BIODIVERSITY STATUS:

SARPANG & GELEPHU MINDFULNESS CITY

Biodiversity Report, 2024

ABSTRACT

Sarpang's biogeographic region is characterized by rich biodiversity. It includes over 129 plant families, 428 genera, and about 637 flowering plant species, which consist of both dicots and monocots. The flora in the area is diverse, with 170 tree species, 140 shrubs, and 204 herbaceous plant species. The region is also home to a diverse range of fauna, including 36 mammalian species, 92 bird species, 34 reptiles, 15 amphibians, 29 fishes, and 48 bat species.

Divisional Forest Office, Sarpang

Comprehensive Biodiversity Report

June **2024**

Author(s):

1. Wangdi, Forestry Officer, Divisional Forest Office, Sarpang.
2. Phub Dhendup, Chief Forestry Officer, Divisional Forest Office, Sarpang.
3. Ngawang Gyeltshen, Senior Forest Ranger, Divisional Forest Office, Wangdue.
4. Tenzin Jamtsho, Forest Ranger-I, Divisional Forest Office, Sarpang.

Contributors:

Data Analysis Team

1. Wangdi, FO
2. Sangay Dorji, SFR
3. Tshewang Dorji, SFR-I
4. Tashi Wangdi, SFR-I
5. Jigme Zangmo, SFR-I
6. Tenzin Jamtsho, FR-I
7. Kezang Wangmo, FR-II
8. Tenzin Dema, FR-II
9. Yeshi Dema, FR-II
10. Chimi Wangmo, FR-I
11. Neten Tshering, FR-II
12. Kencho Zangmo, FR-II
13. Tandin Wangchuk, FR-II

Survey Team

1. Wangdi –(FO)
2. Tashi Wangdi –(SFR)
3. Tshewang Dorji- (SFR)
4. Sangay Dorji-(SFR)
5. Sangay Nidup-(SFR-III)
6. Tshering –(FR-II)
7. Tenzin Jamtsho- (FR-I)
8. RB Mongar – (Sr.Fr.)

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ISBN:
For a copy of this document, contact: 17506599
Divisional Forest Office, Sarpang
E-mail: dfosarpang@gmail.com

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Acknowledgment

The undersigned would like to extend sincere appreciation to the survey team that participated in the National Tiger Survey of 2022 and the Rapid Biodiversity Assessment of 2023. The dedication and hard work exhibited by the surveyors have significantly contributed to the generation of this report. We would also like to express our gratitude to the team involved in data analysis and report writing.

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Additionally, we express our appreciation to Mr. Wangdi, Forestry Officer and BFL Project focal, for his initiatives and contributions.

We would also like to thank Mr. Lobzang Dorji, Director, DoFPS, and all the Chiefs and colleagues of Functional Divisions for their leadership roles and support.

We are also deeply grateful to Bhutan for Life (BFL) for financial support in the Butterfly and Fish survey in 6 BMGs. Finally, we are deeply grateful to the IKI Living Landscape Project and the WWF Bhutan Program Office for their generous funding support, which allowed us to complete this study and generate reliable information on the biodiversity status of the Divisional Forest Office, Sarpang. Without their financial support, this achievement would not have been possible.

Phub Dhendup,
Chief Forestry Officer,
Divisional Forest Office, Sarpang

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IKI INTERNATIONAL CLIMATE INITIATIVE

BHUTAN FOR LIFE

WWF

Foreword

We are excited to share the report "Biodiversity Status of Sarpang." This report is a valuable guide to understanding and protecting the rich biodiversity of Sarpang, a region with a diverse mix of ecosystems and cultures.

Sarpang is home to a variety of plants and animals, from lush forests to meandering rivers, all of which come together to form thriving ecosystems. The report highlights the incredible species diversity in Sarpang and its unique habitats, emphasizing the importance of conserving these precious natural resources,

In a world facing climate change, habitat loss, and mass extinction, this report will serve as a valuable reference for future generations, documenting the species of animals and plants present today. The future of Sarpang's biodiversity is linked to the well-being of its people and the global ecosystem. The report provides recommendations for policymakers, conservationists, and local communities to work together to protect this unique ecological treasure.

We hope this report will inspire you to join us in preserving Sarpang's biodiversity and celebrating its intricate beauty and ecological significance.

Furthermore, the report will be useful for the upcoming Gelephu Mindfulness City, ensuring that conservation efforts are seamlessly integrated with mindful urban growth.

Lobzang Dorji,
Director,
Department of Forests and Park Services.

Acronyms and Abbreviations

BC 3	Biological Corridor 3
BMG	Biodiversity Monitoring Grid
BMSSPB	Biodiversity Monitoring and Social Survey Protocol of Bhutan
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Fora
CR	Critically Endangered
DBH	Diameter at Breast Height
DFO	Divisional Forest Office
DoFPS	Department of Forest and Park Services
EN	Endangered
FMCB	Forest Management Code of Bhutan
ha	Hectare
IKI	International Climate Initiative
IUCN	International Union for conservation of Nature and Natural Resources
JSWNP	Jigme Singye Wangchuck National Park
KBA	Key Biodiversity Area
km	Kilometer
LC	Least Concern
MASL/masl	Meters above sea level
NT	Near Threatened
NTS	National Tiger Survey
PNP	Phrumsengla National Park
RBA	Rapid Biodiversity Assessment
RBA%	Relative Basal Area Percentage
sq.km	Square Kilometer
VU	Vulnerable
JSWNP	Jigme Singye Wangchuk National Park
PWS	Phibsoo Wildlife Sanctuary
RMNP	Royal Manas National Park
IVI	Importance value Index
NBC	National Biodiversity Centre
NT	Near Threatened
TDS	Total Dissolved Salts

Executive Summary

Background

Divisional Forest Office, Sarpang was established in 1959 and it is the second Division to be instituted after the creation of the Department in 1952. Sarpang Forest Division is situated in south-central region of Bhutan and covers a total area of approximately 1011.7023 km². Almost all the Gewogs of Sarpang Dzongkhag falls fully or partially under Divisions Jurisdiction. The elevation within Sarpang District varies from 153 to 3,506 meters above sea level (Tenzin et al., 2021). The region experiences an annual precipitation ranging from 3,500 to 5,500 mm. The areas under the Division's jurisdiction encompass diverse forest types, including subtropical broadleaved forests, warm broadleaved forests, and cool broadleaved forests (Nepal & Dorji, 2020; Tenzin et al., 2021).

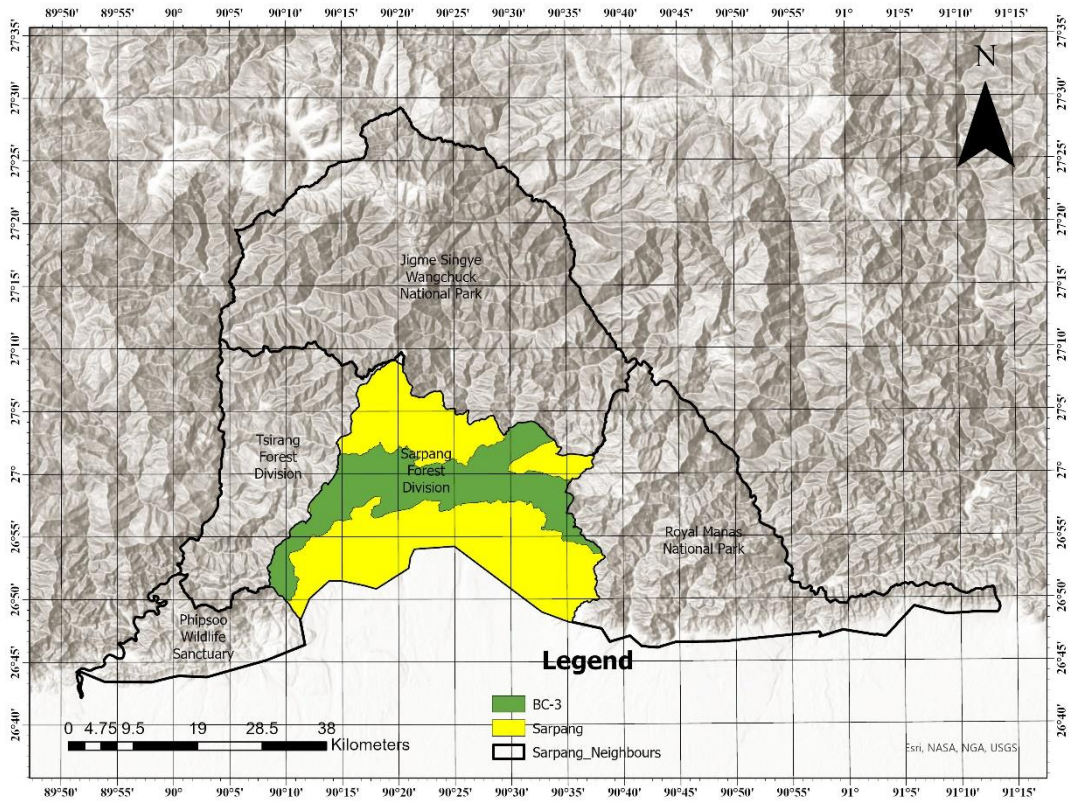


Figure 1: Map of Divisional Forest Office, Sarpang along with Neighboring PAs and Forest Divisions

The Division shares its southern border with the northeast Indian state of Assam and Royal Manas National Park to the east. On the western side, Sarpang Division shares a boundary with Phibsoo Wildlife Sanctuary, which adjoins the Buxa Tiger Reserve (BTR) in the Indian state of West Bengal and Tsirang Forest Division. To the north, it shares a border with Jigme Singye Wangchuk National Park (Tenzin et al., 2021). Biological Corridor 3, connecting the above three protected areas of JSWNP, PWS, and RMNP, falls within the jurisdiction of the Division.

Objective

The primary objective of the "Biodiversity Status of Sarpang" publication is to compile and establish an accurate and reliable baseline dataset on the biodiversity within the Division for effective scientific management purposes. This publication represents a pioneering effort, achieved through collaborative endeavors undertaken by DoFPS, WWF Bhutan, and all the relevant stakeholders in developing a comprehensive biodiversity report.

Flora:

The floral and faunal diversity in this region can be attributed to its climatic and topographic variations. Recent survey records of the Division (RBA, 2023, and NFI, 2022) indicate the presence of over 129 families, 428 genera, and approximately 637 species of flowering plants (Phanerogams). Among these, 109 families (384 genera, 528 species) are dicots, while 20 families (80 genera, 109 species) are monocots. This classification encompasses of 170 tree species, 140 shrubs, 68 climbers, 17 bamboo species, 204 herbaceous plant species, as well as various other species, including orchids, canes, lichens, bryophytes, and grasses. The region's flora exhibits strong affinities with the flora of Assam plains and North Bengal, India.

The dominant species in this area include *Macaranga denticulata, Albizia lebbeck, Alnus nepalensis, Schima Wallichii, and Altingia excelsa*. While the less dominant species comprise *Reevesia pubescens, Phyllanthus emblica, and Lithocarpus fenestratus*. *Shorea Robusta* and *Tectona grandis* tree species are cultivated in mono-culture plantation areas. *Podocarpus neriifolius* was observed for the first time in Sarpang, specifically at an elevation of 1570 meters above sea level during Rapid Biodiversity Assessment survey, 2023. All these floral diversities are distributed among three distinct forest types: subtropical broadleaved forests, warm broadleaved forests, and cool broadleaved forests.

Fauna:

The fauna in this area primarily consists of 36 species of mammals, including large herbivores such as Asiatic elephants, Gaur, Sambar deer, barking deer, and wild boar. Among the carnivores, you can find the Bengal Tiger, common leopard, wild dogs, wild cats, and many more mammals typically found in the Indo-Malayan and Himalayan regions. So far, researchers have recorded over 92 species of birds, 34 species of reptiles, 15 species of amphibians, and 48 species of bats within the Division.

However, there is a significant research gap when it comes to aquatic biodiversity and terrestrial insects' diversity. Fishes are the most documented aquatic species in the region with 29 species recorded, but there is little to no scientific research on other aquatic biodiversity, such as aquatic macroinvertebrates and aquatic vegetation like zooplankton and phytoplankton. Despite playing

crucial ecological roles in food chains and serving as bioindicators, aquatic macro-invertebrates remain understudied.

Similarly, in the case of terrestrial insects, only butterflies have been documented, and most of the species lack significant study. This report includes a checklist of all these species based on a review of available literature. Therefore, there is a need to focus on the study of these taxa to reduce the research gap and generate baseline data in the future.

Background

Bhutan is renowned worldwide for its dedication to environmental conservation. In recognition of this commitment, His Majesty the Fourth Druk Gyalpo, Jigme Singye Wangchuck, was awarded the 2022 Blue Planet Prize by the Asahi Glass Foundation of Japan. This prestigious award acknowledges his visionary leadership and significant contributions to environmental conservation. Bhutan's commitment to preserving its natural heritage is enshrined in its constitution, which mandates the maintenance of at least 60% forest cover for all time. The National Forest Inventory (NFI) of 2022 reveals that this goal has been exceeded, with an estimated forest cover of 69.71% (2.68 million hectares) of the total land area.

