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First Phase

Tiger Status Report

of

Bangladesh Sundarban

WILDLIFE MANAGEMENT AND NATURE CONSERVATION DIVISION, KHULNA

FOREST DEPARTMENT

MINISTRY OF ENVIRONMENT AND FORESTS

OCTOBER, 2015

FIRST PHASE TIGER STATUS REPORT OF BANGLADESH SUNDARBAN

WILDLIFE MANAGEMENT AND
NATURE CONSERVATION DIVISION, KHULNA
FOREST DEPARTMENT
MINISTRY OF ENVIRONMENT AND FORESTS

OCTOBER, 2015

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Preface

Tiger population estimation is a difficult task as they are nocturnal, solitary, elusive and cryptic in nature. It becomes more difficult in Sundarban landscape where tigers do not move in definite tracks. However estimation of tiger density and population size is urgently needed with a statistically robust approach to incorporate into Integrated Forest Resources Management Plans for Sundarban.

There are several methods for tiger population estimation. Bangladesh Forest Department did tiger estimation in 2004 with the financial assistance of United Nations Development Program and technical assistance from West Bengal Forest Department of India and methodology used was tiger pugmark. Wildlife sign survey is very good for distribution and can often provide relative abundance but estimates of absolute abundance are unreliable unless calibrated with more reliable methods. Camera trapping method is more scientific and reliable, but it is not possible to conduct this study throughout Sundarban within statistical frame work. However, double sampling approach of spatially explicit capture mark-recapture using camera traps and covariates of prey, tiger sign and human impacts seems to be statistically robust for Sundarban landscape.

This is the first robust scientific tiger estimation program in Bangladesh Sundarban with the technical assistance from Wildlife Instituate of India and financial assistance from World Bank funded IDA Project "Strengthening Regional Co-operation for Wildlife Protection Project" and comes with a baseline data for planners, researchers and managers. The study will partially fulfill the strategic Plan of Bangladesh Tiger Action Plan and commitments of Dhaka Declaration. We hope this tiger status report will be a landmark and will bring positive changes towards tiger conservation in Bangladesh.

Dr.Tapan Kumar Dey
Md. Jahidul Kabir
Bangladesh Forest Department

ACKNOWLEDGEMENT

We would like to acknowledge with gratitude our Honourable Minister Mr. Anwar Hossain Manju, Ministry of Environment and Forests for his overall support to tiger estimation Program. We would like to express our sincere thanks to Honourable Secretary Dr. Kamal Uddin Ahmed for his all out support and encouragement. Sincere thanks to Mr. Md. Yunus Ali, Chief Conservator of Forests and Chief Advisor of the tiger estimation program for his valuable suggestions and overall supervision.

We are extremely grateful to Member Secretary, National Tiger Conservation Authority, India and Director, Wildlife Institute of India. Without their technical support we could not have this program a successful one. Special thanks to Ahana Dutt assisted with data analysis, Swati Saini and Indranil Mondal of WII provided assistance with GIS and map preperation.

We would like to convey our gratitude to Mr. Kartik Chandra Sarker and Dr. Sunil Kumar Kundu, Conservator of Forests, Khulna Circle, and Mr. Zahir Uddin Ahmed and Mr. Md. Amir Hossain Chowdhury, Divisional Forest Officer of Bangladesh Forest Department for their support and valuable contribution. We acknowledge the contribution of Mr. Hoq Mahbub Morshed, Mr. Mehedi Hassan Khan, Dr. Farhana Rahman, Sohala Sarker, Rathindra Kumar Biswas, Forest Rangers, Foresters, Forest Guards, Junior Wildlife Scout, Boat Man and other supporting staff of Wildlife Management and Nature Conservation Division, Khulna, Sundarban East Forest Division and Sundarban West Forest Division for the tedious and sincere job they did during data collection and report writing.

This Sub-project was formulated to implement the strategic action of Bangladesh Tiger Action Plan 2009-2017 with the financial assistant from IDA supported Strengthening Regional Co-operation for Wildlife Protection (SRCWP) Project of the World Bank. Special thanks to Mr. Aparup Chowdhury, Additional Secretary and Mr. Md. Akbar Hossain, Deputy Chief Conservator of Forests and the Project Director of SRCWP project and all respected members of National Expert Committee of SRCWP Project.

Minister
Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

10 September, 2015

Message

Tiger conservation in the contemporary era has attarcted much global attention due to the highly endangered status of the tiger. A combination of factors such as habitat shrinkage, decline in prey species, poaching for medicinal and cultural value and the ever expanding human population, are direct threats faced by tigers. Tigers are not only a symbol of all that is splendid, mystical and powerful about nature but they are also an integral part of forest ecosystem. The loss of tiger would carry a great catastrophe to the ecosystem of the tiger range countries. In Bangladesh, the Sundarban is the last stronghold of the Bengal tiger (*Panthera tigris tigris*).

Conserving the tiger is our national imperative. By doing so, we save not only a magnificent species and our national animal, but we also end up protecting and regenerating our forest ecosystems and its tremendous wealth of biodiversity. Monitoring tiger population is a crucial component of evaluating the efficacy of our tiger conservation efforts.

There are several methods for determining tiger population in the world but above all, the camera trapping is been proved a very effective method in the tiger range countries. Years of using this method of analysis has proved that photographic capture – recapture sampling is a reliable technique for estimating tiger number. Camera traps are also helpful in quantifying the number of tiger; this is a more effective method than attempting to pug mark method. Camera traps enable collection of baseline population data on elusive mammals where only estimates and often just guesses were possible before.

However, Bangladesh Forest Department (BFD) for the first time implemented program to estimate the tiger in the Sundarban by camera trapping method. I feel proud to the managers to take the lead though they are not professional researcher. As a leader, if you don't lead the parade, it will move by without you. We need to empower forest department to continue such type of initiatives. Now, we have to review our Tiger Action Plan and National Tiger Recovery Program to achieve the vision 2021 of Global Tiger Recovery Program. Bangladesh forest department is the custodian of Royal Bengal Tigers of Sundarban. So, they have the main responsibility to come forward to save tiger. I know they are vibrant and dedicated towards tiger conservation. They have to find out a way how to restore tigers in the Sundarban. They have to sit with other stakeholders immediately and have to propose a plan for tiger conservation.

My sincere complements to the experts of Wildlife Institute of India for giving technical support to the process, My colleagues who involved in the implementation and preparing the report. I trust this report will give base line information how to way forward.

Anwar Hossain Manju, MP
Minister
Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

Deputy Minister
Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

Message

10 September, 2015

The tiger population of the earth is gradually decreasing. In early 21 century, tiger population of this earth was about 100000 but now the population is below 4000. Tigers were present in the major districts of Bangladesh in 1930's. Now, it is only the Sundarban mangrove forest covering an area of 6017 sq. km. where the tiger are still thriving in Bangladesh. The last population census in 2004 by Forest Department and UNDP through pug mark method indicates tiger population in Bangladesh Sundarban around 440 (Approx.) This pug mark methods is very old age practice and always over estimated. So, Scientists do not rely on it and there are debates in using the method. Recent developments in technology are bringing scientists' vision to reality through the use of electronic devices, such as thermal infra- red camera for tiger estimation. Bangladesh Forest Department successfully used the camera trap that is scientifically accepted worldwide to get base line information of tigers in the Sundarban from where we can make policy for the future.

Tiger is the National Animal of Bangladesh and our present Government has strong commitment for Sundarban tiger conservation landscape. Protecting the Sundarban is our obligation to future generations. If we can save tiger, Sundarban will be protected with it.

Her Excellency Sheikh Hasina, Honourable Prime Minister of the Government of the People's Republic of Bangladesh, with her visionary leadership, Bangladesh has taken strong measures to save wild tigers from extinction. She believes that tigers and people rely on the same ecosystems that must be healthy for both to thrive. In the Global Tiger Summit in 2010 at St. Petersburg, Russia she stood with the prime ministers and leaders of other tiger range countries, the World Bank, and other organizations as they pledged to take all possible action to double the number of wild tiger globally by 2022. Her continued leadership and commitment to that pledge is unwavering. I want to re-affirm my support and our Government's support for achieving the National Tiger Recovary Program within 2022.

This is a commendable effort towards Science based monitoring of tigers and will be of immense help in assisting formulation of conservation policy and management strategies for effective conservation of the species and the biota.

Finally I express my heartfelt thanks to all the officers and staffs of Forest Department, and others partners specially Wildlife Institute of India who provided their untiring and relentless effort to implement the project a success.

Abdullah Al Islam Jackob, M.P
Deputy Minister
Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

Secretary
Ministry of Environment and Forests
The Government of
the Peoples' Republic of Bangladesh
Bangladesh Secretariat, Dhaka
09 September, 2015

Message

Tiger conservation is not only significant for Bangladesh but also for the world community, specially the Tiger Range Countries. Tiger is our national animal and we are united saving our heritage and culture. Tiger population estimation and monitoring is very important global issue. There are several methods for determining tiger population in the world but above all, Camera Trapping has been proved to be a very effective method in the tiger range countries. It is highly distressing that the Royal Bengal Tiger, one of the most treasured species of tigers in the world, appears to extinct in its home, the Sundarban, Bangladesh. A recent estimation by the Forest Department shows a decline in number of big cats left in our part of the Sundarban.

As mentioned in the report, poaching of tigers and their prey and commercial traffic through their habitat in the Sundarban are major reasons behind such a steep decline of tiger population. I assume the plan to protect tigers of the Sundarban, Forest Department and other development partners have to be reviewed to arrest the declining tiger population which is concerning for biodiversity in the world's largest mangrove forests.

As it seems that tigers are nearing a point of extinction, priority projects should be undertaken to facilitate breeding of this endangered species. To keep track of the progress of tiger conservation projects regular monitoring through camera trapping and khal surveys should be continued. We must now unmistakable adopt the policy of protecting biodiversity of the Sundarban rather that allowing it to be damaged in the name of development.

Government will do everything for the conservation and protection of the tigers of its Bangladesh habitat in the uniquely beautiful, biodiversity rich Sundarban. Application of camera trapping method on the both side of Sundarban Tiger Conservation Landscape is a strong demand of Tiger experts. However, Bangladesh Forest Department in collaboration with the Wildlife Institute of India and with the financial assistance from IDA funded "Strengthening Regional Co-operation for Wildlife Protection Project" has conducted this study first time to estimate the number of tigers in Bangadesh Sundarban. I also hope that the Wildlife Institute of India and other development partners will maintain their continued supports to protect tiger's through capacity building, scientific monitoring & research findings.

Dr. Kamal Uddin Ahmed
Secretary
Ministry of Environment and Forests
Government of the Peoples' Republic of Bangladesh

Chief Conservator of Forests
Bangladesh Forest Department

Message

The Bangladesh Sundarban is intersected by a complex network of tidal waterways, mudflats and small islands of salt tolerant mangrove forests. The mangrove ecosystem is very complex but unique. The area has been recognized globally for its importance as a reservoir of biodiversity and home to charismatic mega fauna, the Bengal tiger. To conserve any flagship or keystone species it is very important to know the relative abundance or density of that species, prey or on which it depends on, habitat condition and carrying capacity of a given area.

