Sustainable Forests & Livelihoods (SUFAL) Project
Forest Department
Ministry of Environment, Forest and Climate Change

Compendium of Wildlife Research under the SUFAL Innovation Grant

Volume 2

SUFAL

THE WORLD BANK
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This publication is an output from the Sustainable Forests & Livelihoods (SUFAL) Project implemented by Bangladesh Forest Department (BFD) under the Ministry of Environment, Forest and Climate Change.

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Dr. Farhina Ahmed
Secretary
Ministry of Environment, Forest and Climate Change
Government of the People's Republic of Bangladesh

Message

I am pleased to share this volume of research outputs generated under the SUFAL Innovation Grant (SIG) Program, an integral component of the Sustainable Forests and Livelihoods (SUFAL) Project of the Bangladesh Forest Department under Ministry of Environment, Forest and Climate Change. This compilation reflects a significant step forward in our collective efforts to ground forest management and wildlife conservation in robust scientific evidence.

Bangladesh is endowed with a remarkable diversity of flora and fauna, yet this heritage is under mounting pressure from rapid land-use change, habitat fragmentation, climate-induced stresses, and the growing interface between people and wildlife. These complex challenges cannot be addressed through traditional management practices alone. They require interdisciplinary inquiry, empirical data, and context-specific solutions that link ecological integrity with human wellbeing.

The SIG program was conceived precisely with this vision in mind. By offering competitive grants to researchers, universities, and specialized institutions, the program has created space for innovative ideas, rigorous fieldwork, and analytical research on Forestry, wildlife and biodiversity issues.

The findings presented here do not remain confined to academic discussion; they generate clear, actionable recommendations for managers, planners, and policymakers. They provide insights that can inform zoning and management plans, improve conflict mitigation measures, strengthen community participation, and enhance the resilience of forest, wildlife and ecosystems to climate and other anthropogenic pressures.

I wish to acknowledge the dedication of the researchers and their teams, the guidance provided by the various review committees, and the support of partner organizations and development partners who have contributed to the success of the SIG program. Their combined efforts have ensured that the studies uphold scientific rigor while remaining closely aligned with national conservation priorities and international commitments.

It is my expectation that this publication will be used widely by conservation practitioners, government agencies, academia, development partners, and civil society to inform decision-making and to inspire further research and innovation. As we strive to conserve Bangladesh's forest, wildlife, biodiversity and ecosystems for present and future generations, evidence-based knowledge such as that contained in this volume will remain one of our most valuable assets.

Dr. Farhina Ahmed

Md. Amir Hosain Chowdhury
Chief Conservator of Forests
Bangladesh Forest Department

Message

Forests and wildlife in Bangladesh play a vital role in maintaining ecological balance, supporting livelihoods, and contributing to national development. To manage these resources wisely, we need a clear understanding of forest dynamics, species ecology, ecosystem services, and the social context of resource use.

This publication represents significant research on both forestry and wildlife supported by the SUFAL Innovation Grant (SIG) Program of the Sustainable Forests and Livelihoods (SUFAL) Project. The studies compiled here reflect a strong commitment to grounding conservation and forest management in scientific evidence, practical field experience, and the realities faced by forest-dependent communities in Bangladesh.

The research presented in this volume responds to that need. It includes work on forest restoration and productivity, co-management and collaborative forest management, biodiversity assessment, species conservation, human–wildlife interaction, and climate-resilient management practices. Together, these studies demonstrate how well-designed research can guide more sustainable and inclusive management of forests and wildlife.

The importance of this publication lies in its ability to translate research findings into practical guidance. The results offer concrete suggestions for improving forest management plans, enhancing protection and restoration measures, designing and managing Reserved Forests and Protected Areas, and supporting communities that depend on forests and wildlife for their livelihoods. As such, this volume is intended to serve not only researchers and academics but also policymakers, forest managers, conservation practitioners, and development partners.

I hope that the insights and recommendations contained here will be widely used to strengthen evidence-based decision making in the forestry and biodiversity sectors of Bangladesh. This publication will help to formulate our future policies, improve field practices, and inspire further research and innovation. It will make a long lasting contribution to the conservation of our forests, biodiversity and wildlife for present and future generations.

Md. Amir Hosain Chowdhury

Gobinda Roy
Project Director
Sustainable Forests and Livelihoods (SUFAL) Project
Forest Department

Foreword

Sustainable Forests and Livelihoods (SUFAL) Project has supported research and innovation through its Innovation Grant Program, designed to strengthen forestry and biodiversity knowledge in Bangladesh. SUFAL Innovation Grant (SIG) is one of the unique features of SUFAL Project guided by the Innovation Grant Manual. This mechanism was designed to promote scientific and applied research on forestry, wildlife, and biodiversity conservation, while also ensuring transparency, accountability, and quality in both the selection and implementation of research initiatives.

Through this competitive process, 34 research grants were awarded to researchers and institutions after rigorous evaluation. Each proposal and subsequent deliverable was carefully reviewed by the Deliverable Review and Comments Committee, the Research Proposal Evaluation Committee, and the Forestry and Wildlife Research Review Council. This multi-tiered scrutiny ensured that the work undertaken met high professional standards and directly addressed the needs and challenges in forestry and wildlife management.

SUFAL Project also organized result dissemination workshops, where researchers shared their findings with policymakers, practitioners, academics, and other stakeholders. These events served not only as a platform for knowledge exchange but also as an opportunity to foster collaboration and dialogue around future research priorities. Following this, the researchers submitted their final reports, marking the successful completion of all 34 studies under the SIG program.

To make these findings widely accessible, SUFAL is now publishing four volumes of research summaries: two focusing on forestry and two on wildlife. These volumes present the essence of the research in a concise and structured manner, allowing stakeholders, decision-makers, and development partners to draw practical lessons and insights. The outcomes documented here will help shape evidence-based policies, strengthen conservation practices, and guide further research and innovation in the forestry and biodiversity sector of Bangladesh.

I would like to extend my sincere gratitude to the dedicated researchers, the review committees, partner institutions, and the World Bank for their valuable support. Their commitment and contributions have made it possible to generate a body of knowledge that will serve the sector for years to come. This publication will not only enrich our understanding but also support Bangladesh for achieving its national priorities and international commitments related to forest, biodiversity and wildlife conservation.

Gobinda Roy

Table of Content

Research Title

Assessing and cataloging diversity of amphibians and marine reptiles in Bangladesh using integrative taxonomy approach through DNA barcoding and morpho-meristic study

by

Dr. Mahmudul Hasan

Assistant Professor Department of Fisheries, Jamalpur Science and Technology University (JSTU) Jamalpur-2012

CHAPTER I

INTRODUCTION

Title of Research Topic:

Assessing and cataloging diversity of amphibians and marine reptiles in Bangladesh using integrative taxonomy approach through DNA barcoding and morpho-meristic study

1.1 Problem statement:

The Government of Bangladesh is committed to take all measures prerequisite for a sustainable future. In effort, the Government (including BFD) takes myriad programmes and initiatives with the support of different consortia. Bangladesh has recently achieved unprecedented successes in the environmental sector. The overwhelming evidence on the loss of biodiversity all over the world showcases that we, as a nation, must act to conserve biodiversity. Ministry of Environment and Forests has been playing a pivotal role in biodiversity conservation of Bangladesh through Bangladesh Forest Department, and other national and international organizations. Biodiversity, the incredible variety of life on Earth that sustains us, is in peril. Species are becoming threatened at the most expeditious rate ever recorded. Over the past few decades it has become the issue of global concern for its rapid reduction worldwide. Bangladeshis no exception in this regard. Though the country is exceptionally endowed with a vast variety of flora and fauna, it is unfortunate that in recent decades the biodiversity of the country is under pressure due to incrementing population and over- exploitation of natural resources.

Today, many species of Bangladesh have reached a dreadful genetic loss. Unfortunately, detailed information and consummate inventories of such species often do not exist. The Government of Bangladesh is acutely conscious of this, and has in fact been preparing to face this challenge for several years now. Bangladesh has made a tremendous progress in terms of taking development initiatives towards conservation and sustainable use of the threatened species.

Bangladesh is a biologically rich country due to its unique site of Indo-Burma and Eastern Himalaya region, and is traversed by three of Asia`s largest rivers, the Ganga, Bramhputra and Meghna, which reach to the Bay of Bengal From several books and review papers on Bangladeshi wildlife‟s, it is evident, however, that the taxonomy used in wildlife is obsolete and not harmonized with the taxonomy employed globally or even in neighbor countries. There are very few taxonomists in Bangladesh who can name the anurans and marine reptiles accurately based on external morphology. Therefore, the identity and evolutionary relationships of these wild animals is still in ambiguity.

Despite genetic characterization and molecular works on different animals including bar coding of marine/freshwater species performed by several researchers including myself while the attempts are almost absent in case of molecular study of amphibians and sea snake in Bangladesh. Notably, the proposed project is completely new in Bangladesh perspective where no partial fund has been received for the proposed project. Due to their puzzling identification, local herpetologists unable to disclose this hitherto overlooked cryptic diversity in amphibians and marine reptiles. Identifying the amphibians, turtles and sea snakes accurately based on external morphology is a hassle for the local herpetologists.

Because of high rate of evolution, mt DNA often used to resolve the identity of species complex. In connecting this, mitochondrial DNA (*16S*, *Cytb* and *COI* genes) analyses can give the potential for interpretation of divergence of amphibians, turtles and sea snakes. In the background of above facts, we aimed to quantify the amphibians, turtles and sea snakes, contribute gene sequences to the DNA barcode library, find out any unnamed/candidate species and later describe them as a new species using multiple data sets (morphology, ecology and molecular). These data will be useful to formulate the strategies for sustainable management and conservation of amphibians, turtles and sea snakes in Bangladesh.

Considering all the facts above, it is summarized that BFD need to updated information related to amphibians and marine reptiles to meet the demand of SUFAL objectives.

1.2 Objectives of the study:

1) To accurately identify and cataloging amphibian and marine reptiles diversity in Bangladesh.
2. To develop a DNA barcode library and assess genetic diversity to facilitate the wildlife research and conservation in Bangladesh.
3. To discover and describe new species of amphibian and marine reptiles using multiple datasets (morphology, ecology and mt DNA data).
4. To formulate a conservation policy for the threatened species.

1.3 Research Questions

1. How many frog and marine reptiles (sea snakes) are available in Bangladesh where phenotypic plasticity is a major barrier to define their names?
2. Are the all 16S/Cytb/*COI* genes sequences available in the Gen Bank database to uplift the research of wildlife in Bangladesh comparing to neighboring countries?
3. Is there any handy tools (annotated check list and DNA barcode library, easy identification guide including DNA barcodes) to check the status of the current existing amphibian and marine reptile‟s diversity in Bangladesh?

CHAPTER II

LITERATURE REVIEW

After conducting a thorough review of the literature, we discovered a scarcity of research specifically dedicated to Bangladeshi anurans and reptiles. Recent times have witnessed the discovery of numerous novel frog species, despite the ongoing decline in biodiversity (Hasan et al. published papers in 2012, 2014a, 2014b, 2022 and Al-Razi et al. 2020, 2021, Chunskula et al., 2022 and Trageser et al. 2021). Additionally, Hasan et al. (2015, 2017, 2019) included Bangladesh frogs in their research. A recent study by Rahman et al. (2022) suggests that the number of frog species may exceed 62. It suggests that the local IUCN branch in Bangladesh (IUCN-2015) and other herpetologists' assumptions about the species count are incorrect. Integrative taxonomy application is leading to the identification and documentation of numerous previously unknown species, with many more still awaiting reporting. Similarly, the local herpetologist is still unaware of the exact number of sea snake species. Research is necessary to obtain accurate information about the population and status of the estimated 4–5 marine turtles. Sea snakes are reptiles belonging to the Elapidae family that have undergone secondary adaptations to live in saltwater environments. There are two categories of marine elapids: a group of eight species of sea kraits that lay eggs, and a group of nearly 70 species of sea snakes that give birth to live young. According to Sarker et al. (2017, the estimated species of sea snakes in Bangladesh is believed to be between 12 and 15, based on a survey and analysis of their exterior physical characteristics. However, they did not work exclusively, and this figure may be augmented.

CHAPTER III

3.1. Field survey:

Our team (PI Dr. M. Hasan, Co-PI M. Rahsed, Research Associate Z. H. Anik and Md I. Islam) visited Sherpur reserve forest and Kuakata coast for sampling purposes. It is noted that initially

Z. H. Anik was appointed in this project as a Research Associate, however after few months he left the campus due to his postgraduate study. Therefore again we appointed S. N. Bilasi as a research associate.

3.2 Sample collection: Location, sex, picture and voucher number of amphibian and marine reptile"s samples was stored in EDRL, Jamalpur Science and Technology University, Jamalpur- 2012. We gave voucher number of each specimen and took tissue from each sample. Later, they were preserved in 95% ethanol or a saturated DMSO/NaCl solution. Sex and source of each sample including their picture and date of collection was stored in our note book.

3.3 Identification of sample: We identified the collected species based on the literature of herpetology books (Khan, 2015; Kabir et al., 2009, Smith 1931, 1935) and current taxonomy knowledge. If necessary, we will also follow the species name adopted in the system of Frost (2024) and online portal the reptile database (Uetz et al., 2022).

3.4 Location

JSTU-Sherpur Reserve Forest

Our team visited Sherpur reserve forest. Although, it was just ending of winter, the number of frog species was not enough as we expected. The amphibian is generally will be available in coming days when the temperature will be around 30˚C. Presently, we found the *Fejervarya* and *Hylarana* species.

Figure 1: Our team working in Sherpur Reserve Forest.

Figure 2: After specimens collection from Sherpur Reserve Forest, then stored in 99% Ethanol in EDRL, JSTU for further examination and molecular study.

JSTU-Khadimnagar NP, Sylhet

Our team visited Khadim Nagar NP. We collected around 30 specimens.

Figure 3: Lab member of EDRL are working in Khadimnagar NP.

JSTU-Lawachara NP, Moulvi Bazar

Our team went to Lawachara NP and distributed leaflet regarding the specimen collection. It is hard to do sampling inside the Lawahara NP. We need to increase awareness among the people.

Figure 4: Lab member of EDRL are working in Lawachara NP

JSTU-Kaptai Lake

We established a connection through rapport and also developed network with few local herpetologists, who can assist us by delivering specimens whenever they become available. Furthermore, we established a connection with the relevant forest officials and other professionals who can assist us logistically by supplying information.

Our team visited Kaptai Lake area. We collected around few snake specimens. The number on individual and species name area listed in Table 2.

Figure 5: Lab member of EDRL are sampling in Kaptai Lake and Cox's Bazar area. SAU-

Chittagong-**Cox’s Bazar area:**

Our team went to Chittagong-Cox‟s Bazar area and distributed leaflet regarding the specimen collection. It was hard to do sampling inside the Chittagong-Cox‟s Bazar area due to bad weather.

Figure 6: Lab member of Aquatic Bio-resource Laboratory (ABR) are working in SAU (S2407k-4 is potential new species).

SAU-Kuakata coast

Our team went to Kuakata Coast and distributed leaflet regarding the specimen collection. It is hard to get the sea snake because of mass people bad concept on the snake. We need to increase awareness among the people. However, we were able to catch few specimens dring our visit.

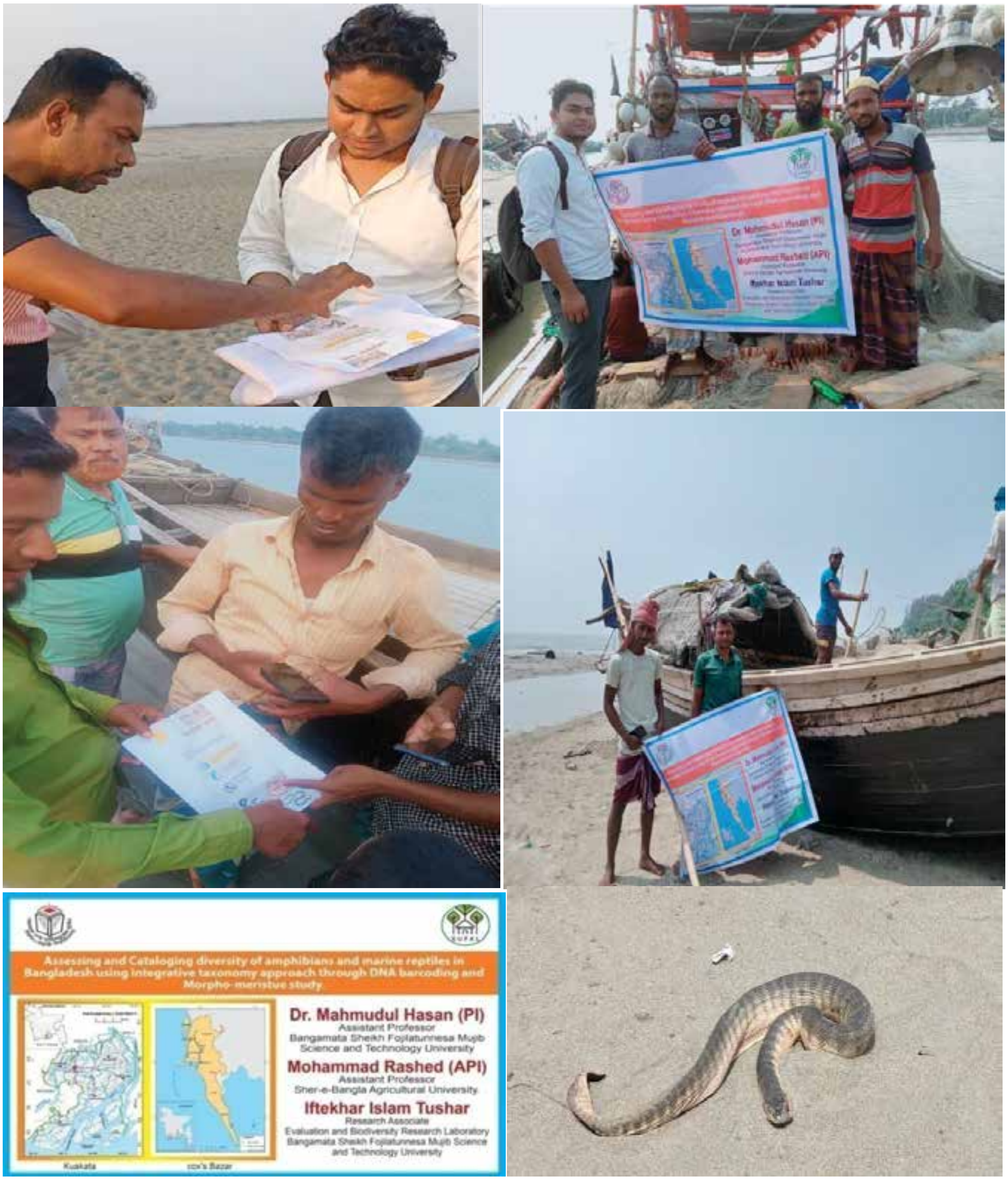


Figure 7: Our team is making rapport with local people and collect the sea snake from the Kuakata Sea Coast.

Figure 8: Our team is working inside the EDRL with other team members.

3.5 : Record of all data in the notebook:

All specimens were brought to EDRL and/or ABR laboratory. Their sex, image and morphological parameters (SVL, TL etc) were measured.

Figure 9: PI (Dr. M. Hasan) is working in ABR, SAU and doing molecular research.

3.6 : Primer design and order:

Total DNA samples for *16S* and *COI* analyses of the all amphibians and marine reptiles specimens was extracted from ethanol-fixed muscle tissue. Specimens and/or tissue samples was stored in the JSTU. Total DNA samples were used to amplify a partial portion of*16S*, *Cytb* and *COI* genes. PCR amplification and sequencing was performed using a set of primers which are listed below:

1. 16S gene: F51 (5́-CCC GCC TGT TTA CCA AAA ACA T -3́), R51 (5́-GGT CTG AAC TCA GAT CAC GTA-3́)
2. Cytb gene: H16064-F: 5′- CTTTGGTTTACAAGAACAATGCTTTA-3′ and Gludg-R: 5′-TGACTTGAARAACCAYCGTTG-3′
3. COI gene: Rep COI-F: 5′-TNT TMT CAA I ACC ACA AAG A-3′ and Rep COI-R: 5′-ACT TCT GGR TGK CCA AAR AAT CA-3′ and Cox-I-F: 5′-TCAGCCATACTACCTGTGTTCA-3′ and Cox-I-R: 5′-TAGACTTCTGGGTGGCCAAAGAATCA-3′

3.7 : Make rapport with local herpetologist and govt. official.

We established a connection with a local herpetologist, who can assist us by delivering specimens whenever they become available. We were unable to visit Khadimnagar and Lawachara National Parks during all times (all the year round). Furthermore, we established a connection with the relevant forest officials and other professionals who can assist us logistically by supplying information.

3.8 : Collection and record of all data inside the EDRL:

All specimens were brought to EDRL laboratory. Morphological and DNA work is going on.

Figure 10: PI (Dr. M. Hasan) is sorting out the frog specimens and doing molecular research in EDRL

Figure 11: PI (Dr. M. Hasan) is presenting SUFAL research work in front of DPD Mr. Md. Yousuf and my univ. colleagues.

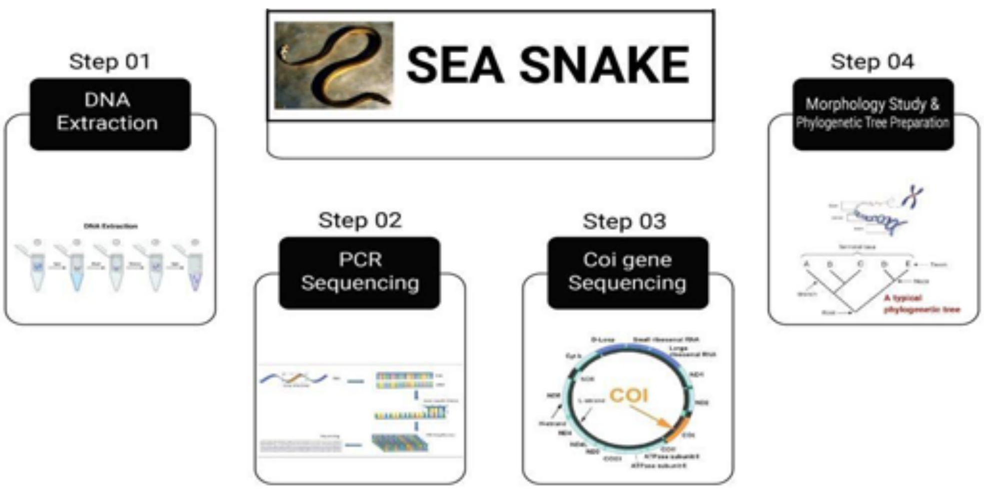


Figure 12: Procedure of COI gene sequencing

3.9 Phylogenetic analysis: The resultant nucleotide sequences of the *COI* genes was aligned using the Clusta lW program. From these three alignment data sets, sequence divergences (uncorrected *p* values) was calculated using MEGA Ver. 4.0 with the pairwise-deletion option, in which all alignable sites were used for calibration, but indel sites were not be counted. Gaps and ambiguous sites were excluded using Gblocks Ver. 0.91b with default parameters. Gap sites in alignments were treated as missing data. Phylogenetic analyses was performed by the maximum likelihood (ML), maximum parsimony (MP), and Bayesian inference (BI) methods. Nucleotide substitution models for ML and BI analyses were selected based on the Akaike information criterion (AIC) and Bayesian information criterion (BIC) respectively, which are implemented in the Kakusan 3.0 program. ML analysis was performed using Treefinder and the resultant tree was evaluated by bootstrap analysis with 1,000 replicates. BI analysis was performed using Mr Bayes Ver. 3.1.2 with the following settings: number of Markov chain Monte Carlo (MCMC) generations = 10 million, sampling frequency = 100, and the first 1 million generations was discarded as burn-in. The number of MCMC generations and burn-in size was determined by checking the convergence of –log likelihood (–ln*L*) values and tree length against generation number by using Tracer ver. 1.4. Statistical support of the BI tree was evaluated by Bayesian posterior probability (BPP). MP was performed with 1,000 bootstrap replicates using PAUP* 4.0b10.

3.10 Morphology study: Morphological, meristic and acoustic data was recorded based on our previous publications (Islam et al. 2008; Hasan et al., 2012b).

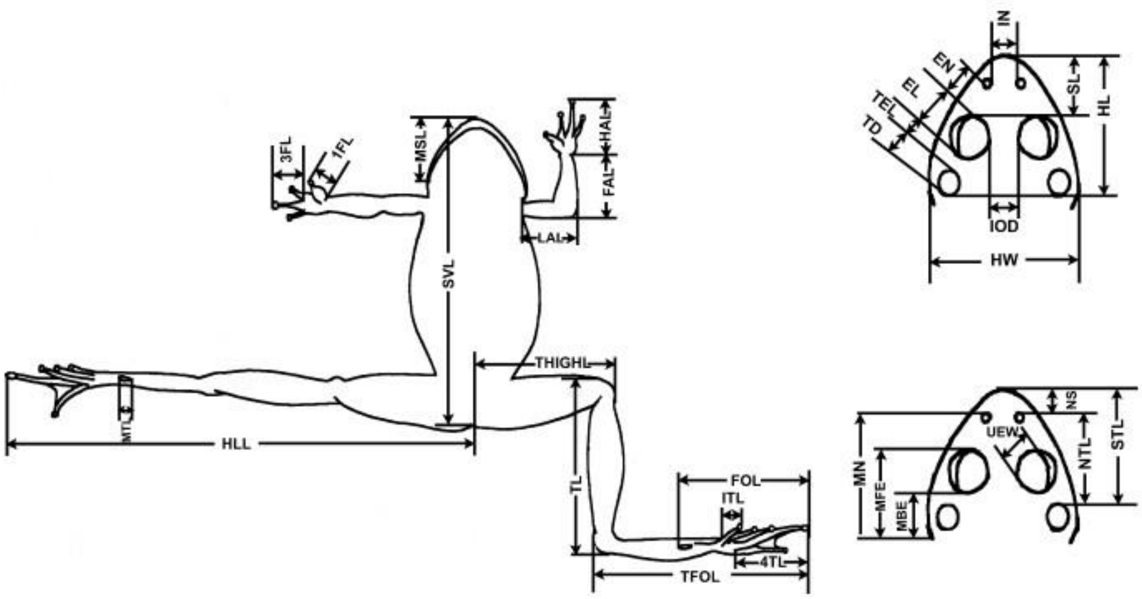


Figure 13: Typical picture for morphology study of frogs

Table 1: Morphological parameters of frogs

Abbreviation	Character
SVL	Snout-vent length
HL	Head length (from back of mandible to tip of snout).
HW	Head width (left side back of mandible to right side back of mandible)
STL	Snout-tympanum length (Tip of snout to front of tympanum)
MSL	Mouth angle-snout length (Tip of snout to end of mouth opening)
NS	Nostril- snout length (Distance from nostril to tip of snout)
SL	Snout length
NTL	Nostril tympanum length (Distance between nostril and front of tympanum)
EN	Distance from front of eyes to nostril
TEL	Tympanum eye length (distance between end of eye to front of tympanum)
TD	Tympanum diameter (Maximum diameter)
MN	Distance from back of mandible to nostril
MFE	Distance from back of mandible to front of eye
MBE	Distance from back of mandible to back of eye
IN	Internarial space (Distance between 2 nostrils)
EL	Eye length (greatest diameter of the eye including upper eyelids)
IOD	Interorbital distance
UEW	Maximum width of upper eyelid
HAL	Hand length (from base of outer palmer tubercle to tip of third finger)
FAL	Fore arm length (from elbow to base of outer palmer tubercle)
LAL	Lower arm length
HLL	Hind limb length
THIGHL	Thigh length
TL	Tibia length
FOL	Foot length (from base of inner metatarsal tubercle to tip of fourth toe)
TFOL	Length of tarsus and foot (from base of tarsus to tip of fourth toe)
3FL	Third finger length
1FL	First finger length
4TL	Fourth toe length
IMTL	Inner metatarsal tubercle length
ITL	Inner toe length

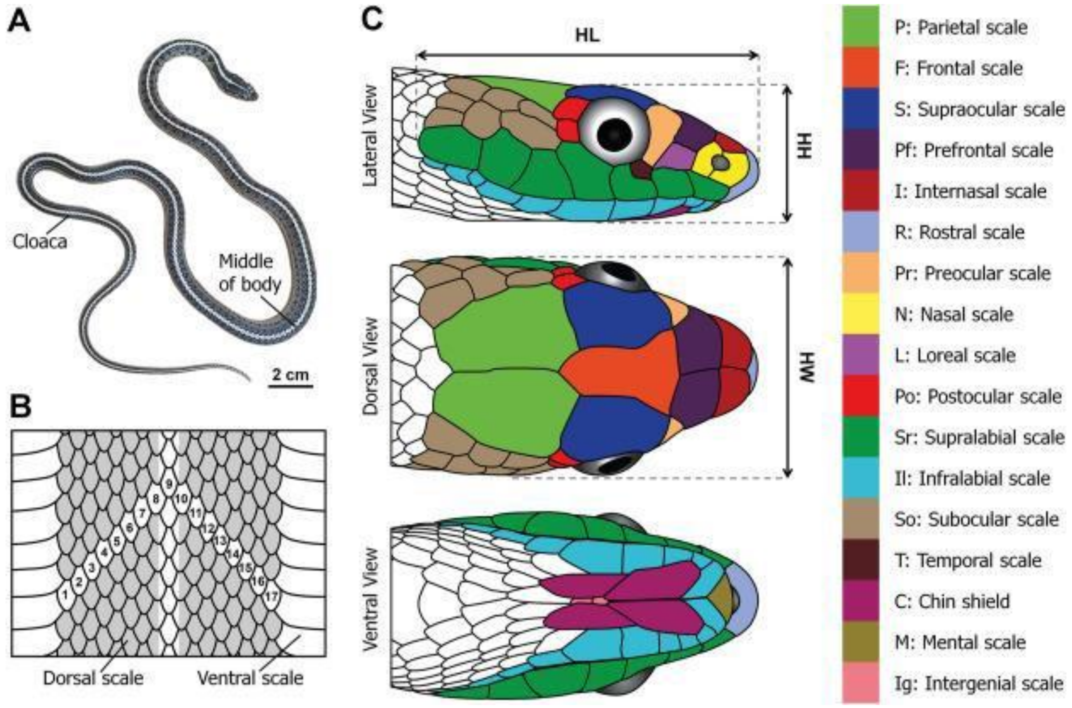


Figure 14: Morphological parameters of snake (Source: internet)

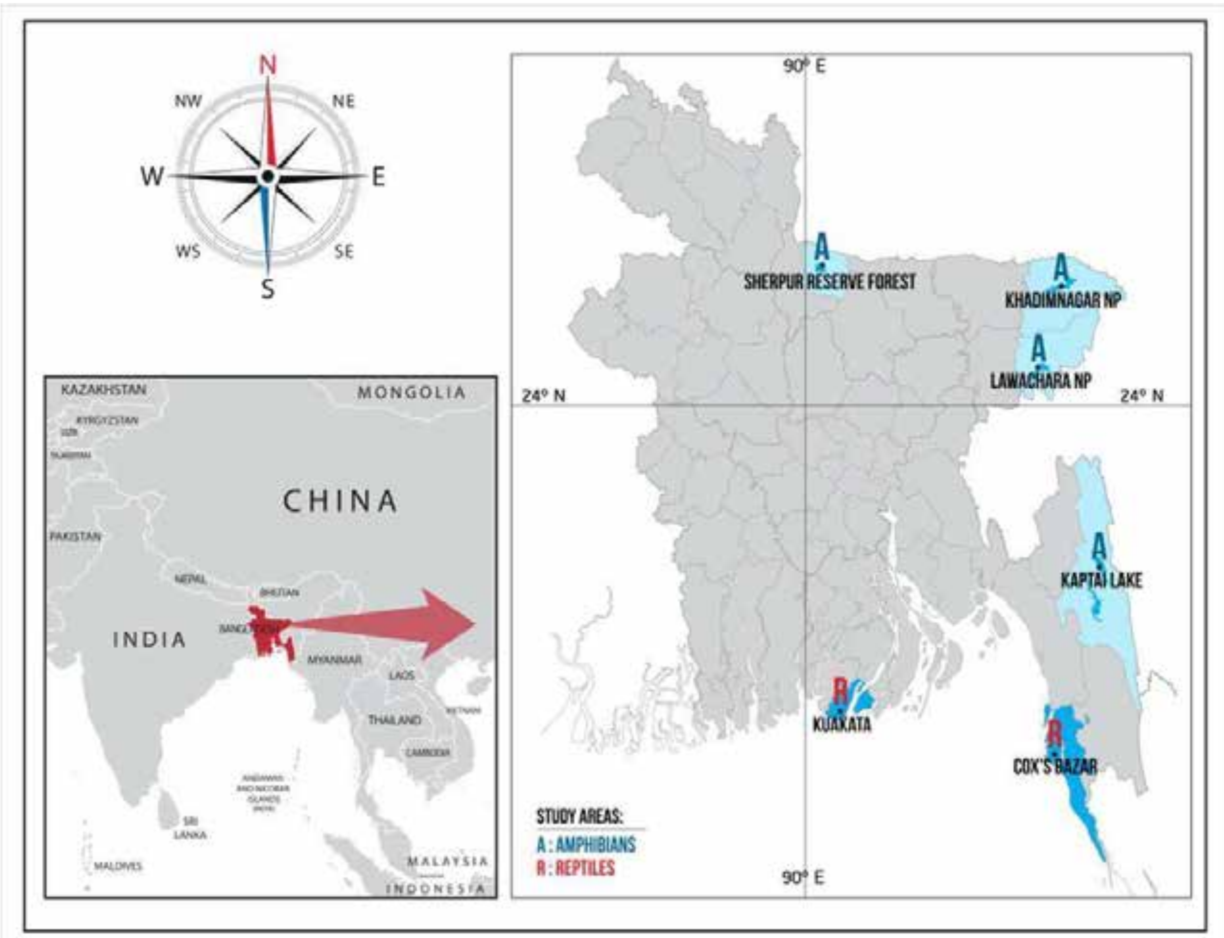
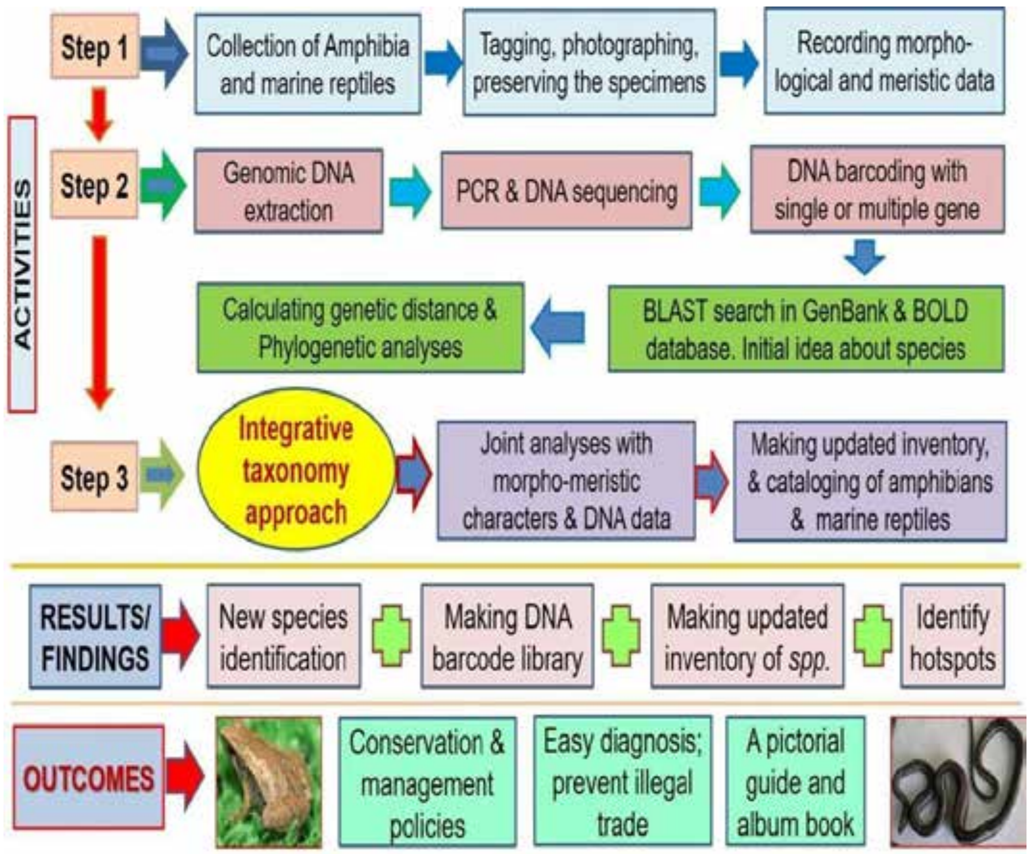


Figure 15: Bangladesh map with study sites. Symbols denote „A" for Amphibians and „R" for reptiles.

3.11 Research process flow



CHAPTER I V

RESULTS AND DISCUSSIONS

Amphibians and reptiles play a vital role in maintaining biodiversity by contributing to ecosystem balance and functioning. Amphibians, such as frogs and salamanders, act as bio indicators, reflecting environmental health due to their permeable skin and sensitivity to pollution. They control insect populations, including pests, while also serving as prey for larger animals. Reptiles, including snakes, lizards, and turtles, help regulate prey species and disperse seeds, promoting plant diversity. Many reptiles are apex predators, maintaining food web stability. Both groups face threats like habitat loss, climate change, and pollution, leading to declining populations and biodiversity loss. Protecting amphibians and reptiles is essential for preserving ecological harmony and ensuring the survival of interconnected species.

Figure 16: *Hylarana* sp. From Bandarban

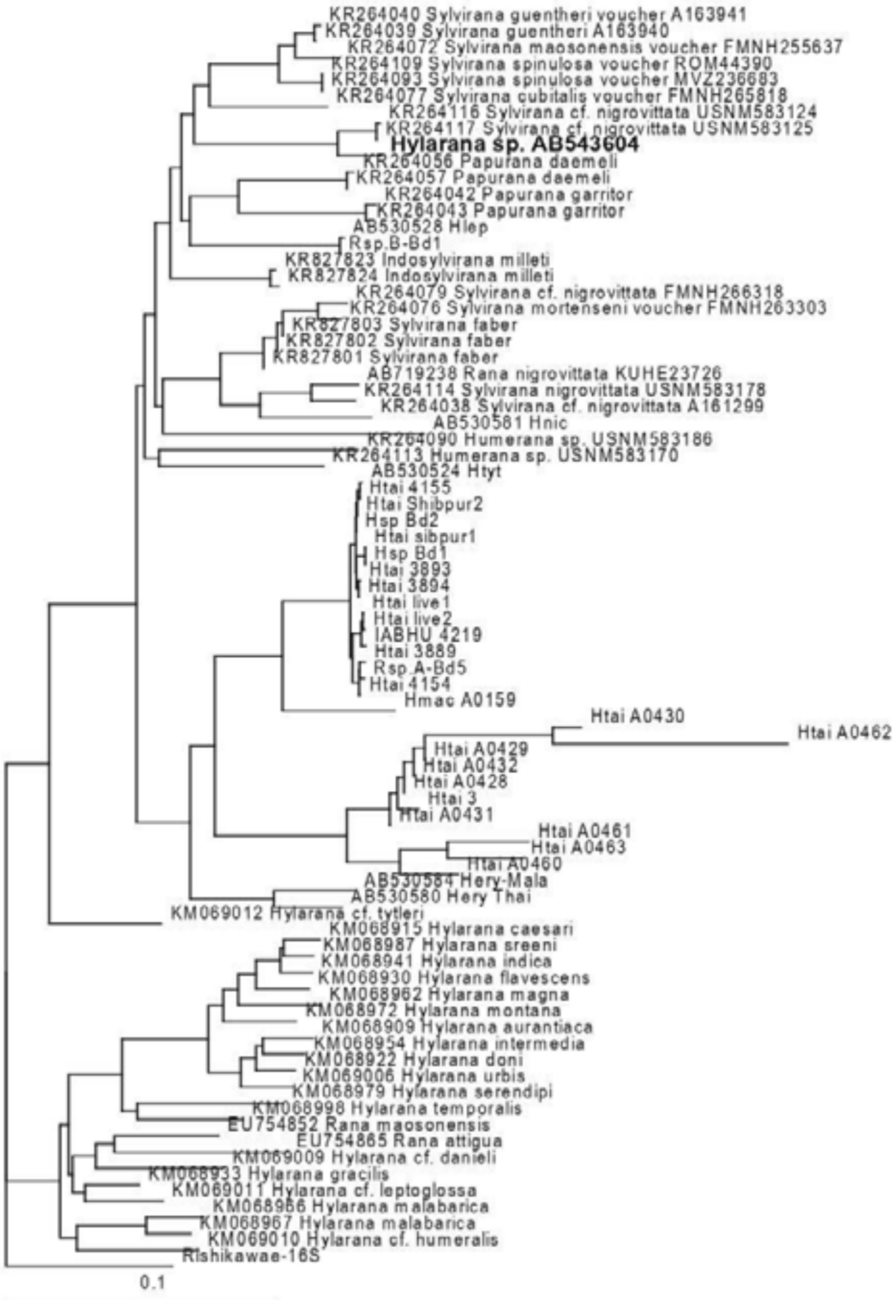


Figure 17: Phylogenetic tree of *Hylarana* new sp. from Bandarban, Bangladesh

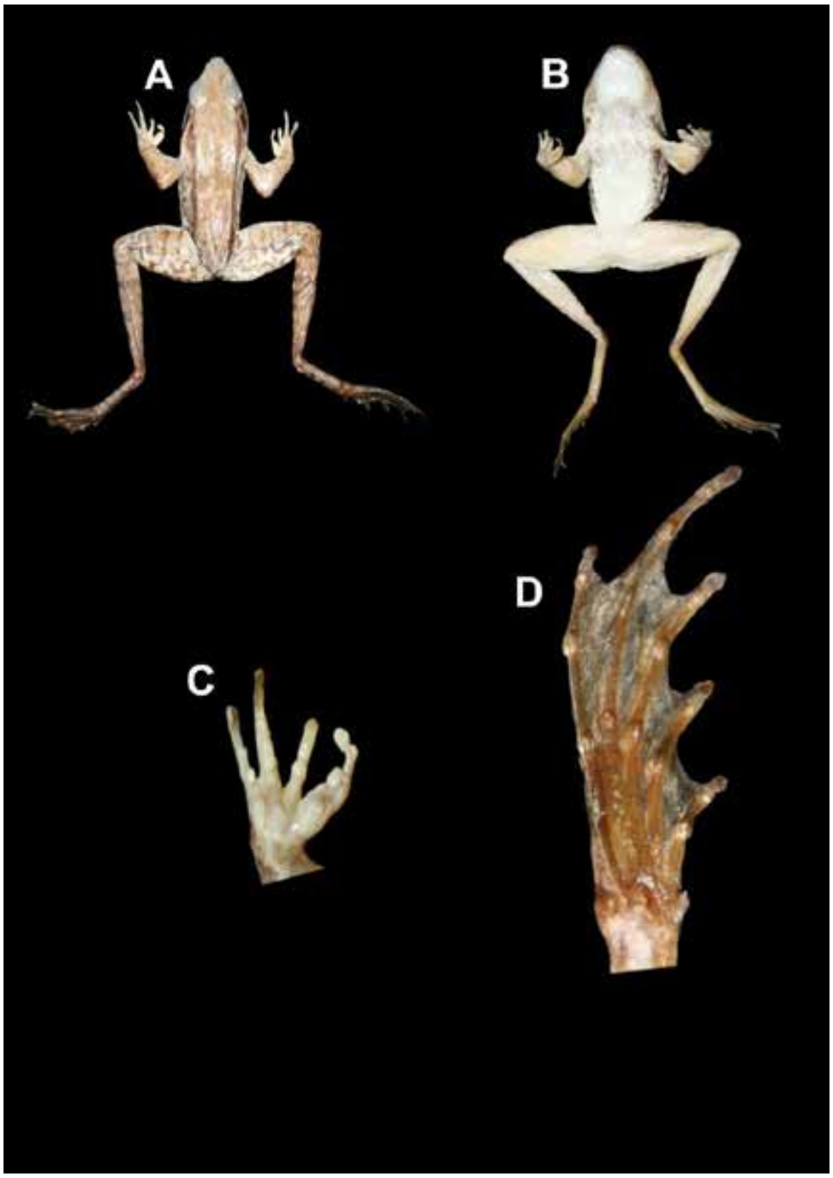


Figure 18: Dorsal, ventral, toe and foot parts of *Hylarana* sp.

Table 2: Field survey report from Khadimnagar and Lawachara NP

SL no.	Date	Collector/ Team member	Locatio n	Time of sampl ing	Temperat ure	Weat her	Species name	Qua ntity	Voucher number	TL (m m)	Sex	Habitat	Note
							BSFMSTU-Khadimnagar NP						
1	21.04. 2024	EDRL members	Khadim Nagar NP, Sylhet	Morni ng- Eveni ng	20˚C	Sunn y	❖ *E. Cyanophlyctis* ❖ *H. tyleri* ❖ *Microhya sp.* ❖ *Polypedatessp* .	1 1 1 1	MHBSF MSTU Frog 01-04	50 26 22 42	♂ - - ♂	Swamp, Pond & Forest stream	It was a hot day All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on.
2	22.05. 2024	EDRL members	Khadim Nagar NP, Sylhet	Morni ng- Eveni ng	25˚C	Clou dy	❖ *K. pulchara* ❖ *Fejervarya sp.* ❖ *Microhya sp.* ❖ *Polypedatessp* .	1 1 1 1	MHBSF MSTU Frog 05-08		♂ - - ♂	Forest	The humidity was high. All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
3	23.05. 2024	EDRL members	Khadim Nagar NP, Sylhet	Morni ng- Eveni ng	20˚C	Torre ntial rainn g	❖ *E. Cyanophlyctis* ❖ *H. tigerinus* ❖ *Kaloula sp.* ❖ *Polypedatessp* .	1 1 1 1	MHBSF MSTU Frog 09-12		♂ - - ♂	Rores	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
4	24.05. 2024	EDRL members	Khadim Nagar NP, Sylhet	Morni ng- Eveni ng	30˚C	Torre ntial rainn	❖ *E. Cyanophlyctis* ❖ *H. tyleri* ❖ *Microhya sp.* ❖ *Polypedatessp* .	1 1 1 1	MHBSF MSTU Frog 13-16		♂ - - ♂	Swamp, Pond & Forest stream	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
2	25.05. 2024	EDRL members	Khadim Nagar NP	Morni ng- Eveni ng	25˚C	Clou dy	❖ *F. limnocharis* ❖ *Fejervarya sp.* ❖ *E. cyanophlyctis* ❖ *H. tigerinus*	1 1 1 1 1	MHBSF MSTU Frog17- 20	15 10 12 40	♂ ♀ ♀ ♂	Pond & Forest stream	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on. Page 26

JSTU-Lawachara NP													
1	26.04.24	EDRL members	Lawachara	Morning-Evening	18°C	Sunny	❖ *E. Cyanophlyctis* ❖ *H. tyleri* ❖ *P. teraensis* ❖ *Polypedatessp*.	1 1 1 1	MHBSF MSTU Frog21- 24	54 40 54 0	♂ ♂ ♂ ♂	Swamp, Pond & Forest stream	There was no electricity. All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
2	27-05, 2024	EDRL members	(Eastern part), Lawachara	Morning-Evening	33°C	Sunny	❖ *E. Cyanophlyctis* ❖ *H. tyleri* ❖ *Microhya sp.* *Polypedatessp.*	1 1 1 1	MHBSF MSTU Frog25- 29	50 30 25 29	- ♂ ♂ ♂	Swamp, Pond & Forest stream	Day long raining. All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on.
	28.05.2024	EDRL members	Do	Do	33°C	Rainy	❖ *E. Cyanophlyctis* ❖ *H. tigerinus* ❖ *Microhya sp.* ❖ *Polypedatessp*.	1 1 1 1	MHBSF MSTU Frog29- 32		♂ - - ♂	Muddy Forest	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
	29-30.05.2024	EDRL members	Do	Do	33°C	Torrential raining	❖ *Rhacoporus sp* ❖ *H. tyleri* ❖ *Bufo sp.* ❖ *Polypedatessp*	1 1 1	MHBSF MSTU Frog33- 36		♂ - -	Swamp, Pond & Forest stream	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on

4.1 : Morphological observation:

We measured the frog specimens by using vernial scale (mm). The result shows in Table 3 are obtained by Mann-Whitney U test:

Table 3: Mann-Whitney U test result of several frog species from Khadimnagar and Lawachara NP.

	U	Z	P			U	Z	P	
HL/SVL	197	0.144	0.8852			74	0.873	0.3826	
HW/SVL	184	0.486	0.6272			41	2.279	0.0227	*
S-N/SVL	185	0.459	0.6460			36	2.492	0.0127	*
N-N/SVL	128	1.956	0.0505			40	2.321	0.0203	*
N-E/SVL	160	1.116	0.2646			32	2.662	0.0078	**
ED/SVL	99	2.717	0.0066	**		17	3.301	0.0010	**
E-E/SVL	19	4.817	0.0000	**		36	2.492	0.0127	*
ELW/SVL	58	3.793	0.0001	**		1	3.983	0.0001	**
TD/SVL	201	0.039	0.9686			17	3.301	0.0010	**
FLL/SVL	187	0.407	0.6841			93	0.064	0.9491	
FHL/SVL	159	1.142	0.2535			50	1.895	0.0580	
FAW/SVL	105	2.559	0.0105	*		93	0.064	0.9491	
HAL/SVL	175	0.722	0.4704			51	1.853	0.0639	
F1/SVL	191.5	0.289	0.7728			55	1.682	0.0925	
F2/SVL	137	1.719	0.0855			64	1.299	0.1939	
F3/SVL	168	0.906	0.3651			66	1.214	0.2248	
F4/SVL	134	1.798	0.0722			84	0.447	0.6547	
HLL/SVL	193	0.249	0.8031			2	3.940	0.0001	**
FEL/SVL	202	0.013	0.9895			16	3.343	0.0008	**
TIL/SVL	98	2.743	0.0061	**		0	4.025	0.0001	**
TFL/SVL	128	1.956	0.0505			7	3.727	0.0002	**
FOL/SVL	117	2.244	0.0248	*		9	3.642	0.0003	**
T1/SVL	179	0.617	0.5373			75	0.831	0.4062	
T2/SVL	199	0.092	0.9268			48	1.981	0.0476	*
T3/SVL	189	0.354	0.7231			28	2.832	0.0046	**
T4/SVL	192	0.276	0.7828			39	2.364	0.0181	*
T5/SVL	146	1.483	0.1380			72	0.958	0.3379	
IMT/SVL	141	1.614	0.1064			20	3.173	0.0015	**
HL/HW	193	0.249	0.8031			2	3.940	0.0001	**
S-N/N-E	165	0.984	0.3249			6	3.770	0.0002	**
ED/E-E	10	5.053	0.0000	**		7	3.727	0.0002	**
TD/ED	109	2.455	0.0141	*		88	0.277	0.7819	
N-N/E-E	4	5.211	0.0000	**		0	4.025	0.0001	**
ELW/E-E	3	5.238	0.0000	**		5	3.813	0.0001	**
F1/F2	124	2.061	0.0393	*		45	2.108	0.0350	*
TIL/FEL	127	1.982	0.0475	*		42	2.236	0.0253	*
FOL/FEL	129	1.929	0.0537			91.5	0.128	0.8983	
TIL/FOL	33	4.449	0.0000	**		65	1.256	0.2090	

Interpretation:

Body ratios relative to SVL (E.g., HL/SVL and HW/SVL) and 10 other ratios (E.g., HL/HW and S-N/N-E) and the results of the Mann-Whitney U test between ratios of *P. teriaiensis*vs. *Polypedates* sp. are shown in Table 3. Mean values of ED/SVL, ELW/SVL, ED/E-E, N-N/E-E, and ELW/E-E are significantly large ($P<0.01$) in *P. teriaiensis*compared with those in *Polypedates* sp. These are apparently derived from relatively large ED, ELW, and N-N and relatively small SVL and E-E of *P. teraiensis.*

4.2 Molecular data:

We also extract DNA and do PCR by using appropriate primer. Later, we sequenced our collected samples and get the following genetic data (COI gene gene):

4.3 Catalogue of Amphibians and Reptiles (*DNA BARCODE LIBRARY*): *Anura:*

1. FR-1E. Kalagars

GAGTCCAGCCTGCCCAGTGATACAATTTAACGGCCGCGGTATACTGACCGTGCGAAGG
TAGCATAATCACTTGTTCTTTAAATGGGGACTAGTATGAACGGCACCACGAGGGCTTTA
CTGTCTCCTCCCTTCAATCAGTGAAACTGACCTCCCTGTGAAGAGGCAGGGATACCAC
TATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAACAACAGCCCAAACACCACCAC
CCCAAAAAGTTTTAAGGGTATTGCTAGTTGGTTTTAGGTTGGGGTGACCGCGGAGTAT
AAACCATCCTCCACGACGAACGGGCCTACCCCCTTACCCAAGAGCTACGCCTCTAAGG
ATTAACACATTAACGTAAAATGATCCAAATATTTGATCAACGAACCAAGTTACCCTGGG
GATAACAGCGCAATCCATTTTTAGAGCCCCTATCGACAAATGGGTTTACGACCTCGATG
TTGGATCAGGGTATCCAGGAGGTGCAGCCGCTTCCAATGGTTTGTTTGTTCAACAATT
AAAGACCCTACGTGATCTGAGTTCAGACCGGA

2. FR-2 Euphlyctis kalasgramensis

GGAGCATAAGAGGTCCAGCCTGCCCAGTGATACAATTTAACGGCCGCGGTATACTGAC
CGTGCGAAGGTAGCATAATCACTTGTTCTTTAAATGGGGACTAGTATGAACGGCACCA
CGAGGGCTTTACTGTCTCCTCCCTTCAATCAGTGAAACTGACCTCCCTGTGAAGAGGC
AGGGATACCACTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAACAACAGCCCA
AACACCACCACCCCAAAAAGTTTTAAGGGTATTGCTAGTTGGTTTTAGGTTGGGGTGA
CCGCGGAATAAAAACCATCCACCAAGACAAACCGGCCTTCCCCCTTAACCCACATTTC
TACCAATAAGGATTTAAACGTTTACTGACCAGGCAACCAATCATTGAACCAAGTAACCC
TGGGGACAGGAGCACAACCTACTTCACAATTTTTTATCCCCAAATAGGCTTACGACTTC
AATGTCGGATCAGGGTATCCCGGTGTTGCAGCCGCTACCGAAGGTTCGTTTGTTCAAC
GATTAAAACCCTACATGACTGTACGTGATCTACTCGGCAACACCGG

3. FR-3Euphlyctis cyanophlyctis

AGAGTCAGCCTGCCCAGTGATACAATTTAACGGCCGCGGTATACTGACCGTGCGAAGG
TAGCATAATCACTTGTTCTTTAAATGGGGACTAGTATGAACGGCACCACGAGGGCTTTA
CTGTCTCCTCCCTTCAATCAGTGAAACTGACCTCCCTGTGAAGAGGCAGGGATACCAC
TATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAACAACAGCCCAAACACCACCAC
CCCAAAAAGTTTTAAGGGTATTGCTAGTTGGTTTTAGGTTGGGGTGACCGCGGAGTAT
AAACTATCCTCCACGACGAACGGGCCTACCCCCTTACCCAAGAGCTACGCCTCTAAGG
ATTAACACATTAACGTAAAATGATCCAAATATTTGATCAACGAACCAAGTTACCCTGGG
GATAACAGCGCAATCCATTTTTAGAGCCCCTATCGACAAATGGGTTTACGACCTCGATG
TTGGATCAGGGTATCCAGGAGGTGCAGCCGCTTCCAATGGTTTGTTTGTTCAACAATT
AAAACCCTACGTGATCTAGT

4. FR-3 Euphlyctis kalasgramensis

AGAGTCAGCCTGCCCAGTGATACAATTTAACGGCCGCGGTATACTGACCGTGCGAAGG
TAGCATAATCACTTGTTCTTTAAATGGGGACTAGTATGAACGGCACCACGAGGGCTTTA
CTGTCTCCTCCCTTCAATCAGTGAAACTGACCTCCCTGTGAAGAGGCAGGGATACCAC
TATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAACAACAGCCCAAACACCACCAC
CCCAAAAAGTTTTAAGGGTATTGCTAGTTGGTTTTAGGTTGGGGTGACCGCGGAGTAT
AAACTATCCTCCACGACGAACGGGCCTACCCCCTTACCCAAGAGCTACGCCTCTAAGG
ATTAACACATTAACGTAAAATGATCCAAATATTTGATCAACGAACCAAGTTACCCTGGG
GATAACAGCGCAATCCATTTTTAGAGCCCCTATCGACAAATGGGTTTACGACCTCGATG
TTGGATCAGGGTATCCAGGAGGTGCAGCCGCTTCCAATGGTTTGTTTGTTCAACAATT
AAAACCCTACGTGATCTAGT

5. FR-4 Minervarya pierrei

GTATAAGAGGTCCAGCCTGCCCAGTGAAATTTTAACGGCCGCGGTACCCTGACCGTGC
GAAGGTAGCATAATCACTTGTTCTTTAAATGAGGACTAGTATCAACGGCATCACGAGG
ATTTTACTGTCTCCTTTTTCCTATCGGTGAAACTGATCTCCCCGTGAAGAAGCGGGGAT

AATATTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAGTAACACCTCAAACACA
CCCCCTCCCAAAAAGTTTTAATGTTCTGTTCACTGGTTTTAGGTTGGGGCGACCGCGG
AGTACAACTTAACCTCCACAGCGCACGGAACTTATTCCTTACCTGAGAGCTACACCTC
AAAGAATTATCACATTAACGTAAAATGATCCAATATTTTCCTTATTGATTAATGAACCAA
GTTACCCTGGGGATAACAGCGCAATCCATTTCTAGAGCCCCTATCGACAAATGGGTTT
ACGACCTCGATGTTGGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATGGTTTGTT
TGTTCAACAATTAAAACCCTACGTGATCTGAGTTCAGACCGGA

6. FR-6Hylarana tytleri

AGAGGTCCAGCCTGCCCAGTGACAAAGTTCAACGGCCGCGGTATCCTGACCGTGCGA
AGGTAGCATAATCACTTGTTCTTTAAATAGGGACTAGTATCAACGGCATCACGAGGGCT
GCACTGTCTCCTTTCTCCAATCAGTGAAACTGATCTCCCCGTGAAGAAGCGGGGATTT
TTATATAAGACGAGAAGACCCCATGGAGCTTTAAGCAATGAATTTACCTTTAATTGAAA
CTTCTACTAATTTCAAAAGCCTAATTCTAGCTTTTGGTTGGGGGGACCGCGGAGTATAA
CTAAACCTCCACAACTAACGGGCTCTGCCCTTATCTACGAGCCACAGCTCTAAGAATTA
ATAAACTAATGCCTTTGACCCGAAAACTCGATCAATGAACCAAGTTACCCTGGGGATA
ACAGCGCAATCTACTTTAAGAGCCCATATCGACAAGTAGGCTTACGACCTCGATGTTG
GATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATGGTTCGTTTGTTCAACGATTAAA
ACCCCACGTGATCTGAGTTCAGACCGGA

7. FR-7Euphlyctis kalasgramensis

AGAGGTCCAGCCTGCCCAGTGATACAATTTAACGGCCGCGGTATACTGACCGTGCGAA
GGTAGCATAATCACTTGTTCTTTAAATGGGGACTAGTATGAACGGCACCACGAGGGCT
TTACTGTCTCCTCCCTTCAATCAGTGAAACTGACCTCCCTGTGAAGAGGCAGGGATAC
CACTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAACAACAGCCCAAACACCAC
CACCCCAAAAAGTTTTAAGGGTATTGCTAGTTGGTTTTAGGTTGGGGTGACCGCGGAG
TATAAACTATCCTCCACGACGAACGGGCCTACCCCCTTACCCAAGAGCTACGCCTCTA
AGGATTAACACATTAACGTAAAATGATCCAAATATTTGATCAACGAACCAAGTTACCCT
GGGGATAACAGCGCAATCCATTTTTAGAGCCCCTATCGACAAATGGGTTTACGACCTC
GATGTTGGATCAGGGTATCCAGGAGGTGCAGCCGCTTCCAATGGTTTGTTTGTTCAAC
AATTAAAACCCTACGTGATCTGATTTCAGACCGGA

8. FR-18Minervarya pierrei

TCCCTATAGAGGTCCAGCCTGCCCAGTGAAATTTTAACGGCCGCGGTACCCTGACCGT
GCGAAGGTAGCATAATCACTTGTTCTTTAAATGAGGACTAGTATCAACGGCATCACGA
GGATTTTACTGTCTCCTTTTTCCTATCGGTGAAACTGATCTCCCCGTGAAGAAGCGGG
GATAATATTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAGTAACACCTCAAACA
CACCCCCTCCCAAAAAGTTTTAATGTTCTGTTCACTGGTTTTAGGTTGGGGCGACCGC
GTACTACATCTTAACCTCCAGAGAGCACGGAATTTATTCTTTACCTGATAGCTACACCT
CAAAGAATTATCACACTAACGTAAAATGATAAGATATTTTCCTACATTGACTAAAGAAC
CACCGTTGACCGCTGGGGATATCCGCCCGACCCATGTCTAGAACCCCTAACCACAAAT
GGGCCCTACGATCTCAAGGCCGGATCAGGTTCGTGCATGTAGCTTCCGAGTATACCAC
ATGCTCCGCCGCTTGTGCGGGACCCCGTCAATTCGTTTTAATTTCAGACTTGCAACCG T

9. FR-21Minervarya pierrei

CATACTCCTATAAGAGGTCCAGCCTGCCCAGTGAAATTTTAACGGCCGCGGTACCCTG
ACCGTGCGAAGGTAGCATAATCACTTGTTCTTTAAATGAGGACTAGTATCAACGGCATC
ACGAGGATTTTACTGTCTCCTTTTTCCTATCGGTGAAACTGATCTCCCCGTGAAGAAG
CGGGGATAATATTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAGTAACACCTC
AAACACACCCCCTCCCAAAAAGTTTTAATGTTCTGTTCACTGGTTTTAGGTTGGGGCG
ACCGCGGAGTACAACTTAACCTCCACAGCGCACGGAACTTATTCCTTACCTGAGAGCT
ACACCTCAAAGAATTATCACATTAACGTAAAATGATCCAATATTTTCCTTATTGATTAAT
GAACCAAGTTACCCTGGGGATAACAGCGCAATCCATTTCTAGAGCCCCTATCGACAAA

TGGGTTTACGACCTCGATGTTGGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATG
GTTTGTTTGTTCAACAATTAAAACCCTACGTGATCTGAGGTTCAGAACCGGA

10. FR-24Polypedates teraiensis
ACGTCCAGCCTGCCCAGTGAATCTTAAACGGCCGCGGTATCCTAACCGCGCGAAGGTA
GCATAATCACTTGTTCTTTAAATGGGGACTCGTATCAACGGCATCACGAGGGCTTTACT
GTCTCCTCTTTTTGATCAGTGAAATTGATCTTCCCGTGAAGAAGCGGGAATATTTTTAT
AAGACGAGAAGACCCCATGGAGCTTTAAACCAAATAGCAACTTAACCACTTATCCCAC
AATAAATTTAAGCCCTGTTATACGGTTTTTGGTTGGGGTGACCGCGGAGTAAAGCATAT
CCTCCACGACGGAAAGAACACAATCTTTATTTAAGAACCACATTTCTAAAAATTAGTAT
ACTAACGTTTACTGACCCGACAATCGATCAACGAACCAAGTTACCCTGGGGATAACAG
CGCAATCTACTTCAAGAGCTCATATCGACAAGTAGGCTTACGACCTCGATGTTGGATC
AGGGTATCCCGGTGGTGCAGCCGCTACCGAAGGTTCGTTTGTTCAACGATTAAAACCC
TACGTGATCTAGT

11. FR-27-Kaloula pulchra
CCAGCCTGCCCAGTGACAAAGTTAAACGGCCGCGGTACCCTAACCGTGCGAAGGTAG
CGCAATCACTTGTTCTTTAAATGAGGACTAGTATGAATGGCATCACGAGGGTTGCACT
GTCTCCCCTTTTTAATCAATGAAACTGACCCCCCCGTGAAGAGGCGGGGATATAACTAT
AAGACGAGAAGACCCCATGGAGCTTTAAACTCAGTACCAACTGCCTAACAATACATCA
TTACAATTTGGCAGATCTGATTACTAGTTTTCGGTTGGGGTGACCGCGGAGTAAAACA
AAACCTCCACGATGAAAGGACCTATACTCCTAATCATAGAGCCACAGCTCAAAGAATC
AAAAAACTGACATAAATTGATCCAATTAATTTGATCAACGAACCAAGTTACCCTGGGGA
TAACAGCGCAATCCACTTCAAGAGCCCCTATCGACAAGTGGGTTTACGACCTCGATGT
TGGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAAAGGTTCGTTTGTTCAACGATTA
AAACCCTACGTGATCTGAGTTCAGAAC

12. FR-29-Polypedates teraiensis
TCAGCCTGCCCAGTGAATCTTAAACGGCCGCGGTATCCTAACCGCGCGAAGGTAGCAT
AATCACTTGTTCTTTAAATGGGGACTCGTATCAACGGCATCACGAGGGCTTTACTGTCT
CCTCTTTTTGATCAGTGAAATTGATCTTCCCGTGAAGAAGCGGGAATATTTTTATAAGA
CGAGAAGACCCCATGGAGCTTTAAACCAAATAGCAACTTAACCACTTATCCCACAATAA
ATTTAAGCCCTGTTATACGGTTTTTGGTTGGGGTGACCGCGGAGTAAAGCATATCCTC
CACGACGGAAAGAACACAATCTTTATTTAAGAACCACATTTCTAAAAATTAGTATACTA
ACGTTTACTGACCCGACAATCGATCAACGAACCAAGTTACCCTGGGGATAACAGCGCA
ATCTACTTCAAGAGCTCATATCGACAAGTAGGCTTACGACCTCGATGTTGGATCAGGG
TATCCCGGTGGTGCAGCCGCTACCGAAGGTTCGTTTGTTCAACGATTAAAACCCTACG
TGATCTGAGTTCAGACCGGG

13. FR-30-Polypedates teraiensis
CAGCCTGCCCAGTGAATCTTAAACGGCCGCGGTATCCTAACCGCGCGAAGGTAGCATA
ATCACTTGTTCTTTAAATGGGGACTCGTATCAACGGCATCACGAGGGCTTTACTGTCTC
CTCTTTTTGATCAGTGAAATTGATCTTCCCGTGAAGAAGCGGGAATATTTTTATAAGAC
GAGAAGACCCCATGGAGCTTTAAACCAAATAGCAACTTAACCACTTATCCCACAATAAA
TTTAAGCCCTGTTATACGGTTTTTGGTTGGGGTGACCGCGGAGTAAAGCATATCCTCC
ACGACGGAAAGAACACAATCTTTATTTAAGAACCACATTTCTAAAAATTAGTATACTAA
CGTTTACTGACCCGACAATCGATCAACGAACCAAGTTACCCTGGGGATAACAGCGCAA
TCTACTTCAAGAGCTCATATCGACAAGTAGGCTTACGACCTCGATGTTGGATCAGGGT
ATCCCGGTGGTGCAGCCGCTACCGAAGGTTCGTTTGTTCAACGATTAAAACCCTACGT
GATCTGAGTTTCAGACCGG

14. FR-31-Polypedates teraiensis
GGTCAGCCTGCCCAGTGAATCTTAAACGGCCGCGGTATCCTAACCGCGCGAAGGTAG
CATAATCACTTGTTCTTTAAATGGGGACTCGTATCAACGGCATCACGAGGGCTTTACTG
TCTCCTCTTTTTGATCAGTGAAATTGATCTTCCCGTGAAGAAGCGGGAATATTTTTATA

AGACGAGAAGACCCCATGGAGCTTTAAACCAAATAGCAACTTAACCACTTATCCCACA
ATAAATTTAAGCCCTGTTATACGGTTTTGGTTGGGGTGACCGCGGAGTAAAGCATATC
CTCCACGACGGAAAGAACACAATCTTTATTTAAGAACCACATTTCTAAAAATTAGTATA
CTAACGTTTACTGACCCGACAATCGATCAACGAACCAAGTTACCCTGGGGATAACAGC
GCAATCTACTTCAAGAGCTCATATCGACAAGTAGGCTTACGACCTCGATGTTGGATCA
GGGTATCCCGGTGGTGCAGCCGCTACCGAAGGTTCGTTTGTTCAACGATTAAAACCCT
ACGTGATCTGAGTTCAGAACGGGA

15. FR-32-Polypedates teraiensis
TATAGAGGTCCAGCCTGCCCAGTGAATCTTAAACGGCCGCGGTATCCTAACCGCGCGA
AGGTAGCATAATCACTTGTTCTTTAAATGGGGACTCGTATCAACGGCATCACGAGGGC
TTTACTGTCTCCTCTTTTTGATCAGTGAAATTGATCTTCCCGTGAAGAAGCGGGAATAT
TTTTATAAGACGAGAAGACCCCATGGAGCTTTAAACCAAATAGCAACTTAACCACTTAT
CCCACAATAAATTTAAGCCCTGTTATACGGTTTTGGTTGGGGTGACCGCGGAGTAAA
GCATATCCTCCACGACGGAAAGAACACAATCTTTATTTAAGAACCACATTTCTAAAAAT
TAGTATACTAACGTTTACTGACCCGACAATCGATCAACGAACCAAGTTACCCTGGGGAT
AACAGCGCAATCTACTTCAAGAGCTCATATCGACAAGTAGGCTTACGACCTCGATGTT
GGATCAGGGTATCCCGGTGGTGCAGCCGCTACCGAAGGTTCGTTTGTTCAACGATTAA
AACCCTACGTGATCTGATGTCCAAAACGGG

16. KNF-7-Hydrophylax leptoglossa
AAATAAGATGTCCAGCCTGCCCAGTGACAAACTTTAACGGCCGCGGTACCCTAACCGT
GCGAAGGTAGCATAATCACTTGTTCTTTAAATAGGGACTAGTATCAACGGCATCACGA
GGGCTGTACTGTCTCCTTTCTCTAATCAGTGAAACTGATCTCCCCGTGAAGAAGCGGG
GATTAAACTATAAGACGAGAAGACCCCATGGAGCTTTAAGCAATGTATTCACCCCTGC
ACCTTTACATCAACCAAACATAAGAGACCTGAATACTAGCTTTAGGTTGGGGGGACCA
CGGAGTATAATATAACCTCCATGACAAACGGGCTACGCCCTTATCCACGAGCTACAACT
CTAAGAATCAATAAACTGATGTTTTATGACCCGATAATTCGATCAACGAACCAAGTTAC
CCTGGGGATAACAGCGCAATCTACTTCAAGAGCCCATATCGACAAGTAGGTTTACGAC
CTCGATGTTGGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATGGTTCGTTTGTTC
AACGATTAAGACCCTACGTGATCTGAGTTCAGACCGGAACCCTACGTGATCTATGACC
CAATGCGGGA

17. KNF-13-Minervarya asmati
CTTAATAGAGGTCCAGCCTGCCCAGTGATATTTTTTAACGGCCGCGGTACTCTGACCG
TGCGAAGGTAGCATAATCACTTGTTCTTTAAATGAGGACTAGTATCAACGGCATCACGA
GGATTTTACTGTCTCCTTTTTCCTATCGGTGAAACTGATCTCCCCGTGAAGAAGCGGG
GATAATTCTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAGAGACACCTCAAAC
CCCCCTTTCCATAAAAGTTTTTATGTGCTGTCCTCTGGTTTTAGGTTGGGGTGACCGC
GGAGTAAAACTTAACCTCCACAACGCACGGAACTTCTTCCTTATCTAAGAGCAACATC
TCAAAGAATTAACATATTGACGTAAAATGATCCAATAACTTTTATTTTGATCAACGAACC
AAGTTACCCTGGGGATAACAGCGCAATCCATTTCCAGAGCCCCTATCGACAAATGGGT
TTACGACCTCGATGTTGGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATGGTTTG
TTTGTTCAACAATTAAAACCCTACGTGATCTGAGTTTCAGACCGGA

18. KNF-16-Minervarya asmati
AAGAGGTCCAGCCTGCCCAGTGATATTTTTTAACGGCCGCGGTACTCTGACCGTGCGA
AGGTAGCATAATCACTTGTTCTTTAAATGAGGACTAGTATCAACGGCATCACGAGGATT
TTACTGTCTCCTTTTTCCTATCGGTGAAACTGATCTCCCCGTGAAGAAGCGGGGATAAT
TCTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAGAGACACCTCAAACCCCCCT
TTCCATAAAAGTTTTTATGTGCTGTCCTCTGGTTTTAGGTTGGGGTGACCGCGGAGTA
AAACTTAACCTCCACAACGCACGGAACTTCTTCCTTATCTAAGAGCAACATCTCAAAG
AATTAACATATTGACGTAAAATGATCCAATAACTTTTATTTTGATCAACGAACCAAGTTA
CCCTGGGGATAACAGCGCAATCCATTTCCAGAGCCCCTATCGACAAATGGGTTTACGA

CCTCGATGTTGGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATGGTTTGTTTGTT
CAACAATTAAAACCCTACGTGATCTGAGTTCAGACCGGA

19. KNF-25-Euphlyctis cyanophlyctis

CCAGTGATACAATTTAACGGCCGCGGTATACTGACCGTGCGAAGGTAGCATAATCACT
TGTTCTTTAAATGGGGACTAGTATGAACGGCACCACGAGGGCTTTACTGTCTCCTCCC
TCCAATCAGTGAAACTGACCTCCCTGTGAAGAGGCAGGGATACCACTATAAGACGAAA
AGACCCCATGGAGCTTTAAACCCAACAACAGCCCAAACACCACCACCCCAAAAAGTTT
TAAGGGTATTGCTAGTTGGTTTTATGTTGGGGTGACCCCGCAGTATAAACTATCCTCCA
CGACAAACGGGCCTACCCCCTTTCTCAAGAACTACCCCTCTAAGGATTAACTCATTAAC
GGTTAATGAACCAAATATATTGATCTCACGAACACACAGTTTTCCCTGTGGGATATCAC
ACGCACTCTATATCTTCAGAGAGCCCCTATACTCACACAATGTAGTGTTTTAGACACTC
TGCATGTGTGTGATATCAGGGTATACTCACCGAAGTGTGTCGACACCCGCGTCTCACA
TATAGTGTGTTTGCGTATGTTGTCTACACACAATTAAAACCCCTACCGTGATCTAAG

20. KNF-29-Hydrophylax leptoglossa

AGGTCCAGCCTGCCCAGTGACAAACTTTAACGGCCGCGGTACCCTAACCGTGCGAAG
GTAGCATAATCACTTGTTCTTTAAATAGGGACTAGTATCAACGGCATCACGAGGGCTGT
ACTGTCTCCTTTCTCTAATCAGTGAAACTGATCTCCCCGTGAAGAAGCGGGGATTAAA
CTATAAGACGAGAAGACCCCATGGAGCTTTAAGCAATGTATTCACCCCTGCACCTTTAC
ATCAACCAAACATAAGAGACCTGAATACTAGCTTTAGGTTGGGGGGACCACGGAGTAT
AATATAACCTCCATGACAAACGGGCTACGCCCTTATCCACGAGCTACAACTCTAAGAAT
CAATAAACTGATGTTTTATGACCCGATAATTCGATCAACGAACCAAGTTACCCTGGGGA
TAACAGCGCAATCTACTTCAAGAGCCCATATCGACAAGTAGGTTTACGACCTCGATGTT
GGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATGGTTCGTTTGTTCAACGATTAA
AACCCTACGTGATCTTGT

21. KNF-35-Hoplobatrachus tigerinus

AGTCAGCCTGCCCAGTGACATAGTTAAACGGCCGCGGTACCCTGACCGTGCGAAGGT
AGCATAATCACTTGTTCCTTAAATAGGGACTTGTATGAAAGGCATCACGAGGGCTTTAC
TGTCTCCTTTCTCCAATCAGTGAAACTGATCTCCCCGTGAAGAAGCGGGGATACAATT
ATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAACGACACCCCTCAACCCCATAAT
CCTTTATAGTTGCTACAGCCCTGTTCGTTGGTTTTAGGTTGGGGTGACCGCGGAGCAT
AAAATATCCTCCACGACGAATGGGACTACCCCCTTACCCAAGAGCTACTCCTCTAAGG
ATCAATAAATTGACGTAAAATGATCCAAGTAATTGATCAACGGACCAAGTTACCCTGGG
GATAACAGCGCAATCCATTTCAAGAGCCCCTATCGACAAATGGGTTTACGACCTCGAT
GTTGGATCAGGGTATCCAAGTGGTGCAGCCGCTACTAATGGTTTGTTTGTTCAACAAT
TAAAACCCTACGTGATCTGA

22. KNF-51-Minervarya asmati

*TTCTGCTCTTATAAGAGGTCCAGCCTGCCCAGTGATATTTTTAACGGCCGCGGTACTC
TGACCGTGCGAAGGTAGCATAATCACTTGTTCTTTAAATGAGGACTAGTATCAACGGC
ATCACGAGGATTTTACTGTCTCCTTTTTCCTATCGGTGAAACTGATCTCCCCGTGAAGA
AGCGGGGATAATTCTATAAGACGAGAAGACCCCATGGAGCTTTAAACCCAGAGACACC
TCAAACCCCCCTTTCCATAAAAGTTTTTATGTGCTGTCCTCTGGTTTTAGGTTGGGGTG
ACCGCGGAGTAAAACTTAACCTCCACAACGCACGGAACTTCTTCCTTATCTAAGAGCA
ACATCTCAAAGAATTAACATATTGACGTAAAATGATCCAATAACTTTTATTTTGATCAAC
GAACCAAGTTACCCTGGGGATAACAGCGCAATCCATTTCCAGAGCCCCTATCGACAAA
TGGGTTTACGACCTCGATGTTGGATCAGGGTATCCCAGTGGTGCAGCCGCTACTAATG
GTTTGTTTGTTCAACAATTAAAACCCTACGTGATCTGAGTTTCAGAACC*

K. pulchara

CCTTTATTTAGTATTTGGTGCCTGAGCCGGAATAGTTGGCACAGCCCTCAGCC
TTTTAATTCGAGCTGAACTCAGCCAACCCGGGTCCCTTCTAGGTGATGATCAAATTTA
CAACGTTATCGTCACTGCCCATGCTTTCGTTATAATTTTCTTTATAGTAATACCAATCCT

TATTGGGGGATTCGGGAACTGACTCCTTCCACTTATAATTGGAGCCCCTGACATAGCA
TTCCCTCGAATAAATAATATAAGCTTTTGACTTCTCCCACCATCTTTTCTTCTCCTTTTA
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H. tigerinus

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Polypedate sp.

