Second Phase

Status of Tigers in Bangladesh Sundarban 2018

Forest Department
Ministry of Environment, Forest and Climate Change
Government of the People's Republic of Bangladesh

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Second Phase

Status of Tigers in Bangladesh Sundarban 2018

This report has been prepared using data collected under the Bengal Tiger Conservation Activity (BAGH) Project implemented by the Forest Department, WildTeam and its partners with financial support from USAID Bangladesh.

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Md. Shahab Uddin, MP
Minister
Ministry of Environment, Forest and Climate Change
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Message

Tiger conservation is our national priority. Conservation of this majestic and beautiful creature will lead to protect the forest ecosystem and thus would be able to conserve the tremendous wealth of biodiversity in the Sundarban.

The Bengal tiger is the national animal of Bangladesh. The importance of tiger conservation has been recognized as an important issue nationally and globally due to its threatened status. Habitat loss, decline in prey species, poaching for medicinal and cultural value and the ever expanding human population are the major threats to tiger's existence. Tigers are symbol of marvelous, numinous and predominant as well as integral part of the forest ecosystem. The loss of tiger is a great catastrophe to the ecosystem where it lives. It is our outmost obligation to save our tigers because Sundarban is the last refuge of the Bengal tigers in Bangladesh.

I am very much happy to know that Forest Department is going to publish the Second Phase Tiger Status Report in Bangladesh Sundarban. This is the second time Forest Department implemented camera-trapping in the Sunadarbans successfully with the financial support from Bengal Tiger Conservation Activity (BAGH) project with technical support from WildTeam, Smithsonian Conservation Biology Institute, USA, Jahangirnagar University, Bangladesh and Wildlife Institute of India. Bangladesh has already formulated the National Tiger Recovery Program and the Bangladesh Tiger Action Plan (BTAP) to achieve the goals of St. Petersburg declaration. I am overwhelmed to share this information with the whole country that the estimated tiger population size of Bangladesh Sundarban is 114. This figure is about 8% increase from the estimate of 2015. The result of this second assessment encourages us to move forward with all possible efforts for our tiger conservation. I expect that Bangladesh will be able to conduct the next survey by its own resource and technical expertise.

My sincere thanks and complements to all officers and staffs of the Bangladesh Forest Department, WildTeam, Smithsonian Conservation Biology Institute, USA and Bengal Tiger Conservation Activity (BAGH) Project, and scientists of Jahangirnagar University, Bangladesh and Wildlife Institute of India for implementation of this second assessment. I believe this report will give us insight about our way forward.

Md. Shahab Uddin, MP

Habibun Nahar, MP
Deputy Minister
Ministry of Environment, Forest and Climate Change
Government of the People's Republic of Bangladesh

Message

With the visionary leadership of our Honourable Prime Minister, Her Excellency Sheikh Hasina, Bangladesh has taken strong measures to save the Bengal tigers from the brink of extinction. In the Global Tiger Summit in 2010 at St. Petersburg, Russia she stood with the Prime Ministers and leaders of other tiger range countries and pledged to take all possible actions to double the number of wild tigers globally by 2022. I would like to convey my all supports in achieving the National Tiger Recovery Program developed in line with the Global Tiger Recovery Program.

Tiger is our national animal and our present government has strong commitment for the conservation of this majestic species. It is therefore our obligation to protect the tigers and to manage this tiger landscape sustainably for the future generation. However, conserving natural resources in the developing country is a real challenge because of excessive human pressure and their high level dependency on biodiversity for survival. Our government has also recognized this fact and taken projects and programs for the wellbeing of local communities who are dependent on the Sundarban for their livelihood.

The SMART patrolling that has been initiated a few years back in the Sundarban and collaborative management approach of the Sundarban appears to be very effective in improved protection of tigers and their habitats. As a result, we found an increasing trend of tiger population in the Sundarban of Bangladesh from the assessment conducted in 2015. It was possible because of continuous support of the government and immense dedication of the frontline staffs and community people.

Finally I express my heartfelt thanks to all officers and staffs of the Forest Department, WildTeam, Smithsonian Conservation Biology Institute, USA and Bengal Tiger Conservation Activity (BAGH) Project, and scientists of Jahangirnagar University, Bangladesh and Wildlife Institute of India for providing their untiring and relentless effort to complete the survey, data analysis and production of this report.

Habibun Nahar, MP

Abdullah Al Mohsin Chowdhury
Secretary
Ministry of Environment, Forest and Climate Change
Government of the People's Republic of Bangladesh

Message

The tiger is one of most charismatic animals on earth that has received the greatest concern for conservation over a few decades. Tiger is our national animal and we are united to save our heritage and culture with all possible efforts. Tiger conservation is not only important for Bangladesh but also for the global community.

There are several methods in assessing tiger population but above all, camera-trapping has been proved to be a very effective method in the tiger range countries. This study is the second successfully accomplished camera-trapping effort in assessing the status of tigers in Bangladesh Sundarban after the first assessment carried out in 2015. The present study has provided about 0.38% increase of tiger density compared to the 2015 assessment.

Tiger is a conservation dependent species that requires good quality habitat with sufficient preybase and undisturbed breeding grounds. Therefore, habitat management using science-based ecological data and protection of tigers and their prey from poaching are the prime prerequisites of meeting the goals of National Tiger Recovery Program and the Bangladesh Tiger Action Plan 2018-2027.

We are committed to take every possible step to conserve and protect our tigers in Bangladesh Sundarban. However, we have to assess the carrying capacity of our Sundarban so that we can determine our future target appropriately of how many tigers could be effectively managed in our Sundarban. Forest Department in collaboration with WildTeam, Smithsonian Conservation Biology Institute, USA, Jahangirnagar University, Bangladesh and the Wildlife Institute of India has conducted this study with the financial assistance from Bengal Tiger Conservation Activity (BAGH) project. I thank all staffs, officers and scientists involved in this study.

Abdullah Al Mohsin Chowdhury

Mohammed Shafiul Alam Chowdhury
Chief Conservator of Forests
Forest Department

Message

I am very happy to know that the Forest Department has assessed the tiger population of the Sundarban for the second time using well accepted camera-trapping method. All the tiger range countries have been using the camera-trap technique to estimate the abundance as well as density of tigers. With this second assessment study, we can now compare the current population estimates with the results of camera-trapping study conducted in 2015.

The Bangladesh Sundarban is intersected by a complex network of tidal waterways, mudflats and mosaics of salt tolerant mangrove forests. The complex ecosystems of the Sundarban have been recognized globally for supporting a rich assemblage of biodiversity and one of the five top global tiger populations of the world. It is therefore very important for us to know the abundance and density of tigers accurately, including scientific information on tiger's prey-base, habitat status and carrying capacity of the Sundarban.

The Spatially Explicit Capture Recapture analysis of the adult tiger individuals provided an overall density of 2.55 tigers per 100 km^2 in the current study. The result seems very realistic compared to the previous estimate which was conducted in 2015. It is also found that the tiger population has increased about 8% which is quite satisfactory given lots of challenges on the ground. The population trend is positive which indicates our current strategies and programmes for tiger conservation are effectively working. However, we will continue our efforts to further improve the protection and management of our Sundarban.

I believe, with the support from government, scientists, local community and above all the active support from the frontline staffs of the Forest Department, we would be able to reach our desired goals of conserving and protecting the tigers for future generation.

Mohammed Shafiul Alam Chowdhury

Md. Amir Hosain Chowdhury
Conservator of Forests, Khulna Circle &
Project Director, Bengal Tiger Conservation Activity (BAGH) Project

Message

I am delighted to say a few words on the occasion of publishing the second report of estimating tiger population which is a joint effort of Forest Department, WildTeam, Smithsonian Conservation Biology Institute, USA, Bengal Tiger Conservation Activity (BAGH) Project and our fellow scientists of the Wildlife Institute of India and Jahangirnagar University, Bangladesh. I am grateful to the Divisional Forest Officer Sundarban West, Divisional Forest Officer Sundarban East and Divisional Forest Officer Wildlife Management and Nature Conservation Division, Khulna for their immense support during the field survey.

We are very happy to affirm that Forest Department is gradually increasing its capacity in the era of camera-trapping for precisely assessing tiger populations. This is the first ever initiative where Bangladeshi scientist conducted the survey of camera-trapping, data analysis using the SECR approach and finally drafting the report. The report has been validated by the scientists of the Wildlife Institute of India. This study has given us tremendous information regarding tiger population and insights into their age and sex structure. This would help to improve the strategic management of our tigers and their habitats – the Sundarban.

I hope this report will be interesting and useful to conservation professionals and protected area managers. Now we look forward to implement the updated second generation Bangladesh Tiger Action Plan to ensure a better future for our tigers in the Sundarban of Bangladesh.

