes*), which is detrimental to normal physiological functioning of the species (Mitra and Banerjee, 2010). The pigments, being the key machinery in regulating the growth and survival of the mangroves require an optimum salinity range between 4 to 15 psu for proper functioning. *Heritiera fomes*, the freshwater loving mangrove species prefers an optimum salinity between 2 to 5 psu (Mitra et al., 2004). Recent evidence suggests that phosphorus availability may be an important factor in dwarf mangrove production, especially in carbonate-dominated environments (Feller, 1995; Davis et al., 2001; McKee et al., 2002; Lovelock et al., 2004).

Considering all the early works and the results of the impact of salinity and other environmental factors on mangroves it appears that that the future of Sundarban mangroves hinges upon the efficiency of managing the limited freshwater resources coupled with appropriate selection of species for afforestation in context to rising salinity. On this background matrix, the following recommendations are suggested:

1. Channelization of freshwater in the central Indian Sundarban:

The Bidyadhari River originates near Haringhata in the Nadia district and then flows through Deganga, Habra and Barasat areas of North 24-Parganas before joining the Raimangal River in the Sundarban. The River has formed a major navigation route for earlier civilizations. The river port of Chandrakethugarh in the 3rd century BC was on the banks of this river. The river has also been the major drainage system of Kolkata and North 24-Parganas. However, due to subsidence phenomenon of the Bengal basin and a gradual eastward tilting of the overlying crust, the Hooghly-Bhagirathi channels have progressively shifted eastwards and the freshwater supply from the Ganges has been completely cut-off. The Bidyadhari River has now almost dried up due to huge siltation and thus the central sector of Indian Sundarban has become hyper-saline in nature. It appears from our results that the growth of the species would be better if freshwater (from the Ganga-Bhagirathi system) in the western sector of Indian Sundarban is channelized to the central sector through capital dredging or periodic dredging (yearly) of the Bidyadhari silt. This process will not only help to ecorestore the system through recruitment of freshwater loving mangrove species (like *Heritiera fomes*, *Nypa fruticans*, *Bruguiera gymnorhiza* etc.), but may also help to combat the intrusion of seawater of Bay of Bengal from the southern part of Sundarban mangrove ecosystem (Mitra et al., 2009 b).

2. Preferred niche based afforestation programme

To avoid the adverse impact of salinity on mangrove species it is also essential to undertake afforestation programme on the basis of preferred zone (more specifically the niche) of the species (Table 10). Salinity preference of the species should also be considered during plantation. Such efforts will not only increase the survival rate of the species, but at the same time will impart natural adaptation to the mangroves in general.

TABLE 10

Selective mangrove species with their preferred preferred niches for afforestation

Zone	Characteristics	Species to be planted
A	Inundated during all the high tides – 30 days in a month – intertidal mud flats and river slopes.	*Avicennia spp., Sonneratia spp., Aegiceros sp., Acanthus sp., Rhizophora apiculata, Aegialitis sp., Porteresia sp., Sueda sp., Salicornia sp., Sesuvium sp.*
B	Inundated during medium high tides – 20 days in a month – river banks and ridge forests	*Rhizophora sp., Bruguiera spp., Ceriops spp., Kandelia sp., Lumnitzera sp., Xylocarpus sp., Phoenix sp., Dalbergia sp., Derris sp., Excoecaria sp., Acanthus sp., Heritiera sp.,*
C	Inundated during normal high tides – 15 days in a month	*Ceriops sp., Avicennia sp., Heritiera sp., Aegialitis sp., Xylocarpus sp., Excoecaria sp.,*
D	Inundated during spring tides – 10 days in a month – ridge forests (Flat lands with dense / sparce vegetation and salty patches)	*Excoecaria sp., Ceriops sp., Hibiscus sp., Acrostichum sp.,*
E	Inundated during abnormal / equinoxes tides – 5 days in a month, during monsoons and summer – ridge forests, sparce vegetation and reclaimed / bare areas	*Sesuvium sp., Hibiscus sp., Thespesia sp., Acrostichum sp., Tamarix sp.*

Considering the significant variation of salinity between the western and central Indian Sundarban, it is recommended to plant species like *Sonneratia apetala*, *Heritiera fomes*, *Nypa fruticans*, *Bruguiera* spp. in the western sector, whereas in the central sector the befitting species are *Excoecaria agallocha*, *Avicennia* spp, *Rhizophora sp*. *Avicennia* spp. that may be planted in both the sectors on account of their wide range of salinity tolerance. Recommended species for low saline zones are *Sonneratia caseolaris* and *Heritiera fomes*, whereas for hypersaline environment species like *Avicennia* spp., *Acanthus ilicifolius* and saltmarsh shrub *Sueda* sp. are better adapted (Spalding et al., 2010).

3. Rain water harvesting

Sundarban being an alluvial archipelago has no direct source of sweet water or underground freshwater at a shallow depth. The rainwater-harvesting project should be launched in high saline areas of Sundarban. For this it is essential to excavate and re-excavate the ponds for rainwater storage. Rainwater harvest activities have the potential to create employment, food security and other multifarious activities for the people to improve their livelihood. Activities like vegetable cultivation, fishery, duckery and plantation can generate income opportunities to island dwellers. This indigenous technology will help to reduce and control salinity in the adjacent areas through freshwater diffusion, which will create congenial environment for the growth and survival of mangroves.

4. **Setting of State-level mangrove wetland conservation and management authority**

A State-level mangrove wetland conservation and management authority should be set up for conservation, development, monitoring and control of inappropriate use and conversions of mangrove ecosystem. Such conversion may be in the form of tourism unit construction, brick kiln develpment or shrimp farm establishment etc. The said authority must put thrust on research and public awareness programmes on wetland values, sustainable development of resources and their utilisation and these should be initiated involving national and state level Institutions, Universities and NGOs. Such approaches could help to address the systemic drawbacks like public ignorance and indifference about this unique ecosystem.

8.3 Impact of Climate Change on Indian Sundarban

Understanding the historical records of sea level rise, sediment runoff, tectonic movement and anthropogenic factors is extremely important to analyse the pulse of climate change induced sea level rise and gradual morphological changes of some islands in Indian Sundarban. Records obtained through satellite imageries reveal that erosion and accretion in the deltaic complex go hand in hand. Human interventions in recent times (through construction of barrages and dams) have altered the sweet water flow and subsequently the sediment budget of the estuarine system. The islands of the western Indian Sundarban are gradually eroding due to current pattern. On contrary, accretion is visualized in the central and eastern parts of Indian Sundarban. It is expected that sea level rise will cause the deltaic ecosystem of Indian Sundarban to function very differently in future. Few changes include: (1) Submergence of certain islands; (2) increase in salinity particularly in central Indian Sundarban; (3) alteration of species composition of plankton, fishes and molluscs; and (4) alteration of mangrove biomass. Research needs include improved precipitation, dam discharge and run-off flow projections for the deltaic system monitoring, modelling, and process studies that critically analyse the non-linear responses of the deltaic system to sea level rise, climate change and their interaction with several other anthropogenic factors. On this background the following recommendations are suggested to combat the threats associated with climate change in Indian Sundarban:

1. **Remedial measures against erosion**

The deltaic system of the Sundarban estuary is an ecologically sensitive area. Therefore traditional constructions using boulders might not be appropriate for the islands here. The nourishment of eroding land with sand, using a sand pumping technique, may be too expensive and may have a negative impact because of the turbulence in the macrotidal estuary. Availability of sand sources will also be a major problem.

Therefore, a „bio-engineering" technique is proposed for the protection of the islands in the Sundarban delta. This technique includes the planting of mangrove floral species and gradual increase of their relative density. This technique worked well for Nayachar Island (Mitra et al., 2004) in the same delta, where the planted species exhibited a high growth rate (Plate 51).

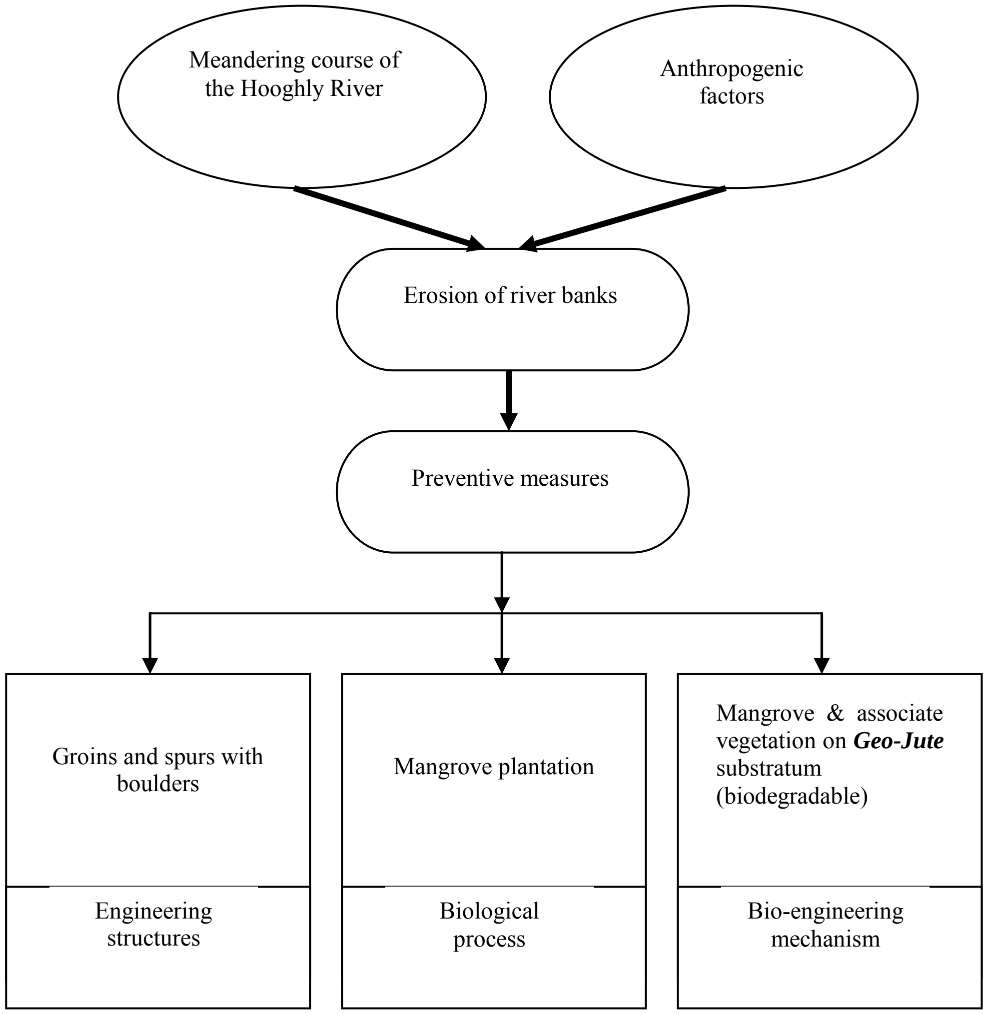


Fig. 28- Flow chart showing the erosion of river banks and remedial measures

In the plantation programme of Nayachar Island species such as *Sonneratia apetela, Rhizophora mucronata, Excoecaria agallocha* and *Bruguiera gymnorhiza* were considered in the afforestation scheme. Species like *S. apetala* attained ~35 feet mean height within a period of 3 years. These are all locally available plants and worked very well in context to erosion protection of Nayachar Island. Considering the positive picture of lessons learnt from Nayachar Island, it is recommended that these species may be seeded during low tide in the monsoon season (July – October). Different types of graminoid species are suitable in relation to the different water depth ranges (Schiechtl & Stern 1997). Table 11 lists some species which can reduce the flow velocity (drag velocity on the river bank face) and can protect the system from topsoil erosion (Felkel 1960). The species may be planted in the intertidal zone or mudflats of the creeks of the islands.

The well adapted saltmarsh grass *Porteresia coarctata* may also be applied in the high saline zone and nalgrass (*Phragmitis karka*) in the low saline zone. Planting of woody mangals to ensure sediment trapping and the saline grass for protection of topsoil erosion may be adopted above the mean high water line, which gets flooded occasionally with estuarine saline water. The source of sediment may be offshore sand and littoral material carried from tidal river stretch due to strong tidal current. Planting of mangrove species on the land, has to be done sector-wise (Paul 1991 & Banerjee 1998), according to the slope of the hinterland area, soil salinity and nutrient availability (Table 12). Slope of the hinterland area is very important here, which indicates the duration of submergence of mangrove trees in saline water.

Mangrove plants such as *Avicennia marina, A. alba* and *A. officinalis* may be planted on the mudflats for their further development, which will help to establish the forest by natural processes. Drought tolerance plants such as *Opuntia dillenii, Pandanus tectorius* etc. may be planted on sandy areas, where the bern /dunes are not sufficiently developed. *Cyperus esculentus* may be seeded /planted on the berm, where berm/dune vegetation has not developed sufficiently.

Table 11

. Characteristics of three graminoid species used for island protection

English name	Scientific name	Family name	Required mean water depth from mean High Tide (m)	Season of seeding
Reed canary grass	*Phalaris arundinacea*	Poaceae	0.0 to 0.5	Whole Year
Reed mace or bulrush	*Typha latifolia*	Typhaceae	0.0 to 2.0	Whole Year
Common bulbrush	*Schoenoplectus lacustris*	Cyperaceae	1.0 to 3.5	Whole Year

Table 12

Mangrove plants and graminoids with different characteristics used for the protection

Mangrove species	Height (m)	Wood volume	Sowing / planting period	Zone of sowing / planting
Avicennia marina	0.5 – 5.0	Medium	July-August	On the mud flats
Avicennia alba	0.5 – 5.0	High	July-August	
Avicennia officinalis	0.5 – 5.0	High	July-August	On the coastal sandy region, where dunes do not sufficiently develolp.
Pandanus tectorius	1.5 – 4.0	Medium	September-October	
Opuntea dillenii	0.5 – 2.5	Low	May-June	On the dunes, where vegetation on sand dunes do not sufficiently develop
Calotropis gigantean	1.2 – 2.0	Low	May-June	
Ipomoea pescaprae	0.5 – 1.0	Low	May-June	
Launaea sarmentosa	0.2 – 0.5	Low	May-June	
Cyperus esculentus	0.5 – 1.5	Low	September-October	

2. Provision of alternative livelihoods and Database management

People living within or near the Sundarban mostly depend on its resources to satisfy many of their basic needs, such as food, fuel, materials for construction of houses, boats, furniture and fishing implements, medicinal herbs and many other items for trade and commerce. Some people, however, extract resources beyond their needs. Due to misuse and random exploitation, the natural resources are depleting fast. There is a clear scope for gentle regulation, in the interest of the very people (preferably the Sundarban island dwellers) who depend on the resources. One observation was a surprisingly low awareness of the resource dependency and the resource utilization implications. An improved awareness seems to be a viable measure, given the fair literacy and education level. Another observation was an apparent attractive scope for introduction of alternative or supplementary livelihoods and income generation, including involvement of the female part of the population. Such development initiatives can work in tandem with measures for poverty alleviation. Good management and good knowledge are required to assure a win-win situation rather than a development where both the mangrove forest and its communities stand to lose. Among other measures in this context is an improved knowledge base, providing for timely and appropriate decision-making and implementation. Considering the sea level rise as the background it is recommended to initiate alternative livelihood schemes for the people of Sundarban. In Indian Sundarban region few anticipatory actions have already been initiated considering the seawater intrusion into the creeks and inlets criss-crossing the islands. These include training the local population with the technology of oyster and seaweed culture, which are widely distributed in the area. The island dwellers, however, have no idea of their edible values and economic benefits (Table 4). Hence awareness programme, trainings and workshops on regular basis need to be carried on to induce these new brackishwater livelihood programmes to the local people.

A majority of the people of Sundarban are involved in pisciculture activities. However, for this, they use traditional feed (containing dried trash fishes as major ingredients). This not only pollutes the waterbodies, but also enhances the microbial load in the water, soil and fish tissue. To prevent this, it is recommended to train the local people the art of preparing fish feed from local plant parts. Already such technologies are available in which fish feed have successfully been prepared from saltmarsh grass like *Porteresia coarctata* (Mitra, 2009; Mitra, 2011). Hence replication and implementation of such programmes through appropriate authority (like Fishery Department, Forest Department or Sundarban Development Board etc.) is extremely essential.

The increase in salinity combined with storms and cyclones will result in creation of ecological refugees as happened during "Aila". There is need to develop island specific "Disaster Management Plan" and related infrastructure to deal with the situation. The arrangement for emergency health care, supply of food and water and back up plan for alternate employment will minimize the impact of people"s dependency on natural resources of Sundarban which otherwise will cause human-wildlife conflict of greater magnitude.

3. **Development of Sundarban Abiotic Information System (SAIS)**

The Gangetic delta of the Indian sub-continent is noted for its rich mangrove biodiversity, natural calamities, livelihood-supporting matrix of millions of people and is the only mangrove base of Royal Bengal tiger (*Panthera tigris tigris*) in the planet Earth. The present trend of industrialization, urbanization and construction of barrage in the upstream zone has changed the landscape of this deltaic complex and the characteristics of the aquatic sub-system have also changed accordingly. This ecosystem offers an ideal site to study a number of variables in relation to changing scenario of the region owing to presence of the thickly populated city of Kolkata, Howrah and the Haldia industrial belt on the bank of Hooghly estuary (the major arm of the mighty River Ganga flowing towards Bay of Bengal in the south). Spatial variations of important hydrological parameters are a unique feature of Indian Sundarban on account of the presence of two drastically different salinity zones (western and central Indian Sundarban). Hence it is extremely important to develop a data bank for different salinity regimes of the deltaic system. A capacity building programme involving the forest staff posted at remote blocks of Sundarban is recommended in this context, who will be trained with the knowledge of hydrological parameter analysis and the duly completed form will be electronically mailed to Forest Head Quarter at Kolkata. The quality of the data should be assured through calibration exercise done with Academic Institutes or Research Laboratories of National repute.

4. Development of Sundarban Biotic Information System (SBIS)

Mangroves are the dominant vegetation of Indian Sundarban. It is difficult to generalise about the effect of climate change on mangrove ecosystems as each system is very much developed on the product of local topographical, climatic and anthropological influences. However, as all mangrove systems occur somewhere between high and low tide marks it is clear that they are likely to be significantly influenced by any changes in sea-level. Different mangrove species appear to have a marked preference for the level of salinity of the surrounding environment and therefore they are to be found at varying distances and elevations from the seaward edge reflecting the degree of mixing of the freshwater input and tidal influx. Mangrove ecosystems accumulate peat or mud and this gives them the opportunity to adjust to a rising sea level. If the sediment accretion rate equals the rate of rise of sea-level then inundation preferences of the different mangroves species can be maintained. If the rate of sea-level rise exceeds the rate of accretion then some rearrangement of existing vegetation will take place and loss of mangroves will occur if the mean tide level becomes higher than the elevation of the substrate. Such research needs to be initiated in context to present geographical locale. The

Sundarban Biotic Information System may be imparted with the task of census of relative density and biomass of mangrove and its associates with respect to sea level and salinity. Sundarban Biotic Information System should also initiate the research on impact of enhanced inundation, impact of rise in temperature and salinity on various lifeforms especially on endangered species so that their ability to withstand changes in the ecosystem can be monitored and suitable conservation strategies can be developed. Also comparison with previous data needs to be done to evaluate the temporal variation.

5. Disseminating lessons learnt

Academic Institutes and Universities possess abundant technical resources that enable comprehensive assessment to predict mangrove response to relative sea-level rise. Disseminating lessons learnt from this study and instituting programs to transfer technical skills and share resources will augment the region‟s capacity to manage coastal ecosystems‟ response to projected sea-level rise.

Projections are available over coming decades for rising sea-level and changes in climate and weather. These changes are expected to alter the position, area, structure, species composition, and health of most coastal communities, including mangroves. Establishing mangrove baselines and monitoring these gradual changes to coastal habitats through regional networks using standardized techniques will enable the separation of site-based influences from global changes to provide a better understanding of the response of coastal habitats to global climate and sea-level change, and alternatives for mitigating adverse effects. The monitoring network, while designed to distinguish climate change effects on mangroves, would also therefore show local effects, providing coastal managers with information to abate these sources of degradation. Establishing a regional wetland monitoring network for the Sundarban Islands is recommended in the Action Strategy for Nature Conservation in the Indian Sundarban region.

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Tables

Table 8

Global distribution of AGB, BGB, H, BA of different mangrove species from other areas of the world

Region	Location	Condition or age	Species	ABG (t ha^{-1})	BGB (t ha^{-1})	Reference
Australia	$27^{0}24^{/}$S, $153^{0}\ 8^{/}$ E	Secondary forest	*A. marina* forest	341.0	121.0	Mackey (1993)
Thailand (Ranong Southern)	9^{0}N, 98^{0} E	Primary forest	*Sonneratia* forest	281.2	68.1	Komiyama et al. (1987)
Sri Lanka	$8^{0}15^{/}$ N, $79^{0}\ 50^{/}$ E	Fringe	*Avicennia*	193.0		Amarasinghe and Balasubramaniam (1992)
Indonesia (Halmahera)	$1^{0}10^{/}$N, $127^{0}\ 57^{/}$E	Primary forest	*Sonneratia* forest	169.1	38.5	Komiyama et al. (1987)
Australia	$33^{0}50^{/}$S, $151^{0}\ 9^{/}$ E	Primary forest	*A. marina* forest	144.5	147.3	Briggs (1977)
French Guiana	$4^{0}52^{/}$N, $52^{0}\ 19^{/}$ E	Matured coastal	*Lagucularia, Avicennia Rhizophora*	315.0	-	Fromard et al.(1998)
South Africa	$29^{0}48^{/}$S, $31^{0}\ 03^{/}$ E	-	*B.gymnorrhiza, A. marina*	94.5	-	Steinke et al (1995)
French Guiana	$5^{0}23^{/}$N, $52^{0}\ 50^{/}$ E	Pioneer stage 1 year	*Avicennia*	35.1	-	Fromard et al.(1998)
Western Indian Sundarban	$21^{0}39^{/}$N $88^{0}04^{/}$E to $21^{0}47^{/}$N $88^{0}22^{/}$E	Natural forest	*Sonneratia apetala*	35.77	10.23	This study
Western Indian Sundarban	$21^{0}39^{/}$N $88^{0}04^{/}$E to $21^{0}47^{/}$N $88^{0}22^{/}$E	Natural forest	*Avicennia marina*	51.98	13.57	This study
Western Indian Sundarban	$21^{0}39^{/}$N $88^{0}04^{/}$E to $21^{0}47^{/}$N $88^{0}22^{/}$E	Natural forest	*Excoecaria agallocha*	17.97	4.69	This study
Central Indian Sundarban	$22^{0}05^{/}$N $88^{0}41^{/}$E to $22^{0}18^{/}$N $88^{0}54^{/}$E	Natural forest	*Sonneratia apetala*	13.20	3.06	This study
Central Indian Sundarban	$22^{0}05^{/}$N $88^{0}41^{/}$E to $22^{0}18^{/}$N $88^{0}54^{/}$E	Natural forest	*Avicennia marina*	57.10	16.00	This study
Central Indian Sundarban	$22^{0}05^{/}$N $88^{0}41^{/}$E to $22^{0}18^{/}$N $88^{0}54^{/}$E	Natural forest	*Excoecaria agallocha*	26.19	7.15	This study

AGB=above ground biomass, BGB=below ground biomass

TABLE 9

Change in land area of selected islands over the period from 1986 to 2009

Sector	Forest Block	Land Area (In Sq. Km.)						Trend Line Equation	R^2 Value
		1986	1989	1999	2001	2005	2009		
Eastern	Arbesi	98.78	97.6	96.09	97.07	70.63	66.50	Y = -6.895X + 111.9	0.743
	Jhilla	89.83	89.3	90.36	88.41	86.6	85.89	Y = -0.850X + 91.37	0.778
	Harinbhanga	82.71	84.91	82.25	82.62	81.97	82.49	Y = -0.272X + 83.78	0.233
	Khatuajhuri	99.66	102.62	100.23	98.41	101.27	101.47	Y = 0.090X + 100.2	0.013
	Gona	79.91	79.24	77.78	78.15	77.54	76.71	Y = -0.592X + 80.29	0.897
	Chamta	167.7	171.11	168.15	166.58	169.09	167.39	Y = -0.262X + 169.2	0.094
	Chandkhali	115.49	116.8	113.77	114.2	116.41	114.53	Y = -0.158X + 115.7	0.057
	Baghmara	161.21	157.58	152.81	153.71	153.07	148.96	Y = -2.110X + 161.9	0.859
Central	Pirkhali	146.8	150.16	147.1	147.06	148.94	148.10	Y = 0.08X + 147.7	0.012
	Panchmukhani	141.82	145.04	144.28	142.09	143.26	144.59	Y = 0.180X + 142.8	0.063
	Netidhopani	56.34	56.15	55.22	55.59	59.11	59.40	Y = 0.701X + 54.51	0.521
	Chhotahardi	76.5	79.79	76.88	77.34	77.89	74.12	Y = -0.489X + 78.80	0.243
	Goasaba	104.49	104.88	103.1	103.53	103.93	101.03	Y = -0.563X + 105.4	0.595
	Matla	122.54	123.36	120.24	122.34	123.15	120.01	Y = -0.319X + 123.0	0.168
	Mayadwip	95.85	93.9	83.49	82.92	80.61	74.43	Y = -4.215X + 99.95	0.930
	Herobhanga	89.00	88.00	91.00	90.00	91.60	84.25	Y = -0.398X + 90.37	0.078
	Ajmalmari	133.00	132.00	132.00	132.00	128.44	122.99	Y = -1.735X + 136.1	0.726
	Dulibasani	129.00	128.00	127.00	126.00	125.71	120.16	Y = -1.487X + 131.1	0.803
	Chulkati	99.00	95.00	92.00	90.00	83.13	84.25	Y = -3.181X +101.7	0.940
	Thakuran	52.00	54.00	62.00	58.00	55.80	53.78	Y = 0.294X + 54.9	0.023
	Saptamukhi	68.00	71.00	73.00	71.00	71.23	68.42	Y = 0.022X + 70.36	0.000
Western	Muriganga	22.00	23.00	17.00	20.00	18.19	16.43	Y = -1.122X + 23.36	0.610

TABLE 13

Few untapped living resources in Indian Sundarban

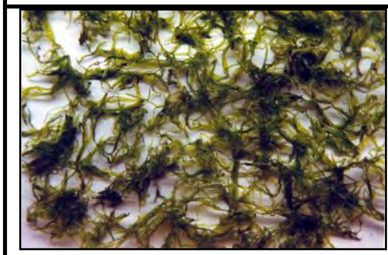
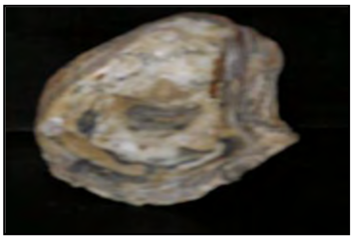
Brackish water resource	Taxonomic position	Economic importance
 *Enteromorpha intestinalis*	Division – Chlorophyta Class – Chlorophyceae Order – Ulvales Family – Ulvaceae Genus – *Enteromorpha* Species – *intestinalis*	1. Used as cattle feed 2. Used as poultry feed after mixing with trash fish dust 3. Used as agent of bioremediation
 *Ulva lactuca*	Division – Chlorophyta Class – Chlorophyceae Order – Ulvales Family – Ulvaceae Genus – *Ulva* Species - *lactuca*	1. Consumed as food 2. Used in salad, soup etc. 3.Used as fodder and manure
 *Catenella repens*	Division – Rhodophyta Class – Rhodophyceae Order – Gigartinales Family – Rhabdoniaceae Genus – *Catenella* Species – *repens*	1. Rich source of astaxanthin and therefore used as an ingredient of fish feed 2. Used as agent of bioremediation
 *Saccostrea cucullata*	Phylum – Mollusca Class - Bivalvia Order - Pterioida Family - Ostreidae Genus - *Saccostrea* Species - *cucullata*	1. Edible with high demand in South Asian countries 2. Shell is a source of lime 1. 3. Shell dust is used in poultry feed as source of calcium
 *Crassostrea gryphoides*	Phylum - Mollusca Class - Bivalvia Order - Pterioida Family - Ostreidae Genus - *Crassostrea* Species - *gryphoides*	1. Edible with high demand in South Asian countries 2. Shell is a source of lime 3. Shell dust is used in poultry feed as source of calcium
 *Crassostrea madrasensis*	Phylum - Mollusca Class - Bivalvia Order - Pterioida Family - Ostreidae Genus - *Crassostrea* Species - *madrasensis*	1. Edible with high demand in South Asian countries 2. Shell is a source of lime 3. Shell dust is used in poultry feed as source of calcium

TABLE 14- Human-tiger conflict in Indian Sundarban - Professionwise human death/ injury by tigers (1985-86 to 2009-10)

YEAR	PERSONS KILLED/INJURED BY TIGER IN SUNDERBAN TIGER RESERVE SINCE 1985-86														PERSONS KILLED/INJURED BY TIGER IN 24 PARGANS (S) DIVISION										TOTAL SUNDARBAN	
	Fisherman		Honey Collector		Wood Cutter		Staff		Total		Outside Forest		Total STR		Fisherman		Honey Collector		Wood Cutter		Staff/ Villager		Total			
	D	I	D	I	D	I	D	I	D	I	K	I	D	I	D	I	D	I	D	I	D	I	D	I	K	I
1985-86	0	6	5	0	2	0	1	0	8	6	0	0	8	6	0	0	0	0	0	0	0	0	0	0	**8**	**6**
1986-87	16	5	8	1	1	0	0	0	25	6	0	0	25	6	0	0	0	0	0	0	0	0	0	0	**25**	**6**
1987-88	15	6	6	1	0	0	0	0	21	7	0	0	21	7	10	0	1	0	0	0	0	0	11	0	**32**	**7**
1988-89	8	2	6	1	0	0	0	0	14	3	0	0	14	3	11	0	1	0	1	0	0	0	13	0	**27**	**3**
1989-90	8	1	1	1	0	0	0	0	9	2	0	0	9	2	3	0	0	0	0	0	0	0	3	0	**12**	**2**
1990-91	35	6	2	1	6	1	0	0	43	8	0	0	43	8	3	0	0	0	0	0	0	0	3	0	**46**	**8**
1991-92	32	4	3	0	2	3	1	0	38	7	0	0	38	7	7	0	1	0	2	0	0	0	10	0	**48**	**7**
1992-93	29	2	5	3	0	0	0	0	34	5	0	0	34	5	6	0	1	0	1	0	0	0	8	0	**42**	**5**
1993-94	24	2	4	2	1	0	2	0	31	4	0	0	31	4	12	0	1	0	3	0	0	0	16	0	**47**	**4**
1994-95	5	0	0	0	0	0	0	0	5	0	0	0	5	0	2	0	0	0	0	0	0	0	2	0	**7**	**0**
1995-96	2	0	2	0	0	0	0	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	**4**	**0**
1996-97	2	1	0	0	1	0	0	0	3	1	0	0	3	1	0	6	0	0	0	0	0	0	0	6	**3**	**7**
1997-98	4	2	0	0	0	0	1	0	5	2	0	0	5	2	0	0	0	0	0	0	0	0	0	0	**5**	**2**
1998-99	2	2	0	0	0	0	0	0	2	2	0	0	2	2	0	0	0	0	1	0	0	0	1	0	**3**	**2**
1999-00	9	0	3	0	1	0	0	0	13	0	0	0	13	0	2	0	0	0	0	0	0	0	2	0	**15**	**0**
2000-01	7	2	8	1	0	0	0	1	15	4	0	0	15	4	0	0	0	0	2	0	0	0	2	0	**17**	**4**
2001-02	10	3	2	2	0	0	0	0	12	5	0	0	12	5	1	0	0	0	0	0	2	0	3	0	**15**	**5**
2002-03	11	6	3	2	0	0	0	0	14	8	0	0	14	8	1	0	0	0	0	0	0	3	1	3	**15**	**11**
2003-04	3	1	5	3	0	0	0	0	8	4	0	0	8	4	2	2	1	1	0	0	0	1	3	4	**11**	**8**
2004-05	1	0	0	0	0	0	0	0	1	0	1	0	2	0	1	0	1	0	0	0	0	0	2	0	**4**	**0**
2005-06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	**1**	**0**
2006-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
2007-08	6	0	0	0	0	0	0	0	6	0	0	0	6	0	2	2	1	0	0	0	0	2	3	4	**9**	**4**
2008-09	6	0	0	0	0	0	0	0	6	0	0	0	6	0	0	3	0	0	0	0	0	0	0	3	**6**	**3**
2009-10	8	0	0	0	0	0	0	0	8	0	0	0	8	0	0	1	0	0	0	0	0	0	0	1	**8**	**1**
Total	243	51	63	18	14	4	5	1	325	74	1	0	326	74	64	14	8	1	10	0	2	6	84	21	410	95