The Divisional Forest Office, Sarpang is actively involved in the International Climate Initiative (IKI) Living Landscape project, supported by WWF Bhutan and the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection of Germany. One of the primary objectives of this project is the development of a comprehensive Divisional Forest Management Plan. As part of this endeavor, the Rapid Biodiversity Assessment (RBA) is of paramount importance, as it provides essential insights into the diversity within the project's landscape, facilitating the understanding of impacts and the planning of conservation efforts.

Using QGIS 3.2, 22 Biodiversity Monitoring Grids (BMG) were selected through a systematic random sampling method, with a sampling intensity of 30%. Within each sampled BMG, 10 plots were generated, maintaining a minimum distance of 500 meters between plots. This resulted in the creation of a total of 220 enumeration plots across the 22 BMGs (some plots were not enumerated due to accessibility issues). A mobile application known as SW Map served as a navigation tool to access these plots, and data were collected using Epicollect5 Apps on smart mobile phones.

The collected data underwent analysis using PC-ORD-5, R Statistics-3.5 and Microsoft Excel, 2021 software. Various diversity indices, including species richness, species evenness, and dominance indices, were calculated for trees, shrubs, regeneration, ground cover, epiphytes, mammals, and birds within the three distinct forest types. The results from this RBA report will play a pivotal role in shaping the management plan of the Divisional Forest Office, Sarpang, providing the foundation for scientifically informed management prescriptions for years to come.

Objectives

The present flora and fauna survey aims to provide baseline information on the structure and floristic composition of all forest types across the altitudinal gradient, as well as to assess faunal diversity, abundance, and distribution for proper management, sustainable utilization, and conservation of the forest resources in the division.

Specifically, the survey aims to achieve the following objectives:

i. ***To determine forest composition and diversity.***
ii. ***To assess the structural attributes of the forest.***
iii. ***To understand the biodiversity status of the Divisional Forest Office, Sarpang.***
iv. ***To use the report's results as guidance in preparing the DFO Management Plan.***

Methods and Materials

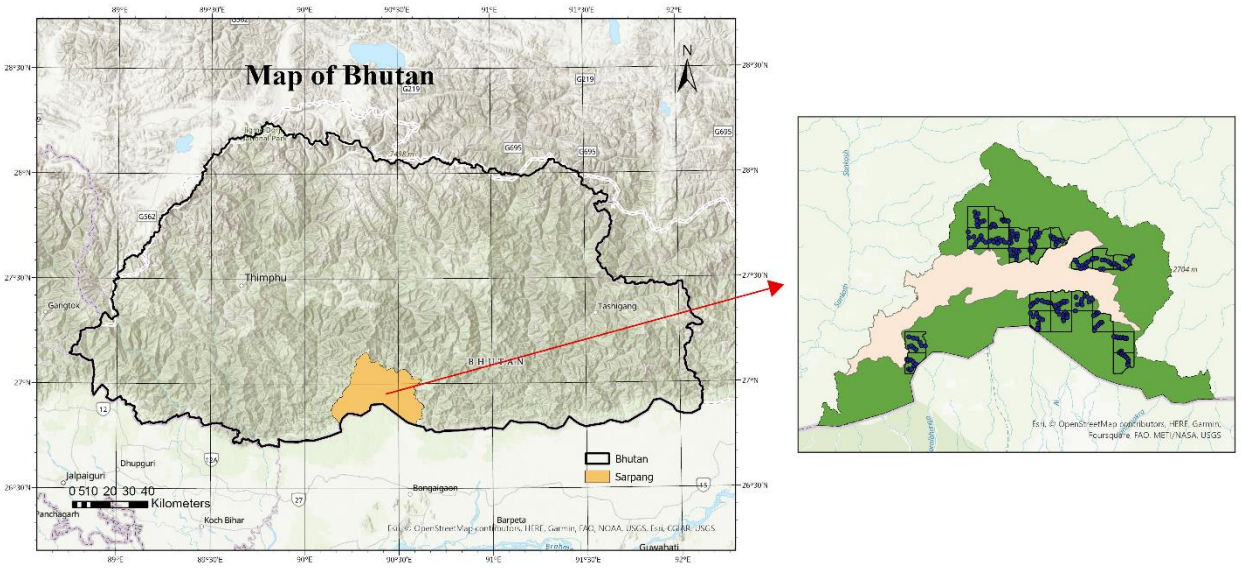


Figure 2: Location map of the survey area: (A) Bhutan map indicating Sarpang Dzongkhag.

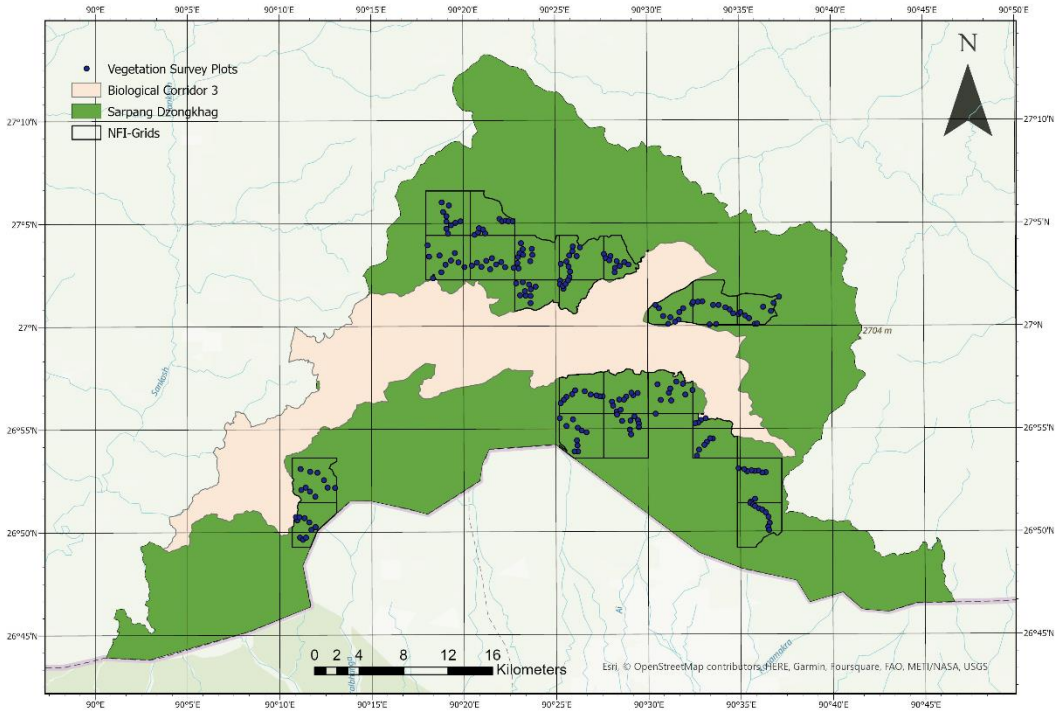


Figure 3:Map of Sarpang Dzongkhag showing the distribution of sampling plots.

Vegetation Survey Study Area

Divisional Forest Office, Sarpang was established in 1959 and it is the second Division to be instituted after the creation of the Department in 1952. Sarpang Forest Division is situated in south-central region of Bhutan and covers a total area of approximately 1011.7023 km². Almost all the Gewogs of Sarpang Dzongkhag falls fully or partially under Divisions Jurisdiction. The elevation within Sarpang District varies from 153 to 3,506 meters above sea level (Tenzin et al., 2021). The

region experiences an annual precipitation ranging from 3,500 to 5,500 mm. The areas under the Division's jurisdiction encompass diverse forest types, including subtropical broadleaved forests, warm broadleaved forests, and cool broadleaved forests (Nepal & Dorji, 2020; Tenzin et al., 2021).

The Division shares its southern border with the northeast Indian state of Assam and connects to Indian Manas National Park (MNP) and Royal Manas National Park to the east. On the western side, Sarpang Division shares a boundary with Phibsoo Wildlife Sanctuary, which adjoins the Buxa Tiger Reserve (BTR) in the Indian state of West Bengal and Tsirang Forest Division. To the north, it shares a border with Jigme Singye Wangchuk National Park (Tenzin et al., 2021). Biological Corridor 3, connecting the above three protected areas of JSWNP, PWS, and RMNP, falls within the jurisdiction of the Division.

Broad land use categories of the area include permanent settlements (villages) and meadows, wetlands, rain-fed agriculture fields, and scrubland confined to the wide valley bottom utilizing the nearby forests for fuel wood, cattle grazing, timber harvesting, and collection of non-timber Forest products.

Survey Method & Sampling Design

1. ***Vegetation survey***

Vegetation composition was surveyed along the altitudinal gradients from lowest (260 MASL) at Shershong to highest (1964 MASL) at Singye. A total of 217 (twelve) trees and shrubs sampling plots were randomly selected and distributed along the elevation. The sample plot sizes of (20 x 20m) were used at different elevations for vegetation description with the objective of including at least 0.01 % of the total area. While one sub-plots sample plot measuring 2 x 2 m were established inside tree sample plot to enumerate the herbaceous (ground layer). Epiphytes were also recorded. Field equipment such as compass, clinometer, GPS, diameter tape, measuring tape and smart phone were used to collect the data.

The vegetation survey was conducted on three levels (Fig.2, A & B); (1) trees and shrub layer enumeration and (2) ground/herb layer enumeration and (3) Epiphyte layer enumeration inside each plot, all free-standing woody plants (including trees, lianas and shrubs) with a stem diameter at breast height (DBH) of > 1 cm was recorded. For tree, all tree individuals occurring within the quadrant attaining a height greater than 1.3 m was measured. Diameter at breast height (DBH) was measured to determine the basal area (BA) and DBH class distribution.

Height of individual trees were also measured to determine the height class distribution. In the ground layer, herbs and shrubs were identified and tallest height of each species were measured and the coverage AOO of each species in % was recorded too (Fig.2B). In addition, altitude, aspect and slope were also recorded at each plot.

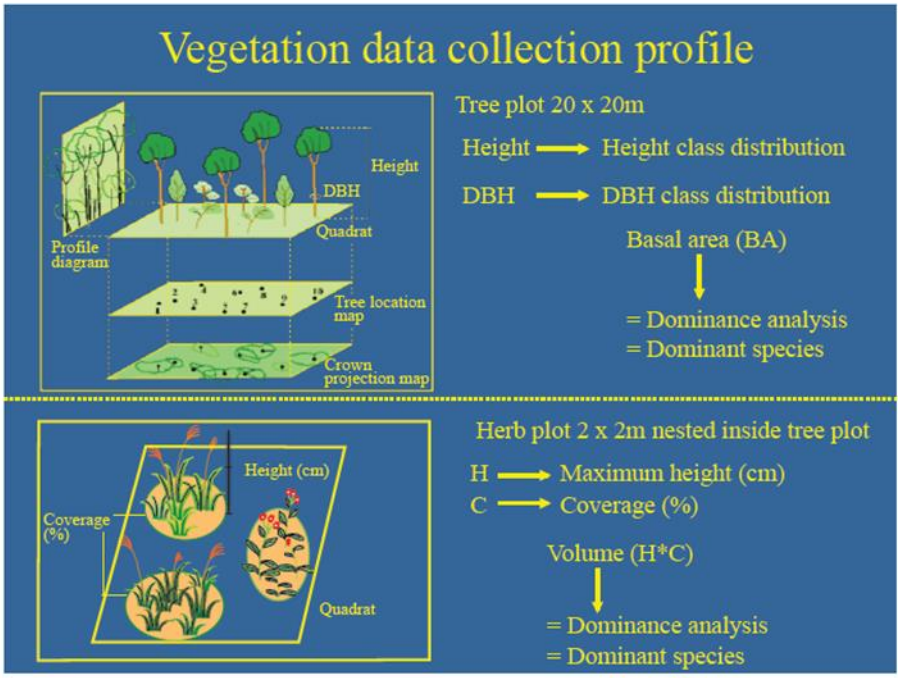


Figure 4: Vegetation survey method: (A) tree layer measurement (B) ground /herb layer measurement (Source: P. Wangda, 2006 & D.Gyeltshen 2012).

