BIODIVERSITY REPORT

A rapid biodiversity assessment in White-bellied Heron habitats along Punatsangchhu and Mangdechhu basins, Bhutan

Supported by:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
based on a decision of the German Bundestag
IKI INTERNATIONAL CLIMATE INITIATIVE
MAVA FONDATION POUR LA NATURE

Developing Ecosystem-based Solutions for Managing Biodiversity Landscapes in Bhutan

Published by:
Royal Society for Protection of Nature
P.O. Box: 325, Lhado Lam, Kawajangsa | Thimphu 11001, Bhutan.

Prepared by:

D.B Gurung (PhD)

Tshering Tobgay
Thinley Phuntsho
Lungten
Indra P. Acharja
Norbu Wangdi (PhD)

Field survey team:

Vegetation Diversity

Dr. D.B Gurung, Yeshi Wangchuk, Tashi Dendup, Kezang Wangchuk, Hem Kumar Subba, Nima,Nima Gyeltshen, Wangchuk Blon, Sonam Norbu, Pem Dem

Bird Diversity

Tshering Tobgay, Tshewang Lhendup, Sonam Tshering, Thinley Phuntsho, Lungten

Fish Diversity

Dr. D.B Gurung, Kinzang Namgay, Laxmi Sagar, Tshering Dendup, Rupesh Subedi, Nima Tenzin, Pem Dem

Aquatic Macroinvertebrate Diversity

Lungten, Thinley Phuntsho, Tshering Tobgay, Tshewang Lhendup, Sonam Tshering, Samten Leki

Butterfly Diversity

Thinley Phuntsho

Layout and design:

Sonam Rinzin

Suggested citation:

RSPN (2022). A rapid biodiversity assessment in White-bellied Heron habitats along Punatsangchhu and Mangdechhu basins, Bhutan. Royal Society for Protection of Nature. Page 1 - 87.

ISBN 978-99936-662-8-8

ACKNOWLEDGEMENTS

The Center for Environment and Development and Royal Society for Protection of Nature (RSPN) prepared this report, under the Developing Ecosystem-based Solutions for Managing Biodiversity Landscapes in Bhutan, a 5-year project implemented by RSPN in partnership with the Royal Government of Bhutan.

The project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag. The MAVA Foundation and RSPN co-funded this project.

The project focuses on developing ecosystem-based solutions for managing biodiversity landscapes, with a special focus on establishing approaches and tools for protecting and managing White-bellied Heron (WBH) habitats along Punatsangchhu and Mangdechhu basins in Bhutan.

We are grateful to all the experts and field assistants for their support in carrying out the field surveys. We also acknowledge the Department of Forests and Park Services and Divisional Forest Offices of Wangdue, Tsirang, Dagana, Zhemgang and the Jigme Singye Wangchuck National Park, Trongsa for the administrative and logistics support during the field surveys.

TABLE OF CONTENTS

ACRONYMS

BMS	Butterfly Monitoring Scheme
DBH	Diameter at breast Height
DoFPS	Department of Forests and Park Services
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
GIS	Geographic Information System
GPS	Global Positioning System
IBA	Important Bird Areas
IPA	Important Plant Areas
IUCN	International Union for Conservation of Nature
KM	Kilometre
M	Meter
MRB	Mangdechhu River Basin
MASL	Meter Above Sea Level
PPS	Proportionate Probability Sampling
SPSS	Statistical Package for the Social Sciences
TDS	Total Dissolved Solute
WBH	White-bellied Heron

EXECUTIVE SUMMARY

White-bellied Heron (WBH) landscape along Punatsangchhu and Mangdechhu basin harbours rich diversity of habitats and organisms. The habitats consist of prime forests, riverine forests and agroecosystems which not only provide the perfect habitat for the critically endangered WBH but also provide the local communities with a range of products and ecosystem services.

The terrestrial biodiversity along Punatsangchhu river basin comprises conifers, deciduous and evergreen forest trees and shrubs. A total of 80 tree species, 85 species of shrubs, and 90 species of herbs were recorded. Within the overall biologically rich landscape, it may be noted that there are pockets along the forest and riverine ecosystem that have been also subject to disturbance and degradation. Stretches of WBH habitat along Punatsangchhu have been under development pressure with increased anthropogenic disturbances. Even, the record of invasive shrub species such as *Chromolaena odorata* and *Ageratina adenophora* and herbs of *Parthenium hysterophorus* could slowly alter the landscape in the long run.

Likewise, Mangdechhu River Basin (MRB) recorded 74 species of trees, 52 species of shrubs. WBH habitats along Mangdechhu are primarily dominated by evergreen and deciduous broadleaved forests that were relatively intact under low development pressures. Forest plots surveys also recorded the presence of invasive species such as *Chromolaena odorata* and *Mikania micrantha.*

In terms of avifaunal diversity, a total of 63 species of birds were recorded during the survey period from the riparian habitat of the landscape. Bird species recorded in Punatsangchhu and Mangdechhu are 49 and 37 species respectively. However, the bird species richness accounts for this survey period can be far less with many congregations of waterbirds and winter visitors' birds seen during winter season in Bhutan. The survey observed maximum diversity of species in the riparian habitats adjacent to the Chir Pine forest compared to the broadleaved and mixed forest habitats.

A total of 54 butterfly species; 28 species from Punatsangchhu and 26 from Mangdechhu basins of 6 families were recorded. This indicates that the WBH landscape in these major rivers are still pristine with high diversity of living organisms.

In terms of aquatic biodiversity, 27 species of fish belonging to nine families and 14 species of fish belonging to four families were recorded from Punatsangchhu and Mangdechhu basin respectively. The most abundant fishes were found in Basochhu and Phochhu River followed by Dangchhu and Dikchhu river. The spring water source and small stream flowing adjacent to the Berti eco-camp was noted as spawning ground for Golden Mahseer (*Tor putitora*), Copper Mahseer (*Neolissochilus hexagonolepis*) and *Garra* spp as evident from fingerlings recorded in this location. The endemic torrent catfish (*Exostoma mangdechhuensis*) was recorded from and known to be mostly confined to the Dakpaichhu. The most abundant of fishes are found in Bipapang chhu followed by Dakpaichhu and Bertichhu. Similarly for the aquatic macroinvertibrates, a total of 2209 individuals belonging to 10 orders and 39 families were recorded from the landscape. The analysis found out that the dominant order was Trichoptera and least dominant order was Megaloptera and Tricladida.

The rapid biodiversity assessment indicates that the WBH landscape, along Punatsangchhu and Mangdechhu is a biologically rich area, but there are also many threats along the landscape that need immediate conservation interventions. This report attempts to document the baseline information on biodiversity, which could be useful for planning specific conservation measures in future for securing the WBH landscapes.

01 Background

White-bellied Heron along Punatsangchhu basin/RSPN Archive

The report is the result of a biodiversity assessment that was carried out over two months from September to October 2021 in the White-bellied Heron (WBH) habitats in Punatsangchhu and Mangdechhu river basins of Bhutan. The assessment was carried out as part of the 'Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM)' fielded by the Royal Society for Protection of Nature (RSPN) under its project ***'Developing Ecosystem-based Solutions for Managing Biodiversity Landscapes in Bhutan.'*** The primary objective of the project is to establish approaches and tools for protection and managing White-bellied Heron habitats along Punatsangchhu and Mangdechhu basins in Bhutan.

The assessment carried out followed the conceptual framework for ESRAM provided in ***Figure 1.1***. The framework illustrates the assessment and mapping of ecosystem conditions, socio-economic status, and climate change to arrive at human and species vulnerability, habitat resilience and options for ecosystem-based adaptation. The data and information generated from the independent assessments are feed into climate vulnerability assessments that guides in formulation of means to carry out ecosystem-based adaptation measures.

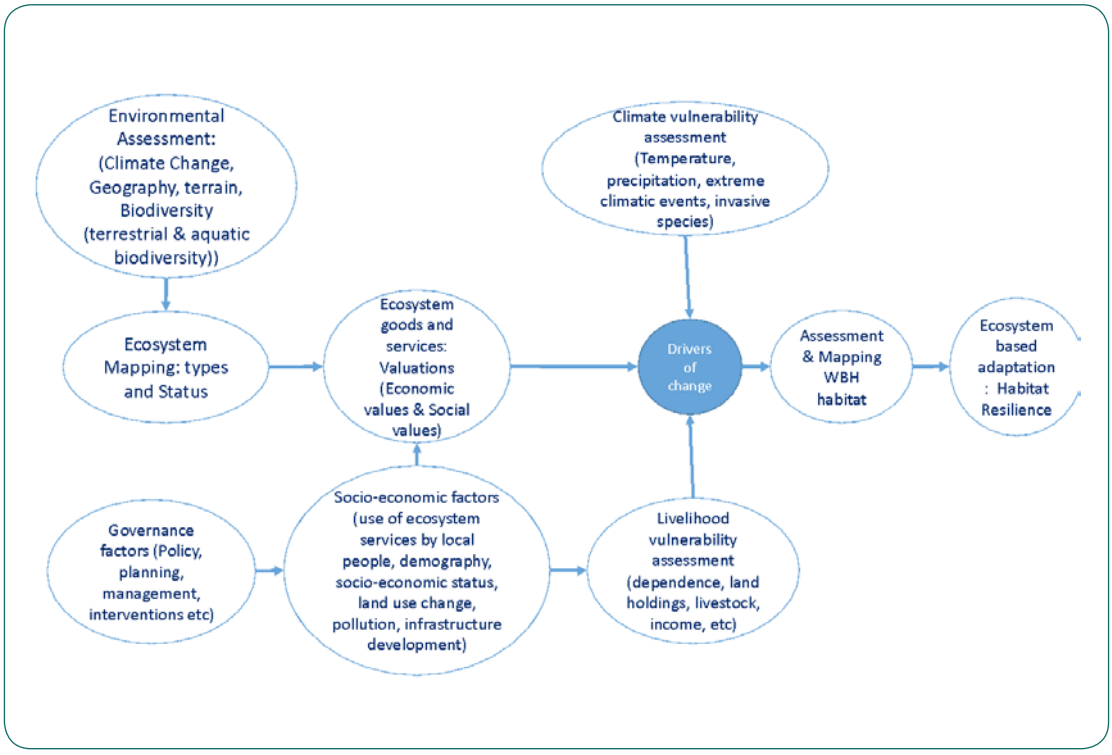
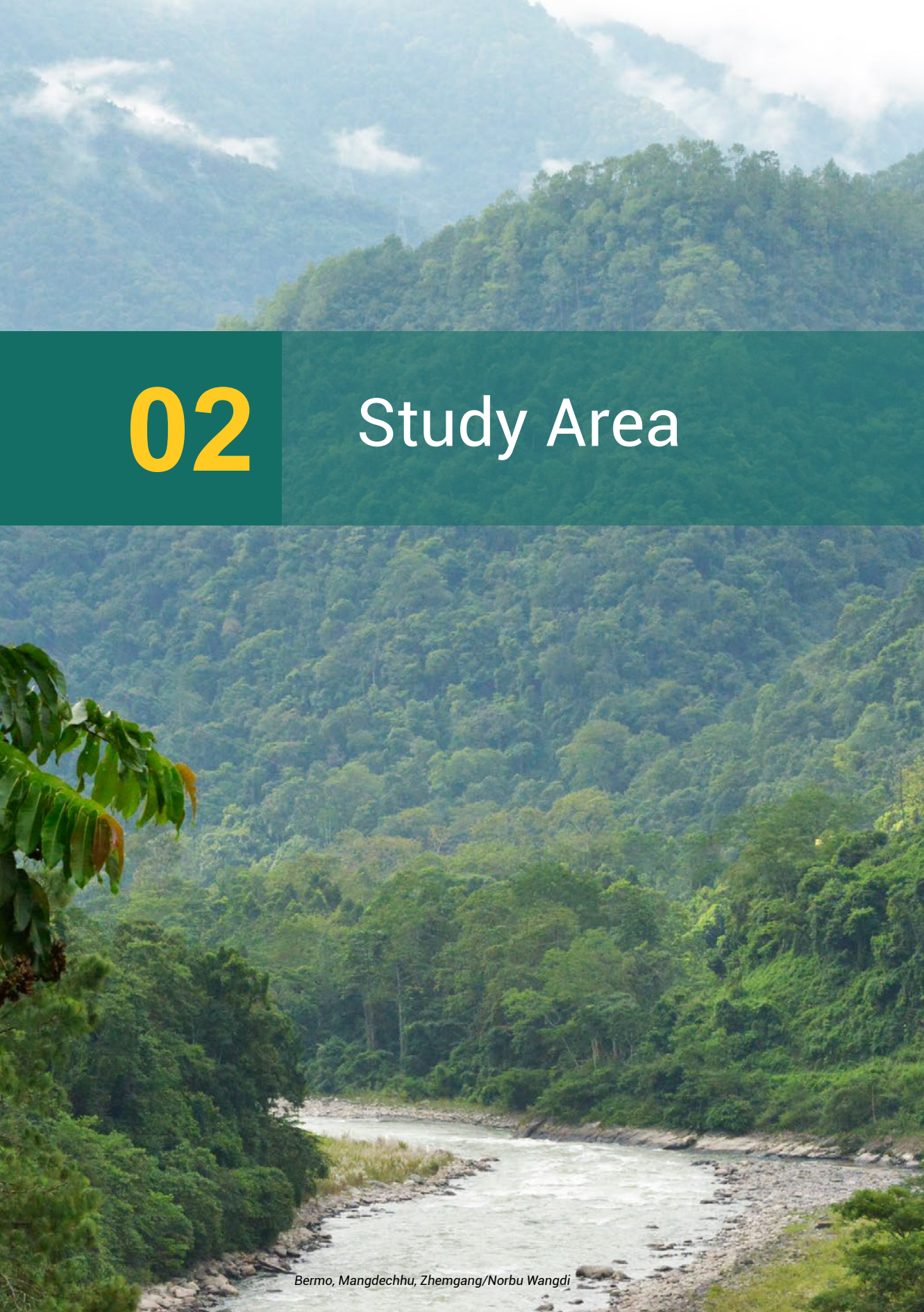


Figure 1.1: *Conceptual Framework for Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM)*

02 Study Area



Bermo, Mangdechhu, Zhemgang/Norbu Wangdi

Punatsangchu and Mangdechu basins are prime habitat for WBH occurence in Bhutan with maximum population and sighting records observed. These basins are defined as ESRAM study area for the conduct of the biodiversity assessment (***Figure 2.1***). The area comprises the natural vegetation cover with riverine ecosystem and also the presence of settlements within the administrative jurisdiction of Dagana, Punakha, Wangduephodrang, Trongsa, Tsirang, and Zhemgang districts. The study area extends from the core riverine ecosystem of aquatic habitat to a buffer of 3 km along either side of the main river of Punatsangchhu and Mangdechhu as depicted by the orange and yellow shaded areas in the map ***(Figure 2.1)***. Therefore, biodiversity assessment comprises two components; i) Terrestrial survey and ii) Aquatic survey.

Punatsangchhu river formed by the two main tributaries of Phochhu and Mochhu flows across western region to southern Bhutan through six districts; Gasa, Punakha, Wangduephodrang, Tsirang, Dagana and Sarpang. For the study area in this river, the elevation ranged from 250-1500 m with dominant vegetation of warm broadleaved forest at lower elevation of 250-500 m, mixed vegetation of chir pine trees and broadleaved trees at elevation between 500-1000 m, and dry chir pine forest between 1000 m -1500 m.

Mangdechhu flows through the central to southern region of Bhutan passing Trongsa and Zhemgang District. The elevation ranges from 250 to 1000 m with dominant vegetation of warm broadleaved forest at lower elevation of 250 - 500 m and mixed vegetation of both chir pine and broadleaved forests at higher elevation of 500-1000 m.

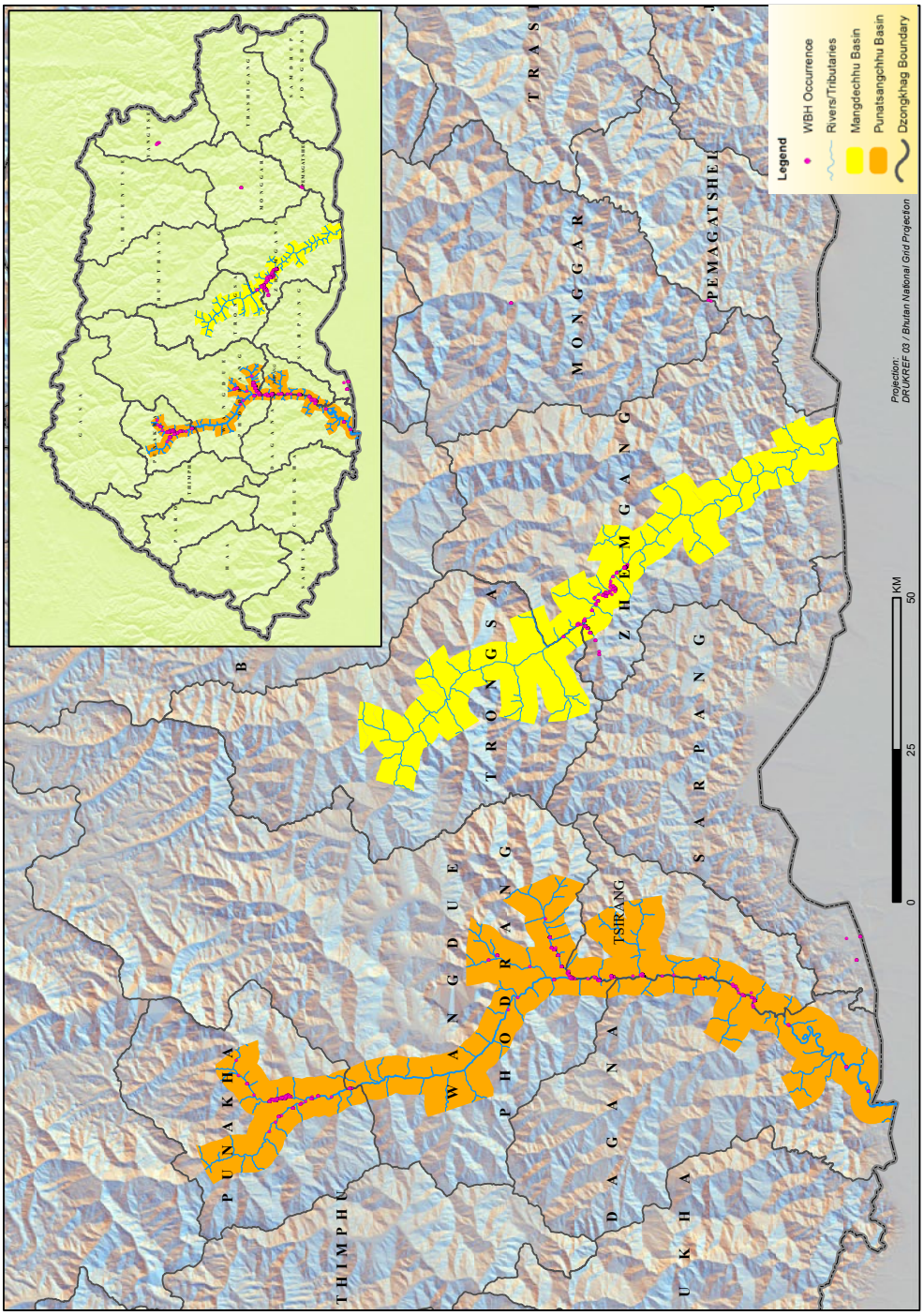


Figure 2.1: *Map of Bhutan showing the ESRAM study area*

03 Methodological Framework

Biodiversity survey

The methodological framework used for this biodiversity assessment aligns with the Biodiversity Monitoring and Social Survey Protocol of Bhutan 2020 (DoFPS 2020a) and the Field Manual - National Forest Inventory of Bhutan 2020 (DoFPS 2020b). For different taxa, different methodologies were used that basically entails in gathering the data rapidly. The methodology employed was also defined by the overall ESRAM framework in achieving conservation goals and enhancing ecosystem services rather than just focusing on keystone species protection of different taxa.

The basis to sampling design used the information of WBH nesting and sightings records maintained in a data repository of RSPN that was aligned to national biodiversity monitoring grid size of 4 x 4 km (DoFPS 2020a). Using GIS, a sampling site map was generated by overlaying two map layers, national grid and information on WBH distribution. The number of sampling sites however differs slightly across different taxa. For instance, 40 sampling sites were covered in Punatsangchhu and 30 sampling sites in Mangdechhu for vegetation. For the fish survey, uniform sampling sites of 30 each in Punatsangchhu and Mangdechhu basin were used.

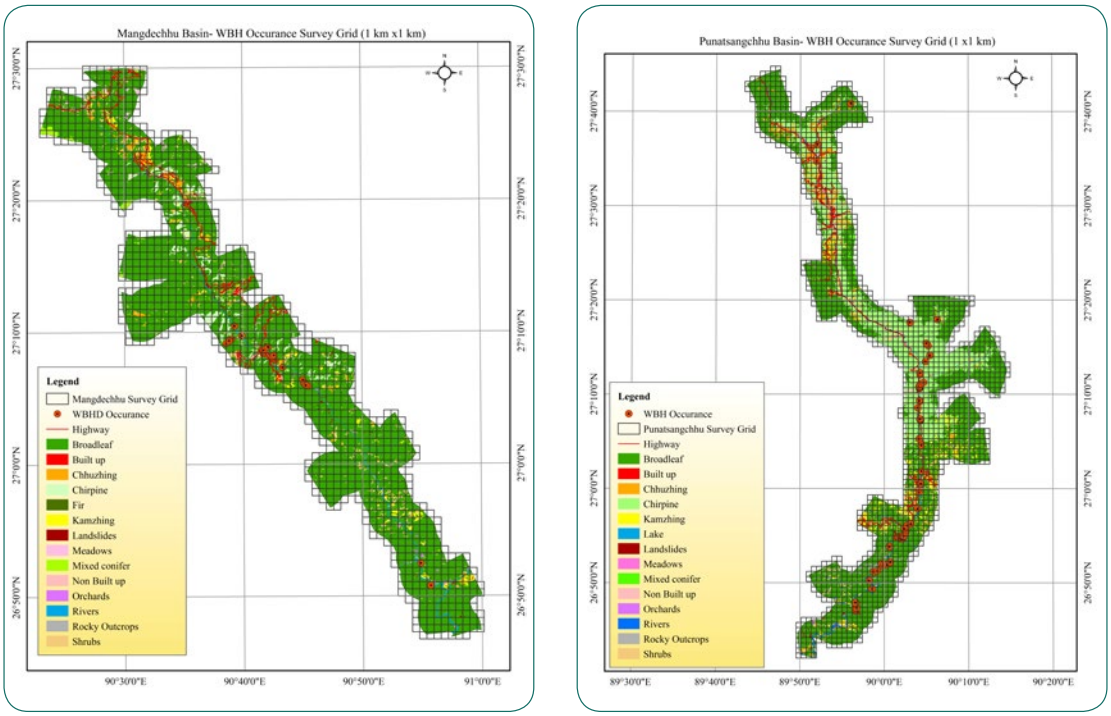


Figure 3.1: *Biodiversity assessment sites over laid with national grid size in WBH landscape*

Based on the sampling protocols and size determined above, the vegetation survey, avifauna, butterfly and the aquatic macro-invertebrate assessment were carried out. To optimise findings from the surveys, the field teams also adopted purposive sampling within the sampling grid.