That's why it is more important to know the trend of tiger population in the Sundarban rather than the absolute number of tiger. Using camera trap for developing relative abundance mapping will play more important role in tiger conservation. Tiger population estimation using camera trapping can be treated as a starting point for future comparison to assess the population trend.

If we consider diet composition, prey species diversity and abundance, food requirements and home range of tigers then it can be easily enumerated that carrying capacity of our Sundarban for 44O tiger is unrealistic. At the same time data enumerated by using camera trap seems a bit UNDERESTIMATED but More Realistic than the previous census. Still we have a viable population of tiger in the Sundarban. If we can reduce/control/ eliminate the major threats to the tigers and the Sundarban, our existing population will be out of the danger within a decade.

We have enough Laws, Treaties, Protocol, and Management Plan etc. to conserve our tiger. National commitment and proper implementation of these involving all stakeholders and strengthen Forest Department capability by human resource development and financial support: implementation of Tiger Summit 2010 declaration and Dhaka declaration 2014: involvement of all law and order implementing agency and local community to stop poaching of tiger and its prey. Being the custodians of the last remaining tigers in the Sundarban, we are taking all necessary initiatives to protect tigers.

I believe with the help of development partners and support from local communities and active support from the frontline staffs of the Forest Department we can reach at a point where our desired goal of protecting tigers can be achieved.

I wish all the best and cooperation.

Md. Yunus Ali
Chief Conservator of Forests
Bangladesh Forest Department.

Project Director
Strengthening Regional Cooperation for Wildlife Protection Project
and Deputy Chief Conservator of Forests
Bangladesh Forest Department

Message

It It is my pleasure to engrave few lines in the eve of publishing the report of estimation of tiger under the sub-project 'Tiger Population Estimation Using Camera Trapping Methods in Sundarban, Bangladesh' of the 'Strengthening Regional Cooperation for Wildlife Protection' Project financed by the World Bank. The sub-project is leading by wildlife Management and Nature conservation Division, Khulna.

It is very encouraging to learn that Bangladesh Forest Department with expert assistance from the Wildlife Institute of India has estimated tigers using camera trap in the Sundarban. The Sundarban is the only mangrove forest habitat that has tigers and it is contiguous habitat extending across Bangladesh and India. At the same time Indian Forest Department has also completed camera trapping tigers in their part of the Sundarban with expert assistance from the Wildlife Institute of India. A coordinated camera trapping exercise in the cross-border tiger habitats between the neighboring countries helps avoid double counting.

We are lack of scientific study that is acceptable to all about the tiger population in the Sundarban. Scientific study, analysis and interpretation of results regarding Tiger population in the Sundarban are required and we hope the attempt of the sub-project will assist to fullfill the government goal to manage tigers, prey, habitat and the Sundarban mangrove biodiversity in a sustainable manner. The scientific study has given us base line information on tiger density in the Sundarban that can help us to impiove overall management of the Sundarban. You know that this is really very difficult to conserve the natural resources in the developing country because of excessive human pressure, lack of ample natural resources, shortage of fund, absence of positive attitude of the local community towards the natural resources and so on. Only Government alone cannot conserve the boon of the Almighty. SMART patrolling throughout the Sundarban and collaborative management approach deemed to be very effective for the tiger conservation in the sundarban.

I would like to convey my thanks to the Divisional Forest Officer, Wildlife Management and Nature Conservation Division, Khulna for taking such initiatives. My thanks to officers and staffs including the experts from Wildlife Life Institute who involved in the process.
I hope this report will be of relevance and useful to both professionals and non professionals. Now, we have to take steps to review our previous activities and renew our plans, activities, and implementation strategies to protect tigers.

Md. Akbar Hossain
Project Director
Strengthening Regional Cooperation for Wildlife Protection Project
and
Deputy Chief Conservator of Forests
Bangladesh Forest Department.

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EXECUTIVE SUMMARY

This report summarizes the outputs of first ever scientific tiger monitoring in Bangladesh Sundarban. The earlier assessment was done in 2004 with the financial assistance of United Nations Development Program and technical assistance from West Bengal Forest Department of India. Methodology used was tiger pugmark and result come with an estimate of 440 tigers of which 121 male, 298 female and 21 cubs. Wildlife sign survey is very good for distribution and can often provide relative abundance but estimates of absolute abundance are unreliable unless calibrated with more reliable methods. The current report is based on robust spatially explicit capture mark-recapture using camera traps and covariates of prey, tiger sign and human impacts obtained from khal survey across Sundarban. The exercise was done between 2014 to early 2015 with an unprecedented effort of about 7500 man days by forest staff and other supporting staffs. The results provide an absolute density of tigers per 100 sq. km, population limits, abundance of tigers and their prey species and habitat condition. This information is crucial for forest/wildlife managers to incorporate conservation objectives into Integrated Resources Management Plan for the Sundarban (2010-2020).

The methodology consisted of a double sampling approach prescribed by Wildlife Institute of India wherein Spatially Explicit Capture-Recapture model is used for estimating absolute density in three representative blocks covering a cumulative area of 1264 sq. km which represent 26.20 % of total tiger habitat (4832 sq.km) of Bangladesh Sundarban. Simultaneously we did 2500 km khal survey and collected data on tiger sign intensity and other ecologically important covariates like prey species signs and sightings and human disturbance indices. A team of trained wildlife and biodiversity conservation officers of Bangladesh Forest Department conducted the field survey under the guidance of Divisional Forest Officer, Wildlife Management and Nature Conservation Division, Khulna and researchers from Wildlife Institute of India using best modern technical tools like remote camera traps, GPS and laser range finders. Total effort of 8787 trap nights yielded 1495 photos of 38 adult individuals and 05 cubs. The indices and covariate information (tiger sign, prey abundance indices, habitat characteristics) generated by khal survey then calibrated against absolute density using Generalized Linear Models (GLM) and relationships were used for extrapolating tiger densities in total tiger occupied habitat of Bangladesh Sundarban using program R.

The result shows that Bangladesh Sundarban has tiger occupancy of 4832 sq. km and estimated population of 83 to 130 tigers with a midpoint of 106. Though the tiger population estimate is much lower than previously believed, it still forms one of the top five largest population in the world and merits enhanced Global conservation investments to ensure the long term survival of this unique mangrove adapted tiger ecotype. The average weighted density in SECR model of three blocks is 2.17 / 100 sq.km. Block wise summery is given below:

Name of block	No of Trap Night	Minimum polygon area (sq km)	No of tiger captured	Tiger Densityper 100 sq km
Block I Sarankhola Range	2389	309	18	3.70
Block II Satkhira Range	2177	366	13	2.70
Block III Khulna Range	4221	588	07	1.08

Tiger is a conservation dependant species requiring connected forests with good prey and a fair interspersion of undisturb breeding areas. Findings of this study show that Bangladesh Sundarbans seems to be below the potential carrying capacity of the habitat. Tiger density is negatively correlated with human disturbance which is very high in Sundarban. Poaching of tigers and their prey are a major concern for tiger conservation globally, Sundarbans being no exception. Low density of tigers in the Sundarbans is an inherent attribute of the hostile mangrove habitat that supports low tiger prey densities. Management of this population for long-term survival is therefore more difficult and conservation strategies need to ensure that the population in the Sundarbans (within Bangladesh and with India) is not fragmented. Large water channels can become potential barriers to dispersal between Sundarban Islands especially when these channels are used as a conduit for commercial boat traffic.

Recommendations comes forward to strengthen coordinated law enforcement activities, strengthen Forest Department with necessary logistics and staff amenities for the frontlines, implement technology aided patrols and ecological monitoring programs, reduce human disturbances and control ship traffic. Habitat monitoring and development program should implement with regular monitoring of tigers, co-predators and prey species. Joint tiger monitoring and patrolling in trans-boundary areas should implement with West Bengal Forest Department.

However, this is the first initiative to estimate the tiger abundance based on a robust scientific protocol in the Sundarbans with the financial support from the World Bank funded " Strengthening Regional Cooperation for Wildlife Protection Project" and technical assistance from Wildlife Institute of India. Through this program forest officers and frontline staffs of Bangladesh Forest Department have developed their capacity on monitoring tigers, co-predators and prey species in Sundarbans. A GIS lab with ten ArcGIS 10.2 version software and a tiger data base centre has been established in Khulna to support any scientific research and monitoring program in Sundarbans. This report will be considered as base line of tiger abundance in Bangladesh Sundarbans and will be of immense help in assessing of conservation policy and management strategies for effective conservation of the species for future generation of Bangladesh and the world community.

INTRODUCTION

About 45 Mya, when the Indian plate collided with the Eurasian landmass, it led to the formation of the Himalayas in the north and the subsiding Bengal Basin region to the south-east. A huge amount of sediments, washed down by the rivers formed by the developing mountains eventually led to the formation of the world's largest tidal mangrove haplophytic forest called the Sundarban. The name Sundarban literally means the "beautiful forest" and in all likelihood is derived from the 'Sundari' trees (*Heritiera fomes*) found in these mangroves. Sundarban, spread across Bangladesh and India, covers an area of 10,000 sq.km. approximately of which 60% lies in Bangladesh between 21°30'-22°30' N latitudes and 89°00'-89°55' E longitudes (Khan 2004, Barlow 2009).