Table 1:Variables and scale of measurements

Variable	**Unit of measurement**	**Material / Source**
Location	Decimal Degree	GPS/ Smart phone (SW map)
Altitude	Metres	Altimeter
Temperature	Degree Celsius	Dorji et al. (2016)
Slope	Degree	Clinometer
Aspect	Degree	Compass
Evapotranspiration	mm	Dorji et al. (2016)
Precipitation	mm	Dorji et al. (2016)
Water balance	mm	Dorji et al. (2016)

2. Fauna Survey

1. Mammals

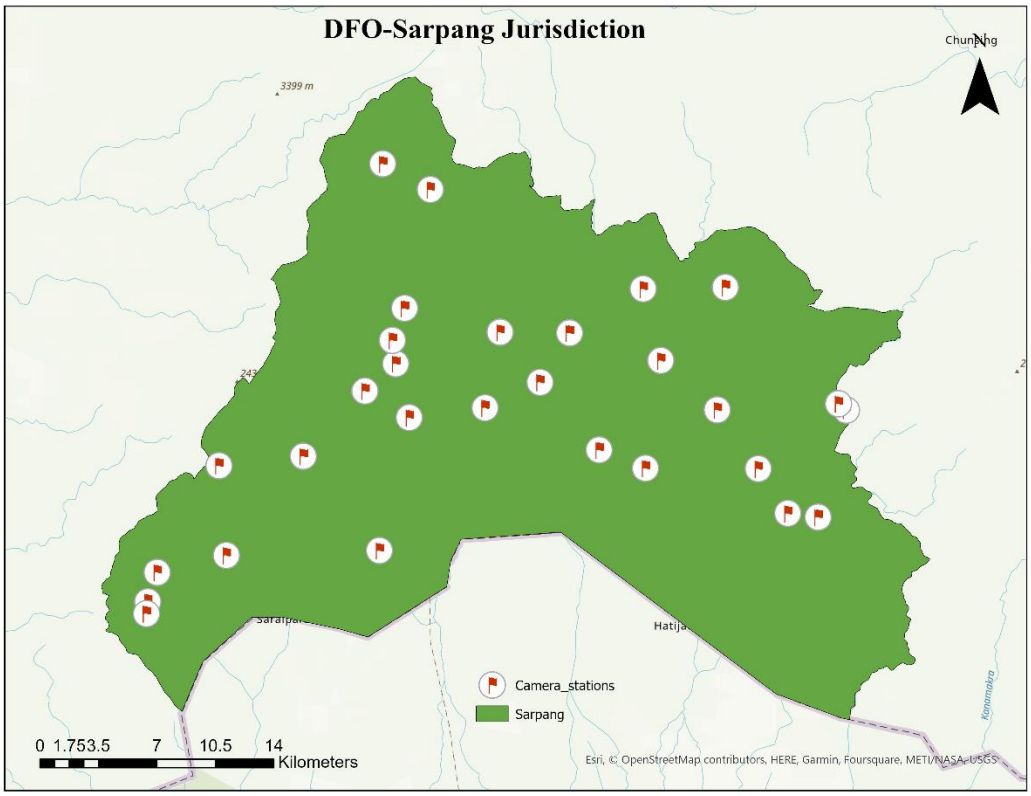


Figure 5: Map of Study Area: Location of Camera Trap Stations -NTS, 2022

Mammal data primarily relies on the Nationwide Tiger Surveys of 2014 and 2022 conducted within the division's area using non-invasive camera traps. The survey was predominantly conducted within 5x5km sampled grids, focusing on Tigers as per the Biodiversity Monitoring Protocol of Bhutan. Mammal data were also gathered using Epicollect5 during the Rapid Biodiversity Survey undertaken in 200/215 plots within the DFO, Sarpang, during April-May 2023, and supplemented with secondary data sources. Images from the camera traps, sign survey records from the Rapid Biodiversity Survey, and information from secondary sources were employed to compile the total count of recorded mammals.

The camera trapping was executed as part of the National Tiger Survey from March 4th to June 13th, 2022, spanning 102 days in total. Camera traps were positioned at 29 stations, with an average spacing of 2.8 km, ranging from a minimum of 0.6 km to a maximum of 6.90 km. The overall camera trap effort amounted to 2385 days (Figure 8).

3. Avifauna Survey

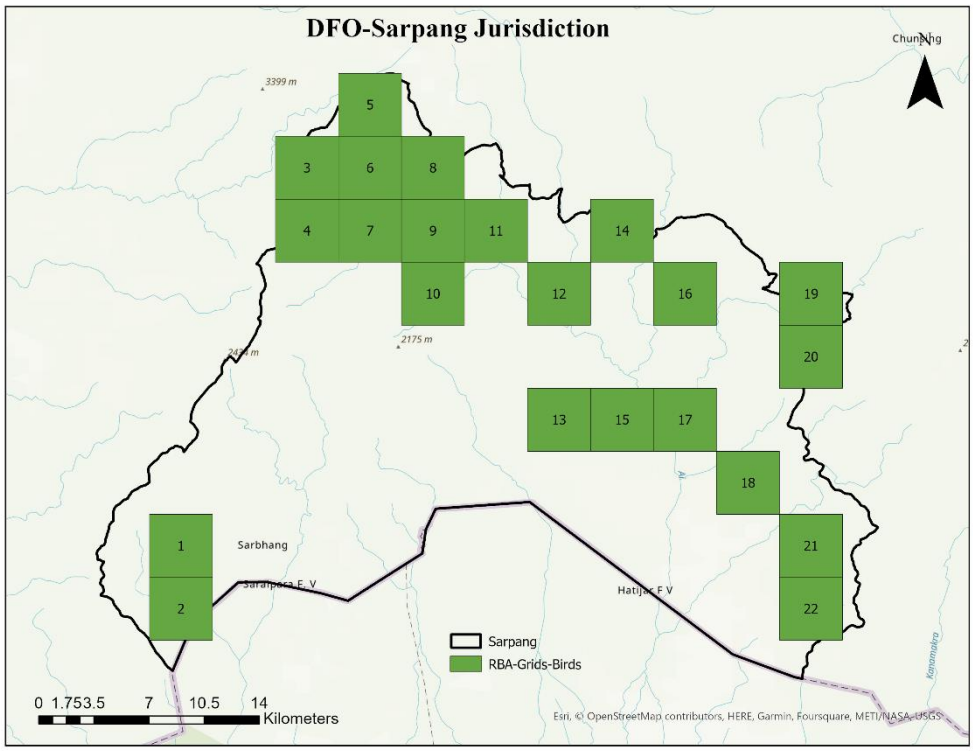


Figure 6: Map of Study area: BMGs assessed during Survey of birds

A comprehensive avian survey was conducted across 22 Biodiversity Monitoring Grids (BMGs), each measuring 4 kilometers by 4 kilometers, situated within the jurisdiction of the Divisional Forest Office (DFO) in the Sarpang landscape. Bird data was collected while traversing approximately 10 kilometers of transects within each grid, utilizing pre-existing motorable roads, footpaths, and trails. The MacKinnon species listing method was employed for data collection, wherein bird observations were documented in sets of 20 species across the 22 BMGs. These listings were recorded in chronological order of detection, ensuring no duplication of species entries. Observations encompassed both direct sightings and indirect evidence, such as calls, feathers, carcasses, and droppings.

Instruments including binoculars, DSLR cameras, field guides, and The CornellLab Merlin app were utilized for bird observation and species identification. Each observation, whether direct or indirect, made along the transects, was logged with precise timestamps, cluster sizes categorized by sex and age, altitude, behavior now of observation, and the geographical coordinates of the observation site. Bird enumeration data was efficiently captured and managed using the Epicollect mobile app.

4. Fish Survey

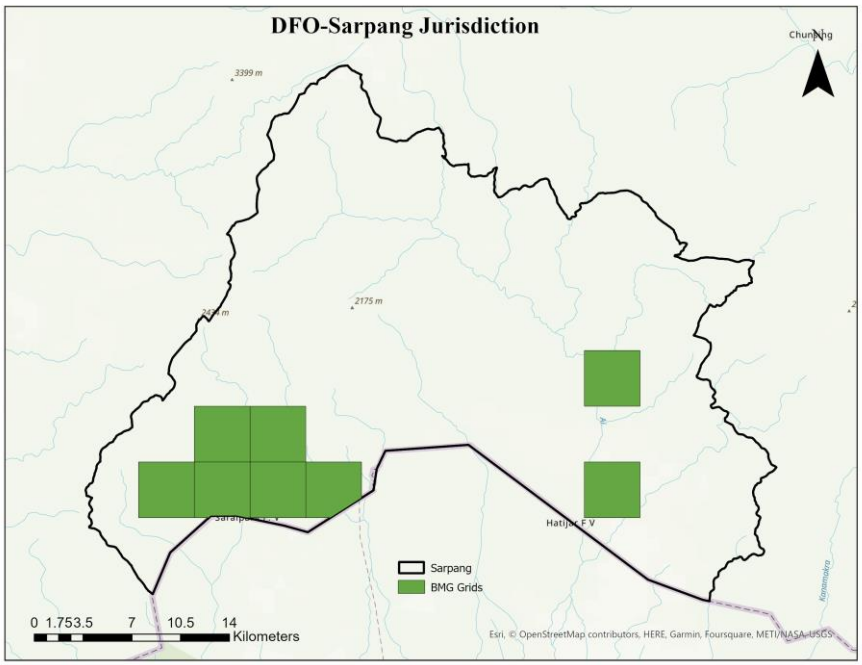


Figure 7: Map of study area: Biodiversity Monitoring Grids Surveyed During Fish and Butterfly Studies.

By the river and stream drainage patterns within various gewog areas, specific rivers were strategically chosen for fish sample collection. These selected rivers included Moakhola, Bhurkhola, Sarpangkhola, Sixtykhola, and Laringkhola.

The sampling methodology employed in this study featured the utilization of line transects, wherein a recording distance of 2000 meters was maintained along the course of each river, with sampling plots established at 500-meter intervals. Fish samples were diligently collected from distinct stream reaches, encompassing riffles, pools, runs, and cascades. Various fishing techniques were applied according to the specific characteristics of the water bodies, such as cast nets for deeper and larger rivers, electrocution, and diversion for smaller streams.

To facilitate accurate species identification, a pictorial guide was used, and the captured fish were meticulously photographed within transparent glass containers. Furthermore, supplementary data including altitude, temperature, water base, salinity, Total Dissolved Solids (TDS), and water conductivity were systematically recorded with the aid of an Apera instrument PC60 pH/conductivity/TDS/salinity tester. The entire data collection process was executed via the Epicollect-5 application.

5. Butterfly survey

The survey was carried out systematically within 2 x 2 km sampling grids inside selected BMGs (Figure: 6). The methodology adopted closely resembles the Pollard Walk method, as originally described by Pollard et al. in 1975 and subsequently by Pollard in 1977. In this survey, six modified line transects were established, each spanning a length of 1.5 km, with a width of 5 meters on either side of the observer, within each of the designated sampling grids across the survey area. The survey was conducted through a transect walk, covering the jurisdiction of the Divisional Forest Office, Sarpang. Direct sightings of various species were recorded along with GPS coordinates and elevations for each observation, using the Epicollect5 Application

6. Other Species

The data pertaining to herpetofauna, aquatic biodiversity, macro-invertebrates (both aquatic and terrestrial), bamboo and grass species, bryophytes, orchids and epiphytes, fungi and mushrooms, lichens, microorganisms, and other relevant information were systematically compiled from available literature sources in Bhutan and neighboring regions, which encompass Sikkim, Assam, Nepal, and the broader Himalayan region. This comprehensive literature review served as the primary source for generating the necessary information and insights on these ecological components.

It is important to emphasize that this checklist was created through a thorough review of scientific literature regarding species in Bhutan and the neighboring region. Furthermore, it's crucial to acknowledge that this list is not comprehensive, and there may be other species in Sarpang, Bhutan, that have yet to be identified or documented. Moreover, it's worth noting that the distribution of species can be influenced by a range of factors, such as climate, habitat, and human activity. Consequently, it's possible that some of the species listed may not be present in all areas of Sarpang, Bhutan.

Data Collection and Analysis

1. ***Vegetation data***

Data collection tool: Epi-collect5

EpiCollect5 is a mobile data collection platform that revolutionizes the gathering of vegetation data by providing customizable forms, offline functionality, geospatial integration, and centralized data management. This versatile tool not only facilitates the collection of vegetation data, including information such as height, DBH (diameter at breast height), and species counts but also simplifies the recording of environmental locations through its built-in features. This platform enhances data accuracy, promotes cost-effectiveness, and enables efficient data sharing, making it indispensable for ecological research, conservation initiatives, and biodiversity assessments. Thus, this platform is used as data collection tool during biodiversity survey.

Analysis

Based on relative frequency, relative density, and relative dominance (cover) values (IVI) Importance value Index (Brown & Curtis 1951) is obtained. Individual tree diameter at breast high (DBH) was classified into various DBH-class and height-class of tree species in 8 gewogs. IVI values of different species were then arranged in decreasing order. Species richness was determined by using the Shannon-Weiner index-**H**' (1963). Shannon-Wiener Diversity Index (H′) was calculated by using RBA data.

$$\text{Relative Basal Area} = \left\{ \frac{\sum_i^x}{\text{nBA}} \right\}$$

Where Σ_i = sum of basal area of i^{th} species in a plot and nBA = Total basal area of all individuals of all species in a plot.

$$\text{Evenness } \mathbf{(J) = H'/\log N2}$$

$$\mathbf{H' = -\Sigma ni/n \log 2\ ni/n}; \quad \text{OR} \quad \mathbf{H'} = \sum_{i=1}^{s} \mathbf{-(P_i * Ln\ P_i)}$$

Basal Area of each tree species (BA, in cm^2) was calculated by using the diameter at breast height (DBH) data and then the relative proportion of each species relative basal area in percent (RBA%) was calculated. DBH data was used to analyze the DBH-class distribution of each tree species and similarly, the height-class was analyzed by using height data of each tree species in each Gewogs. Species abundance was expressed in stem density and basal area. The RBA% of trees and RD% of shrubs and herbs of each species were used as an abundance measure of species in a vegetation community. The dominant species along the altitudinal gradient in each plot were determined based on the dominance analysis in PCORD.