Md. Amir Hosain Chowdhury

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We are extremely grateful to Mr Mohammed Shafiul Alam Chowdhury, the Chief Conservator of Forests (CCF), Mr Md. Zahir Uddin Ahmed, DCCF, Planning Wing and former Project Director of the Bengal Tiger Conservation Activity (BAGH) Project, Mr Md. Bashirul Al Mamun (DFO, Sundarban West Division), Mr Md. Mahmudul Hasan (DFO, Sundarban East Division), Assistant Conservator of Forests of Khulna, Chandpai, Satkhira and Sarankhola ranges for their kind support throughout this work. We are also grateful to Mr Md. Zaheer Iqbal, DCF and his team in the Resource Information Management System (RIMS) Unit of Bangladesh Forest Department who extended their support by giving space and computers for data analysis.

The survey would not have been possible without the help of field staffs of the Forest Department and WildTeam. We are grateful to all foresters, forest guards and boatmen stationed at Sundarban for their support during the survey. The field data were collection successfully with the hard work of members of Village Tiger Response Team and other community people engaged in this work. We acknowledge the dedicated effort and hard work of the boatmen, sampan-drivers and support crews of the Guide Tours Ltd., Bengal Tours and Green Holiday Tours.

We particularly acknowledge and appreciate the outstanding support of Bengal Tiger Conservation Activity (BAGH) Project, WildTeam and Smithsonian Conservation Biology Institute, USA during the study. Our sincere thanks are due to Professor Dr Md. Anwarul Islam, Mr Garry F. Collins, Mr Iqbal Hossain, Mr Mahbubul Alam, Mr Isma Azam, Mr Abu Naim, Mr Tanvir Khan, Mr Zubair Hussni Fahad, Mr Adnan Hossain, Mr Sukur Ali and Dr Mahendara Shrestha.

We are extremely grateful to Mr Mike Meredith, Science Advisor to the Wildlife Conservation Society, WCS Malaysia Program and Vice-Chair of the Biodiversity Conservation Society Sarawak (BCSS) for his kind and invaluable support and advice to overcome the challenges of SECR data analysis. Sincere thanks are due to Dr Y.V. Jhala and his team of the Wildlife Institute of India for their effort in crosschecking all tiger images and useful comments on the report.

Authors

EXECUTIVE SUMMARY

This report presents the results of a camera-trapping survey on assessing the status of tigers (*Panthera tigris*) in Bangladesh Sundarban. Following a standard grid sampling approach, tiger images were obtained using remotely triggered camera-traps deployed at 536 locations. The camera-trapping exercise was carried out across three sample blocks of Satkhira, Khulna and Sarankhola covering 1,656 km^2 of the Bangladesh Sundarban in four phases between December 1, 2016 and May 10, 2018. Simultaneously, the khal (small rivers and creeks) surveys were conducted to record data on tiger sign (pugmark across river banks) in estimating the naïve occupancy of tigers in the Sundarban.

By spending 24,408 camera-trap nights within a total of 249 days, we obtained 2,466 images of tigers from the surveys. From these images, we identified 63 adult tigers, four juveniles and five cubs. The Spatially Explicit Capture Recapture (SECR) analysis of the adult tiger individuals provided an overall density of 2.55 tigers per 100 km^2 and a population of 114 tigers (95% CI: 89-146) for the Bangladesh Sundarban.

In 2015, the first ever status assessment of tigers using standard camera-trapping approach estimated the density of 2.17 tigers per 100 km^2 and a population of 106 (SE: 84-130) for the Bangladesh Sundarban. By comparing our results with the first assessment study, we found about 8% increase of the tiger population abundance from 2015 in the Bangladesh Sundarban.

Sample block-wise density estimates show that Sarankhola has the highest density of tigers (3.33 tigers/100 km^2) whilst the Khulna the lowest (1.21 tigers/100 km^2). A relatively very low density of tigers in Khulna block almost corresponded to the previous estimate of 2015. The exceedingly lower density of tigers in this region should be carefully taken into account in future protection management. Likewise highly skewed sex ratio of tigers in the Sarankhola block warrants immediate investigations of the issue and strengthened protection.

We recommend for future research to assess prey density and distribution across the Bangladesh Sundarban to fully understand the tiger-prey dynamics across the Sundarban. It is also important to assess the carrying capacity of tigers in the Sundarban in relation to the habitat quality and prey abundance to strategize appropriate management actions. We finally suggest proper implementation of SMART patrolling to best ensure that the tiger population can grow up to the carrying capacity of the Sundarban in meeting the goals set aside in the National Tiger Recovery Program and the Bangladesh Tiger Action Plan 2018-2027.

INTRODUCTION

The tiger is one of most charismatic animals on earth that has received the greatest concern for conservation over a few decades. Consequently, the International Union for Conservation of Nature (IUCN) has listed tigers globally Endangered in 1969 on the Red List of Threatened Species (Seidensticker, 2010; Walston et al., 2010a). Despite a long history of conservation efforts, it is quite distressful that tigers have lost 93% of their ancestral range across the globe (Sanderson et al., 2010). Similarly, the global populations have declined to fewer than 4,000 tigers from an estimated 100,000 tigers 100 years ago (Morell, 2007; Seidensticker, 2010). Increasing demand for natural resources leading to habitat degradation, large-scale infrastructural expansion, and the effects of human-induced climate change have placed an unprecedented pressure on biodiversity in general, and on the dwindling tiger population in particular (McNeely, 1997; Shahabuddin, 2010; Sodhi et al., 2004). The remaining global tigers are now restricted to relatively small regions mostly as small remnant populations in isolated forest patches (Walston et al., 2010b). Although it has been speculated that tigers may not go extinct within the next two decades, the current trajectory of population decline will certainly cause wild populations to disappear in many ranges, or to shrink to the point of "ecological extinction" – where their numbers are too few to sustain their role as a top predator in their ecosystem (Sanderson et al., 2006).

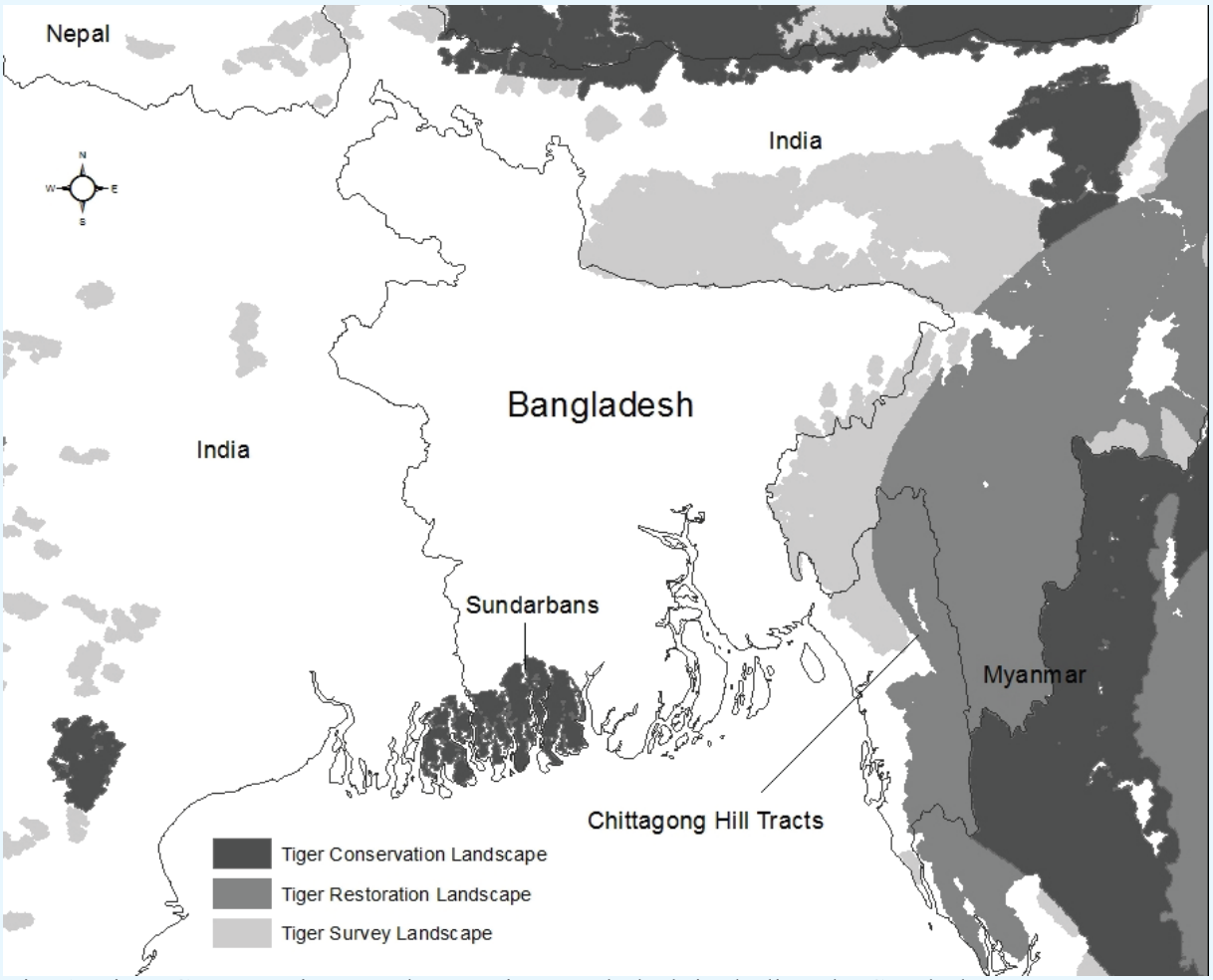

Fig. 1 Tiger Conservation Landscapes in Bangladesh including the Sundarban (data obtained from Sanderson et al., 2006).