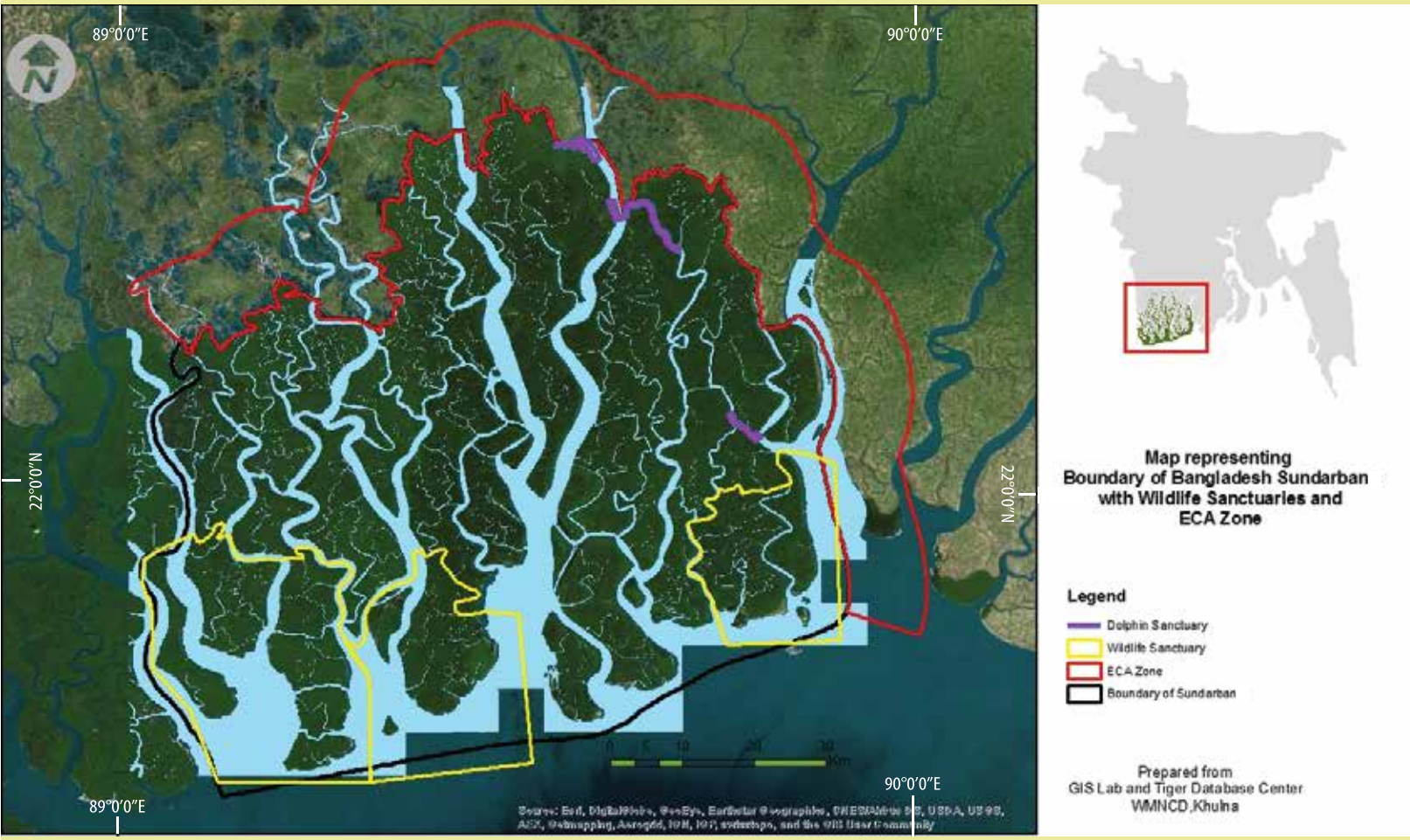

Figure 1: Map of Bangladesh Sundarban showing wildlife Sanctuaries and Ecological Critical Area .

The Bangladesh Sundarban, formed at the mouth of rivers Meghna and Padma joining the Bay of Bengal, represent 44% of the total forested area in the country. It generates 50% of the total forest revenue in the form of tourism, fishing, honey collection, nipa (*Nypa fruticans*) leaves for thatching, etc. (Khan, 2004). The mangrove trees also aid in land maturation and act as a natural barrier against cyclones and tsunamis, protecting the human dominated agricultural land to the north. Three wildlife sanctuaries (Sundarban East, Sundarban South and Sundarban West), comprising an area of 1,397 sq.km. form a UNESCO World Heritage Site and a 10 km wide area surrounding the northern and eastern boundaries of Sundarban Reserve Forest have been declared as Ecologically Critical Area under the Bangladesh Environment Conservation Act, 1995 (IRMP of Sundarban, 2010).

Sundarban is the only mangrove forest where the tiger occurs, giving it the status of a Tiger Conservation Unit Level I (Sanderson et al. 2006). The major prey species of the tiger, found in this region are spotted deer (*Axis axis*) and wild boar (*Sus scrofa*) and also purportedly include Rhesus macaque (*Macaca mulatta*), lesser adjutant stork (*Leptoptilos javanicus*), water monitor lizard (*Varanus salvator*), crabs and fishes. Other carnivores found in this region are leopard cat (*Prionailurus bengalensis*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*), and otter (*Lutra* sp.) (Seidensticker and Hai 1983).

The diverse cetacean community found in the waters of Sundarban include Gangetic river dolphin (*Platanista gangetica*), Irrawady dolphin (*Orcaella brevirostris*), Indo-Pacific hump-backed dolphin (*Sousa chinensis*), and finless porpoise (*Neophocaena phocaenoides*) (Smith et al. 2006). It is also home to the largest living reptile, the estuarine crocodile.

Despite such ecological significance, lack of rigorous scientific study in this region has lead to a paucity of information on tiger and its prey. There has been no proper quantification of the tiger population, even though, the distribution of tigers throughout the Sundarban has been established. The major hindrances to any study of the tiger are the logistic constraints imposed by the tidal ecosystem and a reputation of natural man-eating of the tiger. Without proper monitoring protocols and any information on the abundance of tiger and its prey, it is impossible to measure the response of the population to conservation activities or threats. Keeping this in mind, a collaborative study between Bangladesh Forest Department and Wildlife Institute of India was started in 2014-2015 to establish the first ever robust estimate of tiger density and abundance in Bangladesh Sundarban.

Methods

We determined the extent of tiger occurrence and intensity of habitat use by khal surveys for tiger sign intensity across the entire Sundarban landmass. Simultaneously data on ecologically important covariates like prey species signs and sightings, and human disturbance indices were also recorded during khal surveys. We estimated absolute tiger density through spatially explicit capture mark recapture (Efford 2004, Borchers & Efford 2008, Royle et al. 2009) using camera traps at three representative sample blocks covering a cumulative area of 1264 sq.km. in Bangladesh Sundarban.

Estimating tiger densities using camera traps

Camera trapping was carried out in three blocks spread across Sundarban. The blocks were located in the Sarankhola, Satkhira and Khulna ranges covering areas of 309, 366 and 588 sq.km. respectively. Each block was selected based on size and shape criteria so as to maximize geographic closure over a short time frame. The blocks were surrounded by wide water channels > 1 km on most sides (Figure 1). Suitable camera trap locations were selected near brackish water holes, in elevated places, river bends, regular channel crossing paths frequented by tigers based on local knowledge of tiger biology of frontline forest staff to maximise photo capture and minimise chances of lethal encounters. We set up camera traps using baits and lures to attract tigers to our camera stations. Individual cameras were set 45 cm above ground and distance between two cameras in the same location was maintained at 7-8 m. Inter-trap distances varied between 2 to 4 km. We used nylon nets and cut vegetation to orient the tigers to get proper flank photographs for identifying each individual from their stripe patterns. Trap stations were regularly monitored and constantly supplied with baits to minimize the spatio-temporal variation in photo captures between traps. Due to limited number of cameras and logistic constraints the blocks were divided into sub-blocks for sampling.

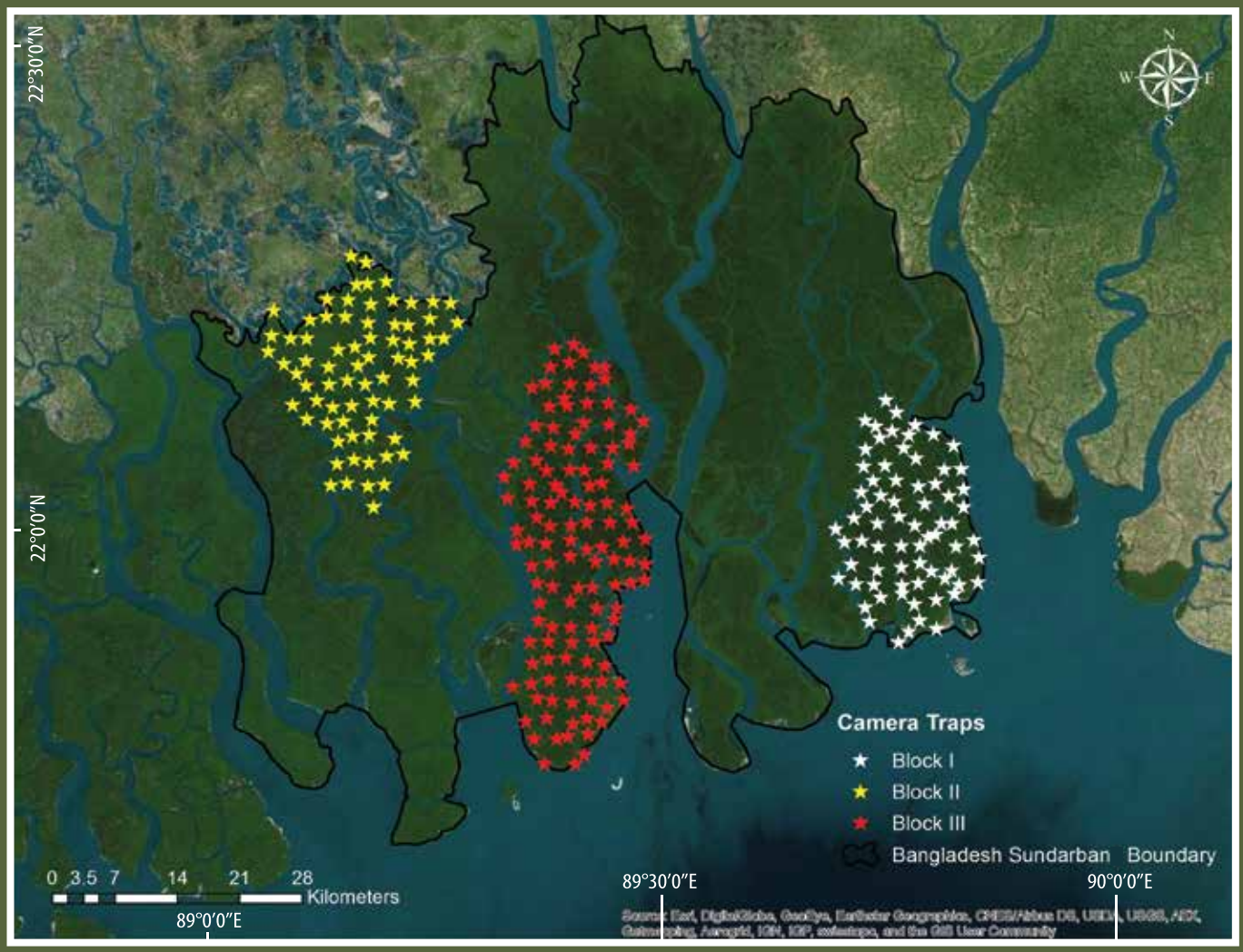

Figure 2. Location of camera traps in three sample blocks (1264 sq.km) of Sundarban

We identified individual tigers by their stripe patterns using a pattern recognition program Extract Compare (Hiby et al. 2009) specifically developed for tigers. Two matrices summarising photo-captured tigers' spatio-temporal detection-history and spatio-temporal camera trap layout were made. We then used this information in the spatially explicit capture-mark-recapture (package secr, Efford 2015) framework in Program R, to estimate tiger densities in the three blocks. SECR estimates densities directly from the spatial histories of individual animals by modelling two parameters – g0, the detection probability at the activity centre and sigma, the spatial movement parameter. Keeping detection function as half-normal, we modelled g0 as constant (null), behaviour (b) and behavioural response specific to trap-site (bk) and sigma as constant (null). The parameters were modelled separately for each block giving us the individual block densities. We used a habitat mask to demarcate non-habitats and buffered the camera trap minimum bounding polygon by 3 sigma to delineate the model inference space. We then selected the models with the lowest AIC as the best model.

Khal surveys

Khal survey of 2500 km was carried out across the entire Sundarban using the Phase I Monitoring Protocol established for the Sundarban (Jhala et al. 2014) (see Figure 2). This exercise was conducted alongside camera trapping study. During khal survey, direct sightings and signs of tiger, fishing cat, otters, estuarine crocodiles, monitor lizard, wild pig, spotted deer and human disturbance along with vegetation covariates were collected. GPS coordinates along with type of mangrove, slope of the bank and width of the upper and lower bank were noted for each sighting/sign encountered.