The preliminary data were processed using the pivot table of Microsoft Excel 2010 and the species compositions table and graphs were prepared. The processed data was analyzed by using PC-ORD version 5.1. (McCune & Grace 2002,) and Cluster analysis was performed using distance measure of Relative Sorensen (Bray-Curtis's method) and Wards as a linkage method. Through this process, a classification of the different natural communities or vegetation types were classified, mainly based on floristic composition.

2. ***Fauna data***

Figure 8: Camera trap study design information.

The presence of mammals plays a crucial role in assessing forest health from an ecological perspective. Various analytical methods were employed to conduct a data-driven survey, which included the analysis of camera trap data. Species-specific observation records were organized and presented using a pivot table.

The images obtained from the National Tiger Survey (NTS) in 2022 were meticulously processed within the R Shiny Application using R-software. This processing aimed to ascertain the activity patterns, occupancy and detection parameters of both top carnivore and herbivore species within the division. The application further facilitated an in-depth analysis of species richness and the detection of mammals in various locations(Maintainer & Rowcliffe, 2023). Several basic analyses such as Mapping of the camera trapping effort, Mapping of the camera detection rate, Mapping of presence for a selected species or the total species richness and Graphic representation of the activity budget for one selected species was conducted using R-shiny software(MacKenzie et al., 2002). The

Sampling Effort is calculated as the total Effort per deployment (camera station) in camera days, the Detection rate is calculated as the number of detections per day per deployment (single species or all species and Species Richness is calculated as the total number of species detected per deployment assuming only 1 or 0 if a single species is selected(Rowcliffe et al., 2014). The activity patterns of animals are also determined using spatial information of camera trap data through R-shiny app(Rowcliffe et al., 2014).

3. Avifauna data

The data collected from the survey was thoroughly cleaned and sorted using Microsoft Excel, utilizing the pivot table function and many other analytical tools. To assess species diversity, richness, and evenness in relation to forest types, the Shannon-Wiener equation (Margalef, 1968) was applied. The resulting abundance values were then determined**.** Furthermore, the family-wise bird species richness was graphed and visually presented.

Shannon-Wiener equation:

$$H' = -\sum(p_i * ln(p_i))$$

Where:

- H' represents the diversity index.
- p_i denotes the proportion of each species in the ecosystem.
- $ln(p_i)$ is the natural logarithm of the proportion of each species.

4. Fish data

The data collected from the survey was thoroughly cleaned and sorted using Microsoft Excel version 2021 utilizing the pivot table function. To evaluate species diversity in connection with habitat types, the Shannon-Wiener equation (Margalef, 1968) was applied. Additionally, an analysis of the descriptive statistics of environmental variables was conducted to ascertain the habitat conditions of the fish. Furthermore, the correlation between species counts and environmental variables was examined to assess the habitat preferences of the fish.

5. Butterfly data

The data collected from the survey was cleaned and organized using Microsoft Excel 2021. The family-wise occurrence and count of species were graphed to see their distribution across different habitat types and dominance.

Results and discussion

1. Flora

1.1. Floristic composition of major life forms of the Tree layer

In the present survey, a total of 170 tree species, belonging to 65 families, were recorded within the three forest types, encompassing two major life form groups: Evergreen trees and Deciduous trees. (Table 4). All the life form groups exhibit contrasting physiognomic patterns along altitudinal gradients. Evergreen trees constitute 77%, while deciduous trees make up 23%.

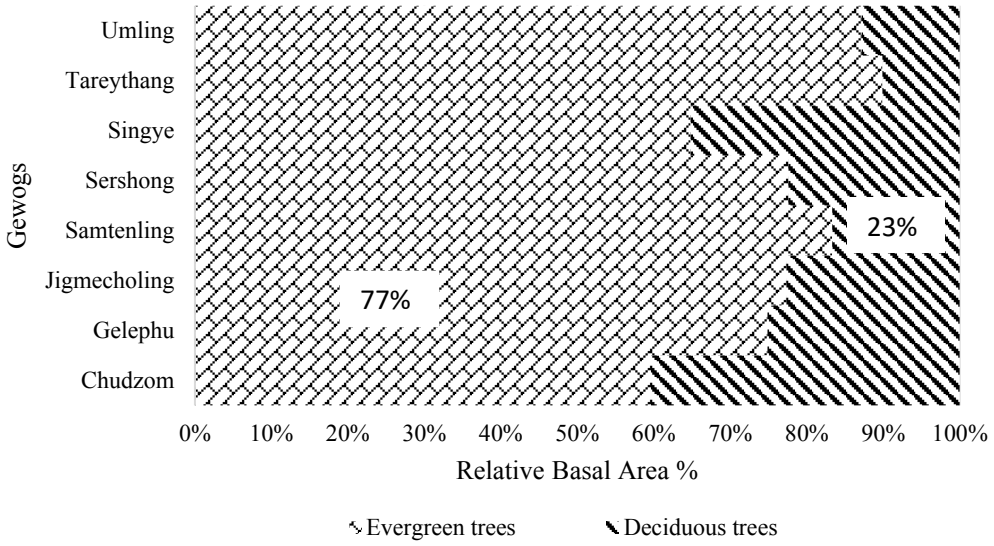


Figure 9:Distribution pattern of two major life forms; evergreen tree and deciduous trees inside 8 gewogs.

The evergreen trees were primarily dominated by broadleaved species such as *Terminalia elliptica, Terminalia myriocarpa, Toona ciliata, Pterospermum acerifolium, Syzygium cumini, Persea fructifera, and Dillenia indica,* among others. The deciduous trees, on the other hand, were predominantly dominated by species like *Albizia lucidior, Alnus nepalensis, Anthocephalus cadamba, Aphamaxis polystachya, Trewia nudiflora, and Tetrameles nudiflora,* among others. *Podocarpus neriifolius* was observed for the first time in Sarpang, specifically at an elevation of 1570 meters above sea level. This discovery was made at the following coordinates: Latitude 27.052323, Longitude 90.479054, within plot number 32 in Chhudzom Gewog. *Podocarpus neriifolius,* commonly known as the Bhutan plum yew or simply Podocarpus, is a species of evergreen coniferous tree native to the Himalayan region, including Bhutan. It is known for its distinctive needle-like leaves and small, plum-like fruits. This discovery in Sarpang at an elevation of 1570 meters above sea level adds to our understanding of the distribution of this species and its presence in the Bhutanese landscape. The diversity of tree species is highest in Gelephu gewog (H'=3.660) and lowest in Umling (H=3.660). Similarly, the basal area (m2/ha) is highest in Jigmecholing gewog (57.864 m2/ha) and lowest in Umling (9.281 m2/ha). The difference in diversity and basal area could be

attributed to variations in the number of sample plots. However, since diversity and basal area represent average values, the variations should be nullified. All the sampling plots fall within the altitudinal range of 260-1964 masl, with the lowest altitude recorded at Shershong (260 masl) and the highest altitude recorded at Singye gewog (1964 masl). The *Shorea Robusta* and *Tectona grandis* tree species were planted in mono-culture plantation areas and were consequently excluded from the assessment. Therefore, the total number of trees recorded consists of 169 species belonging to 167 families for Sarpang Dzongkhag.

Table 2: Floristic composition of seven gewogs along the altitudinal gradients (260-1697 masl) and plot details. Species are arranged into life-form groups (evergreen trees, deciduous trees).

Variables	**Chhudzom**	**Gelephu**	**Jigmechoeling**	**Samtenling**	**Shershong**	**Singye**	**Taraythang**	**Umling**
No.of plots	60.00	20.00	56.00	20.00	20.00	22.00	8.00	9.00
Altitude Range (masl)	353-1697	341-1394	363-1861	262-1196	260-1353	268-1964	268-1735	375-1318
Tree plot size(m^2)	400.00	400.00	400.00	400.00	400.00	400.00	400.00	400.00
Shrub plot size (^2)	400.00	400.00	400.00	400.00	400.00	400.00	400.00	400.00
Herb plot size(m^2)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
BAm^2/Ha (Trees)	51.42	22.42	57.86	25.80	33.00	18.01	16.81	9.28
Diversity H' (Tree)	3.10	3.66	3.26	3.01	3.46	2.94	2.98	2.61
Diversity H' (Ground vegetation}	2.50	1.34	1.74	1.99	1.54	2.06	2.02	2.39
Diversity H' (Epiphyte)	0.50	1.66	1.26	1.01	1.46	0.94	0.98	0.61
Diversity No	71.00	24.00	46.00	57.00	42.00	53.00	32.00	45.00
Max.DBH(cm)-Trees	132.80	99.00	98.00	100.00	115.00	78.00	115.00	110.00
Max.Ht(m}-Trees	62.00	40.00	56.00	48.00	48.00	41.00	48.00	45.00

Relative Basal Area %	**Family**	**RBA %**	**RBA%**	**RBA%**	**RBA%**	**RBA%**	**RBA%**	**RBA%**	**RBA%**
Evergreen trees									
Acer oblongum	Aceraceae		2.761		1.224				
Acrocarpus fraxinifolius	Leguminosae					0.447			
Acronychia pedunculata	Rutaceae		0.170						1.984
Adinanra griffithii	Pentaphylacaceae		0.798						
Aglia spectabilis	Araceae		0.628	0.108		2.733			
Ailanthus integrifolia	Simaroubaceae			1.6		4.3		4.0	1.2
Alstonia scholaris	Apocynaceae		1.7		2.8	0.8	3.6		
Altingia excelsa	Hamamelidaceae	1.903	1.6	6.1	6.2	4.2	4.7	11.5	
Baccaurea ramiflora	Phyllanthaceae		1.1	0.7					0.1
Brassaiopsis hainla	Araliaceae	0.210		0.3					
Callicarpa arborea	Verbenaceae	0.192	1.5	0.6		0.4			
Carallia brachiata	Rhizophoraceae	0.063							
Castanopsis hystrix	Fagaceae	2.603	5.4	6.7	2.5				
Castanopsis indica	Fagaceae	0.006	7.0	1.5	6.5	4.9	3.7	9.8	21.9
Castanopsis tribuloides	Fagaceae		0.9						
Cinnamomum bejolghota	Lauraceae	0.974	0.6	0.3			0.3		
Cinnamomum glanduliferum	Lauraceae		1.1	0.6		0.3		0.9	
Cinnamomum glaucescens	Lauraceae				1.6	0.5		2.0	

Cinnamomum virum	Lauraceae	0.006					0.0		1.4
Cordia obliqua	Boraginaceae			0.6					
Cretava reliogiosa	Compositae					0.1	0.1		
Cryptocarya bhutanica	Lauraceae			0.7					
Dendrocnide sinuata	Urticaceae					1.1		4.1	
Dillenia indica	Dilleniaceae		0.8						
Diploknema butyracea	Sapotaceae						1.5		
Drimycarpus racemosus	Anacardiaceae	0.257		0.7					
Dryepetes indica	Euphorbiaceae						0.9		
Duabanga grandiflora	Sonneratiaceae				0.6	12.7	2.2	10.4	
Echinocarpus tomentosus	Meliaceae							1.0	
Ehirtia laevis	Thymelaeaceae	0.054							
Elaeocarpus lanceifolius	Elaeocarpaceae		0.4	0.1	0.7				1.5
Engelhardia spicata	Juglandaceae	1.513	0.1	6.8	4.6	0.6	2.3		4.2
Erythinia arborecens	Leguminosae					4.8			
Eurya cavinervis	Theaceae		2.3	1.2					
Eurya cerasifolia	Theaceae	0.068		0.2					
Exbucklandia populnea	Hamamelidaceae	0.013	0.7	0.2		0.7		2.2	
Ficus hispida	Moraceae	0.077					0.1		
Ficus neriifolia	Moraceae		0.2	0.2					
Ficus nervosa	Moraceae	0.018		0.6					
Ficus racemosa	Moraceae					0.7		2.2	
Ficus roxburgii	Moraceae	0.054		0.6					
Ficus semicordata	Moraceae	0.219		0.4		2.5	0.1		
Glochidion acuminatum	Euphorbiaceae	0.076							
Glochidion heyneanum	Euphorbiaceae	0.042	0.2				0.3		
Gynocardia ordorata	Flacourtiaceae		0.6	0.1					
Heliacia nilagrica	Proteaceae		2.1			1.9	0.2	2.0	
Heynea trijuga	Meliaceae					1.3			
knema tenuinervia	Myristicacea		0.4						
Kydia calycina	Malvaceae	0.039		0.0		3.1	1.2	4.8	
Lagerstroemia hirsuta	Lythraceae				0.6	0.8			
lagerstroemia speciosa	Lythraceae				0.6				
Lasianthus spp	Rubiaceae	0.045							
Leea indica	Leeaceae						0.2		
Lithocarpus elegans	Fagaceae	0.186	0.4	9.7	1.4				
Lithocarpus fenestratus	Fagaceae						0.0		
Litsea cubeba	Lauraceae	0.649		0.4			0.7		
Litsea monopetala	Lauraceae		0.2						
Litsea nilagirica	Lauraceae						0.2		
Macaranga denticulata	Euphorbiaceae	43.568		1.6	1.9	1.9		1.5	
Macaranga indica	Euphorbiaceae	0.069							
Macropanax dispermus	Araliaceae		0.3				0.5		
Macropanax fragrans	Araliaceae	0.059		3.0					
Magnifera sylvatica	Anacardiaceae	0.010		0.1					
Magnolia hogdsonii	Magnoliaceae	0.074	0.6			2.9		1.6	0.8
Mallotus philippensis	Euphorbiaceae		0.4				1.0		