Tigers now live in only 13 Tiger Range Countries (TRCs): Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Myanmar, Nepal, Russia, Thailand and Vietnam (Seidensticker, 2010). However, it is feared that Vietnam, Lao PDR and China might have lost the breeding populations, with no tigers left at all in Cambodia (Walston et al., 2010c; WWF, 2016). According to the latest estimate, the global population is now close to 3,900 tigers in the wild. This is an increase from the 2010 estimate of 3,200 tigers that has come primarily from India, Russia, Nepal and Bhutan. This increase is likely to be due to new areas being included in the national surveys, improved survey techniques as well as growth in the population from conservation efforts (WWF, 2016).

Fig. 2 Satellite image of the Sundarban (dark green); the red line indicates the border between India and Bangladesh.

The Indian Subcontinent is estimated to support approximately 60% of the global tiger populations, within only an estimated 8–25% of remaining global habitat (Jhala et al., 2008; Sanderson et al., 2006). The Sundarban mangrove forest shared between Bangladesh and India supports one of largest populations of Bengal tigers (Dey et al., 2015; Jhala et al., 2011), which has been ranked as a Class III TCL of global priority (Sanderson et al., 2006) (Fig. 1). The Bangladesh Sundarban (60% of the entire Sundarban) covering 6,017 km^2 is the last stronghold of tigers in Bangladesh (Fig. 2).

Tigers were once distributed across Bangladesh but now a viable population survived only in the Sundarban (Ahmad et al., 2009). Given the high potential of long-term survival of tigers in the Sundarban, it is expected that this important population can significantly contribute to global tiger conservation effort. However, like other tiger ranges, tigers in the Sundarban also face a range of threats including more pressing problems of direct tiger poaching, retaliatory killing of tiger, and human consumption of prey animals (Mohsanin et al. 2013; Saif et al. 2016; Aziz et al. 2017a).

Tiger is the keystone species of the Sundarban and deeply embedded in the very local culture, which has also been a source of local myths, legends and worshipping across communities living next to the Sundarban. Therefore, the loss of tigers may have adverse impact on the integrity and functionality of the entire ecosystem of the Sundarban, which in turn will affect lives and livelihoods of millions of local people (Ahmad et al. 2009).

Fig. 3 A typical view of the Sundarban of Bangladesh (Photograph © M. Abdul Aziz).

Acknowledging the need for concerted and collaborative conservation action to reverse the global tiger decline, heads of the state and representatives from the governments of all TRCs met in St Petersburg, Russia, in 2010 and made an unprecedented commitment to saving wild tigers. During the summit, the St. Petersburg Declaration was made by setting an ambitious goal of doubling the population of wild tigers by 2022, and endorsed the Global Tiger Recovery Program (GTRP) (Wikramanayake et al., 2011). Aligned with this commitment, Bangladesh has formulated the National Tiger Recovery Program, and has updated the first ever Bangladesh

Tiger Action Plan (BTAP) (2009-2017). The updated BTAP (2018-2027) sets the goal to ensure all possible efforts in sustaining the current tiger occupancy in over 6,017 km^2 and to increase the tiger density from the baseline estimate of 2.17 tigers/100 km^2 (Dey et al., 2015) to 4.50 tigers/100 km^2 within the next ten years. This incremental target was to set towards contributing to the GTRP commitment made by Bangladesh (Khan et al., 2018).

The BTAP and Integrated Resources Management Plans for the Sundarban (2010-2020) have recommended monitoring of tiger populations in the Sundarban using reliable scientific methods on regular basis (Ahmad et al., 2009; BFD, 2010). Using remotely triggered camera-traps tiger monitoring have been used widely across tiger ranges that yielded reliable information useful for regular monitoring (Karanth, 1995). Consequently the first ever systematic national survey conducted in 2015 using camera-traps estimated 106 tigers (95% CI: 84-130) for the Bangladesh Sundarban (Dey et al., 2015). Meanwhile, a DNA-based population study also provided an estimate of 121 tigers (95% CI: 84-158 tigers) by sampling over 1994 km^2 of the Bangladesh Sundarban (Aziz et al., 2017b)

Using the motion-triggered camera-trapping technique, the present assessment has been carried out after three years of the first assessment to (i) provide the updated status of tigers, (ii) monitor the population trend using baseline estimates, and (iii) to supplement to the currently implementing SMART (Spatial Monitoring and Reporting Tools) patrol in the Bangladesh Sundarban. To this end, the field data has been collected under the USAID's Bengal Tiger Conservation Activity (BAGH) project implemented by the Forest Department, WildTeam and its partners.

METHODS

2.1 Study Sites

Of the 6,017 km^2 of Bangladesh Sundarban (hereafter Sundarban), 4,267 km^2 is forest land and the remaining areas are waters in forms of rivers, creeks and estuaries (Iftekhar and Islam, 2004) (Fig. 3). The Sundarban is managed as a Reserved Forest (RF), allowing some level of resource collections subjected to permission from the Forest Department. There are three wildlife sanctuaries within the Sundarban that include the Sundarban West Wildlife Sanctuary, Sundarban South Wildlife Sanctuary and Sundarban East Wildlife Sanctuary. These sanctuaries were collectively declared UNESCO World Heritage Sites in 1997. In 2018, these sanctuaries were extended to include adjacent areas which give a total area of 3179.50 km^2, about 52% of total Sundarban of Bangladesh (Fig. 4). Besides, three wildlife sanctuaries covering a cumulative distance of 31 km of river channels of Sundarban rivers have been designated for the conservation of freshwater dolphins. The sanctuaries have a higher degree of protection compared to the reserved forest, and are close to all sorts of resource collections and related activities.

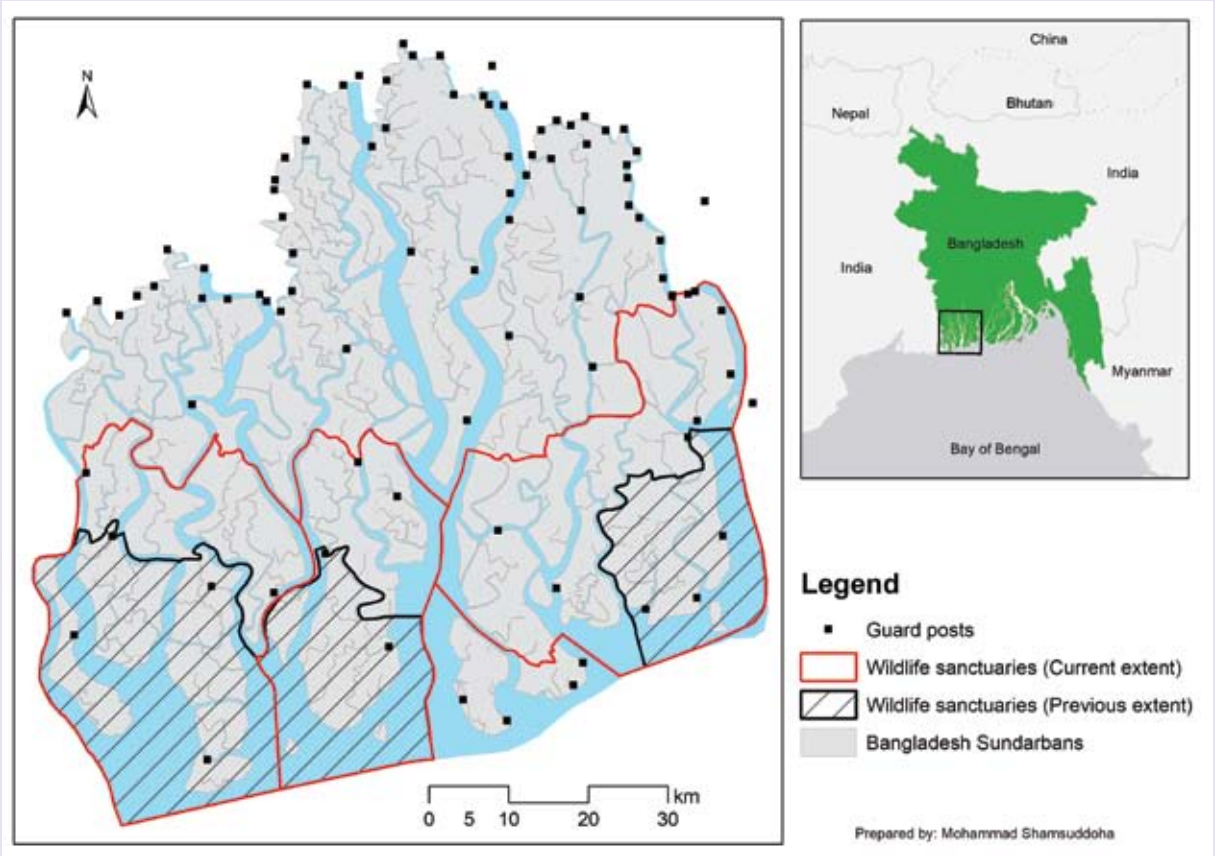

Fig.4 Wildlife sanctuaries and their recent extension within the Bangladesh Sundarban.