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Microhyla sp

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Rana sp.

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Bufo sp.

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M. rubra

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>Hylarana new sp. Bandarban-AB543604_16S (a possible new species):
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>MHBSFMSTU-snake 5, 6
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>MHBSFMSTU-snake 7, 8
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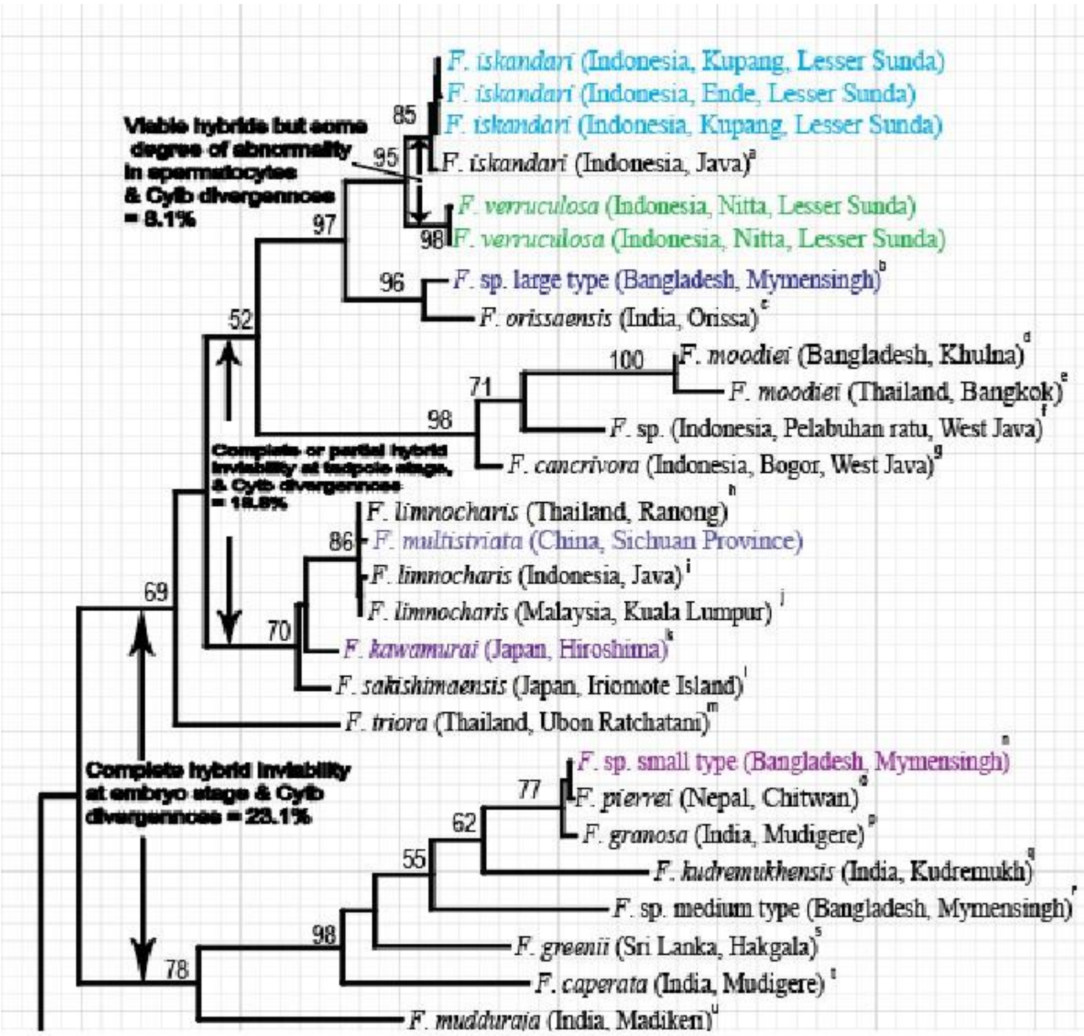

Figure 19: Neighbor-Joining (NJ) tree of our collected frog samples with other congeners.

Advertisement calls of *Microhyla* speciesare low-pitched groans emitted at about 4.4 s interval. Mean call duration is 0.28 s (n=34). The call is composed of about 20 rapidly repeating pulses (Fig. 20).

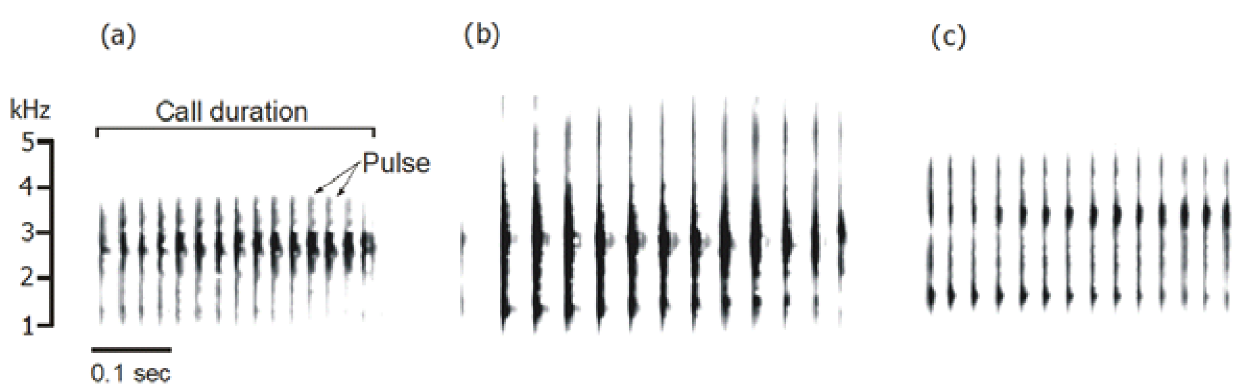

Figure 20: Sonogram of *Microhyla* species.

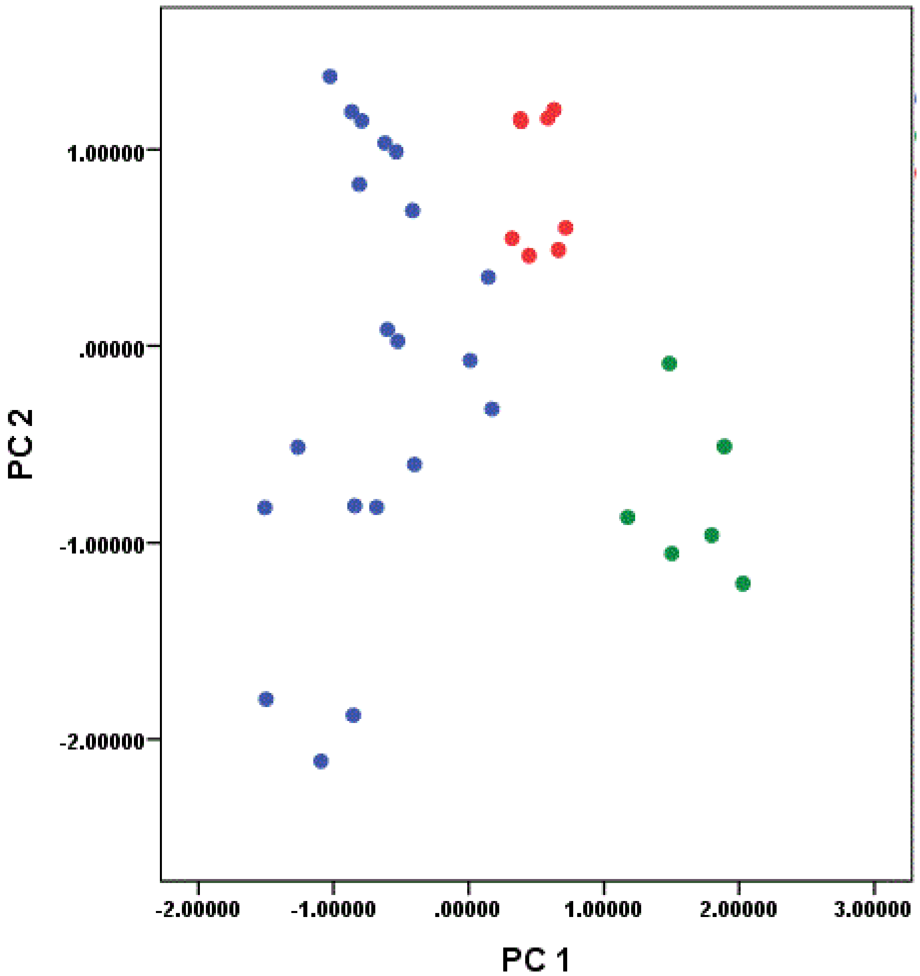

Figure 21: Principal Component Analyses (PCA) of frogs from 3 species of *Microhyla* in Khadimnagar and Lawachara NP

Table 4: Field s urvey rep ort from Kaptai La ke area and Chittagong-Cox's Bazar area

S L n o.	Date	Collector/ Team member	Locatio n	Time of sampl ing	Temperat ure	Weat her	Species name	Qua ntity	Voucher number	TL (m m)	Sex	Habitat	Note
							BSFMSTU-Kaptai Lake area						
1	04.06. 2024	EDRL members	Kaptai lake area, Rangam ati	Morni ng- Eveni ng	32˚C	Rainy	❖ *H. obscures* ❖ *H. schistosus*	1 1	MHBSF MSTU snake 3,4	77 86	♂ -	Sandy coastal belt	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on.
2	05.06. 2024	EDRL members	Kaptai lake area (middle part), Rangam ati	Morni ng- Eveni ng	30˚C	Clou dy	❖ *H. brooki* ❖ *H. curtus*	1 1	MHBSF MSTU snake 5 ,6	78 90	♂ -	As usual sea coast	The humidity was high. All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
3	6.07.2 024	EDRL members	Kaptai lake area, Rangam ati	Morni ng- Eveni ng	31˚C	-	❖ *H. curtus*	1	MHBSF MSTU snake7	88	♂	Sandy	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
4	07.07. 2024	EDRL members	Kaptai lake area	Morni ng- Eveni ng	33˚C	Sunn y	❖ *C. rynchops*.	1	MHBSF MSTU snake 8	78	♀	Sandy coastal belt	All specimens were brought to EDRL, JSTU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on
							SAU-Cox's Bazar area						
1	24.06. 24	EDRL members	Teknaf	Morni ng- Eveni ng	28˚C	Clou dy	❖ *Hydrophis* sp ❖ *H. cyanocinctus* 40	1 1 1	S2407k01 -03	74 76	♂ ♂	Sandy coastal belt	All specimens was brought to Aquatic and Bio-resource Laboratory (ABR Lab), Sher–e–Bangla Agricultural University (SAU). DNA was collected & stored in

													99.99% Ethanol. Morphological examination is going on
2	25.06. 2024	EDRL members	Teknaf	Morni ng- Eveni ng	33˚C	-	❖ *Hydrophis* sp.	1	S2407k04 -06	79	♂	10 Km from sea coast	All specimens were brought to ABR Lab, SAU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going
3	02.07. 2024	EDRL members	Cox‟s Bazar sea belt	Do	33˚C	Sunn y	❖ *H. fasciatus*		S2407k07 -09	85	♂	15 Km from sea coast	It was a thunderstorm day. All specimens were brought to ABR Lab, SAU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on.
4	03. 07.20 24	EDRL members	Cox‟s Bazar sea belt	Do	33˚C	Sunn y	❖ *H. obscures?* ❖ *H. curtus*	1 1	S2407k10 -12	82	♀	Near to shore	All specimens were brought to ABR Lab, SAU; DNA was collected & stored in 99.99% Ethanol. Morphological examination is going on.

4.4 Blast searches and find out any candidate/cryptic species:

We performed blast search of our sequenced COI gene data of Sea snake and found a possible cryptic/candidate species which need to study further by using multiple data set (Figure 4). Our nominal species showed some divergence from its near known congeners. Both ML and BI analyses revealed that one of our sea snake is deviated from other congeners like from *H. brooki.*

4.5 Submission of gene sequence data to Gen Bank:

Our sequenced COI gene data are processing and preparing to submit to Gen Bank. Due to lack of available electricity, bioinformatics work became hampered. Production of gene sequence data is time consuming, laborious and costly. We are in the way to submit our data to Gen Bank and we will get the Accession numbers soon.

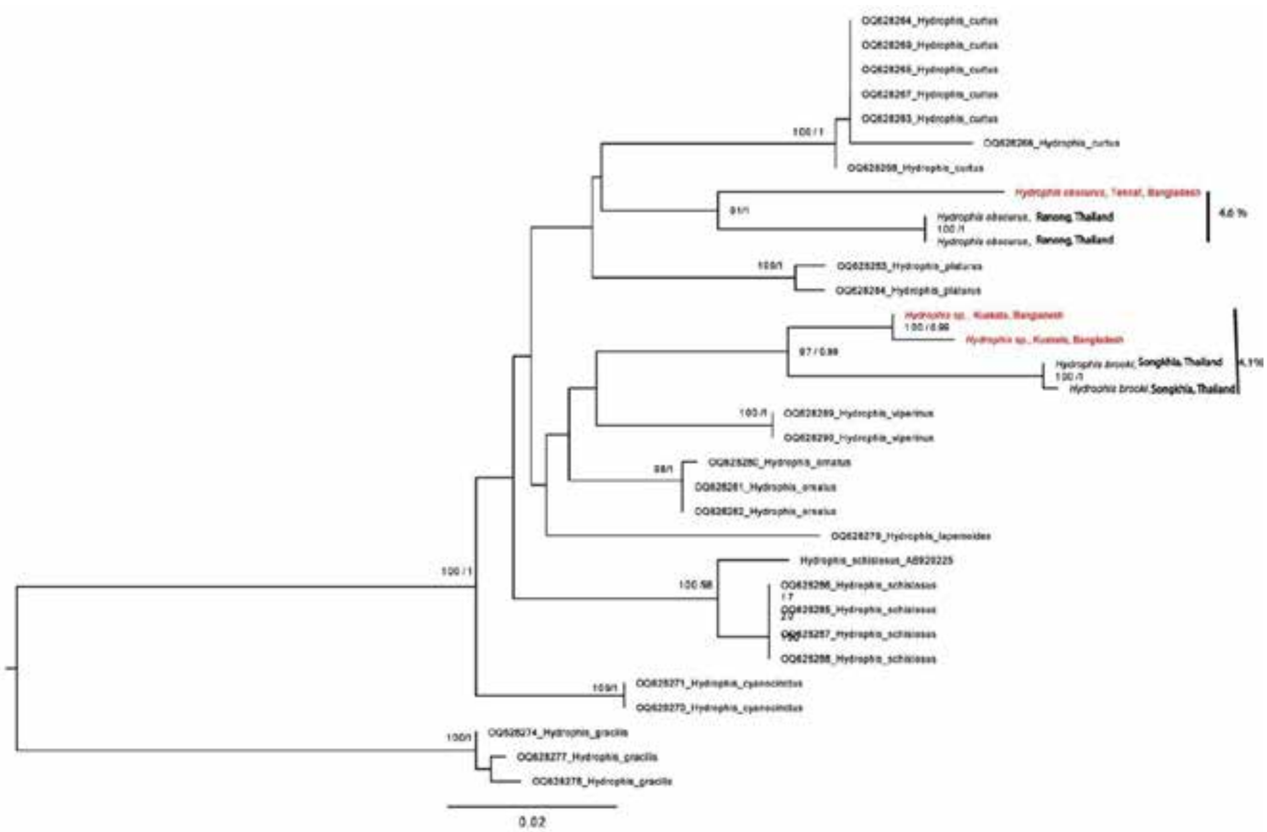

Figure 22: Maximum Likelihood (ML) tree of our collected sea snake samples with other congeners.

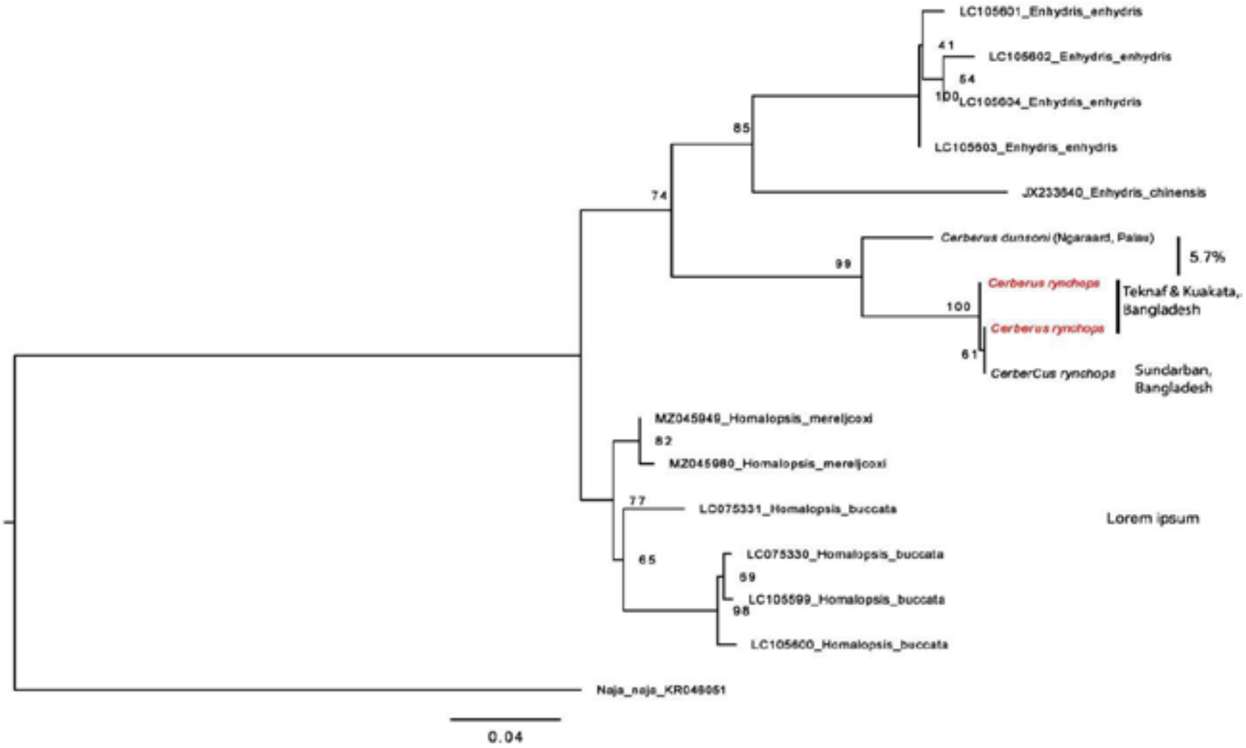

Figure 23: Maximum Likelihood (ML) tree of our collected coastal (water) snake samples with other congeners.

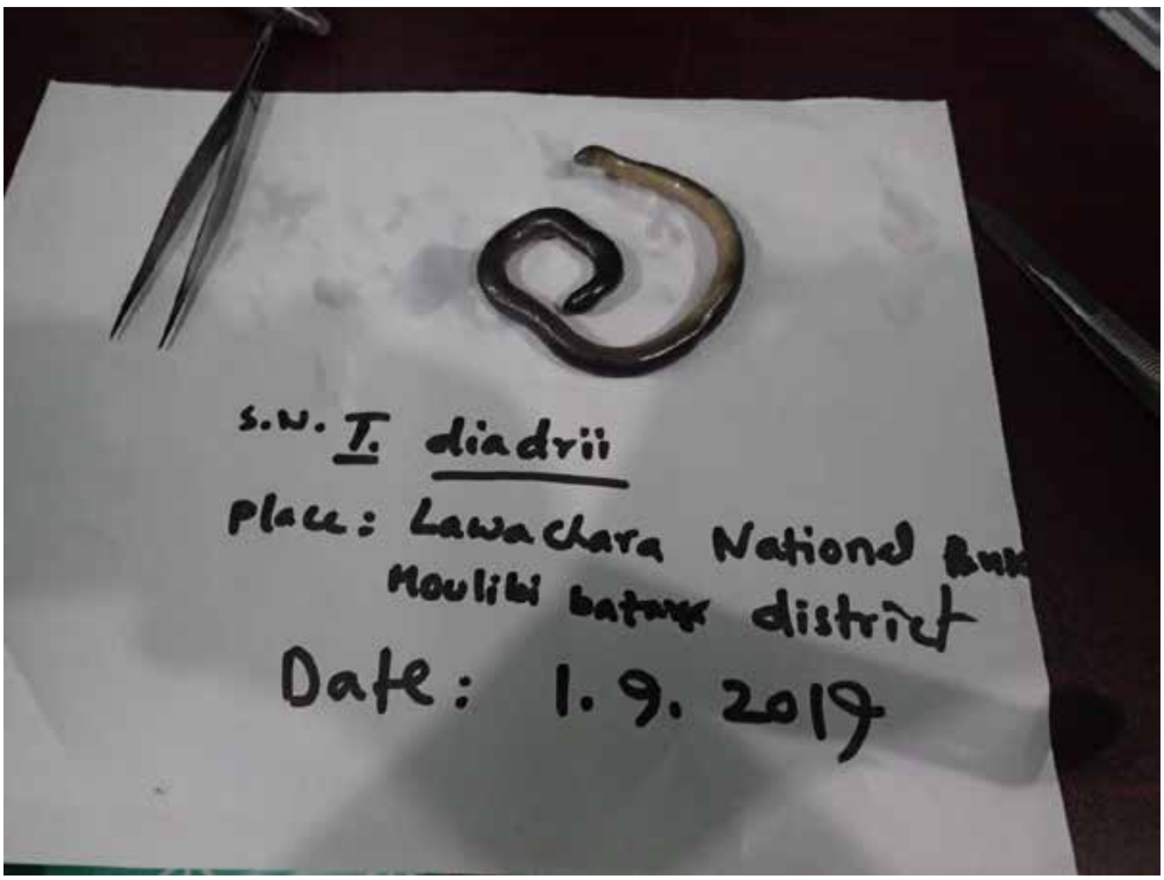

Figure 24: Possible new blind snake.

Figure 25: Possible new sand snake.

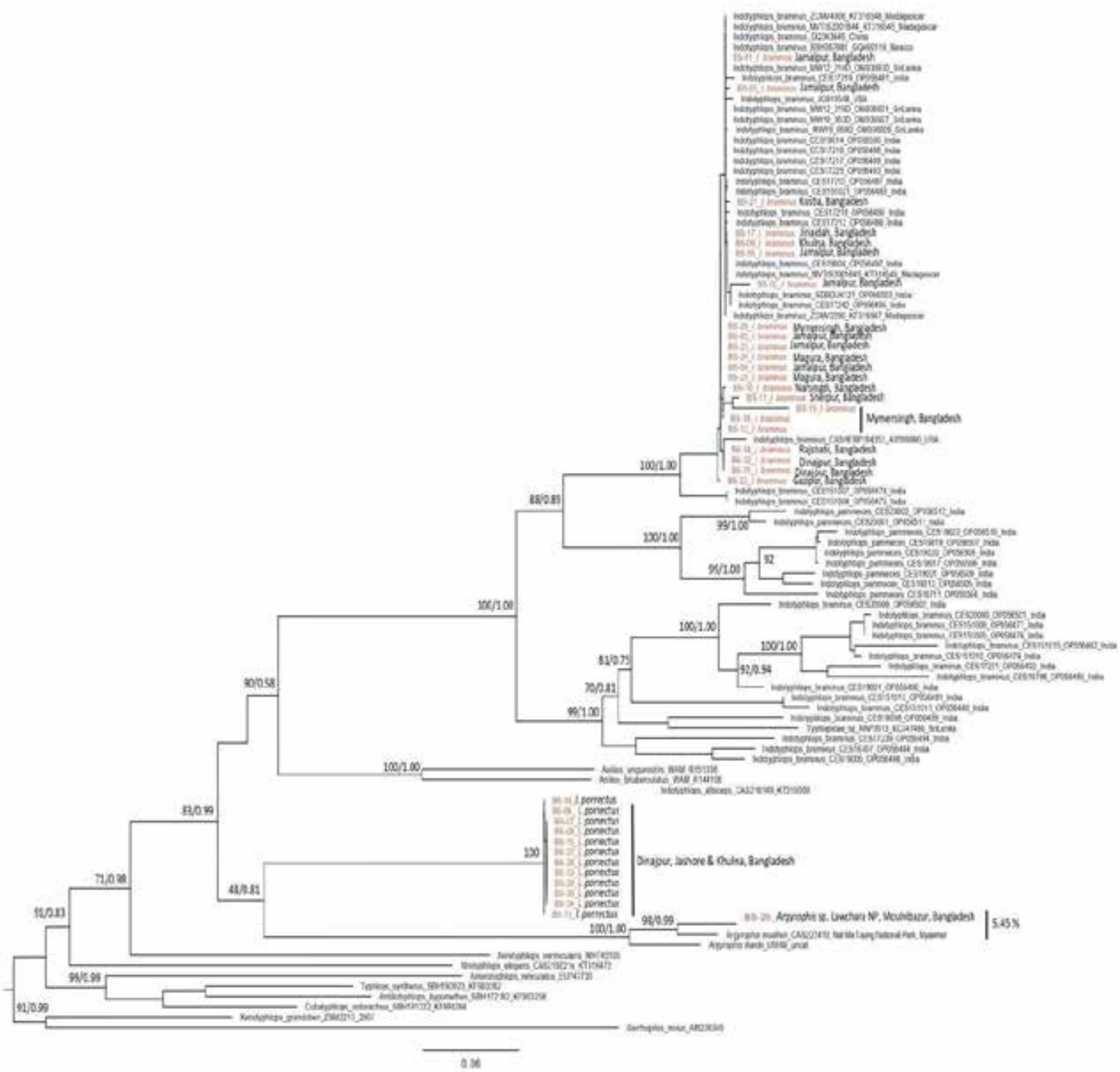

Figure 26: Phylogenetic tree of blind snake based on Cytb hgene data

Table 5: Uncorrected *P* distance among *Hydrophis* species based on COI gene

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S2407K-04_Hydrophis_brooki_RepCOI	0.062102																														
S2407K-09_CoxIF_Hydrophis_brooki	0.059735	0.006637																													
Hydrophis_brooki_AB920214	0.083721	0.036566	0.044248																												
Hydrophis_brooki_AB920212	0.076433	0.038156	0.044248	0.00159																											
Hydrophis_schistosus_AB920225	0.055732	0.049285	0.057522	0.066773	0.06836																										
Hydrophis_obscurus_AB920220	0.051163	0.055644	0.061947	0.06338	0.06359	0.05723																									
Hydrophis_obscurus_AB920218	0.04127	0.055732	0.061947	0.061905	0.06369	0.05732	0																								
OQ628264_Hydrophis_curtus	0.06	0.063032	0.062937	0.076667	0.07496	0.05792	0.056667	0.05263158																							
OQ628265_Hydrophis_curtus	0.06	0.063032	0.062937	0.076667	0.07496	0.05792	0.056667	0.05263158	0																						
OQ628267_Hydrophis_curtus	0.06	0.063032	0.062937	0.076667	0.07496	0.05792	0.056667	0.05263158	0	0																					
OQ628269_Hydrophis_curtus	0.06	0.063032	0.062937	0.076667	0.07496	0.05792	0.056667	0.05263158	0	0	0																				
OQ628263_Hydrophis_curtus	0.06	0.063032	0.062937	0.076667	0.07496	0.05792	0.056667	0.05263158	0	0	0	0																			
OQ628266_Hydrophis_curtus	0.073333	0.076661	0.074592		0.08859	0.07155	0.07	0.06621392	0.01333	0.01333	0.01333	0.01333	0.0133																		
OQ628268_Hydrophis_curtus	0.058333	0.061329	0.060606		0.07325	0.05622	0.055	0.05093379	0.00167	0.00167	0.00167	0.00167	0.0017	0.015																	
OQ628271_Hydrophis_cyanocinctus	0.06	0.056218	0.060606	0.073333	0.07155	0.04429	0.05	0.04584041	0.055	0.055	0.055	0.055	0.055	0.06833	0.05333																
OQ628270_Hydrophis_cyanocinctus	0.06	0.056218	0.060606	0.073333	0.07155	0.04429	0.05	0.04584041	0.055	0.055	0.055	0.055	0.055	0.06833	0.05333	0															
OQ628279_Hydrophis_lapemoides	0.065	0.056218	0.062937		0.07155	0.05792	0.058333	0.05432937	0.065	0.065	0.065	0.065	0.065	0.07833	0.06333	0.04167	0.041667														
OQ628280_Hydrophis_ornatus	0.061667	0.0477	0.04662	0.063333	0.05963	0.046	0.055	0.05093379	0.04667	0.04667	0.04667	0.04667	0.0467	0.06	0.045	0.04		0.04													
OQ628281_Hydrophis_ornatus	0.06	0.0477	0.04662	0.061667	0.05963	0.046	0.053333	0.04923599	0.045	0.045	0.045	0.045	0.045	0.05833	0.04333	0.03833	0.038333	0.04333	0.001667												
OQ628282_Hydrophis_ornatus	0.06	0.0477	0.04662	0.061667	0.05963	0.046	0.053333	0.04923599	0.045	0.045	0.045	0.045	0.045	0.05833	0.04333	0.03833	0.038333	0.04333	0.001667	0											
OQ628283_Hydrophis_platurus	0.058333	0.056218	0.055944	0.063333	0.06303	0.05622	0.058333	0.05263158	0.05		0.05	0.05	0.05	0.06333	0.04833	0.05333	0.053333	0.05833	0.043333	0.04167	0.04167										
OQ628284_Hydrophis_platurus	0.061667	0.056218	0.053613	0.066667	0.06303	0.05622	0.058333	0.05432937	0.05		0.05	0.05	0.05	0.06	0.04833	0.05333	0.053333	0.055	0.04	0.04167	0.04167	0.00667									
OQ628286_Hydrophis_schistosus	0.058333	0.051107	0.055944		0.06814	0.01363	0.058333	0.05432937	0.05333	0.05333	0.05333	0.05333	0.0533	0.06667	0.05167	0.04667	0.046667	0.055	0.043333	0.04167	0.04167	0.05667	0.05667								
OQ628288_Hydrophis_schistosus	0.058333	0.051107	0.055944		0.06814	0.01363	0.058333	0.05432937	0.05333	0.05333	0.05333	0.05333	0.0533	0.06667	0.05167	0.04667	0.046667	0.055	0.043333	0.04167	0.04167	0.05667	0.05667	0							
OQ628287_Hydrophis_schistosus	0.058333	0.051107	0.055944		0.06814	0.01363	0.058333	0.05432937	0.05333	0.05333	0.05333	0.05333	0.0533	0.06667	0.05167	0.04667	0.046667	0.055	0.043333	0.04167	0.04167	0.05667	0.05667	0	0						
OQ628285_Hydrophis_schistosus	0.058333	0.051107	0.055944		0.06814	0.01363	0.058333	0.05432937	0.05333	0.05333	0.05333	0.05333	0.0533	0.06667	0.05167	0.04667	0.046667	0.055	0.043333	0.04167	0.04167	0.05667	0.05667	0	0	0					
OQ628289_Hydrophis_viperinus	0.061667	0.0477	0.053613	0.061667	0.05963	0.0477	0.055	0.05093379	0.05333	0.05333	0.05333	0.05333	0.0533	0.06667	0.05167	0.045	0.045		0.033333	0.03167	0.03167	0.04667	0.04667	0.05	0.04667	0.0467	0.04667				
OQ628290_Hydrophis_viperinus	0.061667	0.0477	0.053613	0.061667	0.05963	0.0477	0.055	0.05093379	0.05333	0.05333	0.05333	0.05333	0.0533	0.06667	0.05167	0.045	0.045		0.033333	0.03167	0.03167	0.04667	0.04667	0.05	0.04667	0.0467	0.04667	0			
OQ628277_Hydrophis_gracilis	0.116667	0.098807	0.111888	0.113333	0.11244	0.10392	0.1	0.09677419	0.11		0.11	0.11	0.11	0.12333	0.10833	0.09333	0.093333	0.095	0.1	0.09833	0.09833	0.10333	0.10333	0.1	0.1	0.1	0.1	0.10167	0.10167		
OQ628278_Hydrophis_gracilis	0.115	0.097104	0.107226	0.111667	0.11073	0.10221	0.098333	0.0950764	0.10833	0.10833	0.10833	0.10833	0.1083	0.12167	0.10667	0.09167	0.091667	0.09333	0.098333	0.09667	0.09667	0.10167	0.10167	0.1	0.09833	0.0983	0.09833	0.1		0.005	
OQ628274_Hydrophis_gracilis	0.113333	0.0954	0.107226		0.10903	0.10051	0.096667	0.09337861	0.11		0.11	0.11	0.11	0.12333	0.10833	0.09		0.09	0.096667	0.095	0.095	0.1	0.1	0.1	0.09667	0.0967	0.09667	0.09833	0.09833	0.0033333	0.005
				0.1					0.11							0.09167															

Table 6: Uncorrected *P* distance of dog watersnake with other congeners based on COI gene

S2407K-01_Cerberus_rynchops_RepCOI-F														
S2407K-05_Cox-I-F-	0.00184162													
Naja_naja_KR046051	0.19903692	0.1992481												
LC075330_Homalopsis_buccata	0.1214511	0.1204379	0.1854103											
LC105599_Homalopsis_buccata	0.12302839	0.1204379	0.1869300	0.0056101										
LC075331_Homalopsis_buccata	0.11671924	0.1172161	0.1732522	0.0495626	0.0494905									
LC105600_Homalopsis_buccata	0.11987382	0.1186131	0.1838905	0.0085592	0.0099715	0.0510204								
LC105601_Enhydris_enhydris	0.13091483	0.1313868	0.1823708	0.1234221	0.1244755	0.1120815	0.1147308							
LC105602_Enhydris_enhydris	0.13091483	0.1350365	0.1823708	0.1268221	0.1295487	0.1124087	0.1282798	0.0131004						
LC105603_Enhydris_enhydris	0.13091483	0.1313868	0.1823708	0.1151079	0.1165467	0.1094890	0.1212121	0.0057554	0.0131386					
LC105604_Enhydris_enhydris	0.13091483	0.1332116	0.1823708	0.1225071	0.125	0.1091703	0.1257142	0.0142045	0.0101892	0.0043165				
OR437970_Cerberus_rynchops	0.00159744		00.1993865	0.1251908	0.1267175	0.1206106	0.1236641	0.1328244	0.1328244	0.1328244	0.1328244			
MH273634_Cerberus_dunsoni	0.05617978	0.0582706		0.20.1175572	0.1190839	0.1099236	0.1160305	0.1206106	0.1206106	0.1206106	0.1206106	0.0552147		
MZ045949_Homalopsis_mereljcoxi	0.10914928	0.1071428	0.1717325	0.0425531	0.0440729	0.0288753	0.0410334	0.1018237	0.1018237	0.1018237	0.1018237	0.1119631	0.10534351	
MZ045980_Homalopsis_mereljcoxi	0.11235955	0.1109022	0.1717325	0.0440729	0.0455927	0.0334346	0.0425531	0.1003039	0.1003039	0.1003039	0.1003039	0.1150306	0.10839695	0.00455927
JX233640_Enhydris_chinensis	0.12359551	0.12593985	0.19300912	0.12462006	0.12613982	0.11094225	0.1231003	0.10638298	0.10638298	0.10638298	0.10638298	0.12730061	0.13129771 0.10638298	0.10486322

Table 7: Morpho-meristic parameters of possible new sand snake (BSFMSTUMHS 01-02)

Characters	BSFMSTMH-01	BSFMSTMH-02	*P. condanarus*	*P.turpanensis* **sp.nov.**	*P. lineolatus*
TL (mm)	1005.7	500	530 + ? (tail cut)	960 + ? (tail cut)	711–786
SVL (mm)	761.7	453.86	450	861	537–591
MD(mm)	30.82	10	12	15.51	7.13–9.05
TaL(mm)	244	46.14	80 + ? (tail cut)	99+ ? (tail cut)	175–199
HL (mm)	20.25	14.23	23.5	23.15	15.39–18.23
HW (mm)	10.25	6.56	11.5	12.84	7.13–9.05
ED(mm)	4.25	4.93	3.3	3.82	2.94–3.45
ELD(mm)	7.75	4.60	5.5	6.62	3.66–5.32
HD(mm)	9.29	6.73	7.5	9.02	4.36–6.03
FL (mm)	7.81	5.47	6	6.23	4.15–5.27
FWM(mm)	1.88	1.23	2.2	1.59	1.33–1.66
FWA(mm)			3	3.31	2.11–2.65
FRD(mm)	6.64		4	5.48	3.33–3.98
FWA/FWM(mm)			1.36	2.08	allsamples<2.0
Prefrontal	2	2	–	1/1	1/1
Frontal	1	1	–	1	1
Parietal	2	2	1/1	1/1	1/1
Preocular	1	1	1	1	2 or 3
Postocular	2	2	2	2	2
Nasal	partially divided	partially divided	partially divided, reachingbetween1sta nd 2nd supralabials	divided, anterior nasal touching2ndsupralabials	divided, anterior nasal touching1stsupralabia ls
Loreal			1/1	1/1	1/1
Temporal			1+2 or 3	2+2	2+3 or 2; 2+1+3
Rostral	1	1	1	1	1
Supralabials			8	9	9
SLE			4th, 5th	4th–6th	4th–6th
Infralabials			10/10	10/10	9/9 or 10/10
Dorsal (mid-body scale rows)			17	17	17:17:13
Anal			divided	divided	divided
Subcaudal			75–93	30+?	83–100

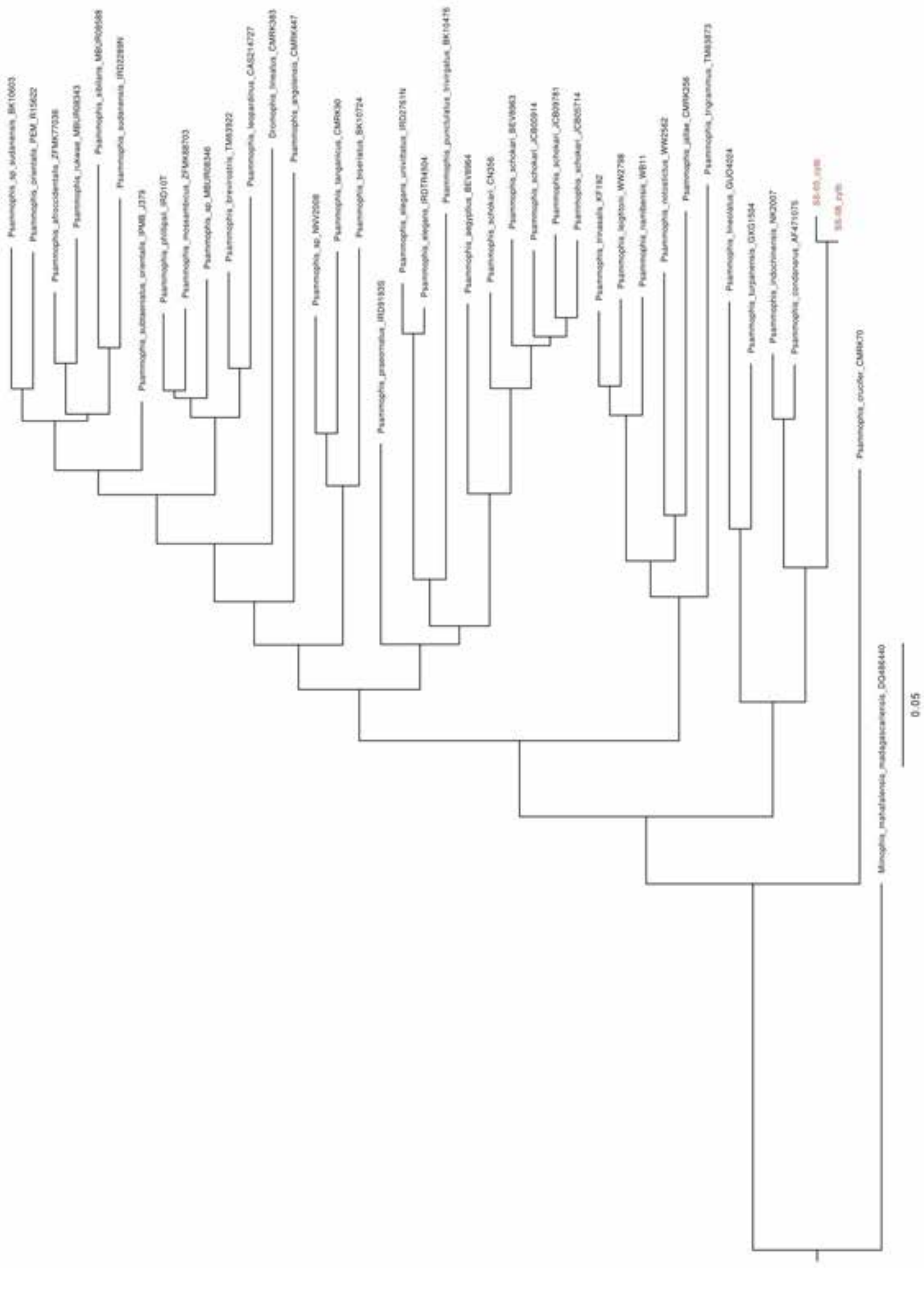

Figure 27: Phylogenetic tree of Bangladeshi sand snake tree based on Cytb gene

We executed an extensive survey across a considerable expanse (about 40–60 km) of islands in the Padma River, in the Barendra region (Godhagari and Lakhipur, Chapai Nawabganj) of northwestern Bangladesh in 2020–2021, adjacent to the Bangladesh-India border. In this investigation, we gathered two adult individuals of a sand snake species that exhibits significant variations from its nearest relatives. We present a new species of sand snake, *Psammophis new* **sp. nov**., from Bangladesh, based on comprehensive morphological and genetic investigations. Unique scale patterns, specific body dimensions, and distinctive colors differentiate this species from its relatives. *Psammophis new* **sp. nov.** can be distinguished from the recognized congeners by a combination of the following characters: 1) Dorsal scale 17 rows at midbody, rostral visible from upper side; 2) Anal scale divided, subcaudals paried; 3) Dorsal stripes without black edged scales; 4) 9 supralabials, of which 4th–5th in contact with the eyes and nasal scale incompletely divided; 5) head subtriangular, and body slightly compressed; and 6) three or five darker dorsal stripes starting from prenasal. The DNA sequences of the mitochondrial cytochrome *b* gene of the new species show significant differences from *P. condanarus* and *P. indochinensis*, with uncorrected pairwise divergences of 11.4% and 11.6%, respectively. This discovery emphasizes the extensive but unrecorded herpetological variety in Bangladesh and reinforces the pressing necessity for further thorough surveys in underexplored environments.

CHAPTER V

RECOMMENDATION AND CONCLUSION

5.1 Recommendations

The Government of Bangladesh is committed to take all measures prerequisite for a sustainable future. Most importantly, how many species (frogs and sea snakes) are exist in this country, is an open question. Therefore, we need to mitigate this research demand. This project is a great deal to uncover the hitherto overlooked cryptic biodiversity of frogs and sea snakes in Bangladesh. We are working and collecting specimens (only one individual for one species) from the targeted six regions keeping all the necessary documents in the note book. All of these samples are analyzing to meet the objectives of this project.

The Government of Bangladesh is committed to take all measures prerequisite for a sustainable future. In effort, the Government (including BFD) takes myriad programmes and initiatives with the support of different consortia. Bangladesh has recently achieved unprecedented successes in the environmental sector. The overwhelming evidence on the loss of biodiversity all over the world showcases that we, as a nation, must act to conserve biodiversity. Ministry of Environment and Forests has been playing a pivotal role in biodiversity conservation of Bangladesh through Bangladesh Forest Department, and other national and international organizations. Biodiversity, the incredible variety of life on Earth that sustains us, is in peril. Species are becoming threatened at the most expeditious rate ever recorded. Over the past few decades it has become the issue of global concern for its rapid reduction worldwide. Bangladesh is no exception in this regard. Though the country is exceptionally endowed with a vast variety of flora and fauna, it is unfortunate that in recent decades the biodiversity of the country is under pressure due to incrementing population and over- exploitation of natural resources.

Most importantly, how many species (frogs and sea snakes) are exist in this country, is an open question. Therefore, we need to mitigate this research demand. This project is a great deal to uncover the hitherto overlooked cryptic biodiversity of frogs and sea snakes in Bangladesh. We are working and collecting specimens (only one individual for one species) from the targeted six regions keeping all the necessary documents in the note book. All of these samples are analyzing to meet the objectives of this project. Our research on this issue is going on and hopefully will complete at the end of 2024.

In summary, it is believed that four new species were found in this study through morphology and molecular approach. This study identified a potential new frog species (*Hylarana* sp.) and a probable new species of sea snake (*Hydrophis* sp.), blind snake (*Argyrophis* sp.), and sand snake (*Psamophis* sp.) in Bangladesh for the first time.

5.2 Conservation Policy

A conservation policy for threatened frog and sea snake species should focus on habitat protection, pollution control, and mitigating climate change impacts. Critical measures include establishing protected areas, restoring wetlands and marine ecosystems, and enforcing strict anti-poaching laws. Reducing pesticide use, plastic waste, and industrial runoff can help minimize pollution affecting these species. Breeding programs and community-based conservation initiatives can aid population recovery, while research and monitoring are essential to track threats like disease and habitat loss. Public awareness campaigns can promote responsible tourism and sustainable practices. International cooperation is also vital, as many frogs and sea snakes cross borders or inhabit shared ecosystems. By implementing these strategies, we can safeguard these vulnerable species and maintain biodiversity.

5.3 Conclusion

Biodiversity globally underpins the extensive range of ecosystem services that are essential to human well-being. However, this diversity, particularly among wild species, is diminishing at an accelerated rate. To create a healthy ecosystem, it is essential to evaluate wild animal populations and identify species for effective management. This study greatly impacts the exploration of amphibians and reptiles in Bangladesh as well as identified four potential new species for the first time: *Hylarana* sp. from Bandarban, *Hydrophis* sp. from Kuakata, Patuakhali (southern Bangladesh), *Argyrophis* sp. from Lawachara National Park, Moulvi Bazar, and *Psammophis* sp. from Chapai Nawabganj, Rajshahi division in Bangladesh. In our forthcoming research, we will define the new species within a systematic framework utilizing further data.

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Ecological and Behavioral Adaptations of the Western Hoolock Gibbon (Hoolock hoolock Harlan, 1834) to Fragmented and Degraded Habitats in Bangladesh

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Western hoolock gibbons (*Hoolock hoolock*), also known as white-browed gibbons, are the only apes that live in the Indian sub-continent. It is found in dense forests northeast India, Bangladesh, and western Myanmar. There may be some populations living in extreme southeastern Tibet.

It is considered as Critically Endangered species in Bangladesh (Feeroz et al., 2015) and Endangered globally (Brockelman et al., 2019). Habitat loss, habitat fragmentation, human interference and huntings are the major threats to the gibbons of Bangladesh as well as Bangladesh (Molur et al., 2005).

Western hoolock gibbon is a charismatic wildlife species of Bangladesh. Islam et al. (2006) provided that the presence about the 282 individuals of gibbons were known to occur in Bangladesh. In the meantime, habitat quality has drastically changed and Islam et al. (2006) did not emphasize to carry census at many gibbon habitats. Naher et al. (2021) had conducted the population survey in Bangladesh by transect sampling and identified only 11 gibbon habitats of Bangladesh. This survey was also excluded many potential gibbon habitats of the country. Naher et al. (2021) suggested that careful evaluation, comprehensive surveys and restoration of habitats identified as suitable for gibbons. Moreover, depending on the habitat types of Bangladesh transects sampling and acoustic samplings do not provide the actual information (Vũ Tiến Thịnh and Rawson, 2011). This proposed project is to dealt with the population ecology with an understanding of group composition, group sizes, reproductive output, parasitic infection risk, ecological and behavioral responses to degraded and fragmented habitats. I have been collecting the gibbon population baseline information since 2017. This initiative has identified more than 10 new and unknown gibbon habitats with observation of significant gibbon habitats of Bangladesh. Rough estimate of population census excluding age-sex and group composition would not be more effective for conservation purposes. It also could provide the population bias due to habitat type of forested areas of Bangladesh and behavior of gibbons (Vũ Tiến Thịnh and Rawson, 2011). My initiative has already published a scientific article on gibbon population composition of the gibbons at Sheikh Jamal Inani National Park with collaboration of Supervisors and Research Advisers (Kabir et al., 2021).

Age-sex and group composition of the gibbons also provide the information on the reproductive outputs. It also indicates the state of habitat suitability of the gibbons for further conservation approach (Kakati et al., 2009). Apart from the population census, there are very few information on group size and composition among the gibbons range countries. In Bangladesh, Ahsan (1994), Islam and Feeroz (1992) Gitins and Tilson (1984) had estimated the groups size from mainly at Lawachara, Chunati which was limited on only 6 to 8 gibbons groups. In India, Kakati (2009) did the comparatively extensive group size estimation of gibbons in Assam. On the other hand, very few and small scale study was conducted on population composition and reproductive output on the western hoolock gibbon in Assam and Arunachal Pradesh of India (Kakati et al. 2009; Chetry et al., 2012) without any information in Bangladesh except the gibbons of Inani (kabir et al., 2021).

All the gibbon habitats of Bangladesh are highly destructed and degraded. Gibbon habitats are illegally encroached and various type activities were observed there (Islam et al., 2006). Cultivation of various types of agricultural crops and fruits are grown at or around the forested areas. So, it is very urgent to understand the impact of habitat fragmentation and human interference on population size (Ray et al., 2015) Socio-ecological studies of gibbon of Bangladesh were conducted mostly at Lawachari National Park, Satchari National and Chunati Wildlife Sanctuary. There is no any ecological study of gibbon at other sites of Bangladesh. Ecological and behavioral responses also can be modified due to degraded and fragmented habitat types (Fan et al., 2012 and Nie et al., 2015). Gibbons are also adapted to unusual foods items due to lack of usual food items which will be caused of nutritional stress (Deb et al. 2014). Borah et al. (2017) had accumulated the seasonal abundance of different food items of gibbon in Assam but there is no adequate data on the seasonal abundance of foods in Bangladesh. Preliminary findings of the Project Applicant showed that some tree species contribute in more in order to availability of the fruit by covering the most season of the year. It will also fill the gap for selection of the species for habitat restoration program.

Infectious disease as well as parasitic infection may linked to environmental changes, can also play role in population declining by increased mortality of the species (Kilbourn et al., 2003). Host diet quantity and quality has major impact on the parasite (Nelson and Demas, 2004). Poor nutritional stress also can influence parasitism among primates species (Deb et al., 2014). Distribution and transmission of parasites of Asian apes is still relatively neglected and or poorly understood (Labes et al., 2010). On the other hand, anthropogenic disturbed habitat has highly risk of parasitic loads of gibbons (Deb et al., 2014).There is also no scientific documentation on threats to gibbon especially occurrences of hunting in Bangladesh but hunting was happened in Bangladesh.

1.2 Overall Objectives

To know the age-sex and group composition with the understanding of the reproductive variants of the gibbons of Bangladesh and comparison of ecological and anthropogenic factors, behavioral and ecological responses, and parasitic load in response to the degraded and fragmented habitats of Bangladesh for the further conservation and management initiative of the highly threatened primates species globally as well as in the country.

1.3 Research Questions

- Understanding the parasitic infection load in response to the degraded and fragmented habitats of Bangladesh with a understanding of group size, group composition and reproductive output of gibbons; and
- Determining the impact of habitat characteristics, habitat fragmentation and anthropogenic factors on population of the gibbons of Bangladesh with understanding the behavioral and ecological adaptation at the degraded and fragmented habitats of Bangladesh.

2 LITERATURE REVIEW

Gittins and AKonda (1982) did the first primates population estimation in Bangladesh and identified the presence of the gibbons from the northeast and southeast Bangladesh. They estimated the primates population by distant sampling and rigorously provided the comments that Bangladesh is a home of 3000 individuals of the gibbons. First comprehensive population census was conducted by Islam et al. (2006) during the survey period from 2002 to 2005. Islam et al., (2006) estimated 282 gibbons from northeast and southeast Bangladesh through surveyed at 35 habitats. Among 35 habitats, gibbons were identified from 22 habitats. They also estimated the gibbons by distance sampling.

Naher et al. (2021) also counted the gibbons by distance sampling methods. They confirmed the presence of gibbons from 11 habitats from 22 habitats and predicted that Bangladesh is home of 468 gibbons. Kabir et al. (2021) estimated the gibbons populations of Sheikh Jamal Inani National Park and estimated that this habitat supported about 7 groups of 18 individuals of gibbons.

First Socio-ecological study was conducted by Ahsan (1994) at Lawachara National Park in northeast Bangladesh and Chunati Wildlife Sanctuary in southeast Bangladesh. He conducted behavioral study by 10 minutes scan sampling methods. Islam and Feeroz (1992) also studied the activity budget and feeding ecology of the western hoolock gibbons at Lawachara National Park in northeast Bangladesh and Chunati Wildlife Sanctuary of Southeast Bangladesh. Naher et al. (2020) studied the feeding ecology of the western hoolock gibbons at Satchari National Park in northeast Bangladesh and identified 76 plant species as food items for the gibbons.

Kabir et al. (2024) conducted the work social flexibility, mate choice of the gibbons and long-term association between the western hoolock gibbons and Phayre's langur (*Trachypithecus phayrei*). They also reported the interspecies grooming behavior for the first time among the gibbons and Phayre's langur.

3 METHODOLOGY

3.1.1 Study Area

3.1.2 Population Ecological Study

Bangladesh is tropical country in south Asia and transitional point for floral and faunal composition between Indo-Himalayan and Indo-chines sub-region (Ali and Kamal, 2019). Forested areas of Bangladesh consist of mixed-evergreen forests (hill forest), deciduous forests (sal forest), mangrove forests, swamp forests, and village forests (https://bforest.gov.bd/). Global Forest Resources Assessment indicates that the total forested area of Bangladesh is 1.429 million hectares which is comprised of 11% of the land area of the country (FAO, 2015).

Population ecology and communities engagement activities of the gibbons were conducted at the mixed evergreen hilly forest of Chattogram, Cox's Bazar and Chattogram Hill Tracts district (Rangamati, Bandarbans and Khagrachari district) of southeast Bangladesh and Habiganj and Moulvibazar district of northeast Bangladesh. These areas are administered by Sylhet Forest Division, Wildlife Management and Nature Conservation Division, Moulvibazar, Chattogram North Forest Division in northeast Bangladesh Chattogram South Forest Division, Cox's Bazar South Forest Division, Cox's Bazar North Forest Division, Lama Forest Division, Bandarbans Forest Division, Chattogram Hill Tract (North) Forest Division and Chattogram Hill Tract (South) Forest Division in southeast Bangladesh.

Areas of hill forests is about 676,000 ha which is about 44% of the total forested areas managed by Forest Department (Source: FD). Soil and climate of the hill forests were classified into tropical wet evergreen forests and tropical semi-evergreen Forests (Khan *et al*. 2007). Hill forests also supported natural terrestrial forests in combine with evergreen and deciduous trees in association with bamboo clumps. Tree cover ranges from 10 - 100% and tree height ranges from 5 m - 35 m. The most common plant species as per the most recent national forest inventory are Shegun (*Tectona grandis*), Burakochi (*Macaranga denticulate*), Akashmoni (*Acacia auriculiformis*), Dumur (*Ficus carica*) and Gamar (*Gmelina arborea*).

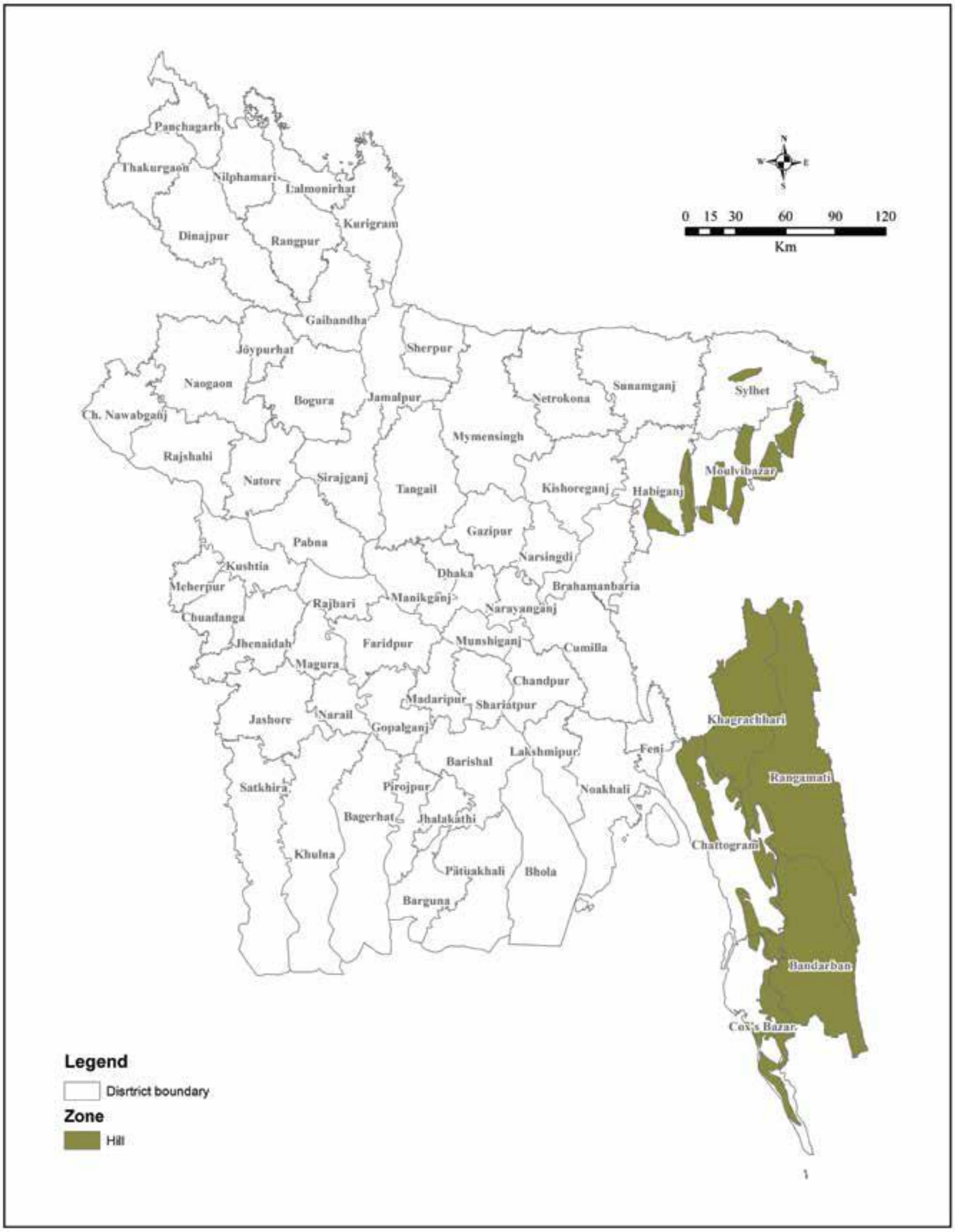


Figure 1: Map of the study showing the hill forests in northeast and southeast Bangladesh

3.1.3 Parasitological Study

Faecal samples were collected from the wild gibbons at Lawachara National Park (24.325440°N, 91.787036°E) and Saltila forest (24.169214°N, 91.407888°E) in northeast Bangladesh, and Sheikh Jamal Inani National Park (hereafter "Inani", 21.228032°N, 92.068139°E) in southeast Bangladesh (Figure 2). The study sites are characterized by a moist tropical climate with highest precipitation from April to September and a drier period from November to March (Uddin and Hassan, 2010).

Lawachara is an isolated forest covering an area of 12.5 km^2 and supporting an estimated population of 40 individuals (Naher et al., 2021). The group density at Lawachara was ca. 1.69 group/km^2 (Naher et al., 2021). This area includes degraded forest interspersed with patches of secondary natural forests and plantation forests (Uddin and Hassan, 2010). Major tree species here are *Aphanamixis polystachia, A. chaplasha*, *Castanopsis tribuloides, Chukrassia tabularis, Dillenia pentagyna*, *Dipterocarpus turbinatus*, *Elaeocarpus floribundus*, *Ficus racemosa, Lagerstroemia parviflora, Lophopetalum fimbriatum, Quercus spicata, Steriospermum personatum, Toona ciliata, Vitex peduncularis* and *Xylia dolabiformis* (Uddin and Hassan, 2010). Threats at Lawachara include illegal logging, forest fires during the dry season, firewood collection, betel leaf cultivation, such as roads and tourism facilities, and uncontrolled mass tourism (Uddin and Hassan, 2010).

Saltila is a 13.55 km^2 fragmented forest that is part of the ca. 26 km^2 Raghunandan Reserved Forest. Within Saltila, only a small patch of disturbed secondary forest (ca. 1 km^2) supports a remnant population of three individual gibbons (Kabir et al., 2024). Vegetation of the Saltila forest is comprised of small areas of natural forest, mixed vegetation, plantation forest, bamboo patches, and grasslands (Hosen and Ahamed, 2017). *Artocarpus chama, A. lacucha, Chickrassia tabulari, Garcinia zanthopyga, Ficus benghalensis, F. nervosa, F. benjamina, Prunus ceylonica,* and *Syzygium cumin* are the major plant species in Saltila (Hosen and Ahamed, 2017). Firewood collection and cattle grazing are the major observed anthropogenic disturbances at Saltila (MT Kabir, pers. obs.).

Inani covers an area of almost 80 km^2 and constitutes a highly degraded and disturbed gibbon habitat without upper canopy trees (Kabir et al., 2021). Here, Kabir et al. (2021) reported the presence of seven gibbon groups (18 individuals). Major plant species at Inani include *Albizia* sp., *Amoora wallichii*, *Aphanamixis polystachya*, *Artocarpus chama*, *Bombax* sp., *Dillenia pentagyna*, *Duabhanga grandiflora*, *Ficus* sp., *Gmelia arborea*, *Hopea odorata*, *Lagerstroemia* sp., *Lannea coromandelica*, *Mesua ferrea*, *Magnifera longipes, Swintonia floribunda*, *Syzygium* sp., and *Tetrameles nudiflora*. Encroachment, illegal logging, expanding *jhoom* cultivation, and betel leaf vineyards are the major observed threats in Inani (Kabir, 2017).