Mangifera sylvatica	Anacardiaceae	0.016				0.3		0.8	
Mesua ferrea	Calophyllaceae	0.176		0.6					
Michelia champaca	Magnoliaceae				7.6				2.5
Michelia doltsapa	Magnoliaceae	0.339		0.7					
Miliusa macrocarpa	Annonaceae		0.2						
Mitrephora harai	Annonaceae					0.1	0.5	1.6	5.6
Myrica esculenta	Myricaceae					0.1	0.2		
Myrsine seguinii	Myrsinaceae	0.078							
Myrsine semiserrata	Myrsinaceae			0.2					0.5
Neocinnamomum caudatum	Lauraceae	0.414		0.8		0.4			
Nyssa javanica	Nyssaceae	0.072		1.8					
Osmanthus suavis	Oleaceae	0.150							
Ostodes paniculata	Euphorbiaceae	0.477	5.5	3.9	2.2	2.0	2.2	0.1	1.7
Persea clarkeana	Lauraceae				0.8				
Persea fructifera	Lauraceae	0.227		2.0	0.7	2.2			
Phlogacanthus thyrsiformis	Acanthaceae						0.1		
Phoebe attenuata	Lauraceae	1.446	2.0	1.8	0.3	0.2	1.7		7.6
Phoebe lanceolata	Lauraceae		0.2						2.2
Podocarpus neriifolius	Podocarpaceae	0.122							
Polyalthia simiarum	Annonaceae		1.1						
Populus glauca	Salicaceae		1.2	0.5					
Prunus cerasoides	Rosaceae	0.033							
Pterospermum acerifolium	Sterculiaceae		0.3		1.3	3.7	2.4	4.4	3.2
Quercus glauca	Fagaceae			0.2					
Quercus lamellosa	Fagaceae	0.333					0.2		
Reevesia pubescens	Sterculiaceae				0.1				
Rhododendron arboreum	Ericaceae			0.6					
Rhus hookeri	Anacardiaceae		3.4		0.1				1.8
Sapindus rarak	Sapindaceae				0.4				
Saurauja nepaulensis	Actinidiaceae	0.096		0.0					
Schima wallichii	Theaceae	1.050	6.1	13.0	23.2	2.2	17.9	13.0	10.6
Shorea robusta	Dipterocarpaceae						5.0		
Sigesbeckia orientalis	Dipterocarpaceae		3.4						
Stereospermum suaveolens	Bignoniaceae						1.5		
Symplocus glomerata	Symplocaceae		0.2						
Symplocus lucida	Symplocaceae		0.2					2.4	2.5
Symplocus sumuntia	Symplocaceae			0.1					
Syzygium cumini	Myrtaceae	0.110	1.9	0.2	6.9	1.5	0.8	4.9	10.2
Syzygium formosum	Myrtaceae	0.572	7.7	1.6		3.7	0.5	0.7	
Syzygium operculatum	Myrtaceae		1.1		8.4				
Syzygium tetragonum	Myrtaceae	0.100	1.7	0.4					
Terminalia elliptica	Combretaceae			1.9	0.0	3.1	1.5	3.3	
Terminalia myriocarpa	Combretaceae	0.112	0.7				6.5		
Toona ciliata	Meliaceae	0.669	2.6	1.2		2.3			5.9
Trevesia palmata	Araliaceae			0.1					
Unknown 1	NA						0.2		
Unknown 2	NA		0.5						

Vetix heterophylla	Euphorbiaceae					2.2		0.7	
Zizyphus Mauritania	Rhamnaceae				0.1				
Sub total		**59.642**	**74.879**	**77.350**	**83.328**	**77.603**	**64.828**	**89.896**	**87.177**
Deciduous tree									
Acer sterculiaceum	Aceraceae			0.09	1.26				
Acer thomsonii	Aceraceae	0.55		0.75					
Actinodaphne obovata	Lauraceae					0.19			
Alangium chinense	Alangiaceae	0.16				0.23	0.12		
Ailanthus grandis	Alangiaceae			0.28					
Albiza procera	Leguminosae			0.22	0.84	1.39	0.25		
Albizia lebbeck	Leguminosae	18.90		2.62	4.06		17.71		
Albizia lucidior	Leguminosae			0.45	0.72	1.38	1.84		
Albizia spp	Leguminosae		2.72						
Alnus nepalensis	Betulaceae	18.35		11.18					
Anthocephalus cadamba	Polygonaceae		0.42		0.61				5.30
Aphamaxis polystacya	Meliaceae		2.45			0.82	0.15	0.13	
Bauhunia variegata	Leguminosae			0.45					
Beilschmiedia gammieana	Lauraceae	0.01	3.38	1.34	1.72	0.80			
Beilschmiedia roxburgiana	Lauraceae							0.97	
Betula alnoides	Betulaceae	0.25	1.89	0.42					
Bombax ceiba	Bombacaceae	0.43			1.92	7.26	0.10		
Bridelia retusa	Euphorbiaceae			0.10	0.13		1.42		
Canarium strictum	Burseraceae					0.78			
Careya arborea	Lecythidaceae		3.85						
Caryota urens	Arecaceae(Palmae)			0.06					1.36
Celtis tetrandra	Cannabaceae		0.75		0.40				
Choerospondias axiliaris	Anacardiaceae	0.23		0.43		0.62	0.09		
Chukrasia tabularis	Meliaceae	0.06	0.93	1.28	1.79	3.66	5.40	1.57	5.48
Cordia myxe	Boraginaceae			0.08					
Docynia indica	Rosaceae	0.03		0.18					
Ehretia acuminata	Boraginaceae	0.12							
Elaeocarpus dasycarpus	Elaeocarpaceae		1.55						
Elaeocarpus decipiens	Elaeocarpaceae		0.10	0.42	0.47				
Elaeocarpus sikkimensis	Elaeocarpaceae					0.51			0.68
Gmelina arborea	Verbenaceae		0.59		2.22				
Hovenia dulcis	Rhamnaceae	0.19							
Lagerstroemia parvifolia	Lythraceae	0.19					0.51		
Lithocarpus spp.	Fagaceae	0.01							
Macaranga peltata	Euphorbiaceae	0.04		0.31					
Morus australis	Moraceae						0.55		
Morus laevigata	Moraceae	0.25					0.56		
Neolitsea cassia	Lauraceae	0.04							
Oroxylum indicum	Bignoniaceae	0.13	0.34	0.05					
Phyllanthus emblica	Euphorbiaceae						0.05		
Quercus griffithii	Fagaceae	0.03		1.76					
Rhus succedanea	Anacardiaceae	0.18	0.63	0.17			0.13		
Sapium insigne	Euphorbiaceae	0.01	0.11				0.66		
Spondias pinnata	Compositae		0.40			0.40			
Sterculia villosa	Sterculiaceae						0.98		
Stereospermum tetragonum	Bignoniaceae		1.08				0.06		

Stereospermum chelonoides	Bignoniaceae				0.54	0.93	0.51	4.17
Terminalia alata	Combretaceae							3.26
Terminalia bellirica	Combretaceae						0.85	
Tetradium fraxinifolium	Rutaceae	0.11						
Tetrameles nudiflora	Datiscaceae		3.93			3.43	3.06	
Trewia nudiflora	Euphorbiaceae	0.09						
Zanthoxylum rhetsa	Rutaceae						0.16	
Sub total		**40.4**	**25.1**	**22.6**	**16.7**	**22.4**	**35.2**	**10.1**
Grand Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**

The greatest recorded DBH (cm) was found in Chhudzom Gewog, measuring 133 cm, while the tallest recorded height (m) was observed in Chhudzom at 68 m. Among the evergreen trees, the highest relative basal area (%) is recorded at 45.568% for *Macaranga denticulata* in Chudzom Gewog. *Schima wallichii* follows with the highest RBA % of 6.1% in Gelephu Gewog, 13% in Jigmechoeling and Taraythang Gewog, 23.2% in Samtenling Gewog, and 17.9% in Singye Gewog. *Duabanga grandiflora* exhibits the highest RBA % of 12.7% in Shershong Gewog, while *Castanopsis indica* shows a significant RBA % of 21.9% in Umling Gewog.

In the case of deciduous trees, *Albizia lebbeck* exhibited the highest relative basal area (RBA) at 18.9% in Chhudzom Gewog, while *Tetrameles nudiflora* had the highest RBA of 3.93% in Gelephu Gewog. *Alnus nepalensis* recorded the highest RBA of 11.8% in Jigmechoeling Gewog, and *Albizia lebbeck* had the highest RBA of 4.06% in Samtenling Gewog. In Singye Gewog, Chukrasia tabularis had the highest RBA at 3.66%, while *Albizia lebbeck* reached 17.71% in Shershong Gewog. *Stereospermum chelonoides* had an RBA of 4.17% in Taraythang Gewog, and *Chukrasia tabularis* exhibited an RBA of 5.48% in Umling Gewog.

1.2. Floristic composition of major life forms of the Shrub layer

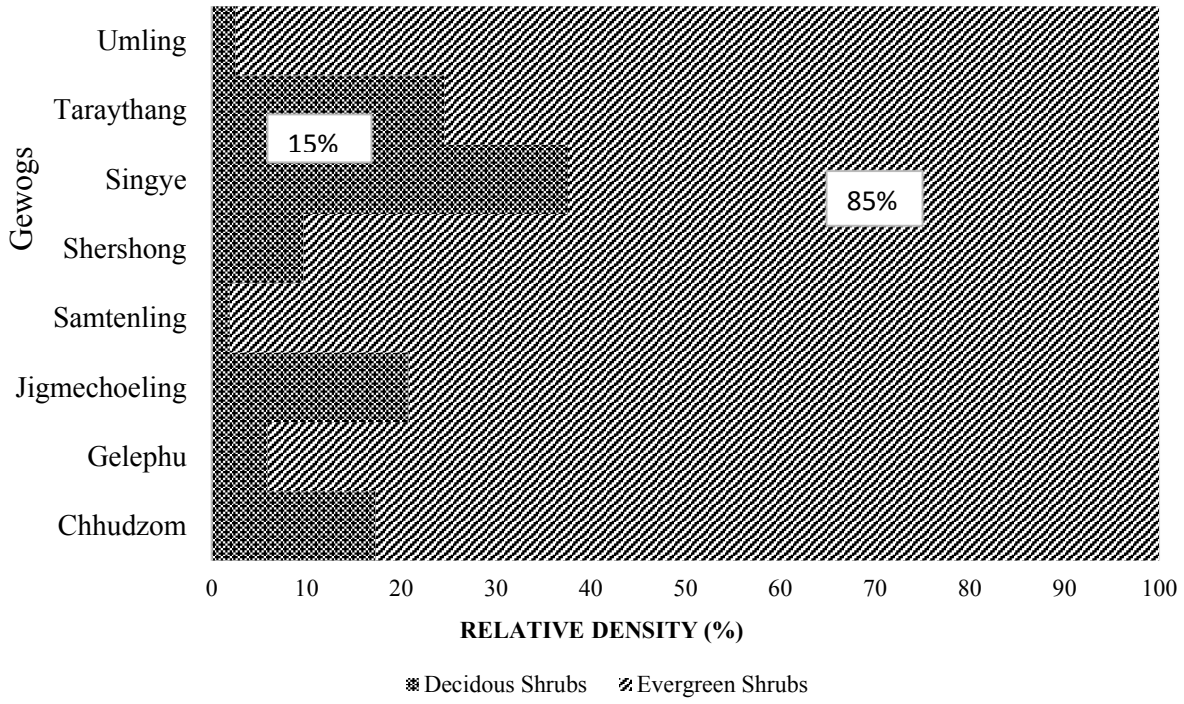


Figure 10:Distribution pattern of two life forms; evergreen shrubs and deciduous shrubs inside 8 gewogs.