TABLE 15

Human death/ injury by tigers in Indian Sundarban (1985-86 to 2009-10)

YEAR	Killed	Injured
1985-86	8	6
1986-87	25	6
1987-88	32	7
1988-89	27	3
1989-90	12	2
1990-91	46	8
1991-92	48	7
1992-93	42	5
1993-94	47	4
1994-95	7	0
1995-96	4	0
1996-97	3	7
1997-98	5	2
1998-99	3	2
1999-00	15	0
2000-01	17	4
2001-02	15	5
2002-03	15	11
2003-04	11	8
2004-05	3	0
2005-06	1	0
2006-07	0	0
2007-08	9	4
2008-09	6	3
2009-10	8	1
TOTAL	**409**	**95**

TABLE 16

Human Killing by tiger in Indian Sundarban- Seasonality

YEAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	TOTAL
1998-99	0	0	0	1	1	0	0	0	0	0	0	0	2
1999-2000	2	1	0	1	0	0	2	0	0	2	3	2	13
2000-01	9	0	1	1	1	0	0	0	0	0	1	2	15
2001-02	4	0	0	0	1	2	0	0	1	1	2	1	12
2002-03	3	0	0	1	2	0	0	3	2	1	1	1	14
2003-04	6	0	0	0	0	0	0	0	0	0	0	2	8
2004-05	1	0	0	0	0	0	1	0	0	0	0	0	2
2005-06	0	0	0	0	0	0	0	0	0	0	0	0	0
2006-07	0	0	0	0	0	0	0	0	0	0	0	0	0
2007-08	0	0	0	2	1	1	1	1	0	0	0	0	6
2008-09	3	0	0	0	0	0	0	0	1	2	0	0	6
2009-10	0	0	0	2	1	2	1	0	0	1	1	0	8
TOTAL	28	1	1	8	7	5	5	4	4	7	8	8	86

TABLE 17

Human Killing by tiger in Indian Sundarban Tiger Reserve-Diurnal Variation

YEAR	MORNING	AFTERNOON	EVENING	NIGHT	TOTAL
	(5 am -10 am)	(10 am -3 pm)	3 pm - 8 pm)	(8pm - 5 pm)	
2003-04	3	3	2	0	8
2007-08	2	1	2	1	6
2008-09	0	1	4	1	6
2009-10	2	0	5	1	8
TOTAL	7	5	13	3	28

Table 18

Human killing by tigers in Sundarban Tiger Reserve-
Core Zone vs. Buffer Zone/ Fishing and honey collection zone vs. Non-fishing and non-honey collection zone

YEARS	Human Killing in Core and Buffer zones		Human killing in Fishing/Honey collection zone and Non-fishing and Non-honey collection zone		TOTAL
	Core Zone	Buffer Zone	Fishing/Honey Collection Zone	Non-Fishing and Non-Honey Collection zone	
1998-99	0	2	2	0	2
1999-2000	4	9	9	4	13
2000-01	2	13	12	3	15
2001-02	6	6	6	6	12
2002-03	5	9	9	5	14
2003-04	3	5	5	3	8
2004-05	0	1	1	0	1
2005-06	0	0	0	0	0
2006-07	0	0	0	0	0
2007-08	0	7	3	4	7
2008-09	1	2	3	0	3
2009-10	1	8	3	6	9
TOTAL	22	62	53	31	

TABLE 19

Year-wise Tiger Straying in Indian Sundarban

Year	Sundarban Tiger Reserve	24 Parganas (south) Division	Total
1986	14	NA*	14
1987	20	NA	20
1988	4	NA	4
1989	4	NA	4
1990	11	NA	11
1991	1	1	2
1992	3	1	4
1993	1	1	2
1994	8	2	10
1995	25	1	26
1996	18	2	20
1997	3	1	4
1998	5	2	7
1999	10	3	13
2000	6	3	9
2001	8	5	13
2002	24	2	26
2003	21	4	25
2004	17	3	20
2005	2	3	5
2006	10	11	21
2007	9	8	17
2008	11	1	12
2009	22	13	35

*NA= Not Avilable

TABLE 20

Location-wise tiger straying in Indian Sundarban

S. No.	Name of Village	No of tiger straying
Tiger Straying 30> (Category-I)		
1	Samsernagar	70
Tiger Straying between 21-30 (Category- II)		
1	Jharkhali	28
2	RajatJubilee	27
Tiger Straying between 11-20 (Category-III)		
1	Kalitala	19
2	Jamespur	16
3	Lahiripur	14
4	Kumirmari	13
5	Kalidaspur	11
Tiger Straying between 01-10 (Categogry-IV)		
1	Satyanarayanpur/Amlamethi	9
2	Sonagaon	8
3	Deaulbari	8
4	Range/Beat Offices	7
5	Hemnagar	7
6	Enpur	6
7	Santigachi	6
8	Ambikanagar	5
9	Mitrabari	4
10	Bijoynagar	4
11	Baikunthpur	4
12	Satjelia	3
13	Perghumti	3
14	Chotomollakhali	3
15	Bali	3
16	Pakhiralaya	3
17	Naginabad	3

Table 7 Continued...

S. No.	Name of Village	No of tiger straying
18	Luxbagan	2
19	Chargheri	2
20	Mathurakhand	2
21	Dayapur	2
22	Kishorimohanpur	2
23	Patharpur	2
24	Hentalbari	2
25	Dulki	1
26	Glasskhali	1
27	Satyadaspur	1
28	K Plot	1
29	Upendranagar	1
30	Buruliapara	1
31	Bhubneshwari	1
32	Petkulchand	1

TABLE 21

Temporal variation of tiger straying in Indian Sundarban

Month	No. of tiger Straying		
	Sundarban Tiger Reserve	**24 Parganas (South) Division**	**Total**
January	30	7	37
February	23	8	31
March	13	1	14
April	19	0	19
May	16	0	16
June	18	1	19
July	23	2	25
August	33	0	33
September	22	3	25
October	11	11	22
November	28	5	33
December	21	11	32

TABLE 22

Seasonal variation of surface water salinity (psu) during 2008 to 2010

LOCATION	2008			2009			2010		
	Prm	Mon	Pom	Prm	Mon	Pom	Prm	Mon	Pom

Harinbari (Stn. 1)
$88^{0}10^{/}44.55^{//}$
$21^{0}43^{/}08.58^{//}$
	14.79	4.17	9.82	14.20	3.89	9.65	13.98	3.65	8.44

Chemaguri (Stn.2)
$88^{0}10^{/}07.03^{//}$
$21^{0}39^{/}58.15^{//}$
	21.77	9.08	17.29	21.20	8.79	16.32	21.00	7.94	15.85

Sagar South (Stn.3)
$88^{0}04^{/}$ $52.98^{//}$
$21^{0}47^{/}01.36^{//}$
	28.79	10.85	18.05	28.36	10.02	17.67	27.96	9.44	16.82

Lothian island (Stn.4)
$88^{0}22^{/}$ $13.99^{//}$
$21^{0}39^{/}01.58^{//}$
	29.10	12.00	19.06	28.99	11.15	18.69	27.49	10.86	17.94

Prentice island (Stn.5)
$88^{0}17^{/}$ $10.04^{//}$
$21^{0}42^{/}40.97^{//}$
	29.02	11.78	18.99	28.56	11.09	18.22	27.05	10.42	16.85

Canning (Stn. 6)
$88^{0}41^{/}16.20^{//}$
$22^{0}18^{/}40.25^{//}$
	14.96	3.12	8.86	15.21	3.95	9.81	15.79	4.01	10.12

Sajnekhali (Stn. 7)
$88^{0}48^{/}17.60^{//}$
$22^{0}16^{/}33.79^{//}$
	28.33	11.38	17.42	29.16	12.00	19.67	29.30	12.56	20.05

Chotomollakhali (Stn.8)
$88^{0}54^{/}26.71^{//}$
$22^{0}10^{/}40.00^{//}$
	24.60	11.55	16.97	25.85	11.02	17.30	26.13	11.55	18.10

Satjelia (Stn. 9)
$88^{0}52^{/}49.51^{//}$
$22^{0}05^{/}17.86^{//}$
	28.70	12.02	18.56	29.83	12.35	19.99	30.02	12.70	20.30

Pakhiralaya (Stn10)
$88^{0}48^{/}29.00^{//}$
$22^{0}07^{/}07.23^{//}$
	27.99	11.85	18.00	28.72	12.20	18.00	28.93	12.34	18.56

TABLE 23

Seasonal variations in AGB and BGB of selected mangrove species along with ambient salinity in the western sector (figures within bracket represents the percentage of BGB of AGB) in 2008

Location	**Species**	**AGB (t/ha)**			**BGB (t/ha)**			**TB (t/ha)**		
		Prm	Mon	Pom	Prm	Mon	Pom	Prm	Mon	Pom
Harinbari (Stn. 1) $88^{0}10^{/}44.55^{//}$ $21^{0}43^{/}08.58^{//}$	A	35.70	42.40	46.29	9.26 (25.96)	11.39 (27.75)	13.39 (28.74)	44.96	53.79	59.68
	B	37.08	41.08	42.98	8.19 (22.10)	9.82 (23.91)	10.78 (25.09)	45.27	50.90	53.76
	C	6.28	9.68	10.85	1.35 (21.51)	2.25 (23.31)	2.65 (24.49)	7.63	11.93	13.50
Chemaguri (Stn.2) $88^{0}10^{/}07.03^{//}$ $21^{0}39^{/}58.15^{//}$	A	24.76	28.90	32.42	6.22 (25.14)	7.78 (26.94)	9.12 (28.14)	30.98	36.68	41.54
	B	40.90	43.15	45.06	9.12 (22.31)	10.4 (24.12)	11.40 (25.31)	50.02	53.55	56.46
	C	9.40	11.41	13.58	2.02 (21.57)	2.66 (23.34)	3.33 (24.54)	11.42	14.07	16.91
Sagar South (Stn.3) $88^{0}04^{/}52.98^{//}$ $21^{0}47^{/}01.36^{//}$	A	17.49	20.09	23.09	4.34 (24.84)	5.34 (26.63)	6.42 (27.83)	21.83	25.43	29.51
	B	41.88	45.3	49.89	9.34 (22.32)	10.92 (24.12)	12.63 (25.32)	51.22	56.22	62.52
	C	8.82	11.45	14.83	1.94 (22.09)	2.73 (23.89)	3.72 (25.09)	10.76	14.18	18.55
Lothian island (Stn.4) $88^{0}22^{/}13.99^{//}$ $21^{0}39^{/}01.58^{//}$	A	13.44	15.73	18.09	3.22 (23.98)	4.05 (25.78)	4.88 (26.98)	16.66	19.78	22.97
	B	45.97	48.68	51.04	10.29 (22.39)	11.77 (24.19)	12.95 (25.39)	56.26	60.45	63.99
	C	8.17	13.1	17.41	1.81 (22.23)	3.14 (24.03)	4.39 (25.23)	9.98	16.24	21.8
Prentice island (Stn.5) $88^{0}17^{/}10.04^{//}$ $21^{0}42^{/}40.97^{//}$	A	16.14	19.2	22.21	3.93 (24.35)	5.02 (26.15)	6.07 (27.35)	20.07	24.22	28.28
	B	43.03	46.82	49.6	9.61 (22.35)	11.3 (24.15)	12.57 (25.35)	52.64	58.11	62.17
	C	6.35	11.47	15.61	1.40 (22.13)	2.74 (23.93)	3.8 (25.13)	7.75	14.21	19.41

Canning (Stn. 6) $88^0 41^/ 16.20^{//}$ $22^0 18^/ 40.25^{//}$	A	10.73	15.05	17.97	1.95 (18.19)	3.01 (20.05)	3.84 (21.37)	12.68	18.06	21.81
	B	29.23	32.76	36.57	6.88 (23.56)	7.92 (24.19)	9.7 (26.53)	36.11	40.68	46.27
	C	3.21	5.54	7.16	0.708 (22.06)	1.37 (24.76)	1.82 (25.49)	3.91	6.91	8.98
Sajnekhali (Stn. 7) $88^0 48^/ 17.60^{//}$ $22^0 16^/ 33.79^{//}$	A	2.54	3.88	5.14	0.49 (19.39)	0.803 (20.7)	1.11 (21.65)	3.03	4.68	6.25
	B	45.96	51.92	56.84	10.9 (23.73)	12.9 (24.86)	15.31 (26.95)	56.86	64.82	72.15
	C	11.42	17.53	21.96	2.56 (22.5)	4.36 (24.91)	5.62 (25.6)	13.98	21.89	27.58
Chotomollakhali (Stn.8) $88^0 54^/ 26.71^{//}$ $22^0 10^/ 40.00^{//}$	A	1.85	5.22	9.12	0.352 (19.07)	1.06 (20.01)	1.95 (21.46)	2.2	6.28	11.07
	B	38.90	41.92	44.61	9.19 (23.63)	10.36 (24.73)	11.98 (26.86)	48.09	52.28	56.59
	C	2.54	6.95	10.8	0.56 (22.07)	1.7 (24.57)	2.73 (25.28)	3.1	8.65	13.53
Satjelia (Stn. 9) $88^0 52^/ 49.51^{//}$ $22^0 05^/ 17.86^{//}$	A	0.99	1.03	1.84	0.189 (19.19)	0.21 (20.51)	0.39 (21.72)	1.17	1.24	2.23
	B	44.57	50.92	55.76	10.56 (23.71)	0.24 (24.76)	15.02 (26.94)	55.13	51.16	70.78
	C	11.89	18.78	23.87	2.68 (22.56)	4.66 (24.83)	6.18 (25.93)	14.57	23.44	30.05
Pakhiralaya (Stn10) $88^0 48^/ 29.00^{//}$ $22^0 07^/ 07.23^{//}$	A	1.38	3.07	4.55	0.26 (19.31)	0.63 (20.66)	0.98 (21.61)	1.64	3.7	5.53
	B	41.35	46.00	48.68	9.77 (23.65)	11.42 (24.83)	13.09 (26.9)	51.12	57.42	61.77
	C	8.56	14.25	19.69	1.9 (22.31)	3.53 (24.8)	5.02 (25.5)	9.65	17.78	24.71

A = *Sonneratia apetala*, B= *Avicennia marina*, C= *Excoecaria agallocha;* Prm=Premonsoon, Mon=Monsoon, Pom=Post monsoon

TABLE 24

Seasonal variations in AGB and BGB of selected mangrove species along with ambient salinity in the western and central sectors in 2009 (figures within bracket represents the percentage of BGB of AGB).

Location	Species	AGB (t/ha)			BGB (t/ha)			TB (t/ha)		
		Prm	Mon	Pom	Prm	Mon	Pom	Prm	Mon	Pom
Harinbari (Stn. 1) $88^0 10^/ 44.55^{//}$ $21^0 43^/ 08.58^{//}$	A	37.91	41.98	49.90	10.24 (27.01)	11.67 (27.80)	13.97 (27.99)	48.15	53.65	63.87
	B	37.23	40.05	44.02	8.62 (23.15)	9.60 (23.96)	10.63 (24.14)	45.85	49.65	54.65
	C	7.55	10.58	12.20	1.7 (22.56)	2.47 (23.36)	2.87 (23.54)	9.25	13.05	15.07
Chemaguri (Stn.2) $88^0 10^/ 07.03^{//}$ $21^0 39^/ 58.15^{//}$	A	25.10	26.97	34.91	6.57 (26.19)	7.28 (26.99)	9.49 (27.19)	31.67	34.25	44.4
	B	39.12	41.07	45.05	9.14 (23.36)	9.23 (24.17)	10.97 (24.36)	48.26	50.30	56.02
	C	9.75	11.47	14.09	2.21 (22.62)	2.68 (23.39)	3.32 (23.59)	11.96	14.15	17.41
Sagar South (Stn.3) $88^0 04^/ 52.98^{//}$ $21^0 47^/ 01.36^{//}$	A	16.70	18.77	22.92	4.32 (25.89)	5.01 (26.68)	6.16 (26.88)	21.02	23.78	29.08
	B	41.48	45.16	51.82	9.69 (23.37)	10.92 (24.17)	12.63 (24.37)	51.17	56.08	64.45
	C	10.04	12.94	16.77	2.32 (23.14)	3.10 (23.94)	4.05 (24.14)	12.36	16.04	20.82
Lothian island (Stn.4) $88^0 22^/ 13.99^{//}$ $21^0 39^/ 01.58^{//}$	A	13.14	14.10	19.00	3.29 (25.03)	3.64 (25.83)	4.95 (26.03)	16.43	17.74	23.95
	B	46.13	48.60	53.03	10.81 (23.44)	11.78 (24.24)	12.96 (24.44)	94.73	60.38	65.99
	C	10.30	14.00	19.85	2.40 (23.28)	3.37 (24.08)	4.82 (24.28)	12.70	17.37	24.67
Prentice island (Stn.5) $88^0 17^/ 10.04^{//}$ $21^0 42^/ 40.97^{//}$	A	13.86	17.28	21.59	3.52 (25.40)	4.53 (26.20)	5.70 (26.40)	17.38	21.81	27.29
	B	43.19	47.34	52.22	10.11 (23.40)	11.46 (24.20)	12.74 (24.40)	53.3	58.8	64.96

	C	8.49	12.22	18.21	1.97 (23.18)	2.93 (23.98)	4.40 (24.18)	10.46	15.15	22.61
Canning (Stn. 6) $88^0 41^/ 16.20^{//}$ $22^0 18^/ 40.25^{//}$	A	14.91	18.92	22.45	2.87 (19.24)	3.80 (20.10)	4.58 (20.42)	17.78	22.72	27.03
	B	28.91	31.86	37.01	7.11 (24.61)	7.72 (24.24)	9.47 (25.58)	36.02	39.58	46.48
	C	4.34	6.43	9.46	1.00 (23.11)	1.60 (24.81)	2.32 (24.54)	5.34	8.03	11.78
Sajnekhali (Stn. 7) $88^0 48^/ 17.60^{//}$ $22^0 16^/ 33.79^{//}$	A	2.79	4.00	5.98	0.57 (20.44)	0.83 (20.75)	1.24 (20.70)	3.36	4.83	7.22
	B	45.67	50.05	57.31	11.32 (24.78)	12.47 (24.91)	14.90 (26.00)	56.99	62.52	72.21
	C	13.58	19.45	25.95	3.20 (23.55)	4.85 (24.96)	6.40 (24.65)	16.78	24.30	32.35
Chotomollakhali (Stn.8) $88^0 54^/ 26.71^{//}$ $22^0 10^/ 40.00^{//}$	A	4.10	7.78	12.27	0.82 (20.12)	1.58 (20.36)	2.52 (20.51)	4.92	9.36	14.79
	B	40.43	42.87	48.9	9.98 (24.68)	10.62 (24.78)	12.67 (25.91)	50.41	53.49	61.57
	C	6.70	10.87	15.79	1.55 (23.12)	2.68 (24.62)	3.84 (24.33)	8.25	13.55	19.63
Satjelia (Stn. 9) $88^0 52^/ 49.51^{//}$ $22^0 05^/ 17.86^{//}$	A	1.05	2.89	3.36	0.21 (20.24)	0.59 (20.56)	0.70 (20.77)	1.26	3.48	4.06
	B	50.57	54.92	61.76	12.52 (24.76)	13.63 (24.81)	16.05 (25.99)	63.09	68.55	77.81
	C	20.77	25.66	32.75	4.90 (23.61)	6.38 (24.88)	8.18 (24.98)	25.67	32.04	40.93
Pakhiralaya (Stn10) $88^0 48^/ 29.00^{//}$ $22^0 07^/ 07.23^{//}$	A	4.10	5.82	7.61	0.83 (20.36)	1.21 (20.71)	1.57 (20.66)	4.93	7.03	9.18
	B	40.37	42.88	50.64	9.97 (24.70)	10.67 (24.88)	13.14 (25.95)	50.34	53.55	63.78
	C	12.26	14.95	22.39	2.86 (23.36)	3.72 (24.85)	5.50 (24.55)	15.12	18.67	27.89

A = *Sonneratia apetala*, B= *Avicennia marina*, C= *Excoecaria agallocha;* Prm=Premonsoon, Mon=Monsoon, Pom=Post monsoon

TABLE 25

Seasonal variations in AGB and BGB of selected mangrove species along with ambient salinity in the western sector in 2010 (figures within bracket represents the percentage of BGB of AGB)

Location	Species	AGB (t/ha)			BGB (t/ha)			TB (t/ha)		
		Prm	Mon	Pom	Prm	Mon	Pom	Prm	Mon	Pom
Harinbari (Stn. 1) $88^{0}10^{/}44.55^{//}$ $21^{0}43^{/}08.58^{//}$	A	43.56	49.80	53.79	12.20 (28.01)	14.84 (29.80)	16.67 (30.99)	55.76	64.64	70.46
	B	40.09	44.15	46.05	9.68 (24.15)	11.46 (25.96)	12.50 (27.14)	49.77	55.61	58.55
	C	9.21	12.66	13.83	2.17 (23.56)	3.21 (25.36)	3.67 (26.54)	11.38	15.87	17.5
Chemaguri (Stn.2) $88^{0}10^{/}07.03^{//}$ $21^{0}39^{/}58.15^{//}$	A	29.75	34.08	37.80	8.09 (27.19)	9.88 (28.99)	11.41 (30.19)	37.84	43.96	49.21
	B	42.98	45.17	47.08	10.47 (24.36)	11.82 (26.17)	12.88 (27.36)	53.45	56.99	59.96
	C	11.60	13.55	15.72	2.74 (23.62)	3.44 (25.39)	4.18 (26.59)	14.34	16.99	19.9
Sagar South (Stn.3) $88^{0}04^{/}$ $52.98^{//}$ $21^{0}47^{/}01.36^{//}$	A	22.35	25.00	27.81	6.01 (26.89)	7.17 (28.68)	8.31 (29.88)	28.36	32.17	36.12
	B	45.34	49.26	53.85	11.05 (24.37)	12.89 (26.17)	14.74 (27.37)	56.39	62.15	68.59
	C	11.89	15.02	18.40	2.87 (24.14)	3.90 (25.94)	4.99 (27.14)	14.76	18.92	23.39
Lothian island (Stn.4) $88^{0}22^{/}$ $13.99^{//}$ $21^{0}39^{/}01.58^{//}$	A	17.79	20.33	22.89	4.63 (26.03)	5.66 (27.83)	6.64 (29.03)	22.42	25.99	29.53
	B	49.99	52.70	55.06	12.22 (24.44)	13.83 (26.24)	15.11 (27.44)	62.21	66.53	70.17
	C	12.15	17.08	21.39	2.95 (24.28)	4.45 (26.08)	5.84 (27.28)	15.1	21.53	27.23

Prentice island (Stn.5) $88^0 17^/ 10.04^{//}$ $21^0 42^/ 40.97^{//}$	A	20.30	23.51	26.48	5.36 (26.40)	6.63 (28.20)	7.79 (29.40)	25.66	30.14	34.27
	B	47.05	51.44	54.25	11.48 (24.40)	13.48 (26.20)	14.86 (27.40)	58.53	64.92	69.11
	C	10.34	15.30	19.84	2.50 (24.18)	3.97 (25.98)	5.39 (27.18)	12.84	19.27	25.23
Canning (Stn. 6) $88^0 41^/ 16.20^{//}$ $22^0 18^/ 40.25^{//}$	A	16.76	21.00	24.08	3.39 (20.24)	4.64 (22.10)	5.64 (23.42)	20.15	25.64	29.72
	B	34.56	38.09	41.90	8.85 (25.61)	9.99 (26.24)	11.98 (28.58)	43.41	48.08	53.88
	C	8.20	10.53	12.49	1.98 (24.11)	2.82 (26.81)	3.44 (27.54)	10.18	13.35	15.93
Sajnekhali (Stn. 7) $88^0 48^/ 17.60^{//}$ $22^0 16^/ 33.79^{//}$	A	4.64	6.05	7.17	0.99 (21.44)	1.38 (22.75)	1.70 (23.70)	5.63	7.43	8.87
	B	51.32	57.28	62.20	13.23 (25.78)	15.41 (26.91)	18.04 (29.00)	64.55	72.69	80.24
	C	17.44	23.55	27.98	4.28 (24.55)	6.35 (26.96)	7.72 (27.65)	21.72	29.9	35.7
Chotomollakhali (Stn.8) $88^0 54^/ 26.71^{//}$ $22^0 10^/ 40.00^{//}$	A	5.95	9.86	13.90	1.26 (21.12)	2.20 (22.36)	3.27 (23.51)	7.21	12.06	17.17
	B	46.08	49.10	51.79	11.83 (25.68)	13.15 (26.78)	14.97 (28.91)	57.91	62.25	66.76
	C	10.56	14.97	18.82	2.55 (24.12)	3.99 (26.62)	5.14 (27.33)	13.11	18.96	23.96
Satjelia (Stn. 9) $88^0 52^/ 49.51^{//}$ $22^0 05^/ 17.86^{//}$	A	2.90	3.96	4.81	0.62 (21.24)	0.89 (22.56)	1.14 (23.77)	3.52	4.85	5.95
	B	53.11	59.46	64.30	13.68 (25.76)	15.94 (26.81)	18.64 (28.99)	66.79	75.4	82.94
	C	21.10	27.99	33.08	5.19 (24.61)	7.52 (26.88)	9.26 (27.98)	26.29	35.51	42.34

Pakhiralaya (Stn10) $88^0 48^/ 29.00^{//}$ $22^0 07^/ 07.23^{//}$	A	4.55	6.27	8.05	0.97 (21.36)	1.42 (22.71)	1.90 (23.66)	5.52	7.69	9.95
	B	46.82	51.20	54.18	12.03 (25.70)	13.76 (26.88)	15.69 (28.95)	58.85	64.96	69.87
	C	14.59	20.28	25.72	3.55 (24.36)	5.45 (26.85)	7.09 (27.55)	18.14	25.73	32.81

A = *Sonneratia apetala*, B= *Avicennia marina*, C= *Excoecaria agallocha;* Prm=Premonsoon, Mon=Monsoon, Pom=Post monsoon

TABLE 26

Correlation between salinity, AGB, BGB and TB of selected mangrove species in the selected stations during 2008

Species	Combination	r-value		
		Prm	Mon	Pom
A	Salinity × AGB	-0.547	-0.587	-0.487
	Salinity × BGB	-0.512	-0.534	-0.431
	Salinity × TB	-0.539	-0.575	-0.475
B	Salinity × AGB	0.858	0.848	0.769
	Salinity × BGB	0.875	0.855	0.719
	Salinity × TB	0.865	0.850	0.762
C	Salinity × AGB	0.543	0.660	0.702
	Salinity × BGB	0.558	0.659	0.692
	Salinity × TB	0.546	0.660	0.701

A = *Sonneratia apetala*, B= *Avicennia alba*, C= *Excoecaria agallocha;* Prm=Premonsoon, Mon=Monsoon, Pom=Post monsoon; All values have p-values at 1% level ($p<0.01$)

TABLE 27

Correlation between salinity, AGB, BGB and TB of selected mangrove species in the selected stations during 2009

Species	Combination	r-value		
		Prm	Mon	Pom
A	Salinity × AGB	-0.6757	-0.7405	-0.6874
	Salinity × BGB	-0.6266	-0.6834	-0.6269
	Salinity × TB	-0.6652	-0.7276	-0.6733
B	Salinity × AGB	0.8946	0.8650	0.8611
	Salinity × BGB	0.8771	0.8723	0.8269
	Salinity × TB	0.8943	0.8671	0.8555
C	Salinity × AGB	0.6474	0.7297	0.7877
	Salinity × BGB	0.6537	0.7252	0.7778
	Salinity × TB	0.6487	0.7289	0.7855

A = *Sonneratia apetala*, B= *Avicennia alba*, C= *Excoecaria agallocha;* Prm=Premonsoon, Mon=Monsoon, Pom=Post monsoon; All values have p-values at 1% level (p<0.01)

TABLE 28

Correlation between salinity, AGB, BGB and TB of selected mangrove species in the selected stations during 2010

Species	Combination	r-value		
		Prm	Mon	Pom
A	Salinity × AGB	-0.6422	-0.7137	-0.6599
	Salinity × BGB	-0.6000	-0.6615	-0.6103
	Salinity × TB	-0.6335	-0.7024	-0.6487
B	Salinity × AGB	0.7098	0.6813	0.6939
	Salinity × BGB	0.5992	0.5917	0.6007
	Salinity × TB	0.6891	0.6632	0.6736
C	Salinity × AGB	0.4299	0.5295	0.6309
	Salinity × BGB	0.4065	0.5032	0.5964
	Salinity × TB	0.4252	0.5239	0.6234

A = *Sonneratia apetala*, B= *Avicennia alba*, C= *Excoecaria agallocha;* Prm=Premonsoon, Mon=Monsoon, Pom=Post monsoon; All values have p-values at 1% level ($p<0.01$)

TABLE 29

Seasonal variation of surface water temperature (in ^{0}C) during 2008 to 2010

Location	2008			2009			*2010*		
	Prm	Mon	Pom	Prm	Mon	Pom	Prm	Mon	*Pom*
Harinbari (Stn. 1) $88^{0}10^{/}44.55^{//}$ $21^{0}43^{/}08.58^{//}$	33.3	32.8	28.7	33.3	32.8	28.8	33.4	32.9	*28.8*
Chemaguri (Stn.2) $88^{0}10^{/}07.03^{//}$ $21^{0}39^{/}58.15^{//}$	33.3	32.7	28.7	33.4	32.8	28.8	33.5	32.8	*28.9*
Sagar South (Stn.3) $88^{0}04^{/}$ $52.98^{//}$ $21^{0}47^{/}01.36^{//}$	33.5	32.9	28.9	33.6	33.0	28.9	33.5	33.0	*28.9*
othian island (Stn.4) $88^{0}22^{/}$ $13.99^{//}$ $21^{0}39^{/}01.58^{//}$	33.5	32.9	28.7	33.6	33.0	28.9	33.5	32.9	*28.9*
entice island (Stn.5) $88^{0}17^{/}$ $10.04^{//}$ $21^{0}42^{/}40.97^{//}$	33.4	32.8	28.7	33.5	32.9	28.8	33.6	33.0	*28.9*
Canning (Stn. 6) $88^{0}41^{/}16.20^{//}$ $22^{0}18^{/}40.25^{//}$	33.3	32.8	28.8	33.34	32.8	28.9	33.5	32.9	*28.9*
Sajnekhali (Stn. 7) $88^{0}48^{/}17.60^{//}$ $22^{0}16^{/}33.79^{//}$	33.4	32.8	28.7	33.5	32.8	28.7	33.5	32.9	*28.8*
otomollakhali (Stn.8) $88^{0}54^{/}26.71^{//}$ $22^{0}10^{/}40.00^{//}$	33.5	32.7	28.8	33.5	32.7	28.8	33.6	32.8	*28.8*
Satjelia (Stn. 9) $88^{0}52^{/}49.51^{//}$ $22^{0}05^{/}17.86^{//}$	33.5	32.8	28.8	33.5	32.9	28.8	33.6	32.8	*28.8*
Pakhiralaya (Stn10) $88^{0}48^{/}29.00^{//}$ $22^{0}07^{/}07.23^{//}$	*33.4*	*32.7*	*28.8*	*33.5*	*32.8*	*28.9*	*33.6*	*32.8*	*28.8*

TABLE 30

Change of land and water areas of Forest areas of Indian Sundarban (in Sq.Km.) for the period from 1986 to 2009

Sundarban Tiger Reserve Forest BlockNames	Comp.	Area 1986(in Sq.Km) Land	Water	Total	Area 1989 (in Sq.Km) Land	Water	Total	Area 1999(in Sq.Km) Land	Water	Total	Area 2001(in Sq.Km) Land	Water	Total	Area 2005(in Sq.Km) Land	Waer	Total	Area 2009(in Sq.Km) Land	Water	Total
Arbesi	1 to 5	98.78	43.74	142.52	97.6	45.54	143.14	96.09	46.7	142.79	97.07	44.13	141.2	70.63	46.7	117.33	66.50	44.99	141.14
Jhilla	1 to 6	89.83	31.16	120.99	89.3	31.84	121.14	90.36	30.63	120.99	88.41	32.05	120.46	86.6	30.63	117.23	85.89	34.28	120.17
Pirkhali	1 to 7	146.8	51.62	198.42	150.16	49.09	199.25	147.1	51.78	198.88	147.06	52.15	199.21	148.94	51.78	200.72	148.10	48.61	196.71
Panchmukhani	1 to 5	141.82	35.16	176.98	145.04	31.58	176.62	144.28	32.84	177.12	142.09	35.45	177.54	143.26	34.08	177.34	144.59	33.06	177.65
Harinbhanga	1 to 3	82.71	33.97	116.68	84.91	31.97	116.88	82.25	34.61	116.86	82.62	34.16	116.78	81.97	34.61	116.58	82.49	34.20	116.69
Khatuajhuri	1 to 3	99.66	20.37	120.03	102.62	16.74	119.36	100.23	19.64	119.87	98.41	21.04	119.45	101.27	19.64	120.91	101.47	18.33	119.80
Chamta	1 to 8	167.7	59.71	227.41	171.11	56.08	227.19	168.15	59.13	227.28	166.58	61.18	227.76	169.09	59.13	228.22	167.39	61.82	229.84
Netidhopani	1 to 3	56.34	21.5	77.84	56.15	21.6	77.75	55.22	22.63	77.85	55.59	22.56	78.15	59.11	22.63	81.74	59.40	19.25	78.62
Matla	1 to 4	122.54	66.92	189.46	123.36	66.37	189.73	120.24	69.03	189.27	122.34	67.4	189.74	123.15	69.03	192.18	120.01	66.34	190.39
Chandkhali	1 to 4	115.49	37.56	153.05	116.8	36.23	153.03	113.77	38.95	152.72	114.2	38.85	153.05	116.41	38.95	155.36	114.53	38.16	153.15
Goasaba	1 to 4	104.49	68.21	172.7	104.88	68.75	173.63	103.1	70.06	173.16	103.53	69.82	173.35	103.93	70.06	173.99	101.03	69.57	172.76
Gona	1 to 3	79.91	68.14	148.05	79.24	69.81	149.05	77.78	71.27	149.05	78.15	70.88	149.03	77.54	71.27	148.81	76.71	72.43	149.79
Chhotardi	1 to 3	76.5	88.38	164.88	79.79	86.29	166.08	76.88	89.62	166.5	77.34	88.86	166.2	77.89	89.62	167.51	74.12	88.70	166.69
Baghmara	1 to 8	161.21	149.57	310.78	157.58	150.3	307.88	152.81	154.84	307.65	153.71	154.11	307.82	153.07	154.84	307.91	148.96	157.32	307.39
Mayadwip	1 to 5	95.85	211.39	307.24	93.9	213.4	307.3	83.49	223.5	306.99	82.92	224.34	307.26	80.61	224.96	305.57	74.43	231.51	306.09
Total-STR		1639.63	987.40	2627.03	1652.44	975.59	2628.03	1611.75	1015.23	2626.98	1610.02	1016.98	2627.00	1593.47	1017.93	2611.4	1565.62	1018.57	2626.88

Table 17 Continued......