3.1.4 Ecological and Behavioral Study

Saltila (24°10'17.99"N, 91°24'24.20"E) is one of the most isolated gibbon habitats in northeast Bangladesh (Figure 3). Saltila is situated between the Deondi Tea Estate and the Jogodishpur Tea Estate. It is part of the Raghunandan Reserved Forest, covering the boundary between Telmachhara, Jogodishpur and Shahpur forest. This fragmented habitat is isolated from the nearest forest of the Raghunandan Reserved Forest (Hosen and Ahamed 2017). Only a very small (*c.*100 ha) patch of secondary forest at Saltila still constitutes gibbon habitat. The Forest Department has planted *Tectona grandis*, *Albizia* sp., and *Xylia dolabriformis* trees inside the gibbon habitat of Saltila in an attempt to enhance the forest quality. The gibbon population of Saltila comprises only one adult male and female that show flexible pair-bonding behavior, and a solitary adult female.

Other primates found in this area are the Bengal slow loris (*Nycticebus bengalensis*), Phayre's langur (*Trachypithecus phayrei*), the capped langur (*T. pileatus*), the rhesus macaque (*Macaca mulatta*), and the northern pig-tailed macaque (*M. leonina*). Barking deer (*Muntiacus muntjak*), hog badger (*Arctonyx collaris*), fishing cat (*Prionailurus viverrinus*), leopard cat (*P. bengalensis*) and large Indian civet (*Viverra zibetha*) are reported from this area (M.T. Kabir, pers. obs.).

3.2 Method of the Study

3.2.1 Population Ecological Study

Community engagement activities were conducted in form of community consultation programs, Focus Group Discussions (FGD) and interviewing with the local communities, Forest Department and wildlife enthusiastic and follow up the social media and newspapers during community engagement activities from January 2019 to December 2022. About 10 to 20 peoples were participated in community consultation programs among from the Forest Department, forest dependent peoples, local communities, local leaders, members from Co-management committee (if available) and school teachers. Participants of the community consultation programs were asked about existence of the gibbons at the surrounding gibbons habitats. Interviewing or FGD with local communities consists of 1-5 people in semi-structure questionnaires for collecting about the gibbons population information. All the community engagement activities were conducted at the nearest villages of the gibbons habitats.

Population census of the western hoolock gibbon was conducted in northeast and southeast Bangladesh during January 2019 from June 2024. A total 952 days were spent in the field separately by TK (411 days) and trained Research Assistants (541 days). Gibbons habitats were identified by community engagement activities, direct field observations, published and unpublished articles (i.e. scientific articles, gray literatures, dissertations).

Extensive population census of the gibbons was conducted at all the identified gibbons habitats by total count methods. Gibbons habitats of Bangladesh are not homogenous and are restricted to small patch of habitats except few habitats (Islam et al., 2006 and FD. 2020). Depending on the habitats types, population census of the western hoolock gibbon was conducted by total count method (Kabir et al., 2021). Groups were detected by set of listening posts. Detected groups were carefully observed and assessed the age, sex and group sizes by number, body sizes, color and behavioral pattern (Kakati 2009; Ahsan, 1994). Neighboring gibbons groups were distinguished by location, group composition, distance and signing times. Then, the identified gibbons groups in each habitats were marked by a unique identification number and these were monitored by the trained research assistants at least minimum 10 days for precise information and avoid double count except the some sites in Chattogram Hill Tracts.

Extensive field works were not possible at Kassalong Reserved Forest, Sangu-Matamuhuri Reserved Forest and few others sites in southeast Bangladesh due to the security problems. Limited field works and trained local research assistants were engaged to collect the population information of the gibbons at these habitats. Population ecological information was also collected from the wildlife biologist who has experience in field work at Kassalaong Reserved Forest and Sangu-Matamuhuri Reserved Forest.

3.2.2 Parasitological Study

3.2.2.1 Faecal Sample Collection

A total of 50 faecal samples were collected during the monsoon and winter seasons from August 2022 to December 2023. Lawachara and Saltila samples were collected during moonson, post moonson and winter seasons. Monsoon and post-monsoon extend from June to November, and the winter season includes December, January, and February (Choudhury, 2008). Samples of three different groups in Lawachara were collected during moonson (n = 8) and winter season (n = 6). The highest number of samples were collected from the only group in Saltila (n=28), including the moonson (n=18) and winter season (n = 10). Eight samples were collected from two gibbon groups of Sheikh Jamal Inani National Park during moonson. No samples were collected during the stormy and rainy seasons. Only freshly defecated samples of the gibbons were collected upon observation.

One group of the same individuals of Lawachara gibbons were sampled in monsoon and winter seasons of which both male and female of Saltila were sampled in both two seasons. Due to difficulties of sample collection, repeated samples were collected from the same individuals at Inani. Repeated samples were collected from the

Saltila gibbons group in both winter and monsoon season.

The ability to continuously follow the gibbons affected the faecal sample collection. Gibbons of Saltila were habituated, which allowed to collect more samples than from Lawachara and Inani. Continuous following of the gibbons of Inani was almost impossible due to the difficulty in terrain and access to follow the gibbons. Weather, time, date, sex of gibbons, and vegetation types were noted (Klaus et al., 2017). Age-sex classes of the gibbons were categorized as infant, juvenile, sub-adult, adult male, and adult female on the basis of coat colors, sexual morpholgy and behavioral patterns (Ahsan 1994; Kakati et al. 2009).

3.2.2.2 Helminth Assessment

A total of 50 faecal samples were collected from six gibbon groups (Lawachara: three groups; Saltila: one group; Inani: two groups) during the monsoon and winter seasons from August 2022 to December 2023 (Table 1). Monsoon samples were collected from April to November and winter samples from December to March. Only freshly defecated samples were collected to avoid contamination. One group of gibbons in Lawachara and the Saltila group were sampled in both the moonson and winter seasons, while the other two Lawachara groups and the Inani groups were sampled only in a single season each.

The ability to continuously follow the gibbons affected the frequency of faecal sample collection. The gibbons at Saltila were habituated, which allowed the research team to collect more samples and to sample more consistently at Saltila than at Lawachara and Inani. Continuous following of the gibbons at Inani was almost impossible due to the difficulty of the terrain and the heavy use of the landscape by Asian elephants.

When samples were collected, we noted the weather, time, date, and age-sex class of the gibbon that produced each sample (Klaus et al., 2018). Gibbon individuals were categorized as infant, juvenile, sub-adult, adult male, or adult female based on coat color, sexual morphology, and behaviour patterns following Ahsan (1994) and Kakati et al. (2009). Anthropogenic disturbances were categorized as agricultural activites (*i.e.,* planting crop fields, lemon orchards, and betel leaf vineyards), road infrastructure, human settlements, and cattle grazing. Anthropogenic disturbances were visually observed and recorded with GPS waypoints. After mapping the locations of these disturbances, distances from these locations to the home ranges of the gibbon groups were calculated in Google Earth.

3.2.2.3 Data analysis

Because the relationship between distance to roads, settlements, and agricultural fields and human activity in the forest is not well understood, and our sample sizes did not permit a detailed exploration of these relationships, we used group identity, rather than specific habitat variables, as an indicator of the underlying habitat quality in each group’s home range for data analysis. We used model selection with generalized linear mixed models (GLMM) to estimate the effects of season, adult sex, and group identity on parasite prevalence (Model 1) and parasite intensity in infected adults (Model 2). Because sampling was unbalanced, we used the Satterthwaite approximation with robust estimation. For parasite prevalence, which involves a binary outcome variable (infected/not infected), we used a binomial distribution with a logit link. Parasite intensity is a count variable, so we used a Poisson probability distribution and a log link in the GLMM for intensity. Individual identity was included as a random factor in both models because most individuals were sampled repeatedly. Because sample sizes for juvenile and subadult individuals were not adequate to determine whether age class affected parasite prevalence or intensity, we included only adult samples in the models. For each analysis, we used the Akaike Information Criterion corrected for small sample sizes (AICc) to compare candidate models with each other and with a null model that had the same error structure and included no predictor variables. We used ΔAICc (the difference between the AICc for a candidate model and the AICc for the model with the lowest AICc) to determine which were the best models, selecting the candidate models with $\Delta AICc \leq 2$.

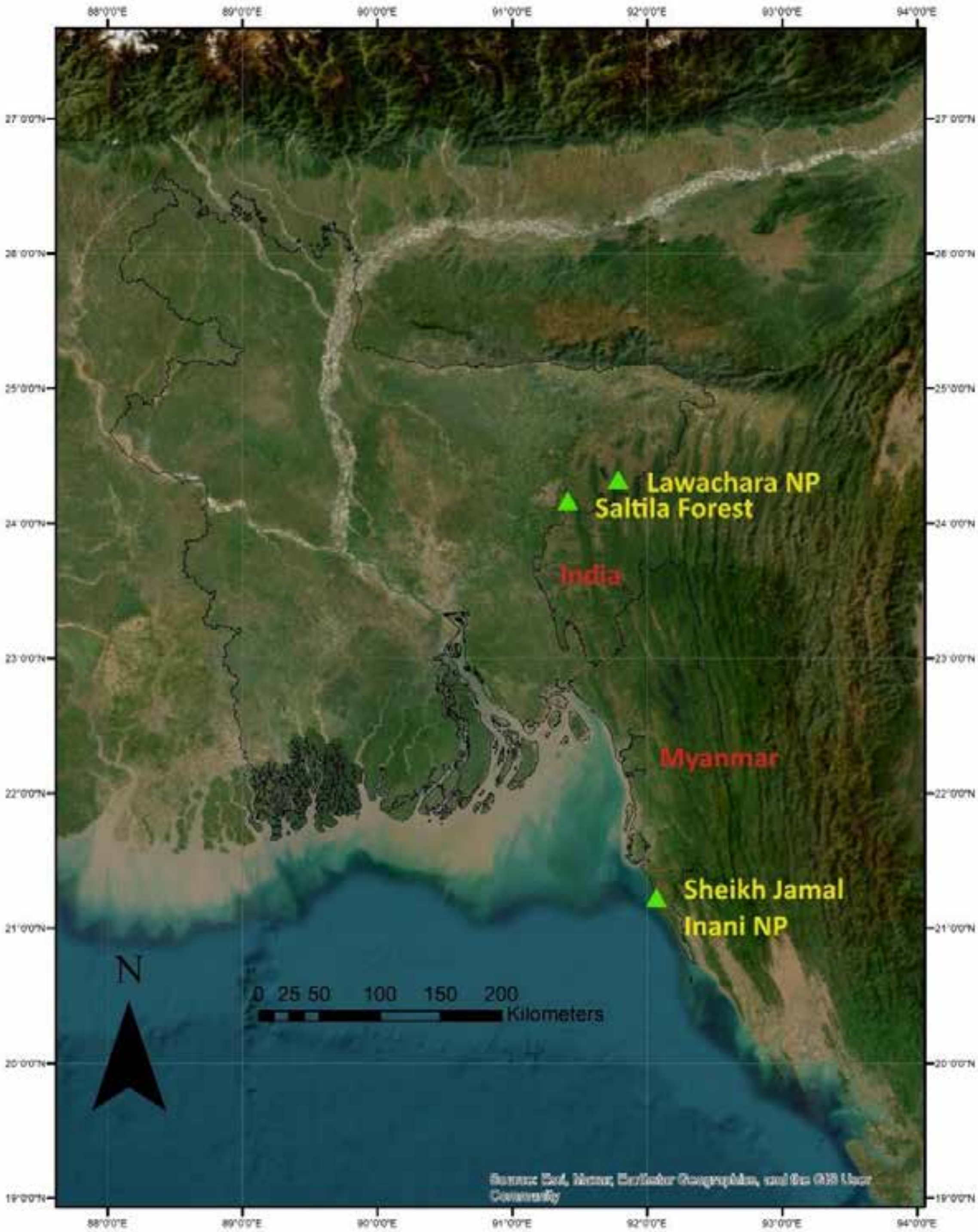


Figure 2: Locations for parasitological study

3.2.3 Behavioural and Ecological Study

The focal gibbon group at Saltila consisted of one adult male (that we named Shibu) and one adult female (named Basanti). We used the instantaneous scan sampling method (Altmann, 1974 and Fan et al., 2012), observing each individual for at least 5 seconds to record its dominant activity, and the approximate distance of the gibbon to the nearest Phayre's langur (in cases where Phayre's langurs were detected), with 5-minute intervals between two scans of the same individual.

The gibbons' home range size was estimated using GPS waypoints of the gibbons (together or individually) and other landmark positions such as large trees, hill streams, bamboo thickets, hills and walking trails (Sharma and Sinha 2022; Kim *et al*. 2011). The location of the solitary gibbon female was recorded whenever encountered. The individual home ranges were calculated by calculating the total area by creating minimum convex polygons in Google Earth Pro (Al-Razi *et al*. 2020). The study area was divided into three areas (Minijhiri Bagan, Kolabon and Kalamia Khura) for population monitoring, and extensive training was provided to the local research assistants to allow them to maintain long-term monitoring of the gibbon group beyond the period of this reported study.

We also conducted a comprehensive focus group discussion (FGD) with twelve senior local community members who regularly enter the forest to collect firewood and grasses and who have known these gibbons for many years. We asked semi-structured, open-ended questions (Maurice *et al*. 2019; Kabir *et al*. 2021) to better understand the past and present status of the gibbons of Saltila. The mean age of the FGD participants was 57.5 years.

Identified food trees of gibbons will be marked to know the fruiting and flowering seasons. About 2 x 0.1 km transects will be also established to record the availability of food items for the gibbons at the site of behavior observation. All marked trees and transects will be visited at fortnight intervals to find out the flowering and fruiting seasons and data collection will be conducted which were ranked as 0 to 1. Value of '0' corresponded the absence of flowers or fruits of which '1' presence of either flower or fruit.

Seasonal abundance of fruiting season will be conducted at Raghunandan Reserved Forest and Satchari National Park which will cover the whole season. Satchari National and Raghunandan Reserved Forest is situated at same hill range and covering the same type of vegetation.

Feeding ecology will be assessed by instantaneous scan sampling at Raghunandan Reserved Forest. Observer(s) will record the food items during the behavioral study. All the observed foraging fruit items carefully noted. Food items were classified into six categories such as mature leaves, young leaves, fruits, flowers, buds and animals matters. All trees, shrubs, lianas, climber, epiphytes and climbing epiphytes will be eaten by western hoolock gibbon in each month will be recorded. Feeding data will be analysed by following equation.

$T_a = N_a \times 100/N$

Where, T_a = Percentage of time on food item a;

N_a = Total number of records of foods a; and

N = Total number of feeding records per day.

Habitat fragmentation will be assessed by considering the perspective of the western hoolock gibbon of Bangladesh. Movement of gibbon is restricted due to discontinue of the canopy coverage. Maximum distance leap of the gibbon was 5.2 m. By considering this approach, more than 5m canopy discontinuation is considered as habitat fragmentation.

Habitat fragmentation will be analyzed by direct visual observations of discontinue canopy by road, agricultural expansion, stream, vacant areas and so forth. GPS location will be noted in fragmented areas. Finally, habitat size will be assessed by GIS-based software and available satellite image.

Impact on human interference on population composition will be conducted by the distance of orchards garden, cultivation crops, human settlements, encroachment, logging and other agricultural practices which will be analyzed by GIS-based software which will be verified from the field by taking GPS location. Threats will be conducted by prepared questionnaires and direct visual observations. Hunting will be noted by presence of any hunter or sign of hunting and prepared questionnaires.

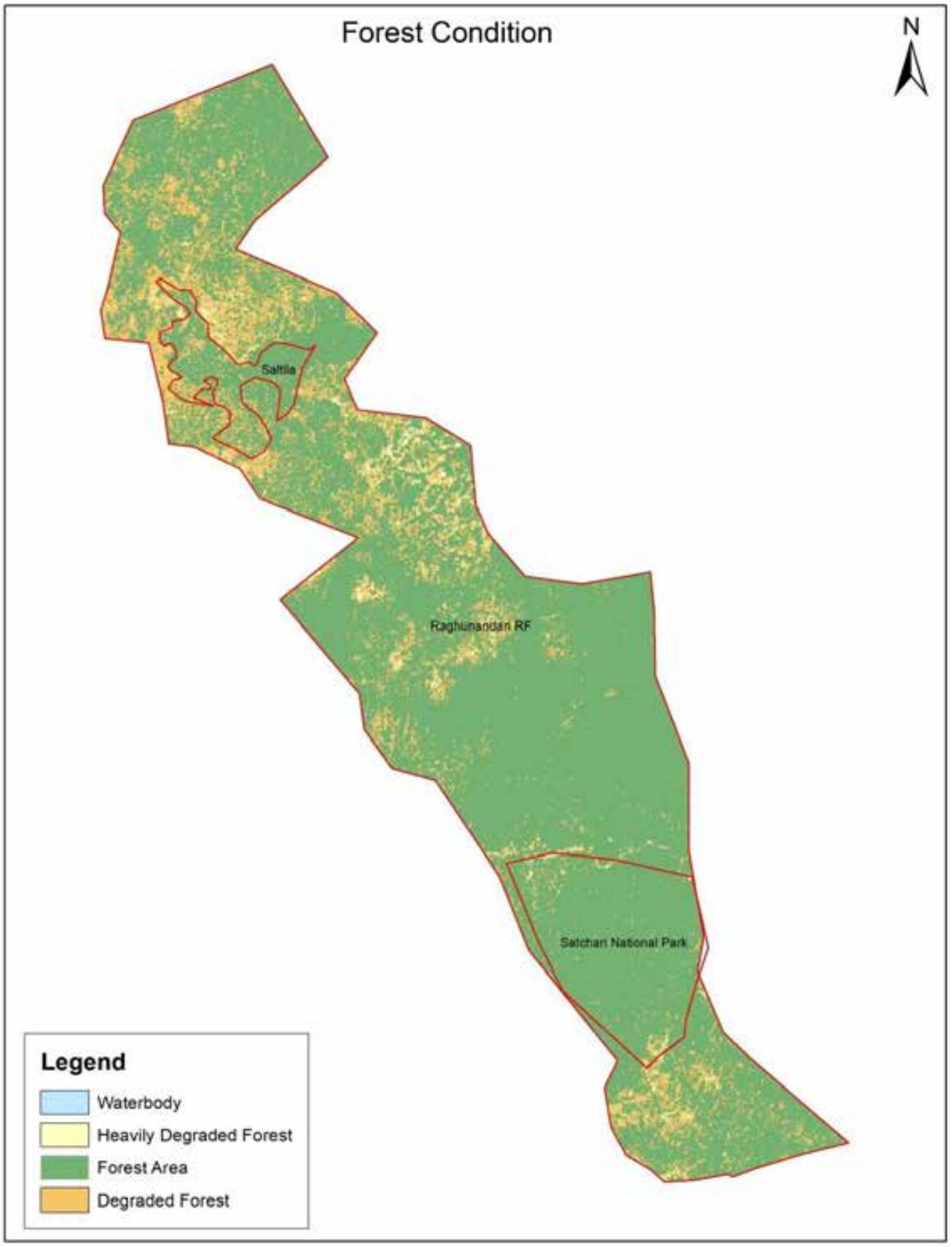


Figure 3: Location of the study area (inside the black circle)

4 RESULTS

4.1 Population Ecology

The presence of the gibbons was confirmed in 46 out of 51 habitats (Table 2; Figure 4 and Figure 5). Among them, 26 and 20 habitats are in southeast and northeast Bangladesh. 46 confirmed gibbon habitats are administered by nine forest divisions of the Bangladesh Forest Department in northeast and southeast Bangladesh (Table 2) and the gibbons here are distributed in protected areas (n = 11), reserved forests (n = 22), unclassified state forests (n = 8), and privately owned forests (Tea estate, n = 4; Khasia Punji (settlement), n =1). All 46 habitat sites lie within 42 forest fragments. We consider the Kassalong Reserved Forest and Sangu-Matamuhuri Reserved Forest a single fragment. The maximum and minimum total areas of confirmed gibbon habitats are 549.51 km^2 to 0.13 km^2, respectively (n = 40 km^2, SD = ± 115.66 km^2, mean = 36.98 km^2).

The estimated gibbon population of Bangladesh consists of at least 816 individuals in 254 groups. Among them, southeast Bangladesh supports at least 458 individuals (n = 148 gibbon groups) and northeast Bangladesh supports 358 (n = 106 groups). The range of the gibbon population in a forest fragment was 1 to 120 individuals (mean = 19.43, STD = ±29.25; standard error of mean = 4.514). About 23 forest fragments hosted less than or equal to 10 individuals and nine habitats supported 11 to 20 individuals. About 10 fragments supported more than 20 individuals.

Gibbons group sizes ranged from two to six individuals with a mean ± SD group size of 3.34±1.09 individuals (n = 108). Group sizes in southeast Bangladesh (N = 53, mean ± SD = 3.22±1.12) were similar to those in northeast Bangladesh (n = 76, mean ± SD = 3.42±1.07; range 2 to 6. Group sizes were lower in completely isolated gibbon habitats that supported <3 groups (n = 23, mean ± SD = 3.09 ±1,06; range = 2 to 5). Group sizes were also lower in habitats with areas <200 ha (n = 11, mean ± SD = 2.85 ± 0.898, range = 2 to 5). Mean group sizes and percentage of forest cover varied significantly across habitats ($t = 21.6$, $df = 52$, $p < 0.05$) predicting that groups in areas of higher forest coverage were larger. This analysis predicting that larger areas with comparatively good forest coverage supported larger groups than smaller habitats with highly degraded forest coverage.

Population densities of the gibbons attotal survey areas in continuous forest were ranging from 0.02 to 3.83 groups/km^2 (n = 23; mean ± SD = 0.6028±0.8134; 25th percentile = 0.0891; 75th percentile = 0.7732). Only Kaptai National Park (forest coverage area = 15.47 km^2, density = 1.03 groups/km^2), Diari Biripata (forest coverage = 0.52 km^2; density = 3.83 groups/km^2) and Kolachi (forest coverage = 0.65 km^2; density = 1.54 groups/km^2) supported more than 1 groups/km^2.

No fragmentation data were collected from Sangu-Matamuhuri RF and Kassalong RF due to security concern field investigators. Hazarikhil WS and Dudpukuria-Kamarchhara were connected with nearby forests. Rest of the gibbons habitats were isolated and fragmented from the nearby forests Kaptai National Park and Dhopachari-Dupukuria WS and adjacent areas were the significant gibbons habitats of the Bangladesh though gibbons populations were isolated from the connecting habitats.

About 15 and 9 identified gibbons habitats supported less than five and 10 gibbons respectively. Gibbons populations composed of 11 to 19 individuals at nine habitats. Rest of the gibbons habitats (n = 11) supported more than 20 gibbons individuals (Figure 3). Lathitila of Patharia Hill Reserved Forest, Korma and Adampur of Rajkandi Hill Reserved Forest, Sagonal and Ragna of Atora Hill Reserved Forest, Lawachara National were stronghold gibbons population in northeast Bangladesh. Sheikh Jamal Inani National Park, Baishari-Bangdhepa Wildlife Sanctuary, Dhopachari and Dudpukuri of Dudpukuria-Dhopachari Wildlife Sanctaury, Kelishahar-Vandaljhuri forests, Kaptai National Park, Kassalong Reserved Forest.

Traditional cultivation practices and logging (jhoom), lemon orchards, expansions of agricultures activities, and betel leaf vineyards were the major reasons for the fragmentation of the gibbons habitats of the Bangladesh.

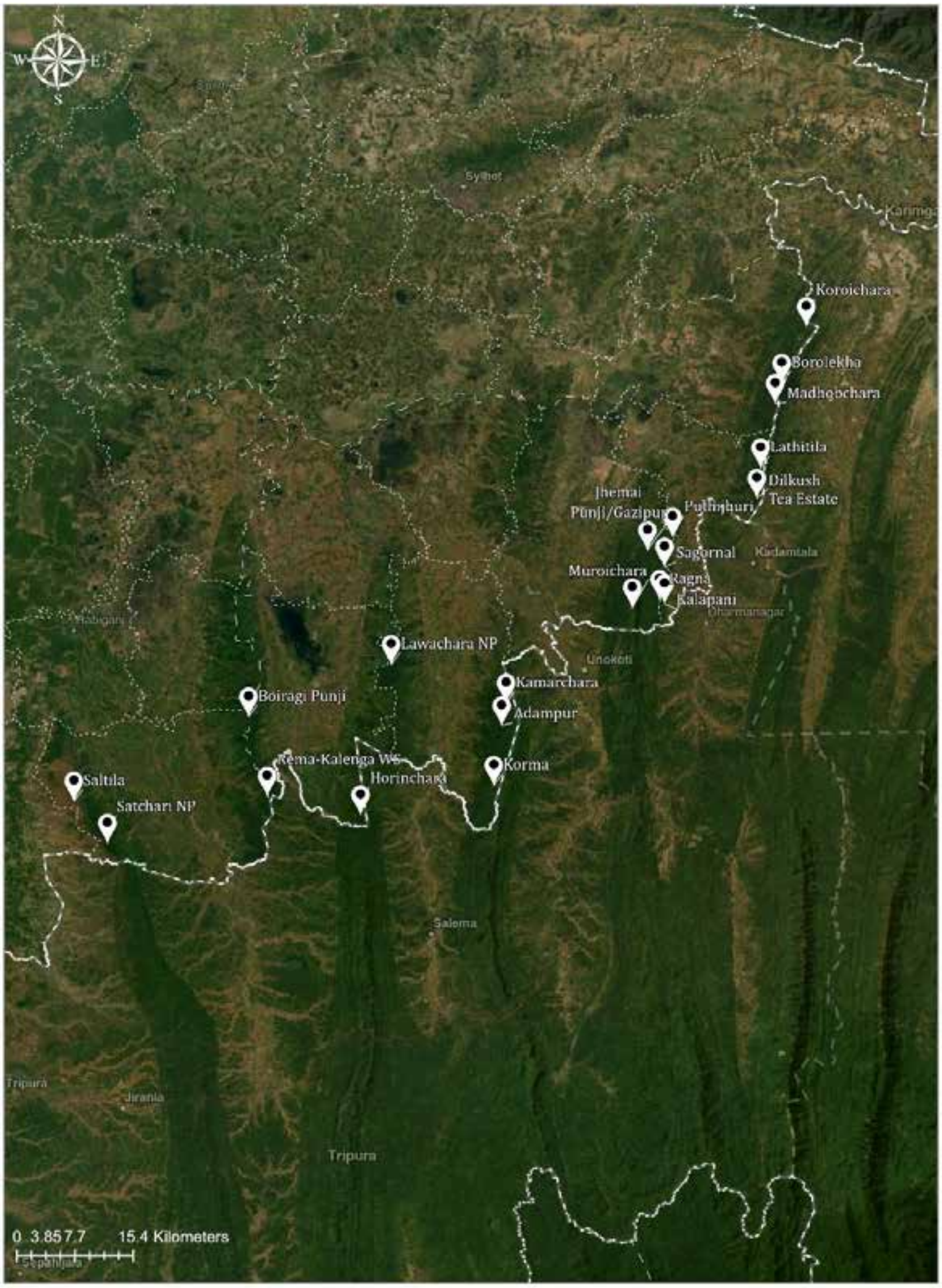


Figure 4: Locations of the gibbons habitats in northeast Bangladesh

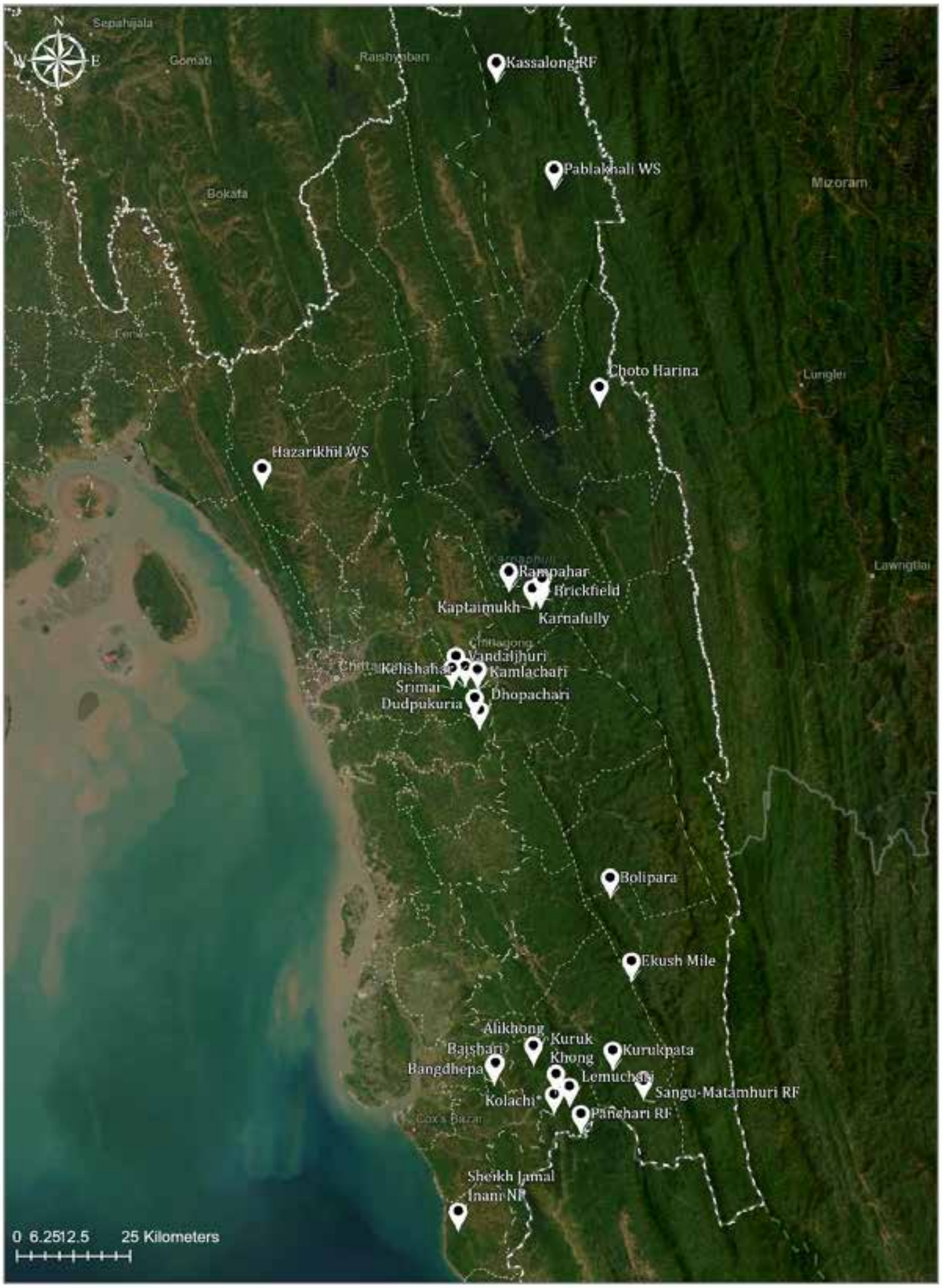


Figure 5: Locations of the gibbons habitats in southeast Bangladesh

Table 2: Population assessment of western hoolock gibbons at southeast and northeast Bangladesh

Sl no*	Forest Range/Area	Forest Beat/Area	Status of the forest	Confirmed Group Number	Confirmed Individuals
1	Hazarikhil WS	Hazarikhil	PA	2	5
2	Dudpukuria-Dhopachari WS	Kamlachhari	PA	1	5
3		Dudpukuria	PA	2	5
4		Dhopachari	PA	17	65
5	Patiya	Vandaljhuri	RF	2	5
6	Patiya	Kelishahar	RF	4	13
7	Patiya	Srimai	RF	2	6
8	Kaptai NP	Rampahar	RF	2	7
9		Karnafully	RF	1	3
10		Kaptai Mukh	RF	12	37
11		Sitapahar	RF	1	2
12	Pablakhali WS	Pablakhali WS	PA	1	2
13	Kassalong RF	Kassalong RF	RF	40	120
14	Inani FR	Inani	PA	7	20
15	Baishari-Bangdhepa WS	Bangdepa	PA	6	22
16		Baishari	PA	1	3
17	Sangu FR	Alikhong	RF	4	12
18	Sangu-Matamuhuri RF	Sangu-Matamuhuri RF	RF	25	75
19	Nikkhongchari	Painchari and adjacent areas	USF	4	13
20		Lemuchari	USF	4	12
21		Kurokkhong	USF	3	9
22		Kolachi	USF	1	2
23	Alikadam	Diari Biripata	USF	2	5
24	Alikadam	Kurukpata	USF	1	2
25	Thanchi	Bolipara	USF	2	6
26	Borkol	Choto Harina	USF	1	2
27	Satchari NP	Satchari NP	PA	3	11
28	Bhanugach RF	Lawachara NP	PA	15	48
29	-	Boiragi Punji	PL	1	1
30	-	Harinchara	TE	5	13
31	Ragna	Kalapani	TE	1	4
32	Lathitila	Dilkush T.E.	TE	1	3
33	-	Koroichara	PL	1	3
34	Raghunandan RF	Saltila	RF	1	3
35	Rema- Kalenga	Kalenga	PA	1	4
36		Putijhuri	RF	1	6
37		Sagornal	RF	11	45

38	Atora Hill RF	Ragna	RF	13	53
39		Muroichara	RF	1	2
40		Gazipur	RF	1	3
41	Patharia Hill RF	Lathitila	RF	13	42
42		Madhobchara	RF	1	2
43		Baralekha	RF	8	22
44	Rajkandi	Korma	RF	13	42
45		Adampur	RF	11	40
46		Kamarchara	RF	4	11
	Total			**254**	**816**

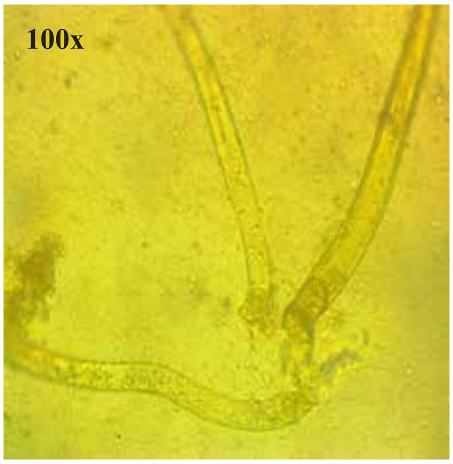
4.2 Parasitic loads of the western hoolock gibbons

Overall, 50 feacal samples were collected and processed for assessment of helminthic parasites, revealing an overall domincance of *Bunostomum* sp. (Ancylostomatidae) and *Enterobius* sp. (Oxyuridae) in collected samples (Figure 6). About 82% of collected samples (n = 41 samples) were positive and 18% (n = 9 samples) were negative for helminthic infections. Occurrences of *Bunostomum* sp. (n = 41 samples), *Enterobius* sp. (n = 2) and eggs of *Enterobius* sp. (n =1) were identified from all three study sites, but parasitic prevalence and intensity were different across sites. Another unidentified nematode parasite was observed in one faecal sample.

Parasitic prevalence (mean 82%) was highest among the gibbons of Lawachara (92.8%), followed by Saltila (85.7%) and Inani (50%). The overall prevalence of *Bunostomum* sp. and *Enterobius* sp. were 82% and 6% respectively. Parasitic prevalence of *Bunostomum* sp. were same as total prevalence of the three sites. Prevalence of the *Enterobius* sp. at the three sites showed the similar trends (2%).

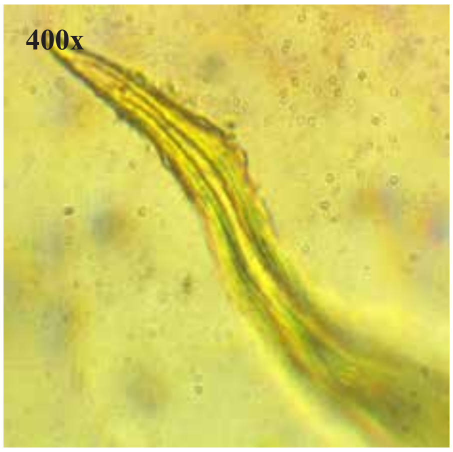
Mean parasitic intensity of *Bunostomum* sp. and *Enterobius* sp. were 12.1 and 0.04, respectively. Parasitic intensity among three sites did not vary significantly (Pearson Chi-Square, $\chi2= 47.45$, df =46, $p>0.05$) and the range of the parasitic intensity was 1 to 45 (N= 41 infected samples, mean = 12.1, SD = ± 9.703). Saltila showed the highest parasitic intensity (n = 24, mean = 14.13, STD = ±11.29), followed by Inani (n = 4, mean = 13.50, STD = ±8.105) and Lawachara (n = 13, mean = 7.92, SD = ±5.02).

Only one gibbon group of Lawachara was sampled in both monsoon (n = 3, mean intensity = 8) and winter season (n = 3, mean intensity = 6). Range of parasitic intensity of the same group of Lawachara in the two seasons was 1 to 11 (n =6, mean = 7.00 and STD = ±3.521), which varied significantly (t = 4.869, df = 5; $p \leq 0.05$). Generally, the intensity of all infected samples of Lawachara in two seasons varied statistically (t = -4.812, df = 12, $p <0.01$). Parasitic intensity range of infected Saltila samples during the moonson season was 3 to 45 (n = 15, mean = 16.73, STD = ±11.78), and in winter 2 to 31 (n = 9, mean = 9.78, STD = ±9.46). Parasitic intensity of the two gibbons of Saltila varied significantly in two seasons (t = 4.866, df =27, $p< 0.05$). Prevalence of Lawachara and Saltila infection was slightly higher during the moonson (95.3%) than winter season (92.9%).



***Bunostomum* sp.**

Head of *Bunostomum* sp.



Tail of *Bunostomum* sp.

***Enterobius* sp.**

Figure 6: Identified parasites in gibbons faecal samples.

4.3 Behavioral and Ecological Study

4.3.1 Gibbon population status at Saltila

The information gathered from the FGD participants showed that Saltila had no gibbons approximately 20 years ago. Members of the local community also reported that they first observed Shibu at Saltila around 15 years ago. About 2 years later, Basanti was first observed to form a pair with Shibu. Around 2–3 years later, another solitary female was first spotted at Saltila. The FGD participants have not observed any offspring in the past 15 years. They said that Shibu and Basanti were occasionally seen separated in the past, but this never lasted for more than a week.

4.4 Home ranges of the gibbons

The monthly home ranges of Shibu, Basanti, and the solitary female were consistent from December 2020 to June 2021, with Shibu ranging over *c.*19 ha, Basanti over *c.*30 ha, and the solitary female over *c.*28 ha, with about 30% overall overlap among the three individual home range areas. In June 2021, Shibu, together with the langurs, extended his home range further into the solitary female's home range, after which he ranged over an area of about *c.*32 ha. During this time, the habitat used by Shibu and Basanti overlapped by *c.*9 ha.

4.5 Separations and reunions of the gibbon pairs

Shibu and Basanti periodically changed between pair separation and reunion from October 2020 to December 2023. They first separated in October 2020 and stayed apart for six months. Subsequently, Shibu and Basanti reunited for 27 days from 26 May to 21 June 2021. Then, they separated again, but stayed in the same area for about a week before Basanti moved *c.*650 m east to Minjiri Bagan. They united again on 18 April 2022 for one day when mating and grooming behaviors were observed. The next reunion, observed in the first week of September 2022, lasted for three days before Shibu went back to the langur group. This separation lasted for three days before the gibbons reunited again for four days, during which they were heard duetting.

On three days in January 2022, Shibu, Basanti, the solitary female and the Phayre's langur group all ranged and foraged together in the Kolabon area. At that time, Shibu spent 33.5% of his time with the langurs. During the same period, Shibu approached Basanti seven times, but they did not reunite. Once they spent around eight minutes together but then Shibu returned to the langur group. Twice Basanti fled from Shibu while calling loudly. The solitary female was seen at the edge of this area, maintaining a distance of *c.*200 m.

In February 2022, Shibu approached Basanti eleven times during a period in which they ranged within *c.*100 m of each other for five days. They duetted during times when they approached each other. During this time, the movements of Shibu, Basanti, and the langurs always followed the same pattern, in which Shibu followed the langurs and Basanti followed Shibu, but the male and female gibbon did not reunite.

On 18 April 2022, Shibu and Basanti were observed mating and grooming for 44 minutes in the morning, and mated twice, after which Shibu went back to the langur group. Shibu returned to Basanti at noon on the same day. After mating four more times with Basanti, Shibu returned to the langur group. Later that day, Shibu approached Basanti again, but she fled and fell to the ground. During the reuniting and separation periods, Basanti was not always receptive of Shibu's approaches but fled. On some occasions, Shibu left Basanti behind and departed with the langurs. Throughout this time, the solitary female was ranging at Kalami Khurum, *c.*400 m apart from the pair. The also united for 2 days in January 2023 and October 2023.

Table 1:Reunion and mating events between a male and female hoolock gibbon in Saltila forest, Bangladesh between prolonged pair separation periods

Month	Observed together (days)	Longest consecutive duration together (days)	Observed mating (days)	Observed mating (times)
May 2021	6	27	0	0
June 2021	21		4	9
April 2022	1	1	1	6
September 2022	7	4	3	7
January 2023	2	2	2	2
October 2023	3	2	2	2

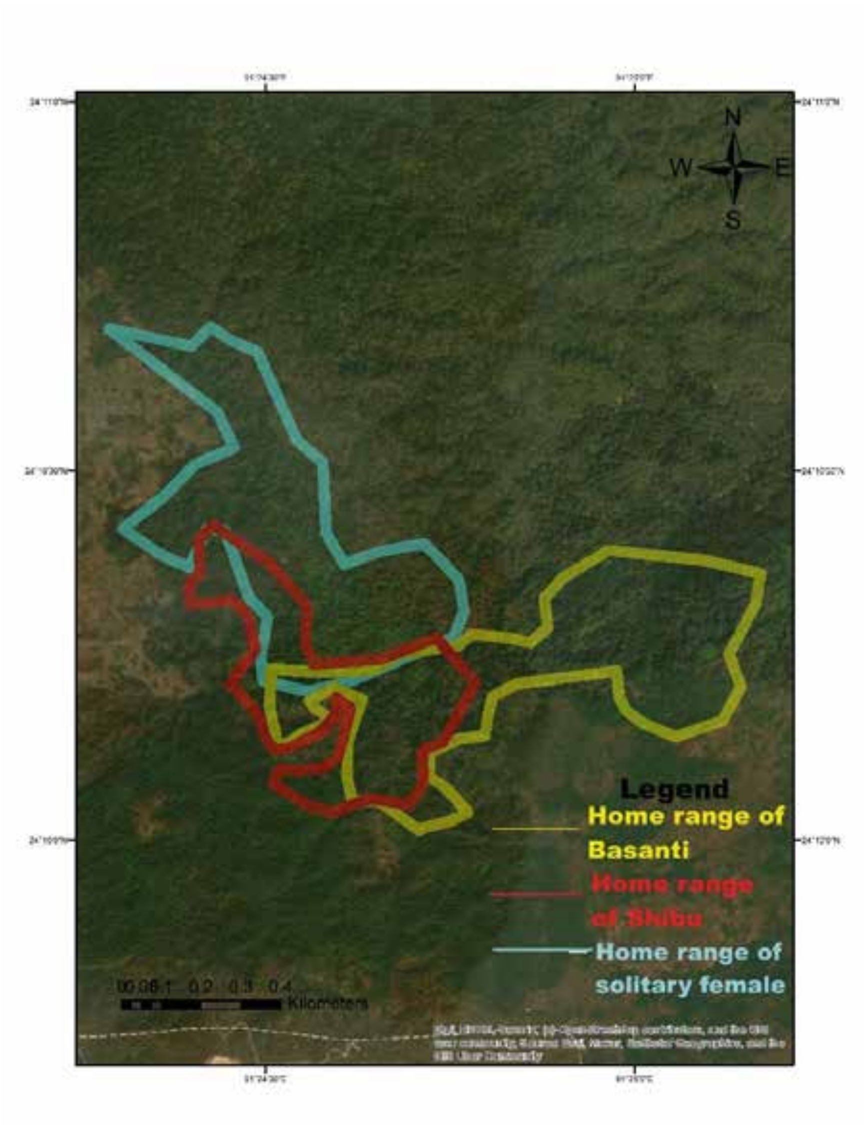


Figure 7: Home ranges of the three gibbons.

A total 20 species were identified to assess the seasonal abundance of the food items of the gibbons (Table 4.1). *Ficus nervosa* was the most abundant food species of the gibbons round the year. *Prunus ceylonica*, *Garcinia zanthopyga* and *Dalbergia* ap. were the second most fruiting trees of the gibbon. Other most abundant fruiting tree species were *Ficus benghalensis, Ficus lampongha, Ficus rumphii, Ficus variegata, Ficus racemose, Phyllanthus embellica,* and *Terminalia bellerica.*

Table 2.1: Seasonal abundance of major gibbon fruit species at Saltila forest, Bangladesh from January 2023 to December 2023.

Sl no	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	*Ficus nervosa*	√	√	√	√	√	√	√	√	√	√	√	√
02	*Ficus benghalensis*	√	√	√									
03	*Ficus rumphii*								√	√	√		
04	*Ficus racemosa*	√									√	√	√
05	*Ficus variagata*			√	√	√							
06	*Ficus lampogha*	√	√	√									
07	*Ficus benjamina*										√	√	
08	*Ficus cutripeps*			√							√	√	
09	*Prunus ceylonica*	√	√	√	√								√
10	*Artocarpus chama*					√	√	√					
11	*Artocarpus lacuchaa*					√	√	√					
12	*Aporusa diotica*						√						
13	*Garcinia cowa*						√						
14	*Garcinia zanthopyga*							√	√	√	√		
15	*Dalbergia* sp.	√	√	√	√								
16	*Microcos paniculata*							√	√	√			
17	*Phyllanthus embellica*								√	√	√		
18	*Terminalia bellirica*							√	√	√			
19	*Syzygium frutica*			√	√								
20	*Protium serratum*						√						

4.6 Feeding ecology

Feeding ecology of the western hoolock gibbons were conducted at Saltila forest which is situated Raghunandan Reserved Forest. The food of the gibbons of Saltila consists of fruits (59.7%), leaves (32%), flowers (2.3%), and insects (6.0%). Gibbons consumed the fruits from 33 plants species of 14 family. Gibbons was spent most of the times on the *Ficus nervosa*, followed by *Ficus benghalensis*, *Prunus ceylonica*, *Dalbergia* sp., *Syzygium formosum* and *Artocarpus chama*.

Intakes of the leaves as food items of the gibbons were much higher at Saltila forest. Gibbons has spent significant times on the consume of *Trichosanthes truncate, Dioscorea* sp., *Syzygium* sp., *Thunbergia grandifolia, Castanopsis indica, Bambusa and unidentified climber and liana*. Gibbons also consumed the flowers *Bombax insigne*, *Castanopsis tribuloides, Thunbergia grandifolia,* unidentified liana's and climber flowers.

Gibbons also role to control teak defoliator (*Hyblaea puera*) and teak skeletonizer (*Eutectona machaeralis*) at Saltila forest . Teak is planted tree species of Saltila forest. In premoonson, gibbons spent significant times for foraging of the teak defoliator and teak skeletonizer. Gibbons almost spent 3.9% for consuming of the teak defoliator and teak skeletonozer.

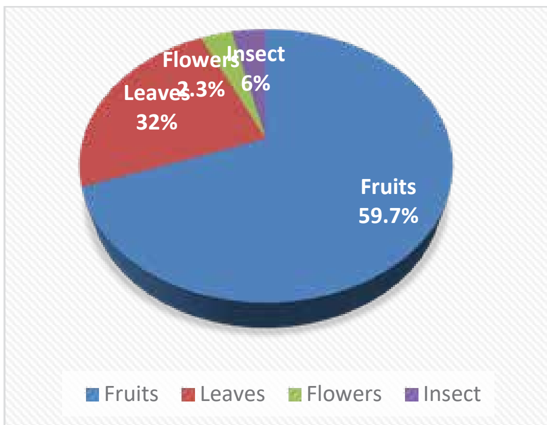


Figure 8: Food items of the gibbons at Saltila

5 DISCUSSIONS

Gittins and Akonda (1982) roughly estimated the gibbons population of Bangladesh and counted 3000 gibbons from northeast and southeast Bangladesh. Islam et al. (2006) conducted extensive gibbons census of Bangladesh and identified 24 locations in northeast and southeast Bangladesh. They estimated 282 gibbons at the hill forest of northeast and southeast Bangladesh by transect sampling methods. Naher et al. (2001) also estimated the gibbons population by distance sampling method and assessed 469 gibbons from 11 forested areas. Among them, six habitats were identified direct field observations another 5 gibbons gibbons habitats were located by interviewing with Forest Department officials and secondary information.

About 18 and 26 new locations/ habitats of the gibbons were identified according to Naher et al. (2021) and Islam et al. (2021). Total 14 and 4 new locations were identified from northeast and southeast Bangladesh respectively (Naher et al. 2021) and 15 and 11 new locations were assessed from northeast Bangladesh and southeast Bangladesh respectively (Islam et al. 2006).

Naher et al. (2021) identified Patharia Hill Reserved Forest, Rajkhandi Reserved Forest and Lawachara National Park in northeast Bangladesh and Kaptai National Park and Sangu-Matamuhuri Reserved Forest in southeast Bangladesh are the significant gibbons habitats of Bangladesh. Islam et al. (2006) recognized Adampur, Lathitila, Lawachara National Park in northeast Bangladesh and Kaptai National Park of southeast are stronghold for the gibbons in Bangladesh. This study identified Lawachara National park, Patharia Hill Reserved Forest (Baralekha, lathitila), Rajkandi (Korma, Adampur, Kamarchara), Atora Hill Reserved Forest, Harinchara Tea Estate in northeast Bangladesh and Sheikh Jamal Inani National Park, Baishari-Bangdhepa Wildlife Sanctuary, Dudpukuria- Dhopachari Wildlife Sanctuary, Kelishahar-Vandaljhuri forests, Kaptai National Park, Sangu-Matamuhuri RF, Kassalong RF in southeast Bangladesh are potential gibbons habitats of the country. Naher et al. (2021) also found the gibbons at Fashiakhali Wildlife Sanctuary and Teknaf Wildlife Sanctuary in southeast Bangladesh but we could find any gibbons there. Further field investigations can be conducted there to confirm the presence of the gibbons.

Identification of the several new gibbons locations and rising total gibbons populations should not provide the overall increasing population trends of the gibbons. This study found the higher populations of the gibbons for engagement of the local communities to locate local communities and extensive and long-term field work approach. Gitins and Tilson (1984) mentioned the mean group sizes of 3.5 (n = 6) from Lawachara Natioanl Park. Ahsan et al. 2001 estimated the group sizes 2.9 (n = 7) and 3.0 (n = 8) at Chunati and Lawachara National Park. Feeroz and Islam (1992) assess the mean group is 3.17 (n = 6) from Lawachara National Park. Kakati et al. (2009) mentioned the smallest mean group sizes (mean= 2.5, n = 2) at small forest fragments which was high for medium-sized ((mean =3.29, n =24)) and comparatively larger forest fragments ((mean 3.9, n = 28 groups). This study also found the similar trends of group sizes of the gibbons due to depend on the habitat characteristics.

Rajkandi RF were the largest continuous gibbons habitats of northeast Bangladesh, followed by Atora Hill RF, Patharia (Patharia-Baralekha-Madhobchara), Lawachara NP, Harinchara Tea Estate and Rema-Kalenga WS (Kalenga) (Range = 407.0 ha to 5320.0 ha, mean = 2505.50 ha and STD = ±2177.48). Satchari NP, Monkhola(Patharia), Koroichara (Patharia), Saltila (Raghunandan RF), Dilkush Tea Estate (Patharia), Bobarthol (Patharia), Pichlatila (Patharia), Boiragi Punji, Kalapani (Atora) were the most isolated gibbons habitats of the northeast of Bangladesh (n =8, Range = 3 to 243 ha, mean = 87.66 ha, STD = ±80.14).

Naher et al. (2021) estimated 76 gibbons individuals from Sangu-Matamuhuri RF. Sangu-Matamuhuri RF and Kassalong RF are largest forest tract in mixed-evergreen hill forest of eastern Bangladesh and supposed to support the healthy population of the gibbons in Bangladesh. Further extensive population survey either through the auditory sampling methods or bio acoustic methods has suggested to precise understand the gibbons of Kassalong RF and Sangu-Matamuhuri RF .

While gibbons were long reported to be exclusively monogamous with enduring pair bonds, several studies over the last few decades have shown that their social organization can be rather dynamic and flexible (e.g., Palombit 1996; Lappan 2007; Morino 2016). The gibbon population in Saltila consists of a single adult male, a female with whom he sometimes associates, and a solitary female. Despite the apparent instability of the male-female pairing, Shibu was not observed mating with the solitary female, and mate replacement did not occur, although Shibu approached the solitary female twice during the observation period. This suggests that the instability of the pair bond was not directly attributable to intrasexual mating competition between the two females.

While food distribution and abundance are important determinants of gibbon group sizes and ranging patterns (Brockelman 2009; Savini *et al*. 2009; Guan *et al*. 2018; Lappan *et al*. 2017), it is unlikely to be the main reason for the separation of the male and female gibbons in Saltila. *Ficus nervosa*, the most important food plant for this population, was available year-round, and by ranging with a group of Phayre's langurs, Shibu likely offset any potential reduction in feeding competition that he might have gained by separating from Basanti, although it remains possible that Basanti or the solitary female benefited from foraging separately.

All observed mating events of Shibu and Basanti were in the ventro-ventral position. Islam and Feeroz (1992) and Ahsan (2001) also reported ventro-ventral mating of wild gibbons in northeast Bangladesh, and Amonge *et al*. (2017) observed ventro-ventral mating of captive gibbons in Arunachal, India. Despite observations of copulations, no births were observed at Saltila from 2018 to 2022, and members of the local community reported not observing any infants in the population in the preceding decade.

Very small populations often show a positive correlation between population density and individual fitness, known as the Allee effect, such that as population density declines, individual fitness also declines. This exacerbates the extinction risk of small populations (Stephens and Sutherland 1999; Angulo *et al*. 2007). Monogamous and social species may be particularly vulnerable to the Allee effect due to the disruption of their social structure, which may result in reduced reproduction or higher infant mortality or both (Bessa-Gomes *et al*. 2004; Angulo *et al*. 2018). For example, individuals in very small populations may experience difficulties in finding suitable mates, which can lead to depressed reproduction at low densities (Shaw and Kokko 2014). The elongated and clearly visible nipples of Basanti indicate that she has at least once nursed offspring, but it is not clear when, where, or if the infant survived. The failure of the gibbons of Saltila to produce surviving offspring over the course of more than a decade indicates that this isolated population is experiencing complete reproductive failure. The habitat fragmentation at Saltila limits dispersal opportunities, and the observations reported here suggest that intolerance and social incompatibility between the male and both females and difficulties in forming a stable pair may be factors leading to reproductive failure in this population. Genetic relationships among the three adults in this habitat are unknown, so it is also possible that the failure of either male-female dyad to form a stable pair bond resulted from inbreeding avoidance, but either mechanism implicates isolation in a small habitat fragment as a potential cause of reproductive failure. As Bangladesh's remaining gibbons live in small habitat fragments, this finding may indicate a more widespread problem (Islam *et al*. 2006). Naher *et al*. (2021) reported the occurrence of only two *H. hoolock* groups in the nearby Satchari National Park. Immediate conservation measures include protecting the larger landscape and creating habitat corridors between Saltila and Satchari National Park (*c*.5.5 km² distance) for arboreal mammals are absolutely crucial to facilitate dispersal and gene flow. This study will continue, and studies on the behavior and genetic diversity of very small gibbon populations in other fragments should be initiated, to gain a better understanding of social strategies adopted by gibbons in badly fragmented habitats and their consequences for the viability and survivability of this Critically Endangered species in Bangladesh

To the best of our knowledge, this is the first confirmed observation of helminthic parasite infection of western hoolock gibbons in the wild. *Bunostomum* sp. was recorded in wild lion-tailed macaques (*Macaca silenus*; Hussain et al., 2013), bonnet macaques (*M. radiata*, Kumar et al., 2018), Rhesus macaques (*M. mulatta*; Adhikari et al., 2022), and Nilgiri langurs (*Trachypithecus johnii*; Tiwari et al., 2018).

Bunostomum sp. (82%) showed comparatively higher prevalence than *Enterobius* sp. (6%). The prevalence for *Bunostomum* sp. in this studywas considerably higher than the reported prevalence in wild lion-tailed macaques (59%; Hussain et al., 2013) and bonnet macaques (1.5%; Kumar et al., 2018). Prevalence of *Bunostomum* sp. in Nilgiri langurs, however, was very low (0.45%; Tiwari et al. 2018). Overall, the highest prevalence of *Bunostomum* (87.6%) was reported from urban Rhesus macaques in Nepal (Adhikari et al., 2022), which was almost similar to the present study and may be due to the higher risk of exposure to parasites in human dominated landscapes. *Ternidens* sp. and *Trichuris* sp. were the most prevalent species (91.3%) of wild white-handed gibbons (*Hylobates lar*), followed by *Strongyloides fuelleborni* (56.5%), *Trichostrongylus* sp. (13.0%), *Nector* sp. (8.7%) and *Ascaris* sp (8.7%). Overall prevalence 36.5% were reported in gorllas (*Gorilla gorilla*), chimpanzees (*Pan troglodytes*), Guinea baboons (*Papio papio*), and Hamydrays babbon (*P. hamadryas*) (Medkour et al., 2020).

The identified strongylid *Bunostomum* sp. is a hookworm (https://www.k-state.edu/parasitology/classes/625nematode20.html). Species of this genus are reported to be present in the gastro-intestinal tract of many mammals, among them sheep, goats, buffaloes, cattle, Indian rhinos, and blackbucks (Gunaithilaka et al., 2018; Sanda et al., 2019). Usually, pathogenicity of *Bunostomum* sp. ranges from severe anaemia, submandibular oedema, dark coloured diarrhoea, weight loss and even death (Barabosa et al., 2017). Higher prevalence in a population may cause serious health burden. In Bangladesh, this species was previously reported from sheep, goats, and buffaloes (Khatun et al., 2021; Islam et al., 2022). Infection of the studied gibbons by this soil helminth suggests that the gibbons climbed down to the grounds where ruminants grazed. Cattle grazing was seen at three study sites during the study period.

Another soil heminth, *Strongyloides* sp., was also reported in wild *Hylobates lar* (DePaoli and Johnsen, 1978). Although gibbons rarely descend to the ground, habitat destruction and fragmentation are driving animals to adapt and develop new feeding strategies, which can lead to an increased risk of parasitic infection (Deb et al., 2013).

Gibbons population of northeast and southeast Bangladesh are distributed in 42 forest fragments. Gibbons population Patharia Hill Reserved Forest were fragmented to Dilkush, Lathitila-Baralekha, Monakhola, Pichlatila, Bobarthol and Koroichara. Gibbons of Kalapani areas were isolated from Atora Hill Reserved Forest. Habitats connectivity can be ensure among the gibbons of Patharia and Kalapani by habitat restoration programs. Gibbons Dhopachari are highly Isolated to Gondamar, Chapachari-Maini, Borguna, Sundarbans areas due to roads, lemons orchards and agricultural expansions. Gibbons of Kaptai National Park were isolated into Rampahar, Sitapahar, Karnafully-Kalabon, East region of Kaptaimukh, and Barrage areas. Either habitat restoration programs by native tree species and artificial canopy bridge should be conducted to connect the isolated habitats.

6 CONSERVATION RECOMMENDATIONS

Threats of the western hoolock gibbons include destruction of the forests habitats, hunting, expansions of Khasia jhooms (betel leaf vineyard), expansions of agricultures, unplanned and exotic plantations activities, brick field, expansions of traditional agricultures expansions (Jhoom) and illegal encroachments.

Legal actions against the hunting, protection and conservation of the forests, management and control of the khasia pan punji (betel leaf vineyard) and involve them into the gibbons conservation, expansion of the banana and other orchards cultivation inside the forests, stop the encroachments, stop the firewood collections for brick field, enforcement of the legal actions for protections of the forests, raising the awareness among the relevant stakeholders, continuation co-management activities, habitat restoration with native fruiting trees species of the gibbons can be effective to mitigate the existing threats of the western hoolock gibbons of Bangladesh.

Translocation and release of rescued animals can be a reservoir of parasites and translocation should be conducted using appropriate guidelines. Enrichment of the gibbon habiats with different types of natural food plants can be helpful to enhance the diet, nutritions and health of the gibbons and thus, minimizing immunsystem stress responses that can make gibbons more susceptible to parasite infections.

Lawachara National Park is one of the popular tourist destinations of the country, which can become detrimental for the gibbons due to the possible widespread transfer of human diseases. Therefore, proper guildline should be prepared and followed to control mass tourism. As parasites can infect these critically endangered gibbons and other sympatric mammals, including humans, the local Forest Department should focus on the parasitic infections and consider a holistic One Health approach for habitat, wildlife and tourism management in the future. Above, all, in all study sites, existing anthropogenic disturbances inside the forest should be controlled and curbed to protect Bangladesh's last gibbons.

The western hoolock gibbon is legally protected in Bangladesh by the Wildlife (Conservation and Security) Act 2012, Schedule I. Hunting, trapping, and shooting of gibbons are strictly prohibited by law. However, all gibbon populations and their habitats have been facing severe threats exacerbating the risk of rapid local extinctions. Therefore, the following conservation initiatives should be comprehensively conducted to protect the remaining western hoolock gibbons of Bangladesh:

- Legal actions and enforcement of the laws against hunting, encroachments, and habitats destruction should be ensured. Mass awareness among the local communities through the conservation awareness and knowledge dissemination can mitigate the risk of gibbons hunting and illegal trade;
- Involvement of the Khasia communities towards the gibbons conservation can be effective to stopover for further extensions pan punji (betel leaf vineyard plantation) and reducing the existing threats to the gibbons;
- Further extensions of orchard plantations (i.e., lemon, banana etc) should be strictly monitored inside the gibbons habitats;
- Any attempt to firewood collection for the brickfield should be strictly monitored ;
- Connecting the isolated gibbons habitats by the fast-growing native tree species and habitat restoration programs by the native fruiting trees of gibbons at the degraded habitats;
- Monoculture plantations should be discouraged inside the gibbons habitats;
- Engagement of the Co-management Committee for reducing the threats to the forests and gibbons habitats is effectively by formulating a long-term conservation plan;
- Development and implementation of the community-based long-term and sustainable conservation strategic plan; and
- Raising the voices to save the western hoolock gibbons and developing a positive behavioral attitude among the relevant stakeholders for sustainable gibbons conservation

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8 APPENDICES

Appendix 1: Food items of the gibbons at Saltila

Sl no	Family	Local Name	Scientific Name	Percentage	Food parts
1	Moraceae	Bot	*Ficus benghalensis*	4.1	fruits
2	Moraceae	Choto dumur	*Ficus nervosa*	34.9	fruits
3	Moraceae	Pani dumur	*Ficus lamponga*	0.7	fruits
4	Moraceae	Bot	*Ficus benjamina*	0.7	fruits
5	Moraceae	Pakur	*Ficus rumphii*	0.13	fruits
6	Moraceae	Dumur	*Ficus variagata*	1	fruits
7	Moraceae		*Ficus auriculata*	0.1	fruits
8	Moraceae		*Ficus racemosa*	0.5	fruits
9	Moraceae		*Ficus cutriceps*	0.2	fruits
10	Moraceae		*Ficus microcarpa*	0.6	fruits
11	Moraceae	Chapalish	*Artocarpus chama*	1.6	fruits
12	Moraceae	Dewa	*Artocarpus lacucha*	1.9	fruits
13	Burseraceae	Neol	*Protium serratum*	1.1	fruits
14	Euphorbiaceae	Lotkon	*Baccaurea motleyana*	0.4	fruits
15	Euphorbiaceae	Kakra	*Aporusa dioica*	0.3	fruits
16	Clusiaceae	Tiputanga	*Garcinia xanthochymus*	1.3	fruits
17	Clusiaceae	Cowfall	*Garcinia cowa*	0.6	fruits
16	Fagaceae	Batna	*Castanopsis indica*	1.2	fruits
17	Rubiaceae	Papra fruit	*Gardenia latifolia*	0.2	fruits
18	Fabaceae	Sada jalpai	*Prunus ceylanica*	6.5	fruits
19	Fabaceae	Vadol kanta	*Dalbergia* sp.	2.1	fruits
20	Fabaceae	Gravi knata	*Dalbergia* sp.	2.9	fruits
21	Fabaceae	Bagmocha Knta	Dalbergia sp.	0.1	fruits
23	Myrtaceae	Khudi Jam	*Syzygium cymosum*	0.2	fruits
24	Myrtaceae	Bon Jam	*Syzygium formosum*	2.2	fruits
25			*Phyllanthus embellica*	0.8	fruits
26	Combretaceae	Bahera	*Terminalia bellirica*	0.5	fruits
27	Anacardiaceae	Bon Amra	*Spondias Pinnata*	0.3	fruits
28	Tiliace	Achar got	*Microcos paniculata*	1.1	fruits

Sl no	Family	Local Name	Scientific Name	Percentage	Food parts
29	Hippocrateaceae	Kanta boroi	*Ziziphus* sp.	0.3	fruits
31	Boraginaceae	Pichla	*Cordia dichotomia*	0.4	fruits
1	Fagaceae	Badam	*Castanopsis indica*	1.3	leaves
2	Lauraceae	Menda	*Litsea cubeba*	0.2	leaves
3	Moraceae		*Ficus nervosa*	0.3	leaves
4	Moraceae		*Ficus lamphonga*	0.4	leaves
5	Moraceae	Bot	*Ficus variagta*	0.4	leaves
6	Euphorbiaceae	Mohali leaf	*Macaranga indica*	1.4	leaves
7	Acanthaceae	Dudlata	*Thunbergia grandifolia*	2.1	leaves
8	Myrtaceae	Khudi Jam	*Syzygium* sp.	0.8	Leave
9	Myrtaceae	Goda Jam	*Syzygium* sp.	1.3	leaves
10	Apocynaceae	Dudhia lata	*Ichnocarpus frutescens*	0.9	leaves
11	Euphorbiaceae	Silpati	*Breynia retusa*	0.5	leaves
12	Euphorbiaceae	kakra	Aporosa dioica	0.3	leaves
13	Verbenaceae	Awal/Arsol	*Vitex pinnata*	0.2	leaves
14	Cucurbitaceae	Bon kakrol	*Trichosanthes truncata*	1.9	lleaves
15	Elaeocarpaceae	Bon Jalpai	*Elaeocarpus floribundus*	0.3	leaves
16	Meliaceae	Bonlichu	Walsura robusta	0.1	leaves
17	Convolvulaceae		*Merremia umbellata*	1.2	leaves
18			*Bambusa sp*	1.3	leaves
19	Leeaceae		*Leea indica*	0.8	leaves
20	Dioscoreaceae	Alu pata	*Dioscorea* sp.	2.5	leaves
21		Liana leaf		1.4	leaves
22		Climber leaf		1.3	leaves
1	Fagaceae	Batna flower	*Castanopsis tribuloides*	0.7	flowers
2	Rubiaceae	Papra	*Gardenia latifolia*	0.1	flowers
3		Bon Shimul	*Bombax insigne*	0.4	flowers
4		Liana flower		0.3	flower
5		Climber flower		0.4	flower
5	Acanthaceae	Dudlata	*Thunbergia grandifolia*	1.4	flowers
1			Teak defoliator	3.3	Animals
2			Insect	3.1	Animals

Assessing the Cryptic Snake diversity, threats assessment, conservation action for snakes in Southeast Bangladesh and developing a mobile app to reduce unanticipated mortality and awareness raising

by

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CHAPTER I: INTRODUCTION

1.1 Project Background and Context

Bangladesh has unique temperate climatic conditions that have created 25 bio-ecological zones throughout the country (Nishat et al. 2002). These ecological zones are predominantly forested habitats, but natural forests and forest patches are limited outside the Sundarbans (Khan 2015).

Knowledge of the herpetofauna of Bangladesh is poor in comparison to that of other Asian countries and in particular its neighbors India and Myanmar (Mahony et al. 2009; Rahman et al. 2019). Until recently, the herpetofaunal assemblages of many of the protected natural areas of Bangladesh were largely unreported, with the first attempt to detail species lists for the regions made in Khan (2008).

Research on the herpetofauna is still inadequate in Bangladesh and this has led to controversy among researchers regarding the exact number of species (Hasan and Feeroz 2014). Herpetofaunal discovery (i.e., species newly described for science) has become common in Bangladesh in recent times (Reza and Perry 2015), and 27 species of amphibians and 57 species of reptiles have been added to the list since 2000 (IUCN Bangladesh 2015). A total of 49 species of amphibians and 167 species of reptiles have been assessed by IUCN Bangladesh in 2015. The number of assessed herpetofaunal species has increased for both groups and many undiscovered species were added to the list after their discovery and assessment of threats (IUCN Bangladesh 2015). About 103 species of snakes have been identified in Bangladesh and 33 of them are venomous including 16 species of sea snakes and 70 are non-venomous (Chowdhury MAW et al. 2021).

lthough regarded as most biodiverse region in Bangladesh, southeastern part is still not properly documented for wildlife fauna, especially snakes. In this part of the southeast Bangladesh, most birds were listed in the late 1960s with the initiation of the Late Professor Kazi Zaker Husain, for instance, birds of the Chittagong Hill Tracts (Husain 1968). Later, researchers worked with other groups of wildlife, for example, the amphibians of Bangladesh (Husain and Rahman 1978), Chittagong Hill Tracts (Chakma 1995) and snakes of Bangladesh (Montaquim et al. 1980), Chittagong district (Parvin 1999). But extensive works on herpetofauna in the PAs of Bangladesh are limited. Previously some works were accomplished on whole biodiversity in a few protected areas, for instances, Rema-Kalenga WS (Feeroz et al. 2011), Dudpukuria-Dhopachari WS (Feeroz et al. 2012), Teknaf WS (Feeroz 2013), Baraiyadhala NP (Karim et al. 2014) and Kaptai NP (Khan 2016).

The geographic position of the study area shows that Southeast Bangladesh is rich in herpetofaunal diversity with the possibility of the occurrence of cryptic species of snakes. No species based (only snake sp.) research or studies have been carried out in any of the proposed areas in southeast region. It is certain that additional species can be found in the proposed project area. This study aims to assess the cryptic snake diversity using of field-based and molecular techniques, evaluate their distribution, and identifying threats in two protected areas: Dudpukuria-Dhopachari Wildlife Sanctuary (DDWS) and Kaptai National Park (KNP). Among the diversity of animal kingdoms snakes, are one of the most charming and colorful animals in nature. Their colors, movement and secretive habits make them more mysterious than other animals. The myths associated with snakes make them more dangerous, ferocious and enigmatic than any other creatures. Snakes, as a part of our ecosystem, maintain the balance in nature by controlling a major portion of rodent pests. Snakes are a source of livelihood or a source of life-saving drugs; they are a part of our life.