3.1 Data Compilation and Analysis

The data gathered were compiled in MS Excel spreadsheet and loaded to different ecological diversity analysis tools for further analysis that will be useful information to conservation managers and project implementers. The analysis tools used include SPSS, R-stats, and PAST that are relevant for producing the result of this assessment.

3.2 Limitations

This biodiversity assessment conducted is subject to limitation with time constraint and smaller number of focused species considered for the assessment. The survey result represents only one time survey that might have created bias in getting enough data for taxa surveyed to represent the WBH landscape. It was also inappropriate in collecting the data for some species like fish with high flood water resulting in reporting of lower species number. Any users of this report are therefore recommended to interpret the result on the basis of rapid assessment conducted.

04 Terrestrial Biodiversity

Balwani, Tsirang/Norbu Wangdi

Introduction

Terrestrial ecosystems cover approximately 148 million square km, corresponding to 29 percent of the total surface area of the earth. There are 34 biodiversity hotspots in the world and the Eastern Himalayas is one of the richest and included among the 234 globally outstanding eco-regions of the world in a comprehensive analysis of global biodiversity undertaken by the World Wildlife Fund (1995-1997) (www.cbd.int).

Spanning between two major Indo-Malayan and Palaearctic biogeographic realms, Bhutan comprises 23 important bird areas (IBA), eight ecoregions, important plant areas (IPA) and wetlands (Banerjee and Bandopadhay, 2016).

A recent assessment identified forests (70.77%) to be the dominant terrestrial ecosystems in Bhutan, followed by shrubland (9.74%), snow and glaciers (5.35%), alpine scrubs (3.39%), agricultural land (2.76%) and meadows (2.51%) with the remaining 5.49 % composed of rocky outcrops, screes, moraines, landslides, built-up areas, and water bodies (FRMD, 2017).

Due to altitudinal variation, with corresponding variation in climatic conditions, the country supports a wide range of forest types and vegetation zones. Broadly, Bhutan is divided into three distinct eco-floristic zones; Alpine Zone Altitude – (4,000+ masl) ;Temperate Zone Altitude – (2,000-4,000 masl) and Sub Tropical Zone Altitude – (150-2,000 masl)(NBC, 2014).

As per the recent statistics, 5,369 plant species, 129 species of mammals, 736 birds, 150 Herpectofauna (amphibians and reptiles) and 3511 insects including 750 species of butterfly ,1115 moths and 86 bees and wasp species have been reported (NBC, 2017).

Despite strong political will and concerted efforts towards biodiversity conservation, Bhutan cannot remain immune to the direct threats, such as land use conversion and forest fire causing habitat degradation and fragmentation further aggravated by Climate change. Over grazing on rangelands and unsustainable agricultural practices are some of the other factors leading to soil erosion and subsequent land degradation (NBC, 2014).

The rapid assessment was focussed on documenting the diversity of vegetation, avifauna, and butterflies. Other groups such as mammals, and herpetofauna were reported as incidental observations. The detailed survey methodology and results are provided in the sections below.

4.1 Vegetation

The use of vegetation description is in the recognition and definition of “different vegetation types and plant communities, which is known as the science of phytosociology, the mapping of vegetation communities and types, the study of relationships between plant species distributions, environmental controls and their interactions with humans and animals, and the study of vegetation as a habitat for animals, birds and insects” (Kent,

2012). Information on vegetation helps us understand ecological problems, for biological conservation and management purposes, to monitor management practices, and to predict the future changes in plant distributions and the effect it can have on the soil and human wellbeing and vice versa.

Floral assessment includes identification and monitoring of ecosystems and habitats followed by inventory, identification, assessment, and monitoring of plant species in an area. Assessment of plant diversity along the riverine tract is critical since the WBH uses the riverine forest for nesting and roosting (Wangchuk, 2016).

The vegetation survey focused on three categories of forest types surveyed in the study area which included: a) prime forest, b) riverine forest, and c) agrobiodiversity – focused on tree species found adjacent to human settlements. Among these three forest types, 13 samples were considered as agrobiodiversity forest, 15 prime forest, and 12 riverine forests. Dzongkhag wise, 9 samples were from Tsirang, 3 from Dagana, 19 from Wangdue, and 9 from Punakha. The altitudinal range of the sampling plots varied from 274 – 1723m above sea level.

4.1.1 Materials and Methods

All sampling sites assessed for plant diversity were within the proximity of the aquatic diversity sampling grid. Distance from the river was based on the buffer zone used in generating sampling site maps in the sampling design. However, the possibility to include high altitude forests such as fir forests was ruled out since WBH will not use such high-altitude forests.

The Biodiversity Monitoring Protocol of Bhutan recommends maintaining 20 x 20 m quadrat for tree diversity assessment (DoFPS 2020a) and circular plots with 12.62 m radius for inventory purposes (DoFPS 2020b). However, for general purpose vegetation analysis quadrat or transect size amounting to 200 m^2 is also appropriate (Gilson, 2006).

Given that the study area covers smaller areas along the main rivers in the two basins and considering the time constraint, this study adopted 15 x 15 m quadrat plots for trees, 4 x 4 m for shrubs and 1 x 1 m for herbs (***Figure 4.1.1***). The smaller plots were consistently placed at the south-west corner of the 15 x 15 m plot to reduce biases.

Using a standard protocol (DoFPS 2020a), heights, counts and diameter of tree species, heights and counts of shrub species, and cover percentage of herbaceous plant species were recorded for each plot.

To optimize findings from the surveys, the field teams adopted purposive sampling within the sampling grid. Forty sampling sites were covered for rapid biodiversity assessment in Punatsangchhu and 30 sampling sites in Mangdechhu study area.

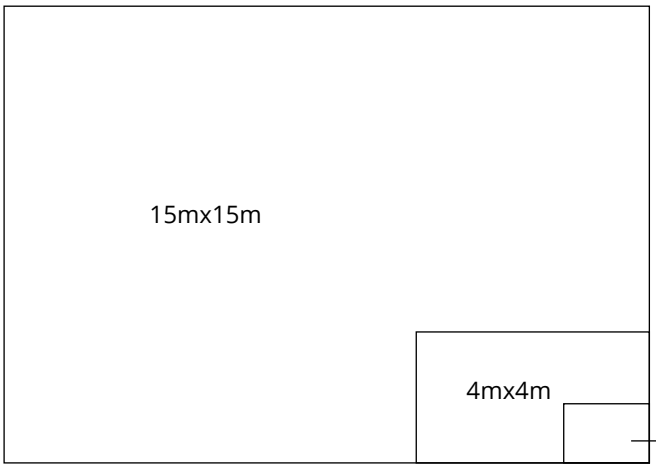


Figure 4.1.1: *Vegetation Survey Plot dimensions*

4.1.2 Survey Equipment

For vegetation survey, instruments and materials such as diameter tape, digital rangefinder, measuring tape, GPS, camera, vegetation survey protocol, polythene bag, plant press, newspaper, and pen and pencils were used.

4.1.3 Results

Punatsangchhu

In the 40 sampling sites, 80 tree species were observed. From these 80 tree species were recorded in the study area, chir pine (*Pinus roxburghii*) had a maximum entry of 71 number followed by 23 entries of Alder (*Alnus nepalensis*) and 19 entries of *Albizia* spp (***Table: 4.1.1***). These species are secondary species and their presence in high numbers in the sampling plots basically indicates that the study area is fairly disturbed. The mean height of the trees in the sampling plots was 12.46 m (± 6.26 SD) with a maximum height of 35 m (*Sapindus rarak*) from Dikchhu in Wangduephodrang Dzongkhag – a riverine forest. The diversity calculated using Basal Area and Relative Basal Area is -2.8 which is good but negative sign indicates that the index is influenced by richness which is otherwise not calculated here. In relation to White-bellied Heron habitat which requires tall trees for nesting, the sampling sites had no trees tall enough for the birds for nesting. However, there is evidence that tall trees required for nesting are available in cliffs, difficult to access sites and areas away from human activities/settlements. These sites were not accessible for the vegetation survey team.

In Punatsangchhu, 85 species of shrubs were recorded (***Table 4.1.2***). *Chromolaena odorata* had the highest count with 25 followed by *Ageratina adenophora*, *Rhus chinensis* and *Artemisia* sp. 13 each. Both the *C. odorata* and *A. adenophora* are invasive species. Similarly in the herb category, *Bidens pilosa* had 15 counts followed by *Chromolaena odorata* with

10 and 9 counts on *Parthenium hysterophorus* with (***Table 4.1.3***). Both the *C. odorata* and *P. hysterophorus* are invasive species.

The species of Punatsangchhu river basin were classified into conifers, deciduous shrubs, deciduous trees, evergreen shrubs and evergreen trees. The average basal area was 0.52 for conifer, 0.98 for deciduous trees, 0.04 for evergreen shrub, and 0.91 for evergreen trees.

Table 4.1.1: *List of tree species of Punatsangchhu river basin*

Sl.	Species	Count	BA	RBA	Pi	LNPi	Pi*LNPi (H')
1	*Acacia sp.*	1	2042.82	0.38	0	-5.56	-0.02
2	*Acer oblongum*	1	0.5	0	0	-13.87	0
3	*Ailanthus integrifolia*	3	8697.5	1.64	0.02	-4.11	-0.07
4	*Albizia gamblei*	1	1385.44	0.26	0	-5.95	-0.02
5	*Albizia lebbeck*	18	28089.77	5.29	0.05	-2.94	-0.16
6	*Alnus nepalensis*	23	34275.76	6.46	0.06	-2.74	-0.18
7	*Bauhinia purpurea*	5	5366.63	1.01	0.01	-4.59	-0.05
8	*Bauhinia variegata*	4	1793.85	0.34	0	-5.69	-0.02
9	*Beilschmeidia gambia*	1	754.77	0.14	0	-6.56	-0.01
10	*Bischofia javanica*	1	2042.82	0.38	0	-5.56	-0.02
11	*Boehmeria sp.*	3	2905.19	0.55	0.01	-5.21	-0.03
12	*Bombax ceiba*	5	10514.91	1.98	0.02	-3.92	-0.08
13	*Brassaiopsis hainla*	1	176.71	0.03	0	-8.01	0
14	*Bridelia sikkimensis*	5	2713.55	0.51	0.01	-5.28	-0.03
15	*Caesalpinia decapetala*	3	1314.76	0.25	0	-6	-0.01
16	*Cassia fistula*	1	226.98	0.04	0	-7.76	0
17	*Cassia occidentalis*	1	153.94	0.03	0	-8.15	0
18	*Cassia spectabilis*	2	1222.08	0.23	0	-6.07	-0.01
19	*Castanopsis sp.*	2	5554.53	1.05	0.01	-4.56	-0.05
20	*Celtis sp.*	9	11597.97	2.19	0.02	-3.82	-0.08
21	*Choerospondias sp.*	1	1885.74	0.36	0	-5.64	-0.02
22	*Cinnamomum sp.*	2	460.24	0.09	0	-7.05	-0.01
23	*Cipadessa baccifera*	1	226.98	0.04	0	-7.76	0
24	*Debregeasia longifolia*	1	95.03	0.02	0	-8.63	0
25	*Desmodium sp.*	8	248.77	0.05	0	-7.67	0
26	*Diploknema butyracea*	5	2843.93	0.54	0.01	-5.23	-0.03

Sl.	Species	Count	BA	RBA	Pi	LNPi	Pi*LNPi (H')
27	*Engelhardia spicata*	6	4344.82	0.82	0.01	-4.81	-0.04
28	*Erythrina sp.*	1	1661.9	0.31	0	-5.77	-0.02
29	*Eucalyptus sp.*	2	105.25	0.02	0	-8.53	0
30	*Ficus cryptophylla*	1	176.71	0.03	0	-8.01	0
31	*Ficus oligodon*	1	176.71	0.03	0	-8.01	0
32	*Ficus racemosa*	2	1972.92	0.37	0	-5.59	-0.02
33	*Ficus semicordata*	7	8040.12	1.52	0.02	-4.19	-0.06
34	*Fraxinus floribunda*	1	0.79	0	0	-13.42	0
35	*Glochidion velutinum*	4	539.76	0.1	0	-6.89	-0.01
36	*Gmelina arborea*	2	3370.93	0.64	0.01	-5.06	-0.03
37	*Grevillea robusta*	1	380.13	0.07	0	-7.24	-0.01
38	*Holarrhena pubescens*	7	150245.88	28.31	0.28	-1.26	-0.36
39	*Illicium griffithii*	1	530.93	0.1	0	-6.91	-0.01
40	*Indigofera*	4	67.54	0.01	0	-8.97	0
41	*Jacaranda mimosifolia*	2	3495.02	0.66	0.01	-5.02	-0.03
42	*Jatropha curcas*	2	113.88	0.02	0	-8.45	0
43	*Juglans regia*	1	1452.2	0.27	0	-5.9	-0.02
44	*Lagerstroemia parviflora*	2	3042.63	0.57	0.01	-5.16	-0.03
45	*Ligustrum sp.*	1	907.92	0.17	0	-6.37	-0.01
46	*Litsea monopetala*	1	380.13	0.07	0	-7.24	-0.01
47	*Lyonia ovalifolia*	9	1064.69	0.2	0	-6.21	-0.01
48	*Macaranga denticulata*	6	5482.08	1.03	0.01	-4.57	-0.05
49	*Macaranga paniculata*	3	2423.74	0.46	0	-5.39	-0.02
50	*Mallotus sp.*	6	1054.79	0.2	0	-6.22	-0.01
51	*Maytenus sp.*	1	28.27	0.01	0	-9.84	0
52	*Melia azedarach*	1	132.73	0.03	0	-8.29	0
53	*Morus alba*	3	5713.77	1.08	0.01	-4.53	-0.05
54	*Oroxylum indicum*	3	1261.55	0.24	0	-6.04	-0.01
55	*Persia sp.*	1	132.73	0.03	0	-8.29	0
56	*Phyllanthus officinalis*	1	3.14	0	0	-12.04	0
57	*Pinus bhutanica*	3	4986.49	0.94	0.01	-4.67	-0.04
58	*Pinus roxburghii*	71	106416.97	20.05	0.2	-1.61	-0.32
59	*Pterospermum acerifolium*	3	3290.03	0.62	0.01	-5.08	-0.03
60	*Punica granatum*	1	95.03	0.02	0	-8.63	0

Sl.	Species	Count	BA	RBA	Pi	LNPi	Pi*LNPi (H')
61	*Quercus glauca*	1	0.64	0	0	-13.63	0
62	*Quercus lanata*	1	1256.64	0.24	0	-6.05	-0.01
63	*Raponia sp.*	1	3.14	0	0	-12.04	0
64	*Rhododendron sp.*	8	232.67	0.04	0	-7.73	0
65	*Rhus chinensis*	11	4035.58	0.76	0.01	-4.88	-0.04
66	*Sapindus rarak*	4	5615.6	1.06	0.01	-4.55	-0.05
67	*Sapium insigne*	10	11967.9	2.26	0.02	-3.79	-0.09
68	*Schima wallichii*	5	7485.63	1.41	0.01	-4.26	-0.06
69	*Solanum erianthum*	2	761.84	0.14	0	-6.55	-0.01
70	*Stereospermum chelonoides*	4	7067.8	1.33	0.01	-4.32	-0.06
71	*Swida sp.*	2	91.11	0.02	0	-8.67	0
72	*Syzygium cumini*	12	23716.86	4.47	0.04	-3.11	-0.14
73	*Terminalia chebula*	2	1032.01	0.19	0	-6.24	-0.01
74	*Terminalia myriocarpa*	12	16945.75	3.19	0.03	-3.44	-0.11
75	*Toona ciliata*	2	1800.92	0.34	0	-5.69	-0.02
76	*Unknown*	4	6121.39	1.15	0.01	-4.46	-0.05
77	*Viburnum cylindricum*	8	1294.53	0.24	0	-6.02	-0.01
78	*Vitex negundo*	1	95.03	0.02	0	-8.63	0
79	*Zanthoxylum sp.*	1	12.57	0	0	-10.65	0
80	*Ziziphus muritiana*	1	1452.2	0.27	0	-5.9	-0.02
Grand Total		**361**		**100**			**-2.8**

Table 4.1.2: *List of shrub species of Punatsangchhu river basin*

Sl.	Shrub species	Count	Sl.	Species	Count
1	*Abelmoschus manihot*	2	39	*Hedychium sp.*	1
2	*Agave angustifolia*	2	40	*Holarrhena pubescens*	3
3	*Ageratina adenophora*	13	41	*Indigofera sp.*	1
4	*Albizia sp.*	2	42	*Inula campanula*	1
5	*Alstonia sp.*	1	43	*Jasminum sp.*	2
6	*Ardisia macrocarpa*	1	44	*Jatropha curcas*	2
7	*Artemisia sp.*	13	45	*Justicia adhatoda*	2
8	*Artemisia vulgaris*	4	46	*Lannea coromendelica*	1
9	*Bauhinia sp.*	2	47	*Ligularia sp.*	1
10	*Berberis asiatica*	3	48	*Ligustrum sp.*	3

Sl.	Shrub species	Count	Sl.	Species	Count
11	*Berberis sp.*	2	49	*Lyonia ovalifolia*	2
12	*Bidens pilosa*	1	50	*Macaranga sp.*	2
13	*Boehmeria heterophyllum*	2	51	*Maesa chisia*	7
14	*Bombax ceiba*	3	52	*Mallotus sp.*	1
15	*Buddleja paniculata*	2	53	*Melastoma sp.*	1
16	*Caesalpinia decapetala*	3	54	*Mikania micrantha*	1
17	*Cassia occidentalis*	7	55	*Murraya koenigii*	2
18	*Cassia sp.*	2	56	*Murraya cf. paniculata*	2
19	*Celtis sp.*	1	57	*Opuntia monacantha*	2
20	*Chromolaena odorata*	25	58	*Oroxylum indicum*	1
21	*Cipaddessa baccifera*	1	59	*Ostodes paniculata*	2
22	*Citrus sp.*	1	60	*Osyris lanceolata*	1
23	*Climber*	1	61	*Parasassafras confertiflora*	1
24	*Colocasia sp.*	2	62	*Phasarey (Lotsam kha)*	2
25	*Coriaria nepalensis*	2	63	*Phyllanthus officinalis*	8
26	*Crotalaria sp.*	2	64	*Pinus roxburghii*	4
27	*Cuscuta sp.*	1	65	*Psidium guajava*	2
28	*Cycas pectinata*	3	66	*Pteridium sp.*	1
29	*Cynoglossum furcatum*	1	67	*Rhus chinensis*	13
30	*Daphne bholua*	2	68	*Ricinus communis*	4
31	*Datura sp.*	1	69	*Rubus ellipticus*	2
32	*Debregeasia longifolia*	2	70	*Schima wallichii*	4
33	*Desmodium sp.*	4	71	*Sida accuminata*	1
34	*Dodonaea angustifolia*	1	72	*Solanum erianthum*	6
35	*Euphorbia hirta*	1	73	*Solanum viarum*	3
36	*Ficus semicordata*	5	74	*Strobilanthes sp.*	4
37	*Ficus sp.*	4	75	*Symplocos sp.*	1
38	*Fraxinus sp.*	1	76	*Thalictrum sp.*	1
77	*Unknown sp.*	1	82	*Yushania sp.*	1
78	*Unknown sp.1*	2	83	*Zanthoxylum armatum*	3
79	*Unknown sp.2*	1	84	*Ziziphus incurva*	2
80	*Urena lobata*	4	85	*Ziziphus mauritiana*	1
81	*Urtica dioica*	3			

Table 4.1.3: *List of herb species of Punatsangchhu river basin*

Sl.	Herb species	Count	Sl.	Species	Count
1	*Cyperus sp.*	1	46	*Ipomea sp.*	1
2	*Achyranthes sp.*	2	47	*Jasminum sp.*	1
3	*Ageratina adenophora*	2	48	*Lamiaceae*	1
4	*Ageratum conyzoides*	8	49	*Maesa chisia*	1
5	*Alternanthera pungens*	1	50	*Mikania micrantha*	
6	*Anapphalis sp.*	1	51	*Mimosa sp.*	1
7	*Apluda sp.*		52	*Mosses*	
8	*Artemisia sp.*	6	53	*Nephrolepis sp.*	1
9	*Arundinaria sp.*		54	*Ophiopogon sp.*	1
10	*Aster sp.*	1	55	*Oplismenus hirtellus*	1
11	*Barleria cristata*	1	56	*Oplismenus sp.*	5
12	*Bidens pilosa*	15	57	*Oxalis sp.*	3
13	*Bidens sp.*	1	58	*Parthenium hysterophorus*	9
14	*Cassia occidentalis*		59	*Persicaria sp.*	2
15	*Chromolaena odorata*	10	60	*Phyllanthus sp.*	1
16	*Clematis sp.*	1	61	*Pilea sp.*	
17	*Colocasia sp.*	3	62	*Piper sp.*	1
18	*Commelina benghalensis*	1	63	*Plantago erosa*	
19	*Commelina sp.*	1	64	*Potentilla sp.*	1
20	*Crassocephalum crepidiodes*	8	65	*Remusatia sp.*	1
21	*Crotalaria sp.*	1	66	*Rubia cordifolia*	1
22	*Cymbopogon sp.*		67	*Saccharum sp.*	
23	*Cyperus sp.*		68	*Salvia sp.*	2
24	*Desmodium sp.*	3	69	*Scutellaria sp.*	1
25	*Dioscorea bulbifera*	1	70	*Sida accuminata*	3
26	*Dioscorea sp.*	2	71	*Sida acuta*	1
27	*Diplazium sp.*	1	72	*Sida sp.*	2
28	*Drymaria cordata*	4	73	*Smilax sp.*	1
29	*Eichhornia sp.*		74	*Solanum nigrum*	2
30	*Eleusine indica*	1	75	*Solanum viarum*	1
31	*Euphorbia hirta*	2	76	*Sonchus sp.*	1
32	*Equisetum sp.*		77	*Stephania sp.*	1
33	*Erigeron cf. sumatrensis*	1	78	*Synedrella nodiflora*	1

Sl.	Herb species	Count	Sl.	Species	Count
34	*Fern*	1	79	*Tetrastigma sp.*	1
35	*Galingsoga parviflora*	2	80	*Thalictrum sp.*	
36	*Gentianaceae*	1	81	*Unknown 1*	1
37	*Grass*		82	*Unknown 2*	3
38	*Gynura sp.*	1	83	*Unknown 3*	1
39	*Hedera nepalensis*	1	84	*Unknown 4*	1
40	*Hedychium sp.*	1	85	*Urena lobata*	3
41	*Hydrocotyle sp.*	1	86	*Urtica dioica*	3
42	*Impatiens sp.*	1	87	*Viola sp.*	4
43	*Indigofera cf. exilis*	1	88	*Wang-pem (Dzongkha)*	1
44	*Indigofera sp.*	1	89	*Yushania sp.*	
45	*Inula cappa*	1	90	*Zingiber sp.*	1

Mangdechhu

In Mangdechhu, 30 sampling sites were enumerated which had 74 tree species (*Table 4.1.4*). The highest count of tree species was observed in case of *Murraya paniculata* (n=70) followed by *Citrus sinensis* (orange with n =40) – cultivated area too was surveyed in this river basis, *Sapium insigne* (n=31) and *Schima wallichii* (n=29). The height of the tallest tree was 80 m (*Toona ciliata*) followed by 61 m (*Tetrameles nudiflora*) and chir pine (*Pinus roxburghii*) growing to 50 m tall. (Since the height of the trees was estimated using a digital rangefinder and the top of the trees are often not visible, erroneous height measurement is possible.) The mean height of trees was 17.39 (±13.76 SD). The diversity index calculated based on Basal Area and Relative Basal Area using DBH is -3.108, which is appreciable.