24 Parganas (Forest) Division Forest Blocks																			
Herobhanga	**1 to 9**	**89.00**	**100.00**	**189.00**	**88.00**	**101.00**	**189.00**	**91.00**	**98.00**	**189.00**	**90.00**	**99.00**	**189.00**	**91.60**	**97.40**	**189.00**	**84.25**	**104.75**	**189.00**
Ajmalmari	**1 to 12**	**133.00**	**113.00**	**246.00**	**132.00**	**114.00**	**246.00**	**132.00**	**114.00**	**246.00**	**132.00**	**114.00**	**246.00**	**128.44**	**117.56**	**246.00**	**122.99**	**123.01**	**246.00**
Dulibasani	**1 to 8**	**129.00**	**160.00**	**289.00**	**128.00**	**161.00**	**289.00**	**127.00**	**162.00**	**289.00**	**126.00**	**163.00**	**289.00**	**125.71**	**163.29**	**289.00**	**120.16**	**168.84**	**289.00**
Chulkati	**1 to 8**	**99.00**	**141.00**	**240.00**	**95.00**	**145.00**	**240.00**	**92.00**	**148.00**	**240.00**	**90.00**	**150.00**	**240.00**	**83.13**	**156.87**	**240.00**	**84.25**	**155.75**	**240.00**
Thakuran	**1 to 4**	**52.00**	**144.00**	**196.00**	**54.00**	**142.00**	**196.00**	**62.00**	**134.00**	**196.00**	**58.00**	**138.00**	**196.00**	**55.80**	**140.20**	**196.00**	**53.78**	**142.22**	**196.00**
Saptamukhi	**1 to 2**	**68.00**	**144.00**	**212.00**	**71.00**	**141.00**	**212.00**	**73.00**	**139.00**	**212.00**	**71.00**	**141.00**	**212.00**	**71.23**	**140.77**	**212.00**	**68.42**	**143.58**	**212.00**
Muriganga	**N.A.**	**22.00**	**304.00**	**326.00**	**23.00**	**303.00**	**326.00**	**17.00**	**309.00**	**326.00**	**20.00**	**306.00**	**326.00**	**18.19**	**307.81**	**326.00**	**16.43**	**309.57**	**326.00**
Total-24Pgns(S)		**592**	**1106**	**1698**	**591**	**1107**	**1698**	**594**	**1104**	**1698**	**587**	**1111**	**1698**	**574.1**	**1123.9**	**1698**	**550.28**	**1147.72**	**1698**
Grand Total Sundarban		**2231.63**	**2093.4**	**4325.03**	**2243.44**	**2082.59**	**4326.03**	**2205.75**	**2119.23**	**4324.98**	**2197.02**	**2127.98**	**4325**	**2167.57**	**2141.83**	**4309.4**	**2115.9**	**2166.29**	**4324.88**

Table 31

Factors considered threat to Sundarban –Opinion survey abstract

Unit	Human-Wildlife Conflict	Climate Change	Salinity change	Prawn Seed Collection	Pressure on N. R.	Environment & Water Pollution
Calcutta University	14	17	15	5	11	1
FPC/EDC Forest Department and staff	36	21	20	19	24	21
NGO	16	16	16	7	10	2
Total	**66**	**54**	**51**	**31**	**45**	**24**

Figures

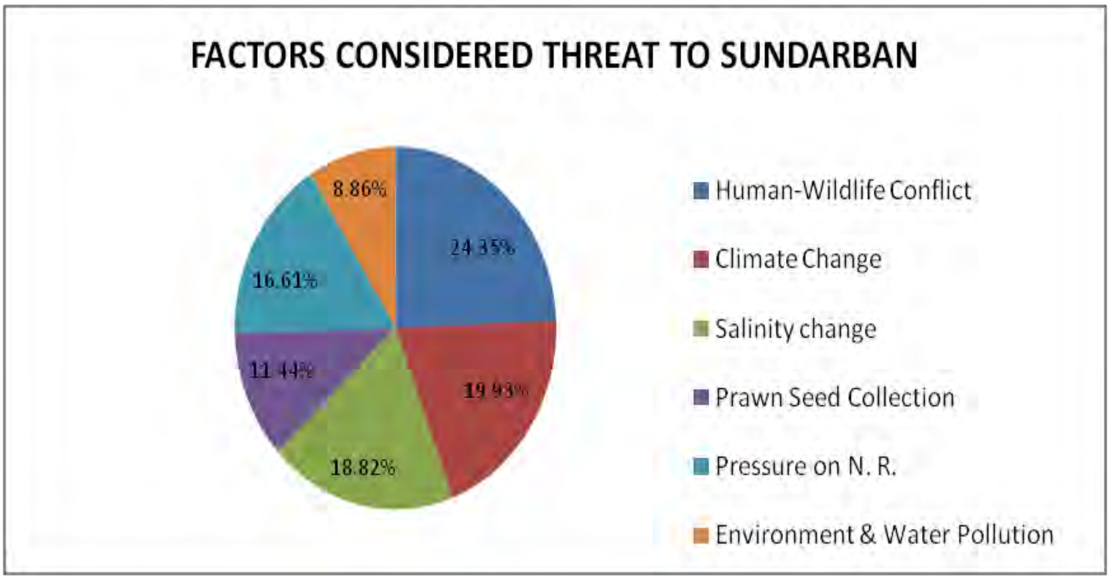
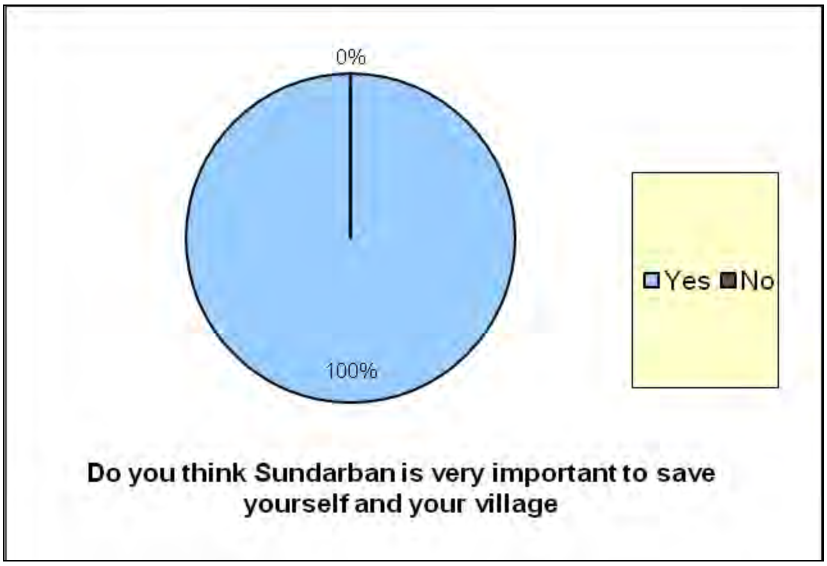


Fig. 29 Factors considered threat to Sundarban

Fig. 30 (a-s)

FOREST PROTECTION COMMITTEE /ECO-DEVELOPMENT COMMITTEE SURVEY OUTCOME 2010-11 ON INDIAN SUNDARBAN

SIGNIFICANCE OF SUNDARBAN



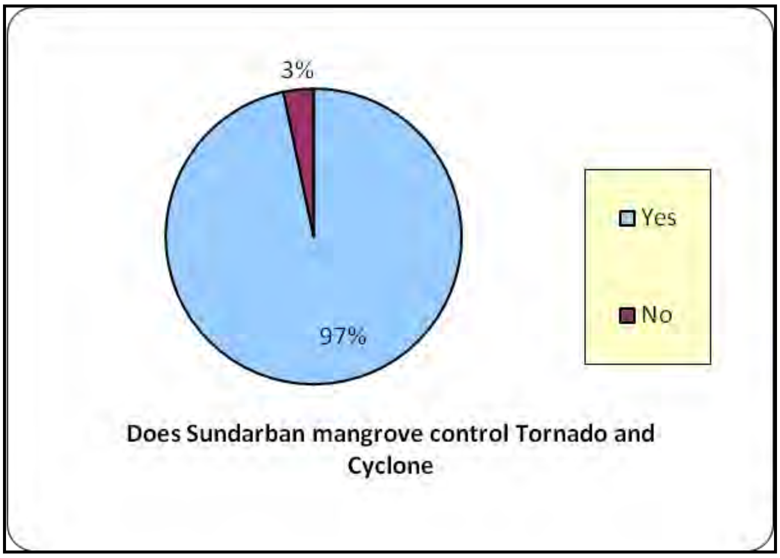
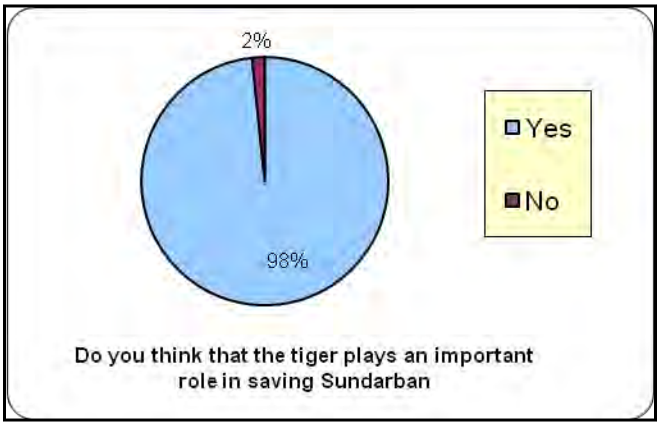
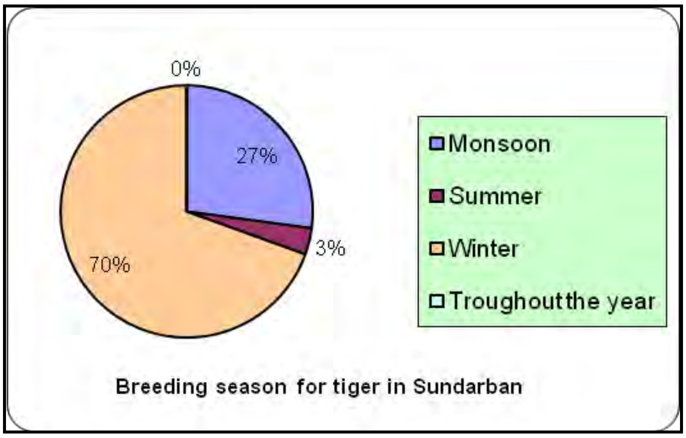


Fig. 30 (a-s) (Continued…….)

FOREST PROTECTION COMMITTEE /ECO-DEVELOPMENT COMMITTEE SURVEY OUTCOME 2010-11 ON INDIAN SUNDARBAN

TIGER BEHAVIOUR





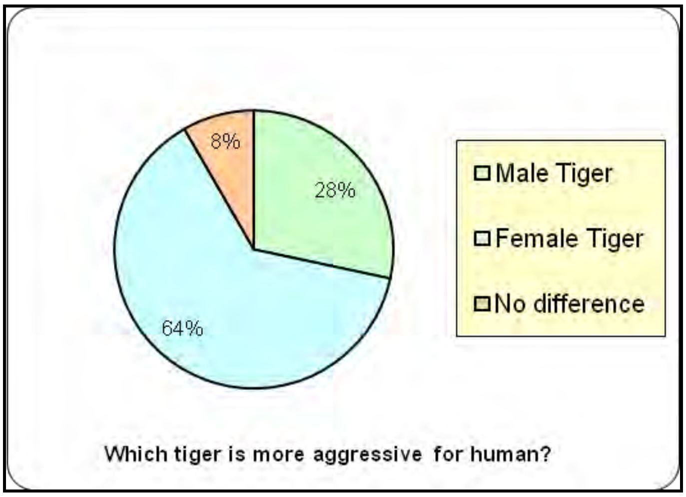
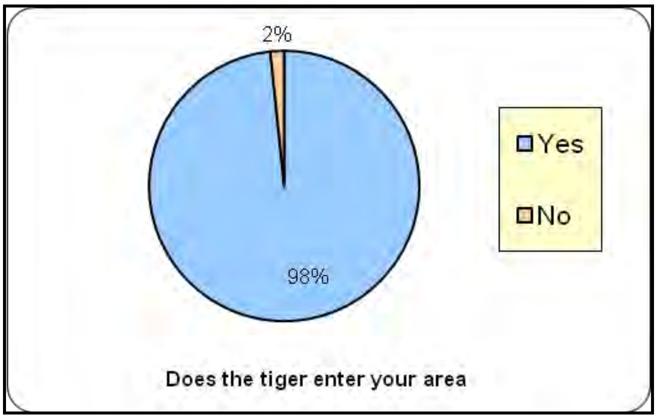
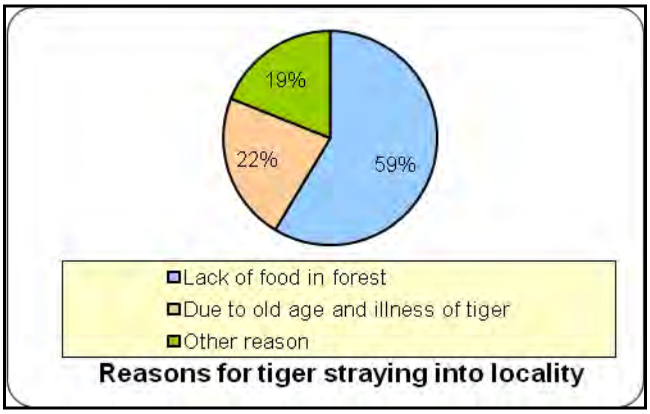


Fig.30 (a-s) (Continued……)

FOREST PROTECTION COMMITTEE /ECO-DEVELOPMENT COMMITTEE SURVEY OUTCOME 2010 -11ON INDIAN SUNDARBAN

HUMAN- TIGER CONFLICT





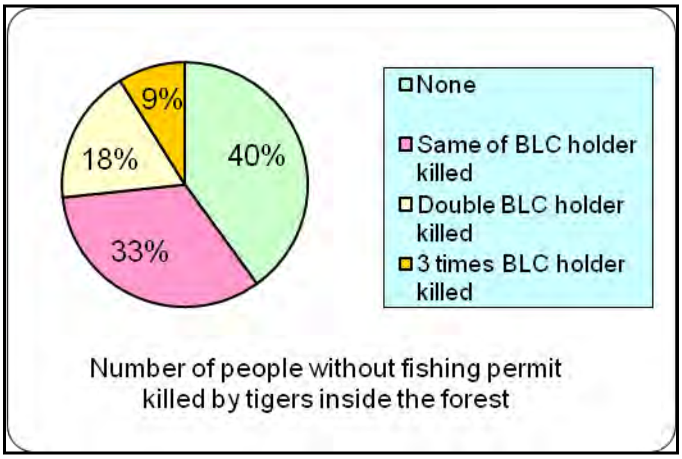
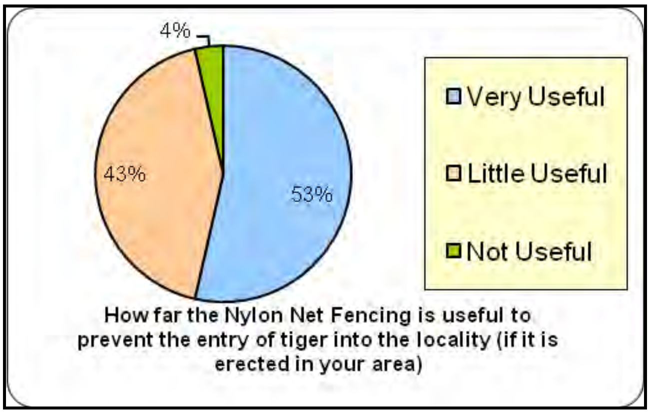
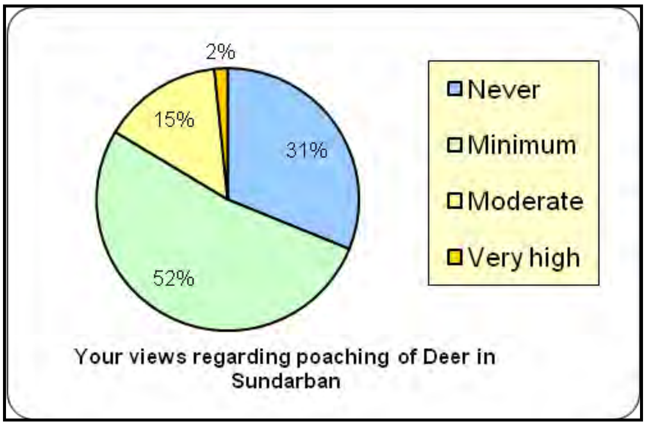


Fig.30 (a-s) (Continued……)

FOREST PROTECTION COMMITTEE /ECO-DEVELOPMENT COMMITTEE SURVEY OUTCOME 2010-11 ON INDIAN SUNDARBAN

HUMAN- TIGER CONFLICT





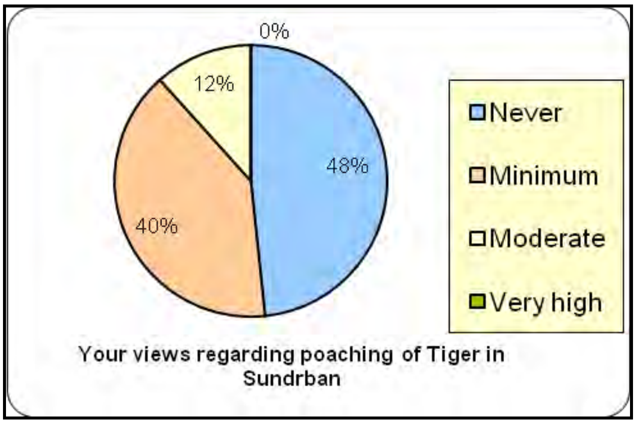
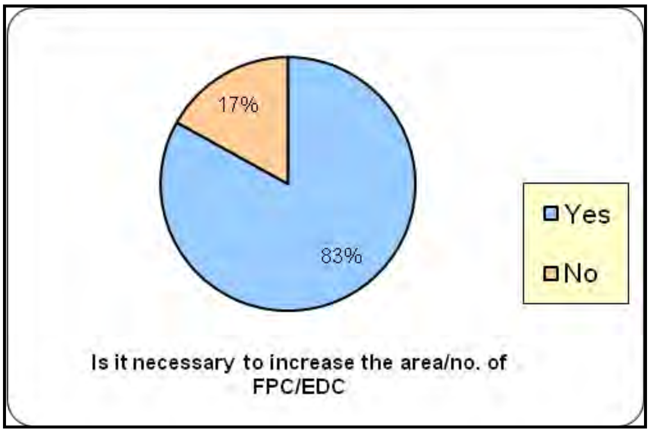
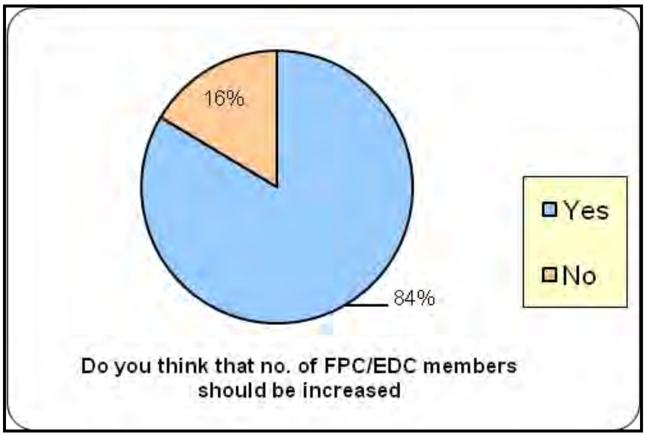


Fig. 30 (a-s) (Continued….)

FOREST PROTECTION COMMITTEE /ECO-DEVELOPMENT COMMITTEE SURVEY OUTCOME 2010-11 ON INDIAN SUNDARBAN

FOREST PROTECTION COMMITTEE / ECO-DEVELOPMENT COMMITTEE FUNCTIONING





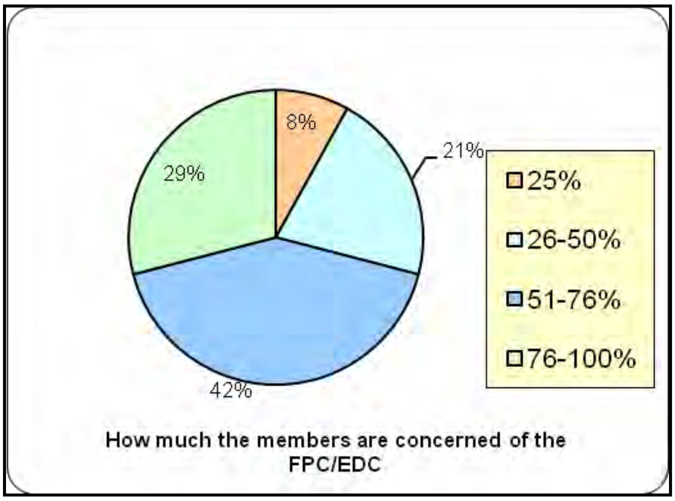
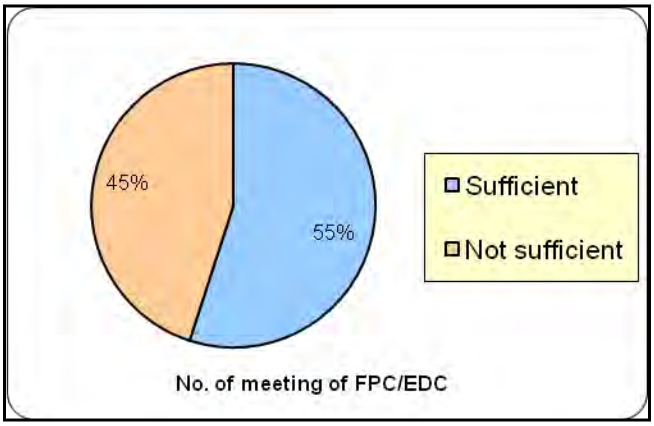
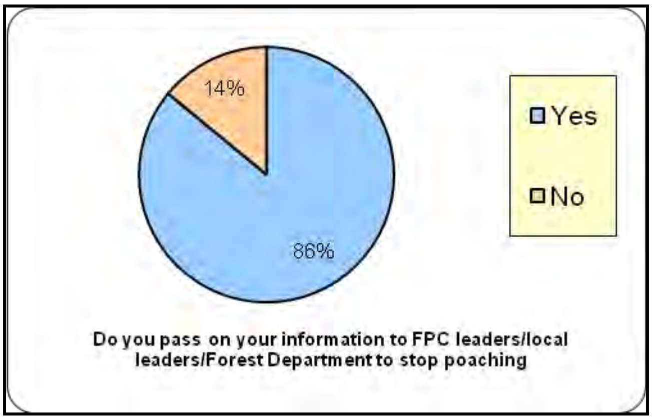


Fig. 30 (a-s) (Continued…….)

FOREST PROTECTION COMMITTEE /ECO-DEVELOPMENT COMMITTEE SURVEY OUTCOME 2010-11 ON INDIAN SUNDARBAN

FPREST PROTECTION COMMITTEE/ ECO-DEVELOPMENT COMMITTEE FUNCTIONING





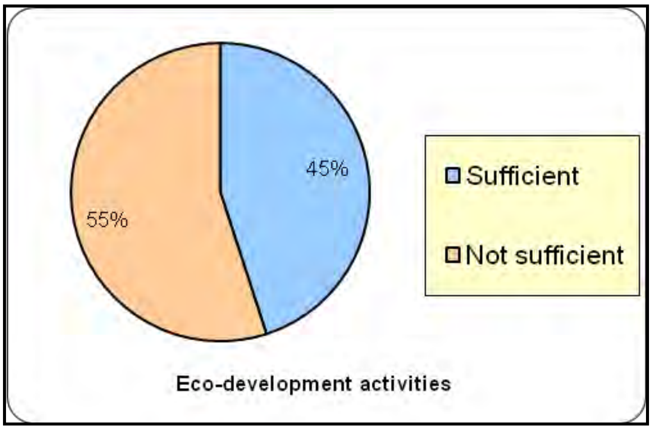
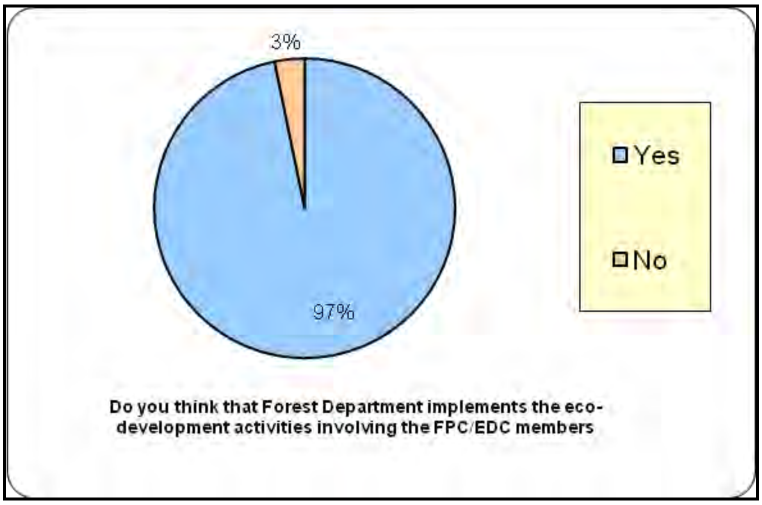


Fig. 30 (a-s) (Continued…….)