Lack of awareness of snakes and snakebites has been identified as the most critical factor in exacerbating snakebite-induced complications, deaths, disabilities and/or increased treatment costs. The majority of people, including some healthcare professionals, are not aware of how to respond to snakes or snakebites. It is also evident from nationwide surveys that inappropriate first aid practices, such as applying tourniquets, incisions, and sucking blood, are common in rural areas. All these activities delay hospital treatment and exacerbate snakebite-induced complications. For various reasons, the treatment-seeking behavior of victims or their relatives is largely influenced by traditional myths related to snakes and snakebites, and the pressure to seek cheaper, more accessible, traditional treatment, which unfortunately delays essential hospital treatment (i.e., they seek hospital treatment only when the situation become emergency). The treatment costs in private hospitals are another major concern, although free snakebite treatment is available in government hospitals all over the country.

The total population of Bangladesh is over 165.16 million (Bangladesh Bureau of Statistics census, 2022) of which more than half live in the rural community reliant on the agro-aqua-livestock-based occupation for their livelihoods. According to a nationwide community-based epidemiological study of snakebite and its socioeconomic consequences in Bangladesh the incidence density of snakebite in rural Bangladesh (which is substantially higher than previously estimated) is 623.4/1000000 person-years (95% C I 513.4-1595.3/100000 person-years) with an estimated 6014 death annually. The majority of bites (71%) happened in the lower extremities. Eighty-six percent of the victims receive some form of management within two hours of snakebites, although only three percent of the victims go directly to a medical doctor or a hospital (NCDCP, DG of health services, MOHFW, 2021).

Most of the victims of are poor, young and active individuals. Biting occurs mostly when individuals are at work, engaged in activities such as cultivation, fishing, plantation, wood collection or tending crops or gardens. Snakebite envenoming in Bangladesh is thus an occupational health hazard of the rural people who suffer bites while engaged in physical work, most often during cultivation. However, bites were fairly common when victims were walking on rural food paths or while sleeping on the floor. Children have a high risk of dying or suffering permanent disability from snake bites envenoming. During the monsoon, snakebite occurrences increase as snakes leave their shelters due to rainfall. Most of the houses in the countryside of Bangladesh are not brick-built and the snakes sometimes live in holes in the muddy floors. In the previous time, some attempts were made across the country to improve public education and awareness regarding snakes and snake bites but that is not sufficient.

So, it was a great opportunity to explore through proper scientific work to assess snake diversity, distribution, existing threats and associated human-snake conflict scenarios in the proposed study sites (two PAs) of southeast Bangladesh which helped to take appropriate conservation action and opportunity to discover previously unreported species and also develop a mobile app to reduce unanticipated mortality and awareness raising from snake bites among the rural people that also helped the institutional capacity building of the Bangladesh Forest Department which is one of the main goals of this mother project SUFAL.

1.2 Problem statements

Very few works have been done on herpetofauna in Bangladesh due to a lack of interest in this group (Asmat 2007; Hasan et al. 2012, 2014; Howlader 2015 and others). In most of the cases, the studies were outside of the southeast area and identifications were done by photography or morphometrics. Reza (2010) conducted a herpetofaunal survey in southeast Bangladesh but he also hasn't used the molecular approach to identify the species. In this project, regarding the snake species, we will assess the cryptic snake diversity, distribution of snakes in two protected areas in southeast Bangladesh on a large scale and use integrative identifying methods.

Tropical evergreen & mixed evergreen forests are considered one of the most important biogeographic zones for snake species diversity. As a tropical country in Asia, Bangladesh implements different types of forest management practices in its forests, which might affect the prevailing forest quality in the existing forest types. The current state of information on the impact of habitat alteration on the snake species community in Bangladesh is inadequate. To evaluate this, we will conduct a study through this project in the area of Dudpukuria-Dhopachari Wildlife sanctuary and Kaptai National Park in Southeast Bangladesh. We will use a combination of snake diversity study techniques in randomly selected transects covering three major habitat types in that study area: forest edge, forest interior and hilly swamp area. After that we expect to find the real scenarios of the community structure of snake species and their distribution and habitat use pattern among forest edge, forest interior and hilly areas.

Snake populations are significantly declining globally including in Bangladesh due to habitat destruction and degradation, environmental pollution, random use of pesticides, gill nets for fishing, trade, killing, illegal collection for snake charming and climate change. Thousands of snakes are needlessly killed every year because of fear and misunderstanding without knowing their importance. In most cases, people believe that all snakes are venomous and a single bite can kill a man. As a result, after seeing a snake they become excited and decide to kill it instantly to get relief from anxiety and nervousness. In Bangladesh, about 5,000 snakes (cobras and rat snakes) are illegally caught by snake catchers yearly from nature for public charming.

In the year of 2009, snakebite was recognized for the first time by WHO in a profile of a neglected tropical disease. Now a days snakebite is an important emerging public health problem in Bangladesh. Based on a nationwide survey Rahman et al. (2010) estimated that 5,89,919 persons are bitten by snakes and 6,041 died every year in rural Bangladesh. The medical importance of snakebites (especially by kraits and cobras) is higher in Bangladesh than that in other South East Asia Regional Countries (WHO, 2009).

In our country, most snakebite deaths occur usually at home or on the way to the hospital. The reason for this is that people still believe that if they go to the Ojhas, they can get treatment for snake bites because this practice has been in practice for a long time. First, they go to Ojha and waste precious time right after the snake bite but there is nothing to do when they reach the hospital at the last moment.

Currently, 55.89% of Bangladeshis (92.30 million) use mobile phones, according to the latest population census in the country. And of the total population, 30.68% use the internet (51 million). If the proposed app is managed properly and promoted among the general people about snakebite prevention, a snakebite patient can use this app to identify the species of snake, venomous or non-venomous snakebite, what to do in first aid after snakebite, and quickly. The risk of death is largely preventable by going to the nearest hospital. Through which the capacity and publicity of the Forest Department will be increased, on the one hand, the real picture of snake bites will emerge among us, awareness will increase among the people at the marginal level and the death rate will be prevented.

An example of a mobile app Sarpa or SARPA (Snake Awareness, Rescue and Protection app) is a snakebite app, an application for mobile devices developed in India to provide rapid, life-saving help for victims of snakebite, which kill an estimated 58,000 people a year in India. The app provides information about snakes and gets fast aid for people bitten. Similar systems developed in India include Snake Hub, Snake Lens, Snakepedia, Serpent and the Big Four Mapping Project. The apps provide rapid response to snakebite incidents, often in remote areas, using a network of volunteers managed by local wildlife departments; their use can save human lives by providing rapid medical care, and also snakes, by helping to avoid interaction between the species.

In conclusion, this study provided a valuable opportunity to explore the cryptic snake diversity, distribution, and existing threats in two protected areas of southeast Bangladesh. The developed Snakebite Awareness, Rescue, and Protection mobile app serves would a modern and effective tool to help reduce untimely and premature deaths from snakebites among rural communities.

1.3 Objectives of the study

Specific objectives

1. To assess the cryptic snake diversity and distribution in KNP and DDWS of Southeast Bangladesh.
2. To identify and assess existing threats in the proposed study sites and associated human-snake conflict scenarios.
3. To develop a mobile app to reduce unanticipated mortality from snakebites by providing proper guidelines.

1.4 Research questions

1. Is there any cryptic snake species prevails in southeastern part of Bangladesh?
2. What is the perception of snakes among local and ethnic communities and the pattern of conflict with snakes?
3. How effective is the mobile app in reducing unanticipated snake bite mortality, and

what will influence its use and adoption by general people?

CHAPTER II: LITERATURE REVIEW

2.1 Literature review and project justification

In this part of the southeast Bangladesh, most birds were listed in the late 1960s with the initiation of the Late Professor Kazi Zaker Husain, for instance, birds of the Chittagong Hill Tracts (Husain 1968). Later, researchers worked with other groups of wildlife, for example, the amphibians of Bangladesh (Husain and Rahman 1978), Chittagong Hill Tracts (Chakma 1995) and snakes of Bangladesh (Montaquim et al. 1980), Chittagong district (Parvin 1999). But extensive works on herpetofauna in the PAs of Bangladesh are limited. Previously some works were accomplished on whole biodiversity in a few protected areas, for instances, Rema-Kalenga WS (Feeroz et al. 2011), Dudpukuria-Dhopachari WS (Feeroz et al. 2012), Teknaf WS (Feeroz 2013), Baraiyadhala NP (Karim et al. 2014) and Kaptai NP (Khan 2016).

The total population of Bangladesh is over 165.16 million (Bangladesh Bureau of Statistics census, 2022) of which more than half live in the rural community reliant on the agro-aqua-livestock-based occupation for their livelihoods. According to a nationwide community-based epidemiological study of snakebite and its socioeconomic consequences in Bangladesh the incidence density of snakebite in rural Bangladesh (which is substantially higher than previously estimated) is 623.4/1000000 person-years (95% C I 513.4-1595.3/100000 person-years) with an estimated 6014 death annually. The majority of bites (71%) happened in the lower extremities. Eighty-six percent of the victims receives some form of management within two hours of snakebites, although only three percent of the victims go directly to a medical doctor or a hospital (Rahman et al. 2010).

This project aimed to explore the cryptic diversity, distribution, and existing threats to snake populations in two protected areas (PAs) of southeast Bangladesh. Additionally, it led to the development of the Snakebite Awareness, Rescue, and Protection App, a modern and practical tool designed to reduce untimely and premature deaths caused by snakebites, particularly among rural communities.

CHAPTER III: METHODOLOGY

3.1 Study Area

3.1.1 Location

The study was conducted in two protected areas located in the southeastern region of Bangladesh: Kaptai National Park and Dudpukuria-Dhopachari Wildlife Sanctuary.

3.1.1.1 Kaptai National Park

Kaptai National Park (KNP), located in the Rangamati District under the Chattogram Hill Tracts South Forest Division. It was established in 1999 under the Bangladesh Wildlife Act 1974. The geographic coordinates are 20°30′1.3″N, 22°29′53.5″E and comprises an area of 5,464.78 hectares. KNPin Rangamati appears to be the greatest wildlife abode despite its relatively smaller size than others areas and is the home of the highest number of 50 percent of the country's total wildlife species. Sambar, Barking Deer, Orange Bellied Himalayan Squirrel, Chinese Pangolin, Binturong, Masked Palm Civet, the elusive Clouded Leopard, Bengal Slow Loris, Rock Python, the uncommon Green Cat Snake etc. are the key species of the National Park.

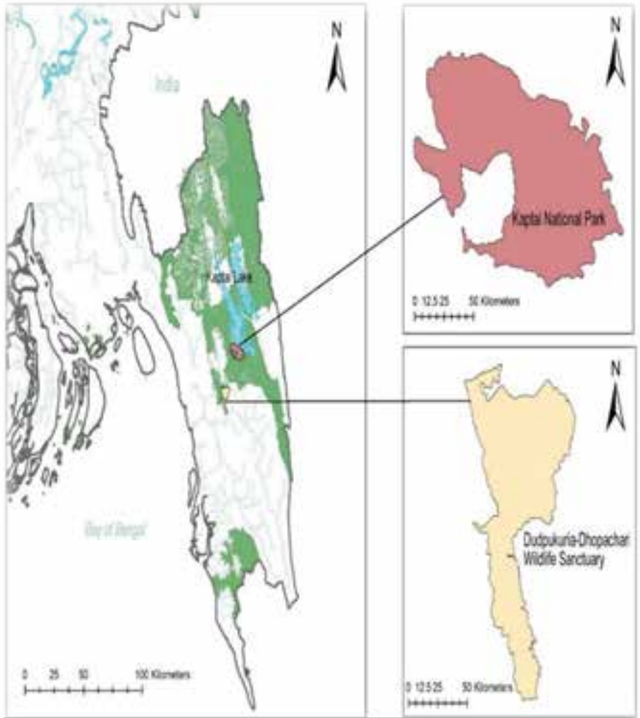


Figure 1: Study Area

3.1.1.2 Dudpukuria-Dhopachari Wildlife Sanctuary

Dudpukuria-Dhopachari was declared as Dudpukuria-Dhopachari Wildlife Sanctuary **(DDWS)** on 6th April, 2010 by the Ministry of Environment and Forest by notification no. MoEF/For-Sec-02/02Wildlife Sanctuary/11/2010/209 dated 06/04/2010 under the power given under section 23(I) 0f Bangladesh Wildlife (Preservation) (Amendment) Act 1974. The administrative jurisdiction of this Wildlife Sanctuary is under Chattogram South Forest Division which geographical location is 22º 09′ to 22º 22′ north latitude and 92º 05′ to 92º 10′ east longitude. DDWS has a rich animal biodiversity. Birds are very well represented in DDWS with 231 recorded species of which 195 are resident and 36 migratory and total of 50 mammals, 56 reptile's species have been recorded in DDWS (Feeroz et al. 2012).

3.2 Methods

3.2.1 Selection of sampling method

The project surveyed snake diversity in two protected areas of southeast Bangladesh using taxonomical and molecular methods. It focused on species diversity, distribution, and conservation across pre-monsoon, monsoon, and post-monsoon seasons, aiming to identify underexplored snake groups in the hilly regions.

3.2.2 Data collection procedure

To achieve the objectives of the project several methodologies were followed. The following data collection procedures were undertaken.

3.2.2.1 Survey and sampling technique

Roadkill Survey and Collection

In the project areas, roads pass through or near the national park and wildlife sanctuary, leading to road accidents involving snakes and wildlife during the pre-monsoon, monsoon, and post-monsoon seasons. We collected dead snake specimens for molecular analysis with the help of local research assistants and forest officials.

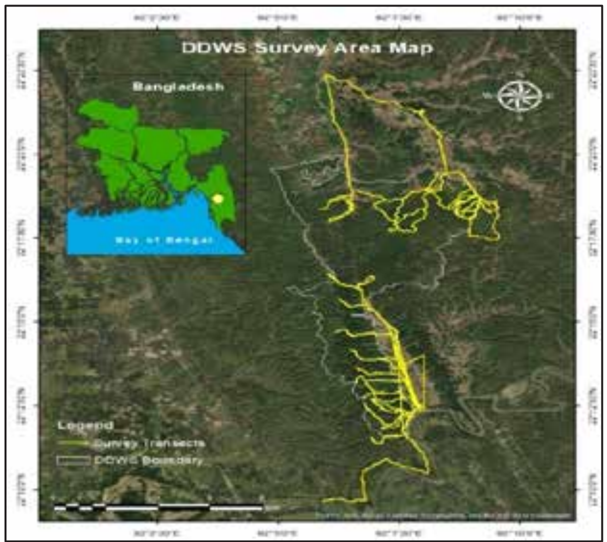


Figure 3: Map showing the survey area covered in the DDWS.

Nocturnal Visual Encounter survey

Most reptile species are nocturnal. Visual searches were conducted for species active on the surface or hard to detect through hand searches or pitfall trapping. Potential habitats were scanned using headlamps and torches.

Pitfall traps

Dry pitfall trapping is effective for detecting ground-active herpetofauna, especially secretive species. Traps were placed along natural 'runs' and used with a drift fence to increase capture rates. Buckets were set every six feet, covering 30 feet, with a three-foot-high plastic fence running along the traps. Pitfalls were checked regularly, and captured wildlife were marked, recorded, and released immediately.

Line Transect

In this method, the enumerator counts animals within designated boundaries on belt transects, excluding those outside. The precision of density estimates depends on the number of animals counted (Caughley, 1977; Eberhardt, 1968; Boyce, 1982). Transect lines were selected based on forest size, with random selection and distance recording of each snake's observation point. To minimize disturbance, pre-established trails were used as transects in well-preserved areas.

Species and community wise habitat survey

Habitat and vegetation patterns were recorded from two study areas that are preferred by the snake. This data is used for analyzing vegetation usage by snakes and testing the similarity of vegetation cover and its relationship with snake abundance. After that, species and community-wise habitat suitability mapping will develop.

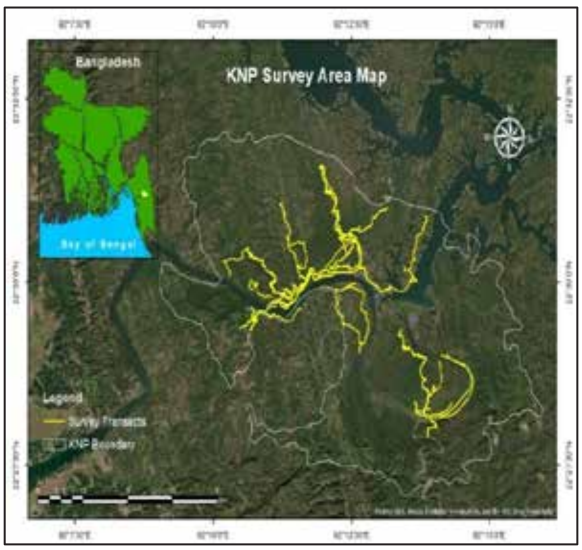


Figure 2: Map showing the survey area covered in the KNP.

Diversity Survey/Field Survey

Fieldwork was conducted from November 2023 to December 2024 over 75 days, covering all major seasons of Bangladesh: summer (March-June), monsoon (July-October), and winter (November-February). To maximize data collection, various snake sampling techniques were used, including Visual Encounter Surveys (VES), opportunistic surveys, and pitfall trapping. Surveys were conducted across Kaptai National Park (KNP) and Dudpukuria-Dhopachari Wildlife Sanctuary (DDWS) over twelve trips, with an average team size of five. Fieldwork mainly occurred at night (5:00 PM – 12:00 AM), with additional daytime roadkill observations. A total of 167.28 km was covered in KNP and 321 km in DDWS.

Threat assessment

For assessing the threats, at each study site, human or natural activities that were considered potentially threatening to the snake population were also recorded. Anthropogenic and other activities were considered based on the intensity of the disturbance on the snake and its habitat. Regarding threat analysis, ten (10) focus group discussions (FGDs) and direct field observation were conducted.

Focus group discussion (FGD)

To understand the situation, we conducted ten focus group discussions (FGD) across all study sites, involving local stakeholders from various socioeconomic backgrounds, including ethnic communities. Background information such as age, sex, religion, occupation, education, social media use, and locality was collected. The discussions focused on local perceptions of snakes, myths, threats, snakebite cases, mortality rates, disabilities, and the role of traditional snake healers (Ojhas).

Conservation efforts and awareness

During the FGD, we educated local people about the environmental importance of snakes, dispelled misconceptions, and shared safety tips for avoiding snakebites, first-aid measures, and proper treatment at hospitals. We also discussed the risks of traditional snakebite treatments by Ojhas (snake healers). Additionally, we introduced our Snakebite Awareness, Rescue, and Protection app, which raised awareness and helped reduce snakebite-related mortality by providing accurate information to rural communities.

Species Identification

To identify a particular snake species, expert knowledge, and observation will be used. In addition, other approaches will be used to strengthen the observation. Additional approaches are as follows:

Photography

High-quality photos are best tools to identify cryptic species. These photograph also can be used as visual contents to aware local community people, scientific documentation and great source for further study.

Morphometric and meristic measurements

In most cases, it is very difficult to identify the herpetofauna without measuring and counting of their different body parts. We will capture the specimens (if needed) and take the necessary measurements to identify them.

Modelling Snake distribution and habitat association at KNP & DDWS

MaxEnt v3.4.4 is a popular tool for modeling species distributions using presence-only data and environmental variables. It applies maximum entropy principles to predict a species' potential range, balancing model complexity and performance. The software supports various feature types (linear, quadratic, hinge, etc.) and provides outputs such as suitability maps, AUC scores, response curves, and jackknife analyses. With both GUI and command-line options, MaxEnt is useful for conservation, climate change assessments, and niche characterization. Despite its strengths, careful interpretation is needed to avoid overfitting and ensure accurate predictions (Steven J. Phillips, 2009).

Data Sources

Bioclimatic variables were obtained from the CHELSA database (https://chelsa-climate.org/downloads/) version 2.1 at 30-arcsecond (~1km) resolution (Karger et al., 2021). The CHELSA data provides downscaled temperature and precipitation estimates using statistical downscaling for temperature and orographic predictors for precipitation, with bias correction. Files are georeferenced GeoTIFFs containing metadata like map projection, coordinate systems, and datums. The data uses the WGS 84 horizontal datum, with coordinates in decimal degrees. The layer extents come from GMTED2010 and SRTM data.

Table 1: The environmental variables are

Variables	Description of Variables	Unit
BIO1	Annual Mean Temperature	ºC
BIO2	Mean Diurnal Range	ºC
BIO3	Isothermality	ºC
BIO4	Temperature Seasonality	ºC/100
BIO5	Max Temperature of Warmest Month	ºC
BIO6	Min Temperature of Coldest Month	ºC
BIO7	Temperature Annual Range	ºC
BIO8	Mean Temperature of Wettest Quarter	ºC
BIO9	Mean Temperature of Driest Quarter	ºC
BIO10	Mean Temperature of Warmest Quarter	ºC
BIO11	Mean Temperature of Coldest Quarter	ºC
BIO12	Annual Precipitation Amount	kg m-2 year-1
BIO13	Precipitation of Wettest Month	kg m-2 month-1
BIO14	Precipitation of Driest Month	kg m-2 month-1
BIO15	Precipitation Seasonality	kg m-2
BIO16	Precipitation of Wettest Quarter	kg m-2 month-1
BIO17	Precipitation of Driest Quarter	kg m-2 month-1
BIO18	Precipitation of Warmest Quarter	kg m-2 month-1
BIO19	Precipitation of Coldest Quarter	kg m-2 month-1
cmi_mean	Mean monthly climate moisture index	kg m-2 month-1
hurs_mean	Mean monthly near-surface relative humidity	%
sfcWind_mean	Mean monthly near-surface wind speed	m s-1
vpd_mean	Mean monthly vapor pressure deficit	Pa

Preprocessing of Variables for Habitat Assessment

In this study, 23 environmental variables were selected. The raster layers of all the variables have been clipped by mask (Table 8) to the Dudpukuria-dhapachari Wildlife Sanctuary and Kaptai National Park and processed it to have the same cell size and spatial extent (nearest neighbor resampling method) using ArcGIS Pro. Clipped raster layers have been converted in to ASCII file format to use in the MaxEnt software version 3.4.4.

Modeling procedure

Using default settings in MaxEnt can risk overfitting, particularly with limited occurrence data. To address this, we customized the model settings to prevent overfitting, achieving accurate distribution predictions. Our analysis used 23 environmental variables, 81 presence records from Dudpukuria-Dhopachari Wildlife Sanctuary and 71 from Kaptai National Park, with 500 iterations and a convergence threshold of 0.00001. We selected 10,000 background points and applied linear and quadratic features based on sample size. Predictors were standardized at ~1 km resolution. MaxEnt's robustness, especially with small sample sizes, outperformed other methods, and we adjusted the regularization parameter to 1 to avoid overfitting. The random test percentage was set to zero, ensuring balanced and accurate predictions.

Model Application and performance

The MaxEnt model's accuracy was evaluated using the Area Under the Receiver Operating Characteristic Curve (AUC), with values closer to 1 indicating better performance. A null model approach assessed whether the AUC value significantly differed from chance. The model's predictions were classified into four suitability categories: unsuitable (<0.1, red), least suitable (0.1–0.3, orange), moderately suitable (0.3–0.6, olive green), and highly suitable (>0.6, green). Classification thresholds were determined using the Jenks Natural Breaks Optimization method in ArcGIS, ensuring a meaningful categorization based on data groupings.

3.2.2.2 Laboratory based molecular analysis

This project emphasizes the importance of accurate species identification and genetic analysis. DNA barcoding helps identify cryptic or morphologically similar species, aiding biodiversity cataloging and conservation efforts. We partnered with the Wildlife Population Genetics and Transmissible Disease Lab, Department of Zoology, Jahangirnagar University, Bangladesh. Molecular methods were used to identify cryptic taxa and assess genetic diversity in local herpetofauna. Samples, including swabs, blood, or tissue, were collected from direct encounters and roadkill, and analyzed using mitochondrial (16S, cytochrome b, COI) and nuclear markers (BDNF, RAG1, tyrosinase) to identify species.

Molecular work protocol

Genomic DNA will be extracted from preserved tissue samples using Qiagen DNAeasy kits. A fragment of the mitochondrial cytochrome b (cyt b), 16S, and CO1 genes will be amplified using primers L14919 & H16064 (Burbrink et al., 2000). The PCR reaction will include Thermo Scientific Dream Taq PCR Master Mix, water, primers, and DNA template, with amplification conducted using the Eppendorf Mastercycler Nexus GSX1. Thermocycling conditions will be: 94°C for 5 min, 30 cycles of 94°C for 30s, 48°C for 50s, 72°C for 1 min, followed by 72°C for 10 min. PCR products will be purified and sequenced with an AB 3730 DNA Analyzer.

Phylogenetic analysis will follow Zaher et al. (2019). Sequences will be aligned in MegaX or Genious using ClustalW, and data will be analyzed using ModelFinder for optimal partitioning and models (ML and GTR+I+G for Bayesian Inference). ML will run for 1000 bootstrap replicates, and BI in MrBayes 3.2.2 for 10 million generations. The tree will be visualized in FigTree and also analyzed on the IQ-TREE online portal.

3.2.2.3 An android Mobile app Development

To achieve the goal, an Android app (Snakebite Awareness, Rescue, and Protection) was developed in Bangla and launched on the Google Play and App Store. This app aims to raise awareness and reduce snakebite mortality across the country.

The app is a native application built specifically for Android, developed in collaboration with a reputable mobile app development company in Bangladesh. It includes key content on the importance of snakes, misconceptions about them, snakebite prevention, first-aid, proper medical care, and the dangers of traditional snakebite treatments by Ojhas (snake healers). It also provides an updated database on snakebite incidents and antivenom availability, sourced from the Ministry of Health and Family Welfare (MOHFW).

3.2.2.4 Qualitative and Quantitative Approach

The project’s research objectives were accomplished by using both quantitative and qualitative approaches. Using various statistical analyses, data gathering, and interpretation techniques, we used quantitative methodologies to evaluate snake diversity, density, distribution, evenness, and species dominance of snakes in study areas. Threat assessments of snakes in study areas and focus group discussion (FGDs) were evaluated in both quantitative and qualitative way.

Statistical data analytical approach: We calculated the average Shannon-Wiener diversity index (Magurran, 1988), evenness (the variation in the abundance of individuals per species within a community) and dominance (proportional importance of the most abundant species) (Magurran,1988) for each habitat type by using PAST software (Hammer et al., 2001). We also used the ‘BiodiversityR’ package of R software (Kindt & Coe, 2005) to extract rank abundance curves and species rarefaction curves.

The Shannon-Wiener Diversity Index, H, will be calculated using the following equation:

$$\mathbf{H = -\sum P_i (\ln P_i)}$$

where P_i is the proportion of each species in the sample.

$$\mathbf{Evenness,\ J = H'/\ln (S)}$$

where H' is Shannon Weiner diversity and **S** is the total number of species in a sample. Kruskal-Wallis test (Spurrier, 2003), which is free of assumptions of normality, will be used to determine if there were significant differences in abundance between habitat types using a significance level of p=0.05. Microsoft Excel®2007 software will be used to calculate and compare the percentage of occurrence of each species in the three major habitat types by dividing the number of plots where a particular species will present by the total number of plots.

The abundance & relative abundance (RA) of particular snake species will be calculated-

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all transect}}{\text{Total number of transect in which the species occurred}}$$

$$\text{Relative abundance (RA)} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

3.2.2.5 Environmental and Social safeguards

Environmental safeguards

When conducting a research project on the environment, it is important to have environmental safeguards in place to ensure that the project is conducted in a manner that minimizes harm to the environment. In the case of the project, several environmental safeguards considered:

This project implemented several environmental safeguards to minimize harm to snake habitats and ensure sustainability. Measures included avoiding harm to snakes during surveys, using environmentally friendly materials, and minimizing the use of non-renewable resources like plastic. These steps ensured that the research was conducted responsibly and with minimal environmental impact.

Social safeguards

This project ensured important social safeguards to protect biodiversity and involve local communities. Specimen collection for molecular analysis, mainly from roadkill or human-killed snakes, was conducted responsibly to avoid harming local biodiversity. Community members, including ethnic groups, were engaged as local guides and through focus group discussions to raise awareness and gather feedback. Researchers followed strict safety protocols, using protective gloves, gumboots, snake hooks, and tongs to minimize snakebite risks. Findings were shared with both scientific and local communities, helping to increase awareness about snake conservation and encouraging future conservation actions.

CHAPTER IV: RESULTS AND DISCUSSION

4.1 Snake diversity, status and relative abundance

Overall, a total 36 species of snakes (208 individuals) were recorded from two study sites during the project implementation period (direct sighting, road kill, rescue and release). A total 26 species of snakes (101 individuals) were recorded from Kaptai National Park and 23 species snake (107 individuals) from Dudpukuria-Dhopachari Wildlife sanctuary respectively. The following table depicts the species name and threat status as per IUCN Red List, 2015.

Table 2: List of snakes recorded from KNP and DDWS.

Sl. No.	Sanke Species		Snake type	Presence in study sites		Status (IUCN Red list, 2015)
				KNP	DDWS	
	Common Name	Scientific Name				
Family- Typhlopidae						
1	Brahminy Worm Snake	*Indotyphlops braminus*	Non venomous	✓		LC
Family- Pythonidae						
2	Burmese python	*Python bivittatus*	Non venomous	✓	✓	VU
3	Reticulated Python	*Malayopython reticulatus*	Non venomous	✓		CR
Family- Colubridae						
4	Short nosed vine snake	*Ahaetulla prasina*	Mildly venomous		✓	LC
5	Striped Keelback	*Amphiesma stolatum*	Non venomous	✓	✓	LC
6	Yunnan Keelback	*Hebius parallelus*	Non venomous	✓		DD
7	Checkered keelback	*Fowlea piscator*	Non venomous	✓	✓	LC
8	Red necked keelback	*Rhabdophis subminiatus*	Venomous	✓	✓	NT
9	Bindee keelback	*Rhabdophis bindi*	Venomous		✓	DD
10	Tawny Cat Snake	*Boiga ochracea*	Mildly venomous	✓		NT
11	Green Cat Snake	*Boiga cyanea*	Mildly venomous	✓		LC
12	Eastern Cat Snake	*Boiga gokool*	Mildly venomous	✓		NT
13	Eyed cat snake	*Boiga siamensis*	Mildly venomous	✓		EN
14	Wall's Bronzeback	*Dendrelaphis cyanochloris*	Non venomous		✓	DD
15	Painted Bronzback tree snake	*Dendrelaphis pictus*	Non venomous	✓	✓	LC
16	Haas's Bronzeback Tree Snake	*Dendrelaphis haasi*	Non venomous		✓	NE
17	Ornate Flying Snake	*Chrysopelea ornata*	Mildly venomous	✓	✓	LC
18	Copper-headed trinket snake	*Coelognathus radiatus*	Non venomous	✓	✓	LC
19	Common Smooth scale water snake	*Enhydris enhydris*	Mildly venomous		✓	LC

20	Common wolf snake	*Lycodon aulicus*	Non venomous	✓	✓	LC
21	Twin-spotted Wolf Snake	*Lycodon jara*	Non venomous		✓	LC
22	Zaws wolf snake	*Lycodon zawi*	Non venomous	✓	✓	LC
23	White barred kukri snake	*Oligodon albocinctus*	Non venomous		✓	LC
24	Assam Snail Eater	*Pareas monticola*	Non venomous	✓	✓	DD
25	Mock Viper	*Psammodynastes pulverulentus*	Mildly venomous	✓	✓	LC
26	Indian Rat Snake	*Ptyas mucosa*	Non venomous	✓	✓	LC
27	Indo-Chinese Rat Snake	*Ptyas korros*	Non venomous		✓	NT
Family- Elapidae						
28	Monocled Cobra	*Naja kaouthia*	Venomous		✓	NT
29	King Cobra	*Ophiophagus hannah*	Venomous	✓		VU
30	Common Krait	*Bungarus caeruleus*	Venomous	✓		LC
31	Banded krait	*Bungarus fasciatus*	Venomous		✓	LC
32	Greater Black krait	Bungarus niger	Venomous	✓		DD
33	Lesser black Krait	*Bungarus lividus*	Venomous	✓		DD
34	Hook nosed sea snake	*Hydrophis schistosus*	Venomous	✓		LC
35	Annulated Sea Snake	*Hydrophis cyanocinctus*	Venomous	✓		LC
Family- Viperidae						
36	Spot tailed pit viper	*Trimeresurus erythrurus*	Venomous	✓	✓	LC

Status Code: CR-Critically Endangered, EN-Endangered, VU-Vulnerable, NT-Near Threatened, LC-Least Concern, DD-Data Deficient, NE-Not Evaluated etc.

Relative Status

Study Area	**Survey Area (Km)**	**Number of Individuals (direct sighting and road kill)**	**Encounter Rate (ER)**	**(Number of individuals/Survey Coverage (km))**
KNP	167.28	76	Relative Abundance (RA)	(Number of individuals of a species/Total number of individuals of all species) *100
DDWS	321.66	107		

Table 3: Relative Status of Snake at KNP

Study Area	Common Name	Scientific Name	Number	Encounter Rate (ER)	Relative Abundance (RA)%	Relative Status
Kaptai National Park	Yunnan Keelback	*Hebius parallelus*	2	0.011	2.63	Rare
	Common wolf snake	*Lycodon aulicus*	6	0.035	7.89	Uncommon
	Red necked keelback	*Rhabdophis subminiatus*	2	0.011	2.63	Rare
	Ornate Flying Snake	*Chrysopelea ornata*	2	0.011	2.63	Rare
	Spot tailed pit viper	*Trimeresurus erythrurus*	20	0.119	26.31	Common
	Painted Bronzback tree snake	*Dendrelaphis pictus*	4	0.023	5.26	Uncommon
	Mock Viper	*Psammodynastes pulverulentus*	3	0.017	3.94	Rare
	Zaws wolf snake	*Lycodon zawi*	3	0.017	3.94	Rare
	Indian Rat Snake	*Ptyas mucosa*	2	0.011	2.63	Rare
	Checkered keelback	*Fowlea piscator*	5	0.029	5.76	Uncommon
	Tawny Cat Snake	*Boiga ochracea*	4	0.023	5.26	Uncommon
	King Cobra	*Ophiophagus hannah*	1	0.005	1.31	Very Rare
	Copper-headed trinket snake	*Coelognathus radiatus*	3	0.017	3.94	Rare
	Brahminy Worm Snake	*Indotyphlops braminus*	3	0.017	3.94	Rare
	Eyed cat snake	*Boiga siamensis*	1	0.005	1.31	Very Rare
	Common Krait	*Bungarus caeruleus*	2	0.011	2.63	Rare
	Reticulated Python	*Malayopython reticulatus*	1	0.005	1.31	Very Rare
	Greater Black krait	*Bungarus niger*	2	0.011	2.63	Rare
	Green Cat Snake	*Boiga cyanea*	3	0.017	3.94	Rare
	Eastern Cat Snake	*Boiga gokool*	1	0.005	1.31	Very Rare
	Lesser black Krait	*Bungarus lividus*	2	0.011	2.63	Rare
	Striped Keelback	*Amphiesma stolatum*	1	0.005	1.31	Very Rare
	Assam Snail Eater	*Pareas monticola*	1	0.005	1.31	Very Rare
	Hook nosed sea snake	*Hydrophis schistosus*	1	0.005	1.31	Very Rare
	Annulated Sea Snake	Hydrophis cyanocinctus	1	0.005	1.31	Very Rare
Total			**76**			

The pie chart shows the relative abundance of snake species recorded in Kaptai National Park (KNP):

- Rare species: 48% (low observation frequency)
- Very rare species: 32% (even lower detection rates)
- Uncommon species: 16% (moderate occurrence)

Common species: 4% (very limited detections)

This highlights that 80% of snake species in KNP are rare or very rare, showcasing the park's unique herpetofaunal diversity.

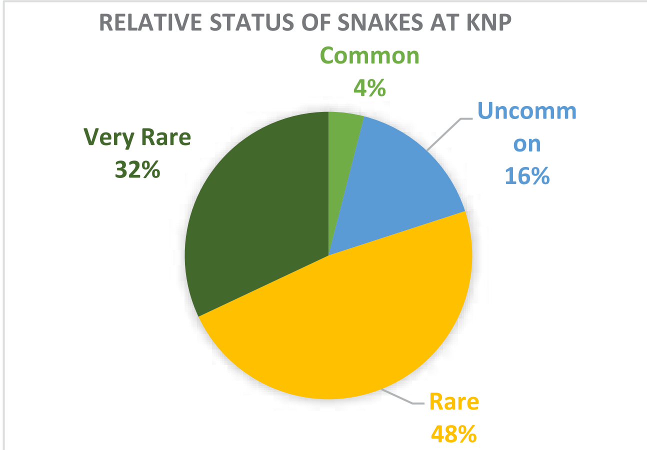


Figure 4: Relative status of snake at KNP.

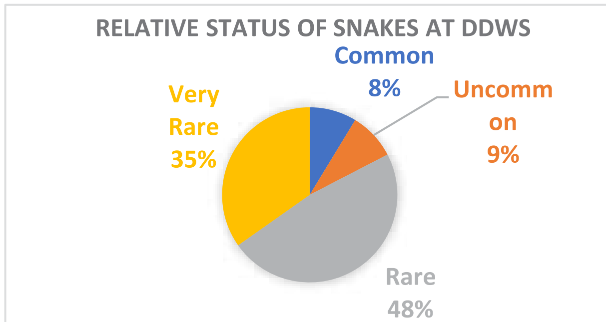
Table 4: Relative Status of Snake at DDWS.

Study Area	Common Name	Scientific Name	Number	Encounter Rate (ER)	Relative Abundance (RA)%	Relative Status
DDWS	Common wolf snake	*Lycodon aulicus*	3	0.009	2.80	Rare
	Red necked keelback	*Rhabdophis subminiatus*	1	0.003	0.93	Very Rare
	Ornate Flying Snake	*Chrysopelea ornata*	1	0.003	0.93	Very Rare
	Spot tailed pit viper	*Trimeresurus erythrurus*	17	0.052	15.89	Common
	Painted Bronzback tree snake	*Dendrelaphis pictus*	39	0.121	36.45	Common
	Haas's Bronzeback Tree Snake	*Dendrelaphis haasi*	1	0.003	0.93	Very Rare
	Mock Viper	*Psammodynastes pulverulentus*	7	0.021	6.54	Uncommon
	Zaw's wolf snake	*Lycodon zawi*	2	0.006	1.87	Rare
	Short nosed vine snake	*Ahaetulla prasina*	1	0.003	0.93	Very Rare
	Burmese python	*Python molurus*	1	0.003	0.93	Very Rare
	Checkered keelback	*Fowlea piscator*	8	0.024	7.47	Uncommon
	Copper-headed trinket snake	*Coelognathus radiatus*	2	0.006	1.87	Rare
	Monocled Cobra	*Naja kaouthia*	4	0.012	3.73	Rare
	Common Smooth scale water snake	*Enhydris enhydris*	2	0.006	1.87	Rare
	Indo-Chinese Rat Snake	*Ptyas korros*	2	0.006	1.87	Rare
	Twin-spotted Wolf Snake	*Lycodon jara*	3	0.009	2.80	Rare

	Banded krait	*Bungarus fasciatus*	3	0.009	2.80	Rare
	Assam Snail Eater	*Pareas monticola*	2	0.006	1.87	Rare
	Striped Keelback	*Amphiesma stolatum*	2	0.006	1.87	Rare
	Bindee keelback snake	*Rhabdophis bindi*	1	0.003	0.93	Very Rare
	Wall's Bronzeback	*Dendrelaphis cyanochloris*	3	0.009	2.80	Rare
	White barred kukri snake	*Oligodon albocinctus*	1	0.003	0.93	Very Rare
	Indian Rat Snake	*Ptyas mucosa*	1	0.003	0.93	Very Rare
Total			**107**			

The pie chart shows the relative abundance of snake species in Dudpukuria-Dhopachari Wildlife Sanctuary (DDWS):

- Rare species: 48% (low encounter rates);
- Very rare species: 35% (extremely low detectability);
- Uncommon species: 8% (moderate presence);
- Common species: 9% (relatively frequent).



Overall, 83% of species are rare or very rare, highlighting the sanctuary's unique but fragile snake diversity. Figure 5: Relative status of snake at DDWS.

4.1.1 Snake diversity in KNP

A total of 26 species of snakes have been recorded from the diverse habitats of Kaptai National Park (Table 4). Habitat wise snake species diversity (Shannon-Winer diversity index) and species evenness is presented below based on direct encountered and road kill information-

Table 5: Habitat wise species diversity of snakes at KNP

SL	Habitat types	Total Species encountered	Individuals count	Shannon-Winer diversity index (H)	Species Evenness (J)
1	Natural Forested areas	9	20	1.61	0.77
2	Hilly streams and waterlogged areas	10	16	2.10	0.91
3	Forest edge and roadside vegetation	18	29	2.79	1.10
4	In and around human habitation	9	11	2.09	1.30

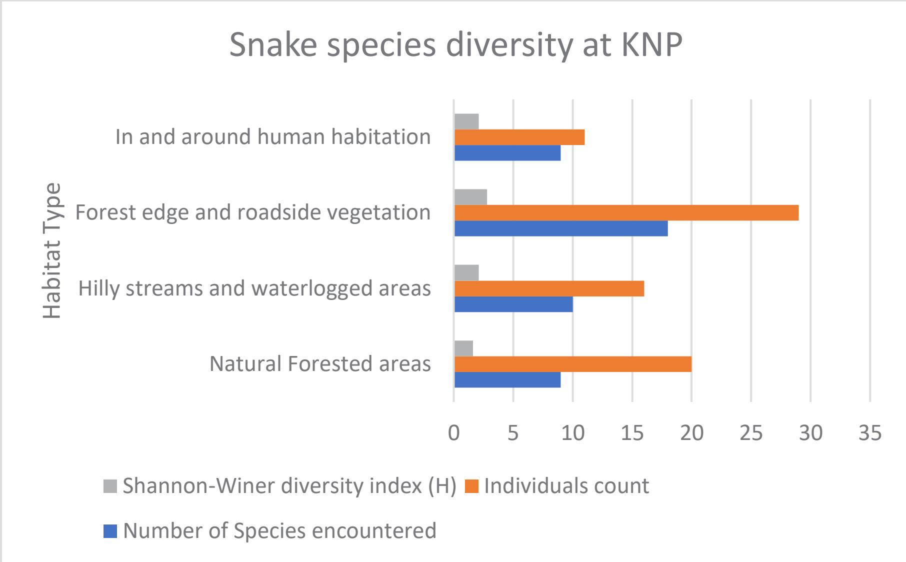


Figure 6: Species diversity of snakes in different habitats of KNP.

Table 6: The following tables show the species richness, evenness, relative abundance and species diversity index of snakes in different habitats of KNP.

Shannon-Wiener Diversity Index in Natural Forested areas of KNP							
Sl	**Species**	**Scientific name**	**Individual count**	**Relative abundance**	**p_i**	**$\ln(p_i)$**	**pilnpi**
1	Brahminy Worm Snake	*Indotyphlops braminus*	1	5.26	0.05	-2.94	-0.15
2	Checkered keelback	*Fowlea piscator*	1	5.26	0.05	-2.94	-0.15
3	Common Krait	*Bungarus caeruleus*	2	10.53	0.11	-2.25	-0.24
4	Common wolf snake	*Lycodon aulicus*	1	5.26	0.05	-2.94	-0.15
5	Green cat Snake	*Boiga cyanea*	1	5.26	0.05	-2.94	-0.15
6	Painted Bronzback tree snake	*Dendrelaphis pictus*	1	5.26	0.05	-2.94	-0.15
7	Red necked keelback	*Rhabdophis subminiatus*	1	5.26	0.05	-2.94	-0.15
8	Spot tailed pit viper	*Trimeresurus erythrurus*	11	57.89	0.58	-0.55	-0.32
9	Tawny Cat Snake	*Boiga ochracea*	1	5.0	0.05	-3.00	-0.33
			19	100			-1.61
Shannon-Winer diversity index, H = 1.61							

Shannon-Wiener Diversity Index in Hilly streams and waterlogged areas of KNP							
Sl	**Species**	**Scientific name**	**Individual count**	**Relative abundance**	**p_i**	**$\ln(p_i)$**	**pilnpi**
1	Checkered keelback	*Fowlea piscator*	2	12.50	0.13	-2.08	-0.26
2	Yunnan Keelback	*Hebius parallelus*	2	12.50	0.13	-2.08	-0.26
3	Spot tailed pit viper	*Trimeresurus erythrurus*	5	31.25	0.31	-1.16	-0.36
4	Eyed cat snake	*Boiga siamensis*	1	6.25	0.06	-2.77	-0.17
5	Green cat Snake	*Boiga cyanea*	1	6.25	0.06	-2.77	-0.17
6	Red necked keelback	*Rhabdophis subminiatus*	1	6.25	0.06	-2.77	-0.17
7	Mock Viper	*Psammodynastes pulverulentus*	1	6.25	0.06	-2.77	-0.17
8	Zaws wolf snake	*Lycodon zawi*	1	6.25	0.06	-2.77	-0.17
9	Painted Bronzback tree snake	*Dendrelaphis pictus*	1	6.25	0.06	-2.77	-0.17
10	Ornate flying snake	*Chrysopelea ornata*	1	6.25	0.06	-2.77	-0.17
			16	100	1	-24.73	-2.10
Shannon-Winer diversity index, H = 2.10							

Shannon-Wiener Diversity Index in forest edge and roadside vegetation of KNP							
Sl	**Species**	**Scientific name**	**Species count**	**Relative abundance**	**p_i**	**$\ln(p_i)$**	**pilnpi**
1	Zaws wolf snake	*Lycodon zawi*	1	3.45	0.03	-3.37	-0.12
2	Tawny Cat Snake	*Boiga ochracea*	2	6.90	0.07	-2.67	-0.18
3	Indian Rat Snake	*Ptyas mucosa*	2	6.90	0.07	-2.67	-0.18
4	Mock Viper	*Psammodynastes pulverulentus*	2	6.90	0.07	-2.67	-0.18
5	Checkered keelback	*Fowlea piscator*	2	6.90	0.07	-2.67	-0.18
6	Spot tailed pit viper	*Trimeresurus erythrurus*	4	13.79	0.14	-1.98	-0.27
7	Brahminy Worm Snake	*Indotyphlops braminus*	1	3.45	0.03	-3.37	-0.12
8	Greater Black Krait	*Bungarus niger*	2	6.90	0.07	-2.67	-0.18
9	Copper-headed trinket snake	*Coelognathus radiatus*	2	6.90	0.07	-2.67	-0.18
10	King Cobra	*Ophiophagus hannah*	1	3.45	0.03	-3.37	-0.12
11	Lesser black Krait	*Bungarus lividus*	1	3.45	0.03	-3.37	-0.12
12	Annulated sea snake	*Hydrophis cyanocinctus*	1	3.45	0.03	-3.37	-0.12
13	Hook nosed sea snake	Hydrophis schistosus	1	3.45	0.03	-3.37	-0.12
14	Assam Snail Eater	*Pareas monticola*	1	3.45	0.03	-3.37	-0.12

15	Painted Bronzback tree snake	*Dendrelaphis pictus*	2	6.90	0.07	-2.67	-0.18
16	Common wolf snake	*Lycodon aulicus*	2	6.90	0.07	-2.67	-0.18
17	Reticulated Python	*Malayopython reticulatus*	1	3.45	0.03	-3.37	-0.12
18	Striped Keelback	*Amphiesma stolatum*	1	3.45	0.03	-3.37	-0.12
			29	100.00	1.00	-53.68	-2.79
Shannon-Winer diversity index, H = 2.79							

Shannon-Wiener Diversity Index in and Around Human Habitation of KNP							
Sl	**Species**	**Scientific name**	**Individual count**	**Relative abundance**	**p_i**	**$\ln(p_i)$**	**pilnpi**
1	Brahminy Worm Snake	*Indotyphlops braminus*	1	8.33	0.08	-2.48	-0.21
2	Lesser black Krait	*Bungarus lividus*	2	16.67	0.17	-1.79	-0.30
3	Ornate Flying Snake	*Chrysopelea ornata*	1	8.33	0.08	-2.48	-0.21
4	Common wolf snake	*Lycodon aulicus*	3	25.00	0.25	-1.39	-0.35
5	Tawny Cat Snake	*Boiga ochracea*	1	8.33	0.08	-2.48	-0.21
6	Eastern Cat Snake	*Boiga gokool*	1	8.33	0.08	-2.48	-0.21
7	Zaws wolf snake	*Lycodon zawi*	1	8.33	0.08	-2.48	-0.21
8	Green Cat Snake	*Boiga cyanea*	1	8.33	0.08	-2.48	-0.21
9	Copper-headed trinket snake	*Coelognathus radiatus*	1	8.33	0.08	-2.48	-0.21
			12	100	1	-20.57	-2.09
Shannon-Winer diversity index, H = 2.09							

4.1.2 Snake diversity in DDWS

A total of 23 species of snakes have been recorded from the diverse habitats of DDWS. Habitat wise snake species diversity (Shannon-Winer diversity index) is presented below based on direct encountered and road kill information -

Table 7: Habitat wise species diversity of snakes at DDWS.

SL	Habitat types	Total Species encountered	Individuals count	Shannon-Winer diversity index (H)	Species Evenness (J)
1	Natural Forested areas	7	8	1.91	0.98
2	Hilly streams and waterlogged areas	14	63	1.81	0.66
3	Forest edge and roadside vegetation	8	20	1.83	0.91
4	In and around human habitation	6	16	2.1	0.95

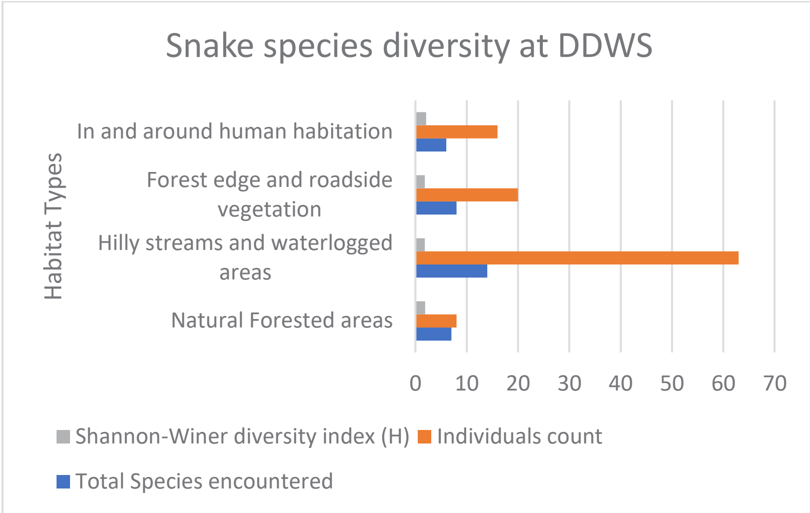


Figure 7: Species diversity of snakes in different habitats of DDWS.

Table 8: The following tables show the species richness, relative abundance and species diversity index of snakes in different habitats of DDWS.

Shannon-Winer diversity index in Natural forested areas of DDWS							
Sl	**Species**	**Scientific name**	**Individual count**	**Relative abundance**	**p_i**	**$ln(p_i)$**	**pilnpi**
1	Monocled Cobra	*Naja kaouthia*	1	12.5	0.13	-2.08	-0.26
2	Indian Rat Snake	*Ptyas mucosa*	1	12.5	0.13	-2.08	-0.26
3	Assam Snail Eater	*Pareas monticola*	1	12.5	0.13	-2.08	-0.26
4	Spot tailed pit viper	*Trimeresurus erythrurus*	1	12.5	0.13	-2.08	-0.26
5	Twin-spotted Wolf Snake	*Lycodon jara*	1	12.5	0.13	-2.08	-0.26
6	Mock Viper	*Psammodynastes pulverulentus*	1	12.5	0.13	-2.08	-0.26
7	Painted Bronzback tree snake	*Dendrelaphis pictus*	2	25.0	0.25	-1.39	-0.35
			8				-1.91
Shannon-Winer diversity index, H = 1.91							

Shannon-Winer diversity index in Hilly Streams and waterlogged areas of DDWS							
Sl	**Species**	**Scientific name**	**Individual count**	**Relative abundance**	**p_i**	**$ln(p_i)$**	**pilnpi**
1	Spot tailed pit viper	*Trimeresurus erythrurus*	11	17.46	0.17	-1.75	-0.30
2	Painted Bronzback tree snake	*Dendrelaphis pictus*	30	47.62	0.48	-0.74	-0.35
3	Indo-Chinese Rat Snake	*Ptyas korros*	2	3.17	0.03	-3.45	-0.11

4	Twin-spotted Wolf Snake	*Lycodon jara*	1	1.59	0.02	-4.14	-0.07
5	Mock Viper	*Psammodynastes pulverulentus*	6	9.52	0.10	-2.35	-0.22
6	Assam Snail Eater	*Pareas monticola*	1	1.59	0.02	-4.14	-0.07
7	Banded krait	*Bungarus fasciatus*	1	1.59	0.02	-4.14	-0.07
8	Bindee keelback snake	*Rhabdophis bindi*	1	1.59	0.02	-4.14	-0.07
9	Blue Bronzeback	*Dendrelaphis cyanochloris*	3	4.76	0.05	-3.04	-0.14
10	Burmese python	*Python molurus*	1	1.59	0.02	-4.14	-0.07
11	Checkered Keelback	*Fowlea piscator*	3	4.76	0.05	-3.04	-0.14
12	Monocled Cobra	*Naja kaouthia*	1	1.59	0.02	-4.14	-0.07
13	Haas's Bronzeback Tree Snake	*Dendrelaphis haasi*	1	1.59	0.02	-4.14	-0.07
14	Short nosed vine snake	*Ahaetulla prasina*	1	1.59	0.02	-4.14	-0.07
			63				-1.81
Shannon-Winer diversity index, H = 1.81							

Shannon-Winer diversity index in Forest edge and roadside vegetation of DDWS							
Sl	**Species**	**Scientific name**	**Individual count**	**Relative abundance**	**p_i**	**$\ln(p_i)$**	**pilnpi**
1	Ornate Flying Snake	*Chrysopelea ornata*	1	5.00	0.05	-3.00	-0.15
2	Common Smooth scale water snake	*Enhydris enhydris*	2	10.00	0.10	-2.30	-0.23
3	Zaws wolf snake	*Lycodon zawi*	1	5.00	0.05	-3.00	-0.15
4	Painted Bronzback tree snake	*Dendrelaphis pictus*	6	30.00	0.30	-1.20	-0.36
5	Spot tailed pit viper	*Trimeresurus erythrurus*	4	20.00	0.20	-1.61	-0.32
6	Banded krait	*Bungarus fasciatus*	1	5.00	0.05	-3.00	-0.15
7	Checkered keelback	*Fowlea piscator*	4	20.00	0.20	-1.61	-0.32
8	Twin-spotted Wolf Snake	*Lycodon jara*	1	5.00	0.05	-3.00	-0.15
			20				-1.83
Shannon-Winer diversity index, H = 1.83							

Shannon-Winer diversity index In and around Human Habitation of DDWS							
Sl	**Species**	**Scientific name**	**Individual count**	**Relative abundance**	**p_i**	**$\ln(p_i)$**	**pilnpi**
1	Common wolf snake	*Lycodon aulicus*	3	18.75	0.18	-1.67	-0.31
2	Red necked keelback	*Rhabdophis subminiatus*	1	6.25	0.06	-2.77	-0.17
3	Checkered keelback	*Fowlea piscator*	3	18.75	0.18	-1.67	-0.31
4	Banded krait	*Bungarus fasciatus*	1	6.25	0.06	-2.77	-0.17
5	Monocled Cobra	*Naja kaouthia*	2	12.5	0.12	-2.08	-0.26
6	Striped Keelback	*Amphiesma stolatum*	2	12.5	0.12	-2.08	-0.26
7	White barred kukri snake	*Oligodon albocinctus*	1	6.25	0.06	-2.77	-0.17
8	Zaws wolf snake	*Lycodon zawi*	1	6.25	0.06	-2.77	-0.17
9	Copper-headed trinket snake	*Coelognathus radiatus*	2	12.5	0.12	-2.08	-0.26
			16				-2.10
Shannon-Winer diversity index, H = 2.10							

4.1.3 Environmental Niche modelling of snake in KNP and DDWS.

Environmental Niche modelling of snake in Kaptai National Park

Environmental niche modeling in Kaptai National Park provided key insights into snake habitat preferences and the environmental factors shaping their distributions. Species were assessed using training/test AUC scores, variable importance, and permutation importance.

Top Performers:

- *Mock Viper*: Training AUC 0.965, Test AUC 0.909; driven by BIO13 (precipitation of wettest month) at 42.5%.
- *Painted Bronzeback Tree Snake*: Training AUC 0.951, Test AUC 0.849; dominated by BIO5 (max temperature of warmest month) at 63.9%.
- *Zaw's Wolf Snake*: Test AUC 0.947; strongly influenced by BIO1 (annual mean temperature) at 92.8%.
- *Lesser Black Krait*: Driven by BIO6 (min temperature of coldest month) at 96.2%.

Other Notable Species:

- *Tawny Cat Snake*: BIO5 (32.4%) and *Spot-Tailed Pit Viper*: BIO15 (23.4%).
- *Brahminy Worm Snake*: BIO1 (75.3%).
- *Checkered Keelback* and *Green Cat Snake*: SfcWind_mean (surface wind speed) at 75.7% and 90.1%.

Poor Performers:
Species like Common Krait, Copper-Headed Trinket Snake, Eyed Cat Snake, and King Cobra had AUC scores near 0.5, indicating unreliable predictions due to limited data or unsuitable variables.

Key Factors Across Species:

- Temperature (BIO1, BIO5, BIO6)
- Precipitation (BIO13, BIO15)
- Wind speed (SfcWind_mean)

Overall, temperature, rainfall, and wind play vital roles in shaping snake habitats, providing critical guidance for conservation efforts. Poorly modeled species highlight the need for better data and refined modeling approaches.

Environmental Niche modelling of snake in Dudpukuria-dhopachari Wildlife Sanctuary:

MaxEnt modeling revealed key environmental drivers shaping snake distributions in DDWS, highlighting species-specific responses to temperature, precipitation, and moisture.

Top Influenced Species:

- **Assam Snail Eater:** Fully driven by BIO3 (isothermality, 100%).
- **Banded Krait:** Temperature seasonality (BIO4, 72.4%) and precipitation of wettest month (BIO13, 60.4% permutation importance).
- **Bindee Keelback & Burmese Python:** Both rely entirely on BIO6 (min temperature of coldest month, 100%).
- **Blue Bronzeback:** Fully shaped by BIO15 (precipitation seasonality, 100%).

Other Key Species:

- **Checkered Keelback:** BIO4 (temperature seasonality, 46.9%).
- **Mock Viper:** BIO4 (56%) and BIO2 (diurnal temperature range, 44%).
- **Monocled Cobra:** BIO6 (86.2%).
- **Painted Bronzeback Tree Snake:** BIO5 (max temperature, 33%) and BIO15 (18.5%).
- **Spot-Tailed Pit Viper:** SfcWind_mean (wind speed, 52.5%) and BIO4 (28.9%).
- **Striped Keelback:** BIO15 (68.2%).
- **Yellow Speckled Wolf Snake:** BIO8 (wettest quarter temp, 45.5%) and BIO9 (driest quarter temp, 35.6%).
- **Zaw's Wolf Snake:** BIO11 (coldest quarter temp, 84.4%).

Key Factors Across Species:

- Temperature (BIO2, BIO4, BIO5, BIO6, BIO8, BIO9, BIO11)
- Precipitation (BIO13, BIO15)
- Moisture (VPD_mean) and Wind speed (SfcWind_mean)

Conclusion:

Temperature and moisture emerge as the most critical drivers, guiding future conservation efforts and highlighting the need for targeted data collection for underrepresented species.

4.1.4 Resolving the diversity of cryptic snakes

To resolve the cryptic species diversity of snakes, a total 10 samples were collected (mostly from road killed, human killed) and analyzed accordingly. Among these, two species of Yunnan Keelback (*Hebius paralleus*) and Haas's Bronzeback Tree Snake (*Dendrelaphis haasi*) were recorded for the first time in Bangladesh. In addition, the presence of Wall's Bronzeback (*Dendrelaphis cyanochloris*) was confirmed as a valid live species record for the country. These findings are supported by both morphological and molecular data.

Detailed results on molecular data are presented below.

Table 9: List of samples analyzed for DNA barcoding.

Sl. No.	Sample Code	Suspected Species	Confirmed Species through DNA Barcoding	Remarks
1	WC1	Mock Viper *Psammodynastes pulverulentus*	Mock Viper *Psammodynastes pulverulentus*	
2	WC2	Painted Bronzeback *Dendrelaphis pictus*	Haas's Bronzeback Tree Snake *Dendrelaphis haasi*	New record for Bangladesh; further study is needed
3	WC3	Cherrapunji Keelback *Hebius xenura*	Yunnan Keelback *Hebius parallelus*	New record for Bangladesh; further study is needed
4	WC4	Assam Snail Eater *Pareas monticola*	Assam Snail Eater *Pareas monticola*	
5	WC5	Bronze-backed Tree Snake? *Dendrelaphis sp.*	Wall's Bronzeback *Dendrelaphis cyanochloris*	Confirmed as a valid live species record for Bangladesh; further study is needed
6	WC6	Bronze-backed Tree Snake? *Dendrelaphis sp.*	Wall's Bronzeback *Dendrelaphis cyanochloris*	
7	WC7	Road Killed_Unknown	Chequered Keelback *Fowlea piscator*	
8	WC8	Red-necked Keelback *Rhabdophis subminiatus*	Red-necked Keelback *Rhabdophis subminiatus*	
9	WC9	Blind Snake (small) *Indotyphlops braminus*	Brahminy Blind Snake *Indotyphlops braminus*	
10	WC10	Blind Snake (large) *Indotyphlops braminus*	Brahminy Blind Snake *Indotyphlops braminus*	

WC 1

Mock Viper (*Psammodynastes pulverulentus*)

The specimen (WC1) showed a monophyletic clade with *Psammodynastes pulverulentus* species from Bangladesh (KT215869). Our species is somewhat different from Mock vipers from other regions of its distribution range (Figure 8). *P. pulverulentus* from our study showed the shortest distance of 0.009 with the *P. pulverulentus* from Bangladesh while these showed greatest distance (0.066) with the *P. pulverulentus* from China (Table 12).

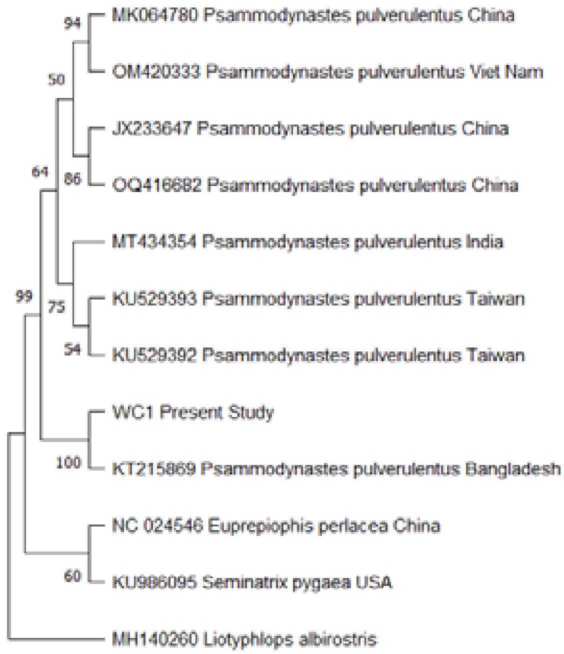


Figure 8: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Psammodynastes pulverulentus. The black box shows the specimens from the present study.*

WC2

Haas's Bronzeback Tree Snake (*Dendrelaphis haasi*)

The specimen (WC2) showed a monophyletic clade with *Dendrelaphis haasi* from Myanmar (MT608083) (Figure 9). *D. haasi* from our study showed the shortest distance of 0.147 with the *D. haasi* from Myanmar while it showed greatest distance (0.205) with the *Dendrelaphis pictus* from India (Table 13).

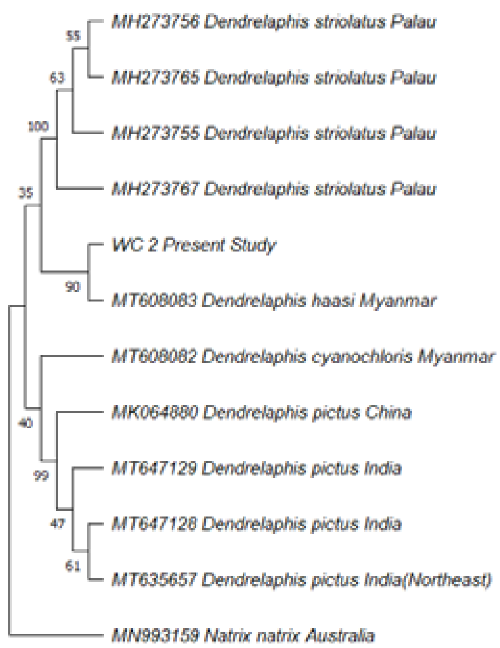


Figure 9: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Dendrelaphis haasi. The black box shows the specimens from the present study.*

WC3

Yunnan Keelback (*Hebius parallelus*)

The specimen (WC3) showed proximity with *Hebius parallelus* from China (MK064915) (Figure 10). Our specimen showed the shortest distance of 0.086 with the *H. parallelus* from China while it showed greatest distance (1.439) with the *Herpestoreas xenura* from India (Table 14).

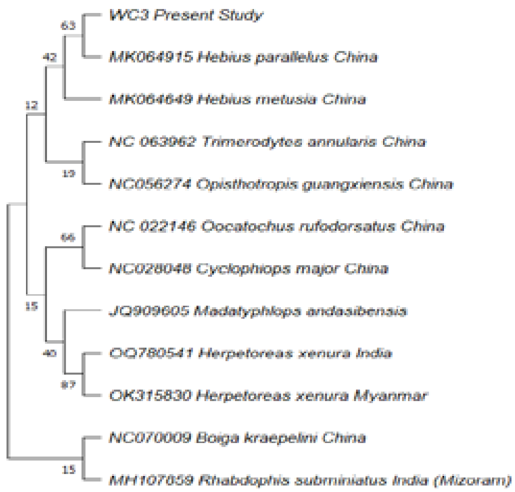


Figure 10: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Hebius parallelus. The black box shows the specimens from the present study.*

WC4

Assam Snail Eater (*Pareas monticola*)

The specimen (WC4) showed proximity with *Pareas monticola* from China (MK604935) (Figure 11). Our specimen showed the shortest distance of 0.047 with the *Pareas monticola* from China while it showed greatest distance (0.191) with the *Coluber constrictor* from USA (Table 15).

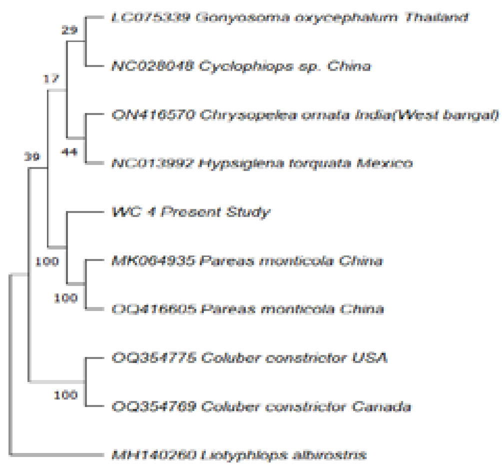


Figure 11: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Pareas monticola. The black box shows the specimens from the present study.*

WC5 and WC6

Wall's Bronzeback (*Dendrelaphis cyanochloris*)

The specimens (WC5 and WC6) showed proximity with *Dendrelaphis cyanochloris* from Myanmar (MT608082) (Figure 12). Our specimen showed the shortest distance of 0.035 with the *Dendrelaphis cyanochloris* from Myanmar while it showed greatest distance (0.138) with the *Dendrelaphis striolatus* from Palau (Table 16).

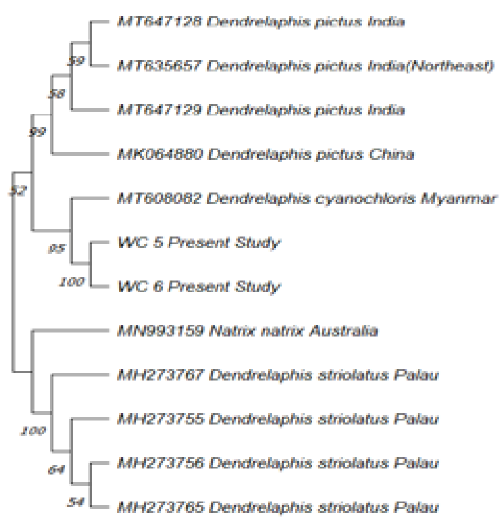


Figure 12: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Dendrelaphis cyanochloris. The black box shows the specimens from the present study.*

WC7

Checkered Keelback (*Fowlea piscator*)

The specimen (WC7) showed proximity with *Fowlea piscator* from Myanmar (MG935710) (Figure 13). Our specimen showed the shortest distance of 0.002 with the *Fowlea piscator* from Afghanistan while it showed greatest distance (0.111) with the *Xenochrophis flavipunctatus* from China (Table 17).

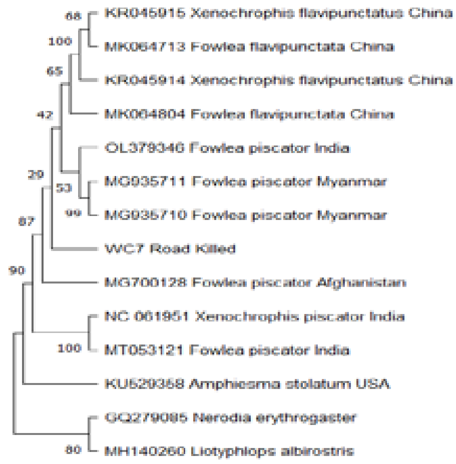


Figure 13: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Fowlea piscator. The black box shows the specimens from the present study.*

WC8

Red-necked Keelback (*Rhabdophis subminiatus*)

The specimen (WC8) showed proximity with *Rhabdophis subminiatus* from India (MH107859) (Figure 14). Our specimen showed the no genetic distance (0.000) with the *Rhabdophis subminiatus* from India while it showed greatest distance (0.088) with the *Rhabdophis subminiatus* from Thailand (Table 18).