In the shrub category there were 52 species recorded (*Table 4.1.5*). *Murraya paniculata* was prevalent with 115 counts followed by members of Rubiaceae with 37 counts. *Chromolaena odorata*, which is an invasive species, was represented with 4 counts only. Likewise, there were 92 species recorded in the herb category (*Table 4.1.6*). *Oplismenus* sp. had a maximum count of 21 numbers followed by three species of ferns with 16 counts, and *C.odorata* and *Mikania micrantha* with 15 counts each. The latter two species are invasive species.

Within each vegetation classification type for all 40 sampling sites combined, the average basal area for conifer tree species was 2.099, for deciduous broadleaved forest it was 1.142 and for evergreen broadleaved forest it was 2.555. This indicates that the area has more evergreen broadleaved tree species. A comparative table of the number of plant species found in the two river basins based on the trees, shrubs and herbs classification is provided in *Figure 4.1.2* below.

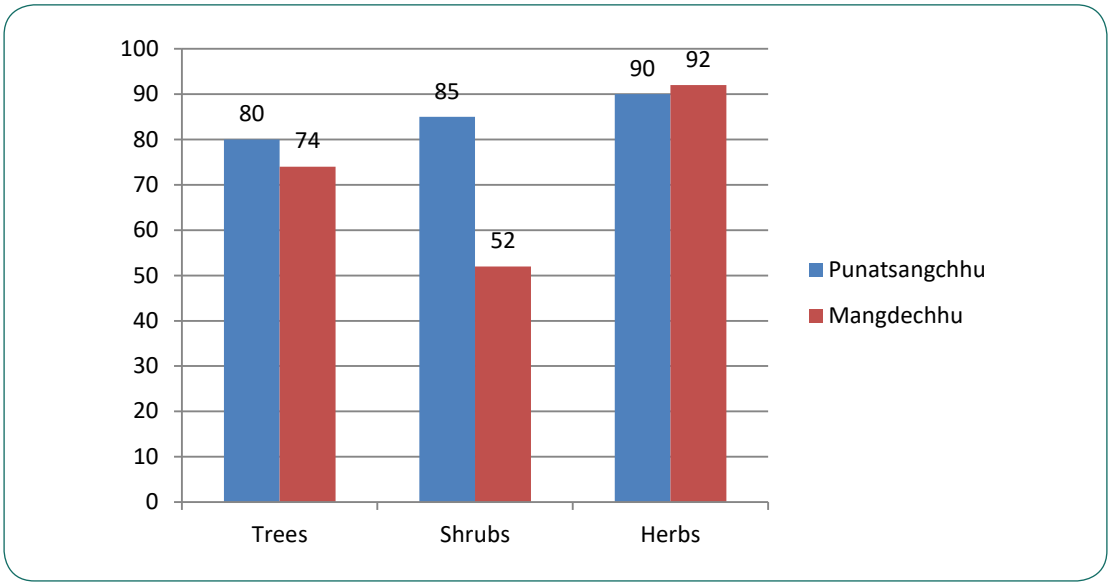


Figure 4.1.2: *Number of plant species based on trees, shrubs and herbs classification*

Table 4.1.4: *List of tree species from Mangdechhu*

Sl.No	Species	Count	BA	RBA%	Pi	LNPi	Pi*LNPi (H')
1	*Abroma augustifolia*	3	358.927	0.106	0.001	-6.846	-0.007
2	*Actinodaphne obovata*	1	63.617	0.019	0	-8.576	-0.002
3	*Albizia chinensis*	1	254.469	0.075	0.001	-7.19	-0.005
4	*Albizia gamblei*	11	12385.729	3.671	0.037	-3.305	-0.121
5	*Albizia lebbeck*	1	283.529	0.084	0.001	-7.082	-0.006
6	*Albizia procera*	11	13404.587	3.973	0.04	-3.226	-0.128
7	*Artocarpus heterophyllus*	1	176.715	0.052	0.001	-7.555	-0.004
8	*Bauhinia purpurea*	7	2206.183	0.654	0.007	-5.03	-0.033
9	*Bauhinia vahlii*	6	1426.283	0.423	0.004	-5.466	-0.023
10	*Bombax ceiba*	12	23300.407	6.905	0.069	-2.673	-0.185
11	*Brassaiopsis hainla*	3	3407.057	1.01	0.01	-4.596	-0.046
12	*Bridelia Sikkimensis*	4	508.349	0.151	0.002	-6.498	-0.01
13	*Callicarpa arborea*	8	3129.026	0.927	0.009	-4.681	-0.043
14	*Cassia occidentalis*	1	0.785	0	0	-12.971	0
15	*Castanopsis hystrix*	18	27497.575	8.149	0.081	-2.507	-0.204
16	*Celtis sp.*	3	185.354	0.055	0.001	-7.507	-0.004
17	*Choerospondias axillaris*	6	4625.995	1.371	0.014	-4.29	-0.059
18	*Citrus limon*	6	573.341	0.17	0.002	-6.378	-0.011

Sl.No	Species	Count	BA	RBA%	Pi	LNPi	Pi*LNPi (H')
19	*Citrus sinensis*	40	7866.548	2.331	0.023	-3.759	-0.088
20	*Clerodendrum sp.*	1	0.785	0	0	-12.971	0
21	*Coffea benghalensis*	3	274.889	0.081	0.001	-7.113	-0.006
22	*Debregeasia longifolia*	1	63.617	0.019	0	-8.576	-0.002
23	*Delonix regia*	2	1480.476	0.439	0.004	-5.429	-0.024
24	*Dendrocnide sinuata*	5	3999.247	1.185	0.012	-4.435	-0.053
25	*Desmodium elegans*	1	50.265	0.015	0	-8.812	-0.001
26	*Duabanga grandiflora*	29	52121.378	15.447	0.154	-1.868	-0.289
27	*Engelhardia spicata*	7	4201.88	1.245	0.012	-4.386	-0.055
28	*Erythrina suberosa*	1	1520.531	0.451	0.005	-5.402	-0.024
29	*Ficus glaberrima*	1	283.529	0.084	0.001	-7.082	-0.006
30	*Ficus roxburghii*	1	113.097	0.034	0	-8.001	-0.003
31	*Ficus semicordata*	22	4712.585	1.397	0.014	-4.271	-0.06
32	*Ficus tinctoria*	1	346.361	0.103	0.001	-6.882	-0.007
33	*Flueggea virosa*	2	123.308	0.037	0	-7.914	-0.003
34	*Gmelina arborea*	3	5907.765	1.751	0.018	-4.045	-0.071
35	*Grewia asiatica*	1	804.248	0.238	0.002	-6.039	-0.014
36	*Helicia nilagirica*	1	78.54	0.023	0	-8.366	-0.002
37	*Indigofera dosua*	4	44.179	0.013	0	-8.941	-0.001
38	*Juglans regia*	2	1452.987	0.431	0.004	-5.448	-0.023
39	*Kydia calycina*	1	380.133	0.113	0.001	-6.789	-0.008
40	*Lagerstroemia parviflora*	3	1323.396	0.392	0.004	-5.541	-0.022
41	*Macaranga peltata*	7	748.681	0.222	0.002	-6.111	-0.014
42	*Maesa chisia*	1	254.469	0.075	0.001	-7.19	-0.005
43	*Mallotus philippensis*	9	2092.96	0.62	0.006	-5.083	-0.032
44	*Mangifera indica*	2	597.688	0.177	0.002	-6.336	-0.011
45	*Mangifera sylvatica*	8	540.228	0.16	0.002	-6.437	-0.01
46	*Melia azadirachta*	2	117.024	0.035	0	-7.967	-0.003
47	*Michelia champaca*	1	380.133	0.113	0.001	-6.789	-0.008
48	*Murraya paniculata*	73	4842.255	1.435	0.014	-4.244	-0.061
49	*Oroxylun indicum*	1	1.767	0.001	0	-12.16	0
50	*Ostodes paniculata*	21	9816.692	2.909	0.029	-3.537	-0.103
51	*Phyllanthus emblica*	8	454.62	0.135	0.001	-6.61	-0.009
52	*Pinus roxburghii*	25	35419.297	10.497	0.105	-2.254	-0.237

Sl.No	Species	Count	BA	RBA%	Pi	LNPi	Pi*LNPi (H')
53	*Psidium guajava*	1	78.54	0.023	0	-8.366	-0.002
54	*Pterospermum acerifolium*	9	4197.168	1.244	0.012	-4.387	-0.055
55	*Quercus glauca*	20	11504.512	3.409	0.034	-3.379	-0.115
56	*Rhus chinensis*	10	896.139	0.266	0.003	-5.931	-0.016
57	*Rhus paniculata*	2	692.721	0.205	0.002	-6.188	-0.013
58	*Rhus sapindaceae*	1	3.142	0.001	0	-11.584	0
59	*Rhus wallichii*	5	956.615	0.283	0.003	-5.866	-0.017
60	*Rubiaceae*	1	0.785	0	0	-12.971	0
61	*Sapium insigne*	30	19629.653	5.817	0.058	-2.844	-0.165
62	*Schefflera impressa*	1	95.033	0.028	0	-8.175	-0.002
63	*Schima wallichii*	29	17231.706	5.107	0.051	-2.975	-0.152
64	*Solanum erianthum*	3	132.732	0.039	0	-7.841	-0.003
65	*Spondias pinnata*	4	918.327	0.272	0.003	-5.907	-0.016
66	*Sterculia villosa*	3	265.465	0.079	0.001	-7.148	-0.006
67	*Syzygium sp.*	1	50.265	0.015	0	-8.812	-0.001
68	*Tabernaemontana divericata*	1	530.929	0.157	0.002	-6.454	-0.01
69	*Terminalia myriocarpa*	7	6223.495	1.844	0.018	-3.993	-0.074
70	*Tetrameles nudiflora*	2	8702.212	2.579	0.026	-3.658	-0.094
71	*Toona ciliata*	9	28315.96	8.392	0.084	-2.478	-0.208
72	*Toxicodendron succedaneum*	2	347.146	0.103	0.001	-6.879	-0.007
73	*Unknown 1*	1	38.485	0.011	0	-9.079	-0.001
74	*Unknown 2*	2	416.261	0.123	0.001	-6.698	-0.008
Grand Total		**537**	**337430.778**	**100**	**1**		**-3.109**

Table 4.1.5: *List of shrub species from Mangdechhu*

Sl.	Species	Count	Sl.	Species	Count
1	*Artemisia myriantha*	12	27	*Maesa chisia*	1
2	*Bauhinia purpurea*	1	28	*Mallotus philippensis*	3
3	*Bauhinia vahlii*	1	29	*Mangifera sylvatica*	5
4	*Boehmeria platyphylla*	14	30	*Manihot esculenta*	4
5	*Boehmeria regulosa*	21	31	*Melastoma normale*	3
6	*Bridelia sikkimensis*	1	32	*Morus macroura*	2
7	*Cassia occidentalis*	12	33	*Murraya paniculata*	115
8	*Castanopsis sp.*	8	34	*Ostodes paniculata*	4

Sl.	Species	Count	Sl.	Species	Count
9	*Celtis tetrandra*	2	35	*Phyllanthus emblica*	2
10	*Choerospondias axillaris*	1	36	*Piper sp.*	2
11	*Chromolaena odorata*	4	37	*Quercus glauca*	6
12	*Citrus limon*	2	38	*Rhus chinensis*	4
13	*Clerodendrum sp.*	3	39	*Ricinus communis*	8
14	*Clerodendrum villosum*	5	40	*Rubiaceae*	37
15	*Coffea benghalensis*	19	41	*Rubus ellipticus*	1
16	*Croton caudatus*	4	42	*Sambucus adnata*	1
17	*Daphne sp.*	4	43	*Schima wallichii*	5
18	*Desmodium elegans*	12	44	*Setaria palmifolia*	3
19	*Eranthemum pulcherrima*	14	45	*Solanum erianthum*	12
20	*Euphorbiaceae*	1	46	*Solanum vairum*	2
21	*Ferns sp.*	2	47	*Spondias pinnata*	1
22	*Ficus sp.*	5	48	*Syzygium sp.*	1
23	*Flueggea virosa*	8	49	*Tabernaemontana divaricata*	5
24	*Indigofera dosua*	13	50	*Urena lobata*	5
25	*Jatropha curcas*	3	51	*Urtica dioica*	7
26	*Justicia adhatoda*	4	52	*Woodfordia sp.*	9

Table 4.1.6: *List of herb species from Mangdechhu*

Sl.	Species	Count	Sl.	Species	Count
1	*Achyranthes sp.*	8	47	*Hedychium sp.*	2
2	*Aconogonum sp.*	2	48	*Ipomea batatas*	1
3	*Ageratina adenophora*	3	49	*Melastoma normale*	1
4	*Ageratum conyzoides*	9	50	*Mikania micrantha*	15
5	*Amaranthus sp.*	1	51	*Murraya paniculata*	3
6	*Amomum subulatum*	1	52	*Musa sp.*	9
7	*Apluda mutica*	2	53	*Nephrolepis cordifolia*	3
8	*Artemisia myriantha*	4	54	*Ophiopogon sp.*	3
9	*Asparagus sp.*	1	55	*Oplismenus sp.*	21
10	*Astragalus frigidus*	1	56	*Oxalis corniculata*	5
11	*Athyrium asplenioides*	1	57	*Paederia foetida*	2
12	*Axonopus compressus*	1	58	*Pandanus furcatus*	1
13	*Barleria cristata*	2	59	*Parthenium hysterophorus*	2

Sl.	Species	Count	Sl.	Species	Count
14	*Bidens pilosa*	3	60	*Passiflora edulis*	1
15	*Cannabis sativa*	1	61	*Persicaria sp.*	1
16	*Cassia occidentalis*	1	62	*Piper boehmeriifolium*	1
17	*Cautleya sp.*	2	63	*Piper longum*	1
18	*Cayratia trifolia*	1	64	*Piper pedicellatum*	1
19	*Cenchrus purpureus*	1	65	*Piper pedunculatum*	1
20	*Cenchrus sp.*	2	66	*Piper sp.*	7
21	*Chromolaena odorata*	15	67	*Poaceae 1*	2
22	*Cissampelos pareira*	4	68	*Poaceae 2*	1
23	*Clematis sp.*	1	69	*Porana grandiflora*	1
24	*Climber 1*	1	70	*Pteridium aquilinum*	2
25	*Commelina benghalensis*	1	71	*Rhaphidophora decursiva*	1
26	*Commelina erecta*	1	72	*Rhynchoglossum obliquum*	2
27	*Commelina odorata*	1	73	*Rubus sp.*	1
28	*Commelina paludosa*	2	74	*Selaginella sp.*	2
29	*Crassocephalum crepidiodes*	5	75	*Setaria palmifolia*	4
30	*Cyperaceae*	1	76	*Sida acuta*	6
31	*Cyperus sp.*	9	77	*Smilax sp.*	2
32	*Dendrocalamus sp.*	6	78	*Solanum viarum*	4
33	*Desmodium sp.*	3	79	*Spermacoce sp.*	8
34	*Dicliptera chinensis*	1	80	*Stachys arvensis*	1
35	*Didymocarpus pedicellata*	1	81	*Synedrella nodiflora*	5
36	*Dioscorea belophylla*	3	82	*Tetrastigma sp.*	4
37	*Dioscorea bulbifera*	2	83	*Thysanolaena maxima*	4
38	*Dioscorea hispida*	1	84	*Torenia violacea*	1
39	*Dioscorea pentaphylla*	1	85	*Unknown 1*	3
40	*Dioscorea sp.*	7	86	*Unknown 2*	1
41	*Duhaldea cappa*	1	87	*Unknown 3*	1
42	*Elastoma sp.*	1	88	*Urena lobata*	3
43	*Fern sp.1*	2	89	*Urtica dioica*	4
44	*Fern sp.2*	1	90	*Urtica sp.*	1
45	*Fern sp.3*	13	91	*Verbena urticifolia*	1
46	*Hedera sp.*	1	92	*Wallichia disticha*	2

4.2 Avifauna

Introduction

Biodiversity consists of a variety of life forms forming a complex ecological interaction in the ecosystem (Bhowmick 2021). The prominent life forms observable as ubiquitous distribution in both aquatic and terrestrial ecosystems are the birds that equally contribute in functioning the natural environmental system and as well provide many ecosystem services (Sekercioglu and Wenny 2016). They form an important ecological role of prey and predator in many food webs and help in functioning the ecosystem with constant ecological interaction with abiotic and other biotic organisms. Birds are also sensitive to the environmental changes, indicating the way ecosystems function and are regarded as an early warning system for any environmental issues (Lovett and Fitzpatrick, 2016; Fiedler, 2009). Birds therefore have ecological significance and determine the conservation planning and management of the environment (Tabur and Ayvaz, 2010).

The bird inventory conducted depends on the different objectives of the study, mainly understanding of species richness and abundance, and to determine the associated habitats. The rapid inventory of avifauna was carried out as an integrated approach of Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM) study in the White-bellied Heron (WBH) landscape. It is aimed to establish the baseline information of other bird species diversity along the WBH landscape. With the lack of baseline information on bird diversity along the WBH landscape, there is a limitation in understanding the ecological interactions and role of other bird species that may be critical to support the survival of WBH. As many organisms in the ecosystem maintain ecological interaction through intraspecific and interspecific competition, the information of bird diversity existing in the ecosystem will give a new approach to managing the WBH.

The bird inventory in WBH landscape was carried out on the basis of the specific ecological niche and habitat usage characteristics of WBH. WBH is river dependent species with the piscivorous nature of foraging, and nesting and roosting in the forest of adjacent rivers (RSPN 2011, Acharja 2019). The survey was therefore conducted to document mainly riverine dependent bird species and other terrestrial bird species that are found in riparian habitat. Though there is no study conducted earlier in understanding interspecific competition maintained between WBH and other birds, there are numerous sightings of other birds in Bhutan (Birdlife International 2021) having a similar niche to WBH and also the records of raptors that are predatory in nature.

4.2.1 Methods

Study site

The bird inventory was conducted in two of the major rivers in Bhutan, Punatsangchhu (26.91162N, 90.337E and 27.5252N, 89.8678E) and Mangdechhu (27.0290N, 90.8802E and 27.14412N, 90.6875E) basins which are critical habitats for WBH. The elevation in the study site ranges from lowest of 250 to highest of 1500 m asl in Punatsangchhu, and for Mangdechhu an elevation ranges from 250 to 1000 m asl. The dominant forest type along the Punatsangchhu riparian habitat is of chir pine forest in upstream, mixed forest of chir pine and broad leaved in the middle section, and broad leaved dominant in the downstream of the river. The study area of Mangdechhu is mainly dominated by broad leaved forest with only a few mixes of chir pine in upstream of the river.

Data collection

A rapid inventory of birds was carried out from September to October in 2021. A systematic sampling was done to establish 16 sampling sites in Punatsangchhu and five in Mangdechhu. A minimum of 6.5 km distance between each sampling site was maintained with some areas inaccessible to conduct the survey. In each sampling site, a 500 m transect was taken along the riparian habitat of the study site recording all the bird species observed within 50 m on both sides of the transect.

A checklist of bird species within the study area was also prepared using secondary sources such as Integrated Biodiversity Assessment Tool (https://www.ibat-alliance.org/), a citizen science portal eBird (https://www.ebird.org), Bhutan Biodiversity portal (https://www.biodiversity.bt), and data repository of RSPN (https://www.rspnbhutan.org). All the occurrence records of the bird species until the current year 2021 in the study area were listed. The data gathered through secondary sources was filtered to produce only those species that are river dependent that includes mostly waterbirds, shorebirds and other terrestrial birds that are commonly found along the rivers such as redstarts, wagtails and forktails.

Data analysis

Statistical analyses were performed in the program R 4.1.3 using the packages vegan, and the PAST 4.2.2 software. For each habitat type of the study area, species richness and Rényi Diversity Index were derived. Species richness was also estimated for different habitat types in the study sites calculated using Chao, Jacknife and Bootstrap through specpool function in vegan package.

Rényi Diversity Index calculated used the following equation as recommended by Oksanen et al. (2020)

H.a = 1/(1-a) log sum(p^a)

Where a is a scale parameter, and 'Hill numbers' defined as N.a = exp(H.a). Hill numbers are the number of species with a = 0, exp(H') or the exponent of Shannon diversity with a = 1, inverse Simpson with a = 2 and 1/max(p) with a = Inf.

4.2.2 Results

Species richness

The field survey recorded a total of 63 bird species within the study site (*Table 4.2.2 & Table 4.2.3*). The species list for respective habitat types include 25 species In the broadleaved forest (BF) having elevation range of 250 - 500 m asl, 28 species in mixed forests (broadleaved and chir pine forests) (BFCP) having elevation range of 500 - 1000 m asl, and 46 species observed in chir pine (CP) forest of elevation range 1000 - 1500 masl (*Figure 4.2.1*)

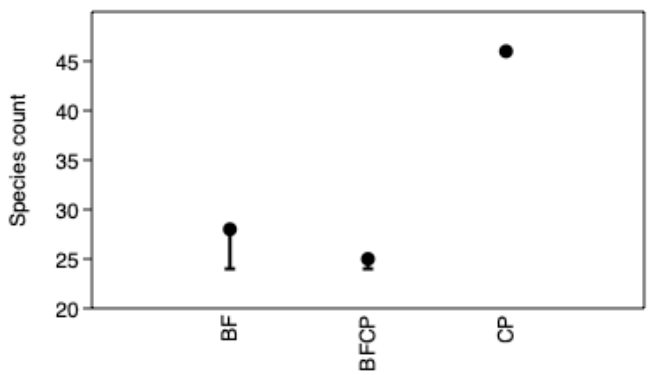


Figure 4.2.1: *Bird species richness for broadleaved (BF), Mixed Forests, and chir pine forests*

However, the extrapolated species richness on the basis of Chao (78.125 ± 7.237), Jackknife (85 ± 17.281) and Bootstrap (73.666 ± 9.888) indicated the possibility of having 70 to more than 100 species of bird species along the studied area of WBH landscape.