Relationship of covariates with camera-trap densities

Distribution of tiger sign at 100 sq.km. grids was used to determine the naïve occupancy by tigers. Encounter rates for signs and sightings were computed for all data based on effort (kms of survey) invested in each 100 sq.km. grid. Exploratory data analyses were used to evaluate the relationship between tiger density and covariates of prey abundance, human disturbance and tiger sign intensity. Covariates that showed a reasonably good relationship (linear and monotonic) were used in a multiple regression framework to model tiger density for 100 sq.km. grids (see example of tiger sign in Figure 3.)

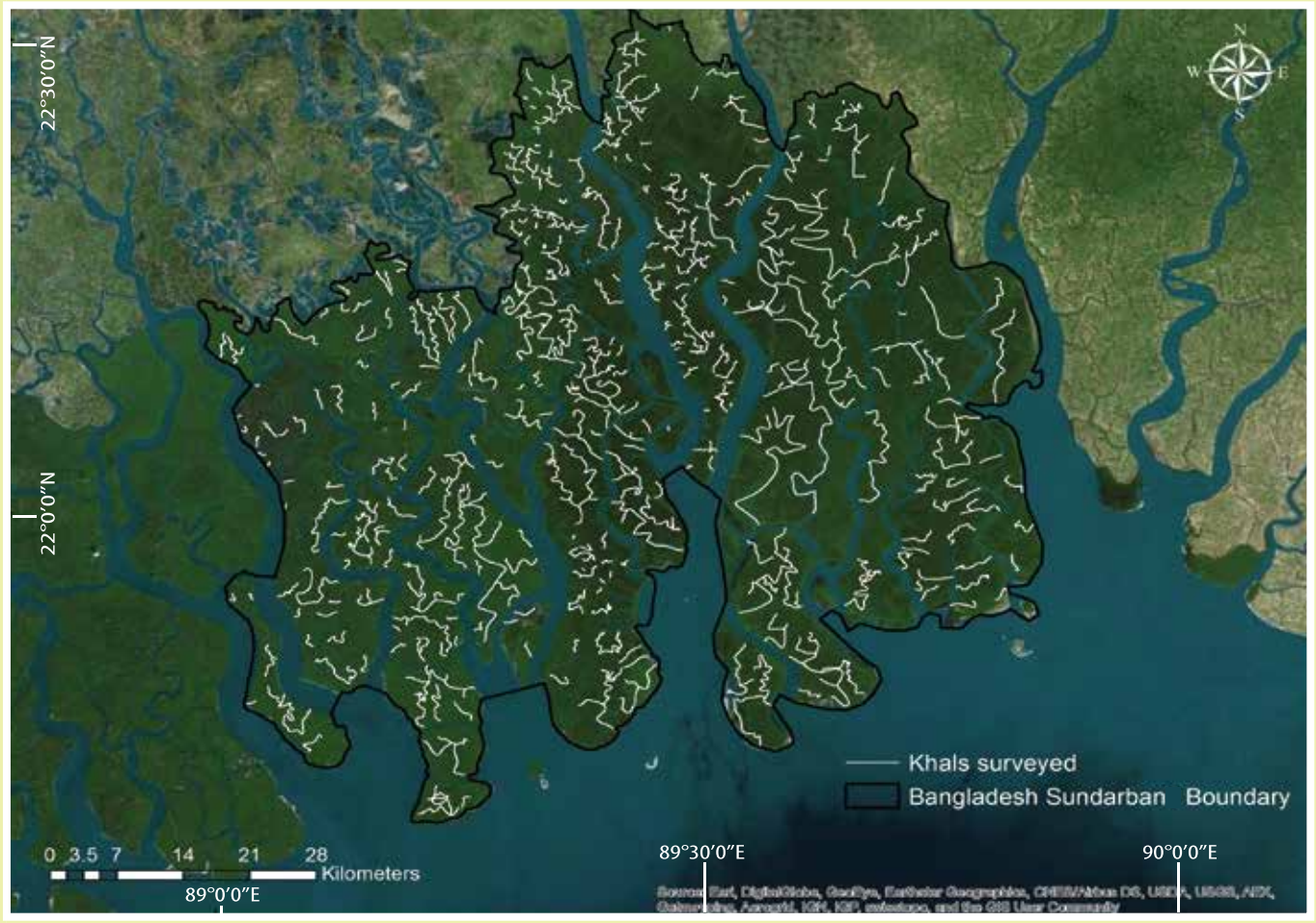

Figure 3. Location of Khal surveys across Sundarban in 2014-15

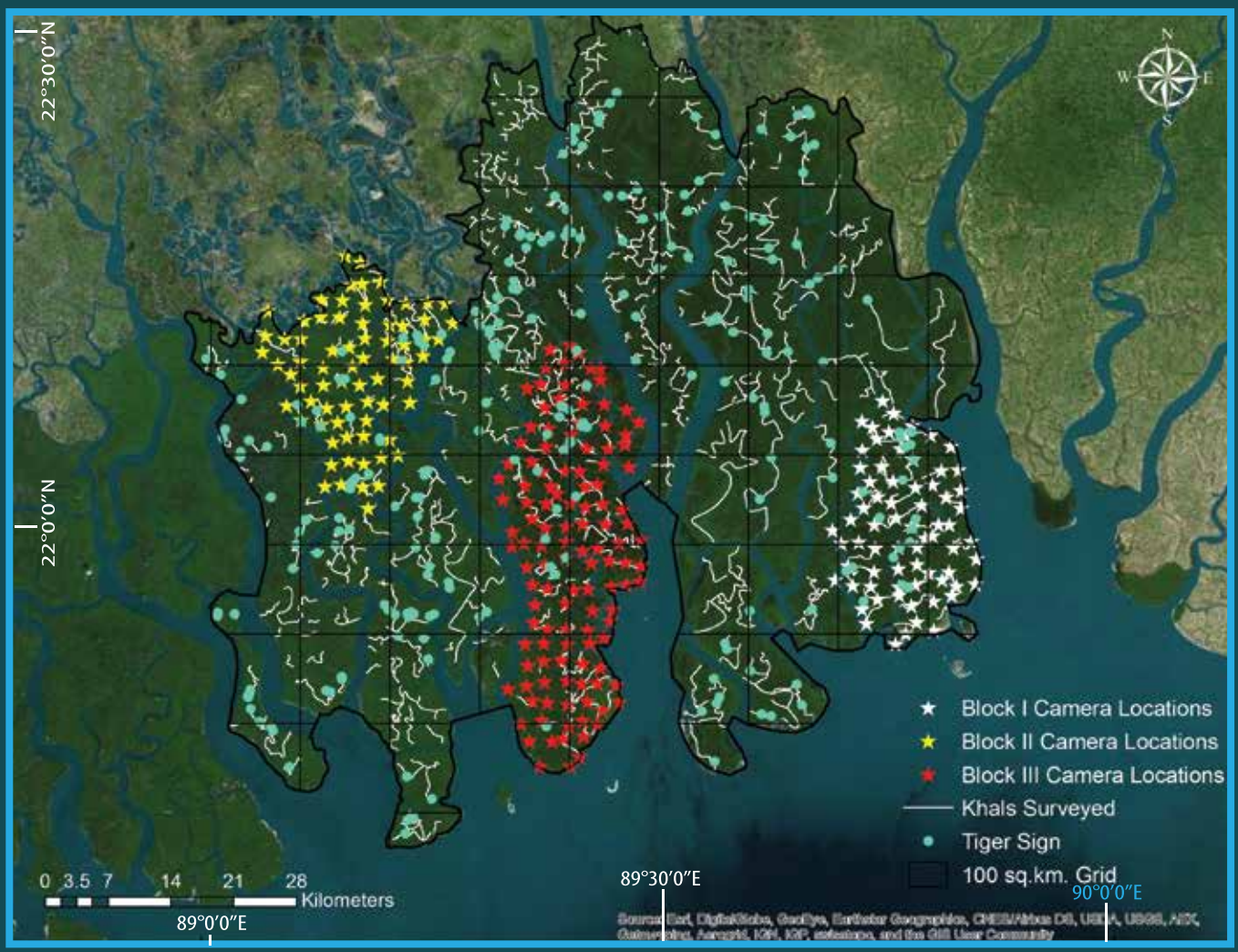

Figure 4. Distribution of tiger signs obtained from Khal surveys overlaid on 100 sq.km. grids and camera trapped sites in the Bangladesh Sundarban in 2014-15.

Results

Population estimation through camera trap based capture-mark-recapture

The best model selected included behavioral and site specific heterogeneity in capture probability, as expected since the trap sites were baited. The highest tiger density was recorded in Block 1 (Sarankhola) while the lowest density was recorded from block 3 (Khulna) (Figure 4, table 1). The area weighted tiger density from the three camera trapped blocks was 2.17 (SE 1.73 to 2.68) tigers/100 sq.km. Extrapolating this tiger density to the tiger occupied area of 4832 sq.km. Bangladesh Sundarban provided a crude tiger population estimate at 105 (SE interval 84 to 130).