FOREST PROTECTION COMMITTEE /ECO-DEVELOPMENT COMMITTEE SURVEY OUTCOME 2010-11 ON INDIAN SUNDARBAN

FPREST PROTECTION COMMITTEE/ ECO-DEVELOPMENT COMMITTEE FUNCTIONING



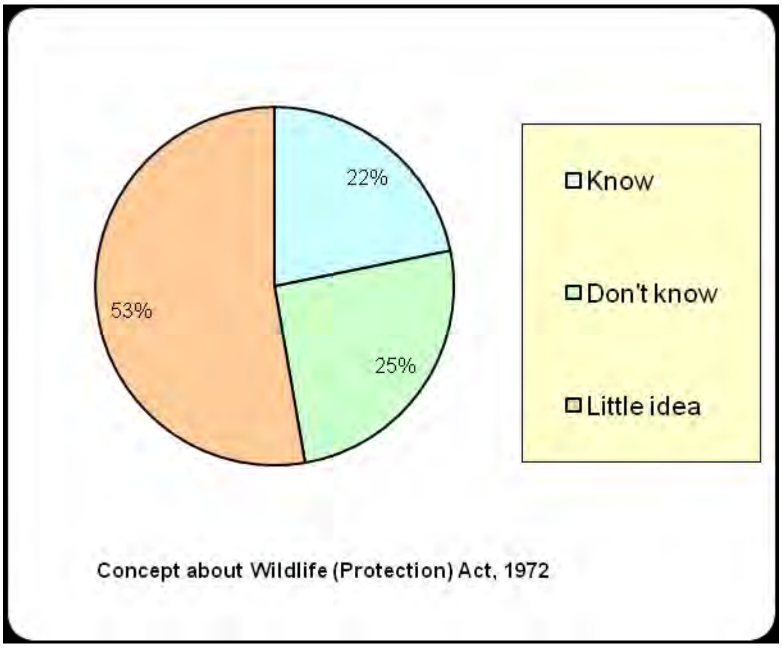


Fig. 31a
Human killings by tigers in Sundarban Tiger Reserve (1998-99 to 2009-10)

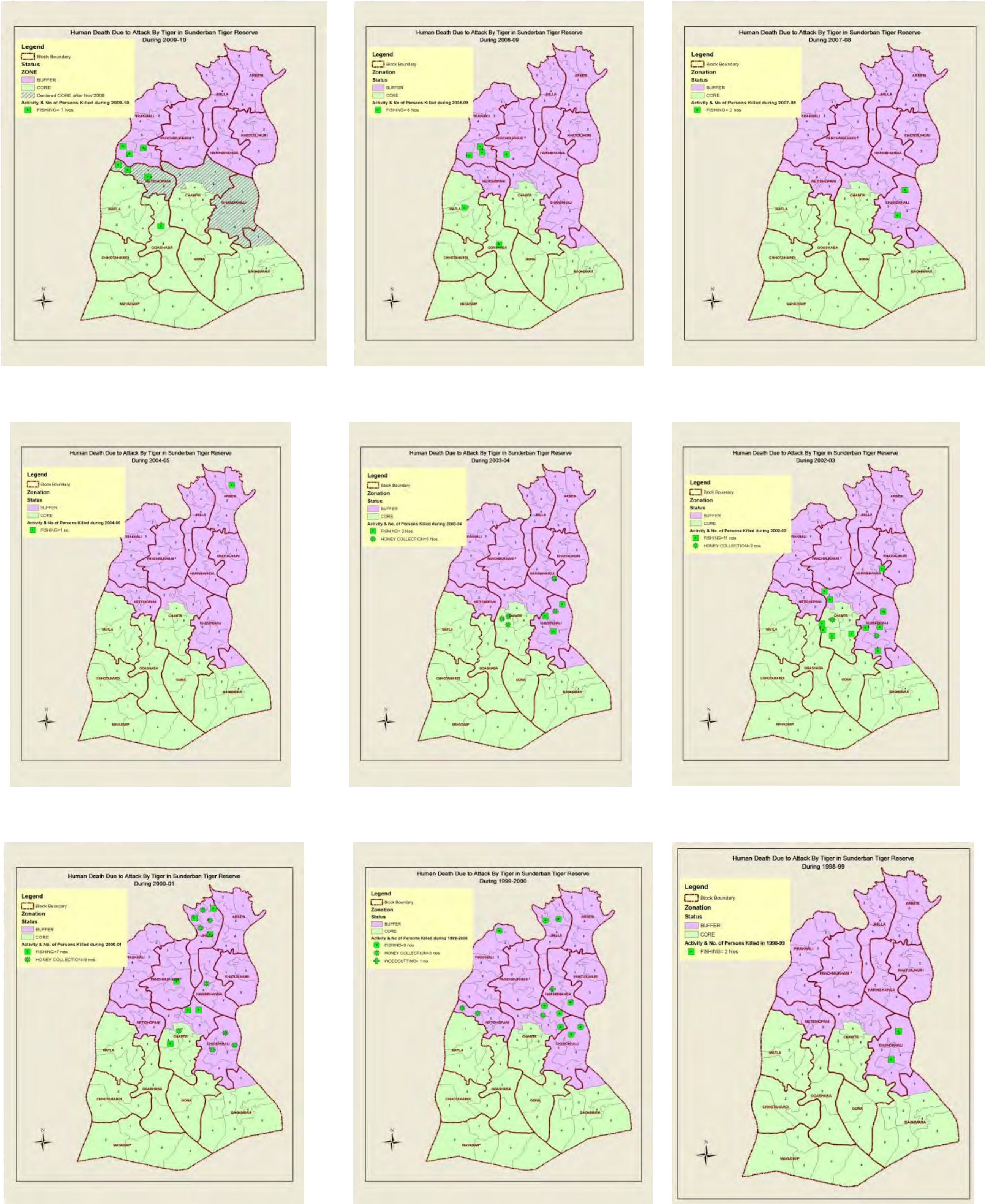


Fig. 31b
Human killing by tigers in Sundarban Tiger Reserve (1998-99 to 2009-10)

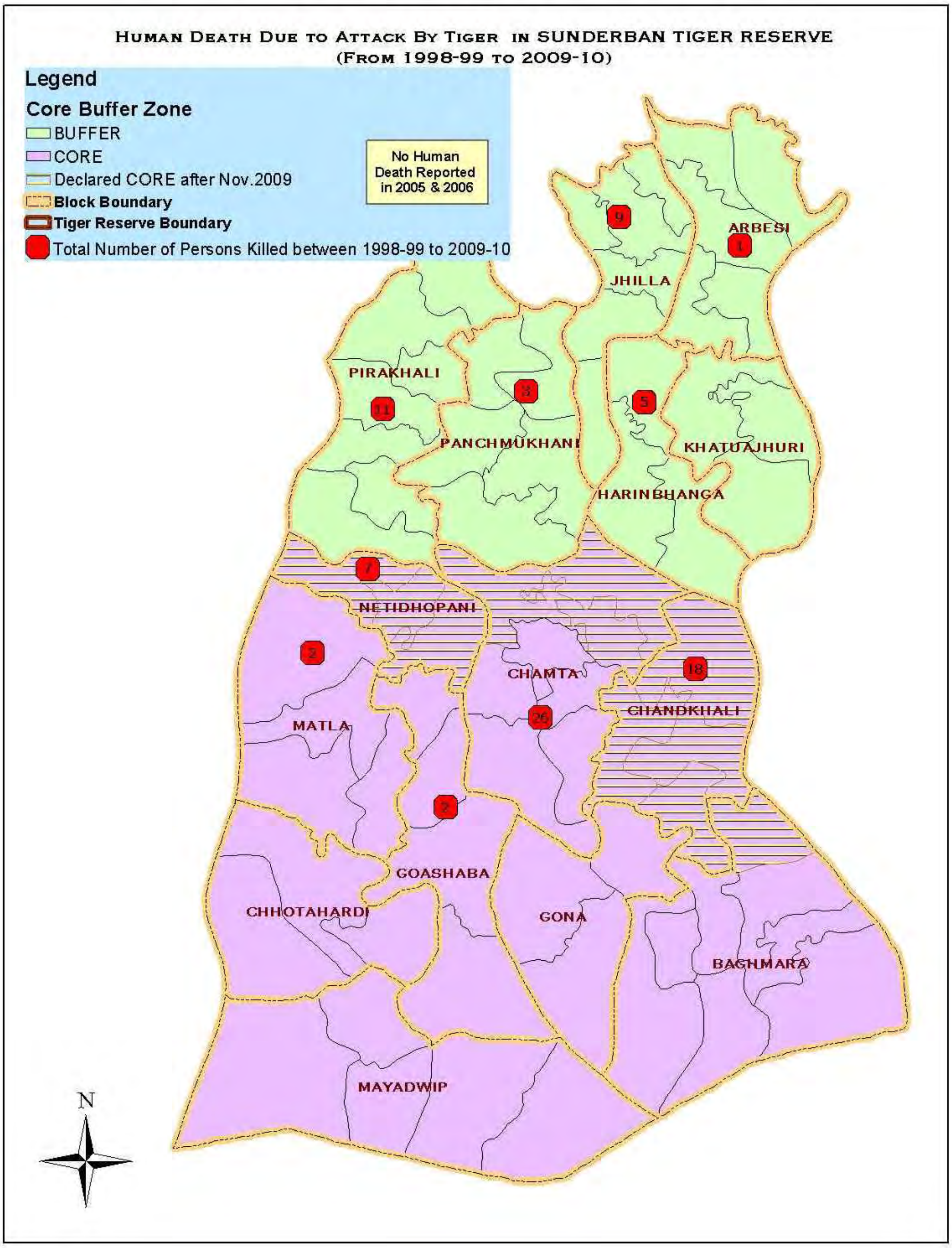
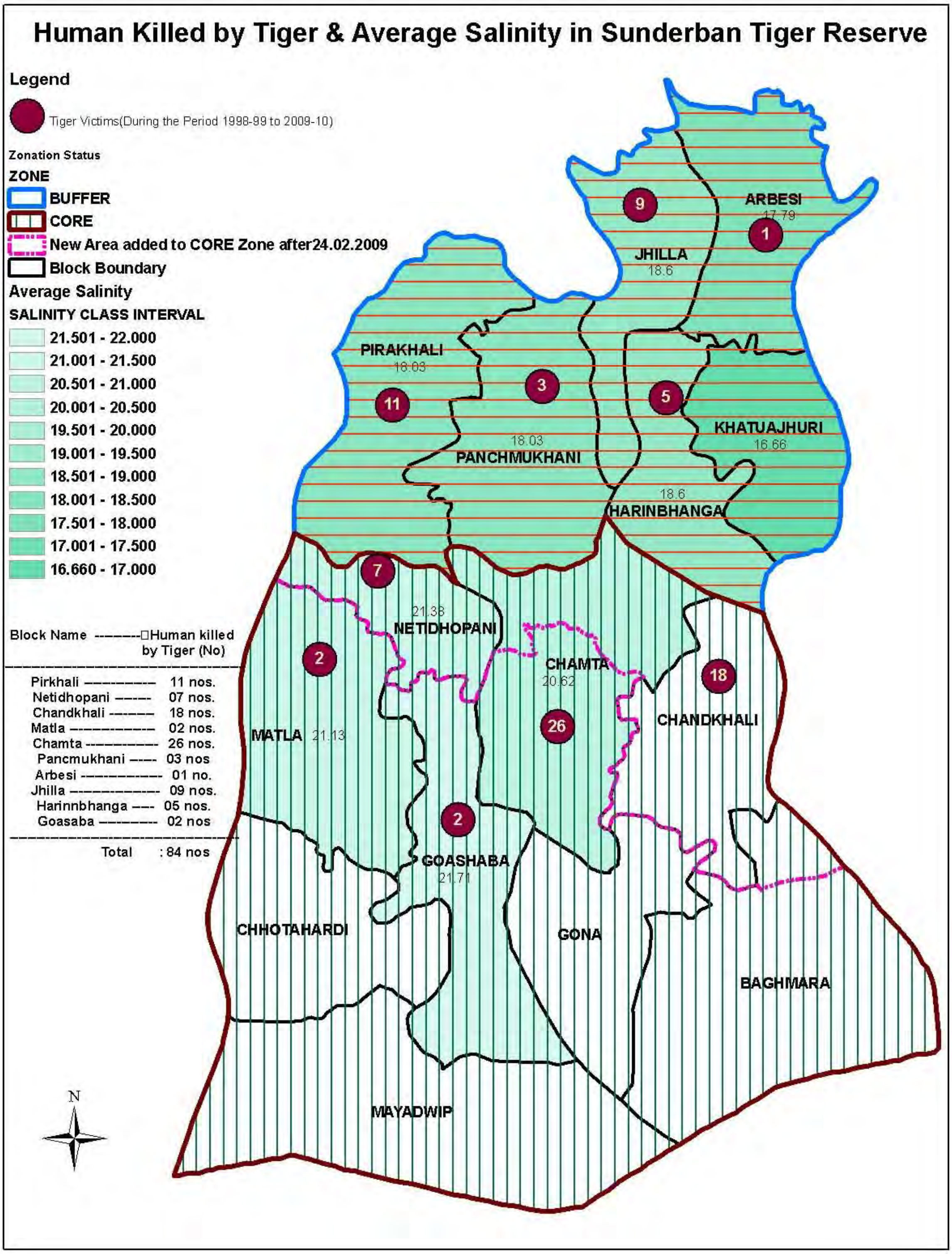


Fig. 32
Human killed (1998-99 to 2009-10) by tigers & average salinity in Sundarban Tiger Reserve



Annexures

ANNEXURE 1

OPINION FORM – SUNDARBAN THREATS

Sundarban mangrove ecosystem, at the apex of Bay of Bengal is one of the most biologically productive, taxonomically diverse and aesthetically celebrated systems of the tropics sustaining 34 species of mangroves. It is the reservoir of wide spectrum of flora and fauna, which includes several commercially important species. Sundarban has been reorganized as "World Heritage Site" and an "International Biosphere Reserve" by UNESCO. It is one of the pioneers Tiger Reserve of the India. It has pride of harbouring one "National Park" and three "Wildlife Sanctuaries". It is presently under threat due to various anthropogenic factors which requires your attention and listing in the space provided below as per their weightage:

1.

2.

3.

4.

Signature : ____________________

Designation : ____________________

ANNEXURE 2

Human killed/ injured by estuarine crocodile in Indian Sundarban (1999 TO 2009)

S. No	Date & time	Place	Name of the person	Address of the person	Forest range and Beat	Remarks
HUMAN KILLING						
1	11.07.1999 at about 2.30 pm	Lahiripur, PS. Gosaba	Sri Deben Baidya, 30 yrs	Lahiripur, PS. Gosaba South 24 – Parganas	Saznekhali Range, Duttar Beat	Sundarban Tiger Reserve, on village Charland while collecting prawn seeds.
2	27.08.2000 10 PM	Rakhalpur	Shyamali Majhi 35 years (Female)	W/o Atindranath Majhi Vill – Rakhalpur PS – Patharpratima South 24 – Parganas	Dhanchi Beat	
3	19.10.2002	Achintanaga r	Niranjan Barman (Male)	S/o Lt Surendranath Barman Vill Achintanagar PS – Patharpratima South 24 – Parganas	Dhanchi Beat	
4	14.05.2003	Chotto Banashyamn agar	Shri Sahadev Besi (Male)	S/o Achinta Besai, Banashyamnagar PS – Patharpratima South 24 – Parganas	Dhanchi Beat	
5	27.06.2003 12:00 AM	Walls creek river	Sandhya Bera (Female)	W/o Bankim Bera Vill + PO – Shibganj PS – Patharpratima South 24 – Parganas	Patharprati ma Beat	
6	03.07.2003	Kisharinagar	Smt Sushila Das 40 years (Female)	W/o Kanai Das Vill – Kisharinagar PS – Patharpratima South 24 – Parganas	Patharprati ma Beat	
7	31.05.2004	Walls creek river	Tarangini Roy 45 year (Female)	W/o S. Roy Vil. Lakhinarayanpur PS – Patharpratima South 24 – Parganas	Patharprati ma Beat	
8	14.06.2004, at about 11.00 A.M	Sonagaon, PS. Gosaba	Sri Sudhangshu Barman, 35	Sonagaon, PS. Gosaba South 24 – Parganas	Saznekhali Range and beat.	Sundarban Tiger Reserve While collecting prawn seeds.
9	14.03.2008 at about 3.30 p.m	Kalitala, PS. Hingalgunge	Md. Ansar Gazi, 40 yrs	Kalitala, PS. Hingalgunge North 24 – Parganas	Bashirhat Range, Katuajhuri beat.	Khatuajhuri-2 of STR, while working for FD.
10	14.06.2008 at about 8.35 a.m.	Anpur, PS. Gosaba	Sri Tapan Mondal, 32 yrs.	Anpur, PS. Gosaba South 24 – Parganas	Saznekhali Range, Duttar beat of STR.	While collecting prawn seeds.
11	22.07.2009 2:00 PM	Satyadaspur	Sandhya Das 35 years	W/o Atul Das Vill – Satyadaspur PS – Patharpratima South 24 – Parganas	Dhanchi Beat	
12	01.08.2009 6:00 PM	Mridanga Bhanga river	Gangamaye Jana 47 years (Female)	W/o Sarbeswar Jana Vill Chotto Banashyamnagar PS – Patharpratima South 24 – Parganas	Patharprati ma Beat	

ANNEXURE 2……Continued….

HUMAN INJURED BY ESTUARINE CROCODILE

S. No	Date and time of incident	Place of incident	Name of the person injured	Address of the injured person	Forest Beat
1	08.08.2000 -	Habila River Near Patharpratima Station office	Smt Sumati Nayek (Female) W/o Shri Bankim Nayek Vill – Dakshin Shibganj PS – Patharpratima	W/o Bankim Nayek Vill – Dakshin Shbganj PS – Patharpratima South 24 – Parganas	Patharpratima Beat
2	12.09.2000 -	Gobadia River	Smt Gitarani Gayen (Female)	W/o Shri Rampada Gayen Vill – Dargagobindapur PS – Patharpratima South 24 – Parganas	Patharpratima Beat
3	26.07.2002 2.30 pm	Walls creek river	Shri Abhimany Hajra (Male)	S/o Shri Bijoy Hazra Vill – Rakhaskhali PS – Patharpratima South 24 – Parganas	Patharpratima Beat
4	07.09.2002 -	Halisur River	Kumari Parbati Guchact (Female)	D/o Shri Billapada Guchact Vill – Banashyamnagar PS – Patharpratima South 24 – Parganas	Dhanchi Beat
5	07.10.2002 -	Habila River near Patharpratima Station Office	Kumari Kabita Barui (Female)	D/o Smt Laxmibala Barui Vill – Khetramohanpur PS – Patharpratima South 24 – Parganas	Patharpratima Beat
6	05.10.2004 -	Jagaddal River	Shri Anil Shandul, 35 years (Male)	S/o Shri Bhagwan Shandul Vill – Shibnagar PO – Banashyamnagar PS – Patharpratima	Dhanchi Beat
7	21.05.2003 3 am	Walls Creek river	Shri Binod Chandra Bera (Male)	S/o Lt Sukesh Bera Vill + PO – Shibganj PS – Patharpratima South 24 – Parganas	Patharpratima Beat
8	22.05.2003 2 pm	Habila river near Patharpratima Station Office	Smt Sumati Mondal (Female)	W/o Jagadish Mondal Vill – Khattra Mohanpur PO – Brajaballabpur PS – Patharpratima South 24 – Parganas	Patharpratima Beat
9	29.05.2003 10:30 pm	-	Smt Binarani Mondal (Female)	W/o Shri Srimanta Mondal	-
10	06.12.2003 4:00 pm	Achintanagar 2 no tank	Smt Momoni Ari 17 years (Female)	D/o Mitunjay Ari Vill + PO – Achintanagar PS- Patharpratima South 24 – Parganas	Dhanchi Beat
11	05.06.2004 8:00 am	Karjan Creek river	Alpana Maity 18 years (Female)	W/o Ghareswar MAity Vill + PO – Abad Uttar Gobindapur PS – Patharpratima South 24 – Parganas	Patharpratima Beat
12	29.10.2008 7:00 am	Thakuran River	Bishnu Priya Samanta (Female)	W/o Kanai Samanta Vill – Sridharnagar PS – Patharpratima South 24 – Parganas	Dhanchi Beat
13	30.10.2009 2 pm	Jagadal River	Smt Pusparani Giri 45 years (Female)	W/o Srimanta Giri	Dhanchi Beat

ANNEXURE 3
Estuarine crocodiles rescued from villages in Indian Sundarban

S. No	Date & Time	From where rescued	Forest Beat
1.	09.09.2005	Parbati Khal Vill – Shibgang PO +PS – Patharpratima South 24 – Parganas	Patharpratima Beat
2.	19.09.2005	Banashyam Nagar PS – Patharpratima South 24 – Parganas	Dhanchi Beat
3.	21.09.2005	Gobardhanpur PS – Patharpratima South 24 – Parganas	Dhanchi Beat
4.	05.10.2005	Achintanagar PS – Patharpratima South 24 – Parganas	Dhanchi Beat
5.	16.10.2008 At 3:40 PM	From the pond of Shri Subol Samanta S/o Gunadhar Samanta Vill – Chotto Rakhaskhali	Patharpratima Beat
6.	30.03.2009 at 4:45 PM	From the pond of Shri Gaur Prodhan at Sridhanrnagar	Dhanchi Beat
7.	27.07.2010 at 7:00 AM	Prasanta Dinda S/o Lt Khudiram Dinda Banashyamnagar PS – Patharpratima	Dhanchi Beat
8.	08.08.2010 at 9:00 AM	Bimal Manik S/o Lt Balaram Manik,R. D. Bazar, RakhalpurPS – Patharpratima	Dhanchi Beat
9.	14.09.2010	Satyadaspur	Patharpratima beat
10	24.09.2010	Sitarampur	Patharpratima beat
11	29.10.2010	Satyadaspur	Patharpratima beat
12	25.10.2010	South Shibgunj	Patharpratima beat
13	08.12.2010	Krishnadaspur	Patharpratima beat

ANNEXURE 4

List of Sharks and rays in Indian Sundarban

S. N.	Species	Distribution	Diet	Length
1.	Carcharhinus limbatus (Blacktip shark) [IUCN status: Lower risk]	Cosmopolitan in distribution near the inshore regions of tropical waters. It is capable of tolerating reduced salinity, but never penetrates into fresh water.	Fish such as sardine, mackerel, croaker, sole along with cephalopods and crustaceans.	Matured ones are 2.5 m in length. Male matures at 140-150 cm. and female matures at 150-160 cm.
2.	Carcharhinus sorrah (Spottail shark)	Commonly found in coral reefs region.	Bony fish such as mackerels, sardines etc. and shellfish like squids and prawns.	Short in length, about 1.5 m. Male matures at 115 cm. and female matures at 120 cm.
3.	Carcharhinus dussumieri White-cheeked shark) [IUCN status: Lower risk]	Common species in inshore waters.	Small fishes, squids and crustaceans.	Matured ones are 1 m. Male matures at 65 cm. and female matures at 75 cm.
4.	Carcharhinus melanopterus (Blacktip reef shark) [IUCN status: Lower risk]	Indo-Pacific tropical shark, migrates into estuaries and brackish waters for delivering its pups.	Fish like mullets, silver bellies, anchovies, hilsa, skate, prawns and squilla.	Matured ones are about 2.5 m.
5.	Carcharhinus macloti (Hardnose shark)	Widely distributed in the inshore region.	Small fishes, squids and crustaceans.	Matured ones are 1 m in length. Male matures at 60 cm and female matures at 70 cm.
6.	Galeocerdo cuvier (Tiger shark) [IUCN status: Lower risk]	Widely distributed tropical shark. It is capable of cruising in mid ocean and shows nocturnal movement into bays and estuaries.	Eels, cat fish, parrot fish, flat fish, flying fish, skates, rays, marine turtle, sea snake, sea birds, sea lion, dolphin etc.	Matured ones are about 7.4 m in length.
7.	Scoliodon laticaudus (Indian dog shark) [IUCN status: Lower risk]	West and south coasts of India, dominant in East coast and in Indian Sundarban.	Small fishes, crustaceans and squids.	Majority of males is 50-55 cm and females are about 65 cm. Males and females mature at 30 cm and 35 cm respectively.

8.	Rhizoprionodon acutus (Brazilian sharpnose shark)	Abundant in the shore waters, particularly in the west coast of India during September to February and east coast during summer months.	Small fishes, squids, cuttle fish, crabs and shrimps.	Matured ones are about 1 m in length.
9.	Sphyrna lewini (Hammerhead shark) [IUCN status: Vulnerable]	Abundantly found in the Indian seas, notable for its unique migratory behaviour.	Sardine, anchovies, mackerel, eel, milkfish, sole fish. It also feeds on sharks and rays.	Matured ones are up to 4.2 m in length.
10.	Rhincodon typus (Whale shark) [IUCN status: Vulnerable]	Appears occasionally at Indian coastal waters.	Filter-feeder and is believed to sieve plankton as small as 1mm diameter through the fine mesh of their gill rakers.	Largest length upto 1200 cm but mean length is around 700 cm.
11.	Atelomycterus marmoratus) (Coral cat shark)	Appears occasionally at Indian coastal waters.	Squids, crabs etc.	
12.	Glyphis gangeticus (River shark) [IUCN status: Extremely endangered; Wildlife Protection Act: Schedule I]	Hooghly-Ganges river system of West Bengal coast.	Fish	Maximum length is around 200 cm. Matured males are about 178 cm.
13.	Glyphis glyphis (Sharptooth shark or Speartooth shark)	Confined to turbid waters of rivers, estuaries and inshore waters of coastal West Bengal.	Fish	Minimum length is around 100 cm.
14.	Glyphis siamensis (Irrawady river shark)	Confined to turbid waters of rivers, estuaries and inshore waters of coastal West Bengal	Fish	Minimum length is around 63 cm.
15.	Carcharhinus limbatus (Blacktip shark) [IUCN status:	Cosmopolitan in distribution near the inshore regions of tropical waters. It is capable of tolerating reduced salinity,	Fish such as sardine, mackerel, croaker, sole along with cephalopods and crustaceans.	Matured ones are 2.5 m in length. Male matures at 140-150 cm. and female matures at

	Lower risk]	but never penetrates into fresh water.		150-160 cm.
16.	Carcharhinus sorrah (Spottail shark)	Commonly found in coral reefs region.	Bony fish such as mackerels, sardines etc. and shellfish like squids and prawns.	Short in length, about 1.5 m. Male matures at 115 cm. and female matures at 120 cm.
17.	Carcharhinus dussumieri (White-cheeked shark) [IUCN status: Lower risk]	Common species in inshore waters.	Small fishes, squids and crustaceans.	Matured ones are 1 m. Male matures at 65 cm. and female matures at 75 cm.
18.	Carcharhinus melanopterus (Blacktip reef shark) [IUCN status: Lower risk]	Indo-Pacific tropical shark, migrates into estuaries and brackish waters for delivering its pups.	Fish like mullets, silver bellies, anchovies, hilsa, skate, prawns and squilla.	Matured ones are about 2.5 m.
19.	Carcharhinus macloti (Hardnose shark)	Widely distributed in the inshore region.	Small fishes, squids and crustaceans.	Matured ones are 1 m in length. Male matures at 60 cm and female matures at 70 cm.
20.	Galeocerdo cuvier (Tiger shark) [IUCN status: Lower risk]	Widely distributed tropical shark. It is capable of cruising in mid ocean and shows nocturnal movement into bays and estuaries.	Eels, cat fish, parrot fish, flat fish, flying fish, skates, rays, marine turtle, sea snake, sea birds, sea lion, dolphin etc.	Matured ones are about 7.4 m in length.
21.	Scoliodon laticaudus (Indian dog shark) [IUCN status: Lower risk]	West and south coasts of India, dominant in East coast and in Indian Sundarban.	Small fishes, crustaceans and squids.	Majority of males is 50-55 cm and females are about 65 cm. Males and females mature at 30 cm and 35 cm respectively.
22.	Rhizoprionodon acutus (Brazilian sharpnose shark)	Abundant in the shore waters, particularly in the west coast of India during September to February and east coast during summer months.	Small fishes, squids, cuttle fish, crabs and shrimps.	Matured ones are about 1 m in length.
23.	Sphyrna lewini (Hammerhead shark)	Abundantly found in the Indian seas, notable for its unique migratory behaviour.	Sardine, anchovies, mackerel, eel, milkfish, sole fish. It also feeds on sharks and rays.	Matured ones are up to 4.2 m in length.

	[IUCN status: Vulnerable]			
24.	Rhincodon typus (Whale shark) [IUCN status: Vulnerable]	Appears occasionally at Indian coastal waters.	Filter-feeder and is believed to sieve plankton as small as 1mm diameter through the fine mesh of their gill rakers.	Largest length upto 1200 cm but mean length is around 700 cm.
25.	Atelomycteru s marmoratus) (Coral cat shark)	Appears occasionally at Indian coastal waters.	Squids, crabs etc.	
26.	Glyphis gangeticus (River shark) [IUCN status: Extremely endangered; Wildlife Protection Act: Schedule I]	Hooghly-Ganges river system of West Bengal coast.	Fish	Maximum length is around 200 cm. Matured males are about 178 cm.
27.	Glyphis glyphis (Sharptooth shark or Speartooth shark)	Confined to turbid waters of rivers, estuaries and inshore waters of coastal West Bengal.	Fish	Minimum length is around 100 cm.
28.	Glyphis siamensis (Irrawady river shark)	Confined to turbid waters of rivers, estuaries and inshore waters of coastal West Bengal	Fish	Minimum length is around 63 cm.

ANNEXURE 5

List of human killed by tiger in Sundarban Tiger Reserve

(1998-99 TO 2009-10)

Y E A R 1998-1999					
Sl. No .	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
1	Insan Ali Sardar Vill.-Moukhali P.S.-Canning Dist.-24 Pgs. (S)	Chandkhali-3	24.07.1998	Not Recovered	Fisherman
2	Md. Mojaffar Sk. Vill.-Kultali P.S.-Kultali Dist.-24 Pgs. (S)	Chandkhali-1	07.08.1998	Not Recovered	Fisherman
ABSTRACT 1998-1999 Fisherman: 2 No.					
Y E A R 1999-2000					
1	Basudeb Roy Vill.-Jharkhali P.S.-Basanti Dist.-24 Pgs. (S)	Chamta	11.04.1999	Not recovered	Honey Collector
2	Gopal Mridha Vill.-Jharkhali P.S.-Basanti Dist.- 24 Pgs (S)	Bhagabanbharani	11.04.1999	Recovered	Honey Collector
3	Bhabasindhu Maity Vill.-Jharkhali P.S.-Basanti Dist.-24 Pgs. (S)	Netidhopani Block	27.05.1999	Not recovered	Honey Collector
4	Deben Baidya Vill. + P.S.-Gosaba Dist.-24 Pgs. (S)	Charland	11.07.1999	Not recovered	Fisherman
5	Baburam Mondal Vill.-Satjelia P.S.-Gosaba Dist.-24 Pgs. (S)	Jhilla block	09.10.1999	Body recovered	Fisherman
6	Bishnu Nath Mondal Vill.-Satjelia P.S.-Gosaba Dist.-24 Pgs. (S)	Tushkhali	13.10.99	Nor recovered	Fisherman

Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
7	Subhas Biswas Vill.-Hentalbari P.S.-Gosaba Dist.-24 Pgs. (S)	Harinbhanga-3	09.01.2000	Not recovered	Fisherman
8	Pulin Mondal Vill.-Jharkhali P.S.-Basanti Dist.-24 Pgs. (S)	Chandkhali-1	06.01.2000	Not recovered	Fisherman
9	Kanai Mondal Vill.-Chotomollakhali P.S.-Gosaba Dist.-24 Pgs. (S)	Harinbhanga-2	12.02.99	Body recovered	Woodcutter
10	Pahar Molla Vill.-Moukhali P.S.-Canning Dist.-24 Pgs. (S)	Chandkhali-1	17.02.2000	Not recovered	Fisherman
11	Bidhan Mondal Vill.-Dulki P.S.-Gosaba Dist.-24 Pgs. (S)	Chamta-1	28.02.2000	Not recovered	Fisherman
12	Kuran Mondal Vill.-Barunhat P.S.-Hasnabad Dist.-24 Pgs (N)	Chamta-1	30.03.2000	Body recovered	Fisherman
13	Susanta Mondal Vill.-Barunhat P.S.-Hasnabad Dist.-24 Pgs (N)	Chamta-1	30.03.2000	Not recovered	Fisherman

ABSTRACT:

Fisherman: 9 Nos.
Honey Collector: 3 Nos.
Woodcutter: 1 No.