The Sundarban is one of the biologically diverse mangrove forests in the world, supporting 330 species of plants, over 440 species of fishes, 8 species of amphibians, 35 species of reptiles, more than 330 species of birds, and 42 species of mammals. The Sundarban forest is dominated by three mangrove species: Sundri (*Heritier afomes*), Gewa (*Excoecaria agallocha*) and Goran (*Ceriops candelleana*), where Sundri and Gewa occur more than 70% of the Sundarban. Most of the area is less than 1 m above the sea level (Canonizado and Hossain, 1998), comprises of many various sizes islands that are inundated daily by two high and low tides (Chaffey et al., 1985).

There are several mighty rivers dividing the entire Sundarban into several isolated forest landscapes: The Baleshwar River forms the eastern boundary of the Sundarban while the Raimangal and Harinbhanga form the international boundary between Bangladesh and Indian Sundarban. The three wide rivers the Passur, the Sibsa and Arpangassia flowing from north to south divide the Bangladesh Sundarban into three major forest regions. All these rivers are more than ~1.5 km wide across their entire courses which have been known to be the effective barrier for tiger dispersal (Aziz et al., 2018; Naha et al., 2016).

Administratively the Sundarban is under the control of the Conservator of Forests in the jurisdiction of the Khulna Circle of the Bangladesh Forest Department. For day to day management, the entire Bangladesh Sundarban have been delineated into two divisions: Sundarban West and Sundarban East which are managed by two Divisional Forest Officers (DFO). An additional DFO under the Wildlife Management and Nature Conservation Division of Khulna is authorised to manage and implement activities in relation to wildlife of the Sundarban. The Sundarban East and West divisions have been further demarked into four ranges that named regionally as Satkhira, Khulna, Chandpai, and Sarankhola range (Ahmad et al., 2009).

Three sample areas were selected for this assessment, namely the Satkhira Block, Khulna Block and Sarankhola Block (Fig. 5). We selected these sample areas using sampling strategy adopted in the baseline survey (Dey et al., 2015), so that our results are comparable to monitor population trends across surveys.

2.1.1 Satkhira Block

The Satkhira sample block is within the Satkhira Range which situated on the west of the Sundarban covering an area of about 1,850 km² (Hussain, 1992). Although many rivers have sliced this forest range into numerous pieces of forest lands, three major patches can be broadly recognized isolated by wide rivers: the extreme south-western part of the Satkhira range locally known as Haldibunia is separated by the Raimangal River. The Haldibunia is a banana-shaped island with an area of approximately 73 km². The northern part of the island is separated from Indian Sundarban by a small river locally known as Chhaya River that is connected with both Raimangal and Harinbhanga (Fig. 2).

Two big rivers, Arpangassia on the east and Raimangal on the west, having width of more than 1.5 km have isolated a larger middle portion of the Satkhira range. The total area of this forest patches is about 1,100 km^2. Besides, another two rivers, namely the Jamuna and the Malancha also run across the middle part. An island named Kalir Char (island) covering an area of 27.7 km^2 but situated in Khulna Range also included in this block, being located adjacent to the Satkhira Range (Fig. 5).

2.1.2 Khulna Block

The Khulna Block includes the South Wildlife Sanctuary (WS) situated on the central southernmost part of the Sundarban which covers an area of 370 km^2. Another small island named'Putney' situated on the south-western part of South WS on the Bay of Bengal, and a newly emerged island called 'Bangabandhu Island' on the south-eastern part of the block were not included in this study.

Several wide rivers, the Morjat and the Namud Samudra on the east and the Malancha and the Boro Panga River on the west, having widths of more than 1.5 km have isolated this sample block from the Sarankhola and Satkhira ranges, respectively. The Bay of Bengal is on the south whilst the sanctuary is separated by the Kagakhal from the rest of the area.

2.1.3 Sarankhola Block

The Sarankhola Block is situated on the south-eastern part of the Sundarban covering an area of 312 km^2 within the East WS. The adjacent Forest Compartment 3 on the north is included considering a continuation of the habitat and previous sampling strategies (Aziz et al., 2017b; Dey et al., 2015). The Sarankhola block is surrounded by Dudhmukhi and Bhola rivers on the north, Betmore Gang on the west, the Bay of Bengal on the south and the Baleshwar River on the east. There is an egg-shaped island called 'Dimer char' situated in the south-eastern part of the area which was not included in this block.

2.2 Sampling Approach

Although the structured grid sampling approach is not mandatory to apply Spatially Explicit Capture Recapture (SECR) for capture-recapture data analysis, setting camera-traps following grid framework helps researchers to assess trap requirements and the distances between camera-traps to be deployed on the ground. We therefore used grid framework where the sampling areas were divided into grid cells (5×5 km in Satkhira block and 2×2 km in Khulna and Sarankhola blocks) for camera deployment. A pair of camera-traps (Cuddeback-X-ChangeTM, Model: 1279) was installed in each grid cell with a few adjustments. The survey team searched for tiger signs (tracks, scrapes, scent, etc.) in each grid cell in order to select a suitable location for setting the camera-trap.