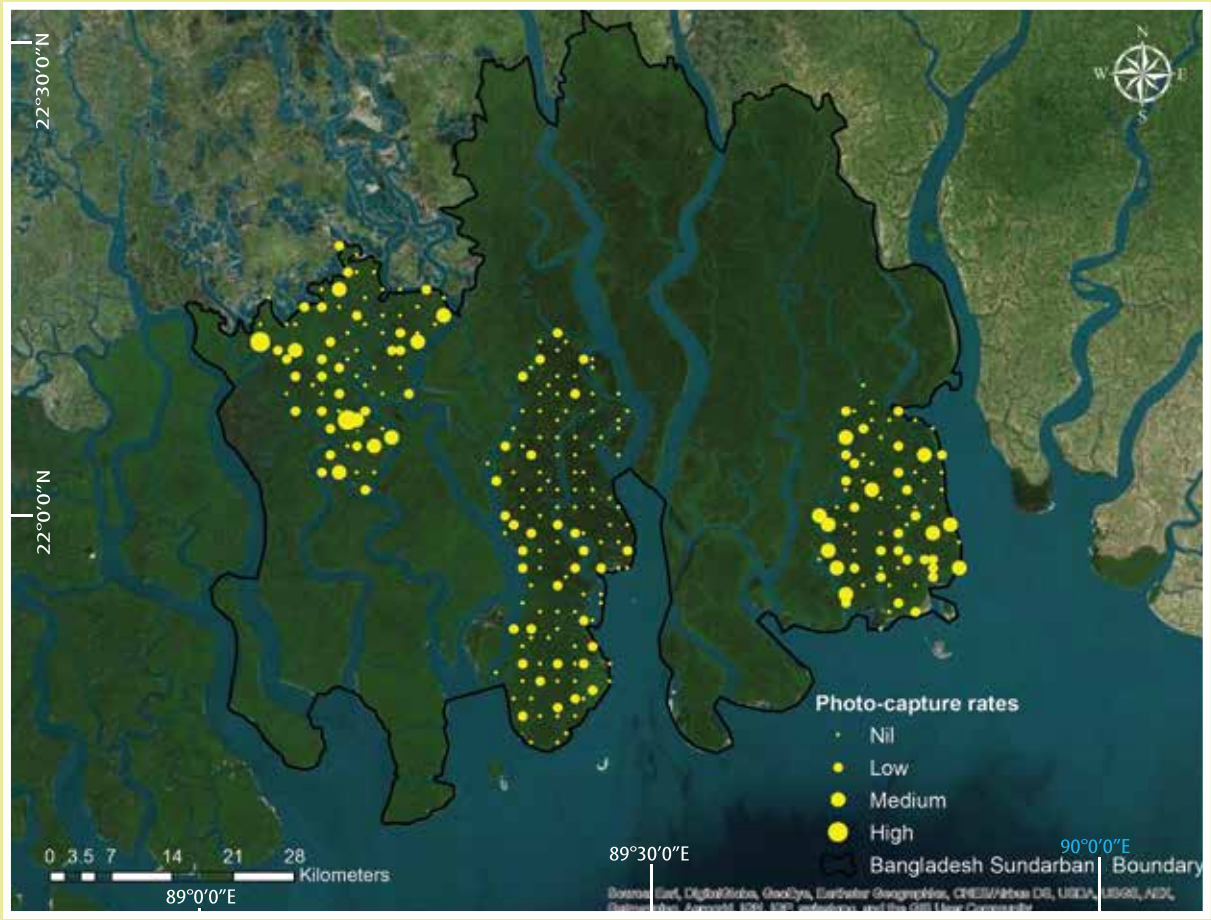

Figure 5. Photo capture rates of tigers in three sampled blocks in 2014-15

Block	Number of days sampled	Number of Camera locations	Number of individuals captured (Mt+1)	Minimum Bounding Polygon Area (sq.km)	Best Model with lowest AIC values in SECR	Density (SE) of tigers/100sq.km	g0 (SE)	Sigma (SE) in kms.
Block I (Sarankhola)	74	71	18	309.18	D(.)g0(bk)σ(.)	3.70 (0.91)	0.01 (0.003)	3.37 (0.35)
Block II (Satkhira)	68	71	13	366.44	D(.)g0(bk)σ(.)	2.77 (0.78)	0.01 (0.002)	4.27 (0.05)
Block III (Khulna)	127	124	7	588.08	D(.)g0(bk)σ(.)	1.08 (0.04)	0.003 (0.0008)	8.98 (1.80)

Table 1. Details and parameter estimates of spatially explicit capture recapture from camera trap sampling conducted in Bangladesh Sundarban in 2014-2015. The model that described g0 as being a function of site specific behavioral response and sigma as constant was selected as best model.

Species sign and human disturbance encounter rates

Encounter rates of species were plotted to depict relative abundance and distribution patterns across Bangladesh Sundarban (Figures 6 to 14). Tiger signs were obtained in all grids while lesser adjutant storks had a very restricted distribution.