A total of 140 Shrub species, belonging to 55 families, were recorded within the three forest types, encompassing two major life form groups: Evergreen and Deciduous shrubs (Table 4). All the life form groups exhibit contrasting physiognomic patterns along altitudinal gradients. Evergreen shrubs constitute 85%, while deciduous shrubs make up 15%.

The evergreen shrubs were predominantly dominated by broadleaved species, including *Bridelia micrantha, Chloranthus elatior, Clerodendrum chinense, Phlogacanthus pubinervius, Daphne bhoula,* and *Maesa chisia,* among others. Conversely, the deciduous shrubs were predominantly dominated by species such as *Boehmeria glomerulifera, Buddleja davidii, Saurauia armata, Pseudostachyum polymorphum,* and *Leea asiatica, etc.*

Table 3:Floristic composition of seven gewogs along the altitudinal gradients (260 -1697masl) and plot details. Species are arranged into life-form groups (evergreen trees, deciduous trees).

		Chhudzom	Gelephu	Jigmechoeling	Samtenling	Shershong	Singye	Taraythang	Umling
Decidous Shrubs	**Family**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**
Baliospermum polyandrum	Euphorbiaceae	0.709		2.383					
Benkara fasciculata	Commelinaceae	0.002		0.068			0.896	1.260	0.169
Blumea aromatica	Compositae	0.001		0.043			1.217	0.419	0.671
Boehmeria cylindrica	Urticaceae	1.175		0.092			1.461	7.586	0.276
Boehmeria glomerulifera	Urticaceae	0.576		0.011	0.044	0.076	0.234	0.019	0.058
Boehmeria himiltoniana	Urticaceae	0.029		0.064	0.654	7.669	0.039	3.645	0.310

Boehmeria macrophylla	Urticaceae	0.017	0.102	5.805	0.509	0.133	0.195	0.419	0.043
Buddleja davidii	Buddlejaceae	0.007	0.081	0.001	0.058	0.046	0.010		0.069
Catunaregam spinosa	Rubiaceae		1.524	0.187	0.015	0.003	1.948		0.037
Caesalpinia decapetala	Leguminosae	0.484	1.524	0.006		0.038	8.893	7.586	0.075
Capparis bodinieri	Capparaceae	2.121	0.051	0.095		0.014	0.164		
Capparis tenera	Capparaceae	0.004	0.013	1.182		0.707	0.031		0.310
Citrus medica	Rutaceae	0.004	0.076	0.016		0.101	0.039		0.043
Clerodendrum colebrookianum	Verbenaceae	0.100	0.467	0.025		0.013	0.195		0.069
Crateva religiosa	Crassulaceae	0.001	0.051	0.119		0.009	0.010		0.037
Debregeasia longifolia	Urticaceae	4.197	0.051	0.330		0.038	1.948		0.075
Debregeasia wallichiana	Urticaceae	0.001		0.103		0.014	8.893		
Elastostema platyphyllum	Elaeocarpaceae	0.031				0.707	0.164		
Elatostema acuminata	Elatinaceae	0.300	0.051			0.101	0.031	0.019	0.069
Elatostema lenolatum	Urticaceae	0.009	0.013	0.011		0.013	1.948		0.037
Elatostema lineolatum	Urticaceae	0.167	0.076	0.064		0.009	8.893		0.075
Flueggea virosa	Euphorbiaceae	0.498	0.467	5.805			0.164		
Gomphostemma parviflorum	Labiatae	0.009	0.051	0.001			0.031	3.645	0.037
Hedychium deceptum	Zingiberaceae	0.004	0.051	0.187					
Hedychium spicatum	Zingiberaceae	0.100		0.006					
Hydrangea febrifuga	Hydrangeaceae	0.001		0.095	0.509				
Indigofera dosua	Leguminosae	4.197		1.182	0.058				
Jusminum dispermum	Cupressaceae	0.001		0.016	0.015				
Koenigia mollis	Polygonaceae	0.031	0.076	0.025	0.058	0.009			
Lantana camara	Verbenaceae	0.300	0.467	0.119	0.015				
Leea asiatica	Leeaceae	0.009	0.051	0.330					
Mallotus philippinensis	Euphorbiaceae	0.167	0.051	0.103			0.164		0.075
Maoutia puya	Urticaceae	0.498		0.006			0.031		
Oreocnide rubescens	Urticaceae	0.009		0.095					
Oxyspora paniculata	Melastomataceae	0.031		1.182					
Phrynium pubinerve	Marantaceae	0.300		0.016					
Piptanthus nepalensis	Leguminosae	0.009		0.025					
Pouzolzia sanguinea	Urticaceae	0.167		0.119					
Pseudostachyum polymorphum	Gramineae	0.498		0.330					
Rhus acuminata	Commelinaceae	0.009	0.467	0.103					
Rubus ellipticus	Rosaceae	0.498	0.051	0.330					
Rubus panniculata	Rosaceae	0.009	0.051	0.103					
Rubus spp	Rosaceae	0.009					0.031		
Saurauia armata	Actinidiaceae		0.051						
Trema micrantha	Umbelliferae								
Vibernum spp	Scrophulariaceae								
Sub-total		***17.29***	***5.91***	***20.78***	***1.93***	***9.70***	***37.63***	***24.60***	***2.53***

Evergreen Shrubs	**Family**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**
Amblyanthopsis bhotanica	Primulaceae	0.015		2.918	0.087				
Benkara sinensis	Commelinaceae	0.062	0.089	0.083	2.625	2.377	0.209	0.121	0.065
Boehmeria platyphylla	Urticaceae	0.009	0.508	0.003	0.407	0.025	2.921	2.154	0.065
Bridelia micrantha	Euphorbiaceae	0.099	0.051	0.147	0.058	0.025	0.438	0.349	0.030
Bridelia mollis	Euphorbiaceae	0.515	0.610	0.227	0.017	0.228	1.052	2.646	0.051
Bridelia retusa	Euphorbiaceae	0.021	0.152	3.389	0.262	0.011	1.096	0.430	0.043

Capparis indica	Capparaceae	0.002	0.305	0.003	6.699	0.111	0.584	1.322	0.032
Chloranthus elatior	Chloranthaceae	0.007	0.051	0.031	1.409	5.912	0.627	0.068	0.530
Clerodendrum chinense	Verbenaceae	17.363	4.534	0.004	0.249	0.051	0.009	0.509	0.026
Clerodendrum japonicum	Verbenaceae	0.156	0.610	0.048	1.323	0.029	0.199	2.053	0.043
Combretum alfredii	Combretaceae	0.009	0.297	0.198	0.349	0.577	0.097	1.013	0.043
Croton caudatus	Euphorbiaceae	0.065	0.038	0.028	1.887	0.032	0.942	3.780	0.224
Daphne bhoula	Thymelaeaceae	0.029	9.834	0.007	1.962	0.111	0.013	1.595	0.003
Dichroa febrifuga	Hydrangeaceae	1.175	4.565	26.033	2.320	0.025	1.058	3.443	0.379
Edgeworthia gardneri	Thymelaeaceae	1.483	0.069	0.028	0.116	8.951	0.084		0.005
Elsholtzia blanda	Labiatae	0.835	4.064	0.653	7.876	0.774	4.090		0.431
Elsholtzia fruticosa	Labiatae	0.007	0.051	0.029	0.015	1.633	1.509		1.292
Eriobotrya dubia	Rosaceae	1.281	0.406	0.002		0.048	1.628		0.646
Eurya acuminata	Theaceae	0.003	0.391	0.083		0.158	1.132		0.344
Ficus cyrtophylla	Moraceae	6.471	0.724	1.800		0.127	0.502		0.646
Goniothalamus sesquipedalis	Asclepiadaceae	0.003	4.960	0.072		7.646	1.169		16.257
Grewia eriocarpa	Tiliaceae		0.110	1.090			5.155	0.349	0.039
Hedyostis scandens	Zingiberaceae			0.024			6.856	2.646	
Justicia santapaui	Acanthaceae			0.177		0.011		0.430	
Leea indica	Leeaceae			0.438	0.017	0.111	0.009	1.322	
lepisanthes rubiginosa	Opiliaceae			1.300	0.262	5.912	0.199	0.068	0.043
Lepisanthes senegalensis	Sapindaceae				6.699	0.051	0.097	0.509	0.032
Leucosceptrum canum	Labiatae			0.007	1.409	0.029	0.942	2.053	0.530
Libistonia rotundifolia	Caprifoliaceae	0.007	0.051	26.033	0.249	0.577	0.013	1.013	0.026
Maesa chisia	Myrsinaceae	17.363	4.534	0.028	1.323	0.032	1.058	3.780	0.043
Maesa indica	Myrsinaceae	0.156	0.610	0.653	0.349	0.111	0.084	1.595	0.043
Magnolia pterocarpa	Myrsinaceae	0.009	0.297	0.029	1.887	0.025	4.090	3.443	0.224
Measa Indica	Scrophulariaceae	0.065	0.038	0.002	1.962	8.951	1.509	0.068	0.379
Melastoma malabathricum	Gentianaceae	0.029	9.834	0.083	2.320	0.774	1.628	0.509	0.005
Mitrephora harai	Annonaceae	1.175	4.565	1.800	0.116	1.633	1.132	2.053	0.431
Molineria capitulata	Hypoxidaceae	1.483	0.069	0.072	7.876	0.048	0.502	1.013	1.292
Murraya koenigii	Rutaceae	0.835	4.064	1.090	0.015	0.158	1.169	3.780	0.646
Murraya paniculata	Rutaceae	0.007	0.051	0.024	1.323	0.127	1.510	1.595	0.344
Mussaenda roxburghii	Musaceae	1.281	0.406	0.177	0.349	7.646	1.389	3.443	0.646
Osbeckia stellata	Melastomataceae	0.003	0.391	0.438	1.887				16.257
Osteodes paniculata	Umbelliferae	6.471	0.724	1.300	1.962				0.039
Pandanus furcatus	Pandanaceae	0.003	4.960		2.320				
Pandanus nepalensis	Pandanaceae		0.110		0.116	0.032			
Pavetta Indica	Passifloraceae				7.876	0.111	4.090		0.379
Pavia indica	Rubiaceae				0.015	0.025	1.509		0.005
Phlogacanthus pubinervius	Acanthaceae					8.951	1.628	0.509	0.431
Phlogacanthus thyrsiformis	Acanthaceae		9.834		1.887	0.774	1.132	2.053	1.292
Phlogacanthus vitellinus	Acanthaceae	1.175	4.565	0.002	1.962	1.633	0.502	1.013	0.646
Piper mullesua	Piperaceae	1.483	0.069	0.083	2.320	0.048	1.169	3.780	0.344
Piper pedicilatum	Piperaceae	0.835	4.064	1.800	0.116	0.158	1.510	1.595	0.646
Pseudocaryopteris panniculata	Acanthaceae	0.007	0.051	0.072	7.876	0.127	1.389	3.443	16.257
Psilanthus bengalensis	Rubiaceae	1.281	0.406	1.090	0.015	7.646	0.730	3.780	0.039
Psychotria nervosa	Rubiaceae	0.003	0.391	0.024			1.389	1.595	0.646
Sarcoclamys pulcherrima	Urticaceae	6.471	0.724	0.177		0.048		3.443	0.344
Schefflera spp	Araliaceae	0.003	4.960	0.438		0.158			0.646
Strobilanthes capitata	Acanthaceae	0.003	0.110	1.300	0.116	0.127			16.257

Strobilanthes cellosa	Acanthaceae	6.471		0.024	7.876		7.646		0.039
Strobilanthes echinata	Acanthaceae	0.003		0.177	0.015				
Strobilanthes exsertia	Acanthaceae			0.438					0.344
Strobilanthes spp	Acanthaceae		0.724	1.300		0.127		1.595	0.646
Tabernaemontana divaricata	Apocynaceae		4.960	0.438	7.876	7.646	0.627	3.443	16.257
Thysanolaena latifolia	Gesneriaceae	6.471	0.110	1.300	0.015				0.039
Trevesia palmata	Araliaceae	0.003							0.039
Xanthozylum bungeanum	Compositae	0.003							
Sub-total		***82.71***	***94.09***	***79.22***	***98.07***	***90.30***	***62.37***	***75.40***	***97.47***
Grand total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1.3. Floristic composition of the ground vegetation