Y E A R 2000-2001					
Sl. No .	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
1	Khalaram Mondal Vill.-Parghumti P.S.-Hasnabad Dist.-24 Pgs (N)	Chamta-1	04.04.2000	Not recovered	Fisherman
2	Jamad Sardar Vill.-Barunhat P.S.-Hasnabad Dist.-24 Pgs (N)	Chandkhali-1	13.04.2000	Body recovered	Honey Collector
3	Kankan Biswas Vill.-Jharkhali P.S.-Basanti Dist.-24 Pgs. (S)	Chandkhali-1	14.04.2000	Body recovered	Honey Collector
4	Bibhash Mondal Vill.-Satjelia P.S.-Gosaba Dist.-24 Pgs. (S)	Chamta Block	15.04.2000	Body recovered	Honey Collector
5	Dukhi Majumder Vill.-Hemnagar P.S.-Hingalgunge Dist.-24 Pgs (N)	Jhilla Block	22.04.2000	Body recovered	Honey Collector
6	Majid Gazi Vill.-Samsernagar P.S.-Hingalgunge Dist.-24 Pgs (N)	Chandkhali	26.04.2000	Body recovered	Honey Collector
7	Chhattar Laskar Vill.-Patlikhanpur P.S.-Hasnabad Dist.-24 Pgs (N)	Harinbhanga-2	29.04.2000	Body recovered	Honey Collector
8	Niranjan Baidya	Jhilla Block	29.04.2000	Not recovered	Honey Collector
	Vill.-Chhotomollakhali				
	P.S.-Gosaba				
	Dist.-24 Pgs. (S)				
9	Abdar Gazi Vill.+P.S.-Sandeshkhali Dist.-24 Pgs (N)	Jhilla-2	30.04.2000	Not recovered	Honey Collector
10	Ashutosh Halder Vill.-Patherdabi P.S.-Hingalgunj Dist.-24 Pgs (N)	Chamta Block	19.06.2000	Not recovered	Fisherman

Sl. No .	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
11	Supada Barman Vill.-Satjelia, P.S.-Gosaba Dist.-24 Pgs. (S)	Jhilla Block	09.07.2000	Not recovered	Fisherman
12	Sukumar Mondal Vill.-Hemnagar P.S.-Hingalgunge 24-Pgs. (N)	Chamta-1	21.08.2000	Recovered , Injured during fishsing; died on the way to hospital	Fisherman
13	Shanta Goal Vill.-Bijoynagar P.S.-Gosaba Dist.-24 Pgs. (S)	Panchamukhani-4	20.02.2001	Not recovered	Fisherman
14	Subhas Sarkar Vill.-Parasmoni P.S.-Gosaba Dist.-24 Pgs. (S)	Jhilla Block	25.03.2001	Body recovered	Fisherman
15	Ganesh Mondal Vill.-Mollakhali P.S.-Gosaba Dist.-24 Pgs. (S)	Jhilla Block	29.03.2001	Body recovered	Fisherman
ABSTRACT: Fisherman: 7 Nos. Honey Collector:8 Nos.					
Y E A R 2001-2002					
1	Sashibhusan Halder Vill.-Hingalgunj P.S.-Hingalgunj 24-Parganas (N)	Jhilla-2	02.04.2001	Not recovered	Fisherman
2	Sunil Biswas Vill.-Jharkhali P.S.-Basanti Dist.-24 Pgs. (S)	Died in Hospital	10.04.2001	Body recovered	Fisherman
3	Swapan Mistri Vill.-Jharkhali P.S.-Basanti Dist.-24 Pgs. (S)	Chamta Block	20.04.2001	Body recovered	Honey Collector

Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
4	Nirmal Samaddar Vill.-Jharkhali P.S.-Basanti Dist.-24 Pgs. (S)	Chamta Block	21.04.2001	Body recovered	Honey Collector
5	Amirul Molla Vill.-Fulbari P.S.-Canning Dist.-24 Pgs. (S)	Chamta Block	23.08.2001	Not recovered	Fisherman
6	Hafizul Gayen Vill.-Satyadaspur P.S.-Patharpratima Dist.-24 Pgs. (S)	Chandkhali	25.09.2001	Body recovered	Fisherman
7	Rabi Sardar Vill.-Satjelia P.S.-Gosaba Dist.-24 Pgs. (S)	Chamta Block	30.09.2001	Not recovered	Fisherman
8	Babulal Gayen Vill.-Pargumti P.S.-Hingalgunj 24-Parganas (N)	Chamta	03.12.2001	Not recovered	Fisherman
9	Abinash Roy Vill.-Doyapur P.S.-Gosaba 24-Parganas (S)	Chamta-2	31.01.2002	Not recovered	Fisherman
10	Biswanath Mondal Vill.-Binod Colony P.S.-Hasnabad 24-Parganas (N)	Chamta-2	03.02.2002	Not recovered	Fisherman
11	Ripon Byapari Vill.-Jharkhali P.S.-Basanti 24-Parganas (S)	Matla-3	19.02.2002	Not recovered	Fisherman
12	Md. Hassan Gazi Vill.-Dhuri P.S.-Basanti 24-Parganas (S)	Chandkhali-2	05.03.2002	Body recovered	Fisherman

ABSTRACT:

Fisherman: 10 Nos.
Honey Collector:2 Nos.

Y E A R 2002-2003					
Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
1	Annes Ali Sardar, Age-55 S/o.-Late Yaar Ali Vill.+P.O.-Satyanarayanpur P.S.-Gosaba, 24-Pgs. (S).	Netidopani	13.04.2002	Body recovered	Honey Collector
2	Abul Hossain Sk., Age-25 S/o.-Md. Ylias Sheikh Vill.-Deulbari, Nikaripara P.S.-Kultali, 24-Pgs. (S).	Chamta Block-5	14.04.2002	Body recovered	Honey collector
3	Sudeb Mondal, Age-50 S/o.-Late Gagan Vill.-Kaikhali, P.S.-Kultali P.O.-Ashram, 24-Pgs. (S).	Chandkhali Block-3	18.04.2002	Not recovered	Honey Collector
4	Netai Pada Mondal, Age-24 S/o.-Kalipada Vill.-Lahiripur Bidhan Clny. P.O.-Lahiripur P.S.-Gosaba, 24-Pgs. (S).	Chandkhali Block-3	27.07.2002	Not recovered	Fisherman
5	Achintya Biswas, Age-37 S/o.-Late Manik Vill.+P.O.-Pakhiralaya P.S.-Gosaba, 24-Pgs. (S).	Chamta Block-3	10.08.2002	Not recovered	Fisherman
6	Panch Kari Haldar, Age-55 S/o.-Kunjabehari Vill.+ P.O.+ P.S.-Hingalgunge	Bara Chamta Block-3	23.08.2002	Not recovered	Fisherman

Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
7	Gobinda Sarkar, Age-55 S/o.-Basanta Vill.+P.O.+Jharkhali P.S.-Basanti, 24-Parganas (S).	Chamta Block-3	13.11.2002	Injured and had been admitted to hospital but died on 15.11.2002	Fisherman
8	Dipu Kotal, Age-32 S/o.-Palan Vill.-Arampur, Gosaba PO+PS-Gosaba, 24-Pgs.(S)	Chandkhali Block-4	21.11.2002	Not recovered	Fisherman
9	Prabhash Mondal, Age-25 S/o.-Rajkumar Vill.+P.O.-Amjhara P.S.-Basanti, 24-Parganas (S)	Chandkhali Block-1	24.11.2002	Not recovered	Fisherman
10	Akhtar Molla, Age-23 S/o.-Late Machhlep Vill.+P.O.-Jeliakhali P.S.-Sandeshkhali	Chamta Block-7	01.12.2002	Injured but, died in Gosaba hospital.	Fisherman
11	Madhu Mondal, Age-40 S/o.-Manmatha Vill.-Moukhali, P.S.-Canning 24-Parganas (S)	Chamta Block	08.12.2002	Not recovered	Fisherman
12	Bhim Das, Age-35 S/o.-Behari Vill.-Bijoynagar P.S.-Gosaba, 24-Pgs. (S)	Chamta-8	05.01.2003	Not recovered	Fisherman
13	Subal Biswas, Age-55, S/o.-Late Gurupada Vill.-Chhaygharia P.S.-Bangaon, 24-Pgs. (N)	Chandkhali-2	18.02.2003	Not recovered	Fisherman

Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
14	Prabhash Mondal, Age-47 S/o.-Manmatha Vill.-Shantigachhi, SatjeliaP.S.-Gosaba, 24-Pgs. (S)	Harinbhanga-3	20.03.2003	Not recovered	Fisherman
ABSTRACT Fisherman: 11 Nos. Honey Collector: 3 Nos.					
Y E A R 2003-2004					
1.	Akhtar Ali Molla, Age-38 yrs. S/o.-Mouz Molla Vill.-Moukhali, PS-Canning 24-Pgs.(S)	Chandkhali-3	04.04.2003 at 9.00 am	DeadBody recovered	Fisherman
2.	Fakir Biswas, Age-50 yrs., S/o.-Late Ramlal Vill.-Sashya Danga, PS-Balagarh Dist.-Hooghly	Chandkhali-1	15.04.2003 at 7.00 am	Body not recovered	Honey Collector
3.	Himangshu Mondal, Age-27 yrs. S/o.-Sudhir Vill.-Jharkhali, PS-Basanti 24-Pgs.(S)	Harinbhanga-3	16.04.2003 at 7.00 am	Recovered	Honey Collector
4.	Manoranjan Mondal, Age-56 yrs.	Chamta-5 Bholakhali Khal	21.04.2003 12.00 noon	Died	Honey Collector
5.	Sukhdeb Mondal, Age-48 yrs. Vill.-Balli No. 7, PS-Gosaba 24-Pgs.(S)	Chamta-5 Bholakhali Kha	21.04.2003 At 12.00 noon	Died	Honey Collector
6.	Dharmenjoy Mondal, Age-44 yrs. Vill.-Balli No. 7, PS-Gosaba 24-Pgs.(S)	Chamta-5, Bholakhali Khal	21.04.2003 At 12.00 noon	Died	Honey Collector

Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
7.	Shobharam Singh, Age-30 yrs. S/o.-Late Shyam Vill.-Kumirmari PS-Gosaba.	Chandkhali-1	25.03.2004 at 4.00 pm	Body not recovered	Fisherman
8.	Raghunath Singh, Age-40 yrs. S/o.-Mahadeb Vill.-Kumirmari PS-Gosaba.	Chandkhali-1	25.03.2004 at 4.00 pm	Body not recovered	Fisherman
ABSTRACT Fisherman- 3 Nos. Honey Collector -5 Nos.					
Y E A R 2004-2005					
01.	Taher Ali Gazi, Age-49, S/o.-Shariff Vill.-Samsernagar, PO-Kalitala PS-Hingalgunge, 24-Pgs. (N)	Arbesi-1	30.10.2004	Recovered	Fisherman
02.	Rupali Baulia, Age-11 D/o.-Bimal Baulia Vill.-Samsernagar, 24-Pgs. (S)	Samsernagar, Vill. No 4, OUTSIDE THE FOREST	11.04.2004	Recovered	Villager
ABSTRACT Fisherman- 1 Other- 1 (Outside the forest) Total – 2 No.					
Y E A R 2005-2006					
NIL					
Y E A R 2006-2007					
NIL					

YEAR 2007-08					
Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
1	Sukumar Bhunia, 40 yrs Vill. Amlamethi PO. Amlamethi PS. Gosaba	Pirkhali-7 under SWLS Range	02.07.2007 At 3.00 pm	Body could not recovered	Fisherman Compensation not paid as the incident took place within Core Area
2	Niranjan Majhi, 40 yrs S/O. Nilambar Majhi Vill. & PO. Satyanarayanpur PS. Gosaba	Pirkhali-7 under SWLS Range	15.07.2007 At 7.30 am	Body recovered	-do-
3	Nimai Roy, 55 yrs S/O. Manohar Vill.& PO. Jharkhali PS. Basanti, 24-PGS(S	Netidhopani-1 under N.P.(W) Range	01.08.2007 At 4.30 pm	Body could not recovered	Fisherman -do-
4	Shankar Golder, 53 yrs S/O. Late Surendra Nath Holder Vill.& PO. Jharkhali PS. Basanti, 24-PGS(S)	Netidhopani-1 under N.P.(W) Range	11.09.2007 At 4.00 pm	Body could not recovered	Fisherman Compensation Paid
5	Nikunja Sadhak, 46 yrs Vill.& PO. Jharkhali PS. Basanti, 24-PGS(S)	Pirkhali-6 under SWLS Range	03.10.2007 At 1.00 pm	Body could not recovered	Fisherman Compensation Paid

Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
6	Kumaresh Mondal, 45 yrs S/O.Late Shukchand Mondal Vill. Jharkhali PO. & PS. Basanti 24-PGS(S)	Pirkhali-7 under SWLS Range	27.11.2007 At 7.30 am	Body could not recovered	Fisherman Compensation not paid as the incident took place within Core Area
7	Md. Ansar Gaazi, 40 yrs S/O. Late Bux Gaazi Vill. Kalitala, PS. Hingalgung 24-PGS(N).	Khatuajhuri-2 [by Crocodile]	20.03.2008 At 4.10 pm	Body recovered	Labour Killed by Crocodile
ABSTRACT Fisherman- 6 Other- 1 Total – 7 No					
2008-09					
1	Sri Sekhar Mondal - 39 yrs Vill. Jharkhali, PS. Basanti 24-PGS(S)	Goasaba-3 under N.P.(W) Range	22.12.08	Body could not recovered	Fisherman Compensation Paid
2	Gourpada Ray, Jharkhali Vill.+PS.Basanti	Basta Burar char under SWLS Range	09.01.09	Body could not recovered	Fisherman Compensation Paid
3	Sri Kshudiram Halder - 38 yrs Vill. Kamakshyapur PS. Gosaba	Pirkhali-7 under N.P.(E) Range	27.01.09	Body could not recovered	Fisherman Compensation Paid
ABSTRACT Fisherman- 3 Total – 3 No.					

Sl No.	Name of Tiger Victim with Address	Place of Occurrence	Date & Time of Occurrence	Whether Body Recovered or Not	Remarks
2009-10					
1	Swapan Baidya S/O. Gangadhar Vill+PO. Chargheri	SWLS Range at Taktamankhal	18.04.09	Body could not recovered	Fisherman Compensation Paid
2	Manoj Kanti Mondal Vill +PO. Chargheri, PS. Coastal Dist. 24-PGS(S)	Tarakkhali Panchamukhani under SWLS Range	19.04.09	Body could not recovered	Fisherman Compensation Paid
3	Sri Bhaben Gayen Vill Tridibnagar, PO.Jharkhali PS. Basanti	Netidhopani-1 (Storekhali & Matla Char) under NP(W) Range	08.07.09	Body could not recovered	Fisherman Compensation paid
4	Sri Ramesh Mridha Jamespur PS. Coastal	Pirkhali-6 near Deul varani under SWLS Range	28.07.09	Injured and died later	Died on way to Sajnakhali
5	Sri Momin Mondal, S/O.Archut Gopalgunj, PS.Kultali	Netidhopani-2 Gosaba River side under NP (W) Range.	23.08.09	Body recovered	Fisherman Compensation paid
6	Sri Adhar Mondal, S/O.Hemanta Deulbari, PS. Kultali	Pirkhali-7 (Nabanki Char) under SWLS Range	04.09.09	Injured	Fisherman Admitted to Gosaba hospital & released after declared fit.

Sl. No	Name of Tiger Victim with Address	Place of Occurrence	Date of Accident	Whether Body Recovered or not	Category
7	Sri Dilip Mondal Basanti, Dist. 24-PGS(S)	Goasaba under NP(W) Range	23.09.09	Injured	Fisherman Admitted to Gosaba hospital & released after declared fit
8	Md. Ahmed Sk., S/O.Dil Alam Sk Vill.Bijoynagar, PS.Gosaba Dist. 24-PGS(S)	Pirkhali-7 (Nabanki-Bidya Jn.) under SWLS Range	01.10.09	Body recovered	Fisherman Compensation paid
9	Sri Arun Mondal Vill. Bijoynagar, PS.Gosaba 24-PGS(S)	Netidhopani-1 under N.P.(W) Range	24.01.10	Body could not recovered	Fisherman Compensation paid
10	Smt. Tarubala Mondal Vill. Sonagaon, PS. Gosaba	Sonaga Village under SWLS Range	22.02.10	Injured in village	Tiger straying injury, admitted to Gosaba Hospital
ABSTRACT Fisherman death- 7 Fisherman Injured-2 Villager Injured-1 (Tiger Straying) Total – Death -7, Injury 3					

ANNEXURE 6

FISHING BOAT LICENSE CERTIFICATES (B.L.C.‟s) IN INDIAN SUNDARBAN

Management Unit	Name of Range	No. of BLCs
Sundarban Tiger Reserve	Headquarter	293
	Sajnekhali Wildlife Sanctuary	289
	Barishat	341
	Sub-total STR	923
24-Parganas (South) Division	Namkhana	1152
	Matla	648
	Ramganga	539
	Raidighi	1687
	Bhagabatpur	563
	Sub-total 24 Parganas (S) Division	4589
	TOTAL INDIAN SUNDARBAN	5512

ANNEXURE 7

Capture of tigers during straying in Sundarban Biosphere Reserve

2001-02 TO 2010-11

Year	Sundarban Tiger Reserve			24-Parganas (South) Division			Sundarban Biosphere Reserve		
	Captured by cage	Captured by immobilisation	Total Capture	Captured by cage	Captured by immobilisation	Total Capture	Captured by cage	Captured by immobilisation	Total
2001-02	-	-	-	1	-	1	1	-	1
2002-03	7	4	11	-	-	-	7	4	11
2003-04	2	-	2	1	1	2	3	1	4
2004-05	2	1	3	2	-	2	4	1	5
2005-06	-	1	1	-	-	-	-	1	1
2006-07	-	1	1	-	-	-	-	1	1
2007-08	1	-	1	2	-	2	3	-	3
2008-09	4	2	6	1	1	2	5	3	8
2009-10	5	2	7	2	1	3	7	3	10
2010-11	5	4	9	1	1	2	6	5	11
TOTAL	26	15	41	10	4	14	36	19	55

ANNEXURE 8

Distribution of Salinity (psu) in water in Sundarban Tiger Reserve (2004-2006)

Name of Stations	Forest Blocks of Sundarban Tiger Reserve	Influencing Rivers	Aug – Sept „04	Decem - 2004	March - 2005	May- 2005	Sept - 2005	Decem - 2005	March - 2006	May - 2006	Averag Annual Sali ity ppt)
DOBANKI	Pirkhali and Panchmu-khani	Influenced by Matla and Bidya.	13.20H	15.10H	25.5L	29.4H	18.6H	16.8H	25.5H	30.0 H	18. 03
SUDHANNY-AKHALI			12.70H 12.70L	14.0H 13.7L	4.6H	29.1L	17.2L	14.7L	24.4L	29.4L	
SUNDARKH-ALI			12.40L	13.30L	24.2H	28.9H	16.8L	13.8L	23.8L	29.2L	
SAZNEKHA-LI			12.40L	13.70L	24.4H 24.4L	28.9H 28.9L	17.1H 17.0L	15.0H 14.3L	24.4H 23.4L	29.5 H	
HALDIBARI	Goasaba	Gosaba, Harinbhanga, Jhila, Raimangal All are dominated by Raimangal River	13.0L	16.60L	26.3L	30.1H	17.8L	17.3L	26.9L	30.0L	21. 71
CHORAMAYA DIP			12.0L	17.20H 16.20L	26.2L	30.0L	15.3L	16.6H	26.3L	30.9L	
KEORASUTI	Matla		12.30H 12.20L	15.60L	25.8L	30.1H 30.0 L	17.5H 17.3L	16.4L	25.6L	29.7l	21. 13
NETIDHOPANI	Netidopani		NC	14.0H	25.2H	29.6L	17.7H	15.7H	26.1L	NC	21. 38
CHANDRAD-UANI VARANI	Chamta		11.40L	15.10L	25.1H	29.8H	16.8L	15.7L	25.6H	29.6 H	20. 62
CHAMTA			11.0H	13.40L	23.6H	29.3H	16.0L	14.7L	24.1L	28.7L	
HARINBHA-NGA & JHILA	Jhila and Harinbhan-ga		11.30H	12.30H	22.0H	28.0H	12.0H	12.8H	21.9H	28.5 H	18. 6
KATWAJHU-RI	Katuajhuri		11.40H	9.80H 9.80L	20.9H 20.7L	27.3L	14.0H	10.6H 10.4L	20.9H	27.5 H	16. 66
BURIRDABRI	Arbesi		NC	8.5L	19.4L	26.3H 26.3L	14.0H 13.4L	9.4L	19.9L	26.6L	17. 70
KALUKHALI			NC	9.8L	20.3L	26.9L	13.8L	10.6H	20.9H	27.2 H	
	Inland Surface water standard (as per IS: 2296)				Not Available						
	Average sea water composition (Goldberg, 1971)				34.2 ppt						

(NC – Not collected due to unavoidable circumstances, H – High tide value, L – Low tide value)(based on: Collaborative study of Sundarban Biosphere Reserve and Institute of environmental studies and wetland management (IESWM), Kolkata, 2006-" monitoring of soil and water quality within sundarban reserve forests"under undp project)

ANNEXURE 9

HUMAN DEVELOPMENT INDICES FOR SOUTH 24 PARGANAS

Block	Standard of Living		Education		Health		Human Development	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Thakurpukur-Maheshtala	0.6	1	0.89	5	0.66	2	0.72	1
Budge Budge-I	0.57	2	0.89	4	0.56	8	0.67	2
Budge Budge-II	0.45	11	0.87	10	0.48	20	0.6	16
Bishnupur-I	0.5	4	0.89	8	0.56	9	0.65	6
Bishnupur-II	0.56	3	0.89	7	0.54	12	0.66	3
Sonarpur	0.5	5	0.84	20	0.59	5	0.64	7
Baruipur	0.48	6	0.85	15	0.52	14	0.62	10
Bhangar-I	0.45	12	0.81	25	0.39	28	0.55	26
Bhangar-II	0.47	8	0.85	17	0.52	15	0.61	11
Falta	0.47	7	0.87	11	0.49	18	0.61	12
Diamond Harbour-I	0.44	14	0.82	23	0.55	11	0.61	14
Diamond Harbour-II	0.47	9	0.85	13	0.64	4	0.65	4
Magrahat-I	0.45	10	0.85	19	0.51	16	0.6	15
Magrahat-II	0.45	13	0.85	18	0.57	7	0.62	9
Kulpi	0.36	23	0.85	16	0.51	17	0.57	20
Mandirbazar	0.44	15	0.83	21	0.41	26	0.56	22
Canning-I	0.41	16	0.8	27	0.7	1	0.64	8
Canning-II	0.32	28	0.76	29	0.44	23	0.51	28
Basanti	0.3	29	0.78	28	0.43	24	0.5	29
Gosaba	0.38	21	0.86	12	0.39	29	0.54	27
Joynagar-I	0.41	17	0.83	22	0.59	6	0.61	13
Joynagar-II	0.39	20	0.8	26	0.46	21	0.55	25
Mathurapur-I	0.4	19	0.81	24	0.49	19	0.57	21
Mathurapur-II	0.37	22	0.85	14	0.56	10	0.59	17
Kultali	0.35	25	0.89	6	0.53	13	0.59	18
Patharpratima	0.35	24	0.9	3	0.43	25	0.56	23
Kakdwip	0.41	18	0.88	9	0.66	3	0.65	5
Namkhana	0.34	26	0.93	1	0.46	22	0.58	19
Sagar	0.34	27	0.91	2	0.41	27	0.55	24
Source: South 24 Parganas Human Development Report, Government of West Bengal, 2004								

ANNEXURE 10

LIST OF SWEET WATER PONDS IN SUNDARBAN TIGER RESERVE

Sl.No.	Range	Beat	No. of Ponds	Compartment	Name of Pond	Maintained / Not maintained
1	Sajnakhali Wildlife Sanctuary	Sajnakhali	4 nos	Pirkhali - 1 (2 nos.)	Sajnakhali Padmapukur	Maintained
					Sudhanyakhali	Maintained
				Panchamukhani - 3 (1 no.)	Choragazi	Maintained
				Panchamukhani - 5 (1 no.)	Panchamukhani Khal Side	Not maintained
		Dobanki	2 nos	Pirkhali - 5 (1 no)	Dobanki Camp side	Maintained
				Pirkhali - 6(1 no)	Deulbharani Pond	Not maintained
		Duttar	3 nos	Jhilla-4 (2 nos)	Bijoybharani, Bhaijhora	Not maintained
				Jhilla-5 (1 no)	Choto Bhaijhora	Not maintained
2	National Park(W)	Haldibari	6 nos	Gosaba-2 (1 no)	-	Not maintained
				Matla-4 (1 no)	-	Not maintained
				Gosaba-3 (2 nos)	Outside camp	Maintained
				Mayadwip-1 (1 no)	-	Not maintained
				Chotohardi-3 (1 no)	-	Not maintained
		Netidhopani	6 nos	Matla-2 (1 no)	-	Not maintained
				Matla-3 (1 no)	-	Not maintained
				Gosaba-1 (1 no)	-	Not maintained
				Netidhopani-1 (2 nos)	Outside Camp	Maintained
				Netidhopani-2 (1 no)	-	Not maintained

Annexure………… Continued

<table>
<tr><th>Sl.No.</th><th>Range</th><th>Beat</th><th>No. of Ponds</th><th>Compartment</th><th>Name of Pond</th><th>Maintained / Not maintained</th></tr>
<tr><td rowspan="8">3</td><td rowspan="8">National Park(E)</td><td rowspan="4">Chamta</td><td rowspan="4">4 nos</td><td>Chamta-4 (1 no)</td><td>Outside Camp</td><td>Maintained</td></tr>
<tr><td>Chamta-6 (1 no)</td><td>Chotodhuya</td><td>Not maintained</td></tr>
<tr><td>Chandkhali-3 (1 no)</td><td>Bakultala</td><td>Not maintained</td></tr>
<tr><td>Chandkhali-3 (1 no)</td><td>Chandkhali Bharani</td><td>Not maintained</td></tr>
<tr><td rowspan="4">Baghmara</td><td rowspan="4">4 nos</td><td>Baghmara-4 (1 no.)</td><td>Gona Bhurkunda</td><td>Not maintained</td></tr>
<tr><td>Baghmara-3 (1 no.)</td><td>Gorankathi</td><td>Not maintained</td></tr>
<tr><td>Baghmara-5 (1 no.)</td><td>Baghmara Khal Site</td><td>Not maintained</td></tr>
<tr><td>Gona-2 (1 no)</td><td>Gona Khejurtala</td><td>Not maintained</td></tr>
<tr><td rowspan="12">4</td><td rowspan="12">Basirhat</td><td rowspan="5">Jhingakhali</td><td rowspan="5">5 nos</td><td>Arbesi-1 (1 no.)</td><td>Outside of Office Compound</td><td>Maintained</td></tr>
<tr><td>Arbesi-2 (1 no.)</td><td>-</td><td>Not maintained</td></tr>
<tr><td>Arbesi-3 (1 no.)</td><td>Jhilla Burirdabri Junction</td><td>Not maintained</td></tr>
<tr><td>Arbesi-4 (1 no.)</td><td>Outside of Burirdabri Camp</td><td>Maintained</td></tr>
<tr><td>Arbesi-5 (1 no.)</td><td>Kalukhali/Gabboni</td><td>Not maintained</td></tr>
<tr><td rowspan="2">Khatuajhuri</td><td rowspan="2">2 nos</td><td>Khatuajhuri-1 (1 no)</td><td>Tushkhali Khal Side</td><td>Not maintained</td></tr>
<tr><td>Khatuajhuri-2 (1 no)</td><td>North Chara South Chara Junction</td><td>Not maintained</td></tr>
<tr><td rowspan="3">Harinbhanga</td><td rowspan="3">3 nos</td><td>Harinbhanga-1 (1 no)</td><td>Balkhali/Jhill side</td><td>Not maintained</td></tr>
<tr><td>Harinbhanga-1 (1 no)</td><td>Cherakarikhali Jhilla Junction</td><td>Not maintained</td></tr>
<tr><td>Harinbhanga-3 (1 no)</td><td>Baraharikhali</td><td>Not maintained</td></tr>
<tr><td rowspan="2">Jhilla</td><td rowspan="2">2 nos</td><td>Jhilla-3 (1 no)</td><td>Kaksa</td><td>Maintained</td></tr>
<tr><td>Jhilla-2 (1 no)</td><td>Chilmari</td><td>Maintained</td></tr>
<tr><td colspan="7">ABSTRACT
TOTAL NO. OF SWEET WATER PONDS MADE: 41
TOTAL NO. OF SWEET WATER PONDS MAINTAINED (NON-SALINE): 12
TOTAL NO. OF SWEET WATER NOT MAINTAINED: 29</td></tr>
</table>

ANNEXURE 11

Radio-collaring in Indian Sundarban

S. N.	Date of Radio Collaring	Sex	Place of trapping /straying	Place of release	Type of collar	Results	Remarks
1	05.12.07	Female	Trapped at Panchamukhan -3	Panchamukhani-3	Satellite	Travelled around 35-42 sq km area	The collar functioned till April, 2008 and then ceased operation, but the animal with collar was seen physically for so many times afterwards.
2	24.02.10	Female	Strayed out in Sonagaon village	Netidhopani-2	Satellite	Travelled around 120 km running distance	The collar recovered on 9th May, 2010 after movement was found static though the animal was sighted directly afterwards.
3	28.02.10	Female	Trapped at Pirkhali – 5	Pirkhali – 7	Satellite	Travelled around 5-10 sq km area	On 10.3.2010 though signal received but location and movement could not be ascertained. On 11.3.10, the collar was recovered from Pirkhali -6.
4	20.03.10	Male	Netidhopani – 1	Pirkhali – 7	Satellite	Travelled around 60 sq km area	Last signal was received from collar on 6th April 2010; afterwards the collar ceased functioning, though the tiger has been directly sighted afterwards with the collar on its neck.
5	22.05.10	Male	Strayed out in Kalidaspur Village	Near Khatuajhuri camp	Satellite & GPS	Travelled around 110 km running distance	Last signal was received from collar on 5th August at Talpatti. Afterwards neither signal from collar received nor animal sighted directly.
6	22.05.10	Male	Netidhopani – 1	Netidhopani – 1	Satellite	Travelled around 35-40 sq km area	It is resident male; always move around the water hole of Netidhopani-1.
7	30.09.10	Male	Netidhopani – 1	Netidhopani – 1	GPS	Last signal received from collar on 15th December near Lakshmikhali Khal	This is the same tiger which was collared on 22.05.2010 at Netidopani, recollared after collar ceased function due to battery drain out. Animal sighted directly with collar on its neck for several time.

Annexure 12

Estimated tiger population in Indian Sundarban

Year	Estimated Tiger Population			Method Used	Remarks
	STR	24 Parganas (S) Div.	Total		
1973	50	Not done	50	Pugmark Method	Incomplete exercise
1976	181	Not done	181		
1977	205	Not done	205		
1983	264	Not done	264		
1989	269	Not done	269		
1992	251	Not done	251		
1996	242	Not done	242		
1997	263	Not done	263		
1999	254	30	284		
2001	245	26	271		
2004	249	25	275		
2006	Analysis Incomplete	Analysis Incomplete	-	Monitoring Tigers, Co-Predators, Prey, and Habitat, NTCA, MOEF and WII methodology.	Analysis of data remained incomplete for want of information on tiger ecology.
2010	-	-	77 (Mean)	As above	64-90 Tigers estimated. Camera Trapping and Satellite telemetry data used.

(Source: A Handbook on Sundarban Biosphere Reserve, 2003. Annual Report, Sundarban Tiger Reserve, 2004 and Status of Tigers, Co-predators, and Prey in India, 2010, NTCA, Govt. of India and WII, Dehradun, 2011)

ANNEXURE 13

Some case studies on "Problem tigers"showing repeated straying behaviour in Indian Sundarban during 2001-02 to 2010-11

<u>CASE STUDY 1 :</u>

On 11/04/2004, a male tiger strayed from Arbesi forest of Sundarban Tiger Reserve to Shamshernagar village and killed a young girl, Late Miss Rupali Baulia near her home in late evening hours. The sounds alerted the people and tiger fled away to forest leaving the body of ill fated girl. The circumstances indicated that girl was killed when she came face to face with strayed tiger. This was the only known incidence of human killing by tigers inside the village in many years. This tiger was trapped on 13/04/2004 and released in Harinbhanga block on 14/04/2004.

Tiger straying and killing of livestock was reported from Hemnagar and Kalitala villages on 22/04/2004. Tiger captured on 23/04/2004 and found to be same tiger, which was released on 14/04/2004. This was first ever documented case of a problem tiger, returning back to its old territory. It was released on 24/04/2004 in Panchmukhani forest of Saznekhali Wildlife sanctuary.

Tiger straying started again in shemshernagar village in third week of May, 2004 and tiger was captured on 20/05/2004. On the basis of its broken canines and stripes, It was found to be same tiger which was captured on 13/04/2004 and on 23/04/2004. This time, it was sent to Alipore zoological garden (Kolkata zoo), as it was believed that it can not sustain itself without straying. Throughout its health was found excellent except the broken canine. This male tiger, named Sundarkant in zoo, is still surviving.

SL NO.	VILLAGE / STRAYING DATE AND FOREST	TRAPPING DATE	RELEASE SITE / DATE	REMARKS
1	Shemshernagar, 11th and 13th April, 2004, Arbesi	13/04/2004	Harinbhanga-2 on 14th April,2005	Male, Lower left canine broken.
2	Hemnagar and Kalitala villages, 22nd and 23rd April, 2004, Arbesi	23/04/2004	Panchmukhani-4 on 24th April, 2004.	Same male tiger with broken lower left canine.
3	Shemshernagar, 17th May, 2004, Arbesi	20/05/2004	Sent to Alipore zoological garden, Kolkata.	Lower left canine broken, named Sundarkant in zoo a

CASE STUDY 2 :

During the year 2009 – 10, a male tiger with its characteristic left lower canine broken had strayed repeatedly in adjacent 3 villages viz. Anpur – Rajat Jubilee, Lahiripur and Sonagaon (within 15 km of distance) in Sundarban Tiger Reserve. It was trapped with live bait thrice and after 4th time, it was sent to Kolkata zoo as it was opined that it might have lost its hunting capability. The tiger was a bit aged one (approx 8-9 yrs of age), though during its course of coming back to the villages repeatedly – it was found that sometime it could cover a distance of 120 km approx (mayadwip-4 to panchamukhani-2) and returned back to the same village almost from Bay of Bengal.