Bird species such as *Vanellus duvaucelii, Megaceryle lugubris, Alcedo atthis, Prinia rufescens, Pycnonotus cafer, Motacilla alba, Motacilla cinerea, Enicurus schistaceus, Cinclus pallasii, Lanius schach, Garrulax leucolophus,* and *Copsychus saularis* are found distributed in the riparian habitat of all the three different types of forest. The most common species to observe in the study site was *Pycnonotus cafer* bird species.

From the analysis of bird data gathered through secondary information and field survey, both Punatsangchu and Mangdechhu river basins formed important wintering migratory ground for many water birds. Waterbirds like *Tadorna ferruginea, Phalacrocorax carbo, Mergus merganser, Anas platyrhynchos, Podiceps cristatus, Anas strepera* and shorebirds have regular sighting records from the area. Globally threatened species that usually inhabit the area include, *Aythya baeri, Aythya ferina, Clangula hyemalis, Haliaeetus leucoryphus, Aquila clanga, Aquila nipalensis and Ardea insignis.*

Species diversity

To explore the difference of the bird diversity in the respective forest type of the studied area, Rényi Diversity Index was calculated for bird species gathered through field survey. According to Tóthmérész (1995), the community can be regarded as more diverse than another if its Rényi diversities are all higher. The Rényi diversities profile (***Figure 4.2.2***) showed that the bird data gathered from mixed forest of broadleaved and chir pine have the highest diversity.

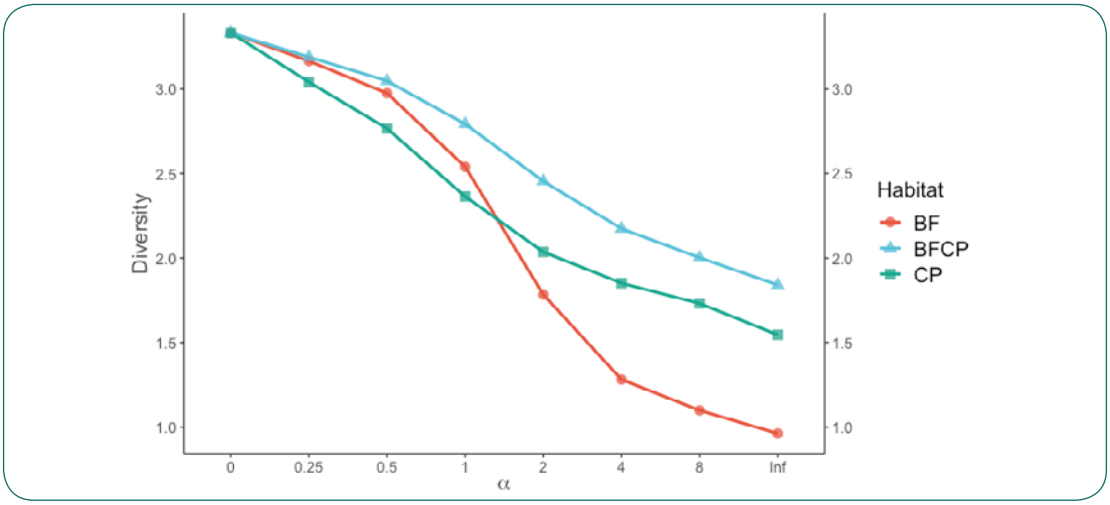


Figure 4.2.2: *Rényi diversity index for three forest cover*

In terms of shannon diversity index, the diversity for each forest type calculated is 2.890847 for broadleaved forest, 3.256785 for mixed forest of broadleaved and chir pine forest, and 2.943632 for dry chir pine forest indicating the more diversity observed in mixed forest of broadleaved and chir pine forest.

4.2.3 Discussion and Conclusion

On account of the presence of the high diversity of bird species and also the presence of globally threatened species including critically endangered White-bellied Heron in the two river basins, it is conclusive for the need of conserving the two river basins. Many of the species found along the riparian habitats of these two river basins include waterbirds and shorebirds that are migratory to Bhutan. These species occur abundantly during fall and winter seasons in Bhutan mainly relying on the large riverine ecosystem of Bhutan as a winter ground. During the summer season, many of the species migrate back to breeding ground, except for few of the species like *Megaceryle lugubris, Vanellus duvaucelii* and *Ibidorhyncha struthersii* that are found throughout the year.

The maximum assemblage of bird species occurs in the upstream of Punatsangchhu river of the study site. This can be attributed to the wide open area of riparian habitat formed by flooded rivers during monsoon period and gentle flow of the river. As described by Rajpar and Zakaria (2011), the vegetation composition and structure of the landscape are important factors for the distribution of the bird in any habitat, the similar might be for influencing the abundance of bird species in the study area. There are other factors like food availability, potential disturbance, and predation risk that also determine the distribution of the species (Noon 1981, Muller *et al.* 1997). However, no attempt has been done in this study to correlate the other environmental variables to the distribution of birds in the area.

Some of the bird species found in the area that have similar choice of habitat and feeding guild preference to WBH include species like *Ardea cinerea*, *Phalacrocorax carbo*, *Pandion haliaetus*, *Haliaeetus leucoryphus*, *Megaceryle lugubris, Ardeola grayii, Ardeola bacchus,* and *Nycticorax nycticorax*. The lack of food resources like fish in the habitats will severely impact the survival of these species. The risk associated due to construction of dams along the river basins will mainly affect the migratory route of fishes blocking the spawning habitat. This will lead to decline in fish population as well as the fish dependent bird species including WBH. Similarly, the bird species like *Haliaeetus leucoryphus*, *Spilornis cheela*, *Nisaetus nipalensis*, *Aquila nipalensis, Ictinaetus malaiensis, Falco peregrinus*, *Lophotriorchis kienerii* and *Corvus macrorhynchos* that are birds of prey family found along the WBH landscape might be potential threats to WBH and their eggs and juveniles. The appropriate measures including the conduct of scientific studies and WBH monitoring is crucial to mitigate such threats.

The landuse change in the WBH landscape will also further aggravate the low population size of WBH. The increase in human settlements and infrastructure development along

the landscape are considered major threats to WBH and have led to fragmentation of the habitat and diminishing in the nesting and foraging ground for WBH (Acharja 2021). The frequent forest fires along the landscape is also another threat to WBH. Several past reports published by RSPN including the newsletters maintained indicate the decline of WBH population and abandoning of past sighting areas. From five WBH that were regularly sighted in Phochhu before decade ago, no WBH was sighted during annual WBH count in 2020 to till date. Similarly, the decline is observed from other places like Zawa, Adha and Harachhu. It was now observed the trend of shifting WBH habitat to lower river basins having sighted more WBH in the area (RSPN, 2021).

There is a need to conserve the WBH landscape having observed diverse kinds of other avifauna species including many of the globally threatened species. There is greater risk of losing these species with increased river related activities along the landscape. The conservation effort of these WBH landscapes requires an inclusive approach involving the communities residing along the landscape and the relevant policy makers. Any of the future intervention measures to conserve these landscapes should focus more on reducing anthropic threats. A WBH landscape management plan and conservation action plans for WBH and other species in the area will guide in securing the landscape. Since only a one-time field survey was conducted due to limited resources and time-limitations, this study has limitations that can underestimate species richness and abundance as the activity of birds are more during the breeding season than during non-breeding season (Antunes, 2008; Volpato, et al. 2009). To get a comprehensive understanding of bird species diversity in the WBH landscape, detailed inventories both during breeding and non-breeding season are recommended to carry out. Future studies such as threat mapping, food base, climatic impacts and understanding ecology of WBH and other bird species in the landscape will also add value in securing the WBH landscape.

Table 4.2.1: *Checklist of Birds in Punatsangchhu (Pu) and Mangdechhu (M) basins from the review of secondary sources*

Sl. No.	Species	Conservation Status	River Basins
1	Greylag Goose *Anser anser*	LC	Pu, M
2	Greater White-fronted Goose *Anser albifrons*	LC	Pu,
3	Bar-headed Goose *Anser indicus*	LC	Pu, M
4	Common Shelduck *Tadorna tadorna*	LC	Pu,
5	Ruddy Shelduck *Tadorna ferruginea*	LC	Pu, M
6	Mandarin Duck *Aix galericulata*	LC	Pu, W
7	Gadwall *Anas strepera*	LC	Pu, W
8	Falcated Duck *Anas falcata*	NT	Pu, W
9	Eurasian Wigeon *Anas penelope*	LC	Pu, M
10	Mallard *Anas platyrhynchos*	LC	Pu, M
11	Eastern Spot-billed Duck *Anas zonorhyncha*	LC	Pu,
12	Northern Shoveler *Anas clypeata*	LC	Pu, M
13	Northern Pintail *Anas acuta*	LC	Pu
14	Garganey *Anas querquedula*	LC	Pu
15	Common Teal *Anas crecca*	LC	Pu, M
16	Red-crested Pochard *Netta rufina*	LC	Pu
17	Common Pochard *Aythya ferina*	VU	Pu
18	Baer's Pochard *Aythya baeri*	CR	Pu
19	Ferruginous Duck *Aythya nyroca*	NT	Pu
20	Tufted Duck *Aythya fuligula*	LC	Pu
21	Long-tailed Duck *Clangula hyemalis*	VU	Pu
22	Goosander *Mergus merganser*	LC	Pu, M
23	Common Goldeneye *Bucephala clangula*	LC	Pu
24	Short-tailed Shearwater *Ardenna tenuirostris*	LC	Pu
25	Little Grebe *Tachybaptus ruficollis*	LC	W
26	Great Crested Grebe *Podiceps cristatus*	LC	Pu,

Sl. No.	Species	Conservation Status	River Basins
27	Black-necked Grebe *Podiceps nigricollis*	LC	Pu
28	Black Stork *Ciconia nigra*	LC	Pu, M
29	Eurasian Spoonbill *Platalea leucorodia*	LC	Pu
30	Cinnamon Bittern *Ixobrychus cinnamomeus*	LC	Pu
31	Black-crowned Night Heron *Nycticorax nycticorax*	LC	Pu
32	Indian Pond Heron *Ardeola grayii*	LC	Pu
33	Chinese Pond Heron *Ardeola bacchus*	LC	Pu
34	Striated Heron *Butorides striata*	LC	Pu
35	Grey Heron *Ardea cinerea*	LC	Pu, M
36	White-bellied Heron *Ardea insignis*	CR	Pu, M
37	Cattle Egret *Bubulcus ibis*	LC	Pu, M
38	Intermediate Egret *Mesophoyx intermedia*	LC	Pu
39	Little Egret *Egretta garzetta*	LC	Pu
40	Great Cormorant *Phalacrocorax carbo*	LC	Pu, M
41	Eurasian Kestrel *Falco tinnunculus*	LC	Pu, M
42.	Amur Falcon *Falco amurensis*	LC	Pu, M
43.	Eurasian Hobby *Falco subbuteo*	LC	Pu, M
44	Oriental Hobby *Falco severus*	LC	Pu, M
45	Peregrine Falcon *Falco peregrinus*	LC	Pu, M
46	Osprey *Pandion haliaetus*	LC	Pu, M
47	Oriental Honey-buzzard *Pernis ptilorhynchus*	LC	Pu, M
48	Black Kite *Milvus migrans*	LC	Pu, M
49	Pallas's Fish Eagle *Haliaeetus leucoryphus*	EN	Pu, M
50	White-tailed Eagle *Haliaeetus albicilla*	LC	Pu, W
51	Crested Serpent Eagle *Spilornis cheela*	LC	Pu, M
52	Hen Harrier *Circus cyaneus*	LC	Pu,
53	Shikra *Accipiter badius*	LC	Pu, M
54	Besra Sparrowhawk *Accipiter virgatus*	LC	Pu, M

Sl. No.	Species	Conservation Status	River Basins
55	Eurasian Sparrowhawk *Accipiter nisus*	LC	Pu, M
56	Himalayan Buzzard *Buteo* (*buteo*) *burmanicus*	LC	Pu, M
57	Long-legged Buzzard *Buteo rufinus*	LC	Pu, M
58	Upland Buzzard *Buteo hemilasius*	LC	Pu
59	Black Eagle *Ictinaetus malaiensis*	LC	Pu, M
60	Steppe Eagle *Aquila nipalensis*	EN	Pu, M
61	Rufous-bellied Eagle *Lophotriorchis kienerii*	NT	Pu, M
62	Mountain Hawk Eagle *Nisaetus nipalensis*	LC	Pu, M
63	Slaty-breasted Rail *Gallirallus striatus*	LC	Pu
64	White-breasted Waterhen *Amaurornis phoenicurus*	LC	Pu, M
65	Black-tailed Crake *Porzana bicolor*	LC	Pu, M
66	Ruddy-breasted Crake *Porzana fusca*	LC	Pu
67	Eurasian Moorhen *Gallinula chloropus*	LC	Pu,
68	Eurasian Coot *Fulica atra*	LC	Pu,
69	Common Crane *Grus grus*	LC	Pu,
70	Black-necked Crane *Grus nigricollis*	NT	Pu,
71	Ibisbill *Ibidorhyncha struthersii*	LC	Pu, M
72	Black-winged Stilt *Himantopus himantopus*	LC	W, M
73	Pied Avocet *Recurvirostra avosetta*	LC	Pu,
74	Northern Lapwing *Vanellus vanellus*	NT	Pu,
75	River Lapwing *Vanellus duvaucelii*	NT	Pu, M
76	Grey-headed Lapwing *Vanellus cinereus*	LC	Pu
77	Red-wattled Lapwing *Vanellus indicus*	LC	Pu, M
78	Pacific Golden Plover *Pluvialis fulva*	LC	Pu,
79	Common Ringed Plover *Charadrius hiaticula*	LC	Pu
80	Long-billed Plover *Charadrius placidus*	LC	Pu
81	Little Ringed Plover *Charadrius dubius*	LC	Pu
82	Kentish Plover *Charadrius alexandrinus*	LC	Pu

Sl. No.	Species	Conservation Status	River Basins
83	Lesser Sand Plover *Charadrius mongolus*	LC	Pu
84	Greater Sand Plover *Charadrius leschenaultii*	LC	Pu
85	Grey Plover *Pluvialis squatarola*	LC	Pu
86	Greater Painted-snipe *Rostratula benghalensis*	LC	Pu
87	Solitary Snipe *Gallinago solitaria*	LC	Pu, M
88	Pin-tailed Snipe *Gallinago stenura/megala*	LC	Pu
89	Common Snipe *Gallinago gallinago*	LC	Pu
90	Whimbrel *Numenius phaeopus*	LC	Pu
91	Eurasian Curlew *Numenius arquata*	NT	Pu
92	Common Redshank *Tringa totanus*	LC	Pu
93	Common Greenshank *Tringa nebularia*	LC	Pu
94	Green Sandpiper *Tringa ochropus*	LC	Pu, M
95	Wood Sandpiper *Tringa glareola*	LC	Pu
96	Common Sandpiper *Actitis hypoleucos*	LC	Pu
97	Little Stint *Calidris minuta*	LC	Pu
98	Temminck's Stint *Calidris temminckii*	LC	Pu
99	Curlew Sandpiper *Calidris ferruginea*	NT	Pu
100	Ruff *Philomachus pugnax*	LC	Pu
101	Red-necked Phalarope *Phalaropus lobatus*	LC	Pu
102	Oriental Pratincole *Glareola maldivarum*	LC	Pu
103	Little Pratincole *Glareola lactea*	LC	Pu
104	Heuglin's Gull *Larus heuglini*	LC	Pu
105	Pallas's Gull *Ichthyaetus ichthyaetus*	LC	Pu, M
106	Brown-headed Gull *Chroicocephalus brunnicephalus*	LC	Pu, W
107	Slender-billed Gull *Chroicocephalus genei*	LC	Pu, W
108	Steppe Gull *Larus barabensis*	LC	Pu
109	Black-headed Gull Chroicocephalus ridibundus	LC	Pu

Sl. No.	Species	Conservation Status	River Basins
110	River Tern *Sterna aurantia*	NT	Pu
111	Common Tern *Sterna hirundo*	LC	Pu
112	Whiskered Tern *Chlidonias hybrida*	LC	Pu
113	Little Tern *Sternula albifrons*	LC	Pu, M
114	Tawny Fish Owl *Ketupa flavipes*	LC	Pu, M
115	Common Kingfisher *Alcedo atthis*	LC	Pu, M
116	Crested Kingfisher *Megaceryle lugubris*	LC	Pu, M
117	White-throated Kingfisher *Halcyon smyrnens*is	LC	Pu, M
118	Black-capped Kingfisher *Halcyon pileata*	LC	Pu
119	Collared Kingfisher *Todiramphus chloris*	LC	Pu
120	Brown Dipper *Cinclus pallasii*	LC	Pu, M
121	Plumbeous Redstart *Phoenicurus fuliginosus*	LC	Pu, M
122	White-capped Water Redstart *Phoenicurus leucocephalus*	LC	Pu, M
123	Slaty-backed Forktail *Enicurus schistaceus*	LC	Pu, M
124	Little Forktail *Enicurus scouleri*	LC	Pu, M
125	Spotted Forktail *Enicurus maculatus*	LC	Pu, M
126	White Wagtail *Motacilla alba*	LC	Pu, M
127	Grey Wagtail *Motacilla cinerea*	LC	Pu, M
128	Citrine Wagtail *Motacilla citreola*	LC	Pu
129	White-browed Wagtail *Motacilla maderaspatensis*	LC	Pu
130	Yellow Wagtail *Motacilla flava*	LC	Pu
131	Large-billed Crow *Corvus macrorhynchos*	LC	Pu, M
132	House Crow *Corvus splendens*	LC	Pu
133	Spot-bellied Eagle Owl *Bubo nipalensis*	LC	Pu

Table 4.2.2: *Bird checklist of Punatsangchhu recorded through field survey*

Sl. No.	Species	Conservation Status	Forest Type
1	Ruddy Shelduck *Tadorna ferruginea*	LC	CP
2	Garganey *Anas querquedula*	LC	CP
3	Grey Heron *Ardea cinerea*	LC	CP
4	Black-crowned Night Heron *Nycticorax nycticorax*	LC	CP
5	Indian Pond Heron *Ardeola grayii*	LC	CP
6	Wood Sandpiper *Tringa glareola*	LC	CP
7	Common Sandpiper *Actitis hypoleucos*	LC	CP
8	Common Greenshank *Tringa nebularia*	LC	CP
9	Ibisbill *Ibidorhyncha struthersii*	LC	CP
10	River Lapwing *Vanellus duvaucelii*	NT	BF, BFCP, CP
11	Temminck's Stint *temminckii*	LC	CP
12	Crested Kingfisher *Megaceryle lugubris*	LC	BF, BFCP, CP
13	Common Kingfisher *Alcedo atthis*	LC	BF, BFCP, CP
14	White-throated Kingfisher *Halcyon smyrnensis*	LC	CP
15	Osprey *Pandion haliaetus*	LC	CP
16	Eurasian Hobby *Falco subbuteo*	LC	CP
17	Eurasian Kestrel *Falco tinnunculus*	LC	CP
18	Crested Serpent Eagle *Spilornis cheela*	LC	CP
19	Black Kite *Milvus migrans*	LC	CP
20	Rufescent Prinia *Prinia rufescens*	LC	BF, BFCP, CP
21	Striated Prinia *Prinia crinigera*	LC	CP
22	Red-vented Bulbul *Pycnonotus cafer*	LC	BF, BFCP, CP
23	White Wagtail *Motacilla alba*	LC	BF, BFCP, CP
24	White-browed Wagtail *Motacilla maderaspatensis*	LC	CP
25	Grey Wagtail *Motacilla cinerea*	LC	BF, BFCP,

Sl. No.	Species	Conservation Status	Forest Type
26	Slaty-backed Forktail *Enicurus schistaceus*	LC	BF, BFCP, CP
27	Little Forktail *Enicurus scouleri*	LC	BF, CP
28	Brown Dipper *Cinclus pallasii*	LC	BF, BFCP, CP
29	Plumbeous Redstart *Phoenicurus fuliginosus*	LC	BF, CP
30	White-capped Water Redstart *Phoenicurus leucocephalus*	LC	BF,CP
31	Blue-whistling Thrush *Myophonus caeruleus*	LC	BF, CP
32	Large-billed Crow *Corvus macrorhynchos*	LC	BF, CP
33	Scaly-breasted Munia *Lonchura punctulata*	LC	CP
34	Eurasian Tree Sparrow *Passer montanus*	LC	BF, CP
35	Eurasian Hoopoe *Upupa epops*	LC	BF, CP
36	Common Myna *Acridotheres tristis*	LC	BF, CP
37	Chestnut-tailed Starling *Sturnia malabarica*	LC	CP
38	Oriental Turtle Dove *Streptopelia orientalis*	LC	BF, CP
39	Spotted Dove *Stigmatopelia chinensis*	LC	BF, CP
40	Ashy Drongo *Dicrurus caerulescens*	LC	BF, BFCP, CP
41	Long-tailed Shrike *Lanius schach*	LC	BF, CP
42	Grey-backed Shrike *Lanius tephronotus*	LC	BF, CP
43	Paddyfield Pipit *Anthus rufulus*	LC	CP
44	Olive-backed Pipit *Anthus hodgsoni*	LC	CP
45	White-crested Laughingthrush *Garrulax leucolophus*	LC	BF, BFCP
46	Siberian Stonechat *Saxicola torquatus*	LC	BF, CP
47	Rusty-cheeked Scimitar Babbler *Pomatorhinus erythrogenys*	LC	CP
48	Oriental Magpie Robin *Copsychus saularis*	LC	BFCP, CP
49	Eurasian Wryneck *Jynx torquilla*	LC	BF

Forest Types: Broadleaved **(BF)**, Mixed Broadleaved and Chir pine **(BFCP)**, Chir pine (**CP**)

Table 4.2.3: *Bird checklist of Mangdechhu recorded through the field survey*

Sl. No.	Species	Conservation Status	Forest Type
1	White Wagtail *Motacilla alba*	LC	BF, BFCP
2	Grey Wagtail *Motacilla cinerea*	LC	BF
3	Slaty-backed Forktail *Enicurus schistaceus*	LC	BF,CP
4	Little Forktail *Enicurus scouleri*	LC	BF
5	Spotted Forktail *Enicurus maculatus*	LC	BF
6	Brown Dipper *Cinclus pallasii*	LC	BF,BFCP
7	Plumbeous Redstart *Phoenicurus fuliginosus*	LC	BF
8	White-capped Water Redstart *Phoenicurus leucocephalus*	LC	BF
9	Crested Kingfisher *Megaceryle lugubris*	LC	BF,BFCP
10	Blue-whistling Thrush *Myophonus caeruleus*	LC	BF
11	Rufous-necked Laughingthrush *Garrulax ruficollis*	LC	BFCP
12	Lesser-necklaced Laughingthrush *Garrulax monileger*	LC	BF, BFCP
13	Common Green Magpie *Cissa chinensis*	LC	BF
14	Great Hornbill *Buceros bicornis*	VU	BFCP
15	Brown Shrike *Lanius cristatus*	LC	BFCP
16	Long-tailed Shrike *Lanius schach*	LC	BFCP
17	Grey-backed Shrike *Lanius tephronotus*	LC	BFCP
18	Red-vented Bulbul *Pycnonotus cafer*	LC	BF,BFCP
19	Blue-bearded Bee-eater *Nyctyornis athertoni*	LC	BFCP
20	Olive-backed Pipit *Anthus hodgsoni*		BFCP
21	Mountain-hawk Eagle *Nisaetus nipalensis*	LC	BFCP
22	Common Myna *Acridotheres tristis*	LC	BFCP
23	Eurasian Tree Sparrow *Passer montanus*	LC	BFCP
24	Spotted Dove *Stigmatopelia chinensis*	LC	BFCP
25	Oriental Turtle Dove *Streptopelia orientalis*	LC	BFCP
26	Oriental Magpie Robin *Copsychus saularis*	LC	BFCP

Sl. No.	Species	Conservation Status	Forest Type
27	Red-headed Trogon *Harpactes erythrocephalus*	LC	BFCP
28	Grey Treepie *Dendrocitta formosae*	LC	BFCP
29	Red Junglefowl *Gallus gallus*	LC	BF
30	Eurasian Hoopoe *Upupa epops*	LC	BFCP
31	Ashy Drongo *Dicrurus caerulescens*	LC	BF, BFCP
32	Taiga Flycatcher *Ficedula albicilla*	LC	BF
33	White-bellied Heron *Ardea insignis*	CR	BF
34	Striated Prinia *Prinia crinigera*	LC	BF
35	Blue-capped Rockthrush *Monticola cinclorhynchus*	LC	BF
36	Large-billed Crow *Corvus macrorhynchos*	LC	BFCP
37	White-crested Laughingthrush *Garrulax leucolophus*	LC	BFCP

Forest Types: Broadleaved **(BF)**, Mixed Broadleaved and Chir pine **(BFCP)**, Chir pine (**CP**)

a. Red-crested Pochard

b. Ibisbill

c. Great Hornbill

d. Red-headed Trogon

e. Crested Kingfisher

f. Ruddy Shelduck

Figure 4.2.3: *Common birds from the study area*

4.3 Incidental Observations

Due to limited time and resources, detailed surveys of all terrestrial biodiversity taxa could not be covered. For mammals and herpetofauna incidental observations were made during the vegetation and aquatic biodiversity surveys.