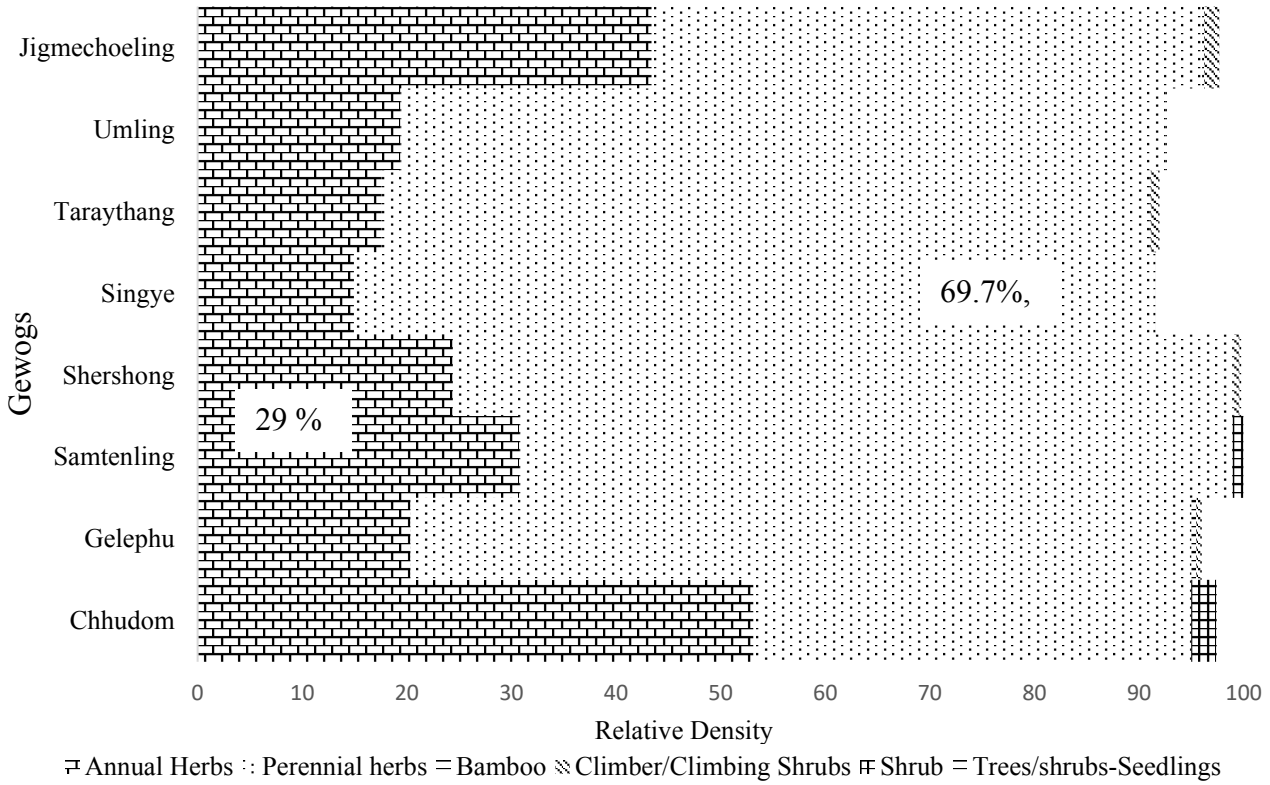


Figure 11: Distribution pattern of five major life-forms; perennial herb, annual herb, deciduous shrub, evergreen shrub and deciduous trees, deciduous shrub and spore-bearing plants inside 8 gewogs.

Total ground vegetation was composed of 77 families with 204 species of which 132 were perennial herbs (42 families), 55 annual herbs (21 families), about 17 species (14 families) of shrubs, bamboo, ferns, tree/shrub seedlings, climbers, etc. Perennial herbs consist of 69.7%, annual herbs 29 %, and 1.3% of other species (shrubs, bamboo, ferns, tree/shrub seedlings, climbers, etc.) respectively.

The result revealed that ground vegetation was primarily dominated by perennial herbs such as *Ageratum houstonianum, Begonia dioica, Colocasia esculenta, etc*., while annual herbs like *Bidens plosa, Digitaria ciliaris, Commelina benghalensis, etc*., comprised the remaining composition of ground vegetation. The highest diversity of (H=2.39) is recorded in Umling and lowest with Shannon diversity of (H=1.34) is recorded in Gelephu Gewog.

Table 4: Distribution pattern of five major life-forms; perennial herb, annual herb, deciduous shrub, evergreen shrub and deciduous trees, deciduous shrub and spore-bearing plants inside 8 gewogs.

Species	Family	Chhudom	Gelephu	Samtenling	Shershong	Singye	Taraythang	Umling	Jigmechoeling
		RD %	RD %	RD %	RD %	RD %	RD %	RD %	RD %
Annual Herbs									
Achyranthes bidentata	Amaranthaceae							0.536	
Acmella uliginosa	Compositae	0.073						0.402	
Ageratinum conizodes	Compositae	0.907	0.402	8.649			0.708	0.335	5.140
Ageratum houstonianum	Compositae	1.089					0.885		7.908
Ageratum houstonianum	Compositae	0.254					0.059		0.539
Amaranthus blitum	Leguminosae	0.036					0.118		0.575
Amaranthus spinosus	Amaranthaceae	0.145					0.089		0.072
Amaranthus viridis	Amaranthaceae	4.719				0.806	0.177		1.438
Ardisia crenata	Myrsinaceae		1.689	5.766	0.235	0.537			2.876
Ageratina Adenophora	Compositae	22.322	1.608	7.688	3.528	0.806		0.803	0.180
Bidens Pilosa	Compositae	0.907	0.804	8.649	0.235	0.806		1.071	0.935
Capsella bursa	Capparaceae	0.145	3.618		1.881	0.430		2.410	0.539
Chenopodium album	Chenopodiaceae	0.073	2.975			1.612	0.059	0.603	6.326
Commelina benghalensis	Commelinaceae	0.109	0.804			1.344	0.118	0.201	0.539
Commelina hasskarlii	Commelinaceae	3.085				1.075	0.089	0.268	0.036
Commelina maculate	Commelinaceae	2.359				1.075	0.177	0.670	1.977
Conyza canadensis	Compositae	5.481				0.537		1.875	0.180
Cyanthillium cinereum	Compositae	0.145				0.806		2.477	0.539
Cynoglossum furcatum	Boraginaceae	1.670				2.687	0.089		0.899
Axonopus compressus	Gramineae	0.181	1.608			1.075	0.708		0.539
Digitaria ciliaris	Gramineae	0.181				1.344	5.962	0.335	0.036
Eleusine indica	Gramineae	0.907					0.708		0.180
Euphorbia indica	Euphorbiaceae	1.924					0.531		
Galium aparine	Rubiaceae	0.363					0.118		
Geranium mole	Geraniaceae	2.396					0.236		
Impatiens arguta	Balsaminaceae	0.726					3.069		
Impatiens exilis	Balsaminaceae	0.363					0.177		
Impatiens radiata	Balsaminaceae	0.218					1.535		
Lactuca dissecta	Compositae	0.181					2.007		
Lobelia nicotianifolia	Campanulaceae	1.996							
Lobelia nummularia	Campanulaceae	0.181							
Maoutia puya	Urticaceae		1.212						
Perennial herbs:	Campanulaceae		1.010						
Perilla frutescens	Labiatae		0.808						
Persicaria barbata	Polygonaceae		0.808						
Persicaria chinensis	Polygonaceae		0.404						
Persicaria maculosa	Polygonaceae		0.606						

Persicaria nepalensis	Polygonaceae		2.021		3.048				0.935
Persicaria runcinate	Polygonaceae				4.689				0.539
Polypogon fugax	Gramineae				0.320				6.326
Pseudognaphalium affine	Compositae				0.341				0.539
Pseudoploymorph stachy	Compositae				0.043				0.036
Ranunculus hispidus	Ranunculaceae				0.852				1.977
Raphanus raphanistrum	Cruciferae				1.705			0.041	0.180
Setaria megaphylla	Gramineae				0.107			1.169	0.539
Setaria palmifolia	Gramineae				0.554			0.894	0.899
Sida acuta	Malvaceae				0.320			2.077	
Siegesbeckia orientalis	Malvaceae				3.751			0.055	
Solanum nigrum	Solanaceae				0.320			0.633	
Solanum spp	Solanaceae				0.021			0.069	
Solunum erianthum	Compositae				1.172			0.069	
Solunum khasinum	Compositae				0.107			0.344	
Solunum torvum	Compositae				0.320			0.729	
Solunum viarum	Compositae				0.533			0.138	
Swertia chirata	Gentianaceae				0.320			0.908	
Urena lobata	Malvaceae				0.021			0.275	
Sub-total		***53.138***	***20.379***	***30.752***	***24.421***	***14.941***	***17.619***	***19.384***	***43.422***
Perennial herbs									
Alpinia malaccensis	Zingiberaceae	0.145				0.430			
Ageratum houstonianum	Compositae	0.073				1.612			1.438
Alocasia flemingia	Araceae	0.109			0.470	1.344			2.876
Arisaema flavum	Araceae	3.085			0.235	1.075			0.180
Amblyanthopsis bhotanica	Amaranthaceae	2.359			0.470	1.075			0.935
Amischotolype hispida	Myrsinaceae	5.481			4.445	0.537			0.539
Arisaema concinnum	Araceae	0.145	0.402		0.470	0.806			6.326
Arisaema tortuosum	Araceae	1.670	0.402		1.176	2.687			0.539
Arisaema serratum	Araceae	0.181	0.402		1.411				0.036
Blastus cochinchinensis	Bixaceae		1.608		8.466				1.977
Arisaema speciosum	Araceae	0.181	0.804		0.235				0.180
Arisaema utile	Araceae	0.907	3.618						0.539
Artimesia nilagirica	Gramineae	1.924	2.975						0.899
Artemisia absinthium	Annonaceae	0.363	0.804			0.806			0.539
Benkara fasciculata	Commelinaceae	2.396	2.412			0.430	3.542	1.071	0.036
Artimesia vulgaris	Gramineae	0.726	0.804			1.612	0.413	0.536	0.180
Bacopa monieri	Compositae	0.363	2.091			1.344	5.371	0.736	
Asystasia macrocarpa	Acanthaceae	0.218	0.402			1.075	6.375	5.724	0.180
Boehemeria macrophylla	Hydrocharitaceae	1.924	2.412	2.883	0.470	1.075	0.944	1.607	0.935
Bacopa monieri	Compositae	1.996				0.537	0.708	0.268	0.539
Baka Kanay-LN	Scrophulariaceae	0.181				0.806	0.531	0.670	6.326
Baliospermum polyandrum	Euphorbiaceae	0.181				2.687	0.118	1.875	0.539
Begonia annulate	Begoniaceae	1.670				0.430	0.236	2.477	0.036
Begonia dioica	Begoniaceae	0.181	0.643			1.612	3.069		1.977
Begonia palmata	Begoniaceae	0.181	1.206		0.470	1.344	0.177		0.180
Blumea aromatica	Compositae	0.907	0.482		4.445	1.075	1.535		0.539
Boehmeria glomerulifera	Urticaceae	2.396	2.091	5.766	1.411	0.806	2.007		0.899
Boehmeria cylindrica	Urticaceae	0.363	0.804	0.961	1.176	0.537			0.539
Boehmeria platyphylla	Urticaceae	0.218		3.844	0.470		3.069	0.603	0.036

Boehmeria himiltoniana	Urticaceae	0.726	0.402	3.844	8.466	2.687	0.118	0.201	0.180
Boehmeria nivea	Urticaceae	0.363	1.608	0.961	0.235		0.236	0.268	0.180
Brugmansia sauveolens	Simaroubaceae								0.036
Curcuma heyneana	Zingiberaceae	0.218	0.804				0.944	0.670	0.539
Brachiaria romasa	Nyctaginaceae	0.181		0.961	1.176		0.177	1.875	0.899
Brachiaria subquadripara	Nyctaginaceae	1.996		2.883	1.411		1.535	2.477	0.539
Brachiaria subquadripara	Nyctaginaceae	0.181		5.766	8.466		2.007		0.036
Cautleya spicata	Zingiberaceae		0.482	3.844	0.235				0.180
Cheilocostus speciosus	Rubiaceae		2.412	0.961					0.539
Chloranthus elatior	Chloranthaceae		0.804	3.844					0.899
Chloranthus spicatus	Chloranthaceae		2.091	0.961					0.539
Citrus medica	Rutaceae								
Colocasia esculenta	Araceae		0.804	2.883	3.528	1.881			0.036
Benkara sienensis	Commelinaceae			7.688	1.881	0.914	5.371	0.536	0.180
Costus speciosus	Costaceae	0.726	3.618		1.881	0.914	5.371	0.736	
Curcuma aromatica	Zingiberaceae	0.363	2.975			2.633	6.375	5.724	0.539
Cyathula prostrata	Amaranthaceae	0.181	2.975			2.633	0.531	1.607	0.036
Caesalpinia decapetala	Leguminosae		3.618	8.649		2.633	0.295	0.736	0.180
Desmodium triflorum	Leguminosae	0.181					6.375	5.724	
Cynodon dactylon	Gramineae	1.996	0.804				0.944	1.607	0.036
Dichrocephala integrifolia	Compositae	0.181					3.069	1.607	0.180
Dichrocephala integrifolia	Compositae						0.177		
Dischidia nummularia	Asclepiadaceae	0.726					0.944		
Discorea divercata	Asclepiadaceae	0.363		3.844			2.007		
Elastestema platyphyllum	Elaeocarpaceae	0.218	2.412	0.961	1.176	1.075			
Elastestema stewardii	Elaeocarpaceae	0.181	0.804	2.883	1.411	1.075			0.180
Elastostema acuminata	Elaeocarpaceae	1.996	2.091		8.466	0.537	3.069	0.670	
Elatostema lineolatum	Urticaceae	0.181	0.402		0.235	0.806	0.177	1.875	
Elatostema sessile	Urticaceae		1.608	0.961	0.235	2.687	1.535	2.477	
Elsholtzia blanda	Labiatae			2.883			2.007		
Elsholtzia fruticosa	Labiatae					1.075			
Elsholtzia regulosa	Labiatae					0.537			
Echornia cordifolia	Gramineae		0.108			0.806			
Elstetoema lenolatum	Labiatae		0.561						
Flemingia macrophylla	Leguminosae		0.324						
Floscopa scandens	Commelinaceae		3.800						
Fragaria nubicola	Rosaceae		0.324						
Geum aleppicum	Rosaceae		0.022						
Geum urbanum	Rosaceae		1.187						
Girardina diversifolia	Rosaceae		0.108						
Globba racemosa	Zingiberaceae	0.363	0.324						
Gomphostemma parviflorum	Labiatae		0.540			2.687	2.007	2.477	
Gynura divaricata	Compositae		0.324						
Hedychium coronarium	Zingiberaceae		0.022						
Hedychium deceptum	Zingiberaceae		0.108					0.099	
Hedychium spicatum	Zingiberaceae		0.108					0.513	
Hedychium thyrsiforme	Zingiberaceae		0.022					0.296	
Houttuynia cordata	Saururaceae		0.324					3.469	
Hydrocotyle javanica	Umbelliferae		0.540					0.296	
Imperata cylindrica	Gramineae		0.324		0.107			0.020	