SL NO.	VILLAGE / STRAYING DATE	TRAPPING SITE / DATE	RELEASE SITE / DATE	REMARKS
1	Anpur – Rajatjubilee on 28th August, 2009	Pirkhali – 1 on 2nd September, 2009	Chamta – 4 on 4th September, 2009	Lower left canine broken
2	Sonagaon on 22nd October, 2009	Pirkhali – 2 on 23rd October, 2009	Netidhopani – 2 on 24th October, 2009	Left lower canine broken, stripes matched with earlier, it came back to Sonagaon village from Chamta-4 ie. 70 km approx. within a period of 2 months
3	Lahiripur on 3rd November, 2009	Panchamukheni – 2 on 4th November, 2009	Mayadwip – 4 on 6th November, 2009 (near Bay of Bengal)	Left lower canine broken, stripes matched with earlier, it covered a distance of 50 km approx within a period of 10 days
4	Lahiripur on 27th December, 2009	Panchamukheni – 2 on 29th December, 2009	Sent toAlipur zoo, kolkata on 29th December, 2009 as identified as the same tiger as mentioned above, it could cover a distance of 120 km within a period of 45 days this time to come to Lahiripur from Mayadwip – 4 (near Bay of Bengal)	

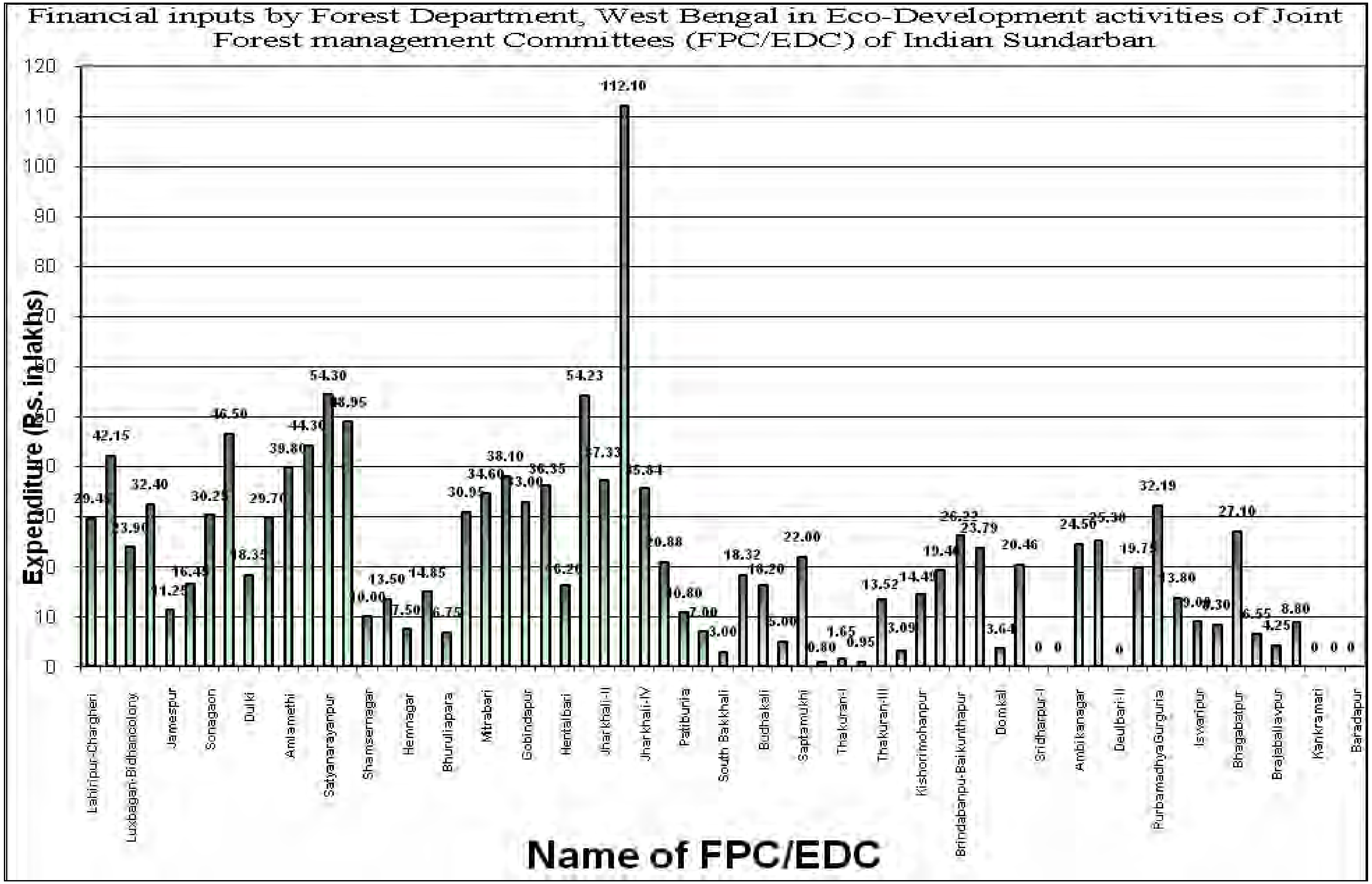
CASE STUDY 3 :

During the year 2009 – 10, a female tiger also showed repeated straying behaviour which was evident from the fact that the tigress was ear-tagged (marked as WLWB – 0001) after it was captured for the first time when it strayed in Kumirmari village of Basirhat Range and with the same ear-tag it came back again to Sonagaon village of SWLS Range (distance 30 km from kumirmari village) within one month only travelling a distance of 110 km approx (from Baghmara-7 compartment to Sonagaon village opposite to Pirkhali – 1). Afterwards, it was released at South 24 Parganas (Forest) Division, at a distance of 130 km approx from where, it never returned.

SL NO.	VILLAGE / STRAYING DATE	TRAPPING SITE / DATE	RELEASE SITE / DATE	REMARKS
1	Kumirmri on 29th June, 2009	Jhilla – 1 on 30th June, 2009	Baghmara - 7 on 3rd July, 2009	Ear tagging (coded as wlwb–0001) and micro-chipping done
2	Sonagaon on 30th July, 2009	Pirkhali – 1 on 31st July, 2009	Dulibasani – 3 of south 24 parganas (forest) division on 2nd August, 2009	Found with the ear tag coded wlwb – 0001, it covered a distance of 110 km approx while coming back to Sonagaon village from Baghmara - 7

ANNEXURE 14

Financial inputs by Forest Department, West Bengal in Eco-Development activities of Joint Forest management Committees (FPC/EDC) of Indian Sundarban



ANNEXURE 15

GOVERNANCE OF JOINT FOREST MANAGEMENT COMMITTEE‟S IN INDIAN SUNDARBAN- ANNUAL GENERAL BODY MEETINGS HELD

Sl. No.	Name of FPC/EDC	Registration Date	Date of Annual general Body Meeting Last held (as on 01/11/2011)
Forest protectionCommittee‟s			
Sundarban Tiger Reserve			
1	Hentalbari	6-5-98	11/01/2011
2	Kalidaspur	6-5-98	10/01/2011
3	Emlibari	6-5-98	16/12/2010
4	Bhuruliapara	6-5-98	In 2009
5	Adibasipara-Kumirmari	6-5-98	In 2009
6	Mitrabari	6-5-98	24/12/2009
7	Bagnapara	6-5-98	12/12/2010
8	Samshernagar	6-5-98	01/08/2009
9	Kalitala-Perghumti	6-5-98	29/08/2009
10	Hemnagar	6-5-98	12/02/2009
11	Gobindapur	10-12-02	05/12/2010
24 Parganas (South) Division			
12	Thakuran-I	17-02-93	Never since registration
13	Thakuran-II	17-02-93	Never since registration
14	Thakuran-III	17-02-93	Never since registration
15	Thakuran-IV	17-02-93	Never since registration
16	Jharkhali-I	01-03-04	19/04/2010
17	Jharkhali-II	01-03-04	02/02/2010
18	Jharkhali-III	01-03-04	20/04/2010
19	Jharkhali-IV	01-03-04	13/06/2010
20	Iswaripur	24-08-94	Never since registration
21	Baradapur	05-09-97	Never since registration
22	Dwarikanagar	15-09-97	Never since registration
23	Bhagawatpur	02-08-93	August, 2010
24	Dakshin Chandanpiri	15-09-97	17/12/2010
25	Brajaballavpur	07-08-03	Never since registration
26	Uttar Chandanpiri	15-09-97	17/12/2010
27	North Bakkhali	15-09-97	Never since registration
28	South Bakkhali	15-09-97	Never since registration
29	Mousani	11-08-03	08/07/2011
30	Patibonia	15-09-97	Never since registration
31	Fatikpur	15-09-97	31/12/2010
32	Bamanagar	29-12-97	30/12/2010

33	Saptamukhi	11-08-03	Never since registration
34	Budakhali	07-08-03	Never since registration
35	Kankaramari	07-08-03	Never since registration
36	Sikarpur	07-08-03	Never since registration
37	Kakdwip	11-08-03	Never since registration
38	Bhubaneswari Char	11-08-03	Never since registration
39	Debipur (Purba)	01-03-04	Never since registration
40	Deulbari	30-08-94	Never since registration
41	Deulbari-2	26-09-04	Never since registration
42	Purba Madhya Gurguria	26-09-04	Never since registration
43	Ambikanagar	26-09-04	17/06/2009
44	Nagenabad	26-09-04	27/08/2010
45	Domkal	26-09-04	03/02/2009
46	K - Plot	26-09-04	12/10/2009
47	Sreedharpur-I (Purba)	29-03-93	12/09/2009
48	Purba Surendra Nagar	15-09-97	14/02/2010
49	Sreedharpur-II (Purba)	29-12-97	03/02/2009
50	Kishorimohanpur	15-09-97	28/03/2009
51	Binodpur - Baikunthapur	15-09-97	28/03/2009
Eco-development committee"s, Sundarban Tiger Reserve			
1	Dayapur	4-5-98	In 2007
2	Pakhiralaya	4-5-98	09/09/2007
3	Dulki	4-5-98	August, 2008
4	Sonagaon	4-5-98	24/02/2008
5	Jemspur	4-5-98	09/02/2007
6	Lahiripur-Chargheri	4-5-98	12/06/2008
7	Bidhan Colony-Luxbagan	4-5-98	In 2008
8	Lahiripur-Santigachhi	4-5-98	23/11/2009
9	Enpur-Rajatjubilee	4-5-98	October, 2008
10	Bijoynagar	5-5-98	24/01/2008
11	Mathurakhand	5-5-98	15/09/2007
12	Satyanarayanpur	5-5-98	10/09/2007
13	Amlamethi	5-5-98	22/09/2007
14	Bally	5-5-98	26/08/2007

ANNEXURE 16

LIST OF JOINT FOREST MANAGEMENT COMMITTEE‟S (FPC‟‟S AND EDCs) IN INDIAN SUNDARBAN

Sl. No.	Name of FPC/EDC	Administrative Unit	Registration Date	No. of members	Number of families				Protected Forest Area (Ha.)	Name of PA protected	
					GC / OBC	SC	ST	Total		Block	Compartment
1	2	3	4	5	6	7	8	9	10	11	12
	FOREST PROTECTION COMMITTEES										
	Sundarban Tiger Reserve										
1	Hentalbari	Basirhat Range/Bagna Beat	6-5-98	376	2	374		376	500	Jhilla	2 & 3
2	Kalidaspur	Basirhat Range/Bagna Beat	6-5-98	572	15	539	18	572	300	Jhilla	3
3	Emlibari	Basirhat Range/Bagna Beat	6-5-98	331		331		331	580	Jhilla	2 & 3
4	Bhuruliapara	Basirhat Range/Bagna Beat	6-5-98	456	12	394	50	456	567	Jhilla	1
5	Adibasipara-Kumirmari	Basirhat Range/Bagna Beat	6-5-98	360	5	332	23	360	875	Jhilla	1
6	Mitrabari	Basirhat Range/Bagna Beat	6-5-98	425	16	347	62	425	360	Jhilla	3
7	Bagnapara	Basirhat Range/Bagna Beat	6-5-98	389	2	361	26	389	500	Jhilla	2
8	Samshernagar	Basirhat Range/Jhingekhali Beat	6-5-98	273	32	203	38	273	2584	Arbesi	1
9	Kalitala-Perghumti	Basirhat Range/Jhingekhali Beat	6-5-98	417	74	331	12	417	1544	Arbesi	1
10	Hemnagar	Basirhat Range/Jhingekhali Beat	6-5-98	266	11	235	20	266	4174	Arbesi	2
11	Gobindapur	Basirhat Range/Bagna Beat	10-12-02	200		195	5	200	860	Jhilla	2
	24-Parganas (South) Divn.										
12	Thakuran-I	Ramganga Range/Dhainchi Beat	17-02-93	222	169	53		222	1120	Patharpratima	1
13	Thakuran-II	Ramganga Range/Dhainchi Beat	17-02-93	345	285	57	3	345	3489	Patharpratima	2
14	Thakuran-III	Ramganga Range/Dhainchi Beat	17-02-93	344	262	82		344	2905	Patharpratima	3
15	Thakuran-IV	Ramganga Range/Dhainchi Beat	17-02-93	425	312	113		425	3887	Patharpratima	4
16	Jharkhali-I	Matla Range/Herobhanga Beat	01-03-04	1536	31	1505		1536	1272	Basanti	Herobhanga-5
17	Jharkhali-II	Matla Range/Herobhanga Beat	01-03-04	1280	38	1216	26	1280	1452	Basanti	Herobhanga-6 & 8
18	Jharkhali-III	Matla Range/Herobhanga Beat	01-03-04	1496	60	1391	45	1496	638	Basanti	Herobhanga-4 & 7
19	Jharkhali-IV	Matla Range/Herobhanga Beat	01-03-04	578	23	549	6	578	586	Basanti	Herobhanga- 8

20	Iswaripur	Bhagawatpur Range/Bhagawatpur Beat	24-08-94	192	68	124		192	200	Patharpratima	Saptamukhi Camp-1
21	Baradapur	Bhagawatpur Range/Bhagawatpur Beat	05-09-97	466	355	111		466	300	Patharpratima	Saptamukhi Camp-2
22	Dwarikanagar	Bhagawatpur Range/Bhagawatpur Beat	15-09-97	464	376	88		464	159	Patharpratima	Saptamukhi Camp-3
23	Bhagawatpur	Bhagawatpur Range/Bhagawatpur Beat	02-08-93	331	109	222		331	500	Patharpratima	Bhagawatpur
24	Dakshin Chandanpiri	Bhagawatpur Range/Chandanpiri Beat	15-09-97	413	298	115		413	58	Namkhana	Dakshin Chandanpiri
25	Brajaballavpur	Bhagawatpur Range/Chandanpiri Beat	07-08-03	318	115	203		318	3839	Namkhana	Lothian
26	Uttar Chandanpiri	Bhagawatpur Range/Chandanpiri Beat	15-09-97	160	61	99		160	125	Namkhana	Uttar Chandanpiri
27	North Bakkhali	Bakkhali Range/Bakkhali Beat	15-09-97	1593	869	724		1593	244	Namkhana	Uttar Bakkhali
28	South Bakkhali	Bakkhali Range/Bakkhali Beat	15-09-97	5400	2160	3240		5400	300	Namkhana	South Bakkhali
29	Mousani	Bakkhali Range/Patibonia Beat	11-08-03	640	462	116	62	640	1950	Namkhana	Jambu Island
30	Patibonia	Bakkhali Range/Patibonia Beat	15-09-97	1033	470	563		1033	550	Namkhana	Patibonia RF
31	Fatikpur	Namkhana Range/Saptamukhi Beat	15-09-97	785	681	104		785	500	Namkhana	Dia-2
32	Bamanagar	Namkhana Range/Saptamukhi Beat	29-12-97	1084	676	401	7	1084	718	Namkhana	Dia-2
33	Saptamukhi	Namkhana Range/Saptamukhi Beat	11-08-03	640	448	179	13	640	500	Namkhana	Junson Island Dia-2
34	Budakhali	Namkhana Range/Saptamukhi Beat	07-08-03	152	83	69		152	200	Namkhana	Kakdwip Char
35	Kankaramari	Namkhana Range/Namkhana Beat	07-08-03	168	153	15		168	400	Namkhana	Kankaramari
36	Sikarpur	Namkhana Range/Namkhana Beat	07-08-03	306	41	265		306	400	Namkhana	Sikarpur Char
37	Kakdwip	Namkhana Range/Namkhana Beat	11-08-03	336	276	60		336	330	Namkhana	Kakdwip Char
38	Bhubaneswari Char	Raidighi Range/Kultali Beat	11-08-03	N.A.							
39	Debipur (Purba)	Raidighi Range/Kultali Beat	01-03-04	157		21	136	157	600	Kultali	Ajmalmari 1 & 2
40	Deulbari	Raidighi Range/Kultali Beat	30-08-94	263	171	92		263	3017	Kultali	Herobhanga-9
41	Deulbari-2	Raidighi Range/Kultali Beat	26-09-04	274	73	1	200	274	500	Kultali	Ajmalmari 1 & 2
42	Purba Madhya Gurguria	Raidighi Range/Kultali Beat	26-09-04	118	50	52	16	118	2260	Kultali	Ajmalmari 1,2 & 3
43	Ambikanagar	Raidighi Range/Nalgara Beat	26-09-04	864	631	233		864	500	Kultali	Ajmalmari 11
44	Nagenabad	Raidighi Range/Nalgara Beat	26-09-04	133	60	70	3	133	500	Kultali	Ajmalmari 11 & 12
45	Domkal	Raidighi	26-09-04	331	109	222		331	500	Kultali	Swan

		Range/Nalgara Beat									Island
46	K - Plot	Raidighi Range/Nalgara Beat	26-09-04	395	175	220		395	500	Patharpratima	Ajmalmari, Thakuran
47	Sreedharpur-I (Purba)	Raidighi Range/Nalgara Beat	29-03-93	88	16	72		88	970	Kultali	Bhubaneswari & Swan Island
48	Purba Surendra Nagar	Raidighi Range/Nalgara Beat	15-09-97	627	381	246		627	500	Kultali	Thakuran Char
49	Sreedharpur-II (Purba)	Raidighi Range/Nalgara Beat	29-12-97	341	195	146		341	2500	Kultali	Bhubaneswari & Swan Island
50	Kishorimohanpur	Raidighi Range/Nalgara Beat	15-09-97	49	36	13		49	2500	Kultali	Thakuran Char, Ajmalmari-11,12
51	Binodpur - Baikunthapur	Raidighi Range/Nalgara Beat	15-09-97	126	62	64		126	1065	Kultali	Bhubaneswari & Swan Island
ECO-DEVELOPMENT COMMITTEES											
	Sundarban Tiger Reserve										
1	Dayapur	SWLS Range/Sajnekhali Beat	4-5-98	326		319	7	326	960	Pirkhali	1
2	Pakhiralaya	SWLS Range/Sajnekhali Beat	4-5-98	517	76	441		517	480	Pirkhali	1 & 2
3	Dulki	SWLS Range/Sajnekhali Beat	4-5-98	189		189		189	640	Pirkhali	1
4	Sonagaon	SWLS Range/Sajnekhali Beat	4-5-98	68		68		68	700	Pirkhali	2
5	Jemspur	SWLS Range/Sajnekhali Beat	4-5-98	347	1	346		347	650	Pirkhali	1
6	Lahiripur-Chargheri	SWLS Range/Dattar Beat	4-5-98	328		328		328	2000	Jhilla	4 & 5
7	Bidhan Colony-Luxbagan	SWLS Range/Dattar Beat	4-5-98	227	12	197	18	227	520	Jhilla	2 & 3
8	Lahiripur-Santigachhi	SWLS Range/Dattar Beat	4-5-98	328		328		328	2400	Panchamukhani	2
9	Enpur-Rajatjubilee	SWLS Range/Dattar Beat	4-5-98	155		155		155	700	Panchamukhani	! & 2
10	Bijoynagar	NP(W) Range/Bidya Beat	5-5-98	471	76	389	6	471	680	Pirkhali	2
11	Mathurakhand	NP(W) Range/Bidya Beat	5-5-98	519	62	419	38	519	550	Pirkhali	4
12	Satyanarayanpur	NP(W) Range/Bidya Beat	5-5-98	580	5	554	21	580	800	Pirkhali	2
13	Amlamethi	NP(W) Range/Bidya Beat	5-5-98	170	24	138	8	170	500	Pirkhali	4
14	Bally	NP(W) Range/Bidya Beat	5-5-98	258	72	176	10	258	770	Pirkhali	2

ANNEXURE 17

Honey Collection in Indian Sundarban (2001-02 TO 2010-11)

Year	Sundarban Tiger Reserve		24-Parganas (South) Division		Sundarban Biosphere Reserve	
	Crude Honey (Kg.)	Bee Wax (Kg.)	Crude Honey (Kg.)	Bee Wax (Kg.)	Crude Honey (Kg.)	Bee Wax (Kg.)
2001-02	15408	1171	17100	952.4	32508	2123.4
2002-03	16415	1363.3	14450	2154.4	30865	3517.7
2003-04	20797	1282.65	17533.5	475	38330.5	1757.65
2004-05	22119.5	1100	8922.3	216.6	31041.8	1316.6
2005-06	30552	1559	30568	458.4	61120	2017.4
2006-07	25170	1142	13037.4	260	38207.4	1402
2007-08	21368	1396	13837	283.6	35205	1679.6
2008-09	12550	566	12015	323	24565	889
2009-10	13800	-	11950	40	25750	40
2010-11	14300	265.3	5775	334	20075	599.3

ANNEXURE 18

IMPORTANT RECORDED BIODIVERSITY OF INDIAN SUNDARBAN

(Based on "The Sundarban Inheritance", Sanctury Asia, by Bittu Sehgal, Sumit Sen & Bikram Grewal)

A CHECKLIST OF SUNDARBAN MANGROVES
CHECKLIST OF MANGROVES AND
MANGROVE ASSOCIATES OF INDIAN SUNDARBAN TRUE MANGROVES (28)
Family: Avicenniaceae
Avicennia alba kala-baen, white mangrove Cr
Avicennia marina peara-baen, gray mangrove Cr
Avicennia marina var. acutissima En
Avicennia officinalis sada-baen, white mangrove En
Family: Bignoniaceae
1Dolichandrone spathacea mangrove trumpet-tree Caesalpiniaceae
1Cynometra iripa wrinkle-pod mangrove
1Cynometra ramiflora singra En
Family: Combretaceae
Lumnitzera racemosa kripa, black mangrove En
Family: Euphorbiaceae
Excoecaria agallocha genwa, blinding tree, blind- your-eye mangrove Vu
Family: Meliaceae
Aglaia cucullata Amur, Pacific maple En
Xylocarpus granatum dhundul, cannonball mangrove, monkey-puzzle En
Xylocarpus mekongensis pitamari, passur, cedar mangrove En
Family: *Myrsinaceae*
Aegiceras corniculatum khalsi, river mangrove En
Family: *Plumbaginaceae*
Aegialitis rotundifolia satali-gach, tora En
Family: *Rhizophoraceae*
Bruguiera cylindrica sona-champa, thushia En
Bruguiera gymnorrhiza kankra, natinga, large-leafed orange mangrove Cr
Bruguiera parviflora champa, kankra bokul, small- leafed orange mangrove Cr
Bruguiera sexangula banduri, kankra, orange mangrove Vu
Ceriops decandra goran En
Ceriops tagal math-goran, yellow mangrove En
Kandelia candel goria En
Rhizophora apiculata garjan, tall-stilted mangrove En
Rhizophora mucronata bhara garjan, stilt-rooted mangrove, red mangrove Vu
Family: *Rubiaceae*
1Scyphiphora hydrophyllacea yamstick mangrove En
Family: *Sonneratiaceae*
Sonneratia apetala keora, mangrove apple En
Sonneratia caseolaris orcha keora, orali, En
Sonneratia griffithii ora Cr
Family: *Sterculiaceae*

Heritiera fomes sundari En
*Heritiera littoralis** sundari, Looking-glass mangrove En
(1 – some authorities treat these as mangrove associates
* – not consistently reported from the area – possibly an introduced species)

MANGROVE ASSOCIATES AND MANGROVE RELATED SPECIES (36)
Family: *Acanthaceae*
2Acanthus ilicifolius harguja, sea holly, holly mangrove En
2Acanthus volubilis Lata-harguja Cr
Family: *Aizoaceae*
Sesuvium portulacastrum jadu-palang, sea purselane, shore purselane En
Family: *Apocynaceae*
Cerbera manghas dagor, pink-eyed cerbera En
Cerbera odollam dabur, dog-bane
Family: *Arecaceae/Palmae*
2Nypa fruticans golpata, water coconut, nipah palm En
2Phoenix paludosa hental, sea date palm En
Family: *Asclepiadaceae*
3Finlaysonia obovata dudhilata Cr
Blechnaceae
Stenochlaena palustris dhekia-sag, climbing swamp-fern
Family: *Boraginaceae*
Heliotropium curassavicum spatulate-leaved heliotrope
Family: *Chenopodiacae*
Arthrocnemum indicum
Salicornia brachiata Lr
Suaeda maritima nonaguri, herbaceous sea-blite, sea- blite En
Suaeda monoica En
Suaeda nudiflora giri-sak En
Family: *Convolvulaceae*
3Ipomoea pes-caprae chhagalkuri, goat‟s foot creeper, beach morning glory
Family: *Cyperaceae*
Fimbristylis ferruginea fringe rush, West Iindian fimbry
Scirpus littoralis sedge
Family: *Leguminosae*
3Caesalpinia bonduc nata, bonduc nut, moluca bean
3Caesalpinia crista natakaranja, kutum-katta, fever nut, Indian filbert
3 Dalbergia spinosa chanda-katta
Derris scandens noalata, hog creeper, forest beanstalk
Derris trifoliata kalilata panlata, threeleaf derris, mangrove beanstalk En
Intsia bijuga bhaela bhadal, Borneo teak, moluccan ironwood
Family: *Gramineae*
2Aeluropus lagopoides En
Myriostachya wightiana ghash En
3Phragmites karka
Porteresia coarctata dhanigash Vu
Family: *Lecythidaceae*
3Barringtonia racemosa kumia, freshwater mangrove, hippo apple
Family: *Malvaceae*

3Hibiscus tiliaceus bhola, cottonwood sea hibiscus
3Thespesia populnea parash, portia tree, Indian tulip tree
3Thespesia populneoides parash, tulip tree, Pacific rosewood
Family: *Pteridaceae*
2Acrostichum aureum hodo, golden leather fern, swamp fern Lr
Family: *Rubiaceae*
2Brownlowia tersa sundari-lata, bola-sundari En
Family: *Verbenaceae*
Clerodendrum inerme sitka-sitki, Banjai, wild jasmine, common hedge bower En
Premna serratifolia
(*2- some authorities treat these as true mangroves*
3 - some authorities treat these as „back mangroves or beach species")

Notes: *1. Taxonomy and grouping follow treatment adopted by K. Kathiresan and B.L. Bingham (2001). This is based on a reconciliation of common features from Tomlinson (1986) and Duke (1992)*
2. Risk status is based on assessment of threat by participants of C.A.M.P. using IUCN categories. The risk assessment applies to mangrove species in India. [Critically Endangered – Cr; Endangered – En; Vulnerable – Vu; Lower Risk – Lr]
3. Ghose et al identified 105 species from the Indian Sundarban. These included true mangroves, mangrove associates, back mangrove species, beach species and parasites.
4. Some plant species found in the Sundarban have not been included in the list as there appears to be considerable difference of opinion amongst authorities on their taxonomic status. These include: Merope angulata, Tylophora tenuis, Ruppia maritima, Cryptocoryne ciliata, Pluchea indica, Sarcolobus globosus *and* Tamarix troupi.