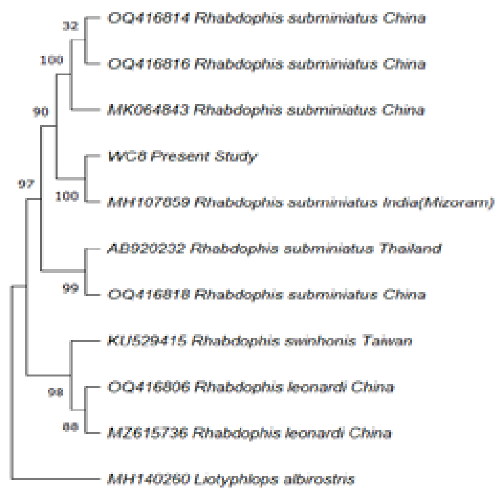


Figure 14: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Rhabdophis subminiatus. The black box shows the specimens from the present study.*

WC9 and WC10

Brahminy Blind Snake (*Indotyphlops braminus*)

The specimens (WC9) showed proximity with *Indotyphlops braminus* from China (OQ414787) while the specimen WC10 showed proximity with *Indotyphlops braminus* from Japan (MH274170) (Figure 15). Our specimens showed no distance (0.000) with the same species of its geographic range except the specimen from Sri Lanka (220) (Table 19).

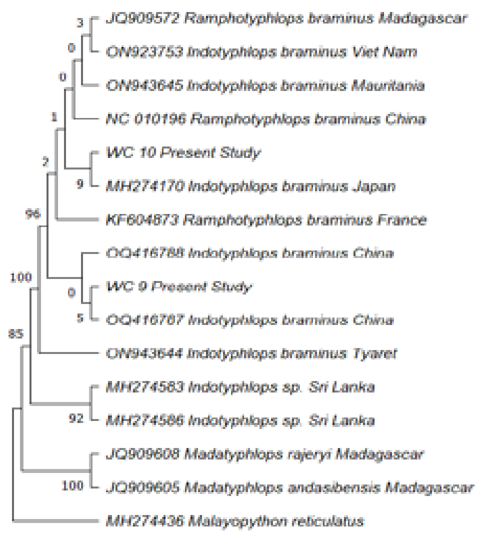


Figure 15: *Maximum likelihood phylogenetic tree based on COI genes, showing the identity of the specimens as Indotyphlops braminus. The black box shows the specimens from the present study*

4.2 Threat assessment and associated human-snake conflicts

4.2.1 Threats for snakes at KNP

Demographic information:

The project team conducted five (05) focus group discussions (FGDs) at Kaptai National Park, Kaptai, Rangamati during project period. A total 101 peoples participated in these five focus group discussions (FGDs) sessions (Table 12).

Table 10: Number FGDs conducted in two ranges of Kaptai National Park.

Protected Area	Name of location	FGD Date	Number of FGDs	People participated
Kaptai National Park	Bangchori Marma Para, Kaptai Range.	08-11-2023	01	17
	Brick field Forest Camp, Karnafully Range.	20-01-2024	01	25
	Proshanti Park, Bangchori Beat, Kaptai Range.	09-02-2024	01	14
	Chitmorom kheya ghat, Bangchori Beat, Kaptai Range.	16-04-2024	01	17
	Chowdhury chara, Nicer bazar, Karnafully sadar beat, Karnafully Range.	19-04-2024	01	28
Total			5	101

Age Group:
Among the 101 participants, the majority were in the 21-30 age group (29%), with the lowest number from the 61-70 and 71+ age groups (5%).

Gender:
86% of respondents were male, and 14% were female.

Ethnicity:
The majority of participants were Muslim (53%), followed by Hindu (20%), Marma (17%), and Chakma (10%).

Occupation:
Participants had diverse occupations, with agriculture (20%) and fishing (14%) being the most common. Other occupations included CNG driver, service workers, housewives (13%), students (12%), day laborers (7%), business (3%), CMC members (2%), and shopkeepers (1%).

Threats to Snakes and Illegal Collection: 31% of respondents identified local consumption as the primary threat to snakes, followed by agricultural expansion (20%), forest encroachment (16%), Jhum cultivation (14%), and roadkill (11%). 4% mentioned illegal snake collection, while habitat loss, forest fires, and other factors contributed to the decline in snake populations.

Figure 15 shows major threats to snakes as perceived by local community people.

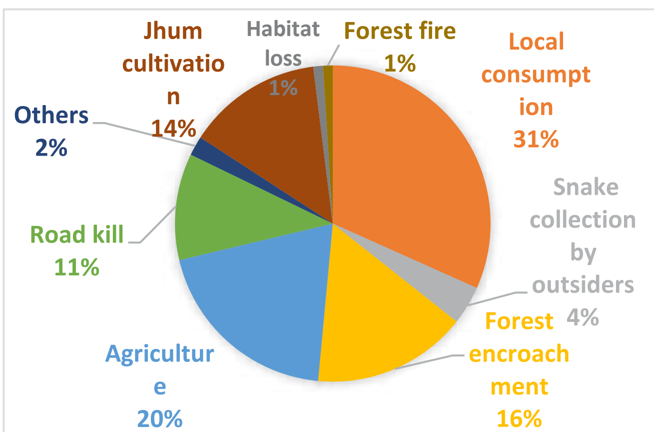


Figure 16: Threats to snakes in study area according to respondents at KNP.

Field Observation:

Human activities have significantly impacted the fauna of Kaptai National Park (KNP). The primary threats to wildlife, particularly snakes, include:

1. **Habitat Destruction and Deforestation**: Deforestation for agriculture, settlement, and infrastructure development, along with illegal logging, fragments snake habitats.
2. **Poaching and Illegal Wildlife Trade**: Snakes are poached for their skin, meat, and traditional medicine.
3. **Human-Snake Conflict**: As settlements expand, snakes are killed out of fear. Agricultural practices also disturb snake habitats.
4. **Forest Fires**: Caused by shifting cultivation, careless cigarette disposal, and fireballs thrown to move wild elephants, forest fires pose a major threat to snake populations.
5. **Pollution:** Use of herbicides and pesticides in agriculture negatively affects snake ecosystems.
6. **Roadkill**: Heavy traffic on roads through KNP leads to many snake roadkill incidents.
7. **Cattle Grazing**: Frequent grazing destroys undergrowth and disrupts forest regeneration.

During the project, 25 snakes were rescued and released, including Burmese Pythons, Reticulated Pythons, Spot-Tailed Pit Vipers, and King Cobras.

4.2.2 Threats for snakes at DDWS

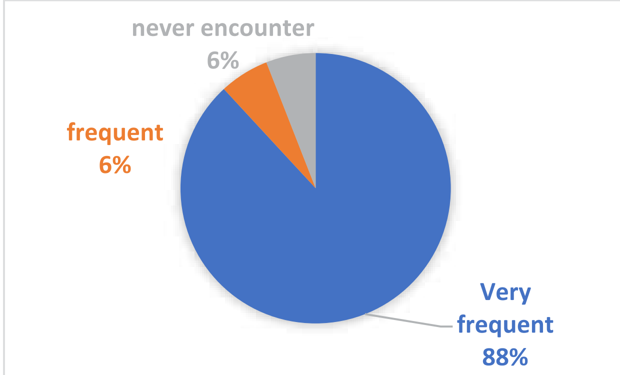
Demographic information:

The project team conducted five (05) focus group discussions (FGDs) at Dudpukuria-Dhopachari Wildlife Sanctuary during project period. A total 94 peoples participated in these five (05) focus group discussions (FGDs) sessions.

Table 11: Number FGDs conducted in two ranges of Dudpukuria-Dhopachari Wildlife Sanctuary.

Protected Area	Name of the location	FGD Date	Number of FGDs	People participated
Dudpukuria-Dhopachari Wildlife Sanctuary	Dudpukuria Beat, Khurasia Range	09-11-2023	01	12
	Dhopachari Beat, Dohazari Range	21-01-2024	01	11
	Local ethnic community (marma) at Koiya Para, Khurushiya range of DDWS.	01-06-2024	01	22
	Baro Chon Khola bazar, Dudpukuria Beat, Khurushiya range of DDWS.	02-06-2924	01	19
	Dhopachori bazar, Dhopachori beat, Dohazari Range of DDWS.	05-06-2024	01	30
Total			5	94

Age Group:
The majority of respondents were in the 31-40 age group (29%), followed by 21-30 years (23%). The lowest was below 20 years (4%). Among the 94 participants, 95% were male, and 5% were female.



Ethnicity:
77% were from the Muslim community, 22% from the Chakma community, and 1% from the Hindu community.

Occupation:
Main occupations: agriculture (50%), business (17%), day labor and service (9%), CNG driver (7%), student (5%), fisherman (1%), housewife (1%).

Threats to Snakes and Illegal Collection:

Main threats identified were forest fire (36%), agricultural expansion (33%), local consumption (16%), forest encroachment (9%), and illegal snake collection (6%).

Figure 17 shows major threats to snakes as perceived by local community people.

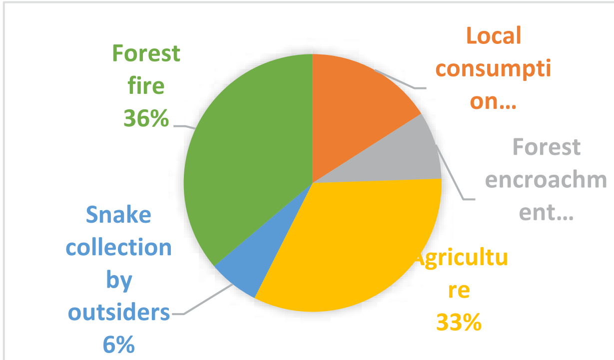


Figure 17: Threats to snakes in study area according to respondents at DDWS

Field Observation:

The project team identified several key threats to the snake population in Dudpukuria-Dhopachori Wildlife Sanctuary (DDWS):

1. **Deforestation and Habitat Loss:** Agriculture, illegal logging, and settlements reduce snake habitats.
2. **Agricultural Expansion and Pesticides:** Agriculture and pesticide use degrade habitats and reduce prey availability.
3. **Pollution:** Poison used for fish harvesting impacts ecosystems.
4. **Forest Fire:** Forest fires damage vegetation and increase illegal activities.
5. **Cattle Grazing:** Grazing destroys undergrowth and hinders regeneration.
6. **Road Kill:** Road accidents, particularly on the Chandroghona-Bandarban Road, result in snake fatalities.

4.2.3 Human-snake conflicts scenarios at KNP

Focus Group Discussion (FGD) Summary:

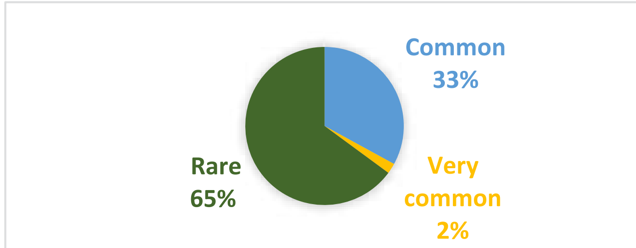
The project team conducted five (05) FGDs at Kaptai National Park, with 101 participants. The focus was on local perceptions regarding snakes and conflicts.

Perception among local and ethnic communities regarding snakes and pattern of conflict at KNP:

Snake Encounters & Actions:

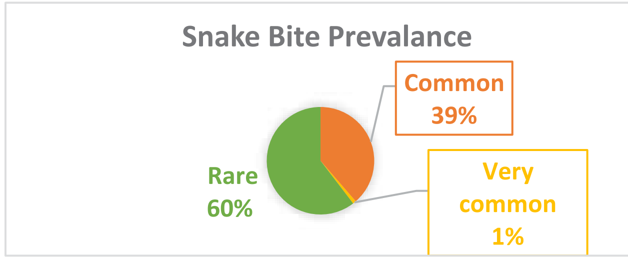
- 88% of respondents encountered snakes frequently; 6% never encountered snakes in the past five years.
- 44% immediately kill snakes found in their homes, 35% do nothing, 13% rescue and release them, and 8%

inform forest officials. Some ethnic communities (Chakma) collect and consume snakes



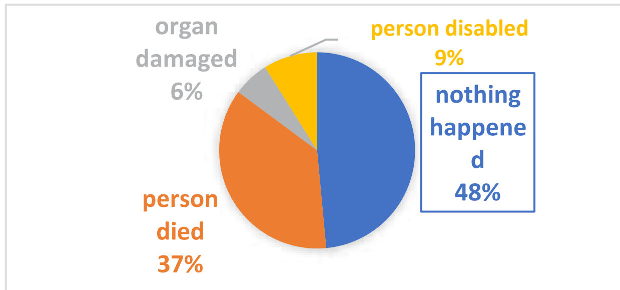
Snake Bite Prevalence:

- 60% have never been bitten by a snake; 39% have been bitten at least once.
- 60% consider snake bites rare in the area, while 40% say they are common.



Snake Bite Fatality/Disability:

- 48% believe snake bites cause no serious harm, 37% think snake bites result in fatalities, 9% believe they cause disabilities, and 6% think they cause organ damage.

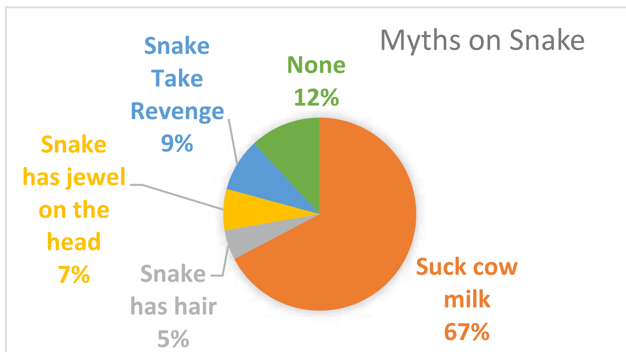


Snake Bite Treatment Preference:

- 57% prefer medical treatment in government hospitals, while 43% trust local ojhas (traditional healers).

Snake Myths:

- 67% believe that snakes, especially Trinket Snakes, can suck cow milk by entangling the cow's feet.
- Other myths include snakes taking revenge (9%), having jewels on their heads (7%), or hair on their heads (5%). 12% do not believe in any snake myths.



4.2.4 Human-snake conflicts scenarios at DDWS

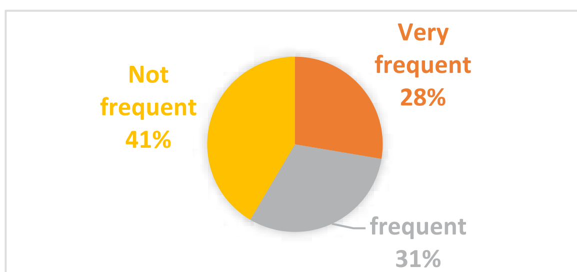
Focus Group Discussion (FGD) Summary:

The project team conducted five (05) FGDs at Dudpukuria-Dhopachari Wildlife Sanctuary (DDWS) with 94 participants. The discussions focused on local perceptions regarding snakes and conflicts.

Perception among local and ethnic communities regarding snakes and pattern of conflict at DDWS:

Snake Encounters & Actions:

- 28% encountered snakes very frequently, 31% frequently, and 41% not frequently.
- 60% of respondents do nothing if they encounter a snake, 28% kill it instantly, 8% collect and consume it (especially Chakma people), 6% rescue and release it, and 5% inform forest officials.



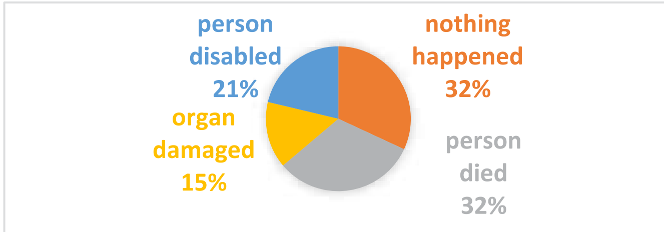
Snake Bite Prevalence:

- 16% had never been bitten by a snake; 84% had experienced a snake bite at least once.

- 65% consider snake bites rare in the area, while 33% believe they are common.

Snake Bite Fatality/Disability:

- 32% believe snake bites cause no serious harm, 32% think they can be fatal, 21% think they cause disabilities, and 15% think they cause partial organ damage.

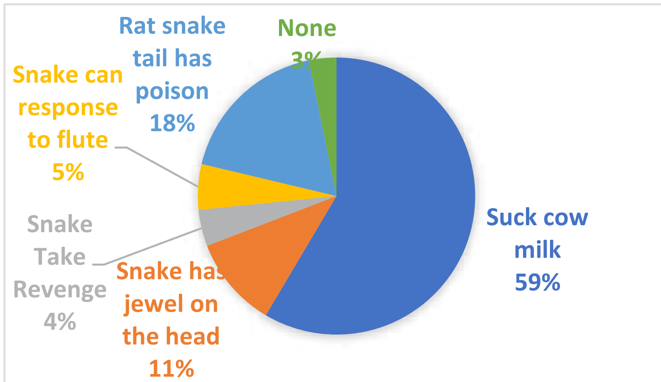


Snake Bite Treatment Preference:

- 67% prefer local ojhas for treatment, while 33% seek medical assistance from government hospitals.

Snake Myths:

- 59% believe snakes (specifically Trinket Snakes) can suck cow milk by entangling the cow's feet.
- 18% think rat snake tails are poisonous, 11% believe snakes have jewels on their heads, 5% think they respond to flutes, and 4% think snakes take revenge if one of a pair is killed. 3% do not believe in any snake myths.

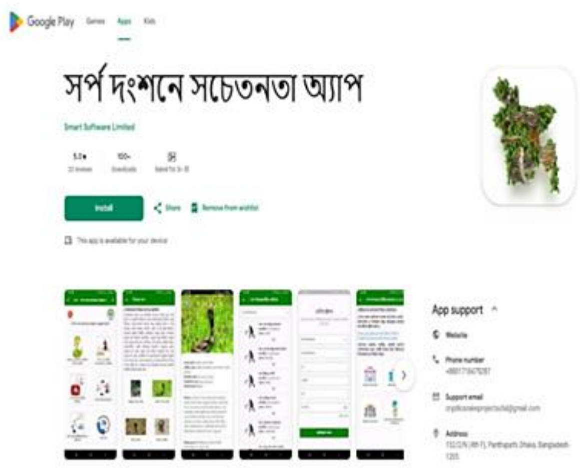


4.3 Developing a mobile app to reduce unanticipated mortality from snakebites

Our newly developed Android mobile application, "সর্প দংশনে সচেতনতা অ্যাপ," is now available on both the Google Play Store and Apple Store.

Key Features of the App:

- বিষধর, মৃদু বিষধর ও অবিষধর সাপের প্রজাতি;
- সর্প দংশন পরবর্তী লক্ষণ, উপসর্গ ও করণীয়;
- সর্প দংশনের প্রাথমিক চিকিৎসা;
- সর্প দংশনের তথ্য প্রদান;
- সর্প দংশনের চিকিৎসাসেবা ও অ্যান্টিভেনম;
- যোগাযোগ;
- সাপের সম্পর্কিত কুসংস্কার ও সাপের গুরুত্ব;
- সাপ সম্পর্কিত ভিডিও ও সাপ উদ্ধারে প্রয়োজনীয় দিক নির্দেশনা;
- বাংলাদেশের সাপের প্রজাতি এবং
- জাতীয় জরুরি নম্বর প্রভৃতি।



The app includes useful resources like:

- A link to contact numbers and Google Maps for all medical college hospitals, district hospitals, and upazila hospitals in Bangladesh.
- Quick access to hospital details regarding antivenom availability.

Download Links:

সর্প দংশনে সচেতনতা অ্যাপ - Apps on Goo7gle Play

Snake Bite Awareness App on the App Store (apple.com)

The app provides a well-structured guide on snakes and related topics, offering detailed descriptions, essential safety measures, and emergency contacts for snakebites. The interactive design and comprehensive information make it an invaluable tool for raising awareness and ensuring safety in snake-related emergencies.

Figure 18: Ten features' details of the android mobile application

4.3.1 Development of the Snake Bite Awareness Dashboard.

As part of Contract Amendment-01, we've successfully developed and integrated a dashboard into the Snake Bite Awareness App (সর্প দংশনে সচেতনতা অ্যাপ). This dashboard provides real-time, data-driven insights on snake bite incidents to help authorities, healthcare professionals, and the public track and analyze cases efficiently.

Key Features:

1. **Monthly and Yearly Snake Bite Statistics**
   - Tracks snake bite incidents over time, helping identify peak seasons and high-risk periods for better resource allocation.
2. **District-wise Snake Bite Information**
   - Provides a geographical breakdown of cases by district to target awareness campaigns and medical preparedness in high-risk zones.
3. **Date-wise Snake Bite Incident Chart (Deaths and Survivors)**
   - Tracks daily incidents, distinguishing between fatal and non-fatal cases to improve medical response and survival rates.
4. **Visual Representation and Data Insights**
   - Interactive charts and filters to refine searches based on time, district, or case severity, ensuring easy access to data for both professionals and the public.

Purpose and Impact: The dashboard enhances public awareness, aids in decision-making, and improves healthcare responses in snake bite-prone areas by:

- Identifying high-risk zones and enabling preventive measures.
- Strengthening emergency responses in affected districts.
- Raising awareness among local communities and authorities.
- Supporting policymakers in developing effective snake bite prevention and treatment strategies.

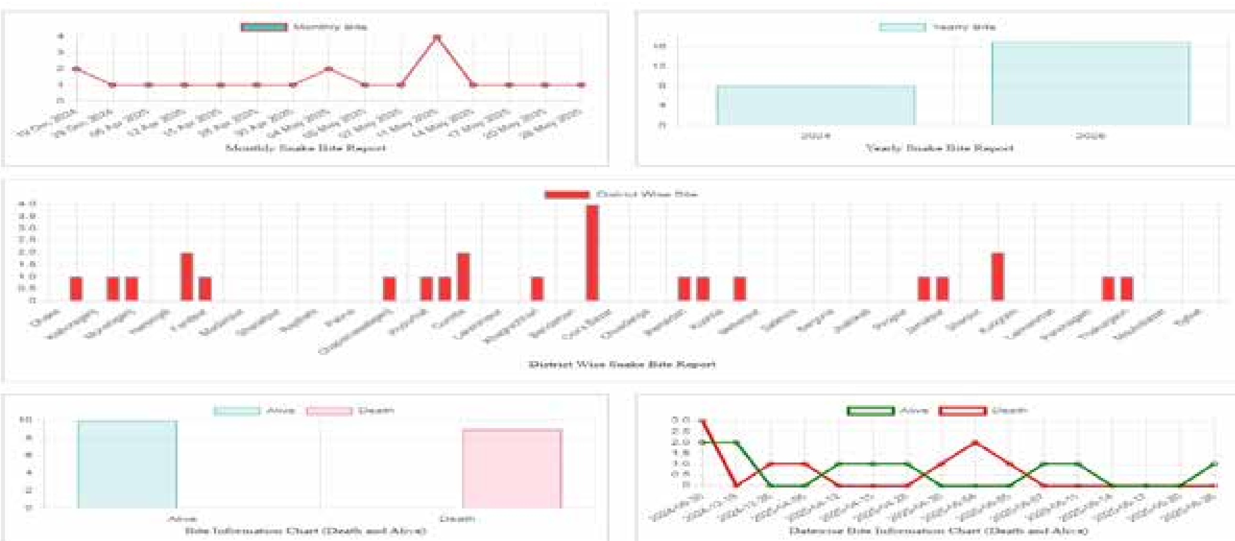


Figure 19: Monthly, yearly and district wise snake bite information along with death and live snake bite cases.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Through extensive fieldwork and genetic analysis, the project documented 208 snakes across 36 species, representing more than one-third of Bangladesh's snake species. Notably, three species were new to the country, highlighting the region's biodiversity importance. These findings contribute valuable data to global conservation efforts.

The project also assessed threats facing snake populations, including habitat destruction, agricultural expansion, pollution, road kills, and human-snake conflict. Climate change and illegal wildlife trade were emerging threats. This data helps prioritize conservation actions.

A key outcome was the development of a mobile app that aids in species identification, provides safety guidance, and addresses human-snake conflicts. The app also educates users about snakes' ecological roles, promoting coexistence.

By combining research, threat assessment, technology, and community engagement (via 10 focus group discussions), the project improved understanding of local snake diversity and fostered greater public awareness and tolerance. Moving forward, continued monitoring and app enhancements will strengthen conservation efforts, ensuring long-term success.

In conclusion, this project not only uncovered new species but also demonstrated how science, technology, and community involvement can drive effective conservation in Bangladesh.

5.2 Recommendations and Suggestions

Upon implementing the project on cryptic snake diversity, threats, conservation, and the mobile app for awareness in Southeast Bangladesh, the following recommendations are proposed:

I. **Enhance Community Engagement:**

- Conduct workshops and awareness programs with local communities and stakeholders.
- Involve community leaders, schools, and NGOs to boost outreach.

II. **Strengthen Research and Monitoring:**

- Implement a regular monitoring program for snake populations and habitat conditions.
- Expand studies to other regions in Bangladesh to discover more cryptic species.
- Use molecular and genetic techniques to resolve species identification challenges.

III. **Enhance Habitat Conservation:**

- Collaborate with communities to restore degraded habitats by planting native vegetation and controlling invasive species.
- Identify key snake habitats for protection.
- Raise awareness about habitat destruction from urbanization, agriculture, and logging.

IV. **Address Threats:**

- Train local enforcement to address illegal snake hunting and trade.
- Educate communities about the dangers of pesticides, herbicides, and activities that harm snake populations.

V. **Mobile App Utilization and Updates:**

- Secure funding for ongoing app development.
- Promote the app on the Bangladesh Forest Department website for greater visibility.

VI. **Raise Awareness and Education:**

- Organize campaigns to highlight snakes' ecological importance and safety tips.
- Develop snake conservation modules for schools with interactive sessions, field trips, and activities.
- Use traditional (radio, newspapers) and digital media (social media, YouTube) to address misconceptions about snakes

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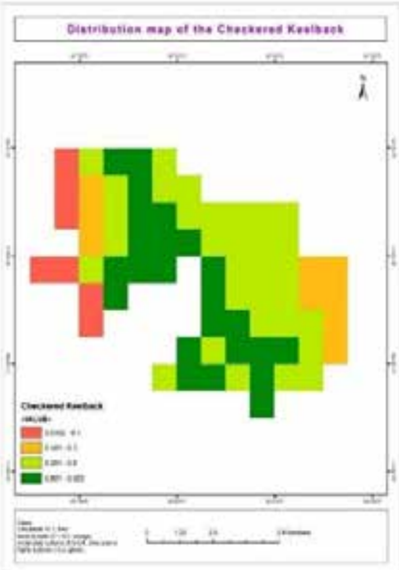
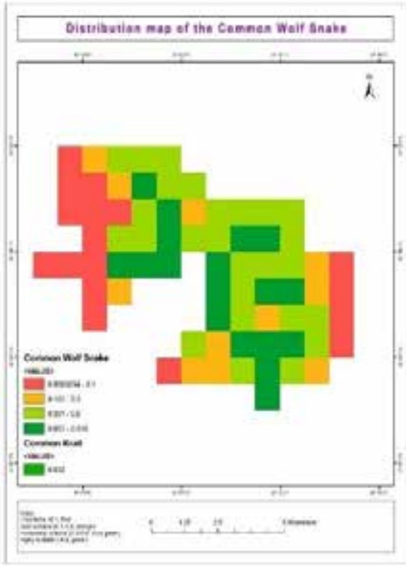
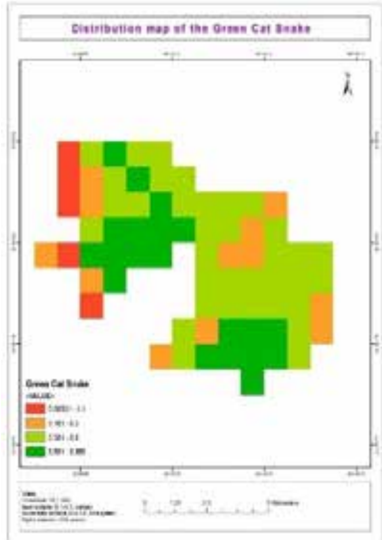
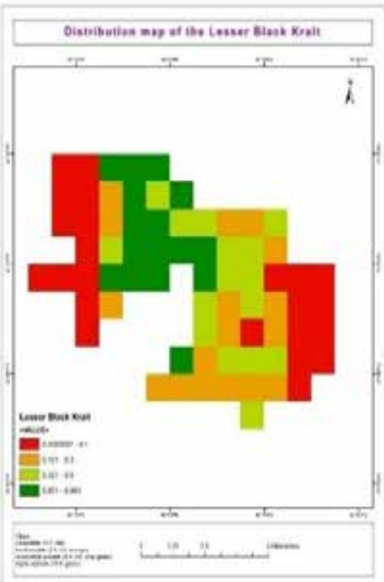
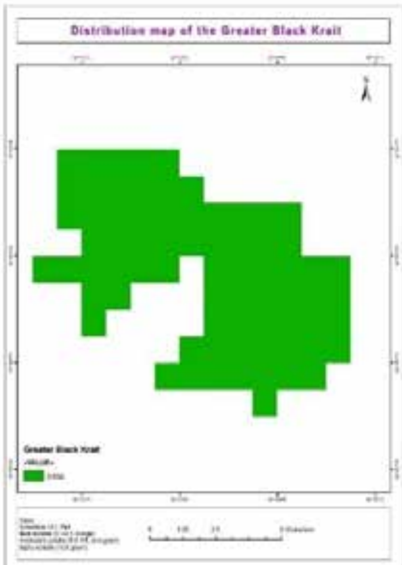
Annexure-1: Habitat Suitability Map of Snakes in Kaptai National Park.

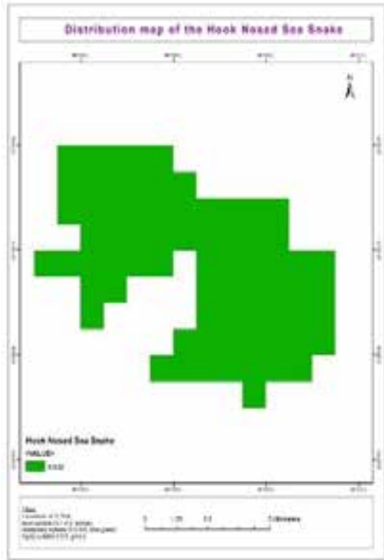


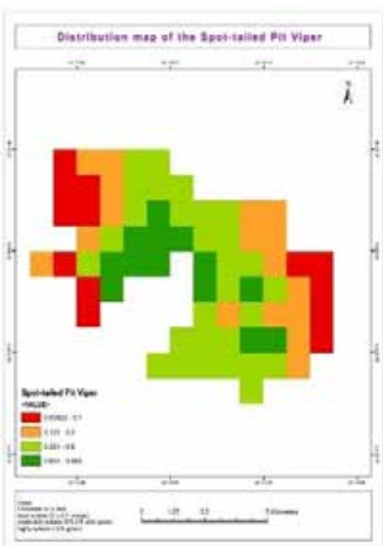


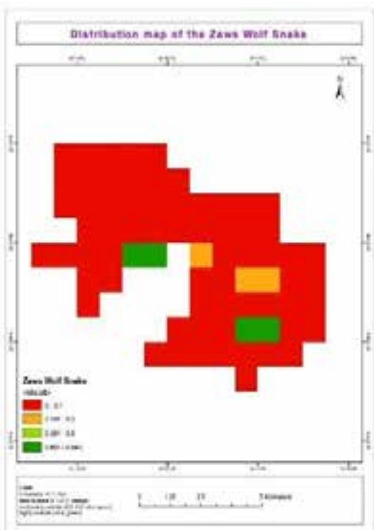


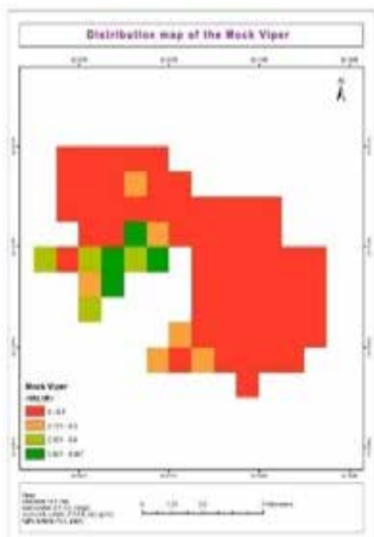




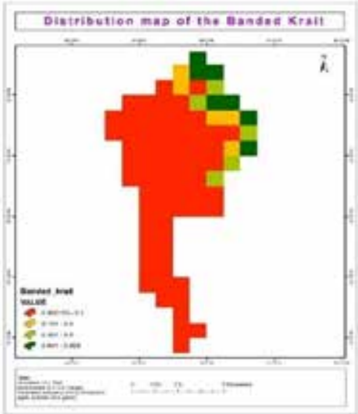


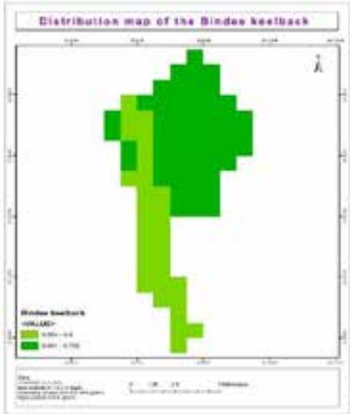


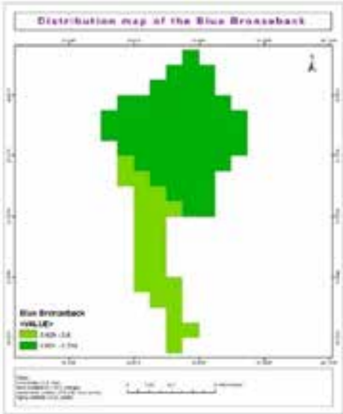


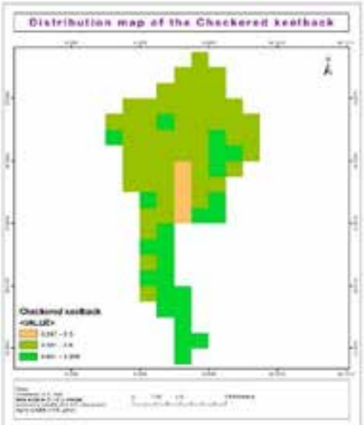


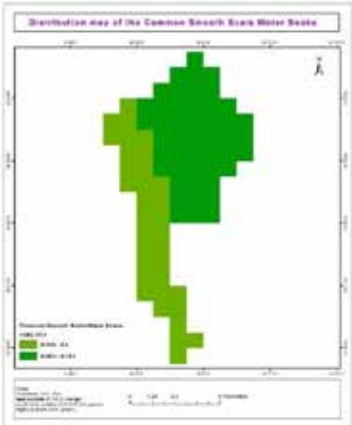
Annexure-2: Habitat Suitability Map of Snakes in DDWS.

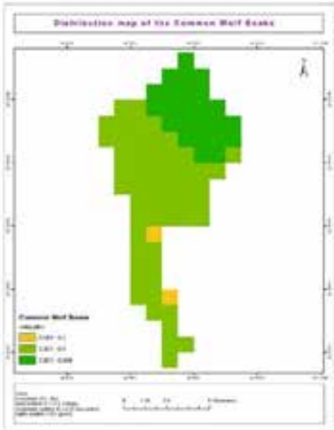


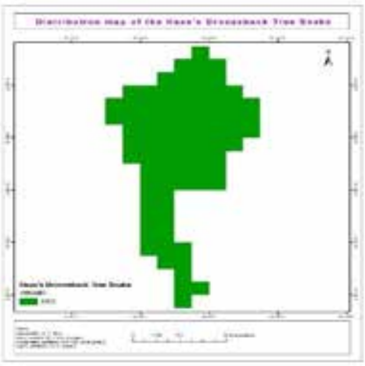


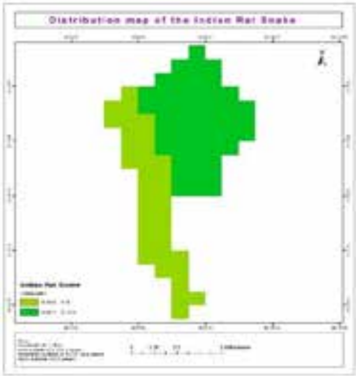


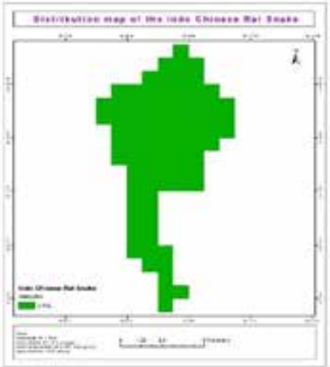


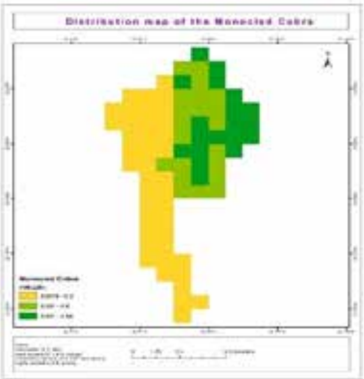


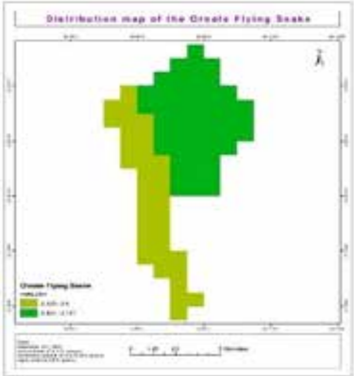


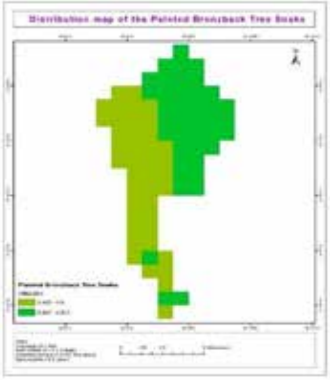












Annexure-3: Field Activities (survey, sample collection, preservation, data collection etc.) at KNP & DDWS.

Annexure-4: Observed direct threats for snakes at KNP & DDWS.

Fire and wood collection activities

Lemon cultivation

Cattle grazing

Little leaf cultivation

Herbicide

Herbicide use

Ginger cultivation

Tobacco cultivation

Pesticide use in waterbodies

Annexure-5: Laboratory based molecular analysis activities (Wildlife Population Genetic lab at the Department of Zoology, Jahangirnagar University).

Towards an understanding of the ecology and conservation of the Bengal Slow Loris, Nycticebus bengalensis in Bangladesh

by

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CHAPTER I

INTRODUCTION

1.1 Problem Statement

Primates form a major component of most of the Asian and other tropical forests (Vijay et al. 2016). Many primates worldwide are classified as Endangered or Critically Endangered by the IUCN (IUCN 2020). Currently, most of the South Asian forests, especially India and Bangladesh, are shrinking due to agricultural expansion or developmental pressures (Huges 2017). Alarmingly, approximately 60% of primates worldwide are now threatened with extinction and approximately 75% have declining populations (Estrada et al., 2017). In the Asian region, many primate species are on the verge of extinction, in particular the slow lorises (IUCN 2020, Boonratana, 2020). Habitat structure, quality and anthropogenic disturbance are known to affect primate diversity and abundance in tropical forests (Pyritz et al. 2010). Animals living in disturbed, degraded or fragmented habitats may also face reduced food resources, loss of roosting sites, escape cover and migratory routes. Many primates worldwide are endangered or critically endangered. Among the non-human primates, the status of slow lorises (*Nycticebus*) are of particular concern. Among the 10 species of primates found in Bangladesh (Ahsan 1984), Bengal slow loris *Nycticebus bengalensis* (Strepsirrhini: Lorisidae) is the only nocturnal species, remaining active throughout the night (IUCN 2015). This arboreal Strepsirrhini primate is native to Bangladesh, north-eastern India, Bhutan, Myanmar, China, Thailand, Cambodia, Lao P.D.R. and Viet Nam (Nekaris et al., 2020). Within its distribution range, *N. bengalensis* inhabits a variety of habitats, including tropical evergreen rainforest, semi-evergreen forest, and mixed deciduous forest from sea level up to 2,400 m (Choudhury, 2001; Nekaris et al., 2020). It shows ecological flexibility, residing in secondary to degraded forests, forest edges, bamboo stands and plantations (Nekaris et al., 2020). Limited information exists on the species in Bangladesh. Al Razi et al. (2020) determined the movement pattern, time activity budgets and home range size of Bengal slow lorises in Satchari National Park (SNP). This study highlighted that Bengal slow lorises could be present in higher densities than previously known. Yet, dwindling habitat quality, reduction of forest cover, decline in essential tree species, and hunting for the pet trade could all be causing declines in the Bengal slow loris. Thus, there is a need to better assess habitat requirements, movement patterns, home range sizes across much larger areas and in different types of forests in Bangladesh. This information is especially lacking in the southeastern forests of Bangladesh.

1.1 Objectives of the Study

Determine population density and estimate the population size of Bengal Slow Loris and other nocturnal mammals in southeastern forests of Bangladesh.

Characterize the movement patterns and propose conservation activities to protect Bengal slow lorises in Bangladesh

1.2 Research Questions

Estimate the abundance and density of slow loris and other nocturnal mammals in different habitat patches.

Assess the survival and adaptation of reintroduce lorises.

Demonstrate the home range, ranging behavior and feeding ecology of Bengal slow loris

CHAPTER II

LITERATURE REVIEW

Eight species of slow lorises are recognized - the Bengal, Bornean, greater, Hiller's, Javan, Kayan, Philippine, pygmy and Sody's slow lorises. Most of these species are either Endangered or Critically Endangered (Mittermeier et al. 2013). Lorises are small to medium-sized primates which range in weight from 103 g to 2100 g. They have a range of habitats over a vast area of southern and south-eastern Asia. The slow loris is a nocturnal primate that has forward-facing eyes and human-like hands with an opposable thumb. The name 'loris' is Dutch and meaning 'clown', which probably comes from the facial features that help to define the species. The slow loris is among the rarest primates on earth; they diverged from their closest cousins, the African bushbabies, around 40 million years ago (Mittermeier et al. 2013). Although slow lorises are seen as slow movers, they frequently 'race to walk' and can move up to 8 km per night.

The Bengal slow loris is thought to be widely distributed in northeastern and southeastern Bangladesh (IUCN 2015). The diet of the Bengal slow loris consists of nectar, plant bark, fruits and small invertebrates; the majority of their wild diet comprises plant exudates, and this is a key staple year-round (Pliosungnoen et al. 2010, Das et al. 2014). Females give birth to one offspring per litter once every two years in semi-wild conditions (Nekaris et al. 2020). Bengal slow lorises prefer forest edges because of the seasonal high density of insect prey found there (Rowe 1996). Thus, any kind of disturbances such as clear felling and burning for shifting cultivation (jhum) at the forest edge increases the vulnerability of the species and forces individuals to move towards other secure habitats for survival. Habitat destruction and disturbance due to shifting cultivation, encroachment, selective logging, road accidents, bushmeat hunting and forest fire have been reported as major threats to the slow loris populations in northeast India (Kumar & Devi 2010). Their toxic bite, once thought to be primarily a deterrent to predators, has been discovered to be primarily used in disputes within the species. The secretion from the arm contains a chemical related to cat allergen but may be augmented by secondary toxins from the diet in wild individuals.

Slow Lorises move slowly and deliberately, making little or no noise, and when threatened, they stop moving and remain motionless (Mittermeier et al. 2013). Their only documented predators—apart from humans—include snakes, changeable hawk-eagles and orangutans, although cats, viverrids and sun bears are suspected. Little is known about their social structure, but they are known to communicate by scent marking. Males are highly territorial. Slow lorises reproduce slowly, and the infants are initially parked on branches or carried by either parent. They are omnivores, eating small animals, fruit, tree gum, and other vegetation.

Bangladesh has a rich biological heritage. The entire country has significant wetlands, homestead forests and forest patches that serve as habitat for wildlife. Among three types of natural forest, the mixed evergreen forest and deciduous forest are facing tremendous pressure of habitat loss; however, they are the main habitat of many endangered wildlife and most of the primates. Bengal slow loris is 'Endangered' in Bangladesh (IUCN 2015) and has recently been downgraded globally from 'Vulnerable' to 'Endangered' (Nekaris et al. 2020). Due to their nocturnal habit, Bengal slow lorises remain among the least studied primates in the world, and very little data are available from India (Radhakrishna et al. 2006; Das et al. 2009; Das et al. 2015; Swapna et al. 2008), Bhutan (Choudhury 2008), Viet Nam (Fitch-Snyder and Thanh 2002), Cambodia (Starr et al. 2010), Thailand (Pliosungnoen et al. 2010) and Bangladesh (Al- Razi et al. 2020).

The distribution of the Bengal slow loris in Bangladesh is still unclear and poorly understood. According to IUCN (2015) this species is thought to be found in some fragmented forest patches of north-eastern and south-eastern Bangladesh. Nekaris et al. (2020) reported a small number of individuals that had been rescued from human habitations in the northern border areas of Bangladesh. In the late 1970s, the Bengal slow loris occurred in the Sal forests of Balijhuri range of Jhinaigati Upazila, beyond the Gajni Reserve of Sherpur district, bordering Tura Hills in Meghalaya state in India (Khan & Ahsan, 1986). The Bengal slow loris is believed to have been extirpated from the Sal forests in Bangladesh over the last three decades (Khan, 1987; IUCN Bangladesh, 2015). Khan (2018) included the northern border areas, where a number of individuals were rescued (Nekaris et al., 2020). Recent sighting reports suggest the presence of Bengal slow loris in the central and north-central Sal *Shorea robusta* (Gaertn) forests (Ahmed and Rupom 2021).

The Bengal slow loris requires a contiguous forest with a closed canopy tree structure (Al-Razi et al. 2020). They appear to survive in a variety of different habitat types in their global distributional range, including tropical evergreen rainforest, acacia-scrub forest, dry dipterocarp forest, semi-evergreen forest, moist deciduous forest (Mittermeier et al. 2013). Several species of slow loris and the slender loris use the dense forest canopy as their preferred habitat for foraging, sleeping and other activities (Nekaris et al. 2017; Nekaris 2003; Pliosungnoen et al. 2010). Their activities had been disrupted in less dense canopy structured forests (Pliosungnoen et al. 2010). However, they may be found in close proximity to agricultural land and plantations (including orchards). In these agro-forest mosaics, they typically use small trees with canopy that may be interconnected with branches and vines, moving at heights of 20m above the ground (Mittermeier et al. 2013). In natural forests, they tend to use tall trees with large diameters and avoid habitats with sparsely connected canopies (Mittermeier et al. 2013). In an earlier study, Bengal slow lorises were observed to utilize gardens and lemon plantations effectively for movement between suitable forest areas or in search of insects and exudates (Al-Razi et al. 2020). This makes the species more resilient than previously thought and could help in developing corridors between forest fragments.

To understand the ecological requirements of a species and its behavioural adaptations to ecological changes it is essential to understand its ability to adapt to such changes (Chapman and Rothman 2009; Sinha 2005; Strier 2008) and to design effective conservation strategies (Twinomugisha and Chapman 2007). Animals use a hierarchical decision-making process during territory and home-range selection. First, they choose the appropriate general habitat, then they assess how to use the various habitat patches (microhabitats) within it, and they finally choose an area to inhabit (Orians and Wittenberger 1991). Foraging activities, movement, and seed dispersal by arboreal species are of particular importance to ecosystem functions such as forest regeneration and maintenance of forest health (McConkey and O'Farrill, 2016). Nocturnal primates have especial importance due to their role in pollination and exudativory (Cabana et al. 2017; Das et al. 2014). The Bengal slow loris dedicates 80% of their feeding bouts to consuming exudates and 4.45% of fruits (Das et al. 2014). Their roles in forest functioning are still unclear.

An earlier study on their basic natural history was the first of its kind in the country (Al- Razi et al. 2020). There is a paucity of information on its status, distribution, ecology and behaviour (Al-Razi et al., 2020) in Bangladesh. The population of Bengal slow loris have been reduced by about 50% in Bangladesh over the last two decades. Much of its remaining habitat is in small, isolated fragments and shrinking rapidly (IUCN Bangladesh, 2015). Proper conservation initiatives should be taken immediately. Specialized nocturnal surveys are crucial to revealing the ecology, distribution and site-specific population status of Bengal slow loris in Bangladesh.

CHAPTER III

METHODOLOGY

3.1 Study Area

3.1.1 Locations

The study areas were selected based on the historical geographic distribution of Bengal slow loris (Hasan, 2015; Ahmed and Rupom, 2021; Al-Razi et al., 2023). To understand the spatial distribution, abundance and population size the surveys were carried out in 14 protected areas of northeastern, southeastern and northern forest patches in Bangladesh (Fig. 2). Also the assessment of people's attitude towards Bengal slow loris were done in all study sites based on questionnaire surveys to classify the intensity of threats. This nocturnal primate prefers closed canopy forests composed of a variety of tree species. Our surveys covered all types of forest except mangroves in Bangladesh where the species is not known to occur. We surveyed three northern deciduous forests: Madhupur National park (24°41'29.94"N, 90° 5'55.73"E), Madhutila Eco Park (25°12'17.96"N, 90° 9'8.89"E), and Gajni reserve Forest (25°15'4.65"N, 90° 2'9.42"E); three northeastern forests: Patharia Hill Reserve Forest (24°37'49.37"N, 92°13'37.16"E), Rema-Kalenga Wildlife Sanctuary (24° 9'10.50"N, 91°37'30.85"E), and Raghunandon Hill Reserve Forest (24° 7'23.28"N, 91°27'4.25"E); and eight southeastern forests: Barkal Reserve Forest (22°43'14.71"N, 92°22'41.40"E), Hazarikhil Wildlife Sanctuary (22°42'24.51"N, 91°40'41.53"E), Kaptai National Park (22°29'52.87"N, 92°10'45.49"E),

Sangu-Matamuhuri Wildlife Sanctuary (21°25'23.52"N, 92°33'54.62"E), Fashiakhali Wildlife Sanctuary (21°42'14.96"N, 92° 5'7.26"E), Bangdepa Wildlife Sanctuary (21°31'28.80"N, 92° 8'43.83"E), Sheikh Jamal Inani National Park (21°13'22.34"N, 92° 3'47.56"E), Dudhpukuria- Dhopachari Wildlife Sanctuary (22°18'5.50"N, 92° 7'34.54"E). The behavioral studies of Bengal slow loris were carried out in Satchari National park and Madhabkunda Eco Park.

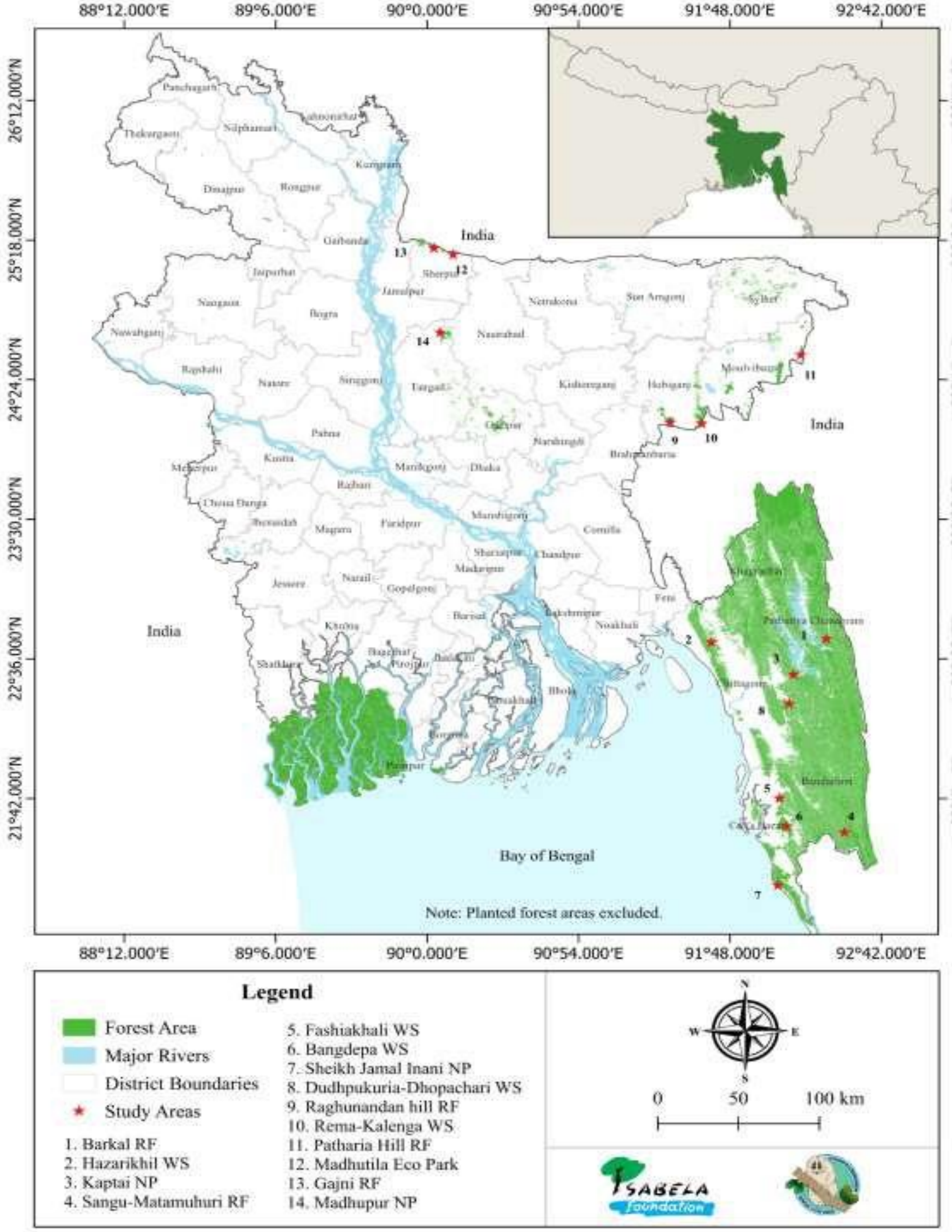


Figure 1 : Map showing the study sites in northeastern and southeastern Bangladesh. The areas consisted of closed canopy forest patches suitable for western hoolock gibbon that were surrounded by human habitation or farmlands. NP = National Park, WS=Wildlife Sanctuary, RF= Reserve Forest.

3.2 Methods

3.2.1 Inauguration and Training Program

We built a research team ‘Walk for Loris’ comprising of 8 members. To involve the future generation in loris research and conservation we arranged a 4-day workshop. About 40 personnel combining graduate and undergraduate students had shown their interest to join in the project. Primarily we selected 16 of them and arranged one day in house and four days on field training program in Madhabkunda Eco Park a known loris habitat. They were trained how to survey loris and collect data in the field

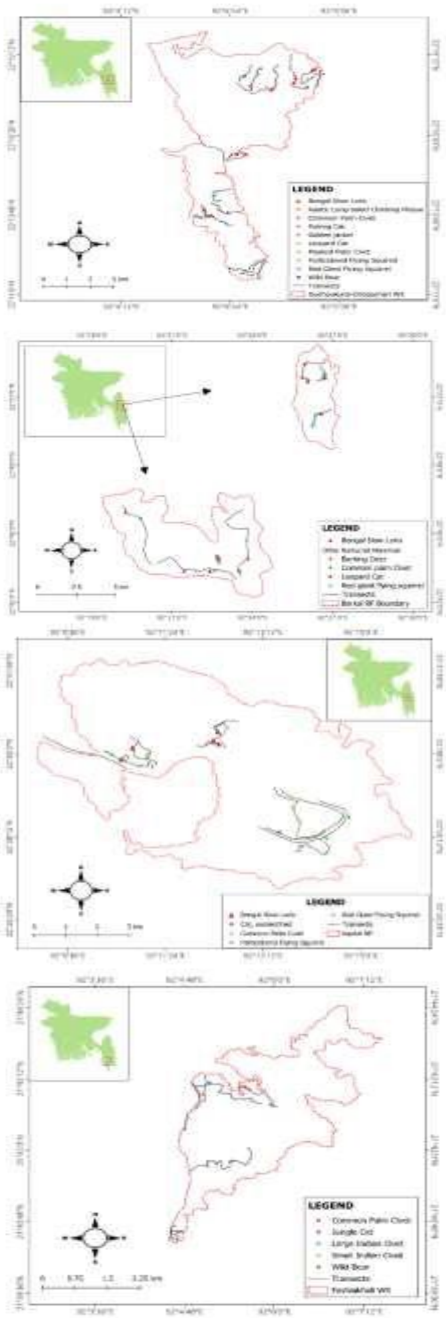
Professor Dr. Anna Nekaris from Oxford Brooks University, UK, Marcel Stawinoga, founder of Plumploris e.V., Germany and Stan Lhota, Research Scientist at Czech University of Life Sciences Prague visited the rescue center in SNP (Fig. 3). Their guidance and suggestion were considered during preparation of the center. They also joined in the nocturnal survey fieldwork. When a Bengal slow loris was encountered we observed it for long time using red-light headlamp and collected the data in their presence. We discussed about the survey methods and protocols in the field. The capacity building session was organized in SNP. Proper training on handling, tagging and caring lorises in captivity was provided by Professor Dr. Anna Nekaris and Marcel Stawinoga.

Figure 2: Inauguration and training program held in Satchari National Park and Madhabkunda Eco Park.

Selection of sampling methods and sites

3.2.1 Population Survey

The study carried was out in 14 selected forests patches from October 2022 to June 2024, which covered a total of 1226 km^2 area (Fig. 3, 4). We invested 113 days for nocturnal survey to estimate the population size, abundance and richness of nocturnal mammals on special focus in Bengal slow loris. We used pre-established trails to record every visible nocturnal mammal from 18:00 to 23.30. The length of each survey trail varied from 0.5 km to 7.5 km (avg. 1.28; SD 1.26 km), and 144 number of transects comprising 307.72 km length were covered during nocturnal surveys. We used the distance sampling method (Burham et al. 1980, Thomas et al. 2010) for population surveys. A group of two to four observers walked on the trails at a speed of ~0.5-1.5 km/hour each night and searched for nocturnal mammals in the forest canopy as well as lower forest levels and on the ground (Fig. 5). Each observer used a 300-lumen headlamp covered with a red filter to minimize disturbance to animals (Das et al. 2014). Once an individual was detected, its location in relation to the transect was determined using a rangefinder (SUAOKI Digital Laser Rangefinder Scope5-600P, China) that provided perpendicular distance. Upon encountering a mammal, we recorded the GPS coordinates, time of detection, moon phase and habitat condition. Habitat were categorized into five types; natural swamp forest, natural hilly forest, monoculture, destructed forest and homestead vegetation.



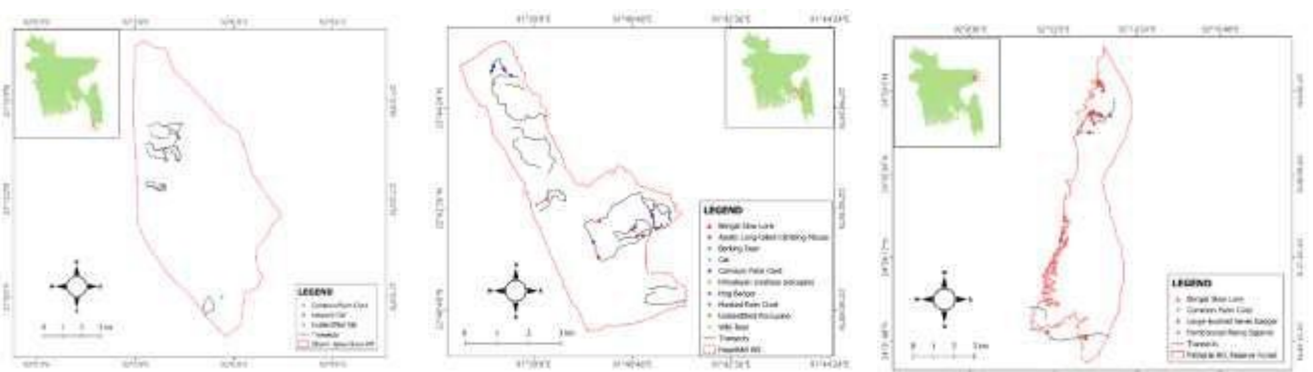


Figure 3: Survey transects and distribution of Bengal slow loris and other nocturnal mammals in 14 study sites.

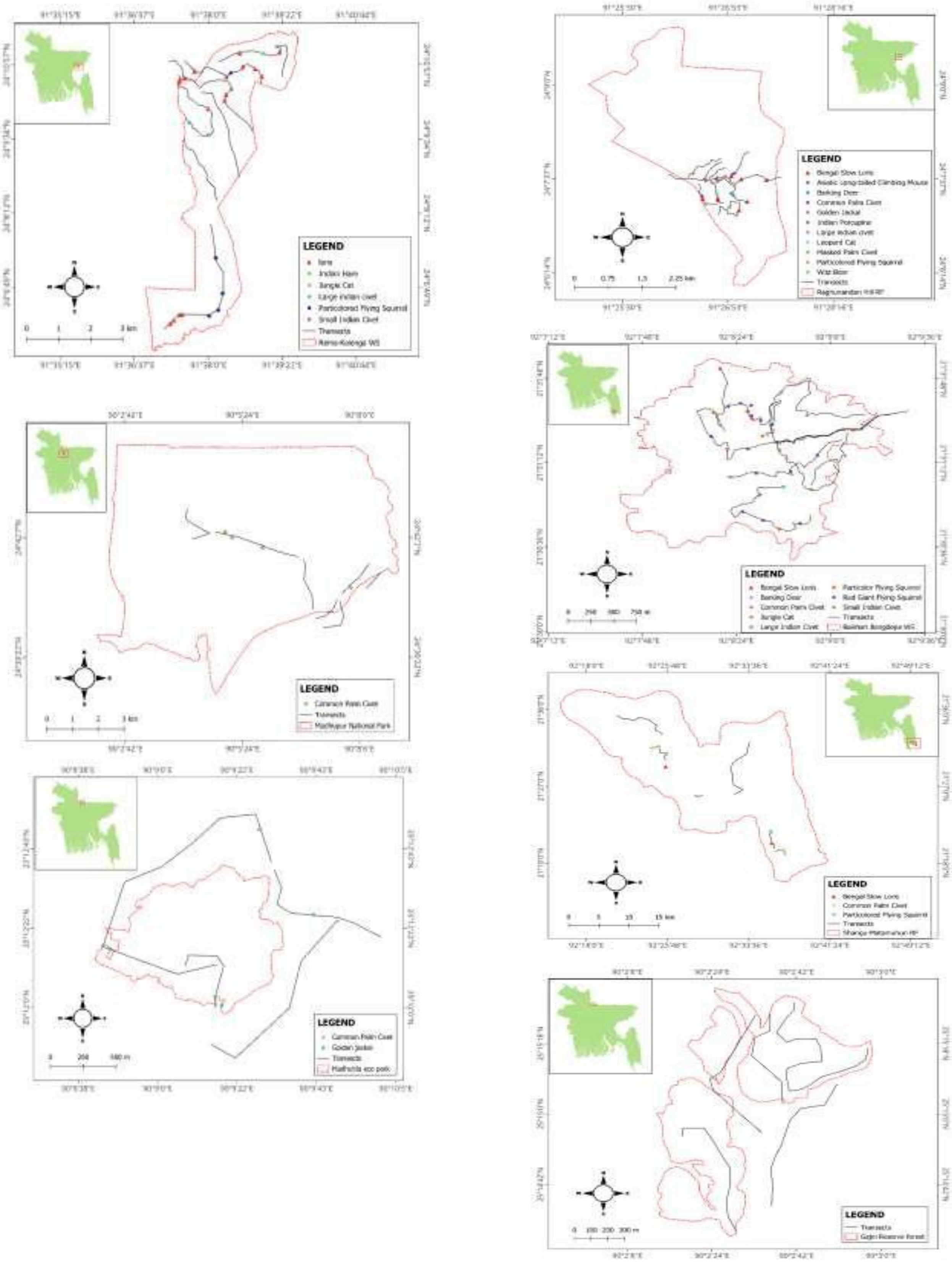


Figure 4: Survey transects and distribution of Bengal slow loris and other nocturnal mammals in 14 study

Figure 5: Nocturnal population survey and awareness campaign of Bengal slow loris and other nocturnal mammals in 14 selected study sites from October 2022 to Jun 2024.

3.2.2 Movement/Ranging Ecology

3.2.2.1 *Captive care, tagging and release of Bengal slow loris:*

Five rescued Bengal slow lorises were tagged using radio collars and three of them were released in Madhabkunda Eco Park and two in Satchari National Park. These lories were rescued by Wildlife Crime Control Unit, WCCU of Bangladesh Forest Department and local community peoples from different locations (Table 1). We created artificial habitat with bamboo, wood box and tree branches and set them in vertical, horizontal and diagonal angle directions within rescue centers. We nursed the loris for four to five days and proper diet and care were provided (Fig. 8; Table 2). The consumption of food in captivity varies according to their age. Lorises ate 115±10 g (mean±standard error) of food daily. For nightlong observation in the enclosure, we installed two camera traps from different angles to provide full coverage of their activities. After health checkup, we tagged the loris by radio collar transmitter (Holohil System Ltd., Model-RI-2DM, with antennas and receivers from ATS Advance Telemetry System) and kept them in the rescue center to ensure radio collar did not create any inconvenience for the tagged individuals (Fig. 6). The weight of transmitters were 7.5g (<3% of the total body weight of the loris) having 14 months of the battery life.

We ensured that the individuals' feeding and movements were normal and the es were fit enough to survive in the wild. After releasing the each loris in the wild, we tracked them and collected behavior data for consecutive days as they settled down and chose a territory (Fig. 7).

Figure 6: Collaring confiscated Bengal slow loris using radio transmitter.

Table 1: Radio collar tagging of rescued Bengal slow loris in Madhabkunda Eco Park and Satchari National park.

SL NO	Tracking ID	Name of the Loris	Rescued from	Released in	Sex	Weight
L1	264925; 148.088 HSL	Chobi	Madhabkunda Pan Punji	MEP	Female	1.145 kg
L2	264923; 148.048 HSL	Liton	Haluaghat, Mymemsing	MEP	Male	1.17 kg
L3	264927; 148.128 HSL	Anna Nekaris	Private land, Homestead	MEP	Female	1.21 kg
L4	264928; 148.028 HSL	Dian Fossey	Haluaghat, Mymemsing	SNP	Female	0.986 kg
L5	264926; 148.108 HSL	Jane Goodall	Rangamati	SNP	Female	0.951 kg



Figure 7: Release of confiscated Bengal slow lorises in Satchari National Park and Madhabkunda Eco Park.

Table 2: Sample captive diet fact sheet of Bengal slow loris (ID: Chobi).

Day	Supplied Items	Weight	Consumed Items	Weight
	Banana	89g	Banana	89g
	Carrot	20g	Tree Gum (ছাতিম, *Alstonia scholaris*)	6g
	Cucumber	23g	Tree Gum (জিগা, *Lannea coromandelica*)	29g
Day-1	Lory Nectar	174g		
	Tree Gum (ছাতিম, *Alstonia scholaris*)	51g		
	Tree Gum (জিগা, *Lannea coromandelica*)	44g		
			Total consumption	**124g**
	Banana	52g	Banana	52g
	Tree Gum (ছাতিম, *Alstonia scholaris*)	33g	Tree Gum (জিগা, *Lannea coromandelica*)	19g
	Tree Gum (জিগা, *Lannea coromandelica*)	19g	Insect larva	5g
Day-2	Insect larva	5g		
	Lory Nectar	174g		
	Cucumber	20g		
			Total consumption	**76g**
	Tree Gum (জিগা, *Lannea coromandelica*)	14g	Tree Gum (জিগা, *Lannea coromandelica*)	14g
Day-3	Boiled Egg	45g	Boiled Egg	35g
	Lory Nectar	101g	Banana	56g
	Banana	56g		
			Total consumption	**105g**
			Average	**101.67g**

Provisioning of lychee for loris in captivity

Provisioning of live insect in captivity for loris

Observing captive behavior of loris through camera trap in SNP Observing captive behavior of loris through camera trap in MEP

Observing captive behavior of loris through camera trap in SNP Observing captive behavior of loris through camera trap in MEP

Provisioning of plant gum for loris

Collection of plant sap for loris

Figure 8: Captive care of Bengal slow loris in Satchari National Park and Madhabkunda Eco Park.

3.2.2.2 Behavioral Data collection

Ecological data of reintroduced Bengal slow lorises were collected from two field sites, Satchari National Park and Madhabkunda Eco Park. Five individuals were tagged using radio collar transmitters. Among them we collected ecological data from four individuals. And, one male individual died within one month. During the behavioral study, a total of 84 nights were spent to collect behavioral data. Among them, we have observed and collected data of 71 full nights. Due to weather and other constraints, we also collected data of 11days of partial nights. We used an antenna and receiver to track the lorises (Fig. 9). Lories were followed from dusk to dawn for three days per month following focal animal sampling protocol (Nekaris 2001). We recorded the activities in different posture and locomotion (Fig. 10, 11), feeding and social behavior of the lorises for 15 minutes with 15 minutes of interval. To understand the ranging pattern we recorded the locations of loris every 15 minute interval using portable GPS. Data collected over an entire night were considered for calculating daily path lengths (DPL). The google earth pro software was used to measure DPL. All location points were used to calculate the home range. We recorded the feeding items and the methods of feeding (by licking, by hand, etc). The locations of sleeping trees were recorded and marked and height was measured by using a portable Laser Range Finder. Diameter at Breast Height, DBH of the sleeping trees were measured using measuring tape.

Figure 9: Tracking and behavioral data collection of Bengal slow loris in Satchari NP and Madhabkunda EP.