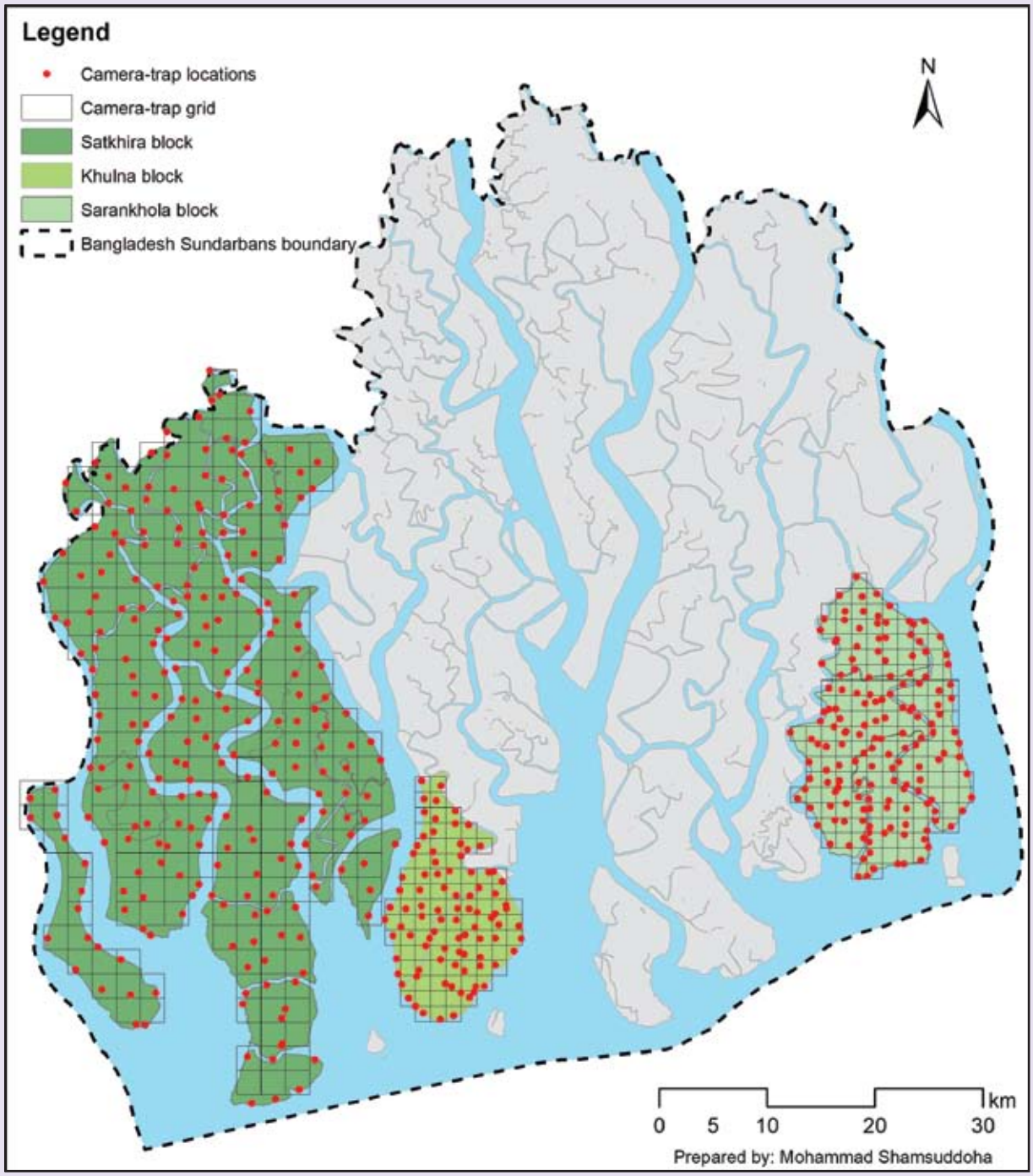

Fig.5 Map showing the sample blocks and camera-trapping positions in the Sundarban.

We considered intensity of tiger signs, elevation (assessing the impression of high tide left on tree trunks), sign of animal presence and low visibility of camera-traps for selecting location for camera-traps. After finding a potential location, we installed a pair of camera-traps on either sides of the location in approximately 45-50 cm height on tree trunks from the ground keeping a distance between two cameras from 7 to 8 m. If the location has high potential of capturing tiger image despite the elevation being very low, we set the camera-traps in relatively higher position from the ground. We assessed the maximum water level during the high or spring tide by detecting tide mark (usually whitish with holding silt) left on tree trunks/leaves. The team removed any obstacle (e.g., dead trees/branches) from between the cameras carefully not to leave any marked habitat modifications along the tracks. In some grid cells, additional sets of camera-traps were deployed that have higher intensity of tiger tracks to achieve greater capture probabilities. In such cases, we considered those additional locations as the separate camera-trap stations if the distance of the nearby camera-trap station were ≥500 m. Given the low probability of capture-recapture of tigers in the Sundarban landscapes (Karanth and Nichols 2000), we used natural lures to attract tigers to the camera-trap stations in order to increase the probability of detection.

Five survey teams comprising a team leader, 2 armed forest guards, 4 field assistants, and a boat driver carried out the camera-trap operations. The country boats (sampans) were used to cruise the khals to reach close to sample grids.

We numbered each camera-trap, memory card, and camera station (two camera-traps in single location) with unique ID so that individual tiger image can be easily sorted out and identified from the large number of images captured in each camera-trap. The geographic coordinates of each camera station were recorded on data sheet with a set of habitat attributes.

Due to the limited number of camera-traps, we sampled three sample blocks in four phases spanning over 40-45 days in each phase. Between December 1, 2016 and March 15, 2017 we conducted camera-trap operations in two phases in the Satkhira block. After finishing approximately first half of the sample block in the first phase between December 1, 2016 and January 28, 2017, we retrieved all camera-traps and deployed in the rest of the block (January29 –March 14, 2017). There were 166 camera-trap stations in the first phase and 87 in the second phase. Following year in 2018, we conducted the third phase and fourth phase of camera-trapping in Khulna and Sarankhola blocks, respectively. In Khulna block, 96 camera-traps were deployed between February 15 and April 24, 2018) and 187 in Sarankhola block between February 22 and May 10, 2018) (Fig. 5). All camera-traps were kept operational for 24 hours, except those were either malfunctioned or being theft. We checked camera-traps, replaced batteries and memory cards in every 10 to 15 days. Images captured by each camera-trap were downloaded on regular intervals (Fig. 6).

2.3 Khal Survey

Alongside the camera-trapping exercise, we have carried out khal (small rivers and canals) survey across the Sundarban in 2017 and 2018. Data were collected on the sign of tiger crossing (tiger track set), tiger's prey sign and human disturbance by covering previously used 65 sample units (Barlow et al., 2008). A total of 4 teams each comprising staff members from Bagh project and the Forest Department carried out the survey (Fig. 7).

Fig.6 Survey team installing a camera-trap in the Sundarban (Photograph © WildTeam)

Fig.7 Khal survey team looking for tiger signs on river bank in the Sundarban (Photograph © WildTeam).

A cumulative linear distance of 1,450 km and 1,183 km of khals were surveyed during 2017 and 2018, respectively. The tiger sign data sets were then overlaid on the 10×10 km^2 grid squares (Fig. 9) to determine the naïve occupancy of tigers that allowed us to compare our results with the 2015 baseline tiger assessment (Dey et al., 2015). In determining the total areas of the Sundarban occupied by tigers, we used the naïve occupancy by removing spatial extent of rivers with >1 km width as non-habitat (Aziz et al., 2017b), and any grid squares devoid of tiger signs (Dey et al., 2015).

2.4 Data Analysis

Initial data analyses were conducted at RIMS unit of the Bangladesh Forest Department by a team of tiger scientists, wildlife biologists, and researchers of the Bangladesh Forest Department, WildTeam and Jahangirnagar University. First, all tiger images were separated from the massive amount of photographs captured by camera-traps. The tiger images were screened based on the clarity of tiger flanks which is important for individual identification. Each qualified image was then labelled, stored and linked the left and right profiles with a unique identification number using camera station number. Individual tigers were identified uniquely based on stripe patterns on flanks, head, tails, and limbs (Karanth, 1995; Karanth and Nichols, 2002). Whenever possible, we also identified the sex of the individual tiger based on external genitalia. The age of tigers was approximately determined by body size and appearance using: cubs for<12 months; juveniles for 12–24 months; and adults for 24 months or older, when clear photographs are available (Karanth et al., 2006; Karanth and Stith, 1999).

We calculated the number of individual tiger capture(s)-recapture(s) in same or different camera location(s) and cumulative tiger numbers from the capture-recapture history and camera trap layout data. Using all data obtained from three sample blocks, we adopted SECR multisession model approach that uses the Maximum Likelihood framework for estimating tiger density and related parameters (Borchers and Efford, 2008; Efford, 2004). The SECR is the latest development of analysing capture-recapture data that allows for precise density estimate within the standard closed population model (Borchers et al., 2002; Otis et al., 1978). To this end, we created capture-recapture history matrix of the identified individual tiger following standard structure of input files (Efford, 2004). We calculated the minimum camera-trap area by drawing a polygon using the outer line of camera-trap locations. Besides, we created habitat mask by drawing a trap polygon with a buffer of approximately 20 km (4×σ, sigma) using the outermost camera-trap locations (Borchers and Efford, 2008; Efford, 2011). We removed water-bodies as 'non-habitat' from calculating habitat mask where there are rivers within the sample areas wider than 1 km (Aziz et al., 2017b; Roy et al., 2016). We considered these rivers as an effective barrier to tiger dispersal as well as 'hard boundary' because tigers rarely crossed the river wider than 400 m in the Sundarban (Naha et al., 2016). We ran SECR inbuilt models (null model and behavioural response model) fitting variable detection probability at animal activity centre (g0), tiger density (D~1), and spatial movement parameter (σ~1) separately for estimating overall and sample block-wise parameters. We finally selected the best-fit model based on low Akaike Information Criterion (AIC) value from the candidate models. Maximum-likelihood analysis was carried out using the package SECR in program R version 3.5.0 (R Core Development Team, 2018). All maps were created using ArcGIS 10.4.

RESULTS

With a sampling effort of 24,408 camera-trap nights, we obtained a total of 2,466 tiger images from 536 camera-trap stations deployed at 491 grid cells. Tigers were detected in 265 (49%) out of the 536 camera-trap stations (Fig. 10). From these images, a total of 63 adult tigers (9 males, 44 females and 10 remained unidentified), 4 juveniles and 5 cubs were identified (Table 1, 2).

Table 1. Summary of the camera-trapping effort and outputs in the Sundarban.