4.3.1 Mammals

Methods

'Visual encounter survey' was used to record the presence of mammals. Indirect evidence of mammals' presence such as dung, scratch marks, or hoof marks were observed.

Results

Punatsangchhu

The sampling plots in the study area basically had no signs of mammals except a report of sighting an otter in Punatsangchhu and Mangdechhu, a bear and wild pig signs in Punatsangchhu. However, this does not mean that the study area does not have mammal diversity, but their presence was not detected in the sampling plots during the rapid survey.

Mangdechhu

In the Mangdechhu study area, droppings of sambar (*Rusa unicolor*), Indian Muntjac deer (*Muntiacus muntjak*), wild pigs (*Sus scrofa*), and Golden langur (*Trachypithecus geei*), and squirrels were observed. The Golden langur is endemic to the Eastern Himalaya, restricting to a small area in Bhutan and India.

4.3.2 Herpetofauna

Methods

Herpetofauna includes reptiles' and amphibians. While several methods of herpetofauna survey are available, in Bhutan the most commonly used method is the 'visual encounter survey'. This is a type of 'opportunistic survey.' Transects for such surveys are usually done along footpaths or along streams or water courses (for amphibians).

Results

Punatsangchhu

The survey team encountered a Bronzeback tree snake (*Dendrolepis* sp.) near Chachey in Tsirang. Past records and other secondary data sources indicate that there are snakes and lizards such as King Cobra, Common Garden Lizards, Monitor Lizards, Black Krait and Monocled Cobra among others.

The survey team observed only one species of frog, *Amolops* sp. commonly known as cascade frog or sucker frog.

Mangdechhu

In Mangdechhu the survey team did not encounter snakes in the sampling plots during the survey. A road kill specimen of Bronzeback tree snake (*Dendrolepis* sp.) was encountered at Tingtibi (Zhemgang). Similar to the Punatsangchhu study area, this area also has species such as King Cobra, Monocled Cobra and various types of pit vipers.

While a detailed survey for this group of animals during the short time was not possible, the team could observe *Amolops* sp. and a tree frog.

4.4 Insects: Butterflies

Introduction

Butterflies are the adult stage of certain insects belonging to an order or group called *Lepidoptera*. Moths also belong to this group. The word "*Lepidoptera*" means "scaly wings" in Greek. The family Lepidoptera, it's divided into two groups' butterflies and moths. In general, butterflies differ from moths in the following ways: (1) Butterflies usually have clubbed antennae but moths have fuzzy or feathery antennae. (2) Butterflies normally are active during the daytime while most moths are active at night. (3) When a butterfly rests, it will do so with its wings held upright over its body. Moths, on the other hand, rest with their wings spread out flat. Butterflies will, however, bask with their wings out-stretched. (4) Butterflies are generally more brightly colored than moths, but there are some colourful moths too (www.butterflyConservation.org).

Butterflies are also known as "flying flowers", displaying their beauty. These insects enhance the aesthetic value of the environments with their exquisite wing colours. Globally, more than 28,000 species of butterflies are found, with about 80 percent in tropical regions. Butterflies require food in liquid form and are solely dependent on nectar that is produced in flowers and also extra-ripe fruits (Larson et al., 2001).

Butterflies play an important role in ecosystems, acting as a pollinator, a food source and an indicator of the ecosystem's well being. Butterflies play a big role in pollinating flowers during the day. Butterflies are also reported to be very sensitive to climate change, such as pollination and habitat loss, and cause them to be more responsive. Therefore, an abundance of butterflies generally indicates a healthier ecosystem. Butterflies also contribute to ecosystem restoration because they support pollination and a source of food. Increased butterfly populations may indicate an increase in plant diversity and other pollinator groups within restored areas (Ghazanfar et al., 2016).Butterflies are also widely considered as indicators of environmental change, habitat fragmentation, agriculture activities, air pollution, and climate change (Nakamura, 2011). They are highly sensitive to climatic variables (Manzoor et al., 2013).

In Bhutan, efforts for the documentation of butterflies have been initiated but mostly focussed on areas of tourist attraction, parks and small pockets. There is no information however from the riverine ecosystems along WBH Habitats in particular. Therefore this rapid assessment of butterflies is carried out near the Non-wadeable river ecosystem that is Punatsangchhu and Mangdechhu rivers which is the prime habitat for White-bellied Heron.

4.4.1 Materials and Methods

The survey was carried out along the two major river basins Punatsangchhu and Mangdechhu *(Figure 4.4.1)* within the ESRAM study area. In Punatsangchhu, the elevation ranged from 250 to 1500 masl covering approximately 92 km of river stretch. The river stretches between 26.91162 N, 90.337 E and 27.5252 N, 89.8678 E. Mangdechhu areas included a 23 km of river stretch with elevation ranging from 250 to 1000 masl, and between 27.0290 N, 90.8802 E and 27.14412 N, 90.6875 E. At the lower elevations, warm broadleaved forest was dominant, and mixed forests consisting of chirpine and broadleaved species at middle elevation and dry chir pine forest were found at upper elevation zone.

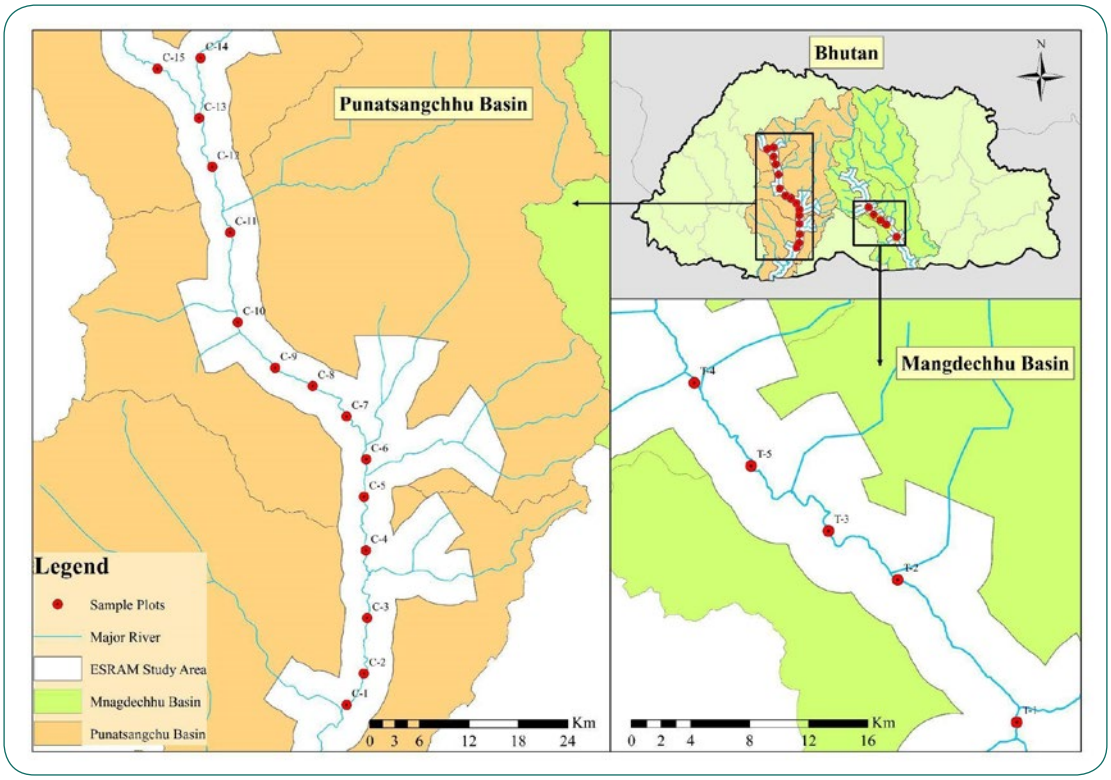


Figure 4.4.1: *ESRAM Study area with butterflies Sample Plots*

At each sampling station, butterflies were recorded within the 10m x 10m rectangular plot *(Figure 4.4.2)*; 5m each to the left and right side and 10m walk both upstream and downstream.

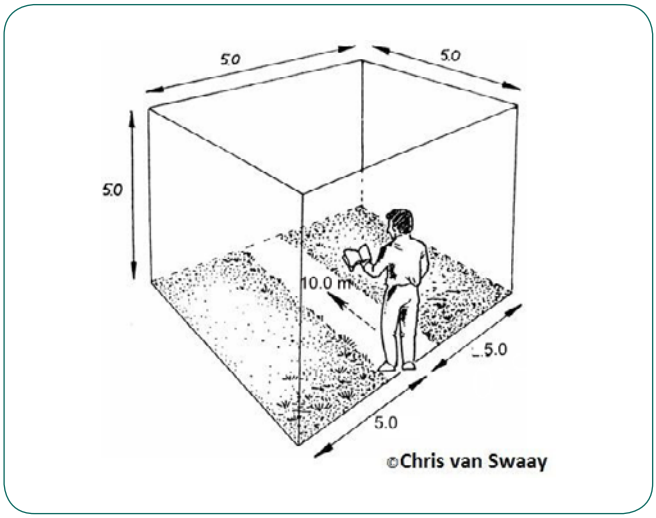


Figure 4.4.2: *Transact Survey and plot dimension by Butterfly Monitoring Schemes (BMSs)*

4.4.2 Sampling Design

A systematic random sampling was done in Arcgis to generate the sampling plots along the river with a minimum plot distance of 6.5 km. A total of 20 sample plots, 15 plots in Punatsangchhu basin and 5 plots in Mangdechhu River were laid. The data was collected during the post monsoon season (September and October). The sampling method based on the Butterfly Monitoring Schemes (BMSs) (Pollard & Yates,1994),was used. Butterfly monitoring makes it possible to assess trends in butterfly populations, and to update these on an ongoing, annual, basis. This method allows the surveyor to track population changes at a local scale as well as across a region, and country scale. In this way, the Butterfly Monitoring provides a regular, standardised method to assess the data for conservation status of butterflies and produce Butterfly indicators that can inform environmental change.

4.4.3 Specimen Identification

The species were photographed using Nikon D850 with 500 mm lens for long distance and 75 mm lens short distance. Known species were identified in the field itself. Specimens were collected for the unknown species, and identified using the available field guides on Butterflies.

4.4.4 Results and Discussion

The study recorded a total of 54 butterflies out of which 26 individuals were recorded from Punatsangchhu (*Table 4.4.1*) and 28 from Mangdechhu basins from 6 families (*Table 4.4.2*). The dominant family was Nymphalidae; with 50 % of the species reported from this family *(Figure 4.4.3)*. The results may be underreported as species were recorded only once a day.

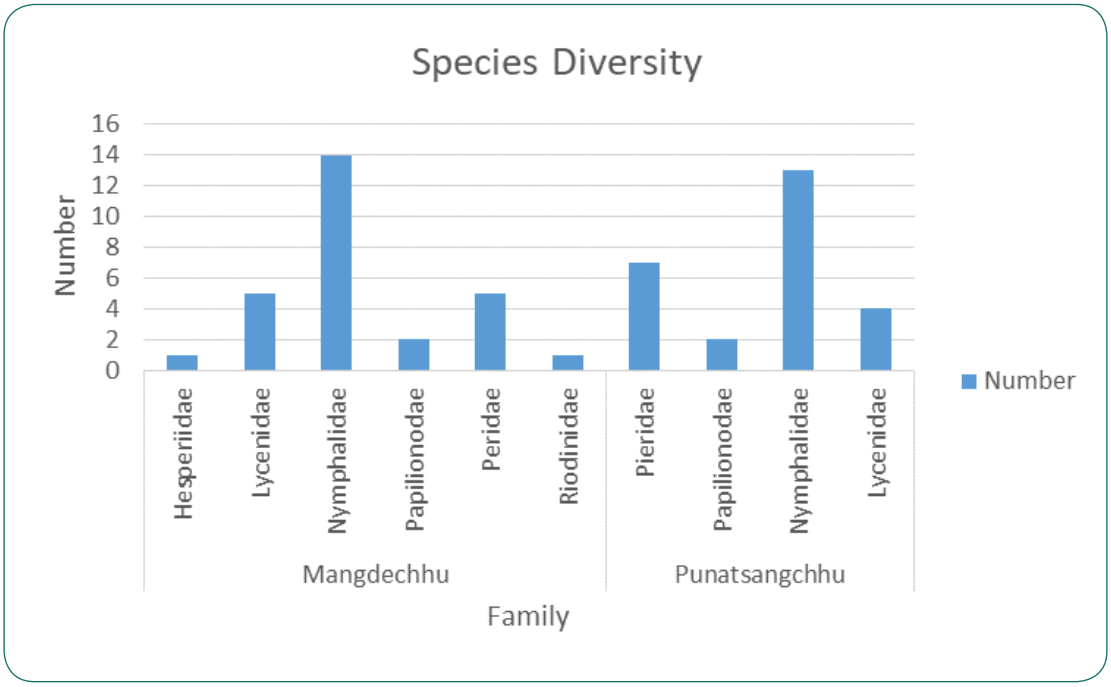


Figure 4.4.3: *Butterflies diversity in Punatsangchhu and Mangdechhu basin*

Table 4.4.1: *Butterfly checklist of Punatsangchhu river basin*

SL.No	Species	Family	Punatsangchhu
1	Banded tree brown	Nymphalidae	Balwani, Changche, Dagachhu, Toesang, Salamije, Burichhu, Zawa, Kamichhu
2	Blue Glassy tiger	Nymphalidae	Balwani, Changche, Dagachhu, Toesang, Salamije, Burichhu, Zawa, Kamichhu, Wangdue, Phochhu
3	Chocolate Albatross	Pieridae	Balwani
4	Chocolate Pansy	Nymphalidae	Balwani, Changche, Dagachhu, Toesang,
5	Common Grass yellow	Pieridae	Balwani, Changche, Dagachhu, Toesang, Salamije, Burichhu, Zawa, Kamichhu, Wangdue, Phochhu
6	Common Mormon	Papilionodae	Balwani, Dagachhu, Toesang, Burichhu, Zawa, Wangdi, Phochhu
7	Common Nawab	Nymphalidae	Balwani, Dagachhu, Toesang, Salamije, Zawa, Kamichhu, Wangdue, Phochhu
8	Common Pierrot	Lycenidae	Balwani, Toesang,
9	Common Sailor	Nymphalidae	Balwani, Changche, Dagachhu, Toesang,
10	Glassy tiger	Nymphalidae	Balwani, Dagachhu, Toesang, Salamije, Zawa, Kamichhu, Wangdue, Phochhu
11	Great Black vine	Nymphalidae	Balwani, Dagachhu, Toesang, Salamije, Zawa, Kamichhu, Wangdue, Phochhu, Mochhu
12	Great egg Fly	Nymphalidae	Balwani, Dagachhu, Toesang, Salamije
13	Hill jezebel	Pieridae	Balwani, Dagachhu, Toesang, Salamije, Zawa, Kamichhu, Wangdue, Phochhu
14	Large cabbage White	Pieridae	Balwani, Changche, Dagachhu, Toesang, Salamije, Burichhu, Zawa, Kamichhu, Wangdue, Phochhu
15	Lesser Grass blue	Lycenidae	Balwani, Changche, Dagachhu, Toesang, Salamije, Burichhu, Zawa, Kamichhu, Wangdue, Phochhu
16	long brand bush brown	Nymphalidae	Balwani, Dagachhu, Toesang, Salamije, Zawa, Kamichhu, Wangdue, Phochhu
17	Mottled Emigrant	Pieridae	Balwani, Toesang, Salamije, Zawa, Wangdi, Phochhu, Mochhu
18	Orange Oak leaf	Nymphalidae	Balwani
19	Pale grass blue	Lycenidae	Balwani, Dagachhu, Toesang, Zawa, Kamichhu, Wangdue, Phochhu
20	Paris Peacock	Papilionodae	Balwani, Dagachhu, Toesang, Zawa, Kamichhu, Wangdue, Phochhu
21	Plain Tiger	Nymphalidae	Dagachhu, Toesang, Zawa, Kamichhu, Wangdue

22	Purple sapphire	Lycenidae	Balwani, Dagachhu, Toesang, Zawa, Kamichhu
23	Red spot Jezebel	Pieridae	Balwani, Changche, Dagachhu, Toesang, Salamije, Burichhu, Zawa, Kamichhu, Wangdue, Phochhu
24	Strip Blue Crow	Nymphalidae	Balwani, Dagachhu, Toesang, Salamije, Zawa, Kamichhu, Wangdue
25	Strip Tiger	Nymphalidae	Balwani, Changche, Dagachhu, Toesang, Salamije, Burichhu, Zawa, Kamichhu, Wangdue, Phochhu, Mochhu
26	Yellow Orange tip	Peridae	Balwani, Changche, Dagachhu, Toesang, Zawa, Kamichhu,Phochhu

Table 4.4.2: *Butterfly checklist of Mangdechhu river basin*

SL.No	Species	Family	Mangdechhu
1	Banded Tree Brown	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
2	Blue Glassy Tiger	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
3	Chocolate Pansy	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
4	Common Grass yellow	Peridae	Chankhachhu, Berti, Ringdebi, Tsedang
5	Common Jester	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
6	Common Map	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
7	Common Mormon	Papilionodae	Chankhachhu, Berti, Ringdebi, Tsedang
8	Common Nawab	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
9	Common Pierrot	Lycenidae	Chankhachhu, Berti, Ringdebi, Tsedang
10	Glassy tiger	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
11	Large cabbage White	Pieridae	Chankhachhu, Berti, Ringdebi, Tsedang
12	Lesser Grass blue	Lycenidae	Chankhachhu, Berti, Ringdebi, Tsedang
13	long brand bush brown	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
14	Mottled Emigrant	Pieridae	Chankhachhu, Berti, Ringdebi, Tsedang
15	Pale grass blue	Lycenidae	Chankhachhu, Berti, Ringdebi, Tsedang
16	Paris Peacock	Papilionodae	Chankhachhu, Berti, Ringdebi, Tsedang
17	Plain Tiger	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
18	Punchinello	Riodinidae	Tsedang,Chamkharchhu
19	Purple sapphire	Lycenidae	Ringdebi, Tsedang
20	Red spot Jezebel	Pieridae	Tsedang
21	Streaked Baron	Nymphalidae	Ringdebi, Tsedang
22	Strip Blue Crow	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
23	Tabby	Nymphalidae	Chankhachhu, Berti, Ringdebi, Tsedang
24	Yellow Orange tip	Pieridae	Ringdebi, Tsedang
25	Indian purple Emperor	Nymphalidae	Ringdebi, Tsedang
26	Fluffy TIT	Lycaenidae	Ringdebi, Tsedang
27	Pale Palm Dart	Hesperiidae	Ringdebi
28	Constable	Nymphalidae	chamkharchhu

a. Common Map

b. Red-base Jezebel

c. Punchinello

d. Paris Peacock

e. Plain Tiger

f. Common Mormom

Figure 4.4.4 *Common butterflies from the study area*

4.4.5 Conclusion

This baseline assessment found that major rivers in White-bellied Heron landscape in Bhutan harbor high diversity of butterflies. The presence of high diversity of butterflies indicates the local environment is pristine and not much impacted by climate change, as butterflies are sensitive to climate variables. However, the findings from this study might be limited due to inadequate sampling and time of survey. A detailed survey of butterflies is suggested to have more in depth records of species from these areas.

05 Aquatic Biodiversity

Aquatic biodiversity is the variety of life and its ecosystems that comprises marine, estuarines and freshwaters of the world and its interaction. It provides huge economic and aesthetic values and it is largely responsible for maintaining and supporting the overall ecological health (Mehta & Kushwaha, 2016). Freshwater ecosystem is one type of aquatic ecosystem that includes both lotic and lentic ecosystems and it provides a wide range of habitats that harbors large portions of living organisms (Dudgeon et al., 2006; Collen et al., 2014). Freshwater bodies are one of the most important natural resources to sustain life and it is also significant for economic development and social well being (WCNP, University of Calcutta and WWF Bhutan, 2012). The pristine freshwater system is vital to provide necessary ecosystem services to human survival and social development (Luo et al., 2018; Song et al., 2018). It is important to protect freshwater bodies from pollution, overexploitation, flow modification, habitat degradation and invasion by exotic species, which are the leading causes of loss of freshwater biodiversity (Dudgeon et al., 2006) that deteriorates the ecological services.