A CHECKLIST OF SUNDARBAN MAMMALS

ORDER: PRIMATES
Family: *Cercopithecidae*
Rhesus macaque *Macaca mulatta*

ORDER: ARTIODACTYLA
Family: *Cervidae*
Indian muntjac *Muntiacus muntjak* (B)
Spotted deer *Axis axis*
Family: *Suidae*
Wild boar *Sus scrofa*

ORDER: CARNIVORA
Family: *Canidae*
Jackal *Canis aureus*
Indian fox *Vulpes bengalensis*
Family: *Felidae*
Tiger *Panthera tigris*
Jungle cat *Felis chaus*
Leopard cat *Prionailurus bengalensis*

Fishing cat *Prionailurus viverrinus*
Family: *Mustelidae*
Smooth-coated otter *Lutrogale perspicillata*
Small-clawed otter *Amblonyx cinereus*
Family: *Viverridae*
Small Indian civet *Viverricula indica*
Large Indian civet *Viverra zibetha*
Common palm civet *Paradoxurus hermaphroditus*
Family: *Herpestidae*
Grey mongoose *Herpestes edwardsii*
Small Indian mongoose *Herpestes javanicus*

ORDER: INSECTIVORA
Family: *Soricidae*
House shrew *Suncus murinus*

ORDER: RODENTIA
Family: *Hystricidae*
Himalayan crestless porcupine *Hystrix brachyura* (B)
Family: *Sciuridae*
Five-striped palm squirrel *Funambulus pennantii*
Family: *Muridae*
Large bandicoot-rat *Bandicota indica*
Lesser Bandicoot-rat *Bandicota bengalensis*
House rat *Rattus rattus*
Long-tailed tree mouse *Vandeleuria oleracea*
Little Indian field mouse *Mus booduga*

ORDER: CHIROPTERA
Family: *Pteropodidae*
Indian flying fox *Pteropus giganteus*
Short-nosed fruit bat *Cynopterus sphinx*
Family: *Rhinopomatidae*
Lesser mouse-tailed bat *Rhinopoma hardwickii*
Family: *Emballonuridae*
Long-winged tomb bat *Taphozous longimanus*
Family: *Hipposideridae*
Tail-less leaf-nosed bat *Coelops frithii*
Family: *Megadermatidae*
Greater false vampire *Megaderma lyra*
Family: *Vespertilionidae*
Asiatic greater yellow house bat *Scotophilus heathii*
Lesser Asiatic yellow house bat *Scotophilus kuhlii*
Indian pipistrelle *Pipistrellus coromandra*
Indian pygmy bat *Pipistrellus tenuis*

ORDER: CETACEA
Family: *Platanistidae*
Ganges river dolphin *Platanista gangetica*

Family: *Phocoenidae*
Finless porpoise *Neophocaena phocaenoides*
Family: *Delphinidae*
Irrawaddy dolphin *Orcaella brevirostris*
Indo-Pacific bottlenose dolphin *Tursiops aduncus*
Common bottlenose dolphin *Tursiops truncatus*
Short-beaked common dolphin *Delphinus delphis*
Spinner dolphin *Stenella longirostris*
Pantropical spotted dolphin *Stenella attenuata*
Indo-Pacific hump-backed dolphin *Sousa chinensis*
Melon-headed whale *Peponocephala electra*
Family: *Balaenopteridae*
Bryde"s whale *Balaenoptera edeni*
Fin whale *Balaenoptera physalus*
Blue whale *Balaenoptera musculus*
Humpback whale *Megaptera novaeangliae*
(B) – Bangladesh only Rodentandbatlistincomplete

PRESUMED EXTINCT FROM THE SUNDARBAN
Swamp deer *Cervus duvaucelii*
Hog deer *Axis porcinus*
Asiatic wild buffalo *Bubalus arnee*
Greater one-horned rhinoceros *Rhinoceros unicornis*
Javan rhinoceros *Rhinoceros sondaicus*
Common leopard *Panthera pardus*

A CHECKLIST OF SUNDARBAN BIRDS

ORDER: GALLIFORMES
Family: *Phasianidae*
Swamp Francolin *Francolinus gularis*
Common Quail *Coturnix coturnix*
Rain Quail *Coturnix coromandelica*
Blue-breasted Quail *Coturnix chinensis*
Red Junglefowl *Gallus gallus*

ORDER: ANSERIFORMES
Family: *Dendrocygndiae*
Lesser Whistling-duck *Dendrocygna javanica*
Family: *Anatidae*
White-headed Duck *Oxyura leucocephala*
Greylag Goose *Anser anser*
Ruddy Shelduck *Tadorna ferruginea*
Common Shelduck *Tadorna tadorna*
Comb Duck *Sarkidiornis melanotos*
Cotton Pygmy-goose *Nettapus coromandelianus*
Gadwall *Anas strepera*

Falcated Duck *Anas falcata*
Eurasian Wigeon *Anas penelope*
Mallard *Anas platyrhynchos*
Spot-billed Duck *Anas poecilorhyncha*
Common Teal *Anas crecca*
Garganey *Anas querquedula*
Northern Pintail *Anas acuta*
Northern Shoveler *Anas clypeata*
Red-crested Pochard *Rhodonessa rufina*
Common Pochard *Aythya ferina*
Ferruginous Pochard *Aythya nyroca*
Baer"s Pochard *Aythya baeri*
Tufted Duck *Aythya fuligula*
Greater Scaup *Aythya marila*
Red-breasted Merganser *Mergus serrator*

Order: PICIFORMES
Family: *Picidae*
Eurasian Wryneck *Jynx torquilla*
Speckled Piculet *Picumnus innominatus*
Rufous Woodpecker *Celeus brachyurus*
Brown-capped Pygmy Woodpecker *Dendrocopos nanus*
Fulvous-breasted Woodpecker *Dendrocopos macei*
Yellow-crowned Woodpecker *Dendrocopos mahrattensis*
Lesser Yellownape *Picus chlorolophus*
Greater Yellownape *Picus flavinucha*
Streak-throated Woodpecker *Picus xanthopygaeus*
Grey-headed Woodpecker *Picus canus*
Common Flameback *Dinopium javanense*
Black-rumped Flameback *Dinopium benghalense*
Greater Flameback *Chrysocolaptes lucidus*
White-naped Woodpecker *Chrysocolaptes festivus*
Family: *Megalaimidae*
Brown-headed Barbet *Megalaima zeylanica*
Lineated Barbet *Megalaima lineata*
Blue-throated Barbet *Megalaima asiatica*
Coppersmith Barbet *Megalaima haemacephala*

ORDER: UPUPIFORMES
Family: *Upupidae*
Common Hoopoe *Upupa epops*

ORDER: CORACIIFORMES
Family: *Coraciidae*
Indian Roller *Coracias benghalensis*
Dollarbird *Eurystomus orientalis*
Family: *Alcedinidae*
Common Kingfisher *Alcedo atthis*
Family: *Halcyonidae*

Brown-winged Kingfisher *Halcyon amauroptera*
Stork-billed Kingfisher *Halcyon capensis*
Ruddy Kingfisher *Halcyon coromanda*
White-throated Kingfisher *Halcyon smyrnensis*
Black-capped Kingfisher *Halcyon pileata*
Collared Kingfisher *Todiramphus chloris*
Family: *Cerylidae*
Pied Kingfisher *Ceryle rudis*
Family: *Meropidae*
Green Bee-eater *Merops orientalis*
Blue-tailed Bee-eater *Merops philippinus*
Chestnut-headed Bee-eater *Merops leschenaulti*

ORDER: CUCULIFORMES
Family: *Cuculidae*
Pied Cuckoo *Clamator jacobinus*
Chestnut-winged Cuckoo *Clamator coromandus*
Common Hawk Cuckoo *Hierococcyx varius*
Indian Cuckoo *Cuculus micropterus*
Eurasian Cuckoo *Cuculus canorus*
Oriental Cuckoo *Cuculus saturatus*
Lesser Cuckoo *Cuculus poliocephalus*
Grey-bellied Cuckoo *Cacomantis passerinus*
Plaintive Cuckoo *Cacomantis merulinus*
Asian Koel *Eudynamys scolopacea*
Green-billed Malkoha *Phaenicophaeus tristis*
Family: *Centropodidae*
Greater Coucal *Centropus sinensis*
Lesser Coucal *Centropus bengalensis*

ORDER: PSITTACIFORMES
Family: *Psittacidae*
Rose-ringed Parakeet *Psittacula krameri*

ORDER: APODIFORMES
Family: *Apodidae*
Asian Palm Swift *Cypsiurus balasiensis*
House Swift *Apus affinis*
Fork-tailed Swift *Apus pacificus*

ORDER: STRIGIFORMES
Family: *Tytonidae*
Barn Owl *Tyto alba*
Family: *Strigidae*
Oriental Scops Owl *Otus sunia*
Indian Scops Owl *Otus bakkamoena*
Brown Fish Owl *Ketupa zeylonensis*
Spotted Owlet *Athene brama*
Short-eared Owl *Asio flammeus*

Family: *Caprimulgidae*
Large-tailed Nightjar *Caprimulgus macrurus*
Indian Nightjar *Caprimulgus asiaticus*
Savanna Nightjar *Caprimulgus affinis*

ORDER: COLUMBIFORMES
Family: *Columbidae*
Rock Pigeon *Columba livia*
Laughing Dove *Streptopelia senegalensis*
Spotted Dove *Streptopelia chinensis*
Red Collared Dove *Streptopelia tranquebarica*
Eurasian Collared Dove *Streptopelia decaocto*
Emerald Dove *Chalcophaps indica*
Orange-breasted Green Pigeon *Treron bicincta*
Yellow-footed Green Pigeon *Treron phoenicoptera*

ORDER: GRUIFORMES
Family: *Heliornithidae*
Masked Finfoot *Heliopais personata*
Family: *Rallidae*
Slaty-legged Crake *Rallina eurizonoides*
Slaty-breasted Rail *Gallirallus striatus*
Water Rail *Rallus aquaticus*
White-breasted Waterhen *Amaurornis phoenicurus*
Baillon‟s Crake *Porzana pusilla*
Ruddy-breasted Crake *Porzana fusca*
Watercock *Gallicrex cinerea*
Purple Swamphen *Porphyrio porphyrio*
Common Moorhen *Gallinula chloropus*
Common Coot *Fulica atra*

ORDER: CICONIIFORMES
Family: *Scolopacidae*
Eurasian Woodcock *Scolopax rusticola*
Wood Snipe *Gallinago nemoricola*
Pintail Snipe *Gallinago stenura*
Swinhoe‟s Snipe *Gallinago megala*
Common Snipe *Gallinago gallinago*
Jack Snipe *Lymnocryptes minimus*
Black-tailed Godwit *Limosa limosa*
Bar-tailed Godwit *Limosa lapponica*
Whimbrel *Numenius phaeopus*
Eurasian Curlew *Numenius arquata*
Spotted Redshank *Tringa erythropus*
Common Redshank *Tringa totanus*
Marsh Sandpiper *Tringa stagnatilis*
Common Greenshank *Tringa nebularia*
Green Sandpiper *Tringa ochropus*
Wood Sandpiper *Tringa glareola*

Terek Sandpiper *Xenus cinereus*
Common Sandpiper *Actitis hypoleucos*
Ruddy Turnstone *Arenaria interpres*
Asian Dowitcher *Limnodromus semipalmatus*
Great Knot *Calidris tenuirostris*
Sanderling *Calidris alba*
Little Stint *Calidris minuta*
Red-necked *Stint Calidris ruficollis*
Temminck‟s *Stint Calidris temminckii*
Long-toed Stint Calidris subminuta
Dunlin *Calidris alpina*
Curlew Sandpiper *Calidris ferruginea*
Spoon-billed Sandpiper *Calidris pygmea*
Broad-billed Sandpiper *Calidris falcinellus*
Ruff *Philomachus pugnax*
Red Phalarope *Phalaropus fulicaria*
Family: *Rostratulidae*
Greater Painted Snipe *Rostratula benghalensis*
Family: *Jacanidae*
Pheasant-tailed Jacana *Hydrophasianus chirurgus*
Bronze-winged Jacana *Metopidius indicus*
Family: *Burhinidae*
Eurasian Thick-knee *Burhinus oedicnemus*
Great Thick-knee *Esacus recurvirostris*
Family: *Charadriidae*
Eurasian Oystercatcher *Haematopus ostralegus*
Black-winged Stilt *Himantopus himantopus*
Pied Avocet *Recurvirostra avosetta*
Pacific Golden Plover *Pluvialis fulva*
Grey Plover *Pluvialis squatarola*
Common Ringed Plover *Charadrius hiaticula*
Little Ringed Plover *Charadrius dubius*
Kentish Plover *Charadrius alexandrinus*
Lesser Sand Plover *Charadrius mongolus*
Greater Sand Plover *Charadrius leschenaultii*
River Lapwing *Vanellus duvaucelii*
Grey-headed Lapwing *Vanellus cinereus*
Red-wattled Lapwing *Vanellus indicus*
White-tailed Lapwing *Vanellus leucurus*
Family: *Glareolidae*
Oriental Pratincole *Glareola maldivarum*
Family: *Laridae*
Pallas‟ Gull *Larus ichthyaetus*
Brown-headed Gull *Larus brunnicephalus*
Black-headed Gull *Larus ridibundus*
Gull-billed Tern *Gelochelidon nilotica*
Caspian Tern *Sterna caspia*
River Tern *Sterna aurantia*
Lesser Crested Tern *Sterna bengalensis*

Great Crested Tern *Sterna bergii*
Common Tern *Sterna hirundo*
Little Tern *Sterna albifrons*
Whiskered Tern *Chlidonias hybridus*
White-winged Tern *Chlidonias leucopterus*
Black Noddy *Anous minutus*
Family: *Accipitridae*
Osprey *Pandion haliaetus*
Black-shouldered Kite *Elanus caeruleus*
Black Kite *Milvus migrans*
Brahminy Kite *Haliastur indus*
White-bellied Sea Eagle *Haliaeetus leucogaster*
Pallas" Fish Eagle *Haliaeetus leucoryphus*
Grey-headed Fish Eagle *Ichthyophaga ichthyaetus*
White-rumped Vulture *Gyps bengalensis*
Slender-billed Vulture *Gyps tenuirostris*
Short-toed Snake Eagle *Circaetus gallicus*
Crested Serpent Eagle *Spilornis cheela*
Eurasian Marsh Harrier *Circus aeruginosus*
Pied Harrier *Circus melanoleucos*
Hen Harrier *Circus cyaneus*
Pallid Harrier *Circus macrourus*
Crested Goshawk *Accipiter trivirgatus*
Shikra *Accipiter badius*
Oriental Honey-Buzzard *Pernis ptilorhyncus*
Greater Spotted Eagle *Aquila clanga*
Indian Spotted Eagle *Aquila hastata*
Changeable Hawk Eagle *Spizaetus cirrhatus*
Family: *Falconidae*
Common Kestrel *Falco tinnunculus*
Red-necked Falcon *Falco chicquera*
Oriental Hobby *Falco severus*
Peregrine Falcon *Falco peregrinus*
Family: *Podicipedidae*
Little Grebe *Tachybaptus ruficollis*
Family: *Anhingidae*
Darter *Anhinga melanogaster*
Family: *Phalacrocoracidae*
Little Cormorant *Phalacrocorax niger*
Indian Cormorant *Phalacrocorax fuscicollis*
Great Cormorant *Phalacrocorax carbo*
Family: *Ardeidae*
Little Egret *Egretta garzetta*
Great Egret *Casmerodius albus*
Intermediate Egret *Mesophoyx intermedia*
Cattle Egret *Bubulcus ibis*
Indian Pond Heron *Ardeola grayii*
Grey Heron *Ardea cinerea*
Goliath Heron *Ardea*

Purple Heron *Ardea purpurea*
Little Heron *Butorides striatus*
Black-crowned Night Heron *Nycticorax nycticorax*
Yellow Bittern *Ixobrychus sinensis*
Cinnamon Bittern *Ixobrychus cinnamomeus*
Black Bittern *Dupetor flavicollis*
Family: *Threskiornithidae*
Glossy Ibis *Plegadis falcinellus*
Black-headed Ibis *Threskiornis melanocephalus*
Eurasian Spoonbill *Platalea leucorodia*
Family: *Pelecanidae*
Great White Pelican *Pelecanus onocrotalus*
Spot-billed Pelican *Pelecanus philippensis*
Family: *Ciconiidae*
Painted Stork *Mycteria leucocephala*
Asian Openbill *Anastomus oscitans*
Black-necked Stork *Ephippiorhynchus asiaticus*
Lesser Adjutant *Leptoptilos javanicus*
Greater Adjutant *Leptoptilos dubius*
Family: *Fregatidae*
Great Frigatebird *Fregata minor*
Family: *Procellariidae*
Wilson‟s Storm-petrel *Oceanites oceanicus*

ORDER: PASSERIFORMES
Family: *Pittidae*
Indian Pitta *Pitta brachyura*
Mangrove Pitta *Pitta megarhyncha*
Family: I*renidae*
Golden-fronted Leafbird *Chloropsis aurifrons*
Family: *Laniidae*
Brown Shrike *Lanius cristatus*
Bay-backed Shrike *Lanius vittatus*
Long-tailed Shrike *Lanius schach tricolor*
Grey-backed Shrike *Lanius tephronotus*
Southern Grey Shrike *Lanius meridionalis*
Family: *Corvidae*
Mangrove Whistler *Pachycephala grisola*
Rufous Treepie *Dendrocitta vagabunda*
House Crow *Corvus splendens*
Large-billed Crow *Corvus macrorhynchos*
Ashy Woodswallow *Artamus fuscus*
Eurasian Golden Oriole *Oriolus oriolus*
Black-naped Oriole *Oriolus chinensis*
Black-hooded Oriole *Oriolus xanthornus*
Large Cuckooshrike *Coracina macei*
Black-winged Cuckooshrike *Coracina melaschistos*
Black-headed Cuckooshrike *Coracina melanoptera*
Rosy Minivet *Pericrocotus roseus*

Small Minivet *Pericrocotus cinnamomeus*
Scarlet Minivet *Pericrocotus flammeus*
Bar-winged Flycatcher-shrike *Hemipus picatus*
White-throated Fantail *Rhipidura albicollis*
Black Drongo *Dicrurus macrocercus*
Ashy Drongo *Dicrurus leucocephalus*
White-bellied Drongo *Dicrurus caerulescens*
Bronzed Drongo *Dicrurus aeneus*
Spangled Drongo *Dicrurus hottentottus*
Greater Racket-tailed *Drongo Dicrurus paradiseus*
Black-naped Monarch *Hypothymis azurea*
Asian Paradise-flycatcher *Terpsiphone paradisi*
Common Iora *Aegithina tiphia*
Family: *Muscicapidae*
Blue Rock Thrush *Monticola solitarius*
Orange-headed Thrush *Zoothera citrina*
Scaly Thrush *Zoothera dauma*
Tickell‟s Thrush *Turdus unicolor*
Red-throated Flycatcher *Ficedula parva*
Little Pied Flycatcher *Ficedula westermanni*
Verditer Flycatcher *Eumyias thalassina*
Pale-chinned Flycatcher *Cyornis unicolor*
Blue-throated Flycatcher *Cyornis rubeculoides*
Tickell‟s Blue Flycatcher *Cyornis tickelliae*
Grey-headed Canary Flycatcher *Culicicapa ceylonensis*
Siberian Rubythroat *Luscinia calliope*
Bluethroat *Luscinia svecica*
Oriental Magpie Robin *Copsychus saularis*
Indian Robin *Saxicoloides fulicata*
Black Redstart *Phoenicurus ochruros*
Siberian Stonechat *Saxicola torquata*
White-tailed Stonechat *Saxicola leucura*
Pied Bushchat *Saxicola caprata*
Family: *Sturnidae*
Chestnut-tailed Starling *Sturnus malabaricus*
Brahminy Starling *Sturnus pagodarum*
Common Starling *Sturnus vulgaris*
Asian Pied Starling *Sturnus contra*
Common Myna *Acridotheres tristis*
Bank Myna *Acridotheres ginginianus*
Jungle Myna *Acridotheres fuscus*
Family: *Sittidae*
Chestnut-bellied Nuthatch *Sitta castanea*
Velvet-fronted Nuthatch *Sitta frontalis*
Family: *Paridae*
Great Tit *Parus major*
Family: *Hirundinidae*
Sand Martin *Riparia riparia*
Barn Swallow *Hirundo rustica*

Red-rumped Swallow *Hirundo daurica*
Streak-throated Swallow *Hirundo fluvicola*
Family: *Pycnonotidae*
Red-whiskered Bulbul *Pycnonotus jocosus*
Red-vented Bulbul *Pycnonotus cafer*
Family: *Cisticolidae*
Zitting Cisticola *Cisticola juncidis*
Grey-breasted Prinia *Prinia hodgsonii*
Yellow-bellied Prinia *Prinia flaviventris*
Ashy Prinia *Prinia socialis*
Plain Prinia *Prinia inornata*
Family: *Zosteropidae*
Oriental White-eye *Zosterops palpebrosus*
Family: *Sylviidae*
Rusty-rumped Warbler *Locustella certhiola*
Blyth‟s Reed Warbler *Acrocephalus dumetorum*
Clamorous Reed Warbler *Acrocephalus stentoreus*
Thick-billed Warbler *Acrocephalus aedon*
Common Tailorbird *Orthotomus sutorius*
Common Chiffchaff *Phylloscopus collybita*
Dusky Warbler *Phylloscopus fuscatus*
Tickell‟s Leaf Warbler *Phylloscopus affinis*
Lemon-rumped Warbler *Phylloscopus chloronotus*
Yellow-browed Warbler *Phylloscopus inornatus*
Hume‟s Warbler *Phylloscopus humei*
Greenish Warbler *Phylloscopus trochiloides*
Large-billed Leaf Warbler *Phylloscopus magnirostris*
Blyth‟s Leaf Warbler *Phylloscopus reguloides*
Golden-spectacled Warbler *Seicercus burkii*
Striated Grassbird *Megalurus palustris*
Puff-throated Babbler *Pellorneum ruficeps*
Indian Scimitar Babbler *Pomatorhinus horsfieldii*
Striped Tit-Babbler *Macronous gularis*
Chestnut-capped Babbler *Timalia pileata*
Yellow-eyed Babbler *Chrysomma sinense*
Striated Babbler *Turdoides earlei*
Jungle Babbler *Turdoides striatus*
Family: *Alaudidae*
Rufous-winged Bushlark *Mirafra assamica*
Ashy-crowned Sparrow Lark *Eremopterix nigriceps*
Oriental Skylark *Alauda gulgula*
Family: *Nectariniidae*
Thick-billed Flowerpecker *Dicaeum agile*
Orange-bellied Flowerpecker *Dicaeum trigonostigma*
Pale-billed Flowerpecker *Dicaeum erythrorynchos*
Scarlet-backed Flowerpecker *Dicaeum cruentatum*
Purple-rumped Sunbird *Nectarinia zeylonica*
Purple Sunbird *Nectarinia asiatica*
Loten‟s Sunbird *Nectarinia lotenia*

Crimson Sunbird *Aethopyga siparaja*
Little Spiderhunter *Arachnothera longirostra*
Family: *Passeridae*
House Sparrow *Passer domesticus*
Forest Wagtail *Dendronanthus indicus*
White Wagtail *Motacilla alba*
Citrine Wagtail *Motacilla citreola*
Yellow Wagtail *Motacilla flava*
Grey Wagtail *Motacilla cinerea*
Richard"s Pipit *Anthus richardi*
Paddyfield Pipit *Anthus rufulus*
Tawny Pipit *Anthus campestris*
Tree Pipit *Anthus trivialis*
Olive-backed Pipit *Anthus hodgsoni*
Black-breasted Weaver *Ploceus benghalensis*
Streaked Weaver *Ploceus manyar*
Baya Weaver *Ploceus philippinus*
Finn"s Weaver *Ploceus megarhynchus*
Red Avadavat *Amandava amandava*
Indian Silverbill *Lonchura malabarica*
Scaly-breasted Munia *Lonchura punctulata*
Black-headed Munia *Lonchura Malacca*
Family: *Fringillidae*
Common Rosefinch *Carpodacus erythrinus*
Chestnut-eared Bunting *Emberiza fucata*

Note: The checklist has been prepared based on available literature and observations of several ornithologists. The difficult terrain and long periods of adverse climatic conditions make it difficult to conduct in-depth field studies in the area. As a result, the checklist, though comprehensive, is by no means complete. In addition, many of the species listed above are vagrants or considered extirpated from the Sundarban and visitors may not expect to see all the species listed.

A CHECKLIST OF SUNDARBAN REPTILES/AMPHIBIANS

REPTILES ORDER: CROCODILIA
Family: *Crocodylidae*
Mugger crocodile *Crocodylus palustris*
Saltwater crocodile *Crocodylus porosus*

ORDER: TESTUDINES OR CHELONIA OR TESTUDINATA
Family: *Dermochelyidae*
Leatherback sea turtle *Dermochelys coriacea*
Family: *Cheloniidae*
Loggerhead sea turtle *Caretta caretta*
Green sea turtle *Chelonia mydas*
Hawksbill sea turtle *Eretmochelys imbricata*
Olive ridley sea turtle *Lepidochelys olivacea*

Family: *Bataguridae*
Indian roofed turtle *Kachuga tecta*
Red crowned roofed turtle *Kachuga kachuga*
River terrapin *Batagur baska*
Spotted pond turtle *Geoclemys hamiltonii*
Family: *Trionychidae*
Narrow-headed soft turtle *Chitra indica*
Asian giant softshell turtle *Pelochelys cantorii*
Dark softshell turtle *Aspideretes nigricans* (B)
Indian flapshell turtle *Lissemys punctata*

ORDER: SQUAMATA; SUBORDER: LACERTILA
Family: *Gekkonidae*
Tokay gecko *Gekko gecko*
Brook‟s house gecko *Hemidactylus brookii*
Yellow-green house gecko *Hemidactylus flaviviridis*
Family: *Agamidae*
Indian garden lizard *Calotes versicolor*
Family: *Chamaeleonidae*
Indian chameleon *Chamaeleo zeylanicus*
Family: *Scincidae*
Keeled grass skink *Mabuya carinata*
Family: *Varanidae*
Bengal monitor *Varanus bengalensis*
Water monitor *Varanus salvator*
Yellow monitor *Varanus flavescens*

ORDER: SQUAMATA; SUBORDER: SERPENTS
Family: *Acrochordidae*
Wart snake or file snake *Acrochordus granulatus*
Family: *Boidae*
Common sand boa *Gongylophis conicus*
Indian rock python *Python molurus*
Family: *Colubridae*
Common vine snake *Ahaetulla nasuta*
Striped keelback *Amphiesma stolatum*
Dog-faced watersnake *Cerberus rynchops.*
Ornate flying snake *Chrysopelea ornata*
Common bronzeback tree snake *Dendrelaphis tristis*
Common smooth water snake *Enhydris enhydris*
White-bellied mangrove snake *Fordonia leucobalia*
Glossy marsh snake *Gerarda prevostiana*
Common wolf snake *Lycodon aulicus*
Banded kukri snake *Oligodon arnensis*
Indian rat snake *Ptyas mucosa*
Checkered keelback *Xenochrophis piscator*
Family: *Elapidae*
Common Indian krait *Bungarus caeruleus*
Banded krait *Bungarus fasciatus*

Monocled cobra *Naja kaouthia*
King cobra *Ophiophagus hannah*
Family: *Hydrophiidae*
Hook-nosed sea snake *Enhydrina schistosa*
Blue sea snake *Hydrophis caerulescens*
Annulated sea snake *Hydrophis cyanocinctus*
Black-banded sea snake *Hydrophis nigrocinctus*
Estuarine sea snake *Hydrophis obscurus*
Ornate sea snake *Hydrophis ornatus*
Malabar sea snake *Lapemis curtus*
Banded laticauda *Laticauda laticaudata*
Family: *Viperidae*
Russell‟s viper *Daboia russelii*
Spot-tailed pit viper *Trimeresurus erythrurus*

PRESUMED EXTINCT
Family: *Gavialiidae*
Gharial Gavialis gangeticus **(B) – Bangladesh only**

AMPHIBIANS ORDER: ANURA
Family: *Bufonidae*
Common Indian toad *Bufo melanostictus*
Family: *Microhylidae*
Ornate narrow-mouthed frog *Microhyla ornate*
Family: *Rhacophoridae*
Common tree frog *Polypedates maculatus*
Family: *Ranidae*
Skittering frog *Euphlyctis cyanophlyctis*
Indian pond frog *Euphlyctis hexadactylus*
Indian bull frog *Hoplobatrachus tigerinus*
Cricket frog *Limnonectes limnocharis*
Assam hills frog *Rana alticola.*

A CHECKLIST OF SUNDARBAN FISH

ORDER: CARCHARHINIFORMES (GROUND SHARKS)
Family: *Carcharhinidae* (Requiem sharks)
Whitecheek shark *Carcharhinus dussumieri*
Bull shark *Carcharhinus leucas*
Blacktip shark *Carcharhinus limbatus*
Blacktip reef shark *Carcharhinus melanopterus*
Tiger shark *Galeocerdo cuvier*
Ganges shark *Glyphis gangeticus*
Milk shark *Rhizoprionodon acutus*
Indian dog shark or Spadenose shark *Scoliodon laticaudus*
Whale shark *Rhincodon typus*
Grey bambooshark *Chiloscyllium griseum*
Slender bambooshark *Chiloscyllium indicum*
Family: *Sphyrnidae* (Hammerhead, bonnethead or scoophead sharks)
Winghead shark, *Eusphyra blochii*

Scalloped hammerhead *Sphyrna lewini*
Great hammerhead *Sphyrna mokarran*

ORDER: PRISTIFORMES (SAWFISHES)
Family: *Pristidae*
Knifetooth sawfish *Anoxypristis cuspidata*
Largetooth sawfish *Pristis microdon*
Smalltooth sawfish *Pristis pectinata*

ORDER: RAJIFORMES (SKATES AND RAYS)
Family: *Dasyatidae* (Stingrays)
Small-eye stingray *Dasyatis microps*
Pale-edged stingray *Dasyatis zugei*
Bleeker"s whipray *Himantura bleekeri*
Ganges stingray *Himantura fluviatilis*
Scaly whipray *Himantura imbricata*
Pointed-nose stingray *Himantura jenkinsii*
Blackedge whipray *Himantura marginatus*
Honeycomb stingray *Himantura uarnak*
Family: *Myliobatidae* (Eagle and manta rays)
Spotted eagle ray *Aetobatus narinari*
Banded eagle ray *Aetomylaeus nichofii*
Family: *Rhinobatidae* (Guitarfishes)
Annandale"s guitarfish *Rhinobatos annandalei*
Smoothback guitarfish *Rhinobatos lionotus*
Giant guitarfish *Rhynchobatus djiddensis*

ORDER: TORPEDINIFORMES (ELECTRIC RAYS)
Family: *Narcinidae* (Numbfishes)
Brown numbfish *Narcine brunnea*

ORDER: OSTEOGLOSSIFORMES (BONY TONGUES)
Family: *Notopteridae* (Featherbacks or knifefishes)
Clown knifefish *Chitala chitala*
Bronze featherback *Notopterus notopterus*

ORDER: ELOPIFORMES (TARPONS AND TENPOUNDERS)
Family: *Elopidae* (Tenpounders and ladyfishes)
Tenpounder *Elops machnata*
Family: *Megalopidae* (Tarpons)
Indo-Pacific tarpon *Megalops cyprinoides*

ORDER:ALBULIFORMES (BONEFISHES)
Family: *Albulidae* (Bonefishes)
Roundjaw bonefish *Albula glossodonta*

ORDER:ANGUILLIFORMES (EELS AND MORAYS)
Family: *Anguillidae* (Freshwater eels)
Indian mottled eel *Anguilla bengalensis*

Indonesian shortfin eel *Anguilla bicolor*
Mottled eel *Anguilla nebulosa*
Family: *Moringuidae* (Worm and spaghetti eels)
Moringua macrocephalus
Purple spaghetti eel *Moringua raitaborua*
Family: *Muraenidae* (Moray eels)
Freshwater moray *Gymnothorax tile*
Family: *Ophichthidae* (Snake eels and worm eels)
Finny snake eel *Caecula pterygera*
Rice paddy eel *Pisodonophis boro*
Greenspot snake eel *Pisodonophis hijala*
Maimed snake eel *Muraenichthys schultzei*
Family: *Muraenesocidae* (Pike conger eels)
Yellow pike conger *Congresox talabon*
Indian pike conger *Congresox talabonoides*
Common pike conger *Muraenesox bagio*
Daggertooth pike conger *Muraenesox cinereus*

ORDER: CLUPEIFORMES (HERRINGS)
Family: *Clupeidae* (Herrings, shads, sardines and menhadens)
Chacunda gizzard shad *Anodontostoma chacunda*
Thai gizzard shad *Anodontostoma thailandiae*
Ganges river sprat *Corica soborna*
White sardine *Escualosa thoracata*
Ganges river gizzard shad *Gonialosa manmina*
Indian river shad *Gudusia chapra*
Kelee shad *Hilsa kelee*
Bloch‟s gizzard shad *Nematalosa nasus*
Tardoore *Opisthopterus tardoore*
Raconda *Raconda russeliana*
Indian oil sardine *Sardinella longiceps*
Hilsa shad, River shad *Tenualosa ilisha*
Toli shad *Tenualosa toli*
Family: *Pristigasteridae*
Elongate ilisha *Ilisha elongata*
Coromandel ilisha *Ilisha filigera*
Kampen‟s ilisha *Ilisha kampeni*
Bigeye ilisha *Ilisha megaloptera*
Indian ilisha *Ilisha melastoma*
Indian pellona *Pellona ditchela*
Family: *Engraulidae* (Anchovies)
Goldspotted grenadier anchovy *Coilia dussumieri*
Ramcarat grenadier anchovy *Coilia ramcarati*
Reynald‟s grenadier anchovy *Coilia reynaldi*
Shorthead hairfin anchovy *Setipinna breviceps*
Dusky hairfin anchovy *Setipinna melanochir*
Gangetic hairfin anchovy *Setipinna phasa*
Scaly hairfin anchovy *Setipinna taty*
Indian anchovy *Stolephorus indicus*

Dussumier‟s thryssa *Thryssa dussumieri*
Hamilton‟s thryssa *Thryssa hamiltonii*
Malabar thryssa *Thryssa malabarica*
Moustached thryssa *Thryssa mystax*
Oblique jaw thryssa *Thryssa purava*
Bengal thryssa *Thryssa spinidens*
Slender thryssa *Thryssa stenosoma*
Orangemouth anchovy *Thryssa vitrirostris*
Family: *Chirocentridae* (Wolf herrings)
Dorab wolf herring *Chirocentrus dorab*
Whitefin wolf herring *Chirocentrus nudus*

ORDER: GONORHYNCHIFORMES (MILKFISH)
Family: *Chanidae*
Milkfish White mullet *Chanos chanos*

ORDER: CYPRINIFORMES (CARPS)
Family: *Cyprinidae* (Minnows, carps, barbs)
Mola carplet *Amblypharyngodon mola*
Mrigal *Cirrhinus cirrhosus*
Sind danio *Devario devario*
Silver razorbelly minnow *Salmostoma acinaces (Chela argentea)*
Large razorbelly minnow *Salmostoma bacaila*
Finescale razorbelly minnow *Salmostoma phulo*
Bengala barb *Bengala elanga*
Zebra danio *Danio rerio*
Flying rasbora (barb) *Esomus danricus*
Slender rasbora *Rasbora daniconius*
Silver hatchet danio *Chela cachius*
Indian glass barb *Chela laubuca*
Catla *Catla catla*
Reba *Labeo ariza*
Bata *Labeo bata*
Kalbosu (Orange-fin labeo) *Labeo calbasu*
Rohu *Labeo rohita*
Swamp barb *Puntius chola*
Rosy barb *Puntius conchonius*
Golden (dwarf) barb *Puntius gelius*
Olive barb *Puntius sarana*
Pool barb *Puntius sophore*
Onespot barb *Puntius terio*
Ticto barb *Puntius ticto*