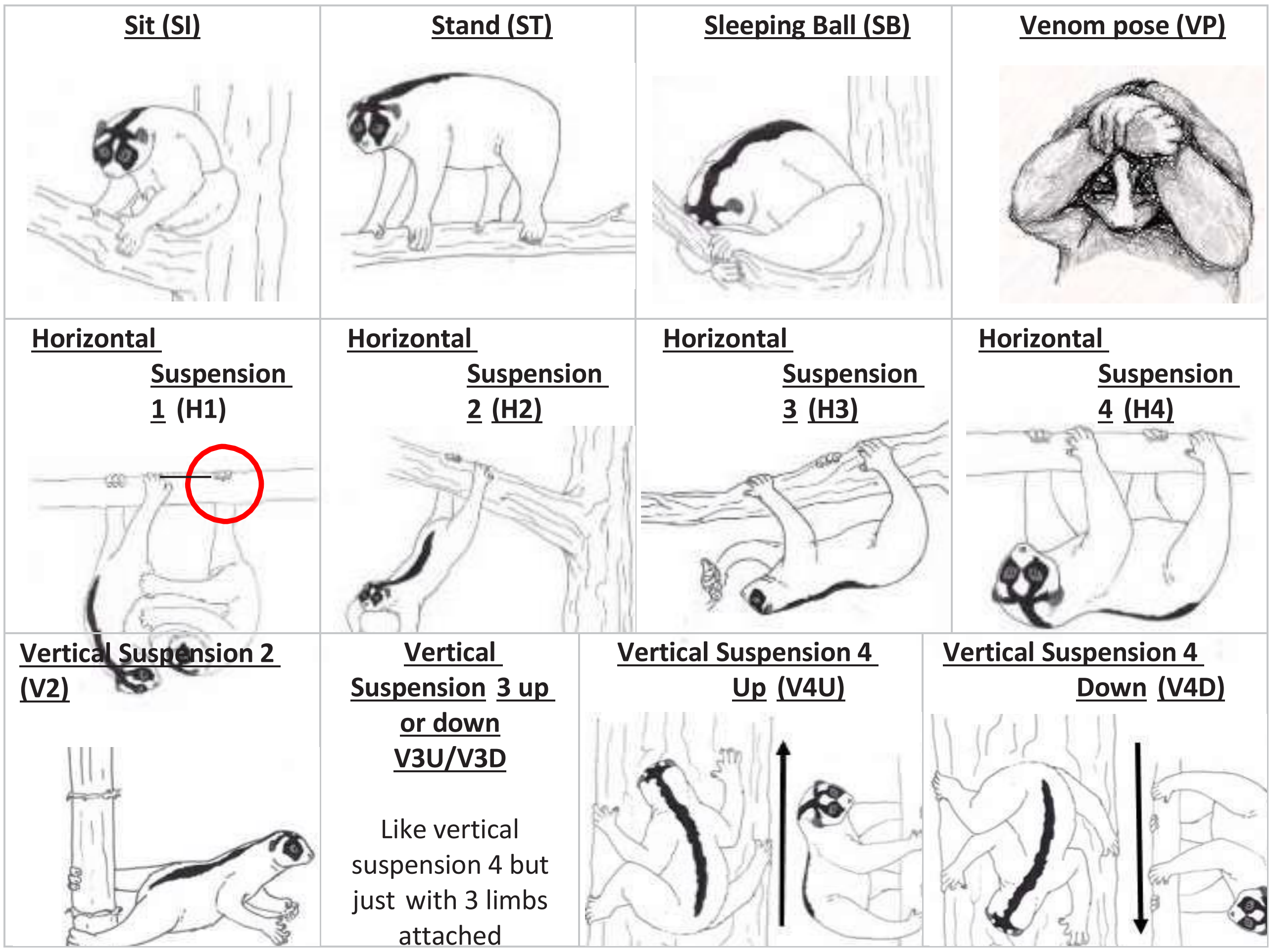


Figure 10: Different postures of Bengal slow loris recorded during activities data collection.

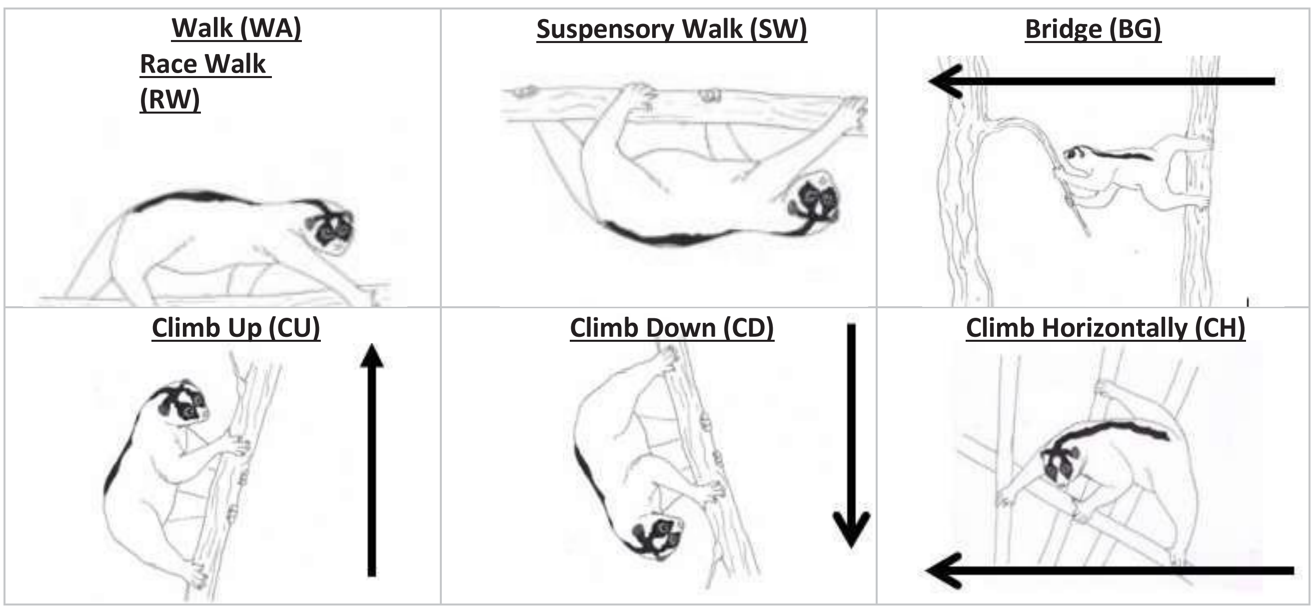


Figure 11: Guideline of data collection using different locomotion of Bengal Bengal slow loris.

3.2.3 Questionnaire survey

From three study regions, we conducted 140 questionnaire surveys; among them 110 were from the southeast region, 15 from northeast, and 15 from northern region. People from different locations and ethnicities who depend on the forest for their livelihoods were interviewed to find out and understand the differences in societal views and relationships with Bengal slow loris and other nocturnal animals. People from Chakma, Marma, Khasiya, Tripura, Garo, and Tanchoinga, and Bengali were interviewed (Fig. 12). The survey was conducted by personal interviews with open-ended and closed-ended questions and focus group discussions with traditional medicine doctors, local hunters, sellers, traders, and farmers from indigenous people were conducted. Among the respondents, 131 were males and 9 were females. Their age ranged from 19 to 90, with the majority being between 31 and 50 years old.

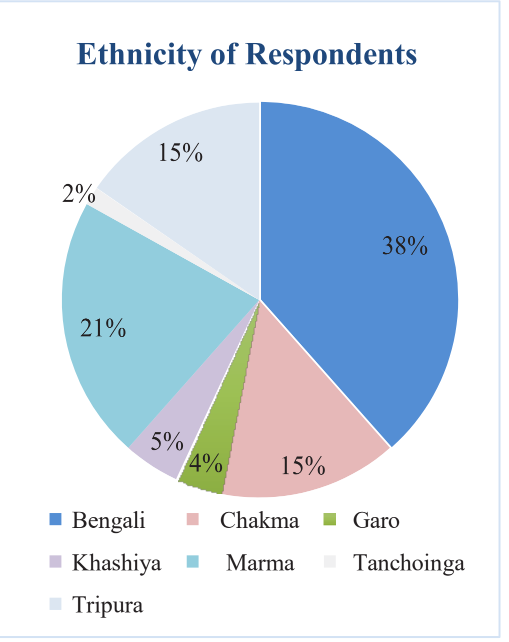


Figure 12: Questionnaire surveys to assess the threats and local people's attitudes towards Bengal slow loris.

3.2.3 Analytical methods

Habitat Suitability Modeling

The habitat suitability model of the Slow Loris was developed using the Weighted Overlay tool in ArcGIS 10.8 by integrating multiple environmental and climatic factors. The analysis incorporated six raster datasets: Elevation, Slope, Land Use and Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), and two bioclimatic variables, Bio10 (Mean Temperature of Warmest Quarter) and Bio15 (Precipitation Seasonality). This approach enabled a comprehensive assessment of habitat suitability by considering topographical, ecological, and climatic influences.

Population size

We used distance sampling protocols to record all encountered data collected during population survey. Population size was estimated using Distance 7.5 software. Conventional distance sampling (CDS) analysis tool was used to run the detection function, encounter rate/ or cluster size and density estimation (Buckland el al. 2004). We selected five detection function models (Half-normal, Cosine; Half-normal, Simple polynomial; Hazard-rate, Cosine; Hazard-rate, Simple polynomial, Uniform, Cosine) and set Akaike Information Criterion (AIC) for term selection criterion for the best fit. The best-fit model, Hazard-Cosine rate was selected based on the minimum AIC value (604.62), Chi-p = 0.30196, f (0)= 0.46981E-01, p= 0.23650 with 95% of confident level. Habitat suitably modeling classified the preferable habitat into four classes based on the five significant factors which influence the loris distribution (described above): Unsuitable, Less suitable, Moderately suitable, and Highly suitable area for Bengal slow loris. After validation and measure, the raster data classified habitat area used in conventional distance sampling analysis for loris population estimation. We excluded the area from the distance analysis where lorises are extirpated confirmed by both survey and locals perception.

Activity and Feeding Behavior

Percentage of food items (fruits, leaves, flowers, animal matters) was calculated based on overall feeding scans for the pre-monsoon season (March – May), monsoon season (June – October) and winter (November – February). Diet was compared between seasons and across years using logistic regression using a logit link (Sokal & Rohlf, 2012). The important feeding plants were ranked based on percentage of consumption.

Daily Path Length and Home range

We used Google Earth Pro software to measure the daily path length as the sum of the linear distances between successive locations from daily group movements (Zhang et al., 2013), using only data for entire nights. We used the previous day's sleeping location as the starting point for daily path length. We compared daily path lengths in different seasons using the Welch's F test (Sokal & Rohlf, 2012). We conducted multiple linear regression with daily path length as the response (dependent) variable and the daily percentage occurrence of dietary items (fruit, leaf, flower, and bud) as explanatory variables (Sokal & Rohlf, 2012). For all analyses, we considered the results significant when $\alpha<0.05$.

CHAPTER IV

RESULT AND DISCUSSION

4.1 Distribution and Population status of Bengal slow loris and other nocturnal mammals

Distribution: Nocturnal mammals were surveyed in 14 protected forests areas based on the historical distribution of Bengal slow loris. Surveys revealed that several forest patches hold a good number of lorises. However, lorises were extirpated from several forest patches due to massive hunting and habitat loss (Table 3). No Bengal slow loris were encountered from the northern deciduous forests; Madhupur National park, and Gajni Reserve forest. Except, one individual was recorded from Madhutila EP. The encounter rate of loris was 0.16/km^2 from southeastern forests and 0.79/km^2 from northeastern forests. No loris was found in Fashiakhali Wildlife Sanctuary, Sheikh Jamal Inani National Park (Fig. 13). Among southeastern forests, the encounter rate was high in Chittagong Hill Tracks (0.21/km^2) and low in the forests situated in Chittagong District (0.04/km^2). About 83% of Bengal slow loris was encountered from natural forest and 9%, 1%, 7% were encountered from Homestead, Agroforestry and Segun Dominated vegetation respectively (Fig. 15). We classified the habitat types based on the condition of habitat and found 78% lorises in good forest conditions, 13% in moderate and 9% in degraded forest conditions (Fig. 14). Bengal slow loris prefer forest edge because of the availability of insects at the edge. About 48% of lorises were found in the forest edge.

Besides Bengal slow loris we found 18 nocturnal mammals during surveys (Table 4; Fig. 16, 17). Among them 11 are threatened, one Data Deficient and two are not recorded according to IUCN red list of Bangladesh (IUCN Bangladesh 2015). A Data Deficient (DD) species, red giant flying squirrel, *Petaurista petaurista* were found in several southeastern forest patches, Barkal RF, Kaptai NP, Dudhpukuria-Dhopachari WS, Baishari Bangdepa WS. Questionnaires survey confirm their distribution in Sangu-Mathamuhuri WS, but no individual was recorded during nocturnal survey. We found large-toothed ferret badger *Melogale personata,* and Himalayan crestless porcupine *Hystrix brachyura* which are not recorded in IUCN Red List of Threatened Species, in Bangladesh. Also our survey recorded particolored flying squirrel *Hylopetes alboniger*, common palm civet *Paradoxurus hermaphroditus*, masked palm civet *Paguma larvata*, large Indian civet *Viverra zibetha*, small Indian civet *Viverricula indica*, leopard cat *Prionailurus bengalensis*, jungle cat *Felis chaus*, fishing cat *Prionailurus viverrinus*, golden jackal *Canis aureus*, Asiatic long-tailed climbing mouse *Vandeleuria oleracea*, wild boar *Sus scrofa*, hog badger *Arctonyx collaris*, barking deer *Muntiacus muntjak*, and Indian hare *Lepus nigricollis*.

Table 3: Forest wise species diversity index value of nocturnal mammals and encounter rate of Bengal slow loris.

Region	Study Sites	Nocturnal Mammals Diversity Index	Encounter rate of Bengal slow loris
Southeastern semi-evergreen forest	Barkal RF	1.24	0.32
	Kaptai NP	1.32	0.19
	Dudhpukuria-Dhopachari WS	1.75	0.35
	Hazarikhil WS	1.83	0.09
	Fashiakhali WS	1.49	0.00
	Baishari Bangdepa WS	1.57	0.06
	Sheikh Jamal Inani NP	1.04	0.00

Region	Study Sites	Nocturnal Mammals Diversity Index	Encounter rate of Bengal slow loris
	Sangu-Matamuhuri WS	1.05	0.06
Northeastern semi-evergreen forest	Raghunandan Hill RF	2.12	0.78
	Rema-Kalenga WS	1.16	0.95
	Patharia HRF	0.89	0.70
Northern deciduous forest	Madhupur NP	0	0.00
	Madhutila Eco Park	0.38	0.00
	Gajni RF	0	0.00

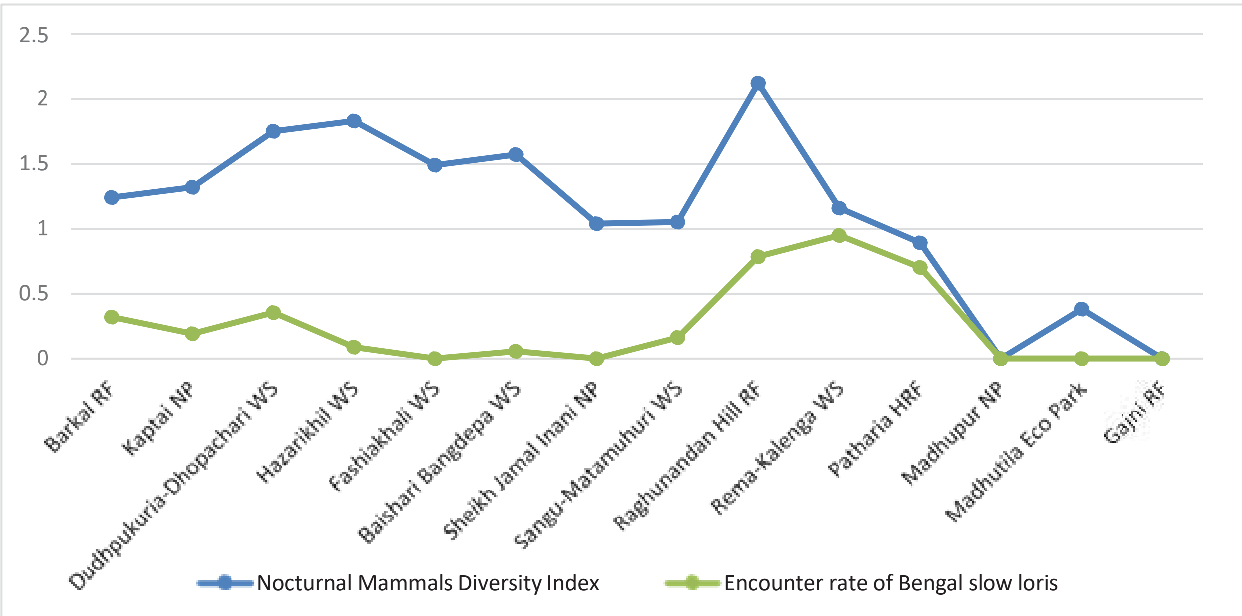


Figure 13: Figure showing Encounter rate of Bengal slow loris and richness diversity index value of nocturnal mammals in study sites.

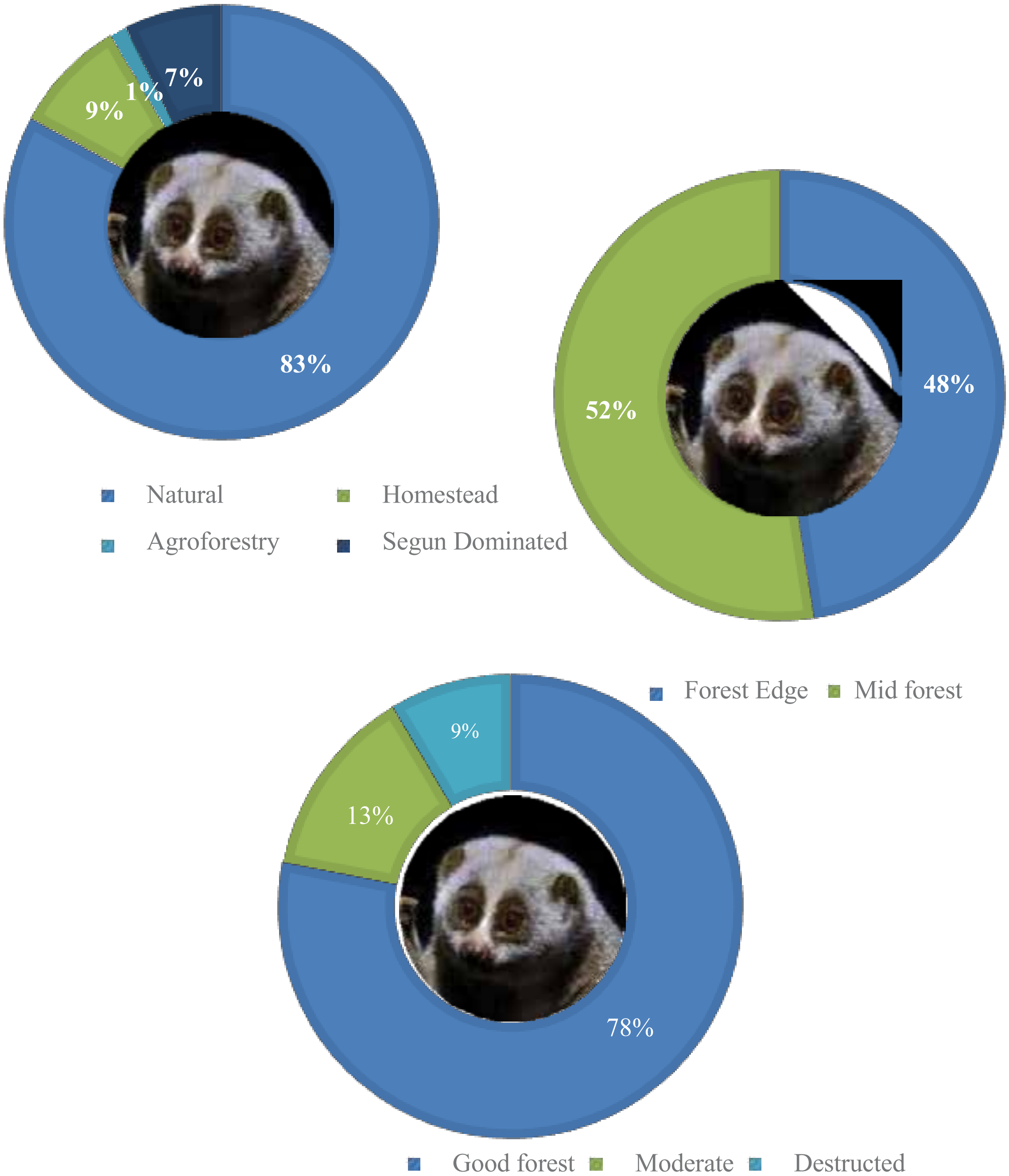


Figure 14: Encounter percentage of Bengal slow loris in different habitat types.

Table 4: Encounter rate of other nocturnal mammals in study sites.

Study Sites	Red Giant Flying Squirrel	Particolored flying squirrel	Common Palm Civet	Masked Palm Civet	Large Indian Civet	Small Indian Civet	Large-toothed ferret badger	Leopard Cat	Fishing Cat	Golden Jackal	Jungle Cat	Himalayan Crestless	Asiatic Long-tailed Climbing	Wild Boar	Hog Badger	Barking Deer	Indian Hare	Unknown Sp.
National IUCN Status	**DD**	**EN**	**LC**	**VU**	**NT**	**NT**	**NR**	**NT**	**EN**	**LC**	**NT**	**NR**	**LC**	**LC**	**VU**	**EN**	**EN**	…
Barkal RF	0.5	0	0.2	0	0	0	0	0.03	0	0	0	0	0	0	0	0.03	0	0
Kaptai NP	0.32	0.03	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
Dudhpukuria-Dhopachari WS	0.15	0.46	0.05	0.03	0	0	0	0.03	0.03	0.1	0	0	0.03	0.05	0	0	0	0
Hazarikhil WS	0	0	0.33	0.03	0	0	0	0	0	0	0	0.06	0.1	0.03	0.06	0.06	0	0.03
Fashiakhali WS	0	0	0.08	0.00	0.16	0.08	0	0	0	0	0.25	0	0	0.08	0	0	0	0
Baishari Bangdepa WS	1.25	0.39	0.28	0	0.11	0.3	0	0	0	0	0.11	0	0	0	0	0.06	0	0
Sheikh Jamal Inani NP	0	0	0.04	0.00	0	0	0	0.04	0	0	0	0	0.08	0	0	0	0	0
Sangu-Matamuhuri WS	0	0.03	0.06	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raghunandan Hill RF	0	0.26	0.26	0.09	0.17	0	0	0.09	0	0.35	0	0.17	0.09	0.09	0	0.17	0	0
Rema-Kalenga WS	0	0.23	0	0.00	0.12	0.06	0	0	0	0	0.06	0	0	0	0	0	0.04	0
Patharia HRF	0	0.18	0.07	0.00	0.00	0	0.04	0	0	0	0	0	0	0	0	0	0	0
Madhupur NP	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Madhutila Eco Park	0	0	0.15	0	0	0	0	0	0	1.04	0	0	0	0	0	0	0	0
Gajni RF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Red Giant Flying Squirrel

Particolored flying squirrel

Jungle cat

Leopard Cat

Golden Jackal

Large-toothed ferret badger

Figure 15: Nocturnal mammals encountered in 14 study sites.

Common Palm Civet

Small Indian Civet

Asiatic Long-tailed Climbing Mouse

Himalayan Crestless Porcupine

Wild Boar

Barking Deer

Figure 16: Nocturnal mammals encountered in 14 study sites.

Habitat Suitability of Bengal slow loris

Weighted overlay tool of ArcGIS (10.8) incorporated six raster datasets: Elevation, Slope, Land Use and Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), and two bioclimatic variables, Bio10 (Mean Temperature of Warmest Quarter) and Bio15 (Precipitation Seasonality) to classify the habitat suitability of Bengal slow loris. The habitat suitability map provided four intensity level of suitability; highly suitable, moderately suitable, Less Suitable and Unsuitable areas (Table 5) for lorises. Model did not provide any estimation for Madhutila EP and Gajni RF because of minimal area of study sites. In general, analysis estimate a total of 0.83% unsuitable, 47.66% less suitable, 42.59% moderately suitable and 9.01% highly suitable area still exist for Bengal slow loris in study sites (Fig. 17, 18)..

Table 5: Percentages of habitat suitability of Bengal slow loris in study sites.

Study area	Percentage of Habitat Condition			
	Unsuitable	Less suitable	Moderately suitable	Highly suitable
Barkal RF	0.2	44.78	52.45	2.57
Hazarikhil WS	0.73	40.08	49.71	9.48
Kaptai NP	0.17	41.17	40.45	18.2
Shangu-Matamuhuri RF	0.01	13.32	39.22	47.45
Fashiakhali WS	1.02	54.94	42.84	1.2
Baishari Bangdepa WS	3.26	41.02	51.59	4.13
Sheikh Jamal Inani NP	2.67	89.44	7.84	0.05
Dudhpukuria- Dhopachari WS	0.001	69.8	29.9	0.3
Raghunadan Hill RF	1.51	10.55	71.2	17.74
Rema-Kalenga WS	0.07	33.14	60.32	6.47
Patharia Hill RF	0.02	67.71	31.94	0.32
Madhutila Eco Park				
Gajni RF				
Madhupur NP	0.29	65.91	33.67	0.12

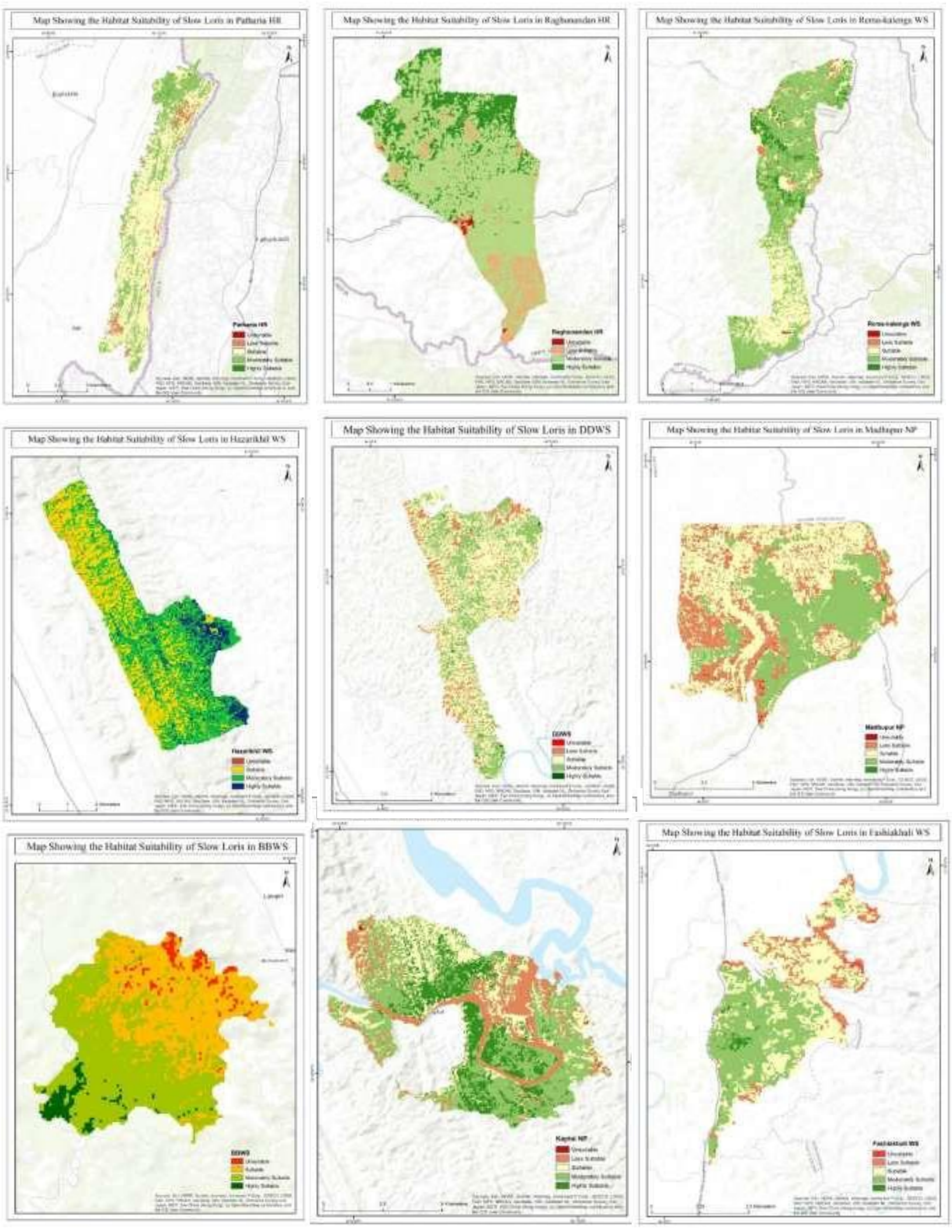


Figure 17: Maps show suitable habitat for Bengal slow loris in Patharia HRF, Raghunandan HRF, Rema-Kalenga WS and Madhupur NP.

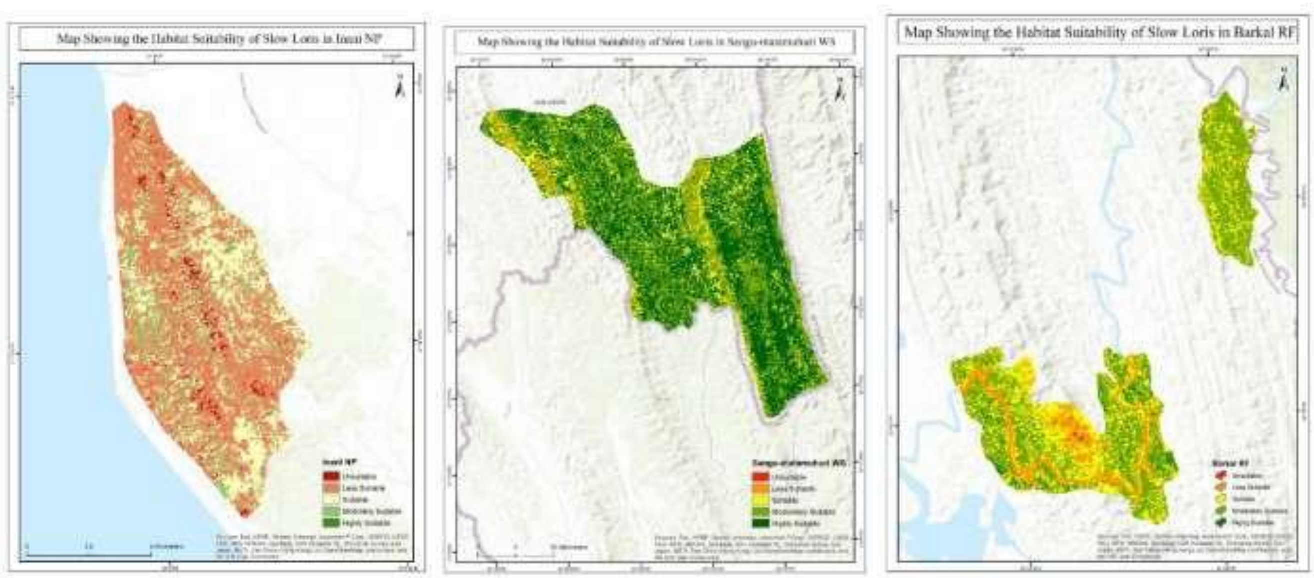


Figure 18: Maps show suitale habitat for Bengal slow loris in Dhopachari-Dudhpukuria WS, Fashiakhali WS, Hazarikhil WS, Kaptai NP.

Population size of Bengal slow loris

From the eastern semi- evergreen forests, we surveyed 11 patches comprising 1138.71 km^2 and three northern forest patches covering 86.39 km^2. We use Distance (7.5) software to estimate the population size in suitable habitat area (Table 5). The graphs of 'Detection probability g(X)' and 'Empirical distribution function versus fitted distribution function' represent the normality of the collected data (Fig. 20). The detection probability was high, about 80% in between 18m, 100% in between 12m (Fig. 20). The density of Bengal slow loris was high in Northeastern semi-evergreen forests because of the suitable habitat. The height number of Bengal slow loris was estimated from Shangu-Matamuhuri RF (379 ± 23), followed by Patharia Hill RF (213 ± 51),

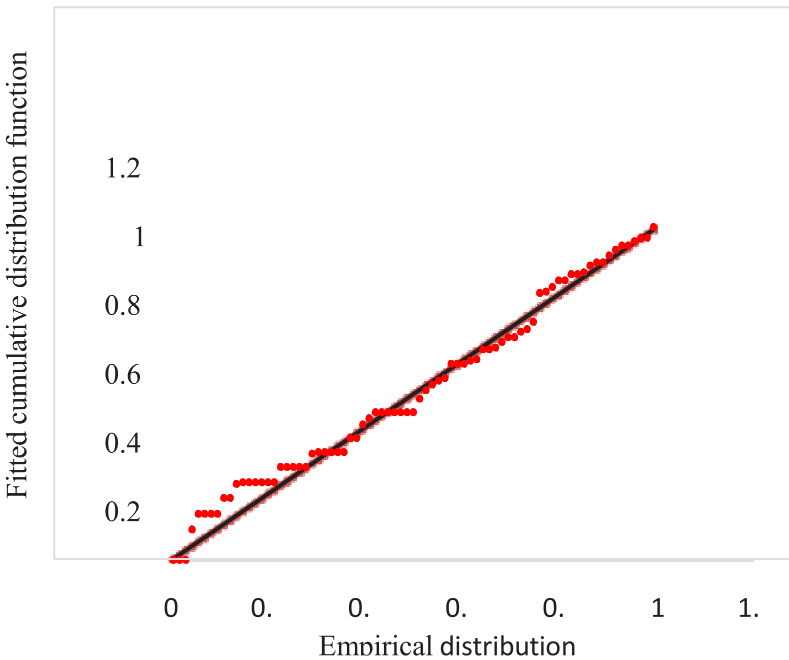


Figure 19: Empirical distribution function fitted in cumulative regression line.

Dudhpukuria-Dhopachari WS (55 ± 16), Rema-Kalenga WS (68 ± 17) and Raghunadan Hill RF (58 ± 12) (Table 6). Among eastern forest patches lorises no lorises were recorded in Fashiakhali WS, and Sheikh Jamal Inani National Park.

We surveyed three northern deciduous forest, where no lorises were encountered from Madhupur NP and Gajni RF. Only one pregnant individual was recorded from Madhutila EP. According to the record of Bangladesh Forest Department, two rescued individuals has been released in Madhutila EP. Besides nocturnal survey loris distribution also confirmed by questionnaires survey to the forest fringe peoples.

Table 6: Distance analysis estimated the population size of Bengal slow loris in different habitat patches (SE, Standard Deviation).

Study Sites	Area (km^2)	Density /km^2	Total Individuals (± SE)[d]
Barkal RF	67.75	0.54	37±13
Hazarikhil WS	23.70	0.38	9±3
Kaptai NP	54.65	0.5	27±5
Shangu-Matamuhuri RF	730.57	0.59	379±23
Fashiakhali WS	13.02	0.00	0
Baishari Bangdepa WS	22.33	0.18	4
Sheikh Jamal Inani NP	70.85	0.00	0
Dudhpukuria- Dhopachari WS	47.20	1.17	55±16
Raghunadan Hill RF	13.79	4.21	58±12
Rema-Kalenga WS	17.99	3.78	68±17
Patharia Hill RF	76.86	2.77	213±51
Madhutila Eco Park	1.067	0.94	1
Gajni RF	0.96	0.00	0
Madhupur NP	84.3613	0.00	0

4.2 Ecology of Bengal slow loris

4.2.1 Behavior in captivity

In captivity, we nursed 6 confiscated loris individuals, of which four individuals were adult female, one adult male and one infant. We observed them physically and using two camera traps for each enclosure. Bengal slow loris preferred complex climbing structures (Fig. 21). We created artificial habitat with bamboo, wood box and tree branches and set them in vertical, horizontal and diagonal angle directions within rescue centers. Two individuals showed stressful behavior in captivity. They tried to escape from the center, used their hind limbs to check every corner of the net to find a hole. Even they used their fore limbs and teeth to cut the net several times.

Figure 20: Bengal slow loris preferred complex climbing structures for travelling into the enclosure.

About 90% of their active time at night, they travelled throughout the enclosure, 10% for feeding, resting and others. All of the loris individuals were very friendly in captivity. They allowed us to feed them insects, fruits by hand.

4.2.1 Survival & Adaptation of reintroduced lorises

Among five tagged lorises, two (named Chobi and Anna) were resident and they settled in their previous territory and survived well. The three confiscated reintroduced lorises faced several difficulties to find a new territory and sometimes were chased and injured by resident lorises. For the male loris (named Liton) released in Madhabkunda Eco Park, who covered 697 m path after first day of release. On his 1st day of travelling two resident individuals chased him and he tried to escaped from them. On the 2nd day, he travelled 718 m path and on the 3rd day, he travelled 456 m and tried to get familiar with the resident lorises. On the 4th day we observed him to stay within the same location and tried to interact with female individuals in the area. He was observed foraging with a resident female loris in the same tree for more than 2 hours. And the next two days he stayed in the same location but was injured by a resident adult male. In the next month we did not find the individual and any trace of his transmitter despite our efforts to locate him in different places in Patharia Hill Reserve Forest. We assumed that the individual died of its injuries.

The female loris (named Jane Goodall) was rescued from Rangamati and released in Satchari National Park. Jane Goodall took 6 days to find a territory to settle down. After one month this individual relocated to an area not far from its first territory. She changed her territory again, was chased by three individuals during this time, but remained without injuries. In the third month, she settled in another territory for a long time. After 13 months of her release we found that female individual with 2/3 week-old baby confirming that she formed a pair, mated, gave birth and had a fixed territory.

The another female confiscated individual (named Dian Fossey) was rescued with her baby (approximately 1 month old) from Haluaghat, Mymensing. We release her in Satchari National Park and observed them in three consecutive days. On the 2nd month they established a territory where we observed them for five consecutive months. On the 5th month, she was seriously injured probably after a fight with neighboring lorises and her radio collar transmitter fell off during fighting. We were unable to continue observing her after that.

4.2.2 Activity pattern

During the behavioral study, a total of 84 nights were spent to collect behavioral data. Among them, we have observed and collected data of 71 full nights. Due to weather and other constraints, we also collected data of 11 days of partial nights. In our study, we observed and categorized 11 types of behavior. We conducted a total of 16,283 scans. Lorises spend most of their time exploring (40.12%). Lorises spend a significant amount of time traveling (17.21%) and feeding (16.58%). They also spend a large amount of time resting (8.96%) and grooming (3.94%). Grooming comprised of both self-grooming and social grooming. During the study, a significant portion of the time lorises were out of sight (7.58%). This could be because at that time lorises were inactive and were obscured by dense vegetation. Figure 22 represents the behavior of lorises.

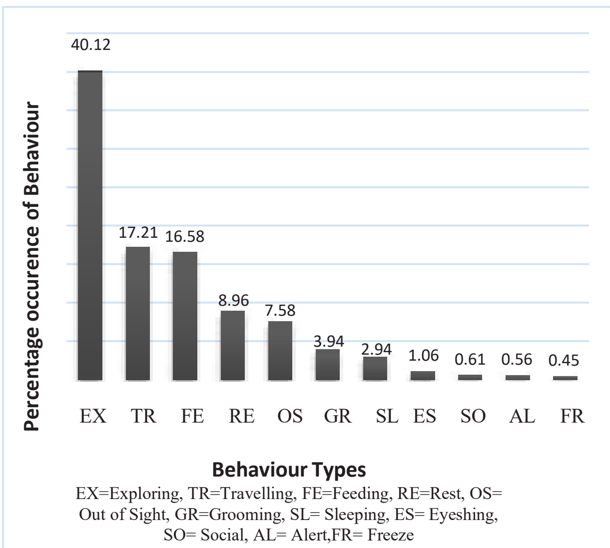


Figure 21: activity budget of lorises.

Postures or positional behavior

During our study, we quantified and documented their postures in every scan. We have categorized 23 types of postures in our study. Among them, lorises demonstrated sitting (SI), climbing up (CU), climbing down (CD), standing (ST), walking (WA) and bridge (BG) to change trees and often to move other branches within the same tree. Loris spent 15.78% of their time in a sitting position. Climbing down (14.87%) or climbing up (14.58%) also were dominant among their postures. They showed 10.52% standing postures, 8.77% walking and 6.17% bridge postures.

Seasonal Variation

Behavioral variation

In all seasons exploring (Ex) behavior was dominant. In monsoon exploring behavior decreased significantly and resting behavior increased. Though movement decreases in monsoon feeding activity increases. Other behavior doesn't change significantly due to seasonal variation. Variation of behavior is shown in the Figure 23.

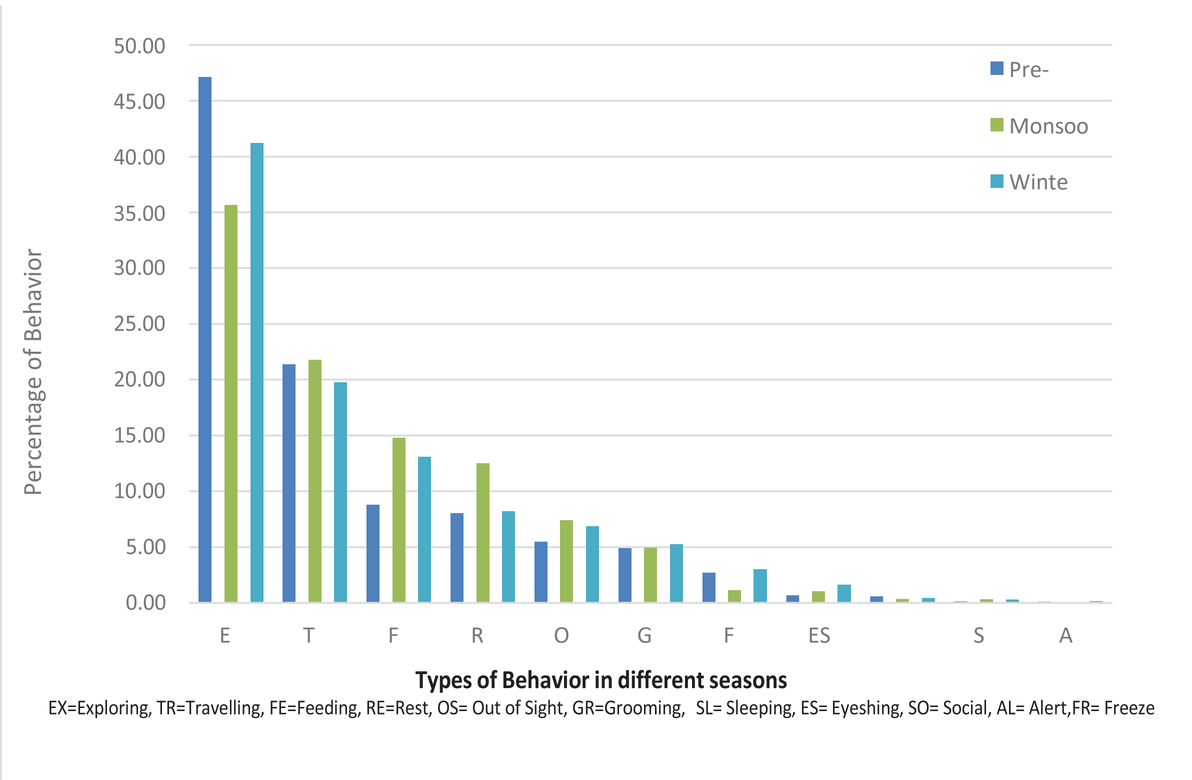


Figure 22: Seasonal variation of behavior in lorises

4.2.3 Ranging Ecology

Daily Path Length, DPL

The average daily path length of Anna was 347.72 m, Chobi was 426.5m, Jane Goodall was 580.5m, and Dian Fossey was 363.5m (Fig. 24). DPL varied significantly between resident and reintroduced lorises and between different habitats, Stachari National Park and Madhabkunda Eco Park (F test, F= 0.158, df=15, p= 0.001). Seasonality had great impact on the ranging behavior of lorises. DPL varied significantly among seasons (t test, t=2.77, p=0.016) (Fig. 25). In pre-monsoon loris covered large DPL and in winter they covered lowest DPL (Fig. 25, 26).

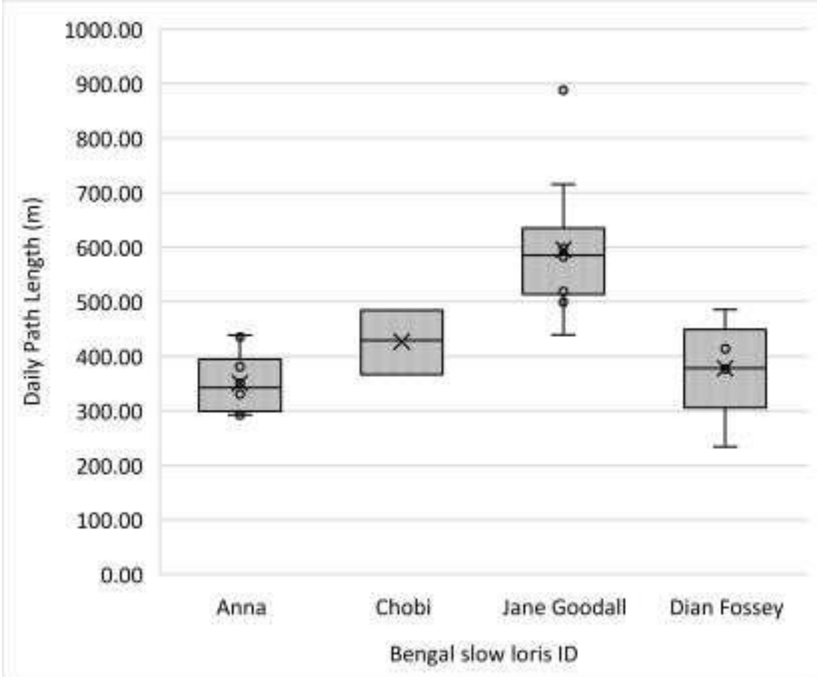


Figure 23: Daily path length of four tadio collared individuals of Bengal slow loris.

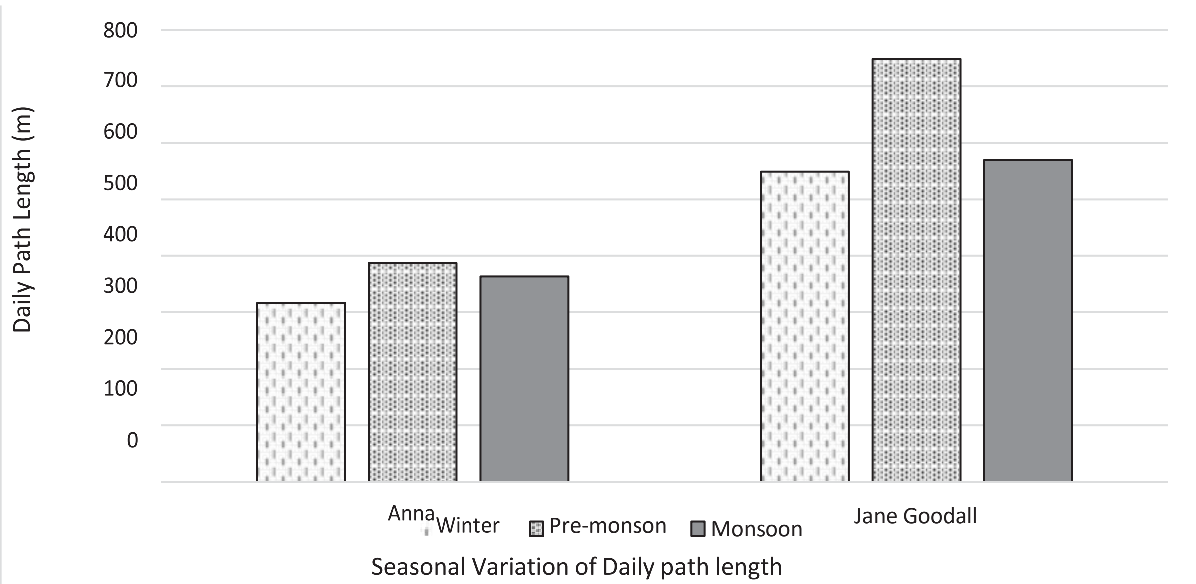


Figure 24: Seasonal variation of Anna and Jane Goodwall from Satchari NP and Madhabkunda EP respectively.

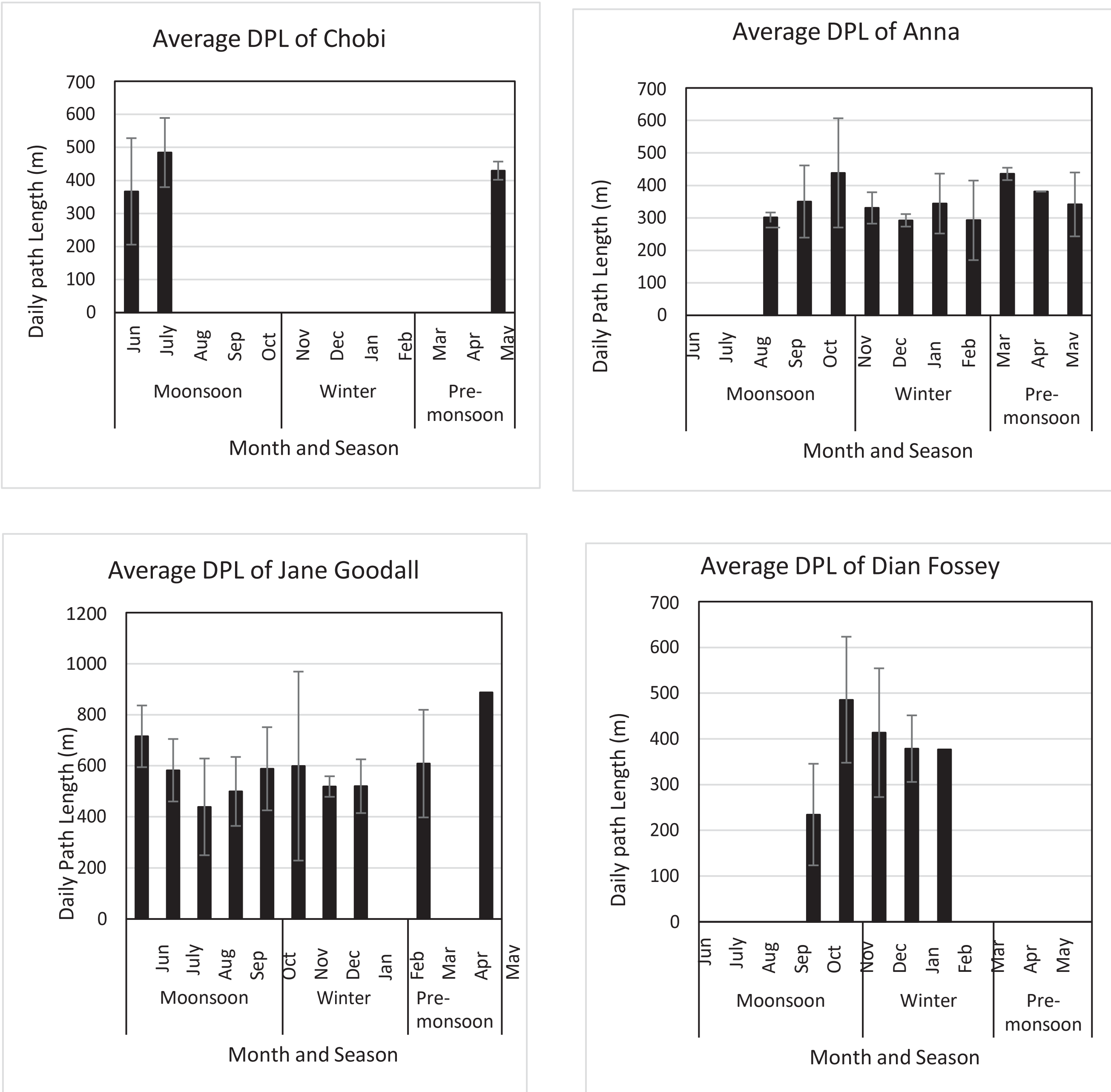


Figure 25: Monthly and seasonal variation of daily path length of reintroduced lorises from May 2023 to May 2024

The average home range was estimated at 3.335 ha (SD ± 1.46 ha). The lowest home range was recorded from Anna (1.99 ha), who lives in a private homestead with minimum resources. The largest home range was recorded from reintroduced loris, Jane Goodall (5 ha), who settled in new territory after 3 months of release in Satchari National Park (Fig. 28; Table 7). The largest home range was recorded from reintroduced lorises and the lowest from resident lorises (Fig. 28). Their daily path length and home range used were greatly influenced by resource distribution (Fig. 28). Presence of Gum producing trees and fruiting trees were the main factor influence the DPL and Home range use

Table 7: Estimated home range of Bengal slow loris using Minimum Convex Polygon (MCP) method in Satchari NP and Madhabkunda EP from May 2023 to May 2024.

Study Area	Loris Name	Rescued from	Home Range, Ha	Number of Month Observed
MEP	Chobi	Resident	2.23	3
	Anna	Resident	1.99	10
SNP	Jane Goodall	Reintroduced	5	10
	Dian Fossey	Reintroduced	4.12	5

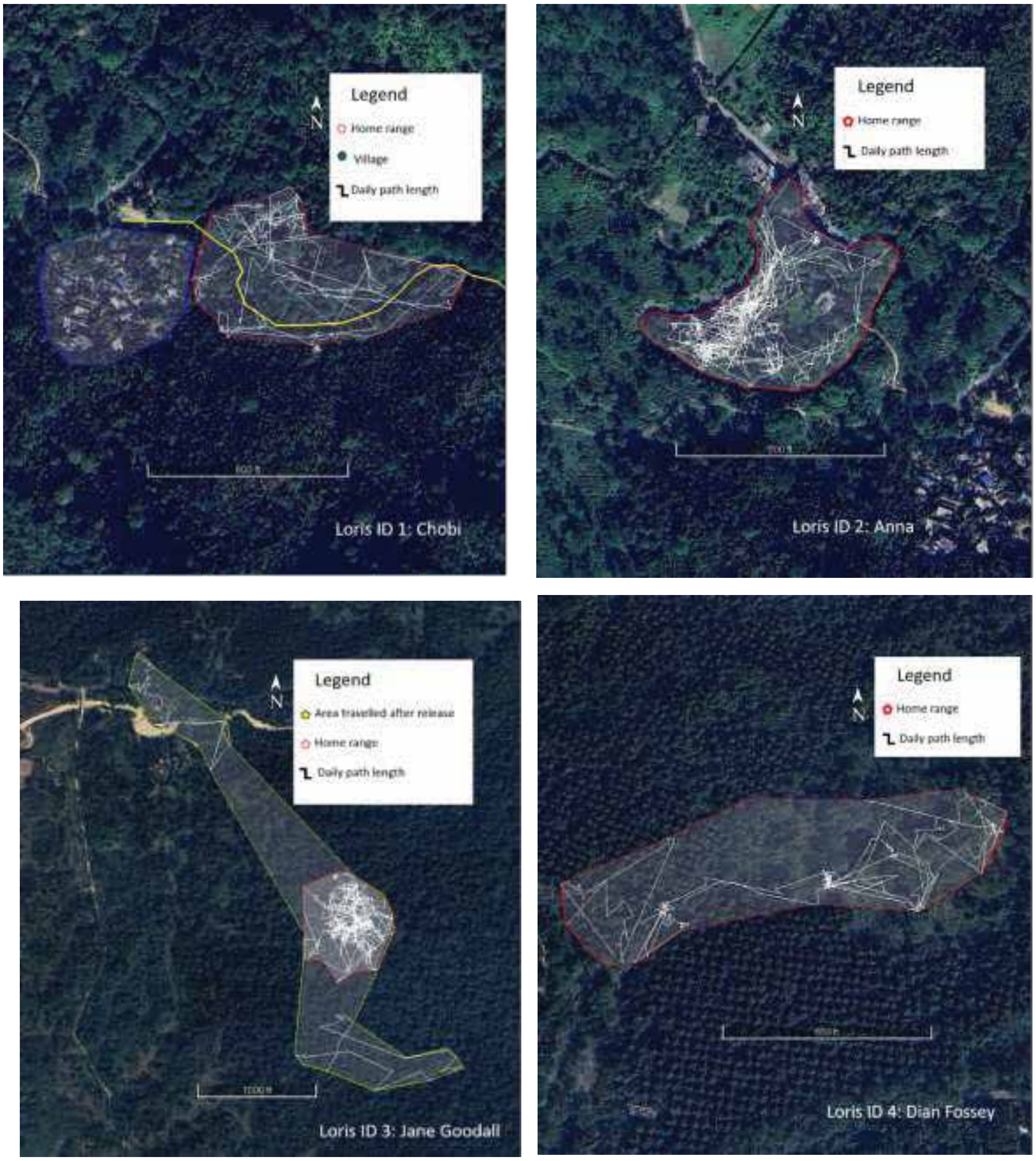


Figure 26: Estimated home range of Bengal slow loris using Minimum Convex Polygon (MCP) method in Satchari NP and Madhabkunda EP from May 2023 to May 2024

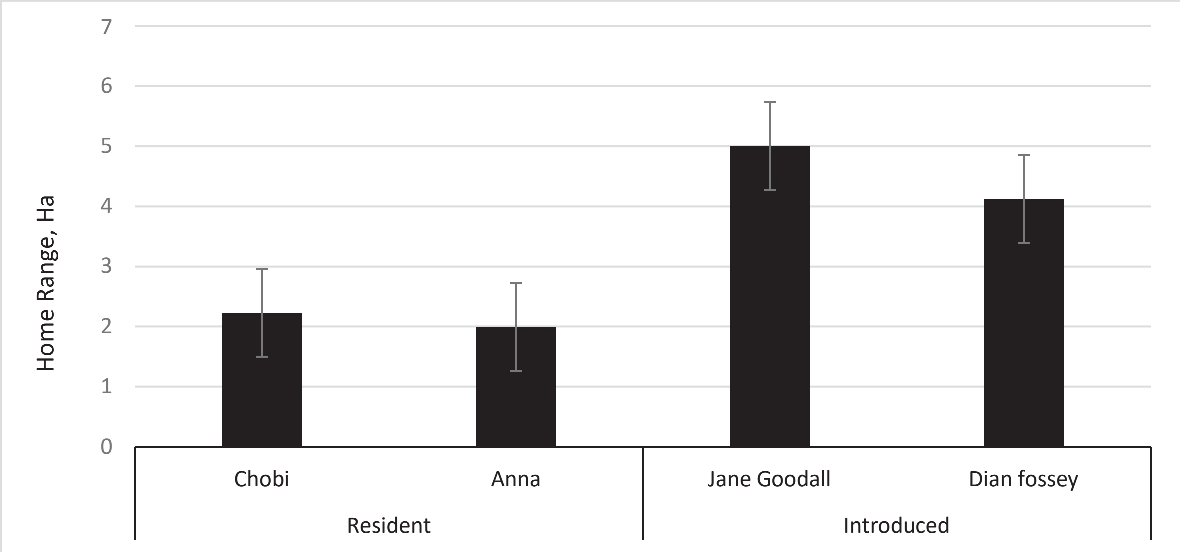


Figure 27: Difference between home range size between resident and confiscated reintroduced lorises.

4.2.3 Feeding Ecology

Bengal slow loris has diverse and unique feeding habits. While primarily feeding on fruit and plant exudates such as sap, gums, resins, and latexes. In addition to these plant-based foods, the Bengal slow loris also feed on insects, snails, and small vertebrates (Fig. 31).

The feeding preferences of the Bengal slow loris were influenced by various factors including the type of forest they inhabit, the availability of plants, and other environmental conditions. For example, they obtain gum from trees like Indian ash tree *Lannea coromandelica*, Bahera *Terminalia bellirica*, and Arjuna *Terminalia arjuna*. Additionally, they consume a variety of fruits such as bananas *Musa sp.*, lychee *Litchi chinensis*, and figs *Ficus sp.*, as well as nectar from wild flowers. This detailed diet provides insight into the adaptability and unique ecological niche of the Bengal slow loris within its forest habitat.

During our study, we meticulously documented a total of 2673 feeding observations of lorises. The majority of the time, they were seen feeding on gum sourced from various plants, which accounted for 1399 instances, constituting 52.34% of the total observations. Additionally, the lorises were observed consuming different fruits 357 times (13.36% of observations) and biting into the bark of different trees 188 times (7.03%). Notably, the lorises also exhibited feeding behaviors involving sap (174 times, 6.51%), nectar (84 times, 3.14%), flowers (49 times, 1.83%), and bamboo shoots (1 time, 0.04%). Furthermore, aside from deriving sustenance from tree-based sources, the lorises were found to consume various insect/ animal components 373 times (13.95%) and water 48 times (1.80%).

Slow loris Anna has been studied in Madhabkunda Eco-Park, and slow loris Jane Goodall at Satchari National Park. Satchari National Park's forests have more gum-producing and fruit- bearing trees than Madhabkunda Eco-park's forests. As a result, when we analyze the loris diet throughout the year, we observed that loris Jane Goodall of Satchari National Park consumed more gum and fruits than loris Anna of Madhabkunda Eco-Park. On the other hand, loris Anna of the Madhabkunda Eco-park consumed a comparatively larger amount of insects, tree sap, flowers, nectar, and other invertebrates. Figure 40 demonstrates the variety of loris diets at the two habitats.
There is a lot of seasonal variation driven by important regional weather systems that influence plant productivity in Bangladesh. The year unfolds in three distinct categories: pre-monsoon (March to May), characterized by

rising temperatures and increasing humidity, preparing for the arrival of the monsoon; monsoon (June to October), marked by heavy rainfall and rejuvenation of the landscape; and winter (November to February), when temperatures drop and nature takes on a serene, hushed charm.

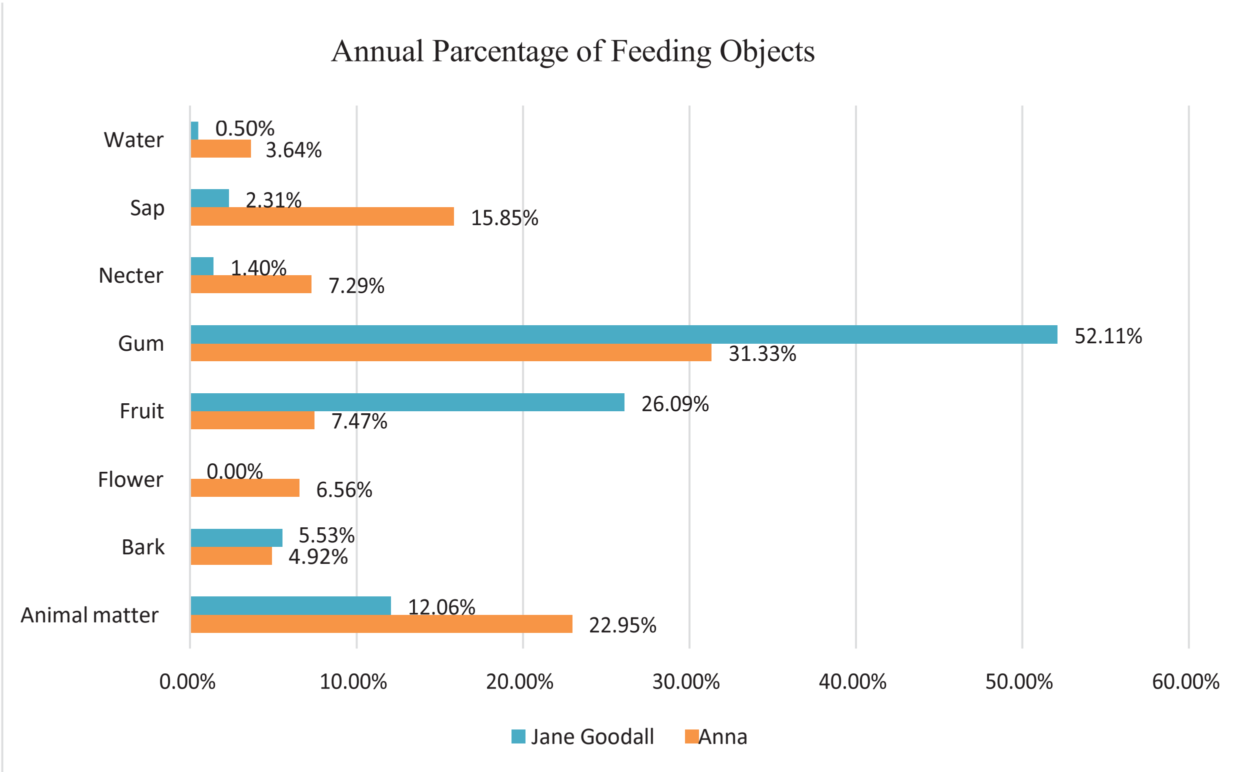
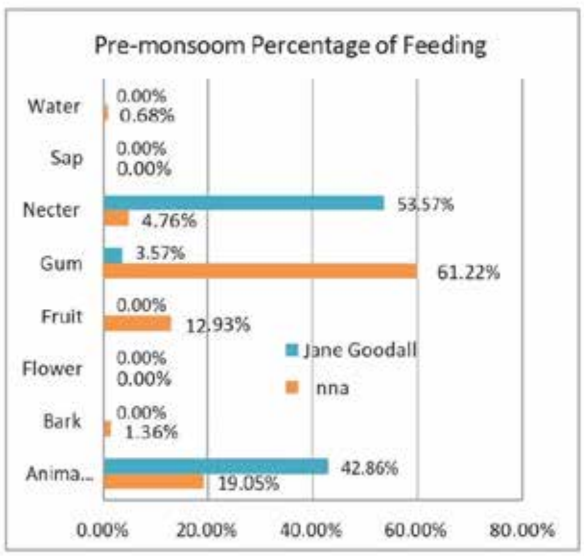


Figure 28: Annual feeding activities of lorises in MEP and SNP.

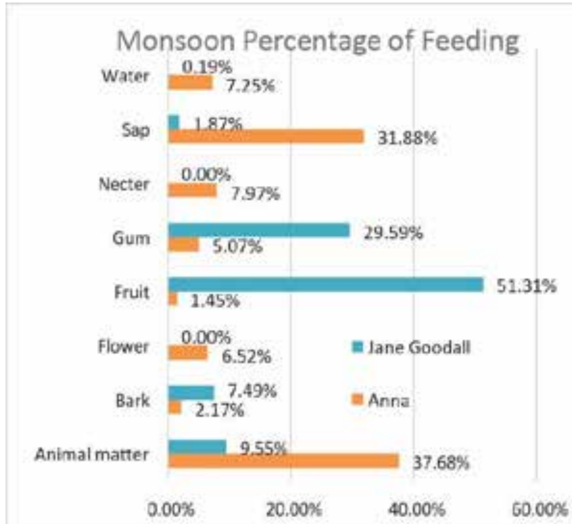
Pre-monsoon- This is the renewal and growth time of year when we observe new leaves sprouting on various plants, and flowers blooming on different trees. As a result of this natural phenomenon, there is a significant increase in the availability of nectar and insects in the environment. This abundance of food sources plays a crucial role in the diet of the loris during this period. The loris takes advantage of this plentiful supply by consuming a diverse array of insects, and also indulging in the consumption of the young fruits of various plants. Figure 30 represents the feeding activities observed during the pre- monsoon season.nectar,



Monsoon- During this specific season, the loris actively seeks out floral nectar, various plant exudates, and tree gums to fulfill its dietary requirements. In addition to these food sources, the loris takes full advantage of the diverse array of ripe fruits and insects available in its natural habitat to fulfill its dietary requirements. The abundance of various fruit species during this particular period prompts the loris to significantly increase its fruit consumption compared to other times of the year.

Figure 30 represents the most diverse feeding activities observed during the monsoon season.

Winter- This time is characterized by a scarcity peri harshness; the loris exhibits a notable shift in its d availability of fruits and other food items, the loris s plant extracts such as gum, sap, and resins. To sec challenging time, the loris demonstrates a remarkab holes in trees that produce gum. These deliberate acti exudate in the bite holes, providing the loris with a sustain itself during this period of hardship. Figure feeding activities that have been observed during the behavior is clearly depicted in the graph or chart, providing a visual representation of the impact of the monsoon season on feeding activities.



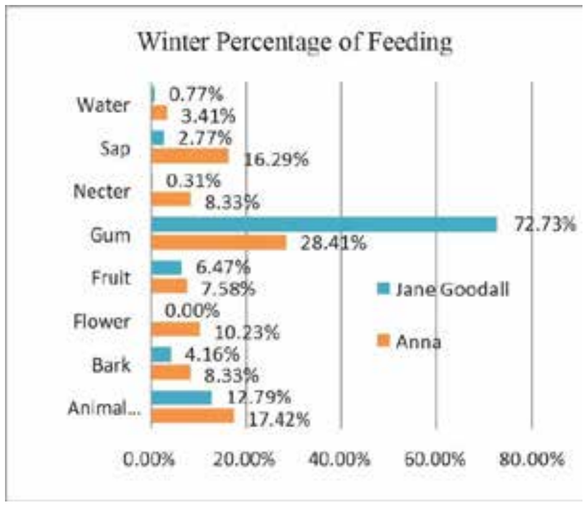


Figure 29: Percentage of feeding items in Pre- monsoon, monsoon and winter season.

Feeding fig

Feeding nectar

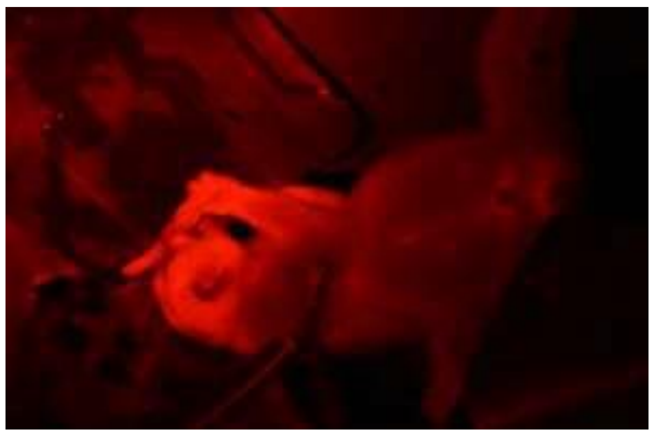
Feeding insect

Feeding banana

Feeding lychee

Feeding gum

Feeding snail



Feeding ant

Figure 30: Different feeding items consumed by Bengal slow loris in the wild.

Feedin g Tree

Loris mostly feeds on gum, sap, or resin from trees including Indian ash tree *Lannea coromandelica*, Ceylon Cherry *Prunus ceylanica*, Raintree *Samanea saman*, Arjuna *Terminalia arjuna*, Baheda *T. bellirica*, chaplaish *Artocarpus chama*, and others. It also consumes various fruits from plants such as fig *Ficus sp.*, banyan *Ficus sp.*, lychee *Litchi chinensis*, wild lychee *Walsura robusta*, and jamun *Syzygium cumini*, including unripe, mature, and ripe fruits. Additionally, when plants like cotton tree *Bombax ceiba*, Indian coral tree *Erythrina variegata*, and Banana *Musa acuminata*, the loris consumes both the flower nectar and the flowers themselves. Furthermore, the loris is known to catch and eat insects that are attracted to the flowers of different plants. For a comprehensive list of trees that the Loris were observed feeding on in our study, please refer to Table 8.