Freshwater systems occupy less than 1% of the earth's surface, yet it harbours 5% of all known biological species of the world (Dudgeon et al., 2006; Grosberg et al., 2012). Pristine water bodies usually harbour a great variety of aquatic life, representing a natural state of freshwater ecosystem (Sharma et al., 2008). Freshwater biodiversity contributes to a wide range of ecosystem services. However, it is most vulnerable to extinction because of anthropogenic activities and infrastructure development, which is further exacerbated by climate change (Wangchuk et al., 2017). The International Union for Conservation of Nature (IUCN) Red List confirms that a high portion of threatened species is among freshwater associated vertebrates (Collen et al., 2014). The freshwater ecosystems in Asia are in great threat due to rapid increases in population and developmental activities that led to degradation of natural environments (Dudgeon, 2000). The freshwater fish and Macroinvertebrates are one of the important components of the freshwater ecosystem. Fish is located at the top of the aquatic food chain and it plays significant role in maintaining food chain (Zhao et al., 2019). The fish is main diet for critically endangered bird White-bellied Heron (Price & Goodman, 2015) and some of the shorebirds (Skagen, 1996). Moreover freshwater fish and macroinvertebrates, exhibits great response signals to environmental stressors (Lopez-Lopez & Sedeño-Diaz, 2015) thus it is used as an ecological indicator of freshwater ecosystems (Abell et al., 2011; Lopez-Lopez & Sedeno-Diaz, 2015; Bogardi et al., 2020).

5.1 Fish Survey

5.1.1 Introduction

Kottelat & Whitten (1996) reported that Asia has about 3500 species of fish with hundreds of other living organisms in various freshwater habitats spending their entire lives in water. It serves as an important source of food for many poor people. In Hindu Kush Himalayan region 8044 species of freshwater taxa were reported including Bhutan (Schmidt-Kloiber & Brace, 2007). In Bhutan freshwater ecosystem is home to diverse ichthyofauna (Changlu et al., 2021) and the first comprehensive documentation of fishes was done by Dubay (1978) with 42 species. Later, Gurung et al., (2013) increased the fish species list to 91 species including the species list of Dubay (1978), Dhendup & Boyd (1994) Petr (1999) and Bhattarai & Thinley (2005). National Biodiversity Centre (NBC) (2017) updated the fish species list to 125 species and 11 species are listed as threatened in IUCN Red list. More recently with discovery of five new fish species (Thoni & Gurung, 2018) and additional 37 species reported by Changlu et al., (2021) increased the number of fish species found in Bhutan to 167 species. Dorji & Gurung (2017) reported that aquatic biodiversity in Bhutan is least explored and there is need of proper assessment of aquatic biodiversity before major threats from developmental activities affect the diversity. Therefore in this study as part of ESRAM study we aim to document freshwater fish in White-bellied Heron landscape in Bhutan.

5.1.2 Materials and Methods

Fish can be surveyed using several methods and fishing gears. In case of population estimation, depletion method is used that is resource extensive. In this rapid assessment, fishing gears such as cast net, seine net, improvised electro-shocker and spinners were used. Use of underwater drones too was tried during the repeat survey at Balwani (Tsirang).

Sampling Design

Biodiversity monitoring grids approximated at 4 x 4 km grids were used in assessing and monitoring biodiversity at the national level by the Department of Forests and Park Services (DoFPS 2020a). While these grids were useful in locating the nearest sampling sites, the nearest locations had to be used in instances where accessibility to the plot was limited. WBH nesting and sightings records maintained by RSPN provided the basis for determining how far away from the river the samples were to be collected. Using GIS, a potential biodiversity assessment sampling site map was generated by overlaying these two maps. Appropriate 100m buffer zone on either side for the given rivers was generated vegetation[1] was used in generating the sampling site map. Using the Proportionate Probability Sampling (PPS) method, 30 sampling sites each were covered in the Punatsangchhu basin and Mangdechhu basin. An additional 10 sites were sampled in

[1] Acharya (2019) identified that WBH preferred habitat is within 74 m from the river bank

the Balwani area along the Punatsangchhu river and its tributary Betini river. A minimum of three sampling stretches were maintained for each tributary in both the river basins.

To optimise findings from the surveys, the field teams adopted purposive sampling within the sampling grid.

Survey Equipment

Cast nets, spinners, PCS tester, GPS, digital rangefinder, camera, measuring tape, weighing balance, alcohol, formalin, micro-tube, cotton, scissors, tray, underwater drone and data collection protocols were used.

Figure 5.1.1: *Using cast net for fishing in Punatsangchhu*

Figure 5.1.2: *Weighing balance used to record the weight of fish in Punatsangchhu*

5.1.3 Results

Punatsangchhu

From the 40 sites that were sampled, the survey team did not record any fish from two sites. Only 17 fish species were captured (***Table 5.1.1***) during the monsoon trip, which is far less than expected. A possible reason for the low number of species captured could be the high (flood) water in the river due to monsoon. A team was fielded again in mid-November to Balwani, further downstream and warmer part of Punatsangchhu river area in Tsirang, which was under water during the monsoon trip. During the survey of this additional site, six sites were sampled in and around Balwani and 18 species were recorded. Combined effort provided 27 species comprising nine families. Considering both the survey, Snow trout (*Schizothorax richardsonii*) was very common (n=243 mature) followed by Copper mahseer (*Neolissochilus hexagonolepis*) with 50 individuals examined. The maximum length of fish caught from this study region was 55 cm and similarly, a maximum weight of fish caught here was 1.7 kg for a Snow trout as well. The team also recorded a Golden mahseer of 53 cm length with 1.1 kg. The most abundant fishes were found in Basochhu and Phochhu followed by Dangchhu and Dikchhu (Table 13). 37 fish species were recorded in an earlier survey of Sama Khola in Dagana (see ***Table 5.1.3***).

Brown trout (*Salmo truta*) was introduced in Bhutan in 1941 (released in rivers and lakes) which was brought to Haa fish hatchery in 1939. This species is carnivorous and preys on native fish and macro-invertebrates.

Figure 5.1.3: *Snow trout from Punatsangchhu river basin, near about Samadingkha, Punakha*

Table 5.1.1: *List of fishes found in Punatsangchhu river basin*

Sl.	Species	Family	First round	Balwani survey
1	*Amblyceps laticeps*	Amblycipitidae	+	-
2	*Badis cf. badis*	Badidae	+	+
3	*Channa sp.*	Channidae	-	+
4	*Bangana dero*	Cyprinidae	-	+
5	*Barilius barna*		+	+
6	*Barilius bendelisis*		-	+
7	*Barilius vagra*		-	+
8	*Cyprinion semiplotum*		+	+
9	*Danio dangila*		+	-
10	*Devario aequipinnatus*		+	+
11	*Garra annandalei*		+	+
12	*Garra arupi*		+	+
13	*Garra birostris*		+	+
14	*Garra cf. gotyla*		+	-
15	*Labeo pangusia*		+	-
16	*Neolissochilus hexagonolepis*		+	-
17	*Schizothorax progastus*		-	+
18	*Schizothorax richardsonii*		+	-
19	*Tor putitora*		+	+
20	*Aborichthys boutanensis*	Nemacheilidae	-	+
21	*Schistura cf. reticulofasciata*		-	+
22	*Schistura sp.*		+	-
23	*Psilorhynchus cf. homaloptera*	Psilorhynchidae	+	-
24	*Salmo trutta*	Salmonidae	+	-
25	*Pterocryptis sp.*	Siluridae	-	+
26	*Parachiloglanis sp.*	Sisoridae	-	+
27	*Pseudecheneis sulcata*		+	+

Mangdechhu

In this study area, 30 sampling efforts were made. However, only 14 species of fish species consisting of four families could be recorded during the field survey (***Table 5.1.2***).This was mainly attributed to the limitation posed by high water due to monsoon. The team encountered a fingerling of Golden mahseer (*Tor putitora*) at about Takabi eco-camp site, Berti. The spring water source was clear and the number of fingerlings of Copper mahseer (*Neolissochilus hexagonolepis*) and *Garra* spp. indicate that the water is used for spawning by these species, including Golden mahseer.

Snow trout (*Schizothorax richardsonii*) was the most common species observed in this study area (n=60 adult, n=11 juvenile) followed by *Neolissochilus hexagonolepis* (n=61 adult, n=9 juvenile). The largest catch was that of a Copper mahseer weighing 4.1 kg and measuring 80.2 cm in length. The mean length and weight of fishes caught were 16.32 cm (±13.35 SD) and 166 g (±494.53 SD). This study area has endemic torrent catfish (*Exostoma mangdechhuensis*) which is mostly confined to Dakpaichhu of Mangdechhu river basin. The most abundant of fishes are found in Bipapangchhu followed by Dakpaichhu and Bertichhu (***Table 5.1.2***).

Figure 5.1.4: *Golden mahseer from Berti, Mangdechhu*

Figure 5.1.5: *Garra annandalei from Berti, Mangdechhu*

Table 5.1.2: *List of fishes found in Mangdechhu river basin*

Sl. No.	Species	Family
1	*Bangana dero*	Cyprinidae
2	*Danio rerio*	
3	*Garra annandalei*	
4	*Garra arupi*	
5	*Garra birostris*	
6	*Neolissochilus hexagonolepis*	
7	*Puntius sp.*	
8	*Schizothorax richardsonii*	
9	*Tor putitora*	
10	*Psilorhynchus homaloptera*	Psilorhynchidae
11	*Schistura cf. multifasciata*	Nemacheilidae
12	*Schistura cf. savona*	
13	*Exostoma mangdechhuensis*	Sisoridae
14	*Pseudecheneis sulcata*	

Table 5.1.3: *List of fish species recorded from Samachhu, a tributary of Punatsangchhu by Kinzang Namgay (CNR, BSc students 2021)*

Sl. No.	Species	Family	IUCN
1	*Anguilla bengalensis (Gray 1831)*	Anguillidae	NT
2	*Barilius barna (Hamilton, 1822)*	Danionidae	LC
3	*Barilius bendelisis (Hamilton, 1807)*	Danionidae	LC
4	*Barilius vagra (Hamilton 1822)*	Danionidae	LC
5	*Danio dangila (Hamilton 1822)*	Danionidae	LC
6	*Devario aequipinnatus (McClelland, 1839)*	Danionidae	LC
7	*Tor putitora (Hamilton 1822)*	Cyprinidae	EN
8	*Neolissochilus hexagonolepis (McClelland 1839)*	Cyprinidae	NT
9	*Cyprinion semiplotus (McClelland, 1839)*	Cyprinidae	VU
10	*Labeo pangusia (Hamilton 1822)*	Cyprinidae	NT
11	*Bangana dero (Hamilton 1822)*	Cyprinidae	LC
12	*Schizothorax progastus (McClelland 1839)*	Cyprinidae	LC
13	*Schizothorax richardsonii (Gray 1832)*	Cyprinidae	VU
14	*Crossocheilus latius (Hamilton 1822)*	Cyprinidae	LC

Sl. No.	Species	Family	IUCN
15	*Garra annandalei (Hora 1921)*	Cyprinidae	LC
16	*Garra arupi (Nebeshwar, Vishwanath & Das 2009)*	Cyprinidae	NE
17	*Garra birostris (Nebeshwar & Vishwanath 2013)*	Cyprinidae	NE
18	*Garra gotyla (Gray, 1830)*	Cyprinidae	LC
19	*Garra parastenorhynchus (Thoni, Gurung & Mayden 2016)*	Cyprinidae	NE
20	*Garra quadratirostris (Nebeshwar & Vishwanath, 2013)*	Cyprinidae	NE
21	*Garra sp. 1*	Cyprinidae	US
22	*Psilorhynchhus cf. homaloptera*	Psilorhynchidae	LC
23	*Aborichthys boutanensis (McClelland, 1842)*	Nemacheilidae	LC
24	*Paracanthocobitis botia (Hamilton 1822)*	Nemacheilidae	LC
25	*Schistura savona (Hamilton 1822)*	Nemacheilidae	LC
26	*Schistura scaturigina (McClelland 1839)*	Nemacheilidae	LC
27	*Batasio merianiensis (Chaudhuri, 1913)*	Bagridae	LC
28	*Olyra longicaudata (McClelland 1842)*	Olyridae	LC
29	*Pterocryptis gangelica (Peters, 1861)*	Siluridae	DD
30	*Amblyceps laticeps (McClelland, 1842)*	Amblycipitidae	LC
31	*Glyptothorax sp. 1*	Sisoridae	US
32	*Parachiloglanis hodgarti (Hora, 1923)*	Sisoridae	LC
33	*Pseudecheneis sulcata (McClelland, 1842)*	Sisoridae	LC
34	*Xenentodon cancila (Hamilton, 1822)*	Belonidae	LC
35	*Badis badis (Hamilton, 1822)*	Badidae	LC
36	*Badis sp.*	Badidae	US
37	*Channa striata (Bloch 1793)*	Channidae	LC
Note:	**NT** = Near Threatened, **LC** = Least Concern, **VU** = Vulnerable, **DD** = Data Deficient, **NE** = Not evaluated, **US** = Unknown Status		

Table 5.1.4: *Relative abundance of fishes in Mangdechhu basin*

Site name (site no.)	Count of Species	Pi (Relative abundance)	LnPi	Pi(LnPi) Shannon Diversity
Bertichhu27	19	0.072	-2.635	-0.189
Bertichhu28	17	0.064	-2.747	-0.176
Berti24	11	0.042	-3.182	-0.132

Site name (site no.)	Count of Species	Pi (Relative abundance)	LnPi	Pi (LnPi) Shannon Diversity
Dakpaichhu18	22	0.083	-2.489	-0.207
Dakpaichhu19	2	0.008	-4.887	-0.037
Dakpaichhu20	3	0.011	-4.481	-0.051
Dakpaichhu21	2	0.008	-4.887	-0.037
Dakpaichhu22	8	0.03	-3.5	-0.106
Mangdechhu1	2	0.008	-4.887	-0.037
Mangdechhu10	3	0.011	-4.481	-0.051
Mangdechhu11	6	0.023	-3.788	-0.086
Mangdechhu12	6	0.023	-3.788	-0.086
Mangdechhu13	6	0.023	-3.788	-0.086
Mangdechhu16	3	0.011	-4.481	-0.051
Mangdechhu17	4	0.015	-4.193	-0.063
Mangdechhu2	4	0.015	-4.193	-0.063
Mangdechhu25	7	0.026	-3.634	-0.096
Mangdechhu26	5	0.019	-3.97	-0.075
Mangdechhu3	3	0.011	-4.481	-0.051
Mangdechhu4	1	0.004	-5.58	-0.021
Mangdechhu5	3	0.011	-4.481	-0.051
Mangdechhu6	14	0.053	-2.941	-0.155
Mangdechhu7	18	0.068	-2.689	-0.183
Mangdechhu8	4	0.015	-4.193	-0.063
Mangdechhu9	7	0.026	-3.634	-0.096
Nimshongchhu29	16	0.06	-2.807	-0.169
Nimshongchhu30	8	0.03	-3.5	-0.106
Takabichhu14	13	0.049	-3.015	-0.148
Takabichhu15	11	0.042	-3.182	-0.132
Bipagangchhu23	37	0.14	-1.969	-0.275
Grand Total	**265**			

Note: *Number after the site name indicates site number for its geographic reference*

5.2 Aquatic Macroinvertebrates

Introduction

Macroinvertebrates are one of the important components of freshwater biodiversity in head water streams and river ecosystems (Clarke et al., 2008). They play a significant role in the circulation and recirculation of nutrients in aquatic ecosystems (Ajao & Fagade, 1990). They accelerate the decomposition of organic matter into simpler inorganic forms (Gallepp et al., 1978). Most macroinvertebrates feeds on debris that settle on bottom of the river and in turn serve a key food source for other freshwater vertebrates such as amphibians and fishes (Idowu & Ugwumba, 2005) which is the main diet for critically endangered white-bellied Heron (Price & Goodman, 2015). In Addition, benthic macroinvertebrates also served as main food source for shorebirds (Skagen, 1996).

In Bhutan, the documentation of freshwater biodiversity is still in its infant state (Dorji, 2014; Gurung & Thoni, 2015). A study initiated by the National environment commission in 2004 in collaboration with experts of Hindu Kush Himalayan region has documented 185 species of Macroinvertebrates in Bhutan (Wangchuk & Dorji, 2018). With lack of experts within the country, the identifications of macroinvertebrates were done only up to order or family level and hardly to genus and species level. Recently several studies in Wangchuck Centennial Park (WCP, 2012), Bumthang, (Wangchuk & Eby, 2013), Trongsa and Thimphu (Dorji et al., 2014), tributary of Punatsangchhu river Toeberongchhu (Gurung & Dorji, 2014), Mangdechhu river (Wangchuk et al., 2017) and Phobjikha valley (Wangchuk & Dorji, 2018) has reported the taxa but no comprehensive study done in major river and wetlands. Therefore this study focuses on documentation of macroinvertebrates and physico chemical water properties in non-wadeable river ecosystems that is Punatsangchhu and Mangdechhu which are the prime habitat for critically endangered White-bellied Heron (RSPN, 2021).

5.2.1 Materials and Methods

Sampling Design

A systematic random sampling was done in ArcGIS to generate the sample plots location along the river with a minimum plot distance of 6.5km. A total of 20 sample plots, 15 plots in Punatsangchhu and 5 plots in Mangdechhu were laid and the plot size was 18sq.m (3x6m) with maximum water depth of 115cm (***Figure 5.2.1***). The inaccessible plots were shifted a maximum of 500m either upstream or downstream from the initial location. Moreover, 34 additional samples were taken from the confluence of the tributaries and the main river (22 plots from Punatsangchhu and 12 plots from Mangdechhu). The data collection was done during the post monsoon season (September and October).

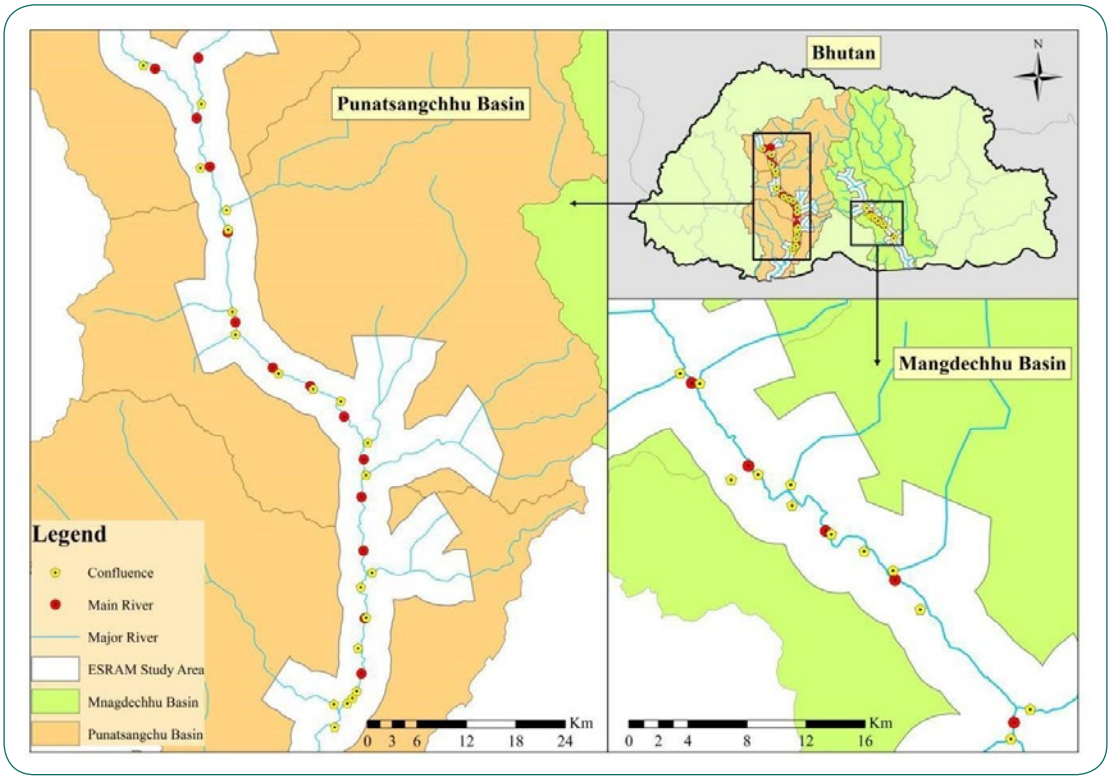


Figure 5.2.1: *ESRAM Study showing Macroinvertebrates Sample Plots*

Field Method and Specimen Identification

The sampling of benthic macroinvertebrates in non-wadeable rivers is usually restricted by depth and strong current of the river and only littoral zones with sufficient current and depth can be sampled (Clapcott et al., 2012). In this study the sample plots were laid only in a littoral zone with sufficient current and maximum depth of 115cm to sample the macroinvertebrates and measure the physicochemical properties for both non-wadeable and wadeable rivers. The sample collections were done using modified D-frame net. The D-frame net was placed against the river current and substrates were disturbed for three minutes to dislodge the macroinvertebrates to wash away by running water into the D-Frame net. The macroinvertebrates were carefully picked from the net with the help of forceps and put in the white tray filled with water before segregating into different taxa. The specimens were euthanized using ethyl alcohol and preserved in 70% alcohols for identification. The repeated samples were released back after counting and recording. Physicochemical properties of water; Salinity, Pressure, Temperature, Total dissolved solute (TDS), Resistivity, pH and Electrical Conductivity were recorded using a multiparameter Tester at each sampling site.

Specimens were assessed using Olympus VT-II stereo-microscope and identified to the lowest taxonomic level possible using multiple existing keys from Hindu Kush Himalayan region and other regions.

Figure 5.2.2: *Sampling macro-invertebrates*

Figure 5.2.3: *Measuring Water parameter*

Data Analysis

The data were analysed following Magurran (2004) to calculate family diversity indices and relative abundance of macroinvertebrates in WBH landscape and in different river basins. Family diversity was calculated using the Shannon index (*H*); computed using formula

$H = -\sum (Pi)\ (lnpi)$.

Where, *pi* is the proportion of each family (*n/N*), *n* is the number of individual family and *N* is the total number of family; *ln* is natural logarithm and ∑ is summation of total calculation.

The family evenness (*E*) was computed using formula

$E = H / H\ max$.

Where, *H* is Shannon index and *H max* is (*lnS*) *S* is the total number of Family in the sample. It is also known as Pielou's index (*J*).

Family richness (*R*) was determined by using formula

$R = (S-1) / (lnN)$.

Where *S* is the total number of families in a sample and *N* is the total number of individuals of all species in the sample. It is also known as Margalef's richness (D_{mg}).

The Relative abundance (RA) was calculated by using formula

$RA = (n / N) \times 100$

Where *n* is Number of individuals in a family and *N* is total number of individuals in all families. All the analyses were done in Microsoft Excel and Basic summary of Physicochemical parameters of the water was analysed using R Statistics.

5.2.2 Result and Discussion

Macroinvertebrates Diversity in WBH Landscape

The study recorded a total of 2209 individuals of macroinvertebrates. Of these 1238 individuals were recorded from Punatsangchhu and 971 from Mangdechhu basins belonging to 39 families and 10 orders. The dominant order was Trichoptera (*S*= 9) that comprised 20.93% of the total family recorded. Similar finding was reported by Wangchuk and Dorji (2018), Trichoptera was the dominant order during the post monsoon season. The least dominant order was Megaloptera and Tricladida (*S*= 1) that comprised only 2.33% of the total family (***Figure 5.2.4***). The most dominant family was Batidae (*n*= 500, *RA* = 22.63%) under order Ephemeroptera and least dominant was Gyrinidae, Athericidae and Peltoperlidae (*n* = 1, *RA* = 0.05%) that belonged to order Coleoptera, Diptera and Plecoptera respectively. High number of individual records in the Punatsangchhu basin might be due to the high number of sample plots (37).