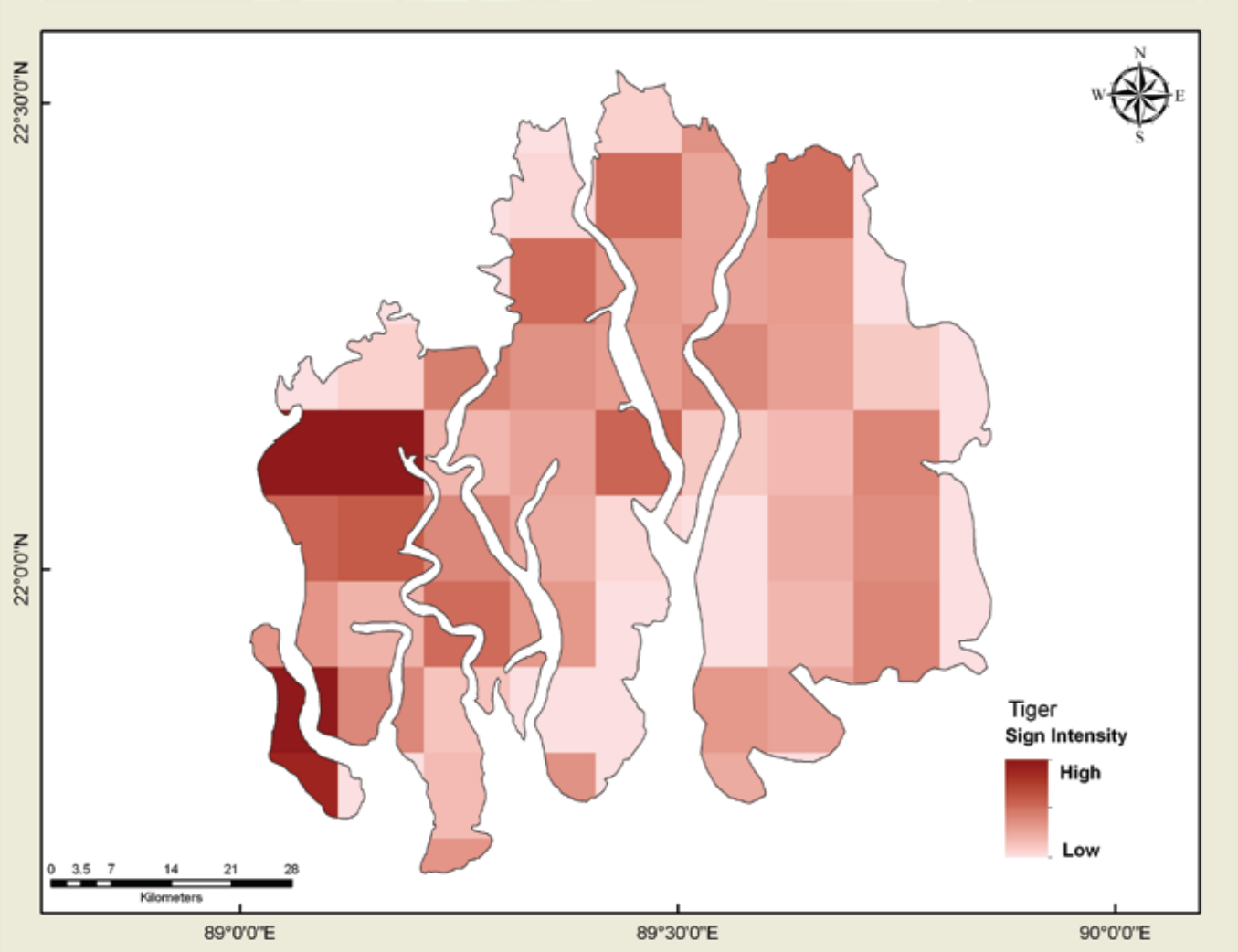

Figure 6: Encounter rate of tiger sign across Sundarban in 2014-15

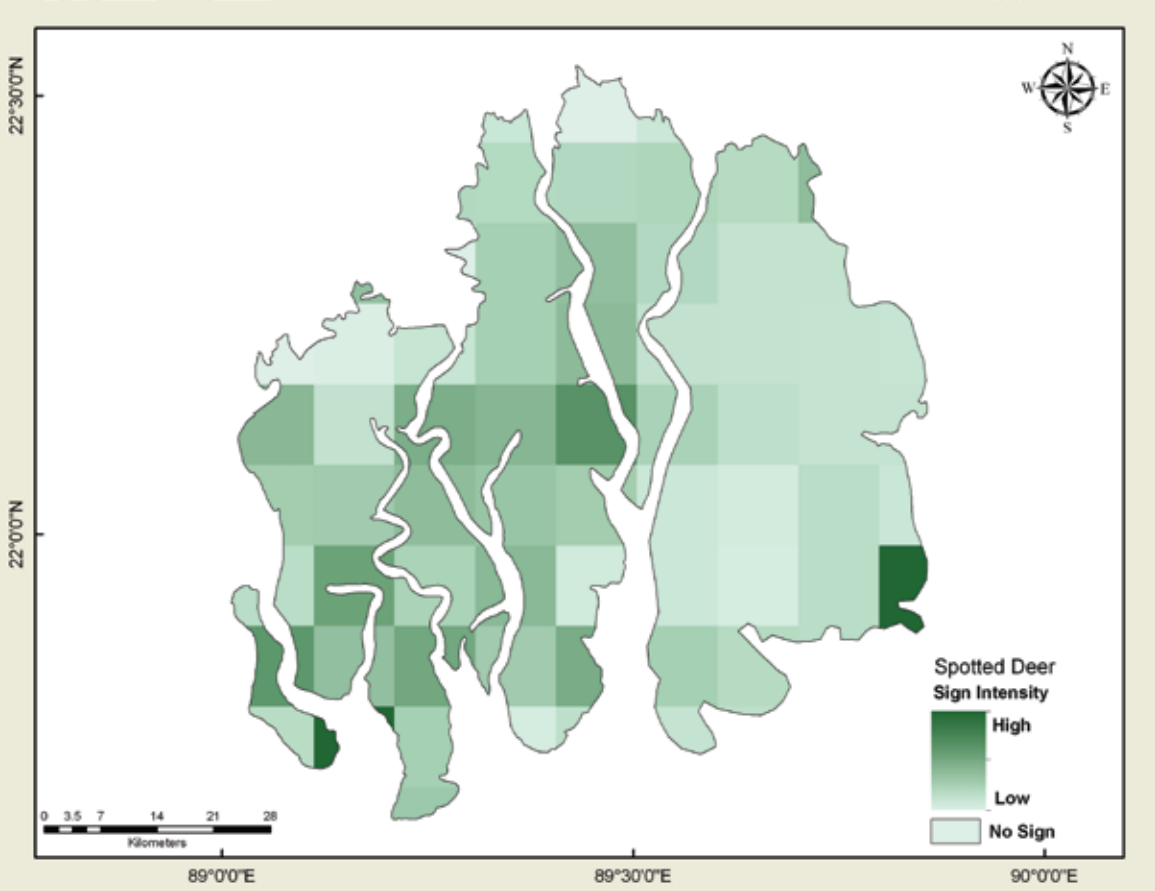

Figure 7. Encounter rate of spotted deer sign across Sundarban in 2014-15

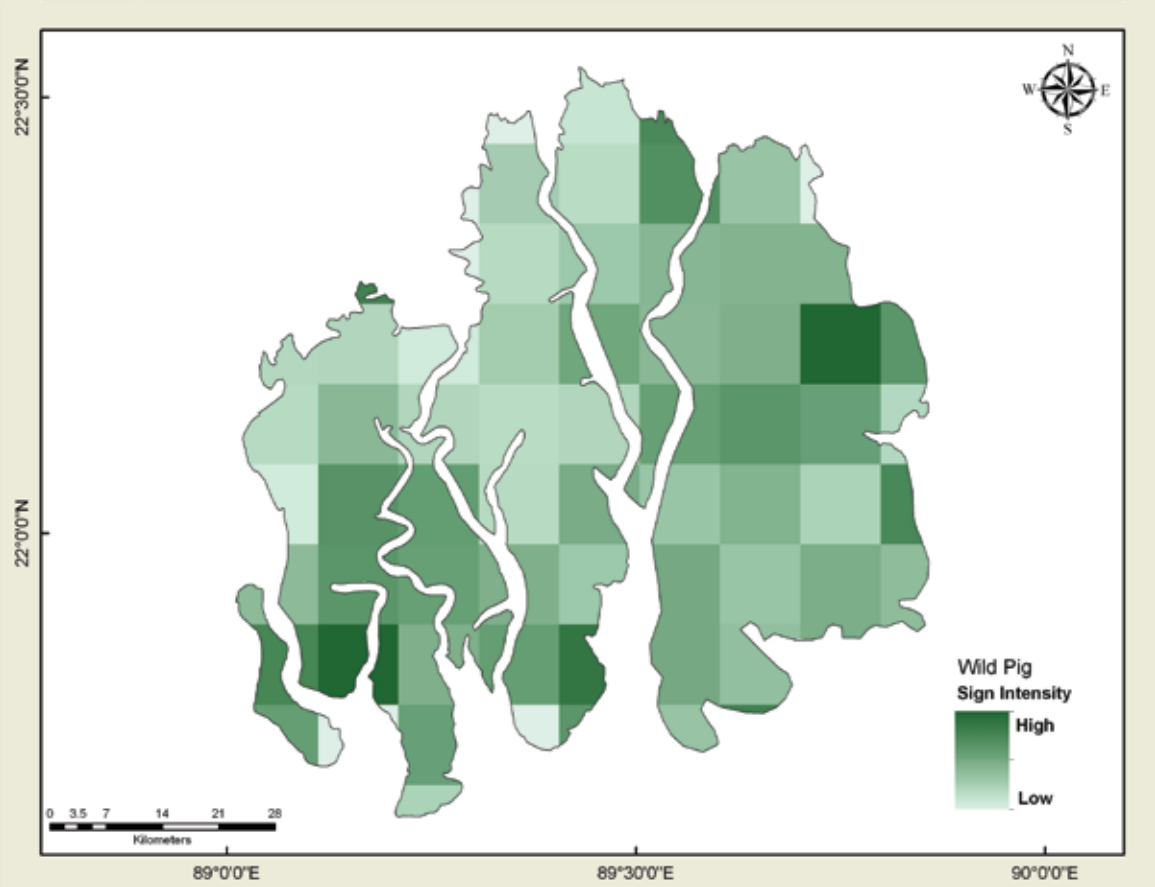

Figure 8. Encounter rate of wild pig sign across Sundarban in 2014-15

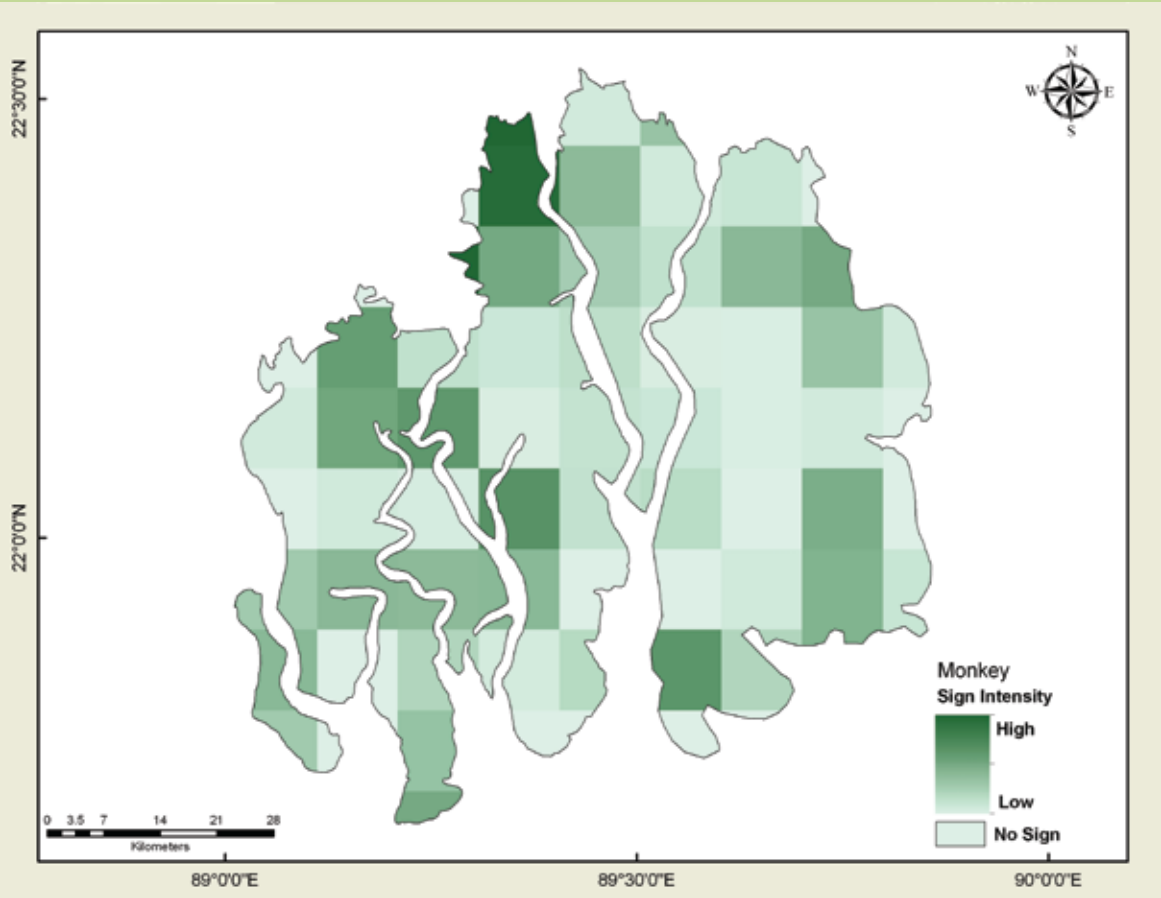

Figure 9. Encounter rate of monkey sign across Sundarban in 2014-15

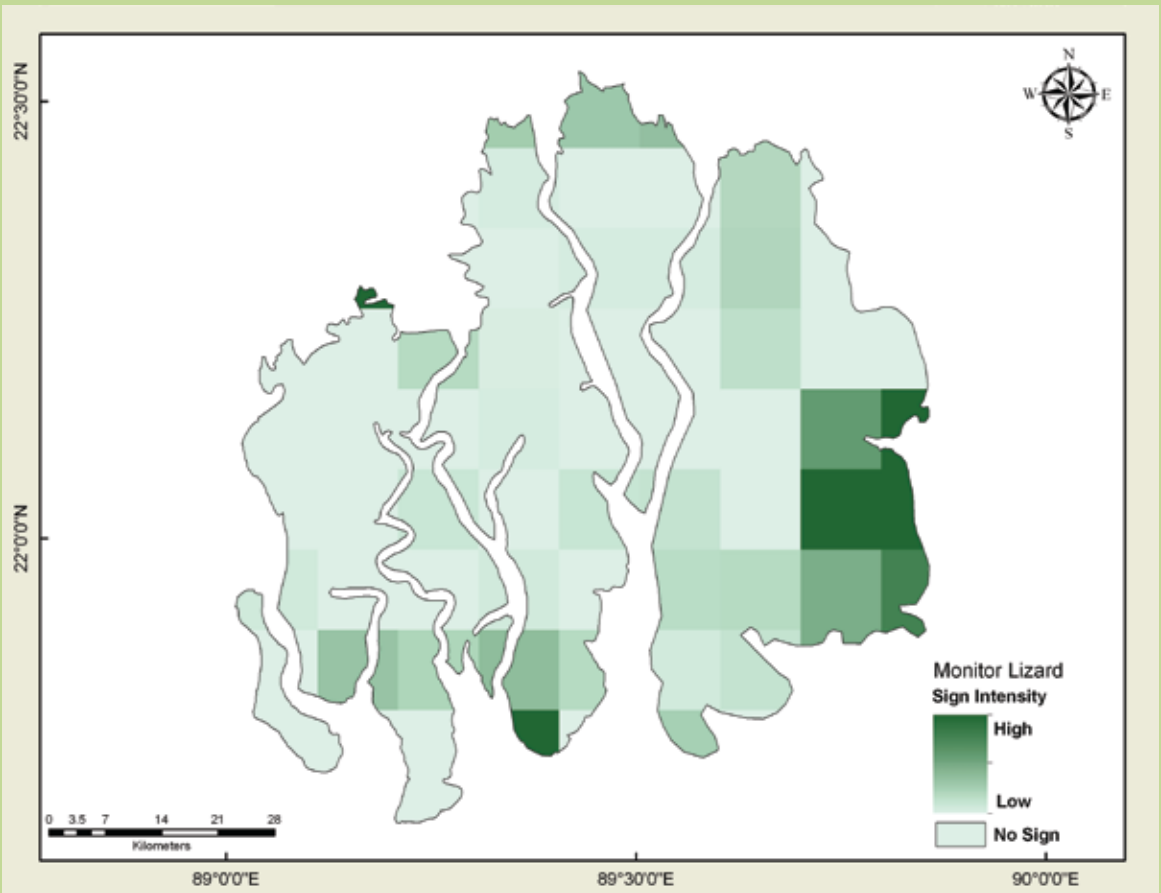

Figure 10. Encounter rate of Monitor lizard sign across Sundarban in 2014-15

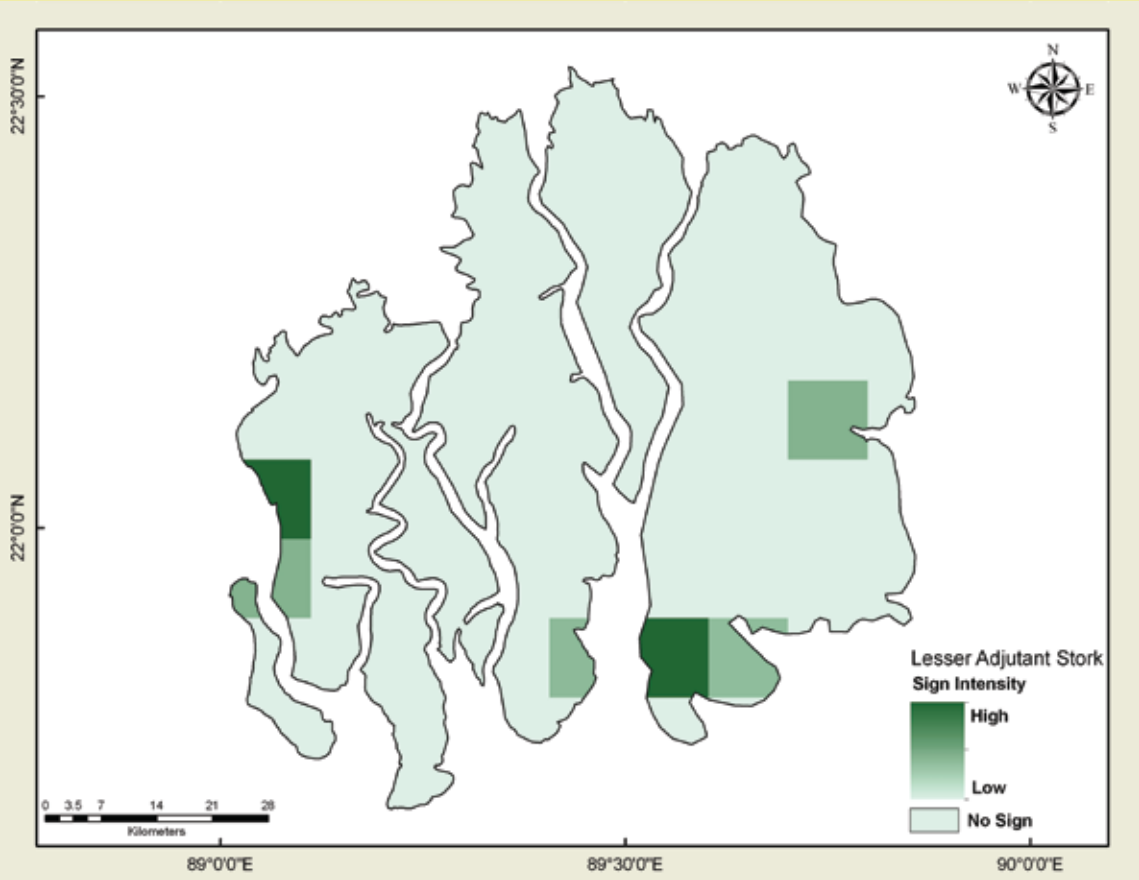

Figure 11. Encounter rate of lesser adjutant stork sign across Sundarban in 2014-15.