Parameters	Satkhira block	Khulna block	Sarankhola block	Overall
Total number of camera-trap stations	253	96	187	536
Number of days sampled	102	69	78	249
Numberof camera-trap stations captured tiger images	146	21	98	265
Total number of tiger images captured	1,675	78	713	2,466
Total Identified adult tiger individuals	36	4	23	63
Male tigers	6	1	2	9
Female tigers	22	3	19	44
Sex-unidentified tigers	8	0	2	10
Number of cubs	2	0	3	5
Number of juveniles	3	0	1	4
Maximum occasion of captures in a single station	14	9	9 (n=2)	14
Maximum individual captured in a single station	3	3	4	4
Maximum capture of a single individual	30 (n=2)	18	33	33
Maximum relocations of a single individual	21	12	22	22
Total camera-trap nights	10,965	4,762	8,681	24,408
Minimum camera-trap area (km^2)	1,208	165	283	1,656
Effective camera-trap area (km^2)	1,421	516	1,405	3,342

Table 2. Sample block, area, camera-trap locations with frequency of capture-recapture and number of individual tigers detected.

Sample block	Minimum camera-trap area (km^2)	No. of camera-trap stations	No. of camera-trap stations captured tigers	No. of individual tiger identified
Satkhira	1,208	253	144 (57%)	36
Khulna	165	96	21 (22%)	4
Sarankhola	283	187	98 (52%)	23
Total	**1,656**	**536**	**263 (49%)**	**63**

The best-fit model comprised the behavioural and site-specific learned response model which is expected because the traps were lured. With a half-normal detection function under the maximum likelihood framework, the sample block-wise analysis provided the highest density estimate for Sarankhola block (3.33 tigers/100 km^2; 95% CI: 1.82-4.13) followed by Satkhira block (2.74 tigers/100 km^2; 95% CI: 2.00-3.84) and Khulna (1.20 tigers/100 km^2; 95% CI: 0.45-3.23). The overall density of tigers in the Bangladesh Sundarban was estimated as 2.55±SE 0.32 (95% CI: 1.99-3.27) tigers per 100 km^2 (Table 3). By extrapolating this overall tiger density on the total area (4,464 km^2) occupied by tiger in the Sundarban, we estimated that the Bangladesh Sundarban may support a population of about 114 tigers (95% CI: 89-146 tigers).

Table 3. Sample area (forest land only), capture-recaptures and density parameter estimates with SECR model for area-wise and overall estimates of tigers of the Sundarban.

Name of sample block	No. of individuals detected	No. of total detections	Tiger density (D ± SE per 100 km^2)	Probability of detection (g0 ± SE)	Spatial distance moved (σ ± SE km)
Satkhira	36	1,675	2.74±0.46	0.012±0.0008	5.74±0.198
Khulna	4	78	1.20±0.64	0.006±0.0016	6.36±1.111
Sarankhola	23	713	3.33±0.71	0.012±0.0011	4.16±0.202
Overall (all sample areas)	**63**	**2,466**	**2.55±0.32**	**0.006±0.0004**	**6.20±0.218**

Fig.8 A breeding pair of tigers captured in a camera-trap in the Sundarban.

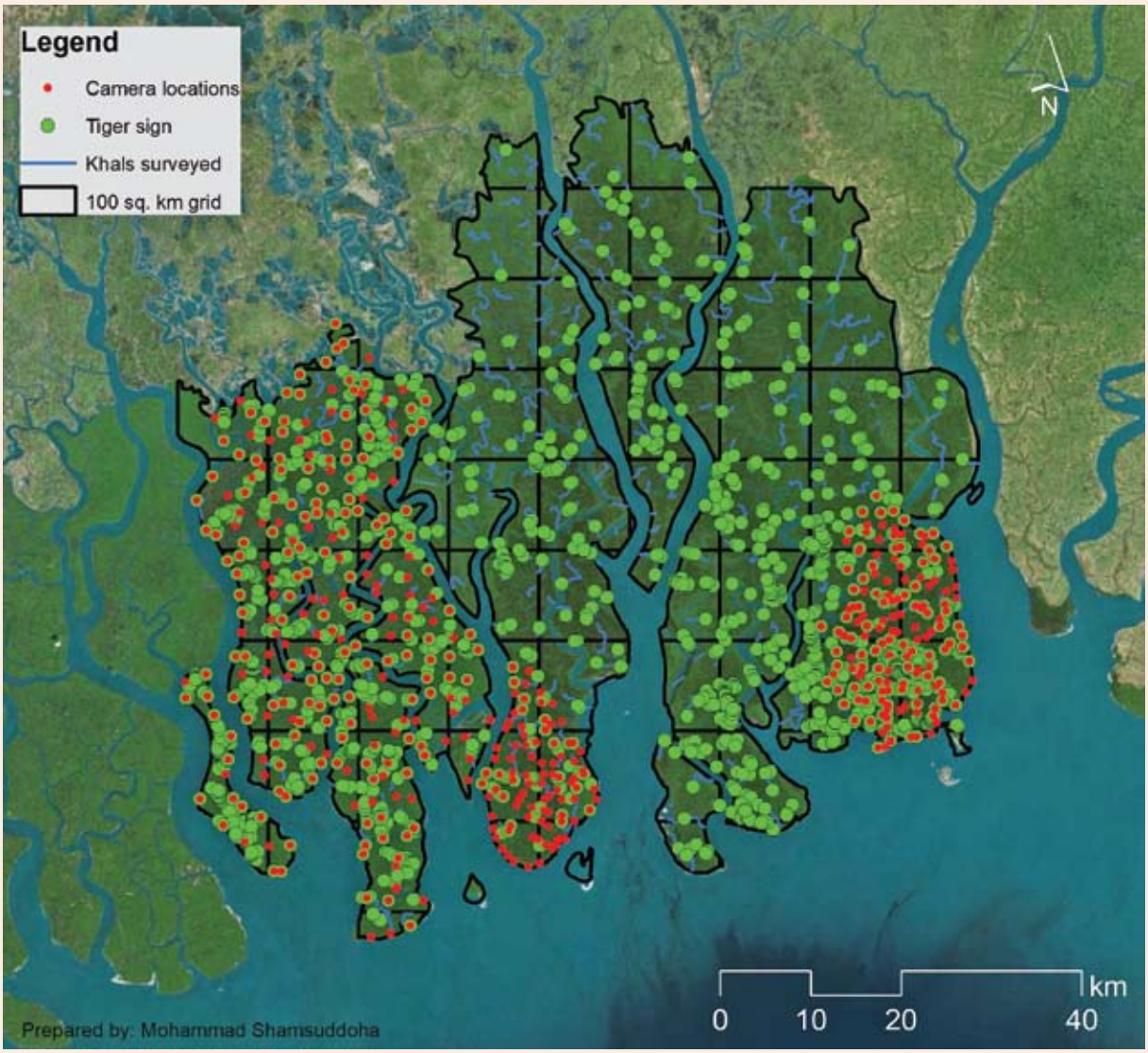

Fig.9 Tiger signs derived from khal surveys were overlaid on 10×10 km^2 grid squares of the Bangladesh Sundarban.

CONCLUSION

This is the second camera-trapping effort accomplished successfully in assessing the status of tigers in the Bangladesh Sundarban after the first assessment being carried out in 2015 (Dey et al., 2015). The present study has provided about 0.38% increase of tiger density compared to the 2015 assessment (Dey et al., 2015), translating into about 8% increase of tiger abundance in the Bangladesh Sundarban. The sample block-wise estimates show that tiger density slightly increases in Khulna block whilst it decreases in Satkhira and Sarankhola blocks (Table 4).