Table 8: List of feeding trees

Sl No	Feeding Tree	Vernacular Name	Family	Part eaten
1.	*Albizia odoratissima*	Moroi/ Tetua-koroi	Fabaceae	Gum, Fruit
2.	*Albizia procera*	Shil koroi	Fabaceae	Gum
3.	*Aphanamixis polystachya*	Pithraj	Meliaceae	Gum
4.	*Bombax ceiba*	Simul	Malvaceae	Flower, Nectar
5.	*Bombax insigne*	Bon simul	Malvaceae	Flower, Nectar
6.	*Citrus limon*	Lebu	Rutaceae	Sap
7.	*Ehretia acuminata*	Kalahuja	Boraginaceae	Fruit
8.	*Elaeocarpus floribundus*	Belpui	Elaeocarpaceae	Fruit
9.	*Erythrina stricta*	Mandar	Fabaceae	Nectar
10.	*Ficus hispida*	Dumur	Moraceae	Fruit
11.	*Ficus nervosa*	Pani Dumur	Moraceae	Fruit
12.	*Ficus racemosa*	Jagadumur	Moraceae	Fruit
13.	*Ficus religiosa*	Ashoth	Moraceae	Fruit
14.	*Lagerstroemia speciosa*	Jarul	Lythraceae	Flower
15.	*Lannea coromandelica*	Jiga	Anacardiaceae	Gum
16.	*Litchi chinensis*	Lichu	Sapindaceae	Fruit
17.	*Litsea glutinosa*	Menda	Lauraceae	Fruit
18.	*Mangifera indica*	Aam	Anacardiaceae	Flower
19.	*Microcos paniculata*	Asar golla	Malvaceae	Fruit
20.	*Musa acuminata*	Kola	Musaceae	Fruit, Flower, Nectar
21.	*Piliostigma malabaricum*	Kanchan	Fabaceae	Flower, Nectar
22.	*Prunus ceylanica*	Asharia	Rosaceae	Gum
23.	*Samanea saman*	Rain Tree	Fabaceae	Gum, Fruit
24.	*Sterculia foetida*	Baksho Badam	Malvaceae	Gum, Sap
25.	*Syzygium cumini*	Jam	Myrtaceae	Fruit
26.	*Syzygium grande*	Dakhijam	Myrtaceae	Fruit
27.	*Terminalia arjuna*	Arjun	Combretaceae	Sap, Gum
28.	*Terminalia bellirica*	Bohera	Combretaceae	Sap, Gum
29.	*Toona ciliata*	Rongi/ Toon	Meliaceae	Flower, Nectar
30.	*Walsura robusta*	Bon lichu	Meliaceae	Fruit

Allogrooming

Mating

Allogrooming

Mother carrying baby

Figure 31: Social behaviors of Bengal slow loris in wild.

4.3 Threats and Conservation Problems

Knowing Slow loris

'Who knows Loris?' This question leads to a comparison of how Bengal slow loris is seen in three forest regions. Figure 33 shows how many people can identify loris. In comparison to other locations, northeasterners are much more knowledgeable of loris; in fact, 88.33% of people are familiar with it. The slow loris is known by several distinct names among indigenous peoples. Mulugo bandor is known to Chakma and Tanchoinga; Marma knows Mukh Lukano bandor, Meo, and Mihau nou; Tripura knows Kuchuklai and Makhra ow chai; Khashia knows Khabrang; and Inani's Bengali people know Bagher mathar Tak and Tak bandor.

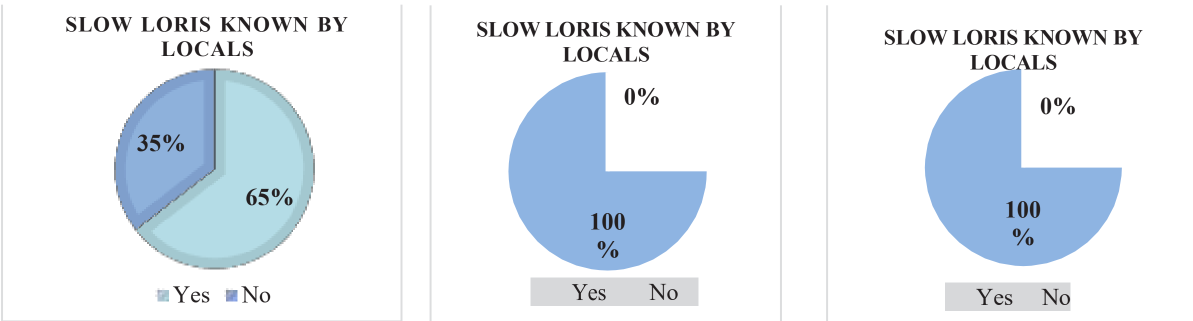


Figure 32: Slow loris known by locals in Southeast, Northeast, and Northern regions. (from left)

Locals were asked about their most recent encounters with slow lorises in the wild. Their responses indicate that 46.36% of populations in the southeast region have never seen slow lorises, while 15.45% had seen them during the previous year. 20.91% have seen within 1 to 6 years.

Southeast region: According to the locals, about 89% in Barkal and 71% in Dhopachari- dudhpukuria confirmed the presence of Bengal slow loris in the forests. Due to massive habitat destruction lorises are gone from Inani NP where 29.41% people still believe their presence in the forest followed by Kaptai (25%), Hajarikhil (15.38%), Fashiyakhali (14.28%), and Bangdepa (11.11%).

In Barkal, 62.96% said they saw a slow loris between one day to one year prior to the interview. In Bangdepa, people first saw loris around 5 years ago, and 72.22% had never seen them before. According to 28.56% of interviewees in Fashiakhali, the last time they spotted slow loris was over 20 years previously and others have no sighting on them in their lifetime. And our nocturnal surveys also confirmed that loris extirpated from Fashiakhali WS. Almost 70.59% of Dhopachari people have seen it throughout their lives. 47.06% had seen it between 2 days to 2 years. 7.69% saw it for the last time in Hajarikhil around 8 months ago. 84.62% of people have never seen them before. Most recent encounters in Inani were three to ten years back, indicating possible recent extirpation from the area. 87.5% have no previous experience seeing it in the wild in Kaptai.

Northeast and Northern regions: All residents (100%) of the adjacent village are aware of the presence of slow lorises in Satchari National Park. In Patharia Hill Reserve Forest, 83.33% of people know about their presence, while in Gajni Reserve Forest 37.5% people believe loris still there. In Patharia, 83.33% of respondents have seen a slow loris in their lifetime, with 50% of encounters occurring within the past 14 days to two years. Similarly, all respondents in Satchari reported sightings in the wild within the last 15 days to two years.

In contrast, only 24.5% of people in Sherpur, Madhutila, and Gajni have seen a slow loris, with most sightings occurring between two months and a year ago. However, all lorises in these areas were later rescued by the Wildlife Crime Control Unit during trade and trafficking incidents and subsequently released back into the forest by authorities.

People have reported spotting slow lorises in the wild for approximately 15 to 30 years ago in Madhupur NP. In Madhupur, residents encountered a single individual about three years ago. Based on all questionnaires data almost 67.27% of participants claimed to have seen one individual in the forest. However, the locals encountered two, three, four, and five individuals together. According to our fieldwork experience, people who visit the forest regularly may have encountered lorises in recent times, whereas others who do not visit the forest frequently have observed them in the past.

Population demography as locals' perceptions

In the Southeast, 42% to 49% of respondents perceive a decreasing population. Similarly, 45% of respondents in the Northeast and 73% in the Northern region share this concern. However, 35% of people across all regions are unaware of the population status.

Approximately 55% of respondents believe habitat destruction is the primary cause of the declining slow loris population. Additionally, 24% attribute the decline to hunting, while 8.75% cite food scarcity as a contributing factor. Illegal wildlife trade and poaching are also considered significant threats to loris populations.

Hunting scenario

The hunting scenario based on local perceptions. Hunting is relatively common in the Southeast and North, whereas it is less frequent in the Northeast, where people express greater concern for wildlife. According to respondents, hunting is reported by approximately 74% in Barkal, 50% in Thanchi, and 72% in Fashiyakhali. In contrast, except for Madhupur, the hunting rate in other forest areas remains below 35%, which is lower than in the Southeast, Northeast, and Northern forests.

In the southeast and northeast, locals hunt Bengal slow loris and all wild animals in the forest for food, including rhesus macaque and other primates, barking deer, wild boar, rabbit, porcupine, jungle cat, wild dog, otter, clouded leopard, jungle fowl, bird, squirrel, monitor lizard, ill fish, wild goat, and pangolin. However, in the north, they hunt wild boar, rhesus macaque, squirrel, and jungle fowl, except slow loris, which does not exist there. 35% of participants said they hunted throughout the year. According to some people, hunting groups are mostly active from September to November during jhum harvesting, with some being active during the winter and monsoon seasons. According to survey results, 39% of respondents ensure that Hunters prefer deep forests for hunting, while others prefer household vegetation and forest edges. 29% of respondents said they are opportunistic hunters. Some individuals go for hunting one to five times per month, although they are active almost every day throughout the winter. Hunting gear includes slingshot (gulti), arrow, trap, netting trap, leash, chopper (daa), stick, hook, spear, bow, and chisel as well as a gun in some places. However, whether hunting, trading, or rearing, some people got injured by loris bites. The bite consequences include bleeding, allergic reactions, mouth swelling, vomiting, headaches, fainting, and swelling of bodily parts.

Hunting purposes

The findings provide an answer to the question 'Why do people hunt loris or other primates or animals?' They often hunt loris or other primates for three reasons: food, trade for pets, and medicine. People in the southeast and northeast eat lorises. Figure 56 shows that the northeastern population (18%) consumes more loris than the southeastern population (4%). However, the southeastern region is important in the trade and production of medicine using loris and body parts of animals. Slow loris are eaten by several ethnic groups in the southeast area, including Chakma, Marma, Pangua, Morong, and Tripura. The Khasia community of Shrimangal in the northeast eats slow loris. The Marma and Tripura communities purchase and trade lorises.

In the southeast, over 6.36% of respondents mentioned that locals are active in commerce, and 18% in creating medication, but the northeastern region is not. Apart from their medical value, loris are kept and traded by locals since they are in high demand as pets across the world. Locals in Kolabunia witnessed a merchant petting a slow loris that died afterwards. Villagers want to keep loris as a pet, and two respondents told us that their neighbors had caught slow lorises and kept them in their homes; one was then released, while the other passed away. In Figure, the market value of loris is present in the southeast but not in the northeast. The market value starts from 3000 BDT and ranges from 10, 15, 20, 25, and 30 thousand BDT to 50 thousand BDT. In the southeast, the Chakma, Marma, and Tripura ethnic communities hunt and consume lorises, and their body parts are used in traditional medicine (Fig. 34). The Boiddoes (Adivasi doctors) buy loris from the villagers to make traditional medications. Adivasi people think that loris body parts may treat fever, stomach pain, headaches, bone pain, breathing difficulties, pregnancy pain, and marriage problems. Loris' skin is used for producing medicine for children's fevers, together with other plant parts. Talismans (Tabij) made from lorises' fur and other body parts are effective against ghosts. The Marma people saw loris' appearance on their home ground as an evil sign. If any slow loris enters their home, they pray to God to release them from danger. If a loris dies or its blood is worn, it is considered a bad sign. If loris dies in a house, Tripura people will leave their homes. They avoid eating loris because they believe it is unlucky or ill-omened. However, they no longer do so since it is considered unlucky by the Tripura community. Buddies pray for God's pleasure by Slow loris.

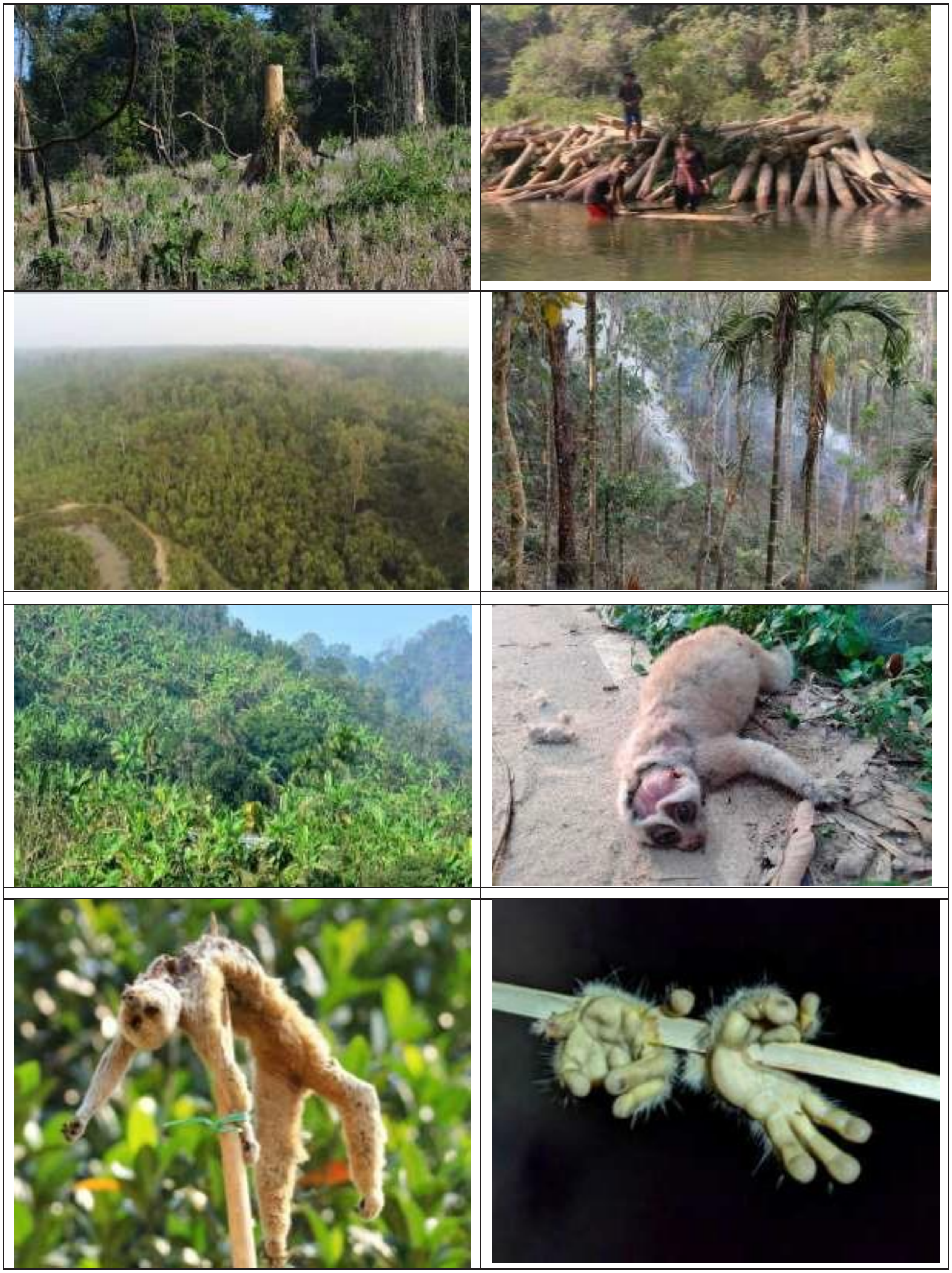


Figure 33: Habitat Destruction for Jhum cultivation, Illegal logging, forest fire, Monoculture plantation, Hunting and Electrocution are the main threats for Loris in Bangladesh.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Recommendations and Suggestions

Captive Care and Handling of Bengal slow loris An ideal rescue center for Bengal slow loris must include a complex climbing structure of branches with vertical, horizontal, and diagonal angles to create an artificial habitat. Therefore, that loris can easily travel throughout the night. It helps to remove long term stress of confiscated individuals. For regular food supply plastic bowls could be used (Fig. 8). Bengal slow loris does not require a sleeping box within the enclosure, they prefer tree branch with high leaf/climber density where they can hide from the sunlight and predators. They need a shade from day sleeping which must be present in the rescue center.

For long term captive care/research we suggest building large sized (10m*15m) rescue center with natural feeding plants within the enclosure (Fig. 35)

FG

Feeding: Usually Bengal slow loris ate on average 115 ± 10g of food daily in captivity. We suggest to supply at least 150g food for per individuals.

Handling: We suggest to use heavy gloves to avoid bite. Also towel could be use for more safety (Fig. 35).

Health Care: For injured individuals a veterinary doctor should check the health condition regularly to provide necessary treatment.

Figure 34: Sample of an ideal rescue center for Bengal slow loris (Picture collecte

Rehabilitation guidelines for confiscated lorises

Bengal slow lorises are widely traded animals, leading to numerous confiscations of live specimens. These individuals are often reintroduced to wild habitats without considering ecological constraints, social dynamics, health checks, and vulnerability to disease. Such unmanaged releases may be as deadly a threat as the trade itself and potentially lead to recapture by poachers or high mortality rates.

Hasan et al. (2024) reported about 9 years of data for rescued individuals where 59% of lorises were found in poor health condition, 14% were electrocuted and 27% were confiscated during illegal trade. Lorises were rescued by law enforcement entities, the Bangladesh Forest Department, and volunteers. Most of the rescued lorises (55%) were released in nearby forests, 12% in distant forests, 5% in safari parks, 9% were taken to local zoos, 2% were taken to rescue centers, and the fate of 17% was unknown. These individuals were released presumably without following any guidelines and there are no data on post-release survivorship.

Wild slow lorises can survive well in disturbed forests and near village homesteads. Many of the rescues were from areas where they were already living in anthropogenic habitats, such as homestead forests, forest fringes, tea gardens and agricultural land) of which many could be considered suitable habitat for lorises. Thus, 'rescuing' them from these habitats could have been unnecessary and translocation to nearby or distant forests could have been detrimental to their survival. Consequently, such rescues and spontaneous, unplanned relocations need to be managed, organized and coordinated. Individuals found in or around human habitation must be assessed by the Forest Department or other entities with trained personnel to determine if a rescue and translocation is warranted.

In Bangladesh, Satchari NP and Lawachara NP are popular for loris reintroduction where our research found numerous fight and one possible death of reintroduced lorises with resident lorises in Satchari NP and Madhabkunda EP. Because the density of loris is higher in these forest patches. Instead, for individuals confiscated from the wildlife trade, we suggest to establish a reintroduction research program in Madhupur National Park where loris was previously distributed. A plantation program focusing on loris should be taken as the same time. Long-term captive care will be needed to give opportunity for pair formation of captive individuals. Before release, lorises should be tagged using radio collar transmitters for long term monitoring of their survival and adaptation.

Conservation insights

- Decreasing forest encroachment and habitat destruction.
- Building capacity of forest staffs, eco-tourists guides and public awareness.
- Proper implementation of laws and acts against illegal activities into the forests.
- Implementation of national park protocols and control tourism.
- Establishing local intelligence network to inform Bangladesh forest department regarding illegal hunting, poaching and trading animals.
- Provide alternative livelihoods to reduce forest dependency of the indigenous people.
- Update protection status of Reserve Forest into national parks or sanctuary.
- Reduce unnecessary rehabilitation of confiscated lorises.

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Study on Threatened wildlife species, Threat assessment and Projection of Coastal afforestation Impacts in habitat enhancement at Nijhum Dwip National Park, Char Kukri-mukri Wildlife Sanctuary and Tengragiri Wildlife Sanctuary

by

Associates for Innovative Research and Development Ltd.

CHAPTER-I

1.1 Introduction

The conservation of threatened wildlife species and their habitats is a critical component of global biodiversity preservation efforts. Coastal ecosystems, particularly those in South Asia, are among the most vulnerable due to the combined pressures of climate change, habitat degradation, and anthropogenic activities. In Bangladesh, the Nijhum Dwip National Park (NDNP), Char Kukri-Mukri Wildlife Sanctuary (CKMWS), and Tengragiri Wildlife Sanctuary (TWS) are vital coastal protected areas that harbor unique biodiversity, including several threatened species. These areas are not only ecologically significant but also provide essential ecosystem services to local communities. However, the rapid pace of environmental change and human encroachment pose significant threats to these habitats and their resident species. This research, titled *"Study on Threatened Wildlife Species, Threat Assessment, and Projection of Coastal Afforestation Impacts in Habitat Enhancement at Nijhum Dwip National Park, Char Kukri-Mukri Wildlife Sanctuary, and Tengragiri Wildlife Sanctuary,"* aims to address these challenges by assessing the current status of threatened wildlife species, evaluating the primary threats to their survival, and projecting the potential impacts of coastal afforestation on habitat enhancement.

Coastal ecosystems are dynamic environments that support a wide range of flora and fauna, many of which are endemic and threatened. However, other coastal protected areas in Bangladesh, such as Nijhum Dwip National Park, Char Kukri-Mukri Wildlife Sanctuary, and Tengragiri Wildlife Sanctuary, are equally important but less studied. These areas are home to a variety of threatened species, including the Bengal tiger (*Panthera tigris tigris*), Irrawaddy dolphin (*Orcaella brevirostris*), and several species of migratory birds (IUCN, 2021). Despite their ecological importance, these habitats are under increasing threat from sea-level rise, salinity intrusion, deforestation, and unsustainable resource extraction (Chowdhury & Hossain, 2018).

Coastal afforestation, the practice of planting trees and vegetation in coastal areas, has been widely recognized as a nature-based solution to mitigate the impacts of climate change and enhance habitat quality. Mangrove afforestation, in particular, has been shown to reduce coastal erosion, improve water quality, and provide critical habitat for wildlife (Rahman & Ahmed, 2017). In Bangladesh, the government and non-governmental organizations have implemented several coastal afforestation projects, but their impacts on wildlife habitats and threatened species remain poorly understood. This study seeks to fill this knowledge gap by conducting a comprehensive assessment of the current status of threatened wildlife species, identifying the primary threats to their survival, and projecting the potential impacts of coastal afforestation on habitat enhancement in the study areas.

Biodiversity loss and ecosystem degradation are critical global issues that undermine the provision of ecosystem services essential for climate change mitigation and adaptation. However, overexploitation of natural resources, deforestation, habitat destruction, population pressure, degradation of coastal and mangrove forests, uncontrolled extraction of freshwater and marine fish, hunting and killing of wild animals, and encroachment of forests and wetlands have severely compromised the integrity and functionality of most natural ecosystems. These activities have led to the loss of biodiversity and ecosystem services, exacerbating the vulnerability of human and natural systems to climate change impacts. The coastal areas of Bangladesh, characterized by shorelands, accreted lands, and numerous water bodies, are particularly significant. These areas are influenced by tidal actions twice daily, making them fragile and highly susceptible to both natural and anthropogenic pressures, as well as climate change impacts.

The Sustainable Forests and Livelihoods (SUFAL) Project, initiated to address these challenges, includes a component focused on protecting coastlines and accreted lands through coastal afforestation. This proposed research study aims to contribute to the SUFAL Project by focusing on biodiversity improvement through habitat restoration and afforestation on newly accreted char lands. Coastal afforestation is a critical strategy for enhancing ecosystem resilience, restoring degraded habitats, and safeguarding biodiversity. By raising coastal plantations, this study seeks to improve the ecological integrity of these areas, thereby supporting wildlife conservation, enhancing ecosystem services, and protecting mainland areas from natural calamities.

1.2 Problem Statement

Bangladesh's coastal regions are endowed with rich biodiversity, encompassing unique ecosystems such as mangrove forests, estuarine environments, and a plethora of wildlife species. However, these areas face escalating threats from both anthropogenic activities and environmental changes. This research focuses on assessing threatened wildlife species, evaluating the extent of these threats, and projecting the impacts of coastal afforestation on habitat enhancement within three pivotal protected areas: Nijhum Dwip National Park, Char Kukri-Mukri Wildlife Sanctuary, and Tengragiri Wildlife Sanctuary. Coastal ecosystems worldwide are under significant pressure due to human-induced activities such as deforestation, urban expansion, and pollution. Mangrove forests, in particular, have witnessed alarming declines. These ecosystems are indispensable, offering services like coastal protection, carbon sequestration, and serving as habitats for diverse species. The degradation of mangroves has precipitated declines in biodiversity and heightened the vulnerability of coastal communities to natural calamities.

Bangladesh's coastal zones are characterized by dynamic ecosystems, including mangroves, mudflats, and estuaries. These areas are vital for fisheries, agriculture, and forestry, supporting the livelihoods of millions. However, they are also susceptible to natural calamities like cyclones and tidal surges, exacerbated by climate change. Coastal afforestation initiatives, primarily involving mangrove plantations, have been implemented to mitigate these challenges and enhance biodiversity. Studies have demonstrated that such afforestation efforts can stabilize shorelines, improve soil quality, and provide habitats for various species. The coastal regions of Bangladesh, particularly areas like Nijhum Dwip National Park, Char Kukri-Mukri Wildlife Sanctuary, and Tengragiri Wildlife Sanctuary, are experiencing significant ecological challenges. These challenges are multifaceted, encompassing threats to wildlife, habitat degradation, and the complexities associated with conservation strategies such as coastal afforestation.

The biodiversity within these sanctuaries is under constant threat from various anthropogenic activities. Illegal poaching, overfishing, and unregulated tourism have led to the decline of several species. For instance, the fishing cat (*Prionailurus viverrinus*), once prevalent in these regions, has seen a significant decrease in population due to habitat loss and human-wildlife conflicts. Similarly, the Asian small-clawed otter (*Aonyx cinereus*), reliant on pristine wetland ecosystems, faces challenges from water pollution and reduced prey availability.

The integrity of habitats within these protected areas is compromised by both natural and human-induced factors. Erosion, sedimentation, and salinity intrusion, exacerbated by climate change, have altered the ecological balance. Human activities such as land reclamation for agriculture and infrastructural developments have further fragmented these habitats, making it challenging for species to thrive. The introduction of invasive species has also disrupted native flora and fauna dynamics, leading to a decline in biodiversity.

The south-western coastal region of Bangladesh has witnessed a decline in wildlife populations, with several species now categorized as threatened or vulnerable due to conflicts with local communities. The key indicator species affected include the Fishing Cat (*Prionailurus viverrinus*), Spotted Deer (*Axis axis*), Golden Jackal (*Canis aureus*), Asian small-clawed otter (*Aonyx cinereus*), Bengal Monitor (*Varanus bengalensis*), and Water Monitor (*Varanus salvator*). Among these, human-deer conflicts have been the most widely recognized by local residents, with additional conflicts recorded involving the Fishing Cat, Golden Jackal, and Oriental Small-clawed Otter. Instances of Fishing Cats and Golden jackals preying on poultry and livestock have also been reported. Prior to 1974, human habitation was minimal in the CKMWS and NDNP regions, allowing the islands to flourish with newly established Keora (Sonneratia apetala) plantations. Over time, NDNP has become home to various terrestrial species, including small carnivores and rodents. Between 1974 and 1979, 13 Spotted Deer and one Barking Deer (Muntiacus muntjak) were introduced into NDNP. The Spotted Deer population successfully adapted to the mangrove forest ecosystem, primarily feeding on Keora leaves and various grasses found in non-forested areas. According to reports from the Bangladesh Forest Department (BFD) and local villagers, the Spotted Deer population peaked around 2007, after which a decline was observed, leading to the present population levels.

The CKMWS and surrounding waters play a crucial role as a wintering habitat for migratory bird species, including several globally threatened shorebirds such as the Black-tailed Godwit (*Limosa limosa*), Black-headed Ibis (*Threskiornis melanocephalus*), Eurasian Curlew (*Numenius arquata*), and Greater Spotted Eagle (*Clanga clanga*). The Spotted Deer population at CKMWS also thrived in the mangrove ecosystem, particularly benefiting from the abundant Keora plantations. Given the luxuriant growth of Keora and its palatability to deer, senior forest officials initiated a deer reintroduction program. In 1979, an initial release of 10 Spotted Deer and six Rhesus Monkeys (*Macaca mulatta*) took place. Subsequent introductions between 1996 and 1999 included 12 Red Junglefowls (*Gallus gallus*), three Grey Peacock Pheasants (*Polyplectron bicalcaratum*), eight Kalij Pheasants (*Lophura leucomelanos*), and five Common Koels (*Eudynamys scolopaceus*).

Following the rapid population increase of Spotted Deer after 1995, human-deer conflicts escalated significantly. The deer began grazing extensively on paddy fields at night, causing substantial crop damage. In response, local communities implemented intensive guarding measures and actively chased the animals away from cultivated lands. Recognizing the growing conflict, conservation authorities took proactive measures to mitigate the issue. In 2005, two drinking ponds were excavated within the forest to reduce the deer's dependency on agricultural areas and discourage their movement into villages and farmlands (*BFD, 2015; Personal communication with the Divisional Forest Office (DFO), Bhola*). These efforts have contributed to managing the conflict, but continued monitoring and adaptive management strategies are necessary to ensure coexistence between wildlife and local communities.

To assess the current status of these conflicts and their ecological impact, this study was conducted, focusing on three key protected areas: Nijhum Dwip National Park (NDNP), Char Kukri-Mukri Wildlife Sanctuary (CKMWS), and Tengragiri Wildlife Sanctuary (TWS).

1.3 Objectives

The main objectives of this research are as follows:

- To assess the abundance, present status and habitat preference of selected wildlife species in the south-western coastal zone focusing at the NDNP, CKMWS and TWS.
- To assess the threats for selected wildlife species and human wildlife conflicts in the selected study areas including the afforestation impacts in the study areas.

1.4 Research Questions

- How many threatened wildlife species exist and their distribution pattern in the selected study sites?
- What are the patterns and extent of human wildlife conflicts?
- What are the threats for selected wildlife species in different study sites and to what extent afforestation program impacts on wildlife habitats?

CHAPTER-II

Literature Review

Bangladesh, with its diverse ecosystems ranging from mangroves to freshwater wetlands, harbors a wide range of wildlife species, many of which are under threat due to habitat destruction, human-wildlife conflict, and climate change (IUCN, 2015). The Nijhum Dwip National Park (NDNP), Char Kukri-Mukri Wildlife Sanctuary (CKMWS), and Tengragiri Wildlife Sanctuary (TWS) are three critical protected areas in the coastal region of Bangladesh. These areas provide habitat for a variety of threatened species, including mammals, birds, reptiles, and amphibians. Over the past decade, numerous studies have been conducted to assess the conservation status, threats, and ecological significance of these species. This literature review synthesizes findings from prior research to highlight key trends and conservation challenges.

NDNP, located in Noakhali District, is a mangrove-dominated ecosystem that was officially declared a national park in 2001 (BFD, 2015). The park is home to a variety of species, including the Spotted Deer (Axis axis), Fishing Cat (*Prionailurus viverrinus*), Golden Jackal (*Canis aureus*), Asian small-clawed otter (*Aonyx cinereus*), and several threatened bird species (Khan, 2018). The park also supports critically endangered shorebirds such as the Spoon-billed Sandpiper (*Calidris pygmaea*) and Black-tailed Godwit (*Limosa limosa*), which rely on the mudflats for wintering (Rahman et al., 2020). Additionally, NDNP harbors reptilian species such as the Bengal Monitor (*Varanus bengalensis*) and Water Monitor (*Varanus salvator*), both of which are listed as threatened due to habitat loss and poaching (IUCN, 2015). The coastal ecosystems of Bangladesh are home to three monitor lizard species: *Varanus bengalensis, V. flavescens*, and *V. salvator.* However, these populations face significant threats due to habitat loss and fragmentation. Despite their ecological importance, research on their population dynamics, activity patterns, abundance, and distribution remains limited. This paper aims to synthesize existing knowledge, identify research gaps, and propose scientific approaches for the effective management and conservation of monitor lizards in ecosystems affected by habitat degradation (Mijanur, R.K. and Iliazovic, R.I., 2016). The primary threats to wildlife in NDNP include illegal poaching, habitat degradation, and human-wildlife conflict (BFD, 2015). Nijhum Dwip National Park and its vicinity are home to diverse wildlife, including Clawless Otters, Fishing Cats, Snakes, Tortoises, Turtles, and Dolphins (Iftekhar & Takama, 2006). A recent survey by the Wildlife Conservation Society (WCS) identified the waters of Nijhum Dwip as a biodiversity hotspot, supporting at least 15 threatened marine species, such as the endangered Irrawaddy Dolphin, porpoises, rays, Olive Ridley Turtles, and Scalloped Hammerhead Sharks (Hassan, 2022). To mitigate human-wildlife conflicts, local conservation initiatives, such as afforestation programs and the establishment of artificial water ponds, have been introduced to keep deer populations within the park (BFD, 2018).

Char Kukri-Mukri Wildlife Sanctuary is a vital ecological region that harbors diverse flora and fauna. This literature review examines the available research on the sanctuary's biodiversity, conservation challenges, and the impact of climate change on its wildlife. CKMWS, located in Bhola District, is a significant mangrove and estuarine habitat that supports both terrestrial and aquatic wildlife (BFD, 2018). The sanctuary supports several mammalian species, some of which are endangered or vulnerable. Studies have recorded the presence of small carnivores like the fishing cat (*Prionailurus viverrinus*) and the jungle cat (Felis chaus), both of which depend on the wetland and mangrove ecosystems for survival (Haque & Alam, 2020). Additionally, the presence of rhesus macaques (*Macaca mulatta*) indicates the ecological richness of the region. However, human encroachment and habitat degradation have led to a decline in mammal populations (Khan et al., 2021). Char Kukri-Mukri is an important habitat for both resident and migratory birds. Studies highlight the presence of species such as the Brahminy kite (*Haliastur indus*), black-crowned night heron (*Nycticorax nycticorax*), and several species of kingfishers (Chowdhury et al., 2018). During the winter months, migratory birds, including sandpipers, plovers, and ducks, visit the sanctuary, making it a crucial stopover site for avian biodiversity. However, habitat destruction and disturbances from human activities threaten bird populations (Rahman, 2022). Various snake species, such as the banded krait (*Bungarus fasciatus*) and monocled cobra (*Naja kaouthia*), have also been documented. Amphibians, including different species of frogs and toads, play an essential role in the ecosystem by controlling insect populations (Ahmed et al., 2020). One of the primary threats to the sanctuary's wildlife is habitat loss due to deforestation and land-use changes. The expansion of agriculture, shrimp farming, and human settlements has led to the destruction of mangrove forests, which serve as critical habitats for numerous species (Haque, 2020). Deforestation not only reduces available shelter and food sources for wildlife but also increases vulnerability to climate-induced disasters such as cyclones and storm surges (Khan & Uddin, 2022). As human settlements expand near the sanctuary, conflicts between wildlife and local communities have become more frequent. For instance, rhesus macaques often raid crops and food supplies, leading to retaliatory actions by farmers (Islam, 2020). The sanctuary provides refuge to species such as the Fishing Cat, Oriental Small-clawed Otter, and several threatened wading birds (Khan, 2020). The sanctuary is a critical wintering ground for migratory birds, including the Greater Spotted Eagle (*Clanga clanga*), Black-headed Ibis (*Threskiornis melanocephalus*), and Eurasian Curlew (*Numenius arquata*) (Rahman et al., 2021). Encroachment for agriculture and shrimp farming is a significant concern in CKMWS, leading to the degradation of wetland and mangrove habitats (Haque & Ali, 2019). The Fishing Cat and Otter populations are particularly at risk due to conflicts with fishermen who view them as competitors for fish resources (Rahman et al., 2021). Conservation efforts in CKMWS include afforestation programs, strict patrolling against illegal fishing and poaching, and habitat restoration to support both resident and migratory bird species (BFD, 2018). Community involvement in wetland conservation has also been promoted to enhance sustainable coexistence between local livelihoods and wildlife (Haque & Ali, 2019).

Tengragiri Wildlife Sanctuary supports diverse wildlife, including mammals, birds, reptiles, and marine species. The coastal ecosystem, consisting of mangrove forests and wetlands, provides critical habitats for numerous species (Rahman et al., 2020). The sanctuary is home to several mammalian species fishing cat (*Prionailurus viverrinus*), and Indian mongoose (*Herpestes edwardsii*) (Haque & Alam, 2021). Tengragiri is an important stopover site for migratory birds and a breeding ground for many resident bird species. Studies have identified the presence of egrets (*Egretta spp*.), herons (*Ardea spp*.), and the globally threatened masked finfoot (*Heliopais personatus*) (Chowdhury et al., 2019). The coastal waters of Tengragiri harbor an abundance of marine life, including fish, crustaceans, and mollusks. The sanctuary serves as a breeding ground for several species of commercially valuable fish, such as hilsa (*Tenualosa ilisha*) (Hassan et al., 2020). Additionally, marine turtles, including olive ridley (*Lepidochelys olivacea*), have been recorded nesting along the shores, although their populations are under threat from human activities (Rahman & Karim, 2022). TWS, is one of the lesser-studied protected areas in Bangladesh. However, existing studies highlight its importance in conserving coastal and mangrove-dependent species (IUCN, 2015). Key threatened species in TWS include the Fishing Cat, Golden Jackal, Spotted Deer, and several raptor species (Khan, 2019). The major threats to TWS include deforestation, coastal erosion, and climate change impacts such as rising sea levels and cyclonic storms (Rahman et al., 2021). Efforts to restore degraded mangrove areas through community-based afforestation projects have shown positive impacts on the ecosystem (Haque & Ali, 2019). Additionally, Tengragiri Wildlife Sanctuary is a critical habitat for numerous wildlife species, playing a vital role in coastal ecosystem stability.

CHAPTER-III

APPROACHES AND METHODS

3.1. Study Area

The present research will be conducted in three coastal mangrove sites namely Nijhum Dwip National Park (NDNP), Char Kukrimukri Wildlife Sanctuary (CKWS), Tengragiri Wildlife Sanctuary (TWS) which lie sharply on the costal belt starting from South-West (Patharghata, Barguna) to South-East (Noakhli) part of Bangladesh. Each site represents a mixed species mangrove vegetation which helps to analyze mangrove community structure, i.e. mangrove health and biodiversity of the coastal region.

3.1.1 Char Kukrimukri Wildlife Sanctuary (CKWS)

Char Kukri Mukri Island is located in the southern side of Char Fassion Upazila of Bhola district, covering an area of about 40 ha, is isolated from the main land facing the Bay of Bengal. It was officially declared as a wildlife sanctuary by the government of Bangladesh on 19 December, 1981. During the year of 1973/1974, Bangladesh Forest Department started forestation program using the species of Keora, Baen and Gewa in all around the Island. The present planted forest area is about 11307.42 ha. Among the forest area, 4973.43 ha is managed by Sadar forest beat and 1360.99 ha by Char Patila beat. The forest floor is muddy and subject to tidal inundation twice daily. Six small canals traverse the island, while its central region is utilized for extensive rice cultivation and human habitation, primarily along flood protected embankments. Navigating the forest can be challenging due to the presence of tidal channels and the pneumatophores of *Keora* (*Sonneratia apetala*) and *Bain* (*Avicennia officinalis*) trees. The waters and surrounding islands of the Char Kukri-Mukri Wildlife Sanctuary (CKMWS) serve as critical wintering grounds for migratory birds, including several threatened shorebird species. Notable species observed in the area include the Black-tailed Godwit (*Limosa limosa*), Black-headed Ibis (*Threskiornis melanocephalus*), Eurasian Curlew (*Numenius arquata*), and Greater Spotted Eagle (*Clanga clanga*), among others. Additionally, the sanctuary supports a thriving population of spotted deer (*Axis axis*), which have successfully adapted to the mangrove ecosystem. These deer primarily feed on Keora (*Sonneratia apetala*) leaves and various grasses found in the island's non-forested areas.

Climate

CKMWS has a tropical climate with significant rainfall throughout most of the year and a brief dry season. The average annual temperature is 25.6°C (78.1°F), with May being the warmest month at 45.6°C (114.1°F), while January is the coldest at 19.5°C (67.1°F). January is the driest month, receiving only 8 mm (0.31 in) of precipitation, whereas July experiences peak rainfall, averaging 671 mm (26.4 in). The annual average rainfall is approximately 3,302 mm (130.0 in), with monthly precipitation ranging from 5 mm (0.2 in) to 290 mm (11.42 in).

Geomorphology

Bangladesh's coastal zone is a dynamic and diverse region where interactions among the land, ocean, and atmosphere shape its ecological character. Based on geographic features, the coastal zone is categorized into three distinct regions: the eastern, central, and western zones. The western region—often referred to as the Ganges tidal plain—comprises a semi-active delta interlaced by numerous channels and creeks (IUCN BD, 2015). The nation's 710 km long coastline forms a vital interface for various ecological and economic systems.

Soils in this coastal zone are varied, including calcareous alluvium, acid phosphate soils, grey floodplain, and grey piedmont soils. These soils are generally saline with pH values ranging from neutral to slightly alkaline, and are well-supplied with potassium and phosphate.

Hydrology

Multiple creeks traverse the islands, channeling water to the principal rivers and ultimately to the Bay of Bengal. During each tidal cycle, these creeks deliver brackish water from the Bay into the mangrove forests and sparsely vegetated areas. The entire southwest region of Bangladesh, extending to the right bank of the Ganges-Padma, is known as the Gengetic Delta. This delta has been primarily formed by alluvial deposits carried by the Ganges, and the current north-south river systems are remnants of its major distributaries.

Salinity measurements taken between 13 and 16 February 2014 using a refractometer recorded values of 11 parts per thousand in the Meghna River at CKMWS.

Biodiversity (Flora)

A total of 272 plant species from 78 families have been documented on Char Kukri Mukri Island (see Appendix 1). The most common families include Cyperaceae, Poaceae, Fabaceae, Convolvulaceae, Asteraceae, Mimosaceae, Caesalpiniaceae, Euphorbiaceae, Verbenaceae, Amaranthaceae, and Acanthaceae. Of these species, 86 are trees, 31 shrubs, 119 herbs, and 36 climbers. Habitat distribution shows the highest species richness in homesteads (97 species), followed by roadsides (81 species), mangrove areas (47 species), and cultivated lands (47 species). Many species in homestead and roadside habitats have been introduced by local communities, government agencies, and research institutions, while fruit-bearing trees are relatively few due to high salinity (Feeroz et al., 2015). Mangrove plantations are widespread, particularly in newly accreted coastal areas. The upper canopy is dominated by *Sonneratia apetala, Sonneratia caseolaris, Avicennia officinalis, Excoecaria agallocha,* and *Bruguiera gymnorrhiza*, with rarer species such as *Heritiera fomes* and *Xylocarpus granatum* also present. Understory vegetation is mainly composed of seedlings of these dominant species, while forest edges support bush species like *Acanthus ilicifolius* and *Dalbergia spinosa*. Intertidal zones feature grasses and sedges, and the banks of tidal canals host diverse tree species including *Pongamia pinnata and Barringtonia acutangular* etc.

Map of Char Kukri-Mukri Range showing the location of Wildlife Sanctuary
Bhola Coastal Forest Division

Fig-1: Location Map of CKMWSin the Char Kukri-Mukri Range

Biodiversity (Fauna)

Char Kukri mukri Wildlife Sanctuary (CKMWS) is home to a diverse array of wildlife. A total of 260 species have been documented, including 7 amphibians, 20 reptiles, 209 birds (123 resident and 86 migratory), and 18 mammals (see Appendix 2 and Table-1). Spotted Deer are particularly abundant, while other notable species include the small-clawed otter, golden jackal, water buffalo monitor lizard, fishing cat, various turtles, and dolphins.

Table-1: Faunal Diversity of CKWS

Wildlife	No. of species available in Bangladesh	No. of species available in the CKMWS	Species biodiversity (%) in the CKMWS as compare to Bangladesh
Amphibians	23	7	30.43
Reptiles	154	25	16.23
Birds	632	209	33.06
Mammals	138	19	13.76
Fishes	325	177	54.46
Shrimps	35	11	31.42
Crabs	11	6	54.54
Total	**1318**	**454**	

**Source: Feeroz et al. 2015*

Population

Char Kukri-Mukri Wildlife Sanctuary is situated within the Char Fasson Upazila of Bhola District, Bangladesh. As per the 2011 Census of Bangladesh, Char Fasson Upazila had a population of 456,437 residing in 94,649 households. Specifically, the Kukri Mukri Union, which encompasses the sanctuary, had a population of 8,362 individuals at that time. It's important to note that the Char Kukri-Mukri Wildlife Sanctuary itself is a designated protected area, and human habitation within its boundaries is minimal or non-existent to preserve its ecological integrity.

Administrative setup and Manpower of CKMWS

The CKMWS is under administrative jurisdiction of Char Kukri-mukri Range under Coastal Forest Division, Bhola. The notified area of CKMWS is 40 ha. The Divisional Forest Officer (DFO) is overall responsible for the management of the PA including administration, protection and improvement of the resources and conservation of biodiversity, environmental management, preparation of budget, and control over all activities within his jurisdiction. The Range Officer (RO) is responsible for management implementation of the sanctuary. He liaises with other related government departments and local NGOs and other organizations. The Forester in Charge of a Beat is responsible for protection and other field activities within his Beat. The management units of the CKMWS are shown in the Table-2.

Table-2: Forest Range and Beats in CKMWS

Name of the Range	Name of the Beat	Name of the Char	Forest area (ha) Declared
Char Kukri-mukri WS	Char Kukri-mukri sadar beat	Char Dighol	703.73
		Char Jomir	687.40
		Char Shafi	843.00
		Char Kukri-Mukri	618.28
		Char Kukri-Mukri (Char Jamir)	40.47
	Char Patila beat	Char Alim	35.00
		Char Rowshan	323.00
		Char Patila	595.00
		Total =	**3845.88**

At the CKMWS there are one range office with two beat offices. The present staffing strength is mentioned in Table-3.

Table-3: Manpower of the CKMWS

Current staff	Char Kukri-Mukri & Char Patila Beat	TOTAL
Forest Ranger / Deputy Ranger	1	1
Forester	2	2
Forest Guard	5	5
Plantation Mali	3	3
Boat man	6	6
Sub-total		**17**

3.1.2 Nijhum Dwip National Park (NDNP)

This is a coastal island under Hatiya Upazila, Noakhali district located at the Meghna Estuary. This island is located between 22°02"23.7" N to 22°06'03.3" N latitude and 90°58'46.04" E to 91°02'12.3" E longitudes. A significant portion of that small island was declared as Nijhum Dwip National Park in 2001. Mangrove forest of Nijhum Dwip acquired in afforestation process. In 1974, Bangladesh Forest Department initiated mangrove afforestation in the island. The major species of the plantation was Keora. Considerable amount of Gewa and Baen have also been noticed in the plantation area. The over exploitation of the coastal resources by local communities has an adverse impact on mangrove forest of Nijhum Dwip. Total area of Nijhum Dwip decreased from about 5350 hectors in 2001 to 4873 hectors in 2016. Mangroves cover an area of 1865 ha. The associated islands include Char Osman, Char Kamala, Char Kabira,

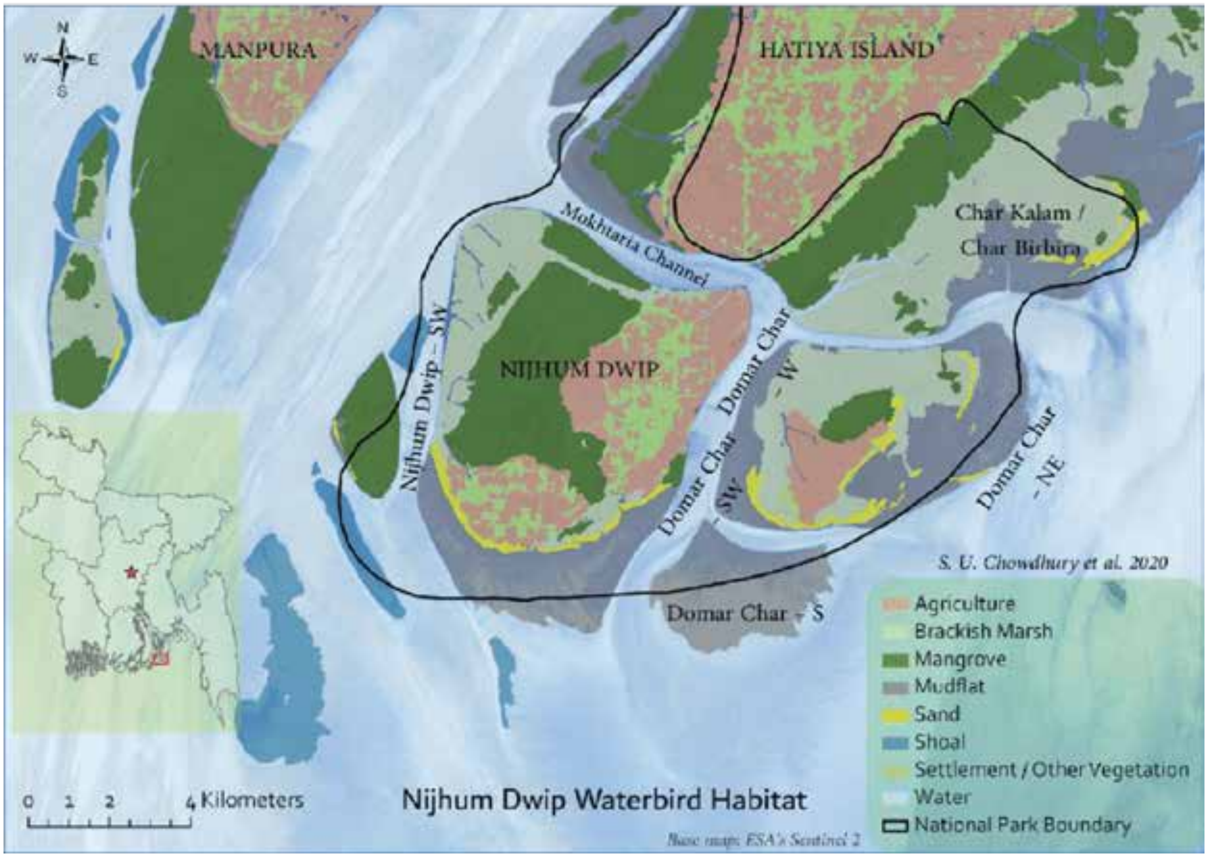

Fig-2: Map of the Nijhum Dweep National Park

Char Yunus, Char Rawsan, Char Kalam, Char Muid, Domar Char, Char Bahauddin, Char Jahan, Char Aftab, Char Balua, and Khaja's Char, among others. Located in the southern region of Bangladesh, this area has developed into a significant mangrove ecosystem of forestland established by the Bangladesh Forest Department. In 2001, the Government of Bangladesh designated Nijhum Dweep as one of the country's national parks to enhance conservation efforts and protect its rich biodiversity.

Climate

Situated on an island in the Bay of Bengal, NDNP's climate is moderated by its maritime influence, although it still conforms to the tropical monsoon pattern. The park receives substantial rainfall during the monsoon, with monthly precipitation often ranging between 200–700 mm, while the dry season (typically from November to April) sees minimal rainfall, sometimes below 10 mm per month.

Geomorphology

Nijhum Dwip National Park is located within Bangladesh's dynamic coastal delta, where fluvial, tidal, and coastal processes continuously reshape the landscape.

Hydrology

Several creeks traverse the islands, draining water to the main rivers and the Bay of Bengal, while at each tide they supply brackish water to the mangrove forests and sparsely vegetated lands. Salinity levels in this area are comparable to those in CKMWS. Nijhum Dwip National Park, situated at the Meghna River estuary, experiences a significant hydrological influence from the river across all seasons.

Biodiversity (Flora)

Land in this region is primarily formed through eolian deposition or marine/fluvial sedimentation. Newly accreted areas are sparsely vegetated, predominantly colonized by *Oryza coarctata* (Dhani grass), whereas older grasslands that experience less frequent flooding are mainly occupied by *Cynodon dactylon* (Durba grass). Over time, these lands may transition into mangrove forests through a combination of plantation efforts and natural succession, initially dominated by *Sonneratia apetala* (Keora) and later increasingly by *Excoecaria agallocha* (Gewa) along with *Avicennia alba, A. marina, and A. officinalis* (Bain). Agricultural areas are primarily dedicated to rice cultivation, while settled regions form a mosaic of constructions, fish ponds, homestead gardens, and tree belts featuring species such as *Albizia saman, Albizia procera, Acacia nilotica, Cocos nucifera, Cocos equisetifolia,* and *Swietenia mahagoni*.

Mangrove Vegetation

Mangrove plantations have been developed around the island, with the Forest Department undertaking annual plantation programs on newly accreted coastal lands. The mangrove canopy is largely formed by *Sonneratia apetala, Sonneratia caseolaris, Avicennia officinalis, Excoecaria agallocha,* and *Bruguiera gymnorrhiza*, while less common species such as *Heritiera fomes, Xylocarpus granatum, Xylocarpus mekansis, Cerbera manghas, Ceriops decandra, Dolichandrone spathacea,* and *Aegiceras corniculata* are also present. The forest floor is primarily covered by seedlings of these dominant species, and the forest edge supports a variety of bush species including *Acanthus ilicifolius, Dalbergia spinosa, Nipa fruticans, Hibiscus populnea, Thespesia lampus,* and *Sapium indicum*. In the intertidal zones, species such as *Poetresia coarctata, Zoysia matrella, Cryptocoryne retrospiralis, Zoysia tenuifolia,* and *Saccharum spontaneum prevail*, while climbers such as *Derris scandens, Derris trifolia, Frazillaria indica, Ipomoea littoralis,* and *Cerclobus carinatus* are common. Additionally, the banks of tidal canals host a diverse assemblage of trees, including *Pongamia pinnata, Barringtonia acutangula, Trewia polycarpa, Crataeva nurvala, Heritiera fomes, Tamarindus indica, Sonneratia caseolaris, Samanea saman, Albizia procera*, and others.

Biodiversity (Fauna)

In November 2013, both systematic surveys following the methodologies of Feeroz and Deodatus (2003) and Van Lavieren (1983) and non-systematic observations were conducted to assess the vertebrate diversity of the study area. The systematic surveys recorded 14 reptile species, 98 bird species (comprising 67 resident and 31 migratory species), and 17 mammal species. In contrast, the non-systematic surveys identified an additional 7 amphibian species, 20 reptile species, 209 bird species (including 123 resident and 86 migratory), and 18 mammal species. Together, these surveys provide a comprehensive inventory of the region’s biodiversity, offering critical insights into its ecological composition and species distribution (Table-4).

Table-4: Faunal diversity in NDNP

Wildlife	No. of species available in Bangladesh	No. of species available in the NDNP	Species biodiversity (%) in the NDNP as compare to Bangladesh
Amphibians	23	7	30.43
Reptiles	154	20	12.99
Birds	632	209	33.06
Mammals	123	17	13.82
Fishes	325	177	54.46
Shrimps	35	11	31.42
Crabs	11	6	54.54
Total	**1303**	**447**	

**Compiled by Author*

Population

Settlement on Nijhum Dwip is concentrated in specific areas, namely Char Osman, Char Bahauddin, Char Muid, and Char Rowshan. The National Population Census (2011) reported a population of approximately 13,000, yet more recent estimates suggest figures ranging from 20,000 to 30,000. Even at the lower end, this translates to a high population density of over 800 persons per square kilometer (excluding forested and newly accreted lands), with residents spread across 17 villages. Many settlers have migrated from Hatiya and Tamijuddin following land loss due to erosion, and given the recent establishment of these communities, most inhabitants maintain familial ties with regions outside Nijhum Dweep, particularly Hatiya.

Administrative Setup of NDNP

The NDNP is under administrative jurisdiction of Jahajmara Range under Coastal Forest Division, Noakhali. The Divisional Forest Officer (DFO) is overall responsible for the management of the PA including administration, protection and improvement of the resources and conservation of biodiversity, environmental management, preparation of budget, and control over all activities within his jurisdiction. The Range Officer (RO) is responsible for management implementation of the sanctuary. He maintain liaison with other related government departments and local NGOs and other organizations. There are 4 beat under Jahajmara Range. The Forester in Charge of a Beat is responsible for protection and other field activities within his Beat. There are 38 sanctioned post at the NDNP including outsourcing stsff and at present 31 staffs are present (Table-5).

Table 5- Manpower of the NDNP

Current staff	Number of post	NDNP
Forest Ranger	1	0
Forester	4	4
Forest Guard	12	11
Plantation Mali	3	3
Boat man	12	7 (including outsourcing)
MLSS	2	3 (including outsourcing)
Speed Boat Driver	4	3
Total	**38**	**31**

Most of the PA in Bangladesh have formed the Co-Management Committees (CMC), Co-management Organization (CMO), Village Conservation forum (VCF) and Community Patrol Group (CPG) in order to protect the forest against any criminal activities with the help of Forest Guards. There is 1 (one) Co-Management Committees (CMC) with 11 Village Conservation Forum (VCF) in TWS. The inhabitant of this area are very cooperative in terms of forest and other resource protection. There is no cultivated land or human habitation inside the PA. Sometimes people around the PA collects some fuel wood and anglers often anchor their boats temporarily on the bank of the PA. Resources inside the sanctuary are managed by BFD through the Beat Offices only.

3.1.3 Tengragiri Wildlife Sanctuary (TWS)

Tengragiri Wildlife Sanctuary, located in the coastal region of southern Bangladesh, is a significant ecological zone known for its rich biodiversity and critical role in preserving coastal habitats. The sanctuary is home to a wide variety of flora and fauna, including threatened and endangered species. This e sanctuary's biodiversity, conservation challenges, and the impact of climate change on its wildlife, drawing from existing research and studies. Tengragiri wildlife sanctuary located near Taltali in Barguna District of Bangladesh. The sanctuary is locally known as Fatrarban. The area of the sanctuary is 27.08 km2. Geographically it is located at 21.8628° N to 21.906° N latitude and 90.0252° E to 90.1152° E longitude. It was officially declared as a wildlife sanctuary by the government of Bangladesh on 24 October, 2010. Keora, Baen, Passur, Sundri increase species in this forest where Keora plantation is more significant and increases rate 13.17 ha/year. Gewa-Goran is an interchanging class and shows decreasing sign over the years. Tengragiri Wildlife Sanctuary supports diverse wildlife, including mammals, birds, reptiles, and marine species. The coastal ecosystem, consisting of mangrove forests and wetlands, provides critical habitats for numerous species (Rahman et al., 2020). With expanding human settlements near the sanctuary, conflicts between wildlife and local communities have increased. Crop raiding by wild animals and attacks on livestock have led to retaliatory actions, endangering key species (Islam, 2021). Sustainable conflict resolution strategies are required to mitigate these issues. Illegal poaching of birds, reptiles, and mammals for trade and subsistence hunting continues to threaten wildlife populations (Khan & Alam, 2019). Overfishing and the unsustainable extraction of marine resources also disrupt the ecological balance, affecting predator-prey relationships (Ahmed & Sarker, 2020).

Fig. 3. Satellite Map of Tengragiri Wildlife Sanctuary

Climate

The coastal regions of Bangladesh experience a tropical climate, predominantly influenced by the southwest monsoon from the Indian Ocean, encompassing three distinct seasons:

Warm Season (March to May) Characterized by the year's highest temperatures, this period accounts for approximately 15% of the annual rainfall, primarily through thunderstorms accompanied by strong winds. Humidity levels remain consistently high. This phase Monsoon Season (June to October) contributes about 75% to 80% of the annual precipitation. Temperatures often exceed 90°F, and humidity nears saturation. The season is marked by prolonged rainstorms.

Cool Season (November to February) has marked by infrequent rainfall and the year's lowest temperatures, ranging from 45°F to 50°F. Daily highs typically remain below 90°F, and skies are predominantly clear. The region is particularly susceptible to natural disasters such as cyclones, tidal surges, waterlogging, and salinity issues. Notable cyclones like those in 1970, 1991, 2009, 2010, and Cyclone Mahasen in 2013 have significantly impacted local communities.

Geomorphology

The geomorphology of the Tidal Wetland Sanctuary (TWS) is characterized by its deltaic landscape, shaped by the confluence of multiple rivers and the influence of tidal actions. The area is predominantly composed of calcareous alluvium, acid phosphate soil, grey floodplain, and grey piedmont soils, all of which are saline and exhibit neutral to slightly alkaline pH levels. These fertile soils facilitate the penetration of mangrove tree roots, supporting the rich biodiversity of the sanctuary. However, the forest ecosystem faces challenges due to natural calamities and increased accessibility, leading to forest degradation.

Hydrology

The hydrology of the Tidal Wetland Sanctuary (TWS) in Bangladesh is intricately linked to the dynamic interactions between freshwater inflows from northern rivers and saline tidal incursions from the sea. Major rivers such as the Payra, Andarmanik, and Tetulia contribute significantly to the freshwater supply, especially during the monsoon season, when they receive substantial overflow from the Meghna River. This influx brings nutrient-rich alluvium, enhancing the fertility of the region's soils and supporting the productivity of its forest ecosystems. Soil salinity within the TWS exhibits a gradient, increasing from east to west, yet generally remaining below 6 dS m^{-1} during the driest months. Peak salinity levels occur from April to May, with soil salinity ranging between 2 and 4.5 dS m^{-1}, considered low. Water salinity fluctuates between 1 to 9 ppt in late monsoon (September) and 4 to 28 ppt during the dry season (May), influencing the types of vegetation and aquatic life the area can support.

Biodiversity (Flora)

Tha mangrove plantations have been developed all around the island. Forest department under plantation programs has under taken each year in the newly accreted land facing to the sea. The top canopy in the mangrove was occupied by *Sonneratia apetala, Sonneratia caselaoris, Avicennia officinalis, Excoecaria agallocha* and *Bruguiera gymnorrhiza.* Apart from such species, a rare presence of *Heritiera fomes, Xylocarpus granatum, Xylocarpus mekansis, Cerbera mangus, Ceriops decandra, Dolichandronae spathacea, Aegiceros corniculata* were also detected in forest. Mainly, seedlings of *Excoecaria agallocha,* sonneratia apetala, and avicennia officinalis covered the forest ground. In the forest edge, the dominant bush species were *Acanthus ilicifolius, Dalbergia spinosa, Nipa fruticans, Hibiscus populnea, Thespesia lampus, Sapium indicum* and *Excoecaria agallocha.* The ground near the intertidal zone mainly dominated *Poetresia coarchtata, Zoysia matrella, Cryptocoryne retrospiralis, Zoysia tenuifolia and Saccharum spontaneum*. Most common climbers in the Mangrove forest were *Derris scandens, Derris trifolia, Frazillaria indica, Ipomoea litiralis, and Cerclobus carinatus.* Some members of sedge species observed in this zone. The banks of the tidal canals were dominated a good number of trees. Suche species were *Pongamia pinnata, Barringtonia acutangula, Trewia polycarpa, Crataeva nurnala, Heritiera fomes, Nipa frutican, Tamarindus indica, Sonneratia apetala, Avocennia officialis, Sonneratia caseolaris, Samanea saman, Albizia procera, Hibiscus populnea, Xylocarpus granatum, Calophylum innophylum, Acacia catechu* and *Albizia recardiana etc*.

Biodiversity (Fauna)

A total of 5 species of amphibians, 14 species of reptiles, 98 species of birds (resident 67and migratory 31) and 17 species of mammals were recorded. 7 species of amphibians, 20 species of reptiles, 209 species of birds (123 species are resident and 86 species are migratory) and 18 species of mammals were recorded (Table-6).

Table-6: Faunal Diversity of TWS

Wildlife	No. of species available in Bangladesh	No. of species available in the TWS	Species biodiversity (%) in the TWS as compare to Bangladesh
Amphibians	23	5	21.73
Reptiles	154	14	9.09
Birds	632	98	15.50
Mammals	123	17	13.82
Fishes	325	177	54.46
Shrimps	35	11	31.42
Crabs	11	6	54.54
Total	**1303**	**328**	

Population

Tengragiri Wildlife Sanctuary (TWS) encompasses 10 northern villages: Sakina, Bara Nishanbaria, Gorapara, Bathipara, Nidrapara, Sawdagarpara, Edupara, Chotaamkhola, Laopara, and Kabirajpara. These villages collectively comprise approximately 3,000 households, with a total population estimated between 17,000 and 18,000 residents. The demographic composition is predominantly Muslim (92.47%), followed by Hindu (6.38%) and Buddhist (1.11%) communities. The literacy rate in the area is below 40%.

Administrative Setup of TWS

The TWS is under administrative jurisdiction of Taltoli Range under Coastal Forest Division, Patuakhali. The Divisional Forest Officer (DFO) is overall responsible for the management of the PA including administration, protection and improvement of the resources and conservation of biodiversity, environmental management, preparation of budget, and control over all activities within his jurisdiction. The Range Officer (RO) is responsible for management implementation of the sanctuary. He maintain liaison with other related government departments and local NGOs and other organizations. The Forester in Charge of a Beat is responsible for protection and other field activities within his Beat. The management units of the TWS are shown in the Table -7.

Table 7- Manpower of the TWS

Current staff	TWS
Forester	1
Forest Guard	5
Plantation Mali	1
Boat man	2
Total	**9**

Most of the PA in Bangladesh have formed the Co-Management Committees (CMC), Co-management Organization (CMO), Village Conservation forum (VCF) and Community Patrol Group (CPG) in order to protect the forest against any criminal activities with the help of Forest Guards. There is 1 (one) Co-Management Committees (CMC) with 11 Village Conservation Forum (VCF) in TWS. The inhabitant of this area are very cooperative in terms of forest and other resource protection. There is no cultivated land or human habitation inside the PA. Sometimes people around the PA collects some fuel wood and anglers often anchor their boats temporarily on the bank of the PA. Resources inside the sanctuary are managed by BFD through the Beat Offices only.

3.2 Methods of Qualitative Data Collection

The research methodology is designed in a structured, systematic, and sequential approach to ensure comprehensive execution and robust results. The first step involves a series of consultations to refine the research objectives and align the study with the specific goals. Following this, an extensive literature review has been conducted to build a strong theoretical and empirical foundation, identifying key studies, trends, and gaps relevant to the research topic. Subsequently, study instruments have been meticulously prepared, ensuring they are appropriate for the data collection process. This includes the development of surveys, interview guides, and other tools necessary for gathering relevant information. In parallel, data sources has been identified, focusing on both primary and secondary data to ensure a comprehensive approach. The next phase involves the collection of primary data using a range of instruments, with a focus on maintaining high standards of quality control throughout the process. This step has been followed by the conducting of key informant interviews (KIIs) and focus group discussions (FGDs) to gather qualitative insights from participants. Additionally, in-depth interviews (IDIs) has been carried out to obtain detailed, personal perspectives on the research topic. Alongside primary data collection, secondary data will also be gathered from relevant sources, such as published reports, databases, and official records. Once data collection is complete, data entry will take place, followed by a thorough analysis using appropriate statistical and qualitative methods to derive meaningful insights. The research findings have been prepared for publication in peer-reviewed journals, contributing to the body of knowledge within the field. Finally, a comprehensive report will be prepared, summarizing the research process, findings, and recommendations, before being submitted to relevant stakeholders and institutions. Quantitative sampling was conducted through the administration of a structured questionnaire survey to ensure a representative selection of participants. The target population for this survey comprised members of communities dependent on forest and wetland resources, including women, youth, ethnic minorities, individuals with disabilities, boat residents/dwellers, and local government officials. These diverse groups were chosen to capture a broad range of perspectives, ensuring that the study accurately reflects the experiences of different stakeholders within the study area. To ensure proportional representation, the total sample size was distributed according to the relative size of each group within the target population. This distribution was carefully calculated to maintain the representativeness of each subgroup, with adjustments made based on the number of participants in each group. The final allocation of participants was determined through collaborative discussions and consultations with focus groups, ensuring that the sample size distribution reflected the community's input and the specific objectives of the study.

3.2.1 Focus Group Discussions (FGD)

Focus Group Discussions (FGDs) has been conducted with beneficiaries to assess the impact, limitations, and challenges associated with the study's focus areas. The FGD has include diverse stakeholder groups such as women, fisherfolk, forest-dependent communities, Village Conservation Forum (VCF) members, Co-Management Committee (CMC) members, and Community Patrol Groups (CPGs). The Focus Group Discussions (FGDs) aim to investigate the impact of buffalo grazing on wildlife habitats, causes of declining the Spotted Deer, illegal fishing practices using poison bait, hunting the migratory birds, deforestation trends, and evaluate compliance with forest management regulations. The discussions have been provided the insights into wildlife hunting and trade, identifying key species targeted and the socioeconomic impact on local communities. Furthermore, the FGDs has assess existing wildlife conservation programs, explore opportunities for sustainable wildlife management, and identify ways to enhance community involvement in conservation efforts. A total of 06, 20 and 06 FGDs have been carried out in NDNP, CKMWS and TWS ensuring representation from all identified beneficiary groups. Each FGD session will comprise approximately 8 to 12 participants, ensuring broad coverage of perspectives from the targeted groups. A semi-structured questionnaire (Annexure-10) covering all relevant discussion topics will guide the FGDs, facilitating structured yet flexible conversations that capture in-depth insights. These discussions will be conducted in person at designated study sites, with locations identified in consultation with key stakeholders, including the client's focal representatives and local community leaders. To ensure the safety and well-being of participants, all FGDs will strictly adhere to health protocols, particularly in relation to pandemic-related precautions and hygiene measures.

3.2.2 Key Informant Interview (KII)

A common questionnaire has been developed for Key Informant Interviews (Annexure-11). The objective of the Key Informant Interviews (KIIs) is to gather expert insights on forest decline, wildlife conservation policies, and management strategies from individuals actively engaged in conservation efforts. The discussions aim to assess the extent of forest degradation, identify challenges in policy implementation, and explore potential solutions for mitigating threats to wildlife. Additionally, the KIIs will provide an understanding of institutional involvement, stakeholder collaboration, and community participation in conservation efforts. The interviews will also help identify ongoing and past projects supporting wildlife conservation and the socioeconomic impact of wildlife trade in the region. The expected findings from the KIIs include a clearer picture of the rate and causes of forest area decline, such as deforestation, land conversion, or resource exploitation. Insights into the effectiveness of current wildlife conservation policies, the level of enforcement, and gaps in management will also be identified. The discussions will reveal the number and specialization of personnel engaged in conservation within key organizations and the extent of collaboration with other agencies, partners, and local stakeholders. Additionally, the KIIs are expected to highlight the scale of wildlife trade, including the approximate number of households involved and the trade's impact on local livelihoods. Recommendations will emerge regarding practical initiatives to mitigate buffalo grazing, conserve species such as Spotted Deer, Otters, and Fishing Cats, and enhance community participation in conservation. The interviews will also provide strategic recommendations for improving conservation policy implementation, strengthening enforcement mechanisms, and increasing local engagement in protecting threatened wildlife species. KII respondents are CMC Leaders, Local Elites, UP Members and other actors relevant to the research objectives. A total of 07, 04, and 04 KIIs have been conducted in NDNP, CKMWS and TWS.