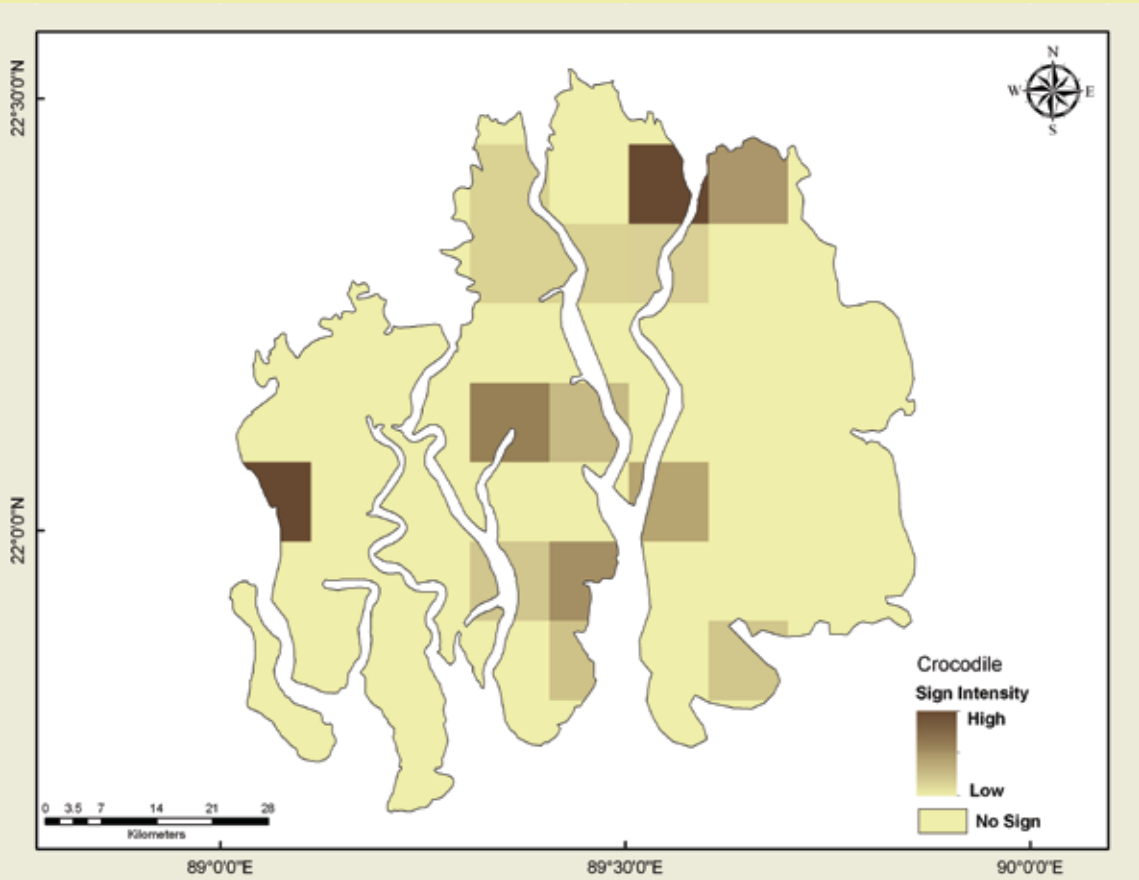

Figure 12. Encounter rate of estuarine crocodile sign across Sundarban in 2014-15.

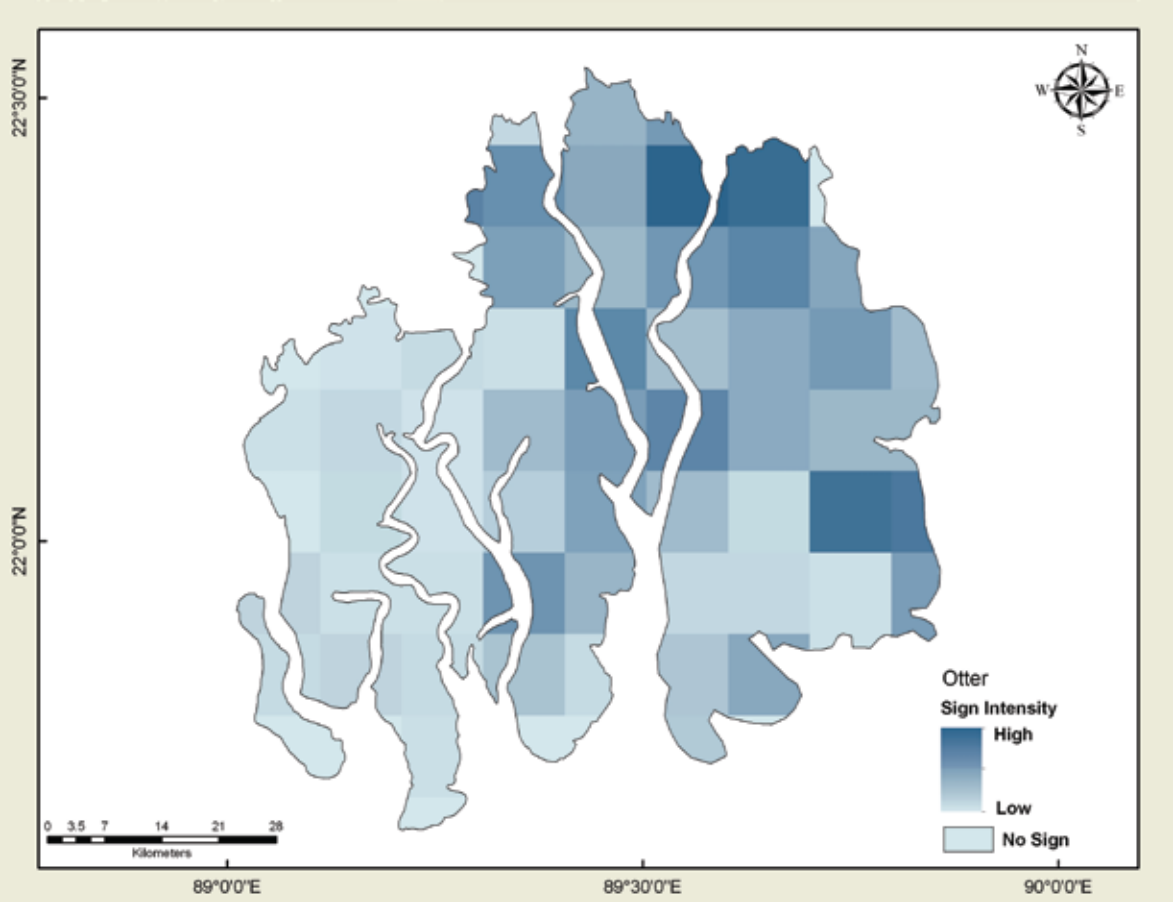

Figure 13. Encounter rate of otter sign across Sundarban in 2014-15.

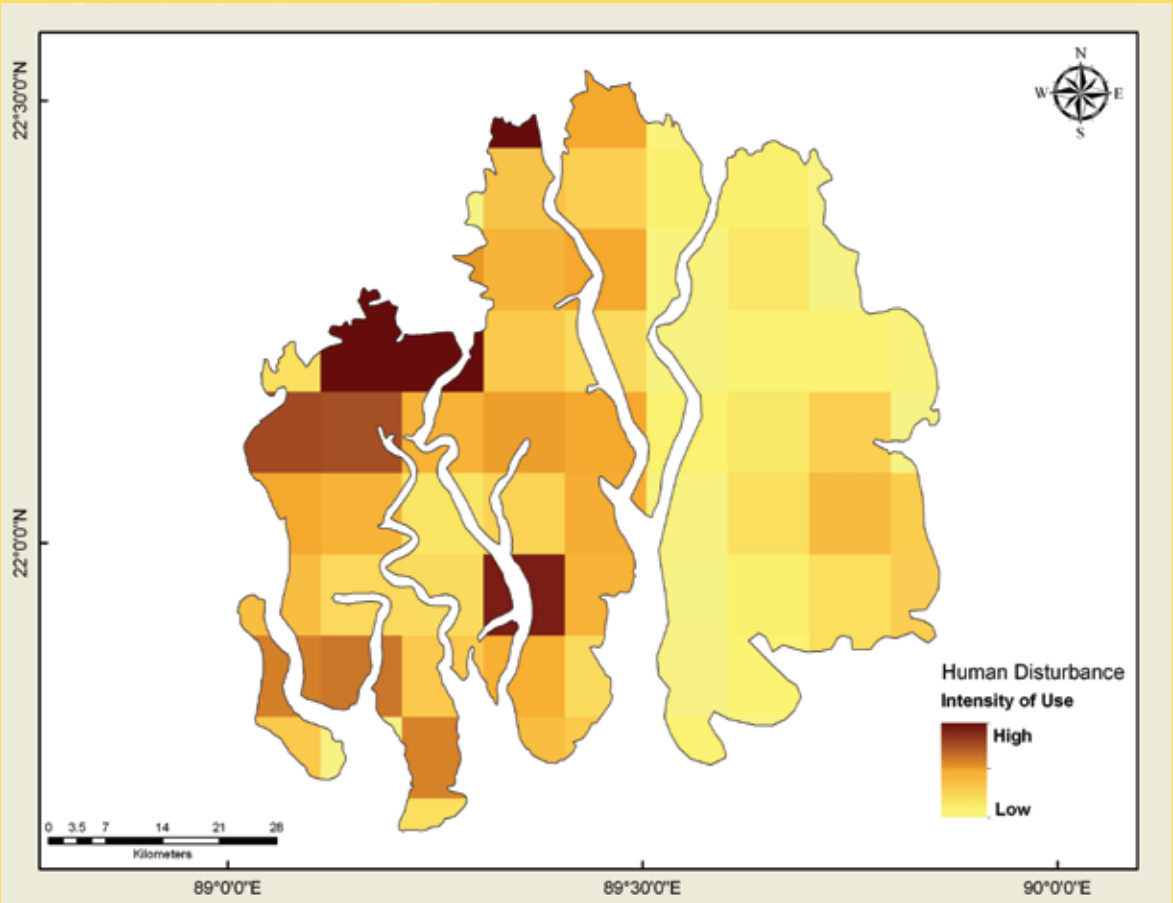

Figure 14. Human sign intensity across Sundarban in 2014-15.