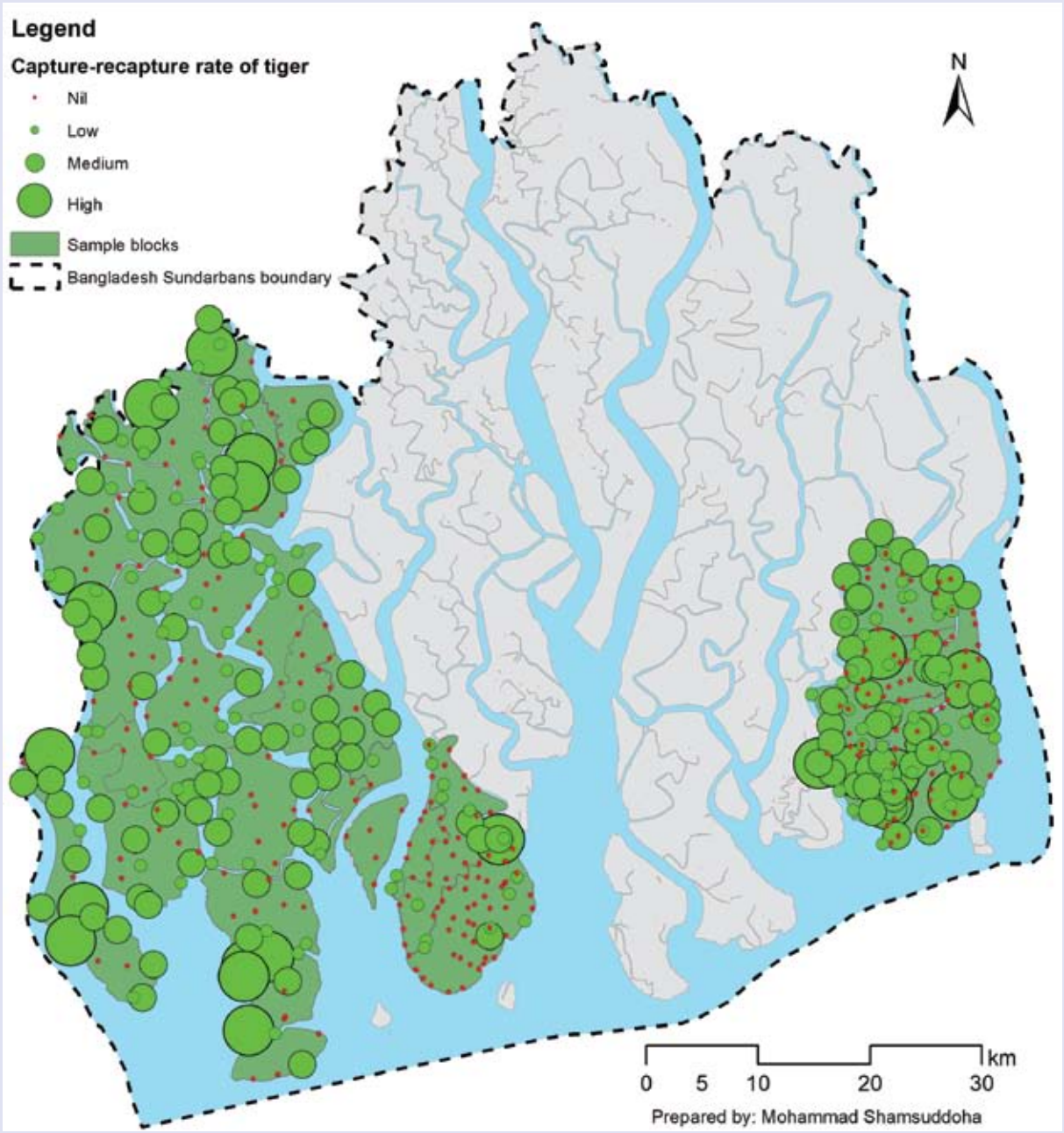

Fig.10 Frequency of tiger capture-recaptures across the sample blocks of the Sundarban.

Table 4.Comparison of sample area-wise and overall tiger density of this study with baseline study of 2015(Dey et al., 2015).

Sample block	Study	Sample area (km^2)	Total number of individual detected	Tiger density (D ± SE per 100 km^2)	Probability of detection (g0 ± SE)	Spatial distance moved (σ ± SE km)
Satkhira	This Study	1,208	36	2.74±(0.46	0.012±0.0008	5.74±0.198
	Dey et al. 2015	366	13	2.77±0.78	0.01±0.002	4.27±0.05
Khulna	This Study	165	4	1.20±0.64	0.006±0.0016	6.36±1.111
	Dey et al. 2015	588	7	1.08±0.04	0.003±0.0008	8.98±1.80
Sarankhola	This Study	283	23	3.33±0.71	0.012±0.0011	4.16±0.202
	Dey et al. 2015	309	18	3.70±0.91	0.01±0.003	3.37±0.35
Overall	This study	1,656	63	2.55±0.32	0.006±0.0004	6.20±0.218
	Dey et al. 2015	1265	38	2.17±NA	NA	NA

NA – not available

In the natural environment, population attributes of wild animals can be changed on temporal and spatial scales in responding to management activities and natural influences of inherent ecological factors (Begon et al., 2006). In case of large carnivores, the availability of prey, and their habitat condition, level of human activity and poaching of both prey and predator might have significant impacts on the density and abundance of tigers (Aziz et al., 2017a; Chapron et al., 2008). The increase in density as well as abundance of tigers in the Sundarban as we found in this study can be attributed to the fact that there might have some positive improvements of tiger and habitat managements. For example, implementing the SMART patrol and removing dacoits (aka parties) and other illegal resource collectors might have contributed to the overall improvement of tiger status. In a nutshell, it can be concluded that tiger populations in the Bangladesh Sundarban has slightly increased since the last assessment carried out in 2015, and reaching the goal of doubling tiger populations in the Sundarban may not be impossible if habitats are adequately protected with an adequate prey population, and no poaching.

RECOMMENDATIONS

5.1 Habitat Management

Tiger is a conservation dependent species that requires good quality habitat with sufficient prey base and undisturbed breeding grounds (Dey et al., 2015). Therefore, scientific management of habitat, protection of tigers and their prey from poaching are the prerequisites of meeting the goals of National Tiger Recovery Program and the Bangladesh Tiger Action Plan 2018-2027. Following key management actions are recommended:

1. The currently implementing SMART patrol should be properly applied (Fig. 11) and continued to carb further reduction of tigers and their prey animals being decimated through direct poaching.
2. There are signs of degradation of forest habitat on the northeastern boundary of the Sundarbandue to livestock grazing by local communities. Local administrative and political will are needed to stop further degradation of the habitat. Excavation of the rivers and khals on the forest borders in Chandpai range can help regulate this activity effectively.

Fig.11 SMART patrol in the Sundarban by the Bangladesh Forest Department (Photograph © WildTeam).

3. The unexpectedly lower density of tigers of Khulna block appearing in both 2015 and 2018 assessments suggest that there might have been serious negative impacts of unprecedented human activities of fisher-folks established in Dubla, Alorkol, Narikelbaria, etc. on tigers, its prey populations and their habitats. These issues need immediate attention.

5.2 Future Research

Tigers should be monitored on regular intervals in the Sundarban. It is recognised that impact of various threats to tigers could not be fully assessed without being able to monitor the tiger populations over time. With this study, two tiger monitoring surveys using camera-trapping technique were executed in the Sundarban – one in 2015 (field survey done in 2013-2014) and the current one in 2018 (field survey done in 2017-2018). However, interval between surveys should not exceed maximum three years. We therefore recommend next camera-trap assessment by 2021. Along with this, following research recommendations are made :

1. One serious concern is such a low density of tigers in Khulna block appeared in both assessments. This survey block completely overlaps with boundary of the South Wildlife Sanctuary, and the sanctuary is meant to be established for higher protection of tigers and their breeding grounds alongside other wild animals. From the very low detection of tigers in this sanctuary, we suspect that this area of the Sundarban might have either suffered from severe tiger and/or prey poaching or undergone to significant habitat degradation. It is therefore recommended to investigate factors affecting the low density as well as abundance of tigers in this region using sound scientific approaches.

2. Secondly, assessed sex of photo-captured tigers in the Sarankhola block demonstrates that tigers in this block have exceedingly skewed sex ratio, with only one male (male: female, 1: 10) in the entire sampled population. We thus recommend conducting a detailed habitat suitability analysis along with meta-analysis (e.g., survival rate/patterns between surveys) of tigers captured in both camera-trapping surveys.

3. Assessment of tiger's prey animals across the Sundarban is urgent to understand the carrying capacity of tigers. Methods for assessing prey abundance and distribution with specific focus to spotted deer and wild boar should be developed and performed along with tiger monitoring. Understanding on the prey dynamics in relation to tiger abundance is critical to undertake appropriate management actions for a healthy population of tigers in the Sundarban. This would allow assessing the carrying capacity of the Sundarban to understand how many tigers should be maintained as an optimum in the Sundarban.

4. Relationship between relative abundance (e.g., khal survey) and absolute abundance of tigers should be assessed so that cost effective and low-tech khal survey can be used frequently to detect population trends and identify emerging threats. This would allow applying khal survey to detect temporal as well as spatial changes of relative tiger abundance within short interval.