The overall diversity index of macroinvertebrates in WBH landscape in Bhutan was *H* = 2.8, Richness index (*Dmg*) = 5.07 and Evenness index (*J*) = 0.3 (***Table 5.2.1***). These diversity indices show that the fresh water system in WBH landscape harbors a high number of macroinvertebrates. The results are further limited as the taxa could be identified till family level only and diversity would increase if the taxa were identified till genus and species level. The lower evenness might be due to the presence of some singleton and double individual species recorded.

Table 5.2.1: *The Overall Diversity Indices of Macroinvertebrates in WBH Landscape*

Shannon Diversity index *(H)*	Margalef species richness index *(Dmg)*	Pielou's evenness Index *(J)*
2.80	5.07	0.36

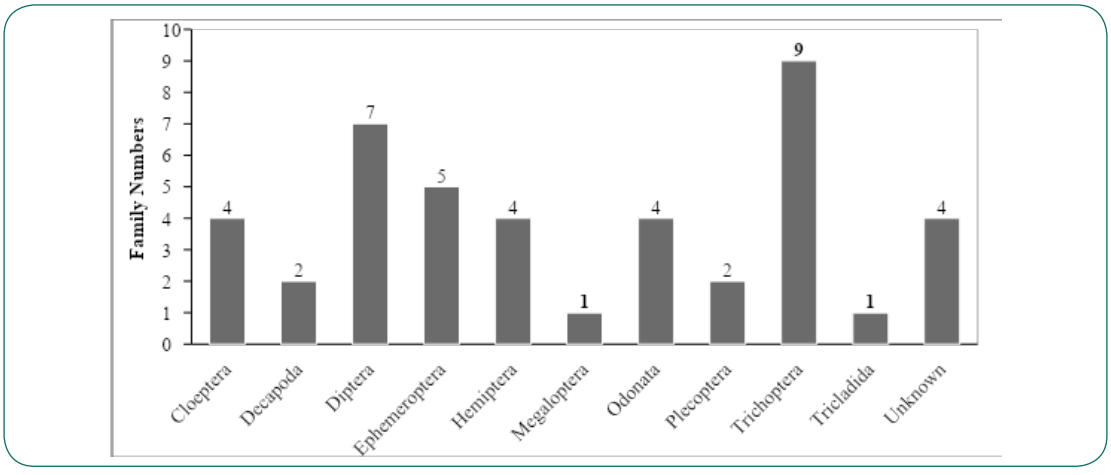


Figure 5.2.4: *Number of families under different orders*

Punatsangchhu Basin

In the Punatsangchhu basin, a total of 1238 individuals; 517 from main Punatsangchhu and 721 from its tributaries from 37 families and 10 orders were recorded (*Table 5.2.3*). The most dominant family was Baetidae (*n* = 387, *RA* = 31.3%) followed by Heptageniidae (*n* = 178, *RA*= 14.4%) and Least dominant family were Athericidae, Calopterygidae, Gyrinidae, Peltoperlidae and Tabanidae (*n* = 1, *RA* = 0.1%). The diversity index of macroinvertebrates was *H* = 2.84, Richness index (*Dmg*) = 5.2 and Evenness (*J*) = 0.4 (*Table 5.2.2*). High diversity and richness indices shows that Punatsangchhu river and its tributaries harbors rich numbers of macroinvertebrates and low evenness index might be due to some singleton and doubleton families.

Table 5.2.2: *Diversity Indices of Macroinvertebrates in Punatsangchhu basin*

Shannon Diversity index *(H)*	Margalef species richness index *(Dmg)*	Pielou's evenness Index *(J)*
2.84	5.20	0.40

Table 5.2.3: *Total number of orders, Family and Individual counts in Punatsangchhu basin*

Order	Family	Total Count (*n*)	Relative Abundance (*RA*)
Coleoptera	Elmidae	24	1.94
	Psephenidae	3	0.24
	Coleoptera1	2	0.16
	Gyrinidae	1	0.08
Decapoda	Dogielinotidae	5	0.4
	Potamidae	4	0.32
Diptera	Tanyderidae	23	1.86
	Limoniidae	13	1.05
	Simuliidae	9	0.73
	Athericidae	1	0.08
	Tabanidae	1	0.08
Ephemeroptera	Baetidae	387	31.26
	Heptageniidae	178	14.38
	Caenidae	55	4.44
	Siphlonuridae	15	1.21
	Ephemerellidae	3	0.24
Hemiptera	Corixidae	23	1.86
	Aphelocheridae	13	1.05

Hemiptera	Gerridae	2	0.16
	Notonectidae	2	0.16
Megaloptera	Corydalidae	18	1.45
Odonata	Gomphidae	51	4.12
	Libellulidae	5	0.4
	Euphaeidae	3	0.24
	Calopterygidae	1	0.08
Plecoptera	Perlidae	116	9.37
	Peltoperlidae	1	0.08
Trichoptera	Hydropsychidae	69	5.57
	Sericosomatidae	64	5.17
	Brachycentridae	47	3.8
	Stenopsychidae	23	1.86
	Lepidostomatidae	13	1.05
	Glossosomatidae	11	0.89
	Odontoceridae	9	0.73
	limnephilidae	6	0.48
	Philopotamidae	4	0.32
Tricladida	Planariidae	4	0.32
	Unknown	29	2.34
Total		**1238**	**100**

Mangdechhu Basin

In Mangdechhu basin, a total of 971 individuals, 236 from main Mangdechhu and 735 from its tributaries belong to 25 families and 10 orders were recorded (***Table 5.2.5***). Heptageniidae (*n* = 254, *RA* = 26.2%) was the most dominant family, followed by Aphelocheridae (*n* = 167, *RA* = 17.2%) and the least dominant families were Potamidae and Elmidae (*n* = 1, *RA* = 0.1%). The diversity index (*H*) of macroinvertebrates was 1.72 and richness (*Dmg*) and evenness (*J*) index of 3.63 and 0.25 respectively (***Table 5.2.4***). The lower diversity and richness index in Mangdechhu basin compared to Punatsangchhu basin might be due to difference in sample size and more inaccessible areas.

Table 5.2.4: *Diversity indices of Macroinvertebrates in Mangdechhu basin*

Shannon Diversity index *(H)*	Margalef species richness index *(Dmg)*	Pielou's evenness Index *(J)*
1.72	3.63	0.25

Table 5.2.5: *Orders, Family and Individual counts in Mangdechhu basin*

Order	Family	Total Count (*n*)	Relative Abundance (*RA*)
Coleoptera	Psephenidae	7	0.72
	Elmidae	1	0.1
Decapoda	Potamidae	1	0.1
Diptera	Blephariceridae	2	0.21
	Ceratopogonidae	2	0.21
	Tabanidae	2	0.21
Ephemeroptera	Heptageniidae	254	26.16
	Baetidae	113	11.64
	Siphlonuridae	69	7.11
	Caenidae	50	5.15
	Ephemerellidae	14	1.44
Hemiptera	Aphelocheridae	167	17.2
Megaloptera	Corydalidae	11	1.13
Odonata	Gomphidae	30	3.09
	Euphaeidae	25	2.57
	Calopterygidae	2	0.21
Plecoptera	Perlidae	89	9.17
Trichoptera	Hydropsychidae	46	4.74
	Philopotamidae	44	4.53
	Glossosomatidae	12	1.24
	Brachycentridae	7	0.72
	Lepidostomatidae	7	0.72
	Stenopsychidae	6	0.62
	Odontoceridae	3	0.31
Tricladida	Planariidae	4	0.41
	Unknown	3	0.31
Total		**971**	**100**

Physico-chemical Properties

In Punatsangchhu River, the mean pH of the study site was 7.65 (± 0.29SD), Conductivity 125.27(±31.37SD) µS/cm, Resistivity 0.01 (± 0.002SD)Ω.cm. Total dissolved solute 62.73(± 15.8SD)mg/L, salinity 0.06((± 0.06 SD) PSU, temperature 17.09 ((± 1.53SD)˚C and Pressure 707.97(± 35.35SD) mmHg ***(Table 5.2.5).*** In Mangdechhu river, the mean pH of the study site was 7.64 (±0.31SD), conductivity 104 (±17.44SD) µS/cm, Resistivity 0.01(±0.002SD) Ω.cm, total dissolved solute 52(±8.72SD) mg/L, salinity 0.05 (±0.01SD), temperature 17.99 (±0.98SD)˚C and pressure 735.26 (± 15.84 SD) mmHg ***(Table 5.2.6)***. pH of both rivers were within the permissible limit; neutral to slightly alkaline (6.5-8.5). The electrical conductivity and resistivity of the water tells about the ionic nature of the water and it is inversely related. In Punatsangchhu and Mangdechhu River, the electrical conductivity and resistivity was far below permissible limit (500µS/cm, 0.002Ω.cm) indicating the water has less dissolved solutes. The total dissolved solute (TDS) determines the taste of the water and in this study the TDS of both the rivers was within the permissible limit (500mg/L). The salinity of the water is the measure of the dissolved salts and the mean salinity of Punatsangchhu and Mangdechhu river was 0.059 and 0.05PSU respectively indicating very less dissolved salts in the river.

The physicochemical parameters, acidity, electric conductivity, TDS, salinity and resistivity analysis found that there is no major pollution in two river basins and supporting diverse living organisms.

Table 5.2.6: *Mean ± SD of various physicochemical properties for Punatsangchhu basin*

Plots	pH	Conductivity	Resistivity	TDS	Salinity	Temperature	Pressure
		µS/cm	Ω.cm	mg/L	PSU	°C	mmHg
P-1	7.63	130	0.0075	65	0.06	18.36	753.5**
P-2	7.57	135	0.0074	68	0.06	18.33	752
P-3	7.67	135	0.0074	67	0.06	19**	741.6
P-4	7.81	135	0.0074	68	0.06	18.91	737.2
P-5	7.77	134	0.0075	67	0.06	17.91	734.3
P-6	7.78	118	0.0085	59	0.06	17.9	728.8
P-7	7.58	114	0.0088	57	0.05	17.7	722.5
P-8	7.7	119	0.0084	60	0.06	17.45	719.7
P-9	7.51	121	0.0083	61	0.06	17.58	702.1
P-10	6.73*	125	0.008	62	0.06	17.17	632*

Plots	pH	Conductivity	Resistivity	TDS	Salinity	Temperature	Pressure
		µS/cm	Ω.cm	mg/L	PSU	°C	mmHg
P-11	7.97**	225**	0.0044*	113**	0.11**	16.1	677
P-12	7.88	94*	0.0106**	47*	0.04*	15.34	678
P-13	7.76	99	0.0101	49	0.05	14.99	686.5
P-14	7.85	98	0.0102	49	0.05	13.96*	677.1
P-15	7.46	97	0.0103	49	0.05	15.57	677.3
Mean	7.63	125.27	0.01	62.73	0.06	17.09	707.97
SD	0.29	31.37	0.002	15.8	0.02	1.53	35.35
Permissible limit	6.5–8.5	500	0.002	500	≤ 0.5	-	-

** Highest, * Lowest

Table 5.2.7: *Mean ± SD of various physicochemical properties for Mangdechhu basin*

Plots	pH	Conductivity	Resistivity	TDS	Salinity	Temperature	Pressure
		µS/cm	Ω.cm	mg/L	PSU/ppt	°C	mmHg
P-1	7.81	98	0.0102	49	0.05	19.36**	759.7**
P-2	7.1*	76*	0.0132**	38*	0.03*	18.4	737.6
P-3	7.67	114	0.0088	57	0.05	18.09	736.2
P-4	7.73	118**	0.0085*	59**	0.06**	17.06	724.2
P-5	7.88**	114	0.0088	57	0.05	17.02*	718.6*
Mean	7.64	104	0.01	52	0.05	17.99	735.26
SD	0.31	17.44	0.002	8.72	0.01	0.98	15.84
Permissible limit	6.5-8.5	500	0.002	500	≤ 0.5	-	-

** Highest, * Lowest

5.2.3 Conclusion and Recommendations

This study was the pilot project and rapid assessment of macroinvertebrate diversity in two major rivers in Bhutan. The study found that major rivers in White-bellied Heron landscape in Bhutan harbor high diversity of macroinvertebrates. The pH and TDS of both the river was within the permissible (pH = 6.5-8.5; TDS = 500 mg/L). All these physicochemical parameters, acidity, electric conductivity, TDS, salinity and resistivity analysis shows that the major rivers in WBH landscape are still pristine and harbor high diversity of living organisms.

The findings of this study might be limited owing to many factors; inadequate sampling, time of survey, and limited expertise for identification of taxa. In this study, samples were collected only from a few accessible areas and tributaries and it does not represent the whole river basin. Moreover, the samples were collected only during the post monsoon season and lack data from other seasons. To obtain comprehensive data of aquatic macroinvertebrates, we recommend sampling both in post and pre monsoon seasons covering all habitat types and the whole river basin. We have used point sampling method and sampled only from major river and one sample from the confluence of major river and its tributaries which give difference in sampling effort and difference in habitat type sampled which caused difficulty in analysis. So, we recommend the need to standardise the number of sampling replicas from major river, tributaries and habitat types to ease the analysis and to get reliable measures of diversity indices. With lack of safety gear, we could take samples only up to the depth of 1.3 m in slow flowing areas and about 60 cm in fast flowing areas in non-wadeable rivers due this we might have left out most of the species. So we recommend taking proper safety gear like life jackets, ropes and if possible rafting boats to take samples from the middle of the river.

We also recommend conducting a detailed survey in collaboration with regional and international experts to get a better understanding of the freshwater macroinvertebrate diversity within the two basins.

Annexure I: Images of the species

1. Order: Plecoptera

Figure 1: *Perlidae*

Figure 2: *Peltoperlidae*

2. Order: Coloeptera

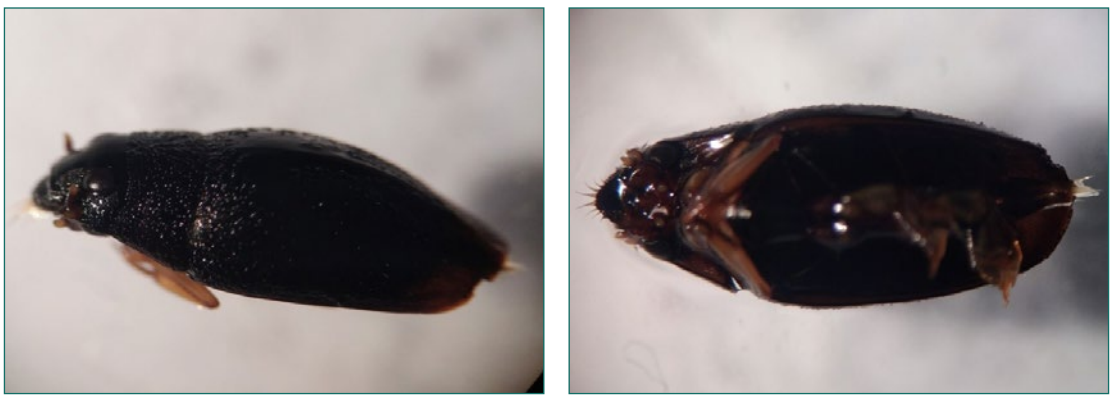


Figure 3: *Gyrinidae*

Figure 4: *Elmidae*

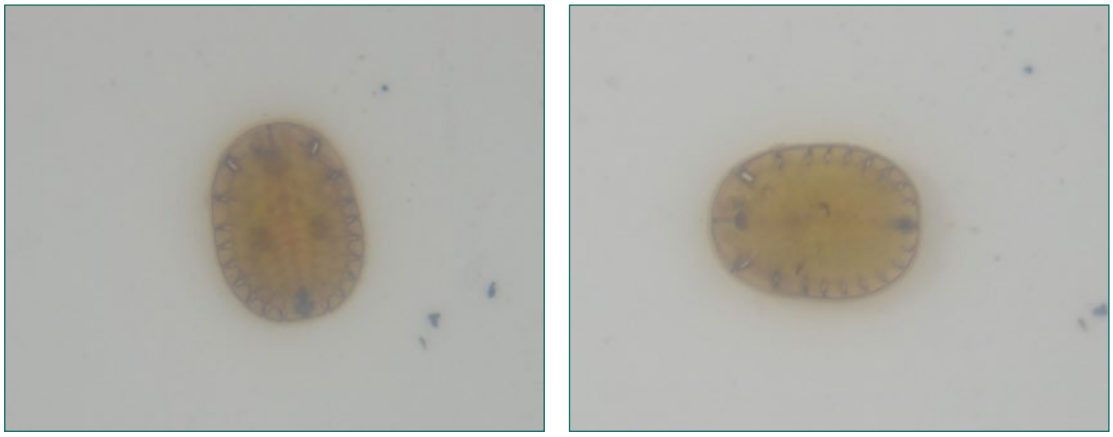


Figure 5: *Psephenidae*

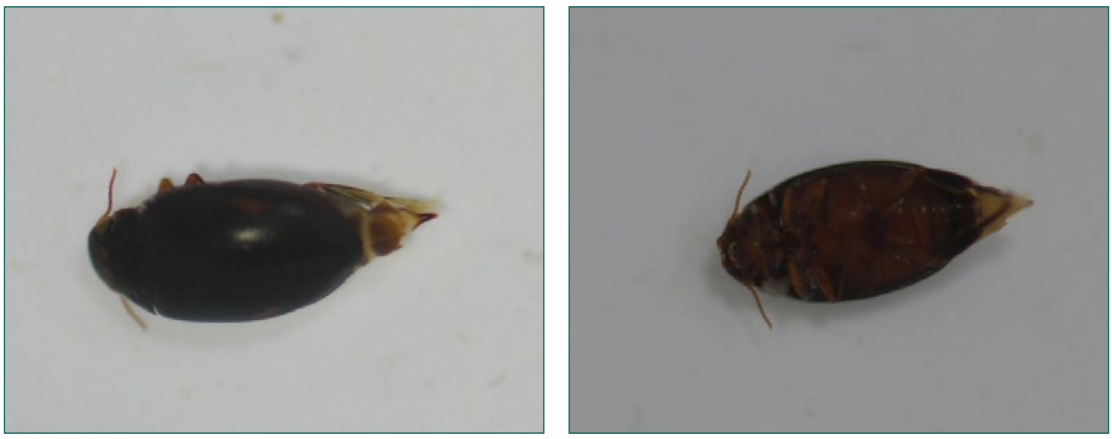


Figure 6: *Unknown1*

Figure 7: *Unknown2*

Figure 8: *Unknown3*

3. Order: Diptera

Figure 9: *Limoniidae*

Figure 10: *Simuliidae*

Figure 11: *Tabanidae*

Figure 12: *Athericidae*

Figure 13: *Tanyderidae*

Figure 14: *Ceratopogonidae*

Figure 15: *Blephariceridae*

4. Order: Decapoda

Figure 16: *Potamidae*

Figure 17: *Dogielinotidae*

5. Order: Ephemeroptera

Figure 18: *Baetidae*

Figure 19: *Heptageniidae*

Figure 20: *Heptageniidae*

6. Order: Hemiptera

Figure 21: *Aphelocheridae*

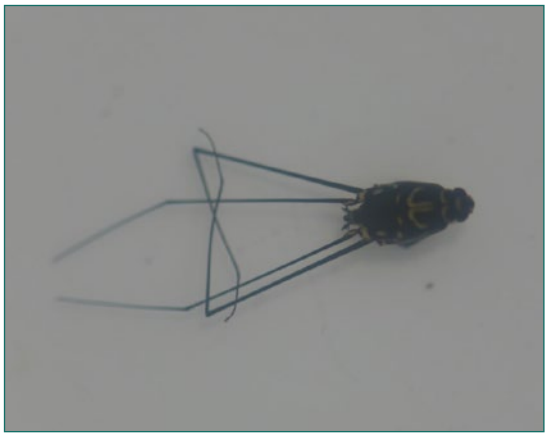


Figure 22: *Gerridae*

Figure 23: *Corixidae*

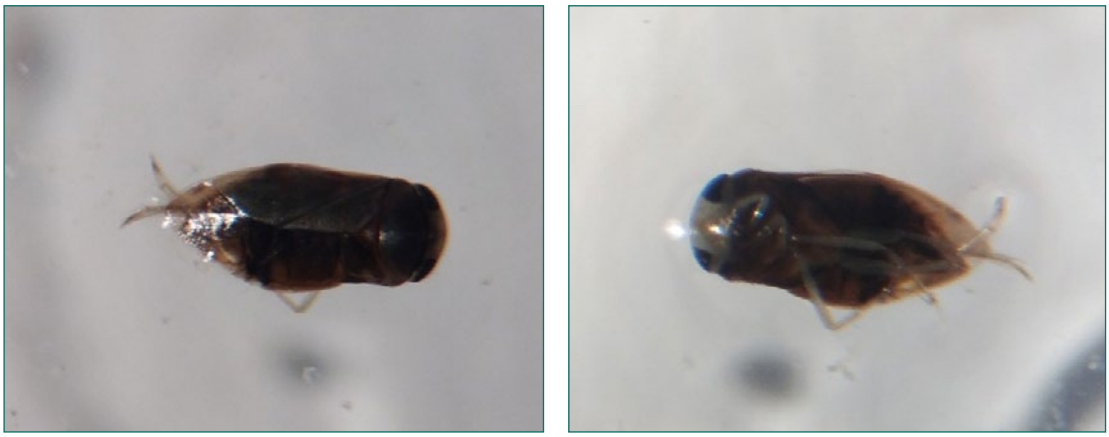


Figure 24: *Notonectidae*

7. Order: Megaloptera

Figure 25: *Corydalidae*

8. Order: Odonata

Figure 26: *Euphaeidae*

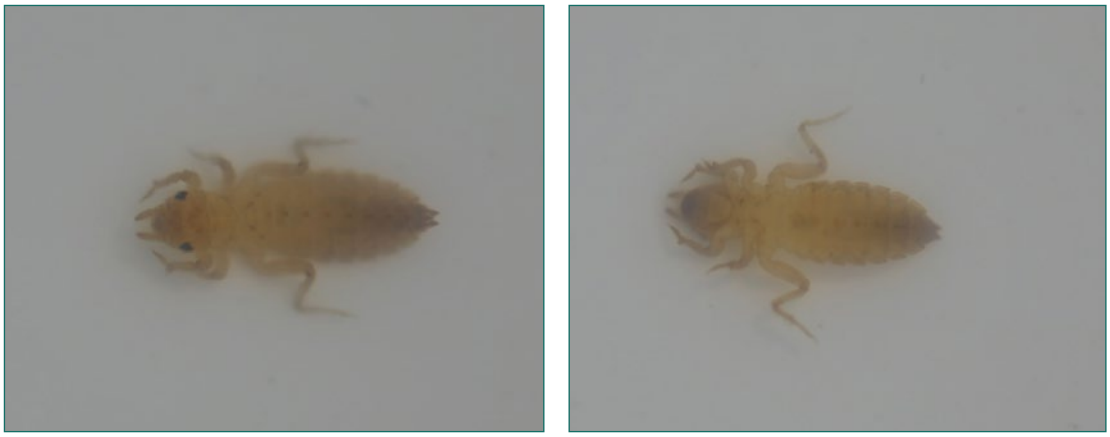


Figure 27: *Gomphidae*

Figure 28: *Calopterygidae*

Figure 29: *: Libellulidae*

Figure 30: *Hydropsychidae*

Figure 31: *Brachycentridae*

Figure 32: *Glossosomatidae*

Figure 33: *Odontoceridae*

Figure 34: *Stenopsychidae*

Figure 35: *Philopotamidae*

Figure 36: *Lepidostomatidae*

9. Order: Tricladida

Figure 37: *Planariidae*

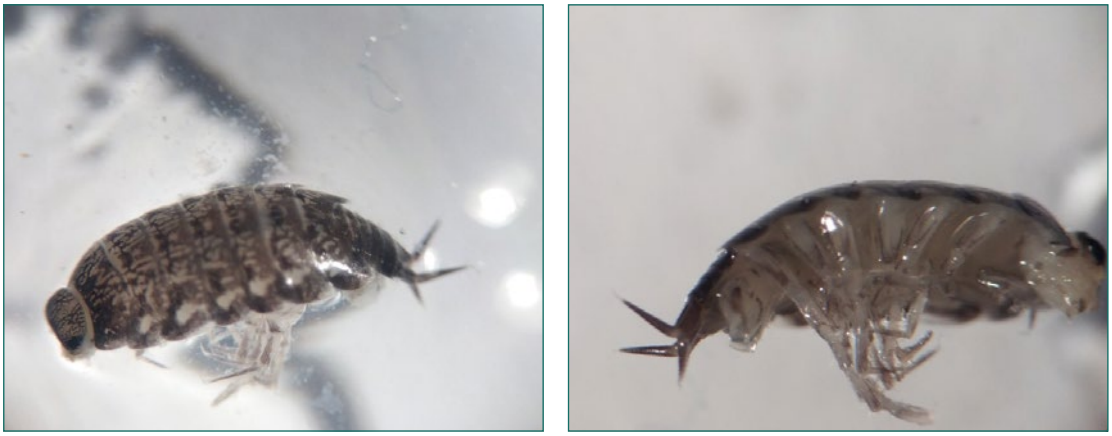


Figure 38: *Unknown*

ANNEXURE

Annexure 1: Vegetation Survey Protocol, ESRAM, Bhutan

SiteNo. ..... Date: ..... Time:.... Collector(s): .....