3.2.3 In Depth Interview (IDI)

The objective of the In-Depth Interviews (IDIs) is to gather detailed insights from key individuals actively engaged in wildlife conservation and forest management (Annexure-12). These interviews aim to assess trends in forest conservation, determining whether deforestation has occurred or if forest cover has increased. They also seek to evaluate the effectiveness of existing wildlife conservation policies, highlighting the need for enhanced supervision, stricter enforcement, and increased security measures. Additionally, the IDIs has explored the presence of conservation programs, such as the SUFAL project, and analyze the role of community-led committees in wildlife management and decision-making. Another key objective is to assess the extent of human-wildlife conflict, particularly in relation to crop damage by deer and monkeys, and to explore potential solutions for coexistence. The interviews will further investigate the impact of livestock grazing on forest ecosystems and identify community-driven strategies for its management. Moreover, the study has examined the necessity of veterinary care for wildlife, including disease prevention and emergency treatment, to improve conservation outcomes. By addressing these aspects, the IDIs aim to provide comprehensive recommendations for strengthening wildlife conservation efforts, enhancing policy implementation, and promoting sustainable community engagement in forest and wildlife protection. A common questionnaire will be developed for In Depth Interviews. A total of 05, 04, and 04 KIIs have been conducted in NDNP, CKMWS and TWS.

3.2.4 Household surveys

Household surveys are a widely used method in wildlife-related research to gather valuable data on community perceptions, human-wildlife interactions, and the socio-economic factors influencing conservation efforts. This method involves structured questionnaires administered to households within or near wildlife habitats, providing insights into local knowledge, attitudes, and practices related to wildlife and their habitats. To gather more comprehensive insights, the team utilized a structured questionnaire for conducting household surveys (HS). This approach was designed to collect quantitative data on community perceptions regarding the abundance, current status, and habitat preferences of selected wildlife species in the three protected areas (PAs). Additionally, the survey aimed to assess threats to these species, human-wildlife conflicts, and the impacts of afforestation in the study areas. A total of 39 Household surveys carried out throughout the research (Table-8).

Table-8: Qualitative data collection in different methods across three different PAs

Tools	Respondents	NDNP	CKMWS	TWS
FGD	Women, Fisher Flock, Forest Dependent Community, VCF Members, CMC Members, CPG Members	6	20	6
KII	CMC Leader, Local Elites, UP Members, Journalist	7	4	4
IDI	FD Officials, Local Admin Personnel	5	4	4
Total		18	28	14

3.3 Methods of Quantitative Data Collection

Quantitative data collection in wildlife research involves systematically gathering numerical data to assess wildlife populations, behavior, distribution, and the health of ecosystems. These methods provide objective, measurable insights that can be analyzed statistically to draw conclusions and inform conservation strategies. The primary goal is to generate data that can be used to make accurate assessments, monitor changes over time, and guide wildlife management decisions.

3.3.1 Line Transect Count (LTC) Method

The Line Transect Count (LTC) method is a widely used survey technique in wildlife population studies and ecological research. It involves systematically counting animals along predefined straight-line transects within a study area to estimate population density, distribution, and abundance. A series of straight-line transects are established across the habitat, ensuring adequate coverage of the study area. The length and placement of these transects depend on the terrain, habitat type, and target species. Observers walk along the transect line at a consistent pace, recording sightings of wildlife species. The distance of each observed individual or group from the transect is measured, along with additional data such as species type, group size, behavior, and environmental conditions. The perpendicular distance of each sighting from the transect line is recorded to account for detectability bias. This helps in adjusting population estimates, as individuals farther from the transect may be less likely to be observed. In this study, the LTC technique has been used for bird and mammal survey.

Sampling and data Collection Procedure of LTC

Unlike fixed-width transect methods, the line transect method does not assume all objects within a set width are detected. Instead, it assumes objects on the line are detected with certainty, while detection probability decreases with distance from the line. In CKMWS, NDNP and TWS 1 km long straight transects (Chilla) were established, considering the topography and geographical constraints. These transects were clearly marked using painted tags. Two trained observers systematically walked each transect, recording prey animals observed on either side. Sampling was conducted between 0600–0900 and 1600–1900 hours when prey species were most active. Sighting distances (15m–180m) were measured using optical rangefinders, and sighting angles were calculated from azimuth bearings. To ensure adequate sampling effort, trained volunteers conducted line transect surveys under supervision, with 10–20 volunteers per site. In Spotted Deer surveys, considering physical barriers such as khals and rivers, 1 km transects were found effective. However, in areas of lower deer density, longer transects may be preferable. A minimum of 5–10 transects were established per vegetation type to ensure representative sampling (Table-9).

During this study, LTC data were collected across four vegetation types. A total of 12 permanent 1 km transect lines were established in CKMWS, NDNP, and TWS. The transect plots measured 10 m × 10 m (100 sq. m). To minimize bias from variations in animal activity, transects were surveyed alternately from start to end. For each sighting, the central location of the animal group was recorded, along with the perpendicular distance to the transect line (20–30 m range). Distance measurements were taken using a range finder (20–60 m range) at 10 m class intervals. Additionally, group composition details were documented, and range finders were used whenever possible to ensure accuracy.

Line-of-sight measurement are used in the King Census Method; in this method measurements are taken perpendicular from the transect to the fleshing location (Webb, 1942). The formula of the King census.

$$P = \frac{AZ}{ZYX} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where P= population, A= total area of study, Z= number flushed, Y = average flushing distance, X = length of line

Flush radius is defined only towards the direction of approach. Here, the probabilities of observing the animals our proportions to the widest part of the pattern (generally proportional to the length of the projection of the pattern on the perpendicular to the line of travel).

Table-9: Line Transect Count (LTC) across three PAs

Transect No.	Name of Protected Area	GPS location		Vegetation	
		Northing	Easting	Vegetation type	Canopy closure (%)
LTC -1	CKMWS	21° 54' 8.62"	90° 38' 33.85"	Keora	
LTC -2	CKMWS	21° 54' 14.44"	90° 38' 43.82"	Keora-Gewa	
LTC -3	CKMWS	21° 54' 20.51"	90° 38' 43.45"	Keora	
LTC -4	CKMWS	21° 54' 26.17"	90° 38' 59.66"	Gewa	
LTC -5	CKMWS	21° 54' 34.71"	90° 39' 8.15"	Keora-Gewa	
LTC -6	CKMWS	21° 54' 44.26"	90° 39' 15.78"	Keora	
LTC -7	CKMWS	21° 54' 50.17"	90° 39' 18.69"	Keora	
LTC -8	CKMWS	21° 54' 52.84"	90° 39' 20.47"	Gewa-Keora	
LTC -9	CKMWS	21° 54' 54.54"	90° 39' 21.61"	Keora	
LTC -10	CKMWS	21° 54' 54.79"	90° 39' 25.66"	Keora-Gewa	
LTC -11	CKMWS	21° 54' 58.43"	90° 39' 24.70"	Keora	
LTC -12	CKMWS	21° 55' 1.96"	90° 39' 28.92"	Keora	
LTC -1	NDNP	22° 02' 42.25"	90° 58' 46.98"	Keora	50-60
LTC -2	NDNP	22° 02' 42.77"	90° 59' 10.94"	Keora-Gewa	70-80
LTC -3	NDNP	22° 02' 49"	90° 59' 26.37"	Keora	75-85
LTC -4	NDNP	22° 02' 45.5"	90° 59' 50.94"	Gewa	40-50
LTC -5	NDNP	22° 02' 35.18"	91° 00' 18.04"	Keora-Gewa	70-80
LTC -6	NDNP	22° 04' 01.26"	91° 00' 09.25"	Keora	70-80
LTC -7	NDNP	22° 04' 07.6"	91° 00' 15.04"	Keora	50-60
LTC -8	NDNP	22° 04' 14.15"	91° 00' 30.39"	Gewa-Baen	70-80
LTC -9	NDNP	22° 04' 21.03"	91° 00' 38.28"	Keora	60-70
LTC -10	NDNP	22° 04' 28.4"	91° 00' 50.3"	Keora-Gewa open grassland	50-60
LTC -11	NDNP	22° 04' 35.8"	91° 00' 57.7"	Keora	50-60
LTC -12	NDNP	22° 04' 43.01"	91° 01' 07.71"	Keora-Gewa	70-80
LTC -1	TWS	21° 53' 45.90"	90° 02' 0.59"	Keora- Gewa - Sundri	50-60

Transect No.	Name of Protected Area	GPS location		Vegetation	
		Northing	Easting	Vegetation type	Canopy closure (%)
LTC -2	TWS	21° 53' 46.20"	90° 02' 18.75"	Keora-Sundri-Goran	70-80
LTC -3	TWS	21° 53' 43.21"	90° 02' 29.81"	Keora	40-50
LTC -4	TWS	21° 53' 40.98"	90° 02' 43.98"	Gewa	5040
LTC -5	TWS	21° 53' 39.5"	90° 02' 51.91"	Sundri-Gewa	70-80
LTC -6	TWS	21° 53' 22.47"	90° 03' 08.35"	Gewa-Passur-Kankra	70-80
LTC -7	TWS	21° 53' 25"	90° 03' 15.14"	Gewa	50-60
LTC -8	TWS	21° 53' 28.35"	90° 03' 21.84"	Gewa-Sundri	70-80
LTC -9	TWS	21° 53' 32.67"	90° 03' 27.81"	Gewa-Sundri	50-60
LTC -10	TWS	21° 53' 35.72"	90° 03' 47.39"	Keora	50-60
LTC -1I	TWS	21° 53' 37.68"	90° 03' 55.51"	Keora- Gewa - Sundri	50-60
LTC -12	TWS	21° 53' 40.81"	90° 04' 03.22"	Keora-Sundri-Goran	70-80

Figure-4: Line Transect Counting Location at the CKMWS

Figure-5: Line Transect Location Map of the Nijhum Dweep National Park

Figure-6: Line Transect Location Map of the Tengragiri Wildlife Sanctuary

3.3.2 Pellet Group Counting (PGC) method

The Pellet Group Counting (PGC) method is a widely used indirect survey technique for estimating deer population density by analyzing the accumulation of fecal pellet groups in a given area. This method is particularly effective in forested habitats where direct sightings of deer are difficult. The process involves establishing systematically placed sampling plots or transects where researchers count and record the number of pellet groups deposited over a known period. Since deer defecation rates are relatively consistent, population estimates can be derived by correlating the number of pellet groups with the estimated defecation rate per individual per day. The PGC method is cost-effective, minimally invasive, and allows for long-term monitoring of deer populations without direct disturbance.

Sampling and data Collection Procedure of PGC

The study utilized a 10 m × 10 m plot (100 sq. m) for data collection. Spotted Deer were observed and classified by sex, age, and herd size based on the vegetation type they occupied. Age classes—adult, sub-adult, juvenile, and young—were estimated using comparative body size. Due to poor visibility in all forest types, except coastal grasslands and Keora forests, direct census methods were impractical. Instead, an indirect method using pellet group counts was applied. Over a 24-hour observation period, all defecations of free-ranging Spotted Deer were recorded, noting the habitat sub-unit where feces were deposited and the associated animal activity at the time of deposition. Every two weeks, a pair of mature deer (or two individuals) were released to roam freely for 24 hours. To ensure accurate observations, two dedicated observers monitored the same pair throughout the 24-hour period. Pellet size was used to distinguish between males, females, and fawns, with fawn pellets being notably smaller. In addition to defecation data, the percentage of total activity time was recorded, categorizing behaviors such as grazing, ruminating, resting, sleeping, traveling, standing, playing, and drinking.

A total of 15 Pellet Group Count (PGC) plots were established across four vegetation classes in CKMWS. Of these, 10 were located in Keora forests, 3 in Keora-Gewa, 1 in Gewa-Keora, and 1 in Gewa forests. A summary of the locations and vegetation descriptions of these 15 PGC plots is provided in Table-2. Followed by a total of 10 PGC plots were established across four vegetation class in NDNP. Of these, 5 were in Keora forests, 2 in Keora-Gewa, 1 in Keora-Gewa open grassland, 1 in Gewa-Baen, and 1 in Gewa forest. A summary of the locations and vegetation descriptions of these 10 PGC plots is provided in (Table-10). And A total of 10 PGC plots was established in TWS based on vegetation types, distributed as follows: Keora-Gewa-Sundri, Keora-Sundri-Goran, Keora, Gewa, Sundri-Gewa, Gewa-Passur-Kankra, Gewa, Gewa-Sundri (two plots), and Keora.

Table-10: Summary of PGC including plot locations and Vegetation Type across three PAs

PGC Plot No.	Name of Protected Area	Name of char land	GPS location		Vegetation type
			Northing	Easting	
PGC -1	CKMWS	Char Shafi	21° 54' 11.72"	90° 38' 42.78"	Keora
PGC-2	CKMWS	Char Shafi	21° 54' 14.58"	90° 38' 48.95"	Keora-Gewa
PGC -3	CKMWS	Char Shafi	21° 54' 18.20"	90° 38' 54.59"	Keora
PGC -4	CKMWS	Char Shafi	21° 54' 21.44"	90° 39' 2.09"	Gewa
PGC -5	CKMWS	Char Shafi	21° 54' 27.35"	90° 39' 3.93"	Keora-Gewa
PGC -6	CKMWS	Char Shafi	21° 54' 29.63"	90° 39' 13.18"	Keora
PGC -7	CKMWS	Char Shafi	21° 54' 35.92"	90° 39' 9.07"	Keora
PGC -8	CKMWS	Char Shafi	21° 54' 36.11"	90° 39' 20.16"	Gewa-Keora
PGC -9	CKMWS	Char Shafi	21° 54' 42.21"	90° 39' 80.72"	Keora
PGC -10	CKMWS	Char Shafi	21° 54' 46.78"	90° 39' 27.96"	Keora-Gewa
PGC -11	CKMWS	Char Shafi	21° 54' 53.54"	90° 39' 23.03"	Keora
PGC -12	CKMWS	Char Shafi	21° 54' 54.02"	90° 39' 32.07"	Keora
PGC -13	CKMWS	Char Shafi	21° 54' 59.16"	90° 39' 33.10"	Keora
PGC -14	CKMWS	Char Shafi	21° 55' 6.59"	90° 39' 40.03"	Keora

PGC Plot No.	Name of Protected Area	Name of char land	GPS location		Vegetation type
			Northing	Easting	
PGC -15	CKMWS	Char Shafi	21° 55' 16.31"	90° 39' 50.96"	Keora
PGC -1	NDNP	Nijhum Dweep National Park	22° 02' 41.3"	90° 58' 48.8"	Keora
PGC-2	NDNP	-do-	22° 02' 41.55"	90° 58' 50.48"	Keora-Gewa
PGC -3	NDNP	-do-	22° 02' 44.81"	90° 58' 43.45"	Keora
PGC -4	NDNP	-do-	22° 02' 47.28"	90° 58' 41.79"	Gewa
PGC -5	NDNP	-do-	22° 02' 49.50"	90° 58' 48.82"	Keora-Gewa
PGC -6	NDNP	-do-	22° 02' 47.77"	90° 58' 58.41"	Keora
PGC -7	NDNP	-do-	22° 03' 06.84"	90° 58' 36.71"	Keora
PGC -8	NDNP	-do-	22° 03' 04.03"	90° 58' 58.22"	Gewa-Baen
PGC -9	NDNP	-do-	22° 03' 23.52"	90° 59' 12.3"	Keora
PGC -10	NDNP	-do-	22° 03' 04.27"	90° 59' 29.53"	Keora-Gewa open grassland
PGC -1	TWS	Tengragiri Eco-park	21° 53' 29.70"	90° 02' 11.58"	Keora- Gewa - Sundri
PGC-2	TWS	Tengragiri Eco-park	21° 53' 14.13"	90° 02' 54.44"	Keora-Sundri-Goran
PGC -3	TWS	Fatrar Char camp	21° 53' 10.45"	90° 03' 36.68"	Keora
PGC -4	TWS	Fatrar Char camp	21° 53' 26.04"	90° 04' 14.47"	Gewa
PGC -5	TWS	Tengragiri Eco-park	21° 53' 50.84"	90° 04' 47.72"	Sundri-Gewa
PGC -6	TWS	Tengragiri Eco-park	21° 53' 41.50"	90° 05' 34.01"	Gewa-Passur-Kankra
PGC -7	TWS	Bar Nishanbaria camp	21° 53' 14.57"	90° 05' 49.52"	Gewa
PGC -8	TWS	Fatrar Char camp	21° 52' 40.07"	90° 05' 15.02"	Gewa-Sundri
PGC -9	TWS	Bar Nishanbaria camp	21° 52' 12.98"	90° 04' 21.18"	Gewa-Sundri
PGC -10	TWS	Tengragiri Eco-park	21° 52' 06.62"	90° 03' 25.53"	Keora

Figure-7: PGC plot in the CKMWS

Figure-8: PGC Grid Locaiton Map of the Nijhum Dweep National Park

Figure-9: PGC Location Map of the Tengragiri Wildlife Sanctuary

3.3.3 Counting at Colonies, Roosts, and Flocks

The Counting at Colonies, Roosts, and Flocks method is a wildlife research technique primarily used to estimate the population size and monitor the behavior and distribution of social, colonial, and migratory species, such as birds and bats, which aggregate in specific locations. This method involves systematically counting individuals or groups in their natural congregation sites—such as colonies (for nesting or breeding), roosts (for resting or sleeping), and flocks (during feeding or migration). This method of survey was used for large colony and flocks of migratory birds in addition to other methods.

3.3.4 Field Diary Method

The Field Diary Method is a qualitative wildlife research technique where researchers or field workers maintain a detailed, daily record of observations, activities, and environmental conditions during fieldwork. This method is particularly useful for documenting wildlife behavior, changes in habitat, and other ecological factors that may not be captured through traditional survey methods. It allows for the collection of contextual information and personal insights, which can enhance the understanding of wildlife dynamics over time.

3.3.5 Photo Documentation Method

The Photo Documentation Method is a widely used wildlife research technique that involves capturing photographic images of species, habitats, or specific behaviors in order to document and analyze wildlife over time. This method provides visual evidence that can be used to monitor species populations, track changes in habitat conditions, assess biodiversity, and support conservation efforts. It is particularly effective for non-invasive monitoring, as it minimizes disturbance to wildlife while allowing researchers to gather valuable data.

3.3.6 Key Indicator Species

The selected key indicator species are Fishing Cat (*Prionailurus viverrinus*), Spotted Deer (*Axis axis*), Golden Jackal(*Canis aureus*), Asian small-clawed otter (*Aonyx cinereus*), Black-tailed Godwit (*Limosa limosa*), Spotted Greenshank (*Tringa guttifer*), Bengal Monitor (*Varanus bengalensis*), Water Monitor (*Varanus salvator*) etc (Table-11).

Table-11: List of Selected Threatened Key Indicator Species

Name of the Species	IUCN Red list (National) category	IUCN Red list (Global) category	Status from any latest study	Why do we want to focus here?
Fishing Cat (*Prionailurus viverrinus*)	EN	EN	Fishing Cat, an endangered mammal of Bangladesh (Rabbi et al. 2017).	To know about the conflicts with human and assess their threats
Golden Jackal (*Canis aureus*)	LC	LC	No study has been done yet.	The presence of Golden Jackalindicates the richness of faunal and floral diversity.
Asian small-clawed otter (*Aonyx cinereus*)	EN	VU	Asian small-clawed otter is seen in the TWS.	To know about the conflicts with human and assess their threats
Spotted Deer (*Axis axis*)	VU	NT	TWS were the suitable habitats for Spotted Deer (*Axis axis*), but at present they are vulnerable (Dey, T. K 2015).	To know about the conflicts with human and assess their threats
Black-tailed Godwit (*Limosa limosa*)	NT	NT	A large number of Black-tailed Godwit was recorded from TWS.	To study about habitat risks, hotspots and their threats
Spotted Greenshank (*Tringa guttifer*)	CR	EN	Recorded in TWS in 2013 and which can be relevant and effective for this research	To study about habitat risks, hotspots and their threats.
Bengal Monitor (*Varanus bengalensis*)	NT	LC	Dey, 2017 worked about the population, breeding and conservation of Bengal Monitor, which can be very effective for this research.	To know about their habitats, hunting records and other threats and conflicts with human
Water Monitor (*Varanus salvator*)	VU	LC	Due to habitat loss and fragmentation all of the Monitor lizards are facing continuous threats for surviving in their natural habitats (Rahman et al. 2016).	To know about their habitats, hunting records and other threats and conflicts with human

CHAPTER-IV

RESULT AND DISCUSSION

4.1 RESULT AND DISCUSSION FOR CKMWS

4.1.1 Results of Line Transect Count Survey at the CKMWS

1) Population density and population size of the Spotted Deer by LTC method

To study the distribution of animals in the CKMWS along transect in the absence of source of disturbance 1 km long walking trail (locally called Chilla) were selected adjacent to the nearest along the RCC walking trail (Char Kukri-Mukri to Kacchapia) inside the wildlife sanctuary. A total of 12 permanent transect lines of 1 km long were laid out as shown in the map and Table-12.

Table – 12: Population density of the Spotted Deer in the 12 different transect vegetation units by LTC method.

Transect No.	Total no. of observed (in days)	Total no. of observed Spotted Deer	Average no. of Deer observed per transect per day	Transect area (sq. km)	Mean density (deer/sq.km)
T-l	8	68	8.572	0.10 sq.km	85.72
T-2	8	44	5.512	0.10 sq.km	55.12
T-3	8	70	8.754	0,10 sq.km	87.54
T-4	8	28	3.471	0.10 sq.km	34.71
T-5	8	24	3.011	0.10 sq.km	30.11
T-6	8	69	8.695	0.10 sqlm	86.95
T-7	8	70	8.781	0.10 sq.km	87.81
T-8	8	24	3.077	0.10 sq.km	30.77
T-9	8	73	9.184	0.10 sq.km	91.84
T-10	8	45	5.618	0.10 sq.km	56.18
T-ll	8	38	8.815	0.10 sq.km	88.15
T-12	8	70	8.722	0.10 sq.km	87.22
	Total			-	

The population density of the Spotted Deer is given in the Table-13 and it is found that 87.89/sq. km in Keora forest, 47.13/sq.km in Keora- Gewa forest, 34.71/sq.km, in Gewa forest, 30.77/sq. km in Gewa- Keora forest. The population density was highest in the Keora forest and lowest in the Gewa forest. The estimated population size of the Spotted Deer in the CKMWS is **52** (Table-13). LTC method is more acceptable to predict population size of Spotted Deer. Among 3845.88 ha area of the Char Kukri-Mukri Range, Spotted Deer habitat suitable area is 2000 ha (approx.) and acceptable population size is about **2600** (approx.).

Table 13: Population density and size of the Spotted Deer at the CKMWS as estimated by the line transect count (LTC) survey.

Sl No	Vegetation types according to predominant species.	Area (sq. km)	Transect units	Total no. of transect	Mean density of Spotted Deer (no./sq, k)	Total no. of Spotted Deer
1	Keora	0.253	T-1, T-3, T-6, T-7, T-9, T-11, T-12	7	87.89	35.15
2	Keora - Gewa	0,097	T-2, T-5, T-10	3	47.13	15.71
3	Gewa	0.021	T-4	1	34.71	0.72
4	Gewa-Keora	0.029	T-8	1	30.77	0.89
	Total	**0.400**		**12**		**52.47 Say 52 (approx)**

The different monitoring reports and personal experience of field staff show that during cyclonic storms and tidal surges (Aila and Siddor), the Spotted Deer population has been dispersed.

Combined Species composition in the transect vegetation units at the CKMWS

During the entire LTC period a total of 1130 individuals 8 (eight) different species of major mammals, reptiles and birds were recorded in the transect vegetation in the CKMWS. The summary of transect counting census is presented in the Table- 14. Cabined species % of the Spotted Deer *(Cervuss axis)* was 55.13 %, Golden Jackel *(Canis aureus*) 2.75 %, Rhesus Monkey *(Macaca, mulatto)* 30.79 %, Monitor Lizard *(Varanus spp)* 6.99%, Fishing Cat *(Prionailurus viverrina)* 1.32 %, Asian small-clawed otter (*Aonyx cinereus*) 1.68 %, Python *(Python morolus)* 0.01 %, and Indian Porcupine *(Hytrix indica)* 0.07%.

Table-14: Total of major ground wildlife including arboreal Rhesus monkey recorded during the LTC survey (T-1 to T-12)

Date of observed on	Total Observati on days	Number of animal observed								Total animal observed
		Spotted Deer	Rhesus Monkey	Monitor Lizard	Golde n Jackel	Fishin g Cat	Clawles s Otter	Pytho n	Porcopi ne	
T-1	8	68	31	5	3	3	2	-	1	113
T-2	8	44	30	4	2	1	4	1	1	87
T-3	8	70	25	6	3	1	2	-	1	108
T-4	8	28	27	8	2	1	3	1	1	71
T-5	8	24	28	7	3	1	1	1	1	66
T-6	8	69	30	6	4	-	1	1	-	111
T-7	8	70	28	8	4	1	2	-	-	113
T-8	8	24	31	7	2	-	1	1	1	67
T-9	8	73	32	9	-	1	-	1	-	116
T-10	8	45	25	8	3	2	2	1	1	87
T-11	8	38	31	5	2	1	-	-	-	77
T-12	8	70	30	6	3	3	1	1	-	114
Species wise total		**623**	**348**	**79**	**31**	**15**	**19**	**8**	**7**	**1130**
Combine d species %		**55.13**	**30.79**	**6.99**	**2.75**	**1.32**	**1.68**	**0.01**	**0.07**	

4.1.2 Results of the Pellet Group Count Survey at the CKMWS

Population size and density of the Spotted Deer

15 (Fifteen) pellet group plots were established in the four different types of vegetation in the CKMWS during November 2023 to April 2024 and the results of the population census was presented in the Table-15. The standard defecation rate of the Spotted Deer was 13 PG/day and. The study shows that the mean population density of Spotted Deer is 82.86/sq.km in the pure Keora forest, 51.11/sq.km in the Keora-Gewa forest, 32.15/sq.km in the Gewa forest, and 29.25/sq.km in the Gewa-Keora forest. It shows that number of Spotted Deer is **28** (approx).

Table-15: Population density and size of the Spotted Deer in relation to the vegetation types in the CKMWS as estimated by the PGC survey method.

SI. No.	Vegetation types according to predominant species	Total area (sq.km)	Data collection period	Duration in days	Number of PGC plots	Total no. of pellet group observed in the PGC plots	Mean no. of PG per plot	Defecation rate/day	Density of Spotted Deer (No/Sq.km)	Total no. of Spotted Deer in each vegetation type.
1	Keora	0.253	January to April 2024	15	10	0.016263	0.0016263	13	82.86	20.96
2	Keora-Gewa	0,097	-do-	15	3	0.015342	0.005114	13	51.11	4.95
3	Gewa	0.021	-do-	15	1	0.004095	0.004095	13	32.15	0.46
4	Gewa-Keora	0.029	-do-	15	1	0.004225	0.004225	13	29.25	0.81
	Total	0.400			15					27.18 **Say 28** (approx)

Discussion: The study area was small as compare to other Protected Areas. There were a lot of limitations in this method during data collection. The PGC plots were not uniformly distributed throughout the CKMWS due to lack of manpower and logistic support. The forest floors were very thick and some plots were established adjacent area considering the same landscape.

4.2 RESULT AND DISCUSSION FOR NDNP

4.2.1 Results of Line Transect Count Survey at at the NDNP

To study the distribution of animals in the NDNP along transect in the absence of source of disturbance 2 km long walking trail (locally called Chilla) were selected adjacent to the nearest Forest offices and also khals were used for this study. A total of 12 permanent transect lines of 1 km long were laid out / selected in the NDNP(Table-16).

Table-16: Population density of the Spotted Deer in the 12 different transect vegetation units.

Transect No.	Total no. of observed (in days)	Total no. of observed Spotted Deer	Average no. of Deer observed per transect per day	Transect area (sq. km)	Mean density (deer/sq.km)
T-1	12	22	1.9048	2000mx40m= 0.08sq.km	23.81
T-2	14	13	0.9264	2000mx60m= 0.12 sq.km	7.72
T-3	9	25	2.8500	0.12 sq.km	23.75
T-4	10	7	0.7284	0.12 sq.km	6.07
T-5	12	36	3.0264	0.12 sq.km	25.22

T-6	15	41	2.7576	0.12 sqkm	22.98
T-7	4	11	2.8596	0.12sq.km	23.83
T-8	15	9	0.6408	0.12 sq.km	5.34
T-9	4	11	2.8668	0.12 sq.km	23.89
T-10	11	10	0.9000	0.12 sq.km	7.50
T-11	4	11	2.7576	0.12 sq.km	22.98
T-12	6	5	0.9420	0.12 sq.km	7.85
	Total	**201**		-	

1) Species composition in the transect vegetation units at the NDNP

During the entire LTC period a total of 270 individuals 9 (nine) different species of major mammals, reptiles and birds were recorded in the transect vegetation in the NDNP. The summary of transect counting census is presented in the Table- 17.

Cabined species % of the Spotted Deer *(Cervuss axis)* was 27.40 % of the total observed animals, the highest of all observed species. The combined species % Wild Boar *(Sus scrofa)* 12.59 %, Golden Jackal (*Canis aureus*) 12.96 %, Rhesus Monkey *(Macaco, mulatto)* 10.74%, Monitor Lizard *(Varanus spp)* 7.40%, Fishing Cat *(Prionailurus viverrina)* 6.66%, Asian small-clawed otter (*Aonyx cinereus*) 4.81 %, Python *(Python morolus)* 2.96 %, and Indian Porcupine *(Hytrix indica)* 2.59%.

Table-17: Total of major ground wildlife including arboreal Rhesus monkey at the NDNP recorded during the LTC survey (T-1 to T-12)

Date of observed on	Total Observation days	Number of animals observed									Total animal observed
		Spotted Deer	Wild Boar	Rhesus Monkey	Monitor Lizard	Golden jackal	Fishing Cat	Clawless Otter	Python	Porcopine	
T-1	12	7	3	3	2	1	2	1	-	-	19
T-2	14	4	2	6	4	2	1	1	1	1	22
T-3	9	8	1	6	2	1	1	2	-	1	22
T-4	10	3	3	7	2	2	1	1	1	1	21
T-5	12	4	2	5	3	2	1	1	1	1	20
T-6	15	7	4	6	2	1	2	1	1	-	24
T-7	8	8	3	4	1	1	2	1	-	-	20
T-8	15	4	4	6	3	2	1	1	1	1	23
T-9	7	7	3	8	2	1	1	1	1	-	24
T-10	11	10	4	7	4	3	3	2	1	1	35
T-ll	8	9	3	2	2	2	1	-	-	-	19
T-12	6	3	2	7	2	2	2	1	1	1	21
Species total		**74**	**34**	**35**	**29**	**20**	**18**	**13**	**8**	**7**	**270**
Combined species %		**27.40**	**12.59**	**12.96**	**10.74**	**7.40**	**6.66**	**4.81**	**2.96**	**2.59**	

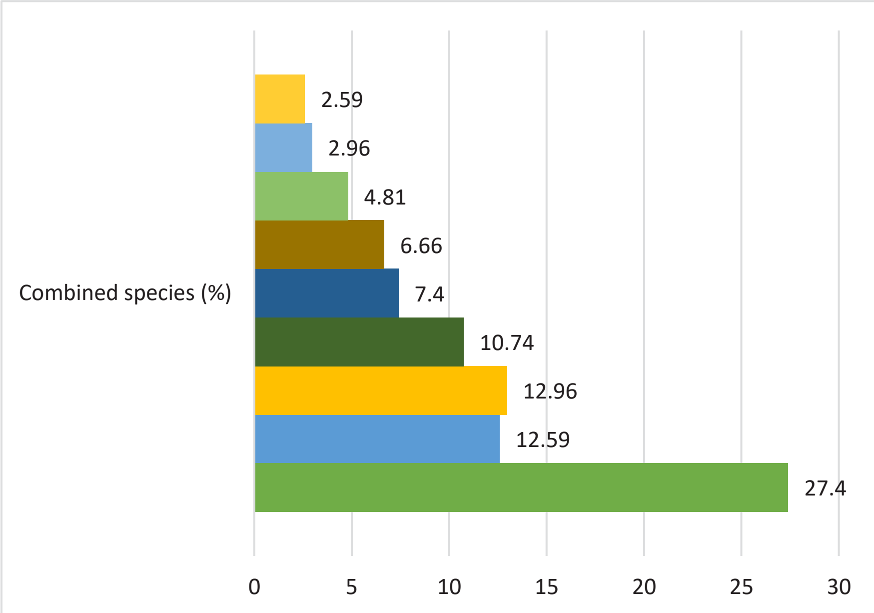

Fig-10: Percentages of Combined Species

2) Population density and population size of the Spotted Deer by LTC method

The population density of the Spotted Deer is given in the Table-18 and it is found that 23.81/sq. km in Keora forest, 7.69/sq.km in Keora- Gewa forest, 6.07/sq.km, in Gewa forest, 5.34/sq. km in Gewa- Baen forest and 25.22/ sq.km in Keora- Gewa open grassland. The population density was highest in the Keora forest and lowest in the Gewa forest.. The estimated population size of the Spotted Deer in the NDNP is **3260** (Table-18).

Table-18: Population density and size of the Spotted Deer at the NDNP as estimated by the line transect count (LTC) survey.

Sl No	Vegetation types according to predominant species.	Area (sq. km)	Transect units	Total no. of transect	Mean density of Spotted Deer (no./sq,k	Total no. of Spotted Deer
1	Keora	103.26	T-1, T-3, T-6, T-7, T-9 and T-11	6	23.81	2458.62
2	Keora - Gewa	35.07	T-2, T-10, T-12	3	7.69	269.68
3	Gewa	40.40	T-4,	1	6.07	245.22
4	Gewa-Baen	30.40	T-8	1	5.34	162.33
5	Keora-Gewa open grassland	4.94	T-5	1	25.22	124.58
	Total	**150.38**		**12**		**3260.43 Say 3260 (approx)**

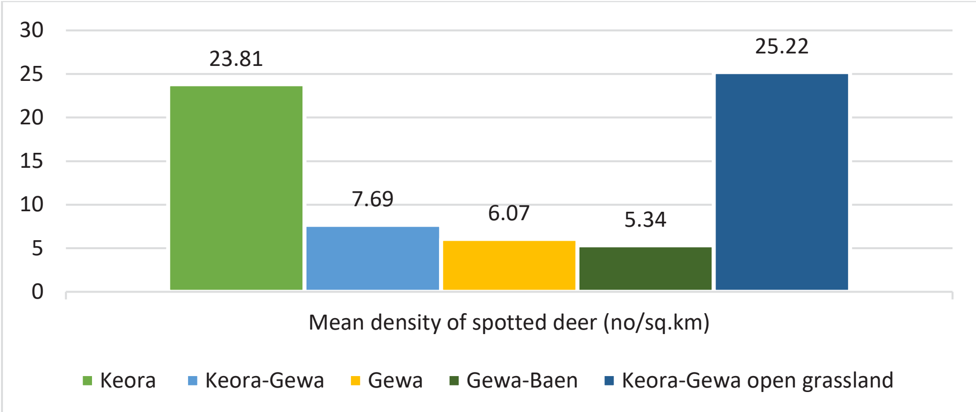

Fig-11: Mean density of Spotted deer (no/sq.km)

4.2.2 Results of the Pellet Group Count survey at the NDNP

1) Population size and density of the Spotted Deer

12 (twelve) pellet group plots were established in the five different types of vegetation in the NDNP during November 2023 to April 2024 and the results of the population census was presented in the Table-8. The standard defecation rate of the Spotted Deer was 13 PG/day and the number of pellet was 70-80 per pellet group. The Spotted Deer was found in all plots. The mean density (no/sq km) of the Spotted Deer in different types of vegetation were presented in the Table-19. It shows that number of Spotted Deer is **3019** (approx).

Table-19: Comparative population density and size of the Spotted Deer in relation to the vegetation types in the NDNP as estimated by the PGC survey during October to December 2001.

SI. No.	Vegetation types according to predominant species	Total area (sq.km)	Data collection period	Durati on in days	Number of PGC plots	Total no. of pellet group observed	Mean no. of PG per plot	Defecati on rate/day	Density of Spotted Deer (No/Sq.k m)	Total no. of Spotted Deer in each vegetation type.
1	Keora	103.26	November 2023 to April 2024	13	6	23	3.833	13	21.75	2245.95
2	Keora-Gewa	35.07	-do-	15	3	9	3.00	13	7.13	250.05
3	Gewa	40.40	-do-	11	1	3	3.00	13	5.79	233.91
4	Gewa-Baen	30.40		11	1	2	2.00		5.13	155.95
5	Keora-Gewa open grassland	4.94	-do-	11	1	4	4.00	13	22.93	133.27
	Total	**150.38**			**12**	**41**				**3019.13** **Say 3019** (approx)

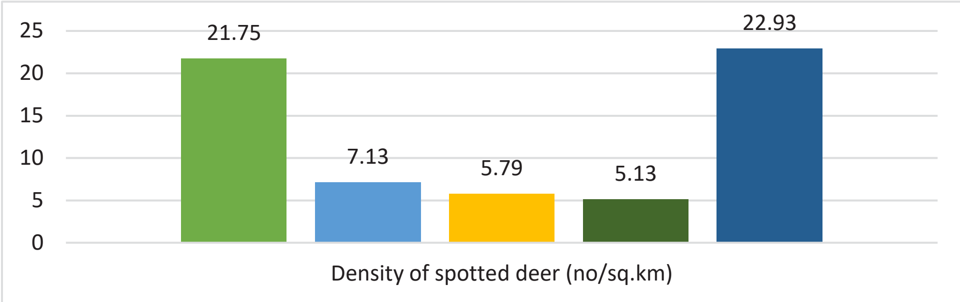

Fig-12: Density of Spotted deer (no/sq.km)

4.3 Results and Observation for the TWS

4.3.1 Results of Line Transect Count Survey at the TWS

To study the distribution of animals in the TWS along transect in the absence of source of disturbance 2 km long walking trail (locally called Chilla) were selected adjacent to the nearest Forest offices and also khals were used for this study. A total of 12 permanent transect lines of 1 km long were laid out / selected in the TWS (Table-20).

Table-20: Population density of the Spotted Deer in the 12 different transect vegetation units.

Transect No.	Total no. of observed (in days)	Total no. of observed Spotted Deer observed	Average no. of Deer observed per transect observation	Transect area (sq. km)	Mean density (deer/sq.km)
T-1	12	2	0.16	2000mx40m= 0.08sq.km	1.02
T-2	14	1	0.07	2000mx60m= 0.12 sq.km	0.58
T-3	9	1	0.11	0,12 sq.km	0.91
T-4	10	1	0.10	0.12 sq.km	0.83
T-5	12	2	0.16	0.12 sq.km	1.33
T-6	15	2	0.13	0.12 sqlm	1.08
T-7	4	-	0	0.12sq.km	0
T-8	15	1	0.06	0.12 sq.km	0.5
T-9	4	-	0	0.12 sq.km	0
T-10	11	2	0.18	0.12 sq.km	1.01
T-ll	4	2	0.15	0.12 sq.km	1.25
T-12	6	3	0.10	0.12 sq.km	0.83
		27	-	-	-

1) Species composition in the transect vegetation units

During the entire LTC period a total of 189 individuals 9 (nine) different species of major mammals, reptiles and birds were recorded in the transect vegetation in the TWS. The summary of transect counting census is presented in the Table-21.

Cabined species % of the Spotted Deer *(Cervuss axis)* was 30.33% of the total observed animals, the highest of all observed species. The combined species % Wild Boar *(Sus scrofa)* 21.69 %, Golden Jackal (*Canis aureus*) 6.36%, Rhesus Monkey *(Macaco, mulatto)* 18.51%, Monitor Lizard *(Varanus spp)* 24.33%, Fishing Cat *(Prionailurus viverrina)* 3.17%, Asian small-clawed otter (*Aonyx cinereus*) 3,36 %, Python *(Python morolus)* 3.70 %, and Indian Porcupine *(Hytrix indica)* 1.58%.

Table-21: Total of Major Ground wildlife including arboreal Rhesus monkey recorded during the LTC survey (T-1 to T-12)

Date of observed on	Total Observation days	Number of animals observed									Total animal observed
		Spotted Deer	Wild Boar	Rhesus Monkey	Monitor Lizard	Golden Jackal	Fishing Cat	Clawless Otter	Python	Porcopine	
T-1	6	3	3	3	3	1	1	1	1	1	23
T-2	7	2	4	6	4	1	_	1	1	1	20
T-3	6	1	-	6	5	2	1	2	-	-	17
T-4	3	2	4	7	4	1	-	1	-	-	22
T-5	5	3	3	5	3	-	-	-	1	-	15
T-6	5	4	5	6	4	1	1	1	2	-	24
T-7	4	-	4	4	4	1	1	1	1	2	18
T-8	5	4	5	6	6	1	1	1	-	-	24
T-9	4	-	6	8	7	1	-	1	-	-	23
T-10	3	3	4	7	3	2	-	2	1	-	22
T-ll	2	2	2	2	2	-	1	-	-	-	9
T-12	3	3	1	7	1	1	-	1	-	-	14
Species total 6256		27	41	35	46	12	6	12	7	3	189
Combined species percentage		**30.33**	**21.69**	**18.51**	**24.33**	**6.36**	**3.17**	**6.36**	**3.70**	**1.58**	

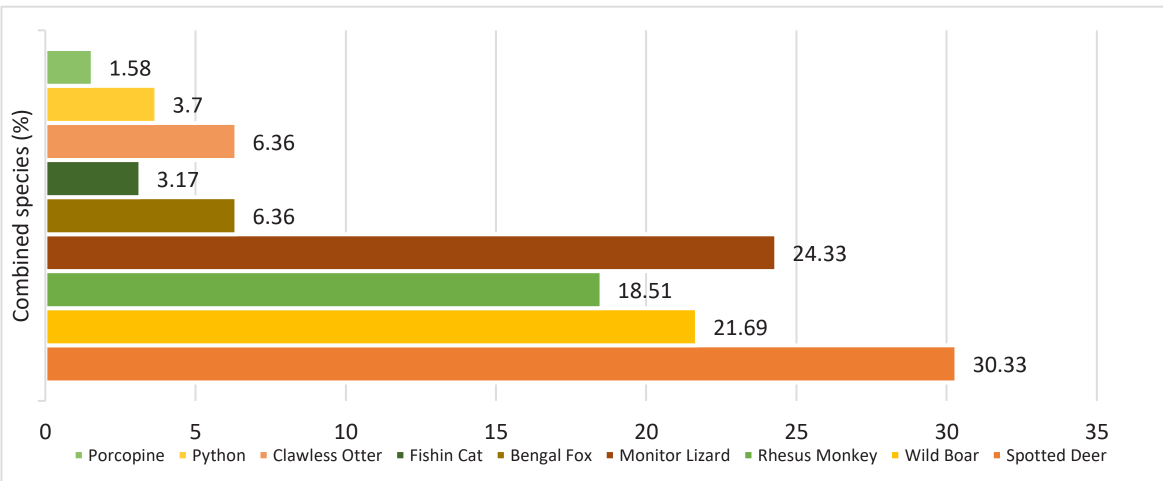

Fig-13: Percentages of Combined Species

(1) Population density and population size of the Spotted Deer by LTC method at the TWS

The population density of the Spotted Deer is given in the Table-23 as following in Sundri forest 3/sq.km which was the lowest, 107 sq.km in Sundri-Gewa, 12/sq.km in Sundri-PassurKankra, 12/sq.krn in Gewa. 6/sq.km; in

Gewa-Sundri, 15/sq. km in Gewa-Goran-Passur, 437sq. km in Goran-Gewa-Keora, 14/sq. km in Passur-Kankra-Baen and 174/sq, km in Keora-Gewa-open grassland.

The population density was highest in the Keora-Gewa open grassland. The estimated population size of the Spotted Deer in the SRF was 79531(Table-22).

Table-22: Population density and size of the Spotted Deer as estimated by the line transect count (LTC) survey.

Sl No	Vegetation types according to predominant species.	Area (sq. km)	Transect units	Total no. of transect	Mean density of Spotted Deer (no./sq,k	Total no. of Spotted Deer
1	Keora-Gewa-Sundri	10. 810	T-1, T-11	2	1.02	12.04
2	Gewa-Sundri	8.610	T-8, T-9	2	0.25	2.15
3	Gewa	7.170	T-4, T-7	2	0.41	2.93
4	Keora	7.170	T-3, T-10	2	0.81	5.80
5	Gewa-Passur-Kankra	2.6958	T-6	1	1.08	2.90
6	Keora-Sundri-Goran	2.680	T-2, T-12	2	0.70	1.82
7	Sundri -Gewa	1.710	T-5	1	1.33	2.27
	Total	**40.4858**		**12**		**29.91**

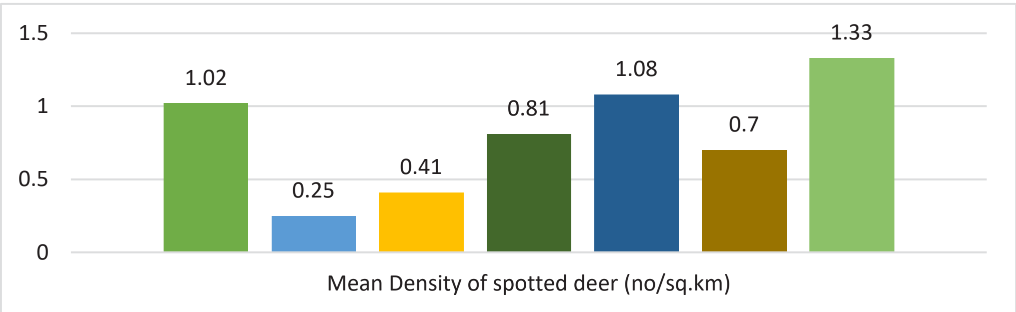

Fig-14: Mean Density of Spotted Dear (no/sq.km)

4.3.2 Results of the Pellet Group Count survey for the TWS

1) Population size and density of the Spotted Deer

10 (ten) pellet group plots were established in the nine different types of vegetation in the TWS during November to December 2023. The standard defecation rate of the Spotted Deer was 13 PG/day and the number of pellet was 70-80 per pellet group. The Spotted Deer was found in all plots. The mean density (no/sq km) of the Spotted Deer in different types of vegetation were presented in the Table-23.

Table-23: Comparative population density and size of the Spotted Deer in relation to the vegetation types at the TWS as estimated by the PGC survey during October to December 2001.

SI. No.	Vegetation types according to predominant species	Total area (sq.km)	Data collection period	Duration in days	Number of PGC plots	Total no. of pellet group observed	Mean no. of PG per plot	Defecation rate/day	Density of Spotted Deer (No/Sq.km)	Total no. of Spotted Deer in each vegetation type.
1	Keora-Gewa-Sundri	10.810	November and December 2023	13	1	3	0.0012	13	0.5	5
2	Gewa-Sundri	8.610	-do-	15	2	2	0.1580	13	0.5	4
3	Gewa	7.170	-do-	11	2	1	0.0178	13	0,5	3
4	Keora	5.180	-do-	11	2	3	0.0578	13	1	2
5	Gewa-Passur-Kankra	2.6958	-do-	10	1	1	0.0095	13	0.5	1
6	Keora-Sundri-Goran	2.680	-do-	9	1	2	0.0014	13	1	2
7	Sundri-Gewa	1.710	-do-	12	1	1	0.0071	13	0.5	1
	Total	**40.4858**			**10**	**13**				**18**

4.4 Habitat Preference of the Indicator Species

Habitat preference is the use of habitat relative to its availability in the environment and is conditional on the availability of all habitat to the animal (Dey, T. K., 2007). A habitat is the natural home or environment of a plant, animal, or other organism. It provides the organisms that live there with food, water, shelter and space to survive. During present study we have analyzed the habitat preference of indicator species.

4.4.1 Habitat Preferance and Aboundace of Indicator Species LTC survey and Khal survey in the NDNP (T-1 to T-13)

Name of the Species	IUCN Red list (National) category	No. of animal identified Keora forest	No. of animal identified Keora-Gewa forest	No. of animal identified Gewa forest	No. of animal identified Gewa-Baen forest	No. of animal identified Keora-Gewa open grassland	No. of animal identified in Open mudflat and charland	Species wise total no. of animal observed	Aboundace of animals
Fishing Cat (*Prionailurus viverrinus*)	EN	3	2	1	1	1	-	8	7.07
Golden Jackal(*Canis aureus*)	VU	4	3	1	2	3	2	15	13.27
Asian small-clawed otter (*Aonyx cinereus*),	EN	5	3	1	2	1	-	12	10.61
Spotted Deer (*Axis axis*)	VU	7	6	5	3	5	2	28	24.77
Black-tailed Godwit (*Limosa limosa*)	NT	2	-	-	-	1	8	8	7.07
Spotted Greenshank (*Tringa guttifer*)	CR	2	-	-	-	1	3	6	5.30

Bengal Monitor (*Varanus bengalensis*)	NT	2	4	4	2	2	1	15	13.27
Water Monitor (*Varanus salvator*)	VU	3	5	4	2	2	2	18	15.92
	Total	**28**	**23**	**16**	**12**	**16**	**18**	**113**	

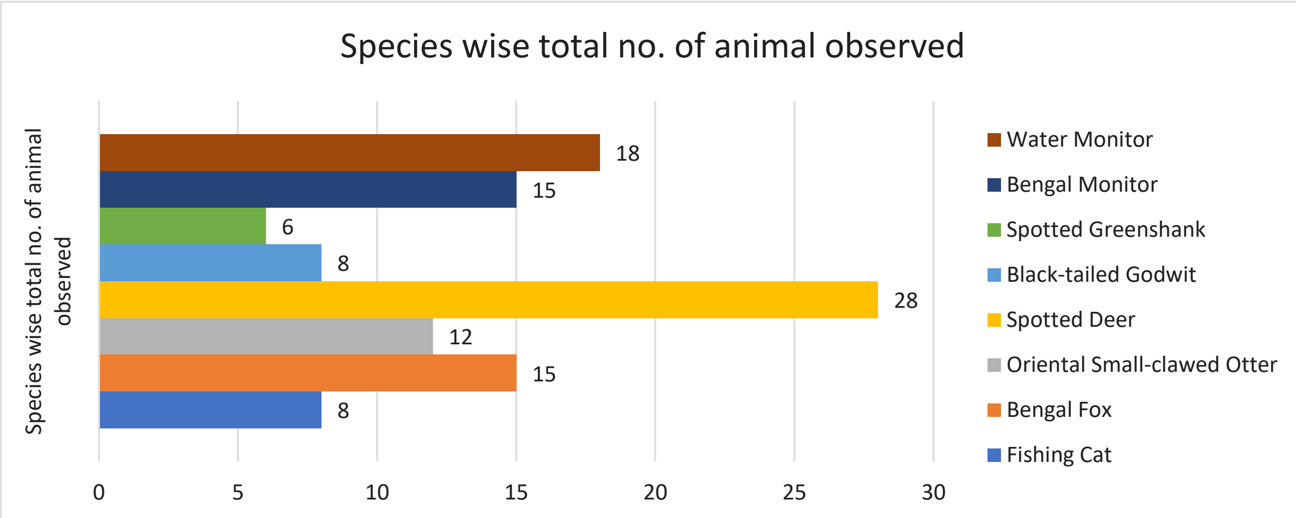

Fig-15: Total No. of Animals Observed (species-wise)

4.4.2 : Habitat Preference and Abundance of Indicator Species LTC survey and Khal survey in the CKMWS (T-1 to T-12)

Name of the Species	IUCN Red list (National) category	No. of animal identified Keora forest	No. of animal identified Keora-Gewa forest	No. of animal identified Gewa forest	No. of animal identified Gewa-Keora forest	Species wise total no. of animal observed	Aboundace of animals
Fishing Cat (*Prionailurus viverrinus*)	EN	7	5	2	1	15	1.95
Golden Jackal (*Canis aureus)*	LC	11	9	6	5	31	4.04
Asian small-clawed otter (*Aonyx cinereus*)	EN	8	7	3	1	19	2.47
Spotted Deer (*Axis axis*)	VU	327	196	75	25	623	82.22
Bengal Monitor (*Varanus bengalensis*)	NT	24	29	14	12	79	9.90
	Total	**377**	**246**	**100**	**44**	**767**	

4.4.3 : Habitat Preferance and Abundance of Indicator Species LTC survey and Khal survey in the TWS (T-1 to T-12)

Name of the Species	IUCN Red list (National) category	No. of animal identified Keora forest	No. of animal identified Keora-Gewa-Sundri forest	No. of animal identified Keora-Sundri-Goran forest	No. of animal identified Gewa forest	No. of animal identified Sundri-Gewa forest	No. of animal identified Gewa-Passur-Kankra forest	No. of animal identified in Open mudflat and charland	Species wise total no. of animal observed	Aboundace of animals
Fishing Cat (*Prionailurus viverrinus*)	EN	1	1	1	1	1	1	-	6	5.40
Golden Jackal(*Canis aureus*)	VU	4	3	2	1	1	1	-	12	10.81
Asian small-clawed otter (*Aonyx cinereus*)	EN	5	3	1	1	1	1	-	12	10.81
Spotted Deer (*Axis axis*)	VU	7	6	6	3	2	1	2	27	24.32
Black-tailed Godwit (*Limosa limosa*)	NT	-	-	-	-	-	-	8	8	7.20
Spotted Greenshank (*Tringa guttifer*)	CR	-	-	-	-	-	-	-	0	0
Bengal Monitor (*Varanus bengalensis*)	NT	2	4	4	3	4	2	1	20	18.01
Water Monitor (*Varanus salvator*)	VU	3	5	4	5	5	2	2	26	23.42
	Total	**22**	**22**	**17**	**14**	**14**	**8**	**11**	**111**	

Spotted Deer: In their native lands, the deer occupy grasslands and very rarely move into areas of dense jungle that may occur adjacent to them. Short grasslands are an important area for them due to a lack of cover for predators such as the tiger. The forest also provides good foraging with regard to fallen fruit and leaves that are high in nutrients needed by the deer. Therefore, the deer require open areas as well as forested areas within their home ranges for optimum habitat. Their terrestrial biomass are savanna or grassland and riparian. In the study area Keora leaves are most preferable food to the deer. Abundance and density of Spotted Deer is comparative higher in the Pure **Keora** forest as compare to other forest (Gewa, Gewa-Keora etc.).

Fishing Cat: Fishing cats are generally found in wetland areas, woodlots and bushes, such as marshes, swamps and mangrove forests. Their habitat is also linked with species of rodents that they eat. Fishing cats can also be seen in cultivated grasslands and agricultural areas with standing water. They are nocturnal and solitary in nature. During present study we have used several Trap Camera to detect the conservation status. We have done sign survey in the CKMWS. Our study team has observed mostly at the bank of small canals, bushes, swamps close to Keora forest.

Golden Jackel: Golden Jackel generally prefer non-forested regions such as open grassland, thorny scrub, semi-desert and arid environments. We have found in agricultural fields, as they are not generally fearful of humans. Golden Jackal s inhabit burrows built approximately two to three feet below ground surface in the high land of the CKMWS, and these burrows have several openings converging towards the center burrow area. They are absent mudflats and deep forests.

Asian small-clawed otter: Asian small-clawed otter *(Aonyx cinereus)* individuals are commonly seen in the shallows of freshwater streams and rivers as well as coastal regions. Nesting burrows are dug into the muddy banks where they live. They have also been seen numerous times in rice paddies. During present study we have identified them at the canal bank and channels of the CKMWS. During FGD survey some people has informed us that they used to catch fishes from the ponds outside the forest, but this frequency is less and in the status of Human-Otter- Conflict.

Bengal Monitor: Unlike other varanid lizards, Bengal monitors have the ability to cope with a broad range of environments, from deserts to rain forests to habitats having seasonally snowy winters. However, generally they are found in areas with continuously warm climates, with mean annual air temperatures of approximately 24 degree centigrade. Thus, precipitation across much of the range for Bengal monitors is highly variable. The most common tropical forest habitats for Bengal monitors are deciduous, semi-deciduous, evergreen tropical forests, and mangrove forests. They are fairly common in the all habitat types of the CKMWS.

Water Monitor: It is semi-aquatic and has a wide range of habitats. They are frequently seen on river banks, khals and in swamps. The Water Monitor is a water-dependent species and has been known to cross large stretches of water, explaining its wide distribution. Though also found on flat land, a typical burrow is in a river bank. The entrance starts on a downward slope but then increases forming a shallow pool of water. The average length is about 9.5 m, the average depth is about 2 m, and the average temperature is around 26 degrees Celsius.They are fairly common in the all habitat types of the CKMWS.

4.5 Analysis of Conservation Threats

The principal constraints and threats, which form the challenges for the management of PAs are more or less same. A large number of trees have been dying every year over the past 15 years or so. Cyclonic storm and tidal surge are causing heavy damage to the forest. Salinity is killing off the tree roots. Loss of sand and soil around the roots also causes the trees to die.

1) **Land tenure** system is the main threat for forest conservation. Leasing out of forest land by the Deputy Commissioner office to the land graver and encroachers is a regular phenomenon at the 3PAs.

2) **Collection of fuel wood**: Sometimes people around the PA collects some fuel wood and anglers often anchor their boats temporarily on the bank of the PA.

3) **Grazing** is a major impact on the PA and it is the main factors of inhibiting natural regeneration. More than 20000 thousands buffaloes graze inside the forest and mudflats of the sanctuary. Open grazing field for cattle is very low and for this reason very high grazing pressure in the at the NDNP and CKMWS. The introduction of livestock is prohibited according to the Wildlife Act (2012), but livestock grazing is common and destructive particularly by interfering with forest regeneration. Livestock roams freely in the sanctuary, even at night.

4) **Unplanned and illegal road construction** of roads by LGED and embankment by WAPDA are very much detrimental to wildlife conservation. Several factors are responsible for conservation are:

- ✓ Natural calamities
- ✓ Salinity
- ✓ Adverse climate change

Ecosystem services such as provisioning (food, fresh water), regulating services (cyclone and storm regulation, water purification), supporting services (soil formation, nutrient cycling) are negatively affected by habitat degradation, which has a negative impact on wildlife as well as on the communities in the area.

5) Climate change

Climate related disasters such cyclone and storms, excessive rainfall, water logging, and drought occur frequently in the area, bringing at risk livelihoods and human life. Forecasted rising temperatures (Islam 2009) may influence life cycles and habitat suitability of animal and plant species. On its turn, these changes may have consequences for the performance of agricultural crops. Habitat changes resulting from climate change may force animals to migrate to other areas. Due increasing fragmentation of landscapes, migration is becoming more difficult. Sea level rise resulting from climate change may also induce human migration to higher areas such as the CKMWS landscape.

6) Tourism

Char Kukri Mukri is very interesting area for eco-tourists to enjoy. Based on survey and observations a number of features have been identified, which have been great values foe conservation and ecotourism. Such features are: Opportunity to watch the isolated and remote island facing to the Bay of bangle; Presence of coastal belt plantations turned into natural ecosystem; Opportunity to enjoy mangrove forest; Presence of introduced wildlife with their natural population; Opportunity to meet friendly local people and also can enjoy local hospitality with fresh sea fish; Opportunity to enjoy serine and virgin environment; Opportunity to roaming and cruising all around the island by boat. Huge opportunity for nature photographers; Opportunity to watch bird's paradise (Feeroz *et all* 2015).

However, garbage pollution like poly-bags, plastic bottles, chips packets, loud music and waste disposal etc causes negative impact on wildlife conservation. Therefore, increasing tourism will not only generate more revenues, but it will also lead to more disturbance of the ecosystem by the visitors that need to be managed.

6) Human-wildlife conflict

During present study Human wildlife conflict were identified through FGD, KII and IDI analysis.

Spotted Deer: Since 1979 there was no natural population of Spotted Deer in the CKMWS, In 1970 five (4) male and 5 female Spotted Deer were collected from Sundarbans and introduced first time at the CKMWS. Gradually their number has been increased and at that time deer were harmful for crops and vegetable gardens. During the present study Spotted Deer population size in the whole Char-Kukri area was about 2000-2500, but there no record of deer population estimation of CKMWS. This population of Spotted Deer are not harmful to local people. During present study our team recorded 28 deer by PGC method and 52 deer by LTC method. Considering the field situation of bothe method LTC estimation is acceptable. Previous monitoring reports and personal experience of field staff show that during cyclonic storms and tidal surges (Aila and Siddor), the Spotted Deer population has been dispersed.

Clawless Otter: There are three types of Otter species found in Bangladesh. Notable number of Asian small-clawed otter (*Aonyx cinereus*) is one of them found in NDNP. Recently total population of otter in NDNP is satisfactory in number and several groups with pregnant individuals recorded.

Due to increase of **Otters** population, human otter conflicts (HOC) are increasing like HDC. Availability of fish and crustacean resources are the main reason for HOC especially dry season. According to local people, in dry season otter come in to their fish culture water body & eat up a bulk amount of fish.

Sensitization is the only way to mitigate HDC as well as HOC. Though local peoples are very much patience about wildlife. No illegal poaching is recorded here. More awareness about presence of wildlife could reduce human wildlife conflicts in this sanctuary.

CHAPTER-V

RECOMMENDATIONS

The study provides a comprehensive analysis of threatened wildlife species, habitat conditions, and conservation challenges in NDNP, CKMWS, and TWS. The use of diverse research methodologies strengthen the credibility of the findings, particularly in assessing population estimates and habitat preferences. However, to further enhance the impact of research, consider the following:

1. Enhancement of habitat protection and restoration through mangrove afforestation

- Prioritize conservation of Keora forests due to their high biodiversity value.
- Implement afforestation strategies that minimize negative impacts on foraging grounds and mudflats.
- Conduct long-term habitat monitoring to assess changes in wildlife populations and ecosystem health.

2. Strengthen Community-Based Conservation

- Establish Co-Management Committees (CMC) and Community Patrol Groups (CPG) in CKMWS to improve local engagement in conservation efforts.
- Provide training programs for local communities on sustainable resource management and eco-tourism.
- Develop incentive-based conservation programs to encourage participation in habitat protection.

3. Improve Wildlife Monitoring and Research

- Conduct additional surveys during the dry season to refine population estimates and validate existing findings.
- Incorporate advanced monitoring technologies such as camera traps and drone surveys for more accurate data collection.
- Study species-specific behaviors and habitat preferences to inform targeted conservation actions.

4. Increase Capacity and Resources for Conservation Authorities

- Strengthen the Forest Department by increasing manpower, training, and funding for conservation initiatives.
- Enhance coordination between government agencies, researchers, and conservation NGOs.
- Develop a standardized monitoring framework for threatened species in coastal ecosystems.

5. Promote Sustainable Eco-Tourism

- Leverage local hospitality to develop eco-tourism initiatives that generate revenue for conservation.
- Establish guidelines to ensure tourism activities do not disturb wildlife habitats.
- Educate visitors on responsible tourism practices to foster conservation awareness.

6. Mitigate Human-Wildlife Conflicts

- Implement awareness campaigns to improve relationships between local communities and forest protection staff.
- Develop compensation programs for communities affected by wildlife-related damages.
- Encourage alternative livelihoods that reduce dependency on forest resources.

CHAPTER-VI

CONCLUSIONS

The study on threatened wildlife species, threat assessment, and the projection of coastal afforestation impacts on habitat enhancement at Nijhum Dweep National Park (NDNP), Char Kukri-Mukri Wildlife Sanctuary (CKMWS), and Tengragiri Wildlife Sanctuary (TWS) has provided critical insights into the status of key indicator species and their habitats. The AIRD research team employed a combination of methods, including Line Transect Count (LTC), Pellet Group Counting (PGC), Focus Group Discussions (FGD), Key Informant Interviews (KII), and In-Depth Interviews (IDI), to gather comprehensive data. While systematic population estimation for all species was challenging, the PGC method proved particularly effective during the dry season, and LTC emerged as a reliable method for predicting population sizes, especially for species like the Spotted Deer. The research highlighted the importance of habitat quality, with Keora forests showing the highest biodiversity (49.15% of observed wildlife) compared to other vegetation types. Coastal plantation areas demonstrated greater biodiversity than barren char lands, though afforestation in foraging grounds or mudflats had some negative impacts. Population density estimates revealed that Spotted Deer were most abundant in Keora forests (87.89/sq. km) and least in Gewa forests (30.77/sq. km), with similar trends observed across other species. A total of 1,130 individuals from eight major species were recorded during LTC surveys, with Spotted Deer (55.13%) and Rhesus Monkey (30.79%) being the most dominant. The study also underscored the role of community involvement and co-management in conservation efforts. While NDNP has functional Co-Management Committees (CMC) and Community Patrol Groups (CPG), CKMWS lacks such organized structures, relying instead on local cooperation and Forest Department management. Despite occasional tensions between local communities and protection staff, relationships are improving, and awareness of conservation is growing. Local communities are generally cooperative, and their hospitality enhances the potential for eco-tourism. However, challenges such as habitat degradation, limited resources, and logistical constraints in data collection highlight the need for further surveys, particularly during the dry season, to refine population estimates and address discrepancies. Strengthening the Forest Department's capacity, increasing manpower, and expanding community-based conservation initiatives are essential for effective wildlife management. In conclusion, this study provides a foundation for future conservation strategies, emphasizing habitat protection, community engagement, and sustainable management practices to ensure the long-term survival of threatened wildlife species in these critical coastal ecosystems.

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Anexure-1

Some Photographs of Field Visit at the CKMWS during November 2023 to October 2024

A herd of Spotted Deer (*Axis axis*) at the western boundary of CKMWS

Oriental Small-clawed otter (*Aonyx cinerea*)

Golden Jackal at CKMWS

Golden Jackal at CKM forest

Bengal Monitor (*Varanus bengalensis*)

Ruddy Shel Duck

Some Photographs of Field Visit and data collection at the CKMWS during November 2023 to October 2024

Field visit with research team

Field visit with research team

Field visit with research team

Field visit with research team

Field visit with research team

Use of Capture camera for wildlife data collection

Some Photographs of Field Visit (22-24 November 2023) to Nijhum Dweep National Park

Some Photographs of Field Visit and Camera traping (13-16 December 2023) at the Tengragiri Wildlife Sanctuary

Some Photographs of Spotted Deer along with pillet group at the Tengragiri Wildlife Sanctuary

Annexure

Research Proposal Evaluation Committee (RPEC)

Serial No.	Name and Designation	Rank
01	Mr. Gobinda Roy, Project Director, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka-1207.	Convener
02	Conservator of Forests, Wildlife & Nature Conservation Circle, Dhaka.	Member
03	Director, Bangladesh Wildlife Center, Gazipur.	Member
04	Professor Dr. Golam Rakkibu, Forestry and Wood Technology Discipline, Khulna University, Khulna.	Member
05	Dr. Noor Jahan Sarkar, Professor (Retd.), Department of Zoology, University of Dhaka, Dhaka.	Member
06	Dr. Md. Mahabubar Rahman, Divisional Officer, Silviculture Genetics Department, Bangladesh Forest Research Institute, Chittagong.	Member
07	Deputy Project Director-1, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Member-Secretary

Grant Review Committee (GRC)

Serial No.	Name and Designation	GRC Rank
01	Mr. Md. Amir Hosain Chowdhury, Chief Conservator of Forests, Forest Department, Bangladesh	Chairperson
02	Dr. Rafiqul Haider, Director, Bangladesh Forest Research Institute (BFRI), Chattogram	Member
03	Prof. Dr. Mohammed Mostafa Feeroz, Pro-vice chancellor (education), Jahangirnagar University.	Member
04	Professor Dr. A.Z.M Manzoor Rashid, Department of Forestry and Environmental Science, Shahjalal University of Science and Technology (SUST), Sylhet.	Member
05	DCCF, Planning Wing, Forest Department. Bana Bhaban, Agargaon, Dhaka-1207	Member
06	DCCF, Education and Training Wing, Forest Department, Bana Bhaban, Agargaon, Dhaka-1207.	Member
07	DCCF, Forest Management Wing, Forest Department, Bana Bhaban, Agargaon, Dhaka-1207.	
08	Mr. Gobinda Roy, Project Director, Sustainable Forest and Livelihood (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka-1207.	Member-Secretary

Forestry Related Research Review Council (FRRRC)

Serial No.	Name and Designation	Rank
01	Md. Rakibul Hasan Mukul, Deputy Chief Conservator of Forests, Social Forestry Wing, Bana Bhaban, Agargaon, Dhaka	Convener
02	Dr. Mohammed Kamal Hossain, Professor (Retd.), Institute of Forest and Environmental Sciences, Chattogram University, Chattogram.	Member
03	Dr. Mohammad Al-Amin, Professor, Institute of Forest and Environmental Sciences, Chattogram University, Chattogram.	Member
04	Dr. Kazi Saiful Islam, Professor, Department of Urban and Rural Planning, Khulna University.	Member

Serial No.	Name and Designation	Rank
05	Dr. Saleh Ahmed Khan, Professor, Department of Botany, Jahangir Nagar University, Savar, Dhaka	Member
06	Dr. A.Z.M Monzoor Rashid, Professor, Department of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet.	Member
07	Mr. Mohammad Yosuf, Deputy Project Director-1, Sustainable Forest and Livelihood (SUFAL) Project, Ban Bhawan, Agargaon, Dhaka.	Member-Secretary

Wildlife Related Research Review Council (WRRRC)

Serial No.	Name and Designation	Rank
01	Mr. Md. Jahidul Kabir, Deputy Chief Conservator of Forests, Education and Training Wing, Bana Bhaban, Agargaon, Dhakap	Convener
02	Dr. Noor Jahan Sarkar, Professor (Retd.), Department of Zoology, University of Dhaka.	Member
03	Dr. Monirul Hasan Khan, Professor and Head of Department, Department of Zoology, Jahangirnagar University.	Member
04	Dr. Md. Zakir Hossain Hawlader, Professor, Biotechnology and Molecular Biology, University of Dhaka.	Member
05	Dr. Md. Shamsul Alam, Professor, Department of Fisheries Biology and Genetics, Bangladesh Agricultural University, Mymensingh.	Member
06	Mr. Md. Sanaullah Patwary, Conservator of Forests, Wildlife and Nature Conservation Area, Bana Bhaban, Agargaon, Dhaka.	Member
07	Mr. Md. Abdullah Abraham Hossain, Deputy Project Director-3, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka	Member-Secretary

Deliverable Review and Comments Giving Committee

Serial No.	Name and Designation	Rank
01	Mr. Mohammad Yousuf, Deputy Project Director-1, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Chairperson
02	Mr. Ishtiaq Uddin Ahmad, Project Management Specialist, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Member
03	Mr. Md. Safiul Alam Chowdhury, Senior Monitoring & Evaluation Specialist, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Member
04	Mr. Md. Abdul Mabud, Senior Collaborative Forest Management Specialist, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Member
05	Dr. Md. Jahangir Hossain, Senior Livelihoods Specialist, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Member
06	Mr. Md. Mahbubur Rahman, Deputy Project Director-2, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Member
07	Mr. Md. Mehedi Hasan Khan, Assistant Project Director-3, Sustainable Forests and Livelihoods (SUFAL) Project, Bana Bhaban, Agargaon, Dhaka.	Member-Secretary

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বন অধিদপ্তর