Relationship between covariates obtained through khal survey and tiger densities generated through SECR.

Tiger density was found to have a positive relation with tiger sign intensity (r = 0.464; P = 0.008); and encounter rate of prey (r = 0.447, P = 0.012), while it had a negative relationship with encounter rate of human disturbance (r =-0.554, P = 0.0012). A multiple regression having all of the above three covariates had the best fit and explanatory power to model tiger density (Table 2).

Table 2. Model coefficients of covariates and tiger sign index for modeling tiger density in the Sundarban.

Parameters	Estimate	SE
(Intercept)	0.027	0.004
Tiger Sign Encounter Rate	12.21	6.15
Prey Encounter Rate	1.81	1.71
Human Disturbance ER	-10.97	4.86

Tiger numbers estimated by camera trapping using SECR within the camera trapped polygons and the multiple regression model for the remaining part of the Sundarban area are ***106 (SE Range 83 to 128)***

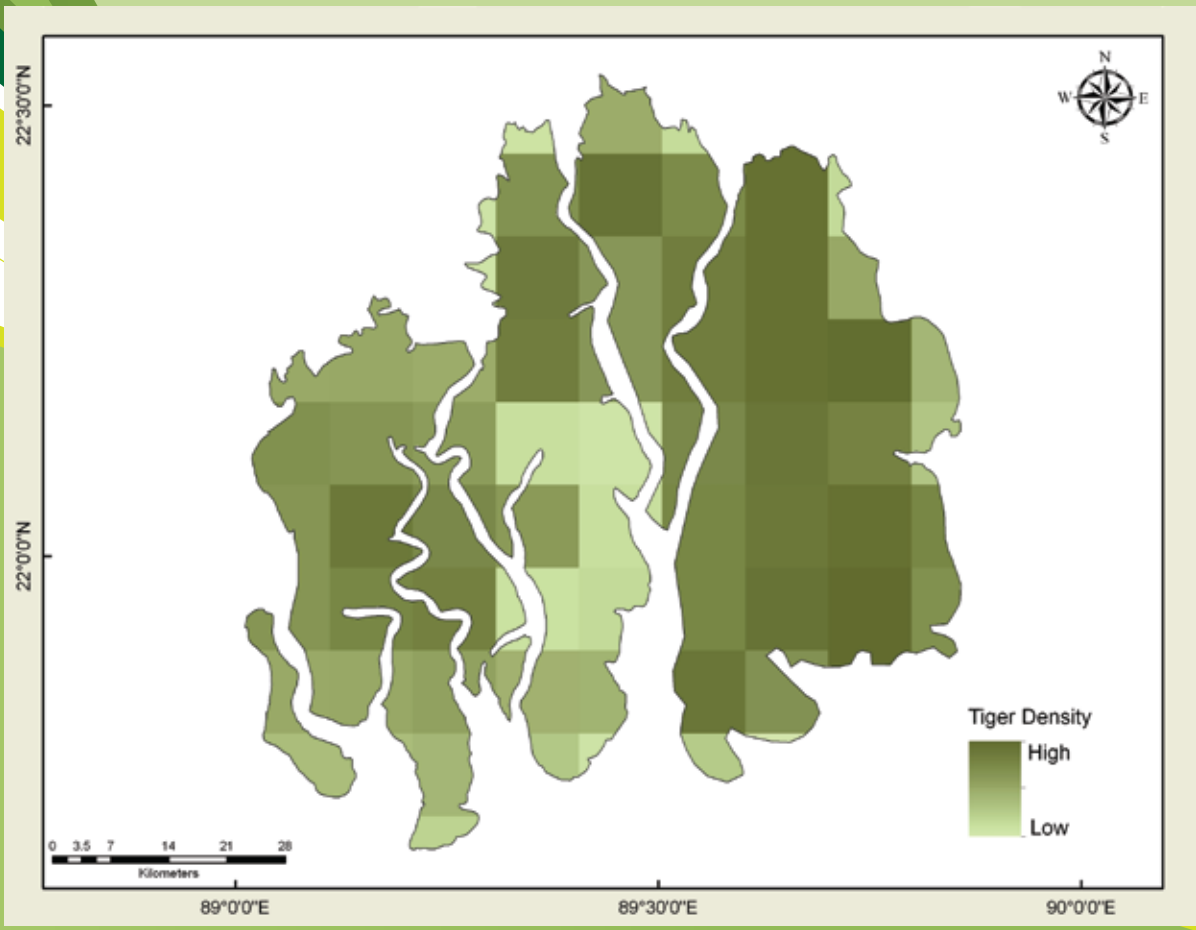

Figure 15. Tiger density across Bangladesh Sundarban obtained from camera trap based spatially explicit capture recapture and covariate based regression model in 2014-15.

Conclusion

This is the first ever effort to quantify tiger abundance in Bangladesh Sundarban based on a robust scientific protocol using camera traps in an SECR framework and double sampling approach. Earlier estimates based on less reliable estimates using home range size of two tigresses (Barlow et al. 2008), pugmark, and khal surveys had estimated tiger abundance between 300 to 500 in Bangladesh Sundarban (GTRP 2012). Khan (2004) provided a more reasonable estimate based on prey availability at about 200 tigers. Tiger density estimated using camera traps in the Indian Sundarban had estimated much lower abundance (4.3 (se 0.3) tigers per 100 sq.km.; Jhala et al 2011; 2014). This assessment prompted the Bangladesh Forest Department to assess the Bangladesh Sundarban using modern scientific approach for tiger abundance estimation.

The current assessment covers a reasonably large area of the Sundarban by camera traps (26.2% of the tiger occupied habitat). Entire Sundarban was surveyed by khal surveys for evaluating tiger occupancy. The tiger population estimate obtained by a weighted average SECR density extrapolated to the tiger occupied area as well as the estimate obtained by covariate modeling were similar. Tiger population in Bangladesh Sundarban was estimated to be between 83 to 130, with a midpoint of 106 tigers. The standard error limits of 83 to 130 were obtained from the extreme values of the weighted average approach and the covariate regression model so as to have a conservative coverage of the actual population.

This study provides a baseline from which we need to work towards addressing commitments to the Global Tiger Recovery Program. It is possible to double the tiger numbers in Bangladesh Sundarban by investing in resources that promote tiger conservation. These include law enforcement activities (staff, patrol boats, arms and ammunition, and equipment); implementation of technology aided patrols and ecological monitoring programs like MSTrIPES/SMART; restricting development and/or investing in mitigation measures; delineating corridors for tiger movement across Sundarban and managing these by controlling ship traffic and human disturbance.

Though the current assessment estimates tiger numbers close to a 100 compared to earlier estimates which were much higher, the Sundarban tigers represent one of the top 5 largest global population of the species. The unique adaptations of the Sundarban tigers for a life in the mangrove forests combined with a large popaulation size (about 182 tigers between Bangladesh and India) makes this population extremely important for global recovery of the species and a pride for Bangladesh.

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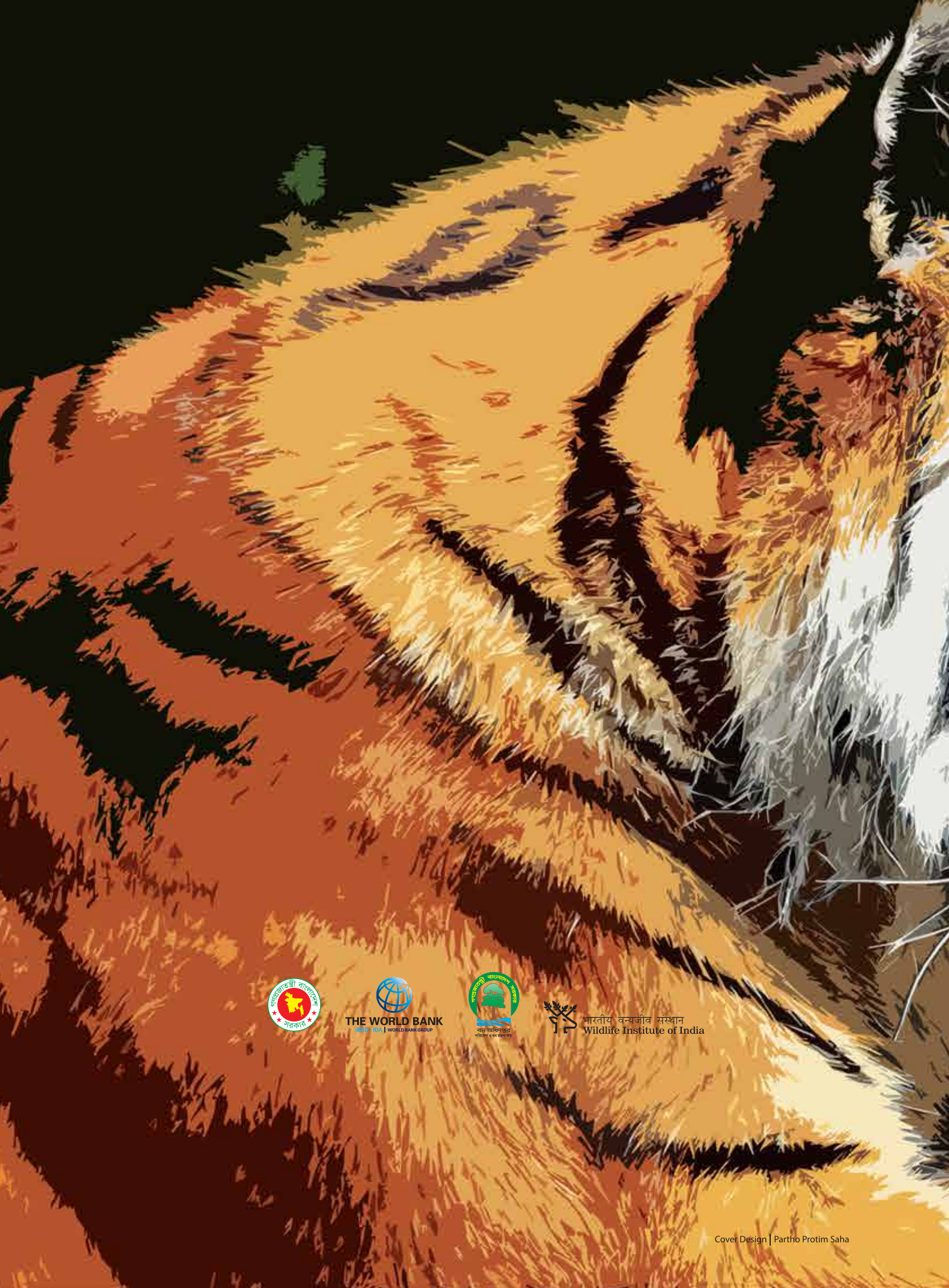

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