Dzongkhag:..... Locality: ..... Aspect: .....

Latitude: ..... Longitude: ..... Altitude: .....

Slope: ..... Plot type (circle): Trees (15 x 15m)

Lopping level (circle): 0, 1, 2, 3, 4 Mining activities (circle): Yes / No

Grazing (circle): 0, 1, 2, 3, 4 Timber extraction (circle): 0, 1, 2, 3, 4

Fire evidence (circle): 0, 1, 2 Distance to road in km:

Distance to nearest settlement in km: Mammals' signs (droppings/scats):

Soil stability (circle): 0, 1, 2, 3, 4 Potential for plantation (circle): 0, 1, 2, 3, 4

Forest type (circle): sub-tropical, warm broadleaved, cool broadleaved, temperate, sub-alpine

Forest canopy cover% (circle): open, partial shade, closed

Birds (esp. predatory): Present / Absent

Species	Height (m)	DBH (cm)	Remarks*

Notes: Lopping level: 0=absent, 1=1 to 3 trees lopped, 2=4 to 6 trees lopped, 3=7 to 9 trees lopped, 4=heavy, 10 or more trees lopped

Soil stability: 0=very unstable (erosion/slips visible), 1=unstable, 2=moderate, 3=stable, 4=very stable

Plantation potential: 0=no potential, 1=low potential, 2=moderate, 3=some potential, 4=high potential

Grazing: 0=absent, 1=less, 2=moderate, 3=heavy, 4=very heavy

Timber extraction: 0=absent, 1=less, 2=moderate, 3=heavy, 4=very heavy

Fire evidence: 0=absent, 1=recent, 2 old

*check for invasive species

Any other notes:

Vegetation Assessment Protocol, ESRAM, Bhutan

Site No.....

(Shrubs – 4x4 m)

Species	**Height (m)**	**Number**	**Remarks**

Note: Plot size can be increased up to 5 x 5 m if resources permit

Annexure 2: Ichthyological Collection Protocol, ESRAM, Bhutan

SiteNo. ..... Date: ..... Time: ..... Collector(s): .....

Dzongkhag:..... Locality: ..... Waterbody name:.....

Latitude:..... Longitude: ..... Altitude:.....

Water body type (circle): seasonal stream, river, lake, spring water, dam, ditch, swamp, cave water

Water bed/substrate (circle): boulder, cobble, sand, mud, vegetable matter, other (name):.....

Water reach type (circle): riffle, pool, cascade, run, other (name).....

Water characteristics (circle): clear, turbid, muddy, sandy. Water temp.:.....

pH: ..... Conductivity:..... TDS:..... Salinity: .....

Stream depth:..... Stream width:..... Capture depth:..... Capture method:.....

Weather (circle): sunny, rainy, cloudy, partly cloudy, windy Water velocity:.....

Forest type (circle): sub-tropical, warm broadleaved, cool broadleaved, temperate, sub-alpine

Cover over water body (circle): open, partial shade, closed, other (name):.....

Fixation in: ..... Preservation in: .....

Species	Length (cm)	Weight (g)	No. if juvenile	Remarks

Notes if any:

Annexure 3: Vegetation Assessment Protocol, ESRAM, Bhutan

Site No. .....

(Herbs – 1 x 1m)

Species	Cover % OR number		Remarks

Note: plot size can be increased up to 2 x 2 m if resources permit

REFERENCES

Abell, R., Thieme, M. and Lehner, B. (2011). *Indicators for assessing threats to freshwater biodiversity from humans and human-shaped landscapes.* In: Cincotta R., Gorenflo L. (Eds.) Human population: its influences in biological divrsity. Springer, Berlin, Heidelberg, pp 103–124. https://doi.org/10.1007/978-3-642-16707-2_7

Acharya, A. P., Pavan-Kumar, A., Gireesh-Babu, P., Joshi, C. G., Chaudhari, A., & Krishna, G. (2019). Population genetics of Indian giant river-catfish, Sperata seenghala (Sykes, 1839) using microsatellite markers. *Aquatic Living Resources*, *32*, 4.

Acharja, I.P. (2019). Evaluation of nest habitat, site preferences and architecture of the critically endangered White-bellied Heron. Ardea insignis in Bhutan. *Bird Conserv Int*. 1–19.

Ajao, E. A., & Fagade, S. O. (1990). A study of the sediments and communities in Lagos Lagoon, Nigeria. *Oil and Chemical Pollution*, *7*(2), 85–117. https://doi.org/10.1016/S0269-8579(05)80017-6

Alldredge, M. W., Pollock, K. H., Simons, T. R., Collazo, J. A., & Shriner, S. A. (2007). Time-of-detection method for estimating abundance from point-count surveys. *The Auk*, *124*(2), 653-664.

Antunes, A. Z. (2008). Diurnal and seasonal variability in bird counts in a forest fragment in southeastern Brazil. *Revista Brasileira de Zoologia*, *25*(2), 228-237.

Banerjee, A., & Bandopadhyay, R. (2016). Biodiversity hotspot of Bhutan and its sustainability. *Current Science*, *110*(4), 521–52

Bhattarai, S., & Thinley, P. (2005). *Survey of fish fauna along with basic water quality in some rivers of Bumdeling Wildlife Sanctuary in eastern Bhutan*. Thimphu*, 15pp*.

Bhowmick, S.R. (2021). Biodiversity assessment of bird species as bioindicators and the impact of air pollution on the ecological community. International Journal of Pure and Applied Mathematics. *9*(2):18-25.

Bibby, C., Jones, M., and Marsden, S. (2000). Expedition field techniques. Bird Surveys. Published by Birdlife International. Wellbrook Court. Cambridge CB3 ONA.

BirdLife International. (2021) Country profile: Bhutan. Retrived on March 20 2022 from http://www.birdlife.org/datazone/country/bhutan. Checked: 2021-11-21.

Bogardi, J. J., Leentvaar, J. and Sebesvári, Z. (2020). Biologia Futura: integrating freshwater ecosystem health in water resources management. *Biologia Futura* 71:337–358. https://doi.org/10.1007/s42977-020-00031-7

Bunge J, Fitzpatrick M. (1993). Estimating the number of species: A review. *J. Am. Stat. Assoc.* 1993; 88:364–373.

BirdLife International(2013). *Ardea insignis*. The IUCN Red List of Threatened Species2013:e.T22697021A49746000. http://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T22697021A49746000.en

Bouchard, R. (2012). Guide to Aquatic Invertebrate Families of Mongolia. *Identification Manual for Students, Citizen Monitors, and Aquatic Resource Professionals. Saint Paul, Minnesota, USA*, 1–214.

Brandis, D., & Sharma, S. (2005). Taxonomic revision of the freshwater crab fauna of Nepal with description of a new species (Crustacea, Decapoda, Brachyura, Potamoidea and Gecarcinucoidea). *Senckenbergiana biologica*, *85*(1)

Changlu, Norbu, S., Wangchuk, K., Khanal, G. P., Tshering, S., & Tshering, P. (2021). Diversity of fishes across hydrological basins and elevational gradients in eastern Bhutan: a preliminary analysis. *Bhutan Journal of Animal Science*, *5*(1), 27-36.

Clapcott, J., Pingram, M., & Collier, K. J. (2012). Review of functional and macroinvertebrate sampling methods for non-wadeable rivers. *Prepared for Marlborough District Council Cawthron Report*, (2222), 55.

Clarke, A., Mac Nally, R., Bond, N., & Lake, P. S. (2008). Macroinvertebrate diversity in headwater streams: a review. *Freshwater Biology*, *53*(9), 1707–1721. https://doi.org/10.1111/J.1365-2427.2008.02041.X

Clifford, H. F. (1991). Aquatic Invertebrates of Alberta. Retrieved May 24, 2012, from http://www. sunsite.ualberta.ca/Projects/Aquatic_Invertebrates/)

Collen, B., Whitton, F., Dyer, E. E., Baillie, J. E. M., Cumberlidge, N., Darwall, W. R. T., Pollock, C., Richman, N. I., Soulsby, A.-M.&B¨ohm, M.(2014). Global patterns of freshwater species diversity, threat and endemism. *Global Ecology and Biogeography* 23, 40–51.

Dubey, G.P. (1978). *Survey of the waters of Bhutan physiography and fishery potential. Document Repository*. FAO, Rome.

DoFPS (2020a). Biodiversity Monitoring and Social Survey Protocol of Bhutan. Ministry of Agriculture and Forests, Royal Government of Bhutan, Thimphu, Bhutan.

DoFPS(2020b). National Forest Inventory Report. Department of Forests & Park Services. Ministry of Agriculture and Forests, Royal Government of Bhutan, Thimphu, Bhutan.

Dorji, U. & Gurung, D.B. (2017). Aquatic Biodiversity of Bhutan. *An introduction to the Biodiversity of Bhutan:In context of Climate change and Economic development.* Kuensel Coorporation Limited: Thimphu. ISBN 978-99936-994-0-8

Dorji, T., Thinley, K., & Jamtsho, S. (2014). Macroinvertebrate diversity in Thelpang and Kawangjangsa freshwater stream in Bhutan. *NeBIO*, *5*(1)

Dobson, M. (2013). Family-level keys to freshwater fly (Diptera) larvae: a brief review and a key to European families avoiding use of mouthpart characters. *Freshwater Reviews*, *6*(1), 1-32.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z.-I., Knowler, D. J., L´evˆeque, C., Naiman, R. J., Prieur-Richard, A.-H., Soto, D., Stiassny, M. L. J. & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews* 81, 163–182.

Dudgeon, D. (2000). Conservation of freshwater biodiversity in Oriental Asia: constraints, conflicts, and challenges to science and sustainability. *Limnology*, *1*(3), 237-243.

Fiedler, W.(2009). Bird ecology as an indicator of climate and global change. In Trevor M.Letcher, editor: Climate change: Observed impacts on Planet Earth, The Netherlands, pp. 181-195.

FRMD, (2017). *Land Use and Land Cover Assessment of Bhutan 2016, Department of Forests and Park Servcies*, Ministry of Agriculture and Forests , 1-28.

Gallepp, G. W., Kitchell, J. F., & Bartell, S. M. (1978). Phosphorus release from lake sediments as affected by chironomids: *Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen*, *20*(1), 458-465. DOI: 10.1080/03680770.1977.11896548

Ghazanfar, M., Malik, M. F., Hussain, M., Iqbal, R., & Younas, M. (2016). Butterflies and their contribution in ecosystem: A review. *Journal of Entomology and Zoology Studies*, *4*(2), 115-118.

Gillison, A. N. (2006). A field manual for rapid vegetation classification and survey for general purposes. *International Forestry*, 3-10.

Gibbins, C., Vericat, D., Batalla, R.J.(2007). When is stream invertebrate drift catastrophic? The role of hydraulics and sediment transport in initiating drift during flood events. *Freshw. Biol*. *52* (12), 2369–2384. https://doi.org/10.1111/j.1365- 2427.2007.01858.x.

Global Biodiversity Information Facility (2021). GBIF Occurrence Download. Retrieved on 25 November, 2021 from https://doi.org/10.15468/dl.g8rwf6

Grosberg, R. K., Vermeij, G. J., & Wainwright, P. C. (2012). Biodiversity in water and on land. *Current Biology*, *22*(21), R900-R903.

Gurung, D.B. & R.J. Thoni (2015). *Fishes of Bhutan; A Preliminary Checklist. Royal University of Bhutan, College of Natural Resources,* Center for Rural Development Studies, Lobesa, 40pp.

Gurung, P. B., & Dorji, T. (2014). Macroinvertebrate diversity and relationship with environmental variables in the headwater streams of Toebirongchhu sub-watershed, Bhutan. *NeBIO*, *5*(3), 5-10.

Gurung, D.B., Dorji, S., Tshering, U. & Wangyal, J.T. (2013). An annotated checklist of fishes from Bhutan. *Journal of Threatened Taxa 5*(14):4880–4886.

Hurlbert, S.H. (1971). "The nonconcept of species diversity: a critique and alternative parameters." *Ecology*, 52, 577–586.

IUCN, (1980). World Conservation Strategy. IUCN, Glands, Switzerland, 50 pp.

IUCN. (2003). *IUCN Red List of Threatened Species.* The IUCN Species Commission.

Idowu, E. O., & Ugwumba, A. A. A. (2005). Physical, chemical and benthic faunal characteristics of a Southern Nigeria Reservoir. *The Zoologist*, *3*, 15-25.

Kissling, M. E. & E. O. Garton, (2006). Estimating detection probability and density from point-count surveys: a combination of distance and double-observer sampling. *The Auk 123(*3):735–752.

Kushlan, J. A. (2007). *Conserving Herons, A Conservation Action Plan for the Herons of the World.* Arles, France: Heron Specialist Group and Station Biologique de la Tour du Valat.

Kushlan, J. A. and Hafner, H. (2000). *Heron Conservation.* London: Academic Press.

Kushlan, J. A. and Hancock, J. A. (2005). *The Herons.* Great Clarendon street, Oxford OX2 6DP: Oxford University Press.

Kottelat, M., & Whitten, T. (1996). Freshwater Biodiversity in Asia: With Special Reference to Fish.

Larson, B. M. H., Kevan, P. G., & Inouye, D. W. (2001). Flies and flowers: taxonomic diversity of anthophiles and pollinators. *The Canadian Entomologist*, *133*(4), 439-465.

López-López, E., & Sedeño-Díaz, J. E. (2015). Biological indicators of water quality: The role of fish and macroinvertebrates as indicators of water quality. In *Environmental indicators* (pp. 643-661).

Lovette, Irby J. & Fitzpatrick. (2016). *Handbook of Bird Biology*. United Kingdom: Wiley-Blackwell.

Luo, Z., Zuo, Q., Shao, Q. (2018). A new framework for assessing river ecosystem health with consideration of human service demand. Sci. Total Environ. 640, 442–453. https://doi.org/10.1016/j.scitotenv.2018.05.361.

Magurran, A. E. (2004). *Measuring biological diversity*. Malden, Ma: Blackwell Pub.

Manzoor, F., & Bin Sadat, H. (2013). Butterflies as an indicator of climate change. *Zoo's Print*, *28*(2), 19-21.

Mehta, K. R., & Kushwaha, U. K. S. (2016). An assessment of aquatic biodiversity of River Bagmati Nepal. *Ecology and Evolutionary Biology*, *1*(2), 35-40.

NBC. (2017). *Biodiversity Statistics of Bhutan 2017*, National Biodiversity Centre, Thimphu. ISBN 978-99936-987-6-0

Nakamura, Y. (2011). Conservation of butterflies in Japan: status, actions and strategy. *Journal of Insect Conservation*, *15*(1), 5-22.

Nesemann, H., Shah, R. D. T., & Shah, D. N. (2011). Key to the larval stages of common Odonata of Hindu Kush Himalaya, with short notes on habitats and ecology. *Journal of Threatened Taxa*, *3*(9), 2045–2060. https://doi.org/10.11609/JoTT.o2759.2045-60

Petr, T. (1999). *Coldwater fish and fisheries in Bhutan.* Food and Agriculture Organization Fisheries Technical Paper, Rome, 6-12pp.

Pollard, E., & Yates, T. J. (1994). *Monitoring butterflies for ecology and conservation: the British butterfly monitoring scheme*. Springer Science & Business Media.

Oksanen, J.F., Blanchet, G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G.
L., Solymos, P., Henry, M., Stevens, H., Szoecs, E. and Wagner, H. (2018) Vegan: Community Ecology Package. R package version 2.5–7. Available at https://CRAN.R-project.org/package=vegan.Google Scholar.

Pradhan, R. (2007). White-bellied Heron Project 2005-2007: Annual Report December 2005-December 2006.

Pradhan, R.; Norbu, T.; Frederick, P. (2007). Reproduction and ecology of the world's rarest Ardeid: the White-bellied Heron (*Ardea insignis*) in Bhutan. *31st Annual Meeting of the Waterbird Society, 30 October - 3 November 2007, Edifici HistÃ²ric, Universitat de Barcelona*, pp. 97.

Price, M. R. S. & Goodman, G. L. (2015) *White-bellied Heron conservation strategy 2015*. Thimphu, Bhutan: Royal Society for Protection of Nature.

Rajpar, M. N., and Zakaria, M. (2011). Bird Species abundance and their correlationship with microclimate and habitat variables at natural wetland reserve, peninsular Malaysia.International Journal of Zoology, Volume 2011 (2011), Article ID 758573, 17 pages http://dx.doi.org/10.1155/2011/758573.

RSPN (2021). *White Bellied Heron Annual population Survey Report 2021*. Thimphu

RSPN [Royal Society for the Protection of Nature], (2011). *The Critically Endangered White-bellied Heron.* Thimphu, Bhutan: Royal Society for Protection of Nature.

RSPN (2011) The critically endangered White bellied Heron (R. Pradhan and P. Frederick, eds). Thimphu, Bhutan: Royal Society for Protection of Nature.

Schmidt-Kloiber, A. & Brabec, K. (2007). Current Status of the HKH Macroinvertebrate Taxa Catalogue With Ecological Information. Assess HKH. Boku, Vienna.

Sekercioglu, C,H., and Wenny, D.(2016). Why birds matter. Avian Ecological functions ecosystem services. Accessed in the research gate. file:///Users/tsheringtobgay/Downloads/why-birds-matter_ch1.pdf.

Sharma, A., Bouchard, F., Ryan, S., Parker, D., & Hellmann, J. J. (2013). Species are the building blocks of ecosystem services and environmental sustainability. *Ethics, Policy & Environment*, *16*(1), 29-32.

Sharma, M. P., Sharma, S., Goel, V., Sharma, P., & Kumar, A. (2008). Water quality assessment of Ninglad stream using benthic macroinvertebrates. *Life Science Journal*, *5*(3), 64-72.

Skagen, S. K. (1996). Dietary flexibility of shorebirds in the western hemisphere. *Can Field Nat*, *110*, 419-444.

Song, J., Tang, B., Zhang, J., Dou, X., Liu, Q., Shen, W.(2018). System dynamics simulation for optimal stream flow regulations under consideration of coordinated development of ecology and socio-economy in the Weihe River Basin, China. *Ecol. Eng. 124*, 51–68. https://doi.org/10.1016/j.ecoleng.2018.09.024.

Tabur, M,A., and Ayvaz, Y.(2010). Ecological Importance of Birds. Conference paper. https://www.researchgate.net/publication/272153124_Ecological_Importance_of_Birds

Thoni, R.J. & Gurung, D.B., (2018). Morphological and molecular study of the torrent catfishes (Sisoridae: Glyptosterninae) of Bhutan including the description of five new species. Zootaxa 4476(1):040–068.

Tóthmérész, B. (1995). Comparison of different methods for diversity ordering. *Journal of Vegetation Science* 6, 283–290.

Volpato, G.H., Lopes, E., Serafini, P., and Anjos, L.D. (2009). The use of the point count method for bird survey in the Atlantic forest. Article *in* Zoologia (Curitiba Impresso).

Wangchuck Centennial Park (2012). Preliminary report on Freshwater biodiversity in Wangchuck Centennial Park. Bumthang, 52pp.

Wangchuk, J., & Dorji, K. (2018). Stream macro-invertebrate diversity of the Phobjikha Valley, Bhutan. *Journal of Threatened Taxa*, *10*(1), 11126-11146. DOI:http://doi.org/10.11609/jptt.3138.10.1.11126-11146.

Wangchuk, J., Yoezer, D., Wangdi, N., Wangdi, K., Singye, R., & Dorji, T. (2017). Macroinvertebrate and fish diversity in Ecosystems Services of Wetlands in Bhutan. *NeBIO An International Journal of Environment and Biodiversity*, *8*(4), 335–342.

Wangchuk, J & Eby, A. L (2013). Aquatic Biodiversity Assessment –A pilot study in Bumthang, Bhutan. Royal Government of Bhutan, UWICE Press, Bumthang.

Zhao, C., Shao, N., Yang, S., Ren, H., Ge, Y., Zhang, Z., Zhao, Y., Yin, X.(2019). Integrated assessment of ecosystem health using multiple indicator species. *Ecol. Eng. 130*, 157–168. https://doi.org/10.1016/j.ecoleng.2019.02.016.

RSPN

Inspiring personal responsibility for environmental conservation since 1987

Royal Society for Protection of Nature
P.O. Box: 325, Building No.: 25
Lhado Lam, Kawajangsa | Thimphu 11001, Bhutan
Phone: +975 2 322056 | 326130 | Fax: +975 2 323189
Website: http://www.rspnbhutan.org | E-mail: rspn@rspnbhutan.org

ISBN 978-99936-662-8-8

/rspnbhutan /rspnbhutan /rspn_bhutan /rspnbhutan