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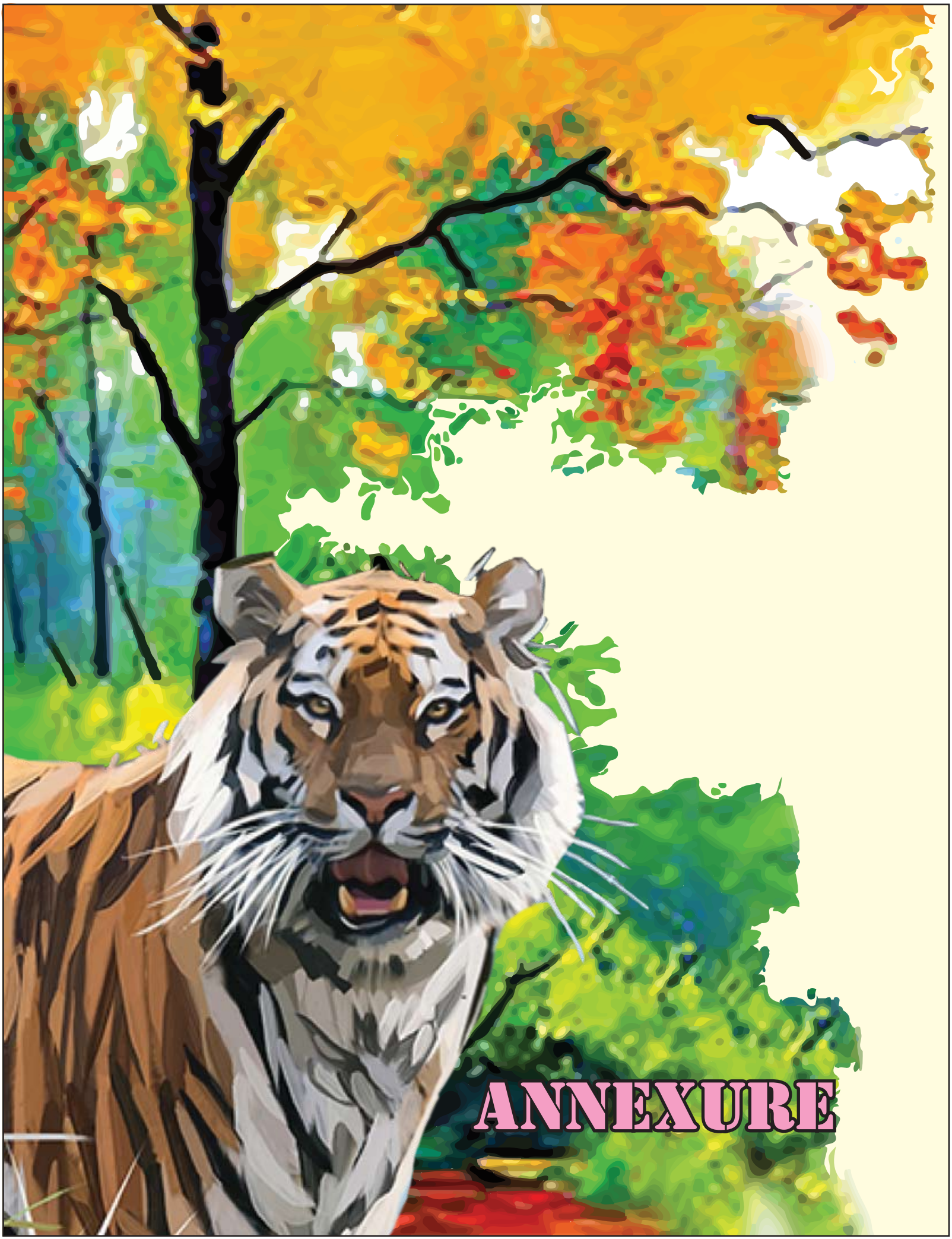

ANNEXURE


Photo Gallery

BLOCK - 1

Satkhira

T01-SK RF

RF T02-SK

T03-SK LF

LF T04-SK

T05-SK RF

RF T06-SK

T07-SK RF

LF T08-SK

T09-SK RF

RF T10-SK

T11-SK RF

LF T12-SK

T13-SK RF

LF T14-SK

T15-SK RF

LF T16-SK

T17-SK RF

LF T18-SK

T19-SK RF

LF T20-SK

T21-SK LF

LF T22-SK

T23-SK RF

RF T24-SK

T25-SK LF

RF T26-SK

T27-SK LF

LF T28-SK

T29-SK RF

LF T30-SK

T31-SK LF

RF T32-SK

T33-SK RF

LF T34-SK

T35-SK LF

RF T36-SK

T37-SK RF

BLOCK - 2

Khulna

T38-KL LF

RF T39-KL

T40-KL LF

RF T41-KL

BLOCK - 3

Sarankhola

T42-SR LF

LF T43-SR

T44-SR RF

RF T45-SR

T46-SR RF

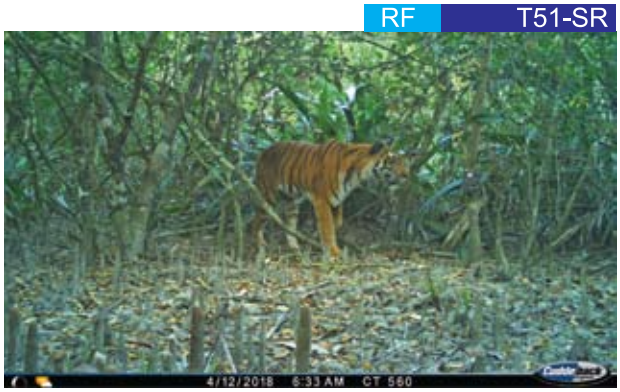
RF T47-SR

T48-SR RF

RF T49-SR

T50-SR RF

RF T51-SR



T52-SR RF

LF T53-SR

T54-SR LF

LF T55-SR

T56-SR RF

RF T57-SR

T58-SR LF

LF T59-SR

T59+T60-SR RF

RF T61-SR

T62-SR LF

LF T63-SR

TIGER CUBS

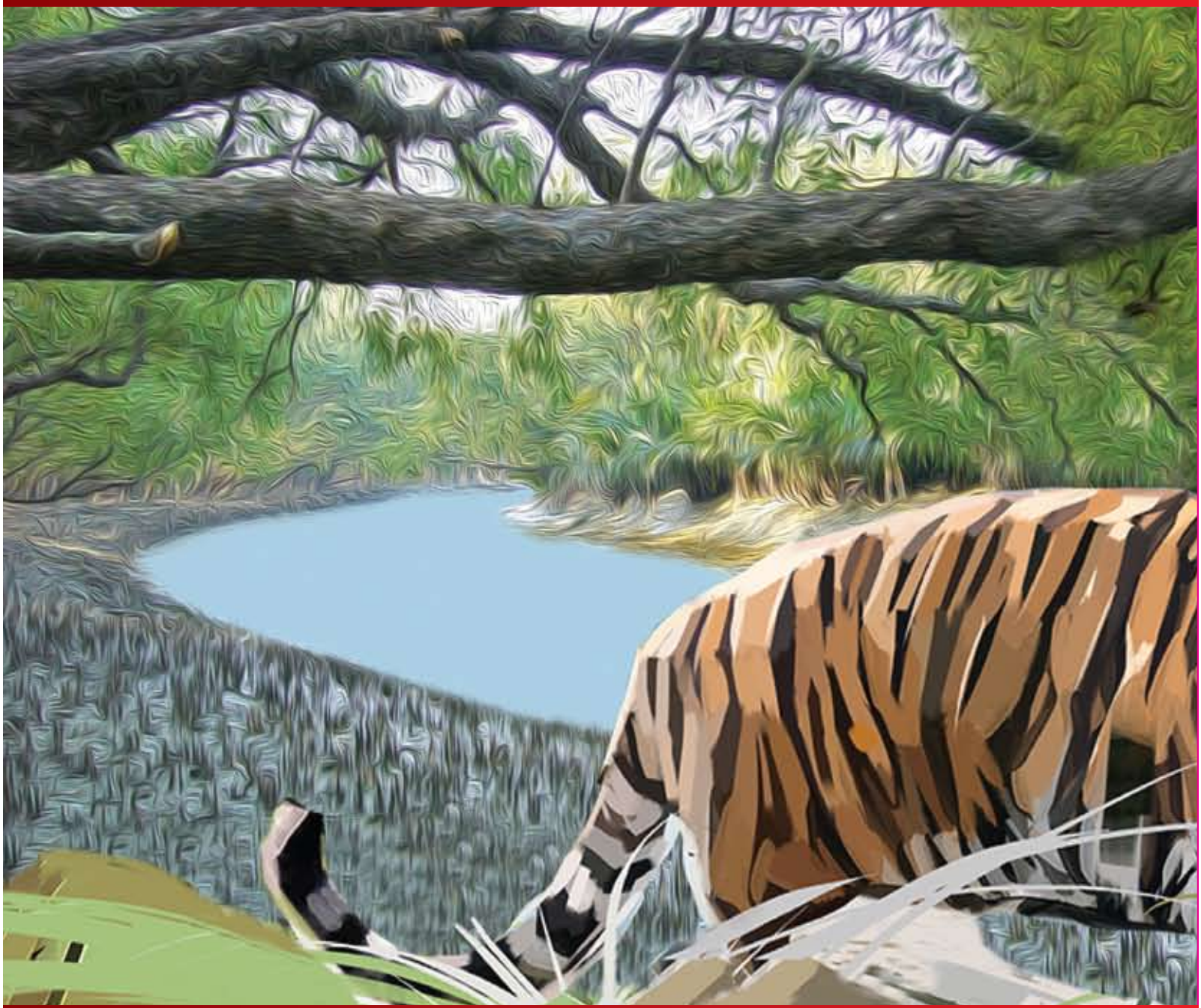
TC01-SR

TC02-SR

TC03-SK

TC04-SK

TC05-SK



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