ORDER: SILURIFORMES (CATFISH)
Family: *Bagridae* (Bagrid catfishes)
Menoda catfish *Hemibagrus menoda*
Day‟s mystus *Mystus bleekeri*
Gangetic mystus *Mystus cavasius*
Long whiskers catfish *Mystus gulio*

Striped dwarf catfish *Mystus vittatus*
Rita *Rita rita*
Long whiskered catfish *Sperata aor*
Giant river catfish *Sperata seenghala*
Family: *Siluridae* (Sheatfishes)
Butter catfish *Ompok bimaculatus*
Pabdah catfish *Ompok pabda*
Wallago *Wallago attu*
Family: *Schilbeidae* (Schilbeid catfishes)
Gangetic ailia *Ailia coila*
Garua catfish *Clupisoma garua*
Sharpnose catfish *Eutropiichthys vacha*
Indian potasi *Pseudeutropius atherinoides*
Silond catfish *Silonia silondia*
Family: *Pangasiidae* (Shark catfishes)
Yellowtail catfish, River pangus *Pangasius pangasius*
Family: *Sisoridae* (Sisorid catfishes)
Dwarf goonch *Bagarius bagarius*
Goonch *Bagarius yarrelli*
Indian gagata *Gagata cenia*
Gagata gagata
Glyptothorax botius
Glyptothorax telchitta
Gogangra viridescens
Kosi nangra *Nangra nangra*
Sisor catfish *Sisor rabdophorus*
Family: *Clariidae* (Airbreathing catfishes)
Walking catfish *Clarias batrachus*
Family: *Chacidae* (Squarehead catfishes)
Squarehead catfish *Chaca chaca*
Family: *Ariidae* (Sea catfishes)
T hreadfin sea catfish *Arius arius*
Engraved catfish *Arius caelatus*
Blacktip sea catfish *Arius dussumieri*
Gagora catfish *Arius gagora*
Blackfin sea catfish *Arius jella*
Spotted catfish *Arius maculatus*
Smooth headed catfish *Arius nenga*
Flat mouth catfish *Arius platystomus*
Sagor catfish *Arius sagor*
Sona sea catfish *Arius sona*
Shovelnose sea catfish *Arius subrostratus*
Beardless sea catfish *Batrachocephalus mino*
River catfish *Hemipimelodus jatius*
Soldier catfish *Osteogeneiosus militaris*
Family: *Heteropneustidae* (Airsac catfishes)
Stinging catfish *Heteropneustes fossilis*
Family: *Plotosidae* (Eeltail catfishes)
Gray eel catfish *Plotosus canius*

Striped eel catfish *Plotosus lineatus*

ORDER: AULOPIFORMES (GRINNERS)
Family: *Synodontidae* (Lizard fishes, Bombay duck)
Greater lizardfish *Saurida tumbil*
Brushtooth lizardfish *Saurida undosquamis*
Bombay duck *Harpadon nehereus*

ORDER: BATRACHOIDIFORMES (TOADFISHES)
Family: *Batrachoididae*
Grunting toadfish *Allenbatrachus grunniens*

ORDER: GADIFORMES (CODS)
Family: *Bregmacerotidae* (Codlets)
Spotted codlet Bregmaceros mcclellandi

ORDER: CYPRINODONTIFORMES (RIVULINES, KILLIFISHES AND LIVE BEARERS)
Family: *Aplocheilidae* (Killifishes)
Blue panchax *Aplocheilus panchax*

ORDER: BELONIFORMES (NEEDLEFISHES)
Family: *Belonidae*
Banded needlefish *Strongylura leiura*
Spottail needlefish *Strongylura strongylura*
Freshwater garfish *Xenentodon cancila*
Family: *Hemiramphidae*
Gangetic halfbeak *Dermogenys brachynotopterus*
Wrestling halfbeak *Dermogenys pusilla*
Jumping halfbeak *Hemiramphus archipelagicus*
Congaturi halfbeak *Hyporhamphus limbatus*
Long billed halfbeak *Rhynchorhamphus georgii*
Ectuntio halfbeak *Zenarchopterus ectuntio*
Family: *Adrianichthyidae* (Ricefishes)
Ricefish *Oryzias carnaticus*

ORDER: SYNGNATHIFORMES (PIPEFISHES AND SEAHORSES)
Family: *Syngnathidae*
Freshwater pipefish *Ichthyocampus carce*
Crocodile tooth pipefish *Microphis cuncalus*
Deocata pipefish *Microphis deocata*

ORDER: SYNBRANCHIFORMES (SWAMP AND SPINY EELS)
Family: *Synbranchidae* (Swamp eels)
Cuchia, Gangetic mud eel *Monopterus cuchia*
Bengal eel *Ophisternon bengalense*
Family: *Mastacembelidae* (Spiny eels)
Lesser spiny eel *Macrognathus aculeatus*
One-stripe spinyeel *Macrognathus aral*

Barred spiny eel *Macrognathus pancalus*
Zig-zag eel, Tire-track spiny eel *Mastacembelus armatus*
ORDER: SCORPAENIFORMES (SCORPIONFISHES & FLATHEADS)
Family: *Platycephalidae* (Flatheads)
Bartail flathead *Platycephalus indicus*

ORDER:PERCIFORMES (PERCH-LIKE)
Family: *Latidae* (Perches)
Barramundi, Giant seaperch *Lates calcarifer*
Waigieu seaperch *Psammoperca waigiensis*
Family: *Ambassidae* (Glass fishes)
Bald glassy Ambassis *gymnocephalus*
Elongate glass-perchlet *Chanda nama*
Highfin glassy perchlet *Parambassis lala*
Indian glassy fish *Parambassis ranga*
Family: *Serranidae* (Sea basses: groupers and fairy basslets)
Orange spotted grouper *Epinephelus coioides*
Giant grouper *Epinephelus lanceolatus*
Family: *Terapontidae* (Grunters and tigerperches)
Fourlined terapon *Pelates quadrilineatus*
Jarbua terapon *Terapon jarbua*
Small-scaled terapon *Terapon puta*
Largescaled therapon *Terapon theraps*
Family: *Sillaginidae* {Sillagos (Smelt-whitings)}
Flathead sillago *Sillaginopsis panijus*
Clubfoot sillago Sillago chondropus
Silver sillago, Silver whiting *Sillago sihama*
Soringa sillago *Sillago soringa*
Family: *Carangidae* (Jacks and pompanos)
Indian threadfish *Alectis indicus*
Razorbelly scad *Alepes kleinii*
Longnose trevally *Carangoides chrysophrys*
Malabar trevally *Carangoides malabaricus*
Bigeye trevally *Caranx sexfasciatus*
Japanese scad *Decapterus maruadsi*
Golden trevally *Gnathanodon speciosus*
Torpedo scad *Megalaspis cordyla*
Black pomfret, Brown pomfret *Parastromateus niger*
Barred queenfish *Scomberoides tala*
Bigeye scad *Selar crumenophthalmus*
Yellowstripe scad *Selaroides leptolepis*
Family: *Menidae* (Moonfishes, batfishes)
Moonfish *Mene maculata*
Family: *Leiognathidae* (Ponyfishes)
Goldstripe ponyfish *Leiognathus daura*
Common ponyfish *Leiognathus equulus*
Striped ponyfish *Leiognathus fasciatus*
Splendid ponyfish *Leiognathus splendens*
Pugnose ponyfish *Secutor insidiator*

Deep pugnose ponyfish *Secutor ruconius*
Family: *Lutjanidae* (Snappers)
Mangrove red snapper *Lutjanus argentimaculatus*
Humpback red snapper *Lutjanus gibbus*
John"s snapper *Lutjanus johnii*
Malabar blood snapper *Lutjanus malabaricus*
Russell"s snapper *Lutjanus russellii*
Family: *Datnioididae*
Fourstripe perch *Datnioides polota*
Family: *Lobotidae* (Tripletails)
Atlantic tripletail *Lobotes surinamensis*
Family: *Gerreidae* (Mojarras)
Whipfin silver-biddy *Gerres filamentosus*
Saddleback silver-biddy *Gerres limbatus*
Slender silver-biddy *Gerres oblongus*
Common silver-biddy *Gerres oyena*
Strong spine silver-biddy *Gerres phaiya*
Small Bengal silver-biddy *Gerres setifer*
Family: *Haemulidae* (Grunts)
Bluecheek silver grunt *Pomadasys argyreus*
Silver bream *Pomadasys hasta*
Family: *Sparidae* (Porgies and sea breams)
Yellowfin seabream *Acanthopagrus latus*
King soldierbream *Argyrops spinifer*
Goldlined seabream *Rhabdosargus sarba*
Family: *Nemipteridae* (Threadfin breams and spinycheeks)
Japanese threadfin bream *Nemipterus japonicus*
Family: *Sciaenidae* (Croakers and drums)
Chaptis bahaba *Bahaba chaptis*
Reeve"s croaker *Chrysochir aureus*
Bengal corvina *Daysciaena albida*
Goatee croaker *Dendrophysa russelii*
Belanger"s croaker *Johnius belangerii*
Karut croaker *Johnius carutta*
Coitor croaker *Johnius coitor*
Cuja croaker *Macrospinosa cuja*
Soldier croaker *Nibea soldado*
Bronze croaker *Otolithoides biauritus*
Pama croaker *Otolithoides pama*
Hooghly croaker *Panna heterolepis*
Pennahia ovata
Blackspotted croaker *Protonibea diacanthus*
Blotched tiger-tooth croaker *Pterotolithus maculatus*
Family: *Polynemidae* (Threadfins)
Fourfinger threadfin *Eleutheronema tetradactylum*
Indian threadfin *Leptomelanosoma indicum*
Striped threadfin *Polydactylus plebeius*
Sixfinger threadfin *Polydactylus sexfilis*
Paradise threadfin *Polynemus paradiseus*

Family: *Mullidae* (Goat fishes)
Sulphur goatfish *Upeneus sulphureus*
Family: *Toxotidae* (Archerfishes)
Largescale archerfish *Toxotes chatareus*
Family: *Drepaneidae* (Sicklefishes)
Concertina fish *Drepane longimana*
Spotted sicklefish *Drepane punctata*
Family: *Monodactylidae* (Moonyfishes or fingerfishes)
Silver moony *Monodactylus argenteus*
Family: *Nandidae* (Asian leaf fishes)
Gangetic leaf fish *Nandus nandus*
Family: *Badidae*
Badis *Badis badis*
Family: *Kurtidae* (Nurseryfishes)
Indian hump head *Kurtus indicus*
Family: *Mugilidae* (Mullets)
Largescale mullet *Liza macrolepis*
Gold-spot mullet *Liza parsia*
Greenback mullet *Liza subviridis*
Tade mullet *Liza tade*
Flathead mullet *Mugil cephalus*
Corsula *Rhinomugil corsula*
Cascasia mullet, Yellowtail mullet *Sicamugil cascasia*
Bluetail mullet *Valamugil buchanani*
Bluespot mullet *Valamugil seheli*
Speigler‟s mullet *Valamugil speigleri*
Family: *Cichlidae* (Cichlids)
Green chromide *Etroplus suratensis*
Family: *Uranoscopidae* (Stargazers)
Uranoscopus guttatus
Family: *Callionymidae* (Dragonets)
River dragonet *Callionymus fluviatilis*
Arrow dragonet *Callionymus sagitta*
Family: *Eleotridae* (Sleepers)
Duckbill sleeper *Butis butis*
Gangetic sleeper *Odonteleotris macrodon*
Dusky sleeper *Eleotris fusca*
Lutea sleeper *Eleotris lutea*
Family: *Gobiidae* (Gobies)
Tropical sand goby *Acentrogobius caninus,*
Acentrogobius cyanomos
Spotted green goby *Acentrogobius viridipunctatus*
Dragon goby *Apocryptes bato*
Scribbled goby *Awaous grammepomus*
Largesnout goby *Awaous melanocephalus*
Bathygobius ostreicola
Bumblebee goby *Brachygobius nunus*
Boddart‟s goggle-eyed goby *Boleophthalmus boddarti*
Mudskipper *Boleophthalmus dussumieri*

Tank goby *Glossogobius giuris*
Glass goby *Gobiopterus chuno*
Rubicundus eelgoby *Odontamblyopus rubicundus*
Maned goby *Oxyurichthys microlepis*
Taileyed goby *Parachaeturichthys polynema*
Giant mudskipper *Periophthalmodon schlosseri*
Periophthalmodon septemradiatus
Atlantic mudskipper *Periophthalmus barbarus*
Pearse‟s mudskipper *Periophthalmus novemradiatus*
Elongate goby *Pseudapocryptes elongatus*
Many-finned eelgoby *Pseudotrypauchen multiradiatus*
Walking goby *Scartelaos histophorus*
Knight goby *Stigmatogobius sadanundio*
Eel worm goby *Taenioides anguillaris*
Burmese gobyeel *Taenioides buchanani*
Bearded worm goby *Taenioides cirratus*
Burrowing goby *Trypauchen vagina*
Family: *Scatophagidae* (Scats)
Spotted scat *Scatophagus argus*
Family: *Siganidae* (Rabbitfishes)
Streaked spinefoot *Siganus javus*
Family: *Sphyraenidae* (Barracudas)
Great barracuda *Sphyraena barracuda*
Family: *Trichiuridae* (Cutlassfishes and scabbardfishes)
Longtooth hairtail *Eupleurogrammus glossodon*
Smallhead hairtail *Eupleuroarammus muticus*
Coromandel hairtail *Lepturacanthus pantului*
Savalani hairtail *Lepturacanthus savala*
Gangetic hairtail *Trichiurus gangeticus*
Largehead hairtail *Trichiurus lepturus*
Family: *Scombridae* (Mackerels, tunas and bonitos)
Kawakawa *Euthynnus affinis*
Indian mackerel *Rastrelliger kanagurta*
Narrow-barred Spanish mackerel *Scomberomorus commerson*
Indo-Pacific king mackerel *Scomberomorus guttatus*
Family: *Stromateidae* (Butterfishes)
Silver pomfret *Pampus argenteus*
Chinese silver pomfret *Pampus chinensis*
Pampus cinereus
Family: *Anabantidae* (Climbing gouramies)
Climbing perch *Anabas testudineus*
Family: *Osphronemidae* (Gouramies)
Banded gourami *Colisa fasciata*
Spiketail paradise fish *Pseudosphromenus cupanus*
Dwarf gourami *Colisa lalia*
Frail gourami *Ctenops nobilis*
Honey gourami *Trichogaster chuna*
Family: *Channidae* (Snakeheads)
Barca snakehead

Channa barca
Channa gachua
Great snakehead *Channa marulius*
Walking snakehead *Channa orientalis*
Spotted snakehead *Channa punctata*
Snakehead murrel *Channa striata*

ORDER: PLEURONECTIFORMES (FLATFISHES)
Family: *Psettodidae* (Psettodids)
Indian spiny turbot *Psettodes erumei*
Family: *Paralichthyidae* (Largetooth flounders)
Largetooth flounder *Pseudorhombus arsius*
Deep flounder *Pseudorhombus elevatus*
Malayan flounder *Pseudorhombus malayanus*
Three spotted flounder *Pseudorhombus triocellatus*
Family: *Citharidae* (Chitarids)
Yellow-dabbled flounder *Brachypleura novaezeelandiae*
Family: *Soleidae* (Soles)
Oriental sole *Brachirus orientalis*
Pan sole *Brachirus pan*
Eyed sole *Heteromycteris oculus*
Kaup‟s sole *Synaptura albomaculata*
Highfin sole *Zebrias altipinnis*
Family: *Cynoglossidae* (Tongue fishes)
Largescale tongue-sole *Cynoglossus arel*
Bengal tongue-sole *Cynoglossus cynoglossus*
Long tongue-sole *Cynoglossus lingua*
Malabar tongue-sole *Cynoglossus macrostomus*
Speckled tongue-sole *Cynoglossus puncticeps*
Bengal tongue-sole *Cynoglossus semifasciatus*
Doublelined tongue-sole *Paraplagusia bilineata*

ORDER: TETRADONTIFORMES (PUFFERS AND FILEFISHES)
Family: *Triacanthidae* (Triplespines)
Short-nosed tripodfish *Triacanthus biaculeatus*
Family: *Tetraodontidae* (Puffers)
Immaculate puffer *Arothron immaculatus*
Milkspotted puffer *Chelonodon patoca*
Green rough-backed puffer *Lagocephalus lunaris*
Lattice blaasop *Takifugu oblongus*
Ocellated pufferfish *Tetraodon cutcutia*
Green pufferfish *Tetraodon fluviatilis.*

A CHECKLIST OF SUNDARBAN CRUSTACEANS

ORDER: DECAPODA SUBORDER: DENDROBRANCHIATA
Family: *Penaeidae*
Jinga shrimp *Metapenaeus affinis*
Yellow prawn *Metapenaeus brevicornis*

Speckled prawn, ginger prawn *Metapenaeus monoceros*
Indian white shrimp *Penaeus indicus*
Kuruma prawn *Penaeus japonicus*
Banana prawn *Penaeus merguiensis*
Giant tiger prawn *Penaeus monodon*
Green tiger prawn, flower prawn *Penaeus semisulcatus*
Coral prawn, rainbow shrimp *Parapenaeopsis sculptilis*
Kiddi shrimp *Parapenaeopsis stylifera*
Fleshy prawn *Penaeus orientalis/Fenneropenaeus orientalis*
Redtail prawn Penaeus *penicillatus/Fenneropenaeus penicillatus*
Kadal shrimp, pink shrimp *Metapenaeus dobsoni*
Family: *Solenoceridae*
Solenocera indica
Family: *Sergestidae*
Tsivakihini paste shrimp *Acetes erythraeus*
Jawla paste shrimp, Jawala *Acetes indicus*
SUBORDER: PLEOCYEMATA
Family: *Atyidae*
Basket shrimp *Caridina gracilipes*
Bengal caridina *Caridina propinqua*
Family: *Palaemonidae*
Rushna shrimp, roshma prawn *Exopalaemon styliferus*
Ganges delta prawn *Leptocarpus fluminicola*
Java river prawn *Macrobrachium javanicum*
Kuncho river prawn *Macrobrachium lamarrei*
Monsoon river prawn *Macrobrachium malcolmsonii*
Shortleg river prawn *Macrobrachium mirabile*
Giant river prawn, scampi *Macrobrachium rosenbergii*
Hairy river prawn *Macrobrachium rude*
Goda river prawn *Macrobrachium scabriculum*
Spider prawn *Nematopalaemon tenuipes*
Family: *Alpheidae*
Brownbar snapping shrimp *Alpheus lobidens/*
Alpheus crassimanus
Alpheus paludicola
Family: *Hippolytidae*
Hunter shrimp *Exhippolysmata ensirostris*
Family: *Thalassinidae*
Scorpion mud lobster *Thalassina anomala*
Family: *Palinuridae*
Mud spiny lobster *Panulirus polyphagus*
Family: *Scyllaridae*
Flathead lobster *Thenus orientalis*
Family: *Diogenidae*
Striped hermit crab *Clibanarius padavensis*
Family: *Coenobitidae*
Land hermit crab *Coenobita cavipes*
Family: *Ocypodidae*
Sand bubbler crab *Scopimera globosa*

INFRAORDER: BRACHYURA (True crabs)
Family: *Dorippidae* (Stalk eyed crabs or porter crabs)
Porter crab *Dorippe facchino*
Jellyfish crab *Ethusa indica*
Family: *Calappidae*
Fountain crab *Calappa lophos*
Box crab *Calappa pustulosa*
Moon crab *Matuta lunaris*
Flower moon crab *Matuta planipes*
Common moon crab *Matuta victor*
Family: *Leucosiidae* (Pebble crabs)
Leucosia craniolaris
Purse crab *Philyra globosa*
Philyra globulosa
Family: *Majidae* (Spider crabs)
Doclea canalifera
Doclea japonica
Family: *Hymenosomatidae* (Pill-box crabs)
Hairy pillbox crab *Hymenicus inachoides*
Wood pill box crab *Hymenicus masoni*
Family: *Portunidae*
Cross and angle crab, coral crab *Charybdis cruciata*
Red crab *Charybdis feriata*
Spiny hands *Charybdis hellerii*
Indo-Pacific swimming crab *Charybdis orientalis*
Flower crab *Portunus pelagicus*
Three spot swimming crab *Portunus sanguinolentus*
Giant mud crab *Scylla serrata*
Family: *Xanthidae*
Euricarcinus grandidieri
Stone crab/thunder crab *Myomenippe hardwickii*
Family: *Potamidae*
Freshwater field crab *Paratelphusa jacquemontii*
Paddy field crab *Paratelphusa hydrodromus*
Freshwater crab *Sartoriana spinigera*
Family: *Ocypodidae*
Soldier crab *Dotilla blanfordi*
Dotilla brevitarsis
Dotilla myctiroides
Ghost crab/red crab *Ocypode ceratophthalma*
Ghost crab *Ocypode macrocera*
Tympanomerus gangeticus
Common fiddler crab *Uca acuta*
Porcelain fiddler *Uca annulipes*
Uca dussumieri
Brackishwater crab *Uca lactea annulipes*
Rosy fiddler *Uca rosea*
Fiddler crab *Uca triangularis bengali*
Orange fiddler *Uca vocans*

Sentinel crab *Macrophthalmus depressus*
Macrophthalmus pectinipes
Family: *Grapsidae*
Tree-climbing mangrove crab *Episesarma tetragonum*
Signallar crabs, mangrove crabs *Metaplax crenulata Metaplax dentipes*
Mangrove crab *Metaplax distincta*
Metaplax indica
Metaplax intermedia
Grapsid crab *Metapograpsus maculatus*
Purple climber crab *Metapograpsus messor*
Red clawed crab *Perisesarma bidens*
Fancy crab, rainbow Crab *Sesarma chiromantes*
Sesarma impressa
Sesarma (Sesarmoides) longipes
Mangrove grapsid crab *Sesarma (Parasesarma) pictum*
Sesarma taeniolatum
Varuna Varuna litterata

ORDER: STOMATOPODA (MANTIS SHRIMP)
Family: *Squillidae* (Sqillid mantis shrimp)
Mantis shrimp *Oratosquilla nepa*

ORDER: XIPHOSURA SUBORDER: LIMULINA
Family: Limulidae (Horseshoe crabs)
Mangrove horseshoe crab *Carcinoscorpius rotundicauda*
Horseshoe crab *Tachypleus gigas*

Plate 1: A view of Indian Sundarban, the study area

Plate 2: An aftermath of cyclone “Aila” on 25th May, 2009

Plate 3: Inter-tidal habitat of Indian Sundarban

Plate 4: A typical tiger habitat in Indian Sundarban

Plate 5: Tigers in Indian Sundarban are excellent swimmers

Plate 6: Estuarine Crocodile is top aquatic predator of Indian Sundarban

Plate 7: Pioneer mangrove succession with Dhani grass (*Porteresia coarctata)*

Plate 8: Climax mangrove succession with Hental (*Phoenix paludosa*)

Plate 9: Earthen embankments to protect villages from tidal water

Plate 10: Flodding of saline water due to breach of enbankment

Plate 11: Stakeholder Consultations to identify the threats to the biodiversity of Indian Sundarban

Plate 12: Measurement of hydrological parameters (salinity, temperature and pH) in study area

Plate 13: Honey collection in Indian Sundarban

Plate 14 a: Recovery of the body parts of tiger killed during straying at Pakhiralaya village in 2001

Plate 14 b: Carcass of tiger killed by people at Kishorimohanpur village in 2001

Plate 15: Nylon- net fence to prevent tiger straying in Indian Sundarban


Plate 16: Immobilization Team in Sundarban Tiger Reserve

Plate 17: Radio Collaring of tiger in Indian Sundarban

Plate 18: Tiger prawn seed collection in Indian Sundarban

Plate 19: A juvenile estuarine crocodile in Indian Sundarban

Plate 20: The weight of Sundarban tiger is less as compared to the tigers of tarai and central India

Plate 21: Banbobi, the goddess of tigers is worshipped by Fishermen and Forest Department staff before entering the Sundarban forest

Plate 22: Honey bees collecting nectar from Hental (*Phoenix paludosa*) flowers

Plate 23: Shri Debnath Mondal, Forest Guard, injured by tiger at Netidopani in Indian Sundarban

Plate 24: A fisherman killed by tiger in Indian Sundarban

Plate 25: A strayed tiger on rooftop in Bali village in Indian Sundarban

Plate 26: "Chorapata Jal", the cause of major disturbance in Sundarban

Plate 27: Silted "Shakun Khal" bordering Shamshernagar and Kalitala villages, the worst affected areas for tiger straying in Indian Sundarban

Plate 28 a: A poorly maintained "Nylon-net fence"

Plate 28 b: Short height of Nylon- net fence- poor maintenance

Plate 28c: A severally damaged Nylon-net fence

Plate 29: Nylon –net fence with Bamboo post

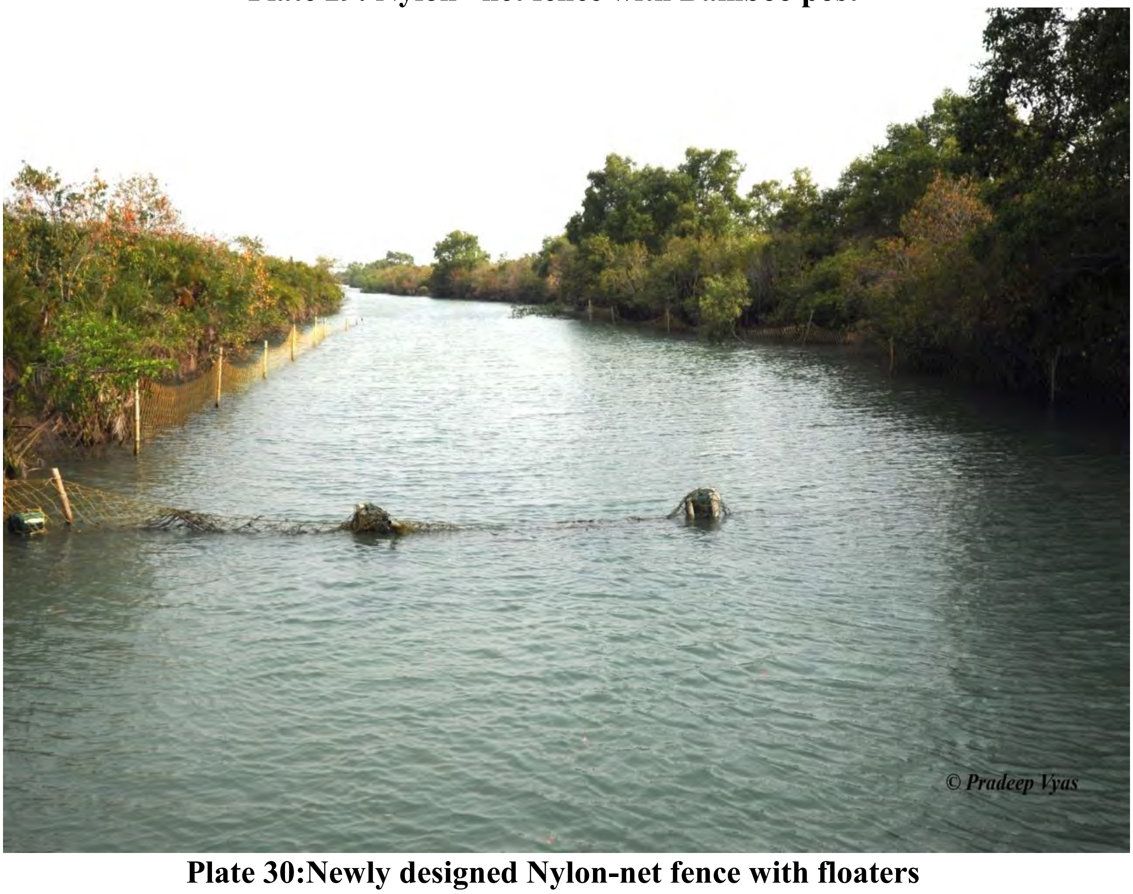


Plate 30:Newly designed Nylon-net fence with floaters

Plate 31: A wild animal rescued by people

Plate 32: A Forest Protection Committee meeting

Plate 33: "Rain water harvesting", an eco-development activity under Joint Forest Management programme

Plate 34: A "Self Help Group" under Joint Forest Management programme

Plate 35: A Camera-trap result in Indian Sundarban

Plate 36: Radio Collaring in Indian sundarban

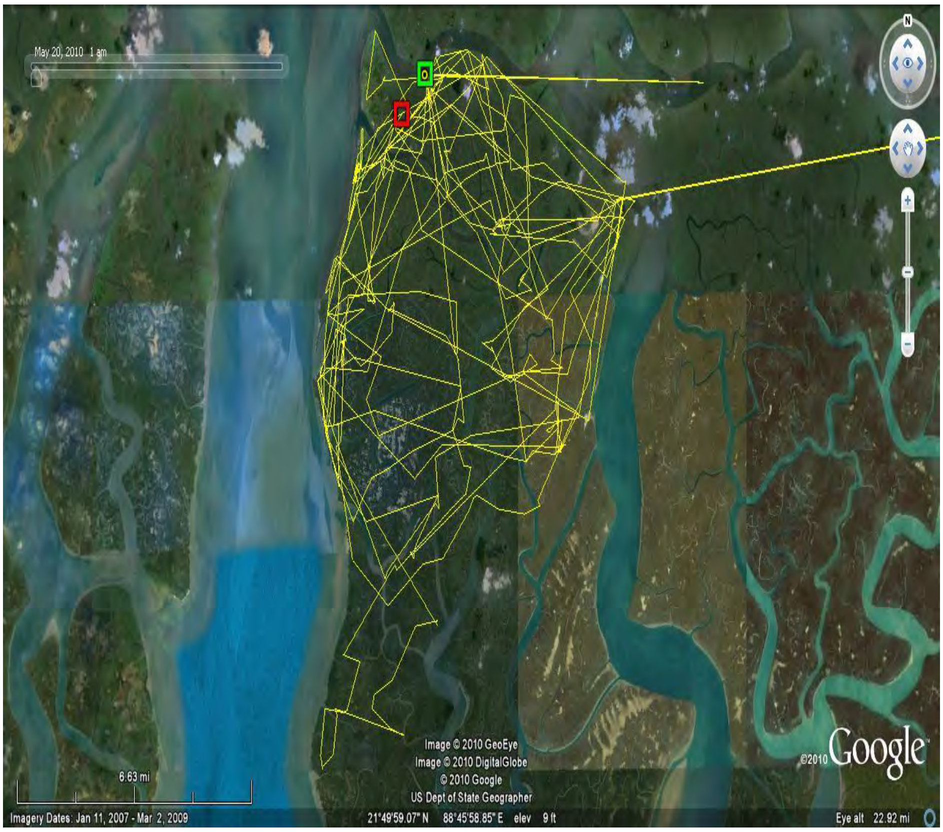


Plate 37: Movement of a "resident tiger" in Indian Sundarban

Plate 38: Movement of "Strayed tiger" from India to Bangladesh

Plate 39: Semi-digested King Cobra found during post-morteum of a tiger

Plate 40: “Deer Acclimatization Centre” at Dobanki in Indian Sundarban

Plate 41: Women are often part of fishing teams in 24 Parganas (South) Division whereas they are not involed in fishing in Sundarban Tiger Reserve

Plate 42: The root system of Keora (*Sonneratia apetala*)

Plate 43: Bidyadhari River, an earlier source of fresh water to Central Indian Sundarban has now silted up

Plate 44: A newly developed mudflat in Central Indian Sundarban

Plate 45: Severe land erosion in Central Indian Sundarban coast.

Plate 46: Erosion and mangrove mortality in Mayadwip block (Siamari) of Indian Sundarban

Plate 47: Prawn Seed collection by "Boat Method" may reduce human-crocodile and human-shark conflict

Plate 48: Crocodile nesting site in fresh water pond at Haldi camp

Plate 49: Development of "Prey Base Estimation Methodology" by Forest Department, West Bengal in collaboration with WWF, India

Plate 50 a: "Trap Cage", currently in use in Indian Sundarban

Plate 50 b: "Transportation Cage", currently in use by Forest Department, West Bengal in Indian Sundarban

Plate 51: Mangrove plantation on Geo-jute substratum around Nayachar Island.