Isoglossa collina	Acanthaceae	0.022	0.554		1.084	
Justicia santapaui	Acanthaceae	0.108	0.320		0.099	
Koenigia mollis	Polygonaceae	0.324	3.751		0.296	
Laportea bulbifera	Verbenaceae	0.540	0.320		0.493	
Laportea bulbifera	Verbenaceae		0.021		0.296	
Lysimachia congestiflora	Primulaceae		1.172		0.020	
Maranta arundinacea	Urticaceae		0.107		0.099	
Marrubium vulgare	Urticaceae		0.320		0.099	
Melinis minutiflora	Gramineae		0.533		0.020	
Mentha spicata	Labiatae		0.320		0.296	
Mikania micrantha	Compositae		0.021		0.493	
Molineria capitulata	Hypoxidaceae		0.107		0.296	
Nelsonia canescens	Rosaceae		0.107		0.020	
Ophiopogon japonicus	Convallariaceae		0.021		0.099	
Oplismenus burmannii	Gramineae		0.320		0.296	
Oplismenus hirtellus	Gramineae		0.533		0.493	
Oplismenus undulatifolious	Gramineae		0.320			
Oxalis corniculata	Oxalidaceae		0.021			
Oxalis corymbosa	Oxalidaceae		0.107			
Oxyspora paniculata	Melastomataceae		0.320			0.180
Palisota Hiruta	Ranunculaceae		0.533			0.935
Paspalum conjugatum	Gramineae					0.539
Paspalum pasloides	Gramineae					6.326
Peliosanthes macrophylla	Convallariaceae			4.106		0.539
Pellionia radicans	Convallariaceae			6.317		0.036
Pennisetum clandestinum	Gramineae			0.431		1.977
Phryma leptostachya	Phrymaceae			0.459		0.180
Phrynium placentarium	Marantaceae			0.057		0.539
Phrynium pubinerve	Marantaceae			1.148		0.899
Pilea bracteosa	Urticaceae			2.297		0.539
Pilea pumila	Urticaceae			0.144		0.036
Piper betleoides	Piperaceae			0.747		0.180
Piper betleoides	Piperaceae			0.431		0.180
Piper longum	Piperaceae			5.053		0.036
Piper longum	Piperaceae			0.431		0.539
Piper mullesua	Piperaceae			0.029		0.899
Piper nigrum	Piperaceae			1.579		0.539
Piper pedicilatum	Piperaceae			0.144		0.036
Piper peduloides	Piperaceae			0.431		0.180
Plantago major	Plantaginaceae	0.108		0.718		0.539
Plectranthus spp	Labiatae	0.561		0.431		0.899
Pliea bractosa	Umbelliferae	0.324		0.029	2.819	
Pogostemon amaranthoides	Labiatae	3.800		0.144	4.337	
Pollia hasskarlii	Commelinaceae	0.324			0.296	
Potentilla indica	Rosaceae	0.022			0.315	
Pouzolzia hirta	Urticaceae	1.187			0.039	
Pouzolzia sanguinea	Urticaceae	0.108			0.788	
Rubia cordifolia	Gramineae	0.324			1.577	
Rumex nepalensis	Polygonaceae	0.540			0.099	
Sajesbeckia orientalis	Alismataceae	0.324			0.513	

Salvia coerulea	Labiatae		0.022				0.296		
Solanum anguivi	Solanaceae		0.108				3.469		
Solanum spp	Solanaceae		0.108				0.296		
Strobilanthes crispa	Acanthaceae		0.022				0.020		
Strobilanthes cusia	Acanthaceae		0.324				1.084		
Strobilanthes penstemonoides	Acanthaceae		0.540				0.099		
Strobilanthes spp	Acanthaceae		0.324				0.296		
Strobilanthus exserta	Acanthaceae		0.022				0.493		
Thysanolaena latifolia	Gesneriaceae		0.108				0.296		
Urtica dioica	Urticaceae		0.324				0.020		
Sub-total		***41.850***	***74.662***	***68.231***	***74.555***	***76.449***	***73.370***	***73.167***	***52.624***
Bamboo									
Cephalostachyum capitum	Gramineae		0.402		0.107				0.180
Drepanostachyum falcatum	Gramineae						0.156		
Sub-total			***0.402***		***0.107***		***0.156***		***0.180***
Climber/Climbing Shrubs									
Pavetta Indica	Passifloraceae		0.108				0.156		0.180
Rhaphidophora pertusa	Araceae		0.108		0.107		0.156		0.180
Rhaphidophora spp	Araceae		0.022		0.107		0.031		0.036
Rubus elipticus	Rosaceae		0.324		0.021		0.468		0.539
Rubus panniculata	Rosaceae				0.320				0.539
Schefflera spp	Araliaceae								
Sub-total			***0.561***		***0.554***		***0.811***		***1.474***
Shrub									
Chromolaena ordorata	Compositae	0.109	2.975				6.375	5.724	1.653
Croton caudatus	Euphorbiaceae		0.108		0.235	8.438	0.413	1.607	
Bridelia mollis	Euphorbiaceae	0.260	0.804				0.944		
Daphne bhoula	Thymelaeaceae	1.937	0.108						0.647
Pseudocaryopteris panniculata	Acanthaceae	0.260					0.156		
Sanguinaia canadensis	Caprifoliaceae						0.156		
Sub-total		***2.567***	***3.995***		***0.235***	***8.438***	***8.044***	***7.331***	***2.301***
Ferns									
Equisetum diffusum	Gesneriaceae	0.260		0.242		0.144			
Lycopodium japonicum	Solanaceae	0.052		0.048		0.029			
Selaginella doederleinii	Crassulaceae	0.780		0.726					
Selaginella involvens	Crassulaceae	1.300							
Sub-total		***2.393***		***1.017***		***0.172***			
Trees/shrubs									
Dracaena angustifolia	Dracaenaceae	0.052			0.107			0.099	
Vibernum spp	Scrophulariaceae				0.021			0.020	
Sub-total		***0.052***			***0.128***			***0.118***	
Grand Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

1.4. Floristic composition of the climber/vine species and fern (pteridophytes) species

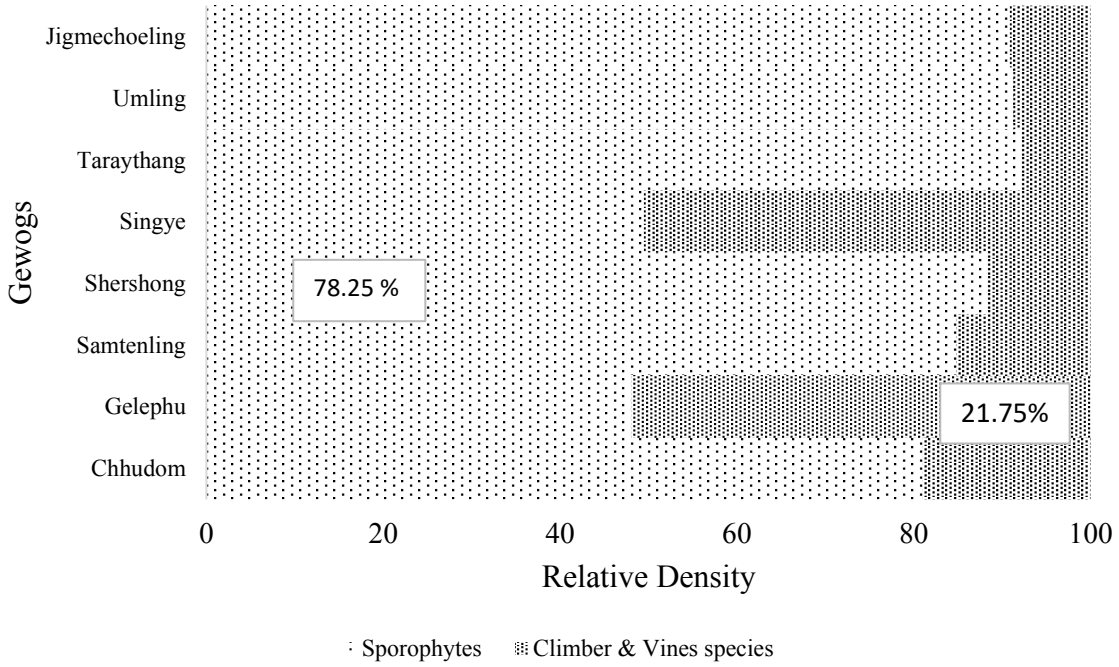


Figure 12:Distribution pattern of climber & Vines and sporophytes inside 8 gewogs

68 species of ferns, belonging to 16 families, were recorded during the survey. There were 26 species of climbers/vines recorded, which belonged to 15 families. The highest number of sporophytes was recorded in Taraythang (RD% = 92.04545), and the highest number of vines or climbers was recorded in Gelephu Gewog (RD% = 51.9139).

Table 5:Distribution pattern of climber & Vines and sporophytes inside 8 gewogs

Sporophytes		**Chhudom**	**Gelephu**	**Samtenling**	**Shershong**	**Singye**	**Taraythang**	**Umling**	**Jigmechoeling**
Species	**Family**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**	**RD %**
Dennstaedtia appendiculata	Dennstaedtiaceae	0.81							
Davallia assamica	Davalliaceae	5.24							
Microlepia speluncae	Dennstaedtiaceae	4.44							
Diplazium esculentum	Athyriaceae	18.95							
Polystichum nepalense	Dryopteridaceae	6.05		0.84					
Drynaria spp.	Polypodiaceae	4.03		5.49					
Selaginella monospora	Selaginellaceae	12.90		4.64					1.82
Tectaria polymorpha	Tectariaceae	3.23		19.83	26.01				1.54
Tectaria morata	Tectariaceae	6.45	0.48	6.33	0.45				6.58
Pteris normalis	Pteridaceae	14.52	3.11	4.22	0.90		0.45		2.10
Arachniodes foeniculaceum	Dryopteridaceae	3.23	2.63	13.50	1.35		2.50		1.40
Pteris wallichiana	Pteridaceae	1.21	11.24	3.38	0.90		6.36	1.83	4.48
Asplenium obscurum	Aspleniaceae		3.59	6.75	4.93		0.91	1.55	1.12
Pteridium revolutum	Dennstaedtiaceae		2.39	15.19	12.56		1.36	6.61	2.24
Asplenium obliquissimum	Aspleniaceae		7.66	3.38	1.79		0.68	2.11	5.04
leptochilus pedunculatus	Polypodiaceae		1.91	1.27	2.69	14.57	0.45	1.41	1.12
Asplenium amoenum	Aspleniaceae		3.83		1.35	0.25	0.91	4.50	0.42
Thelypteris papilio	Thelypteridaceae		8.61		0.90	0.50	1.14	1.13	0.70

Pteris pellucens	Pteridaceae	1.91	1.79	0.75	4.09	2.25	8.12
Thelypteris procera	Thelypteridaceae	0.72	2.24	0.50	0.91	5.06	0.14
Polystichum bolbitis	Dryopteridaceae		8.07	2.76	6.82	1.13	0.28
Diplazium spp 2	Athyriaceae		1.79	7.04	3.64	0.42	0.42
Tectaria ingens	Tectariaceae		13.45	1.01	0.23	0.70	0.28
Bolbitis angustipinna	Dryopteridaceae		7.17	1.51	0.91	8.16	1.54
Microlepia platyphylla	Dennstaedtiaceae			0.75	0.23	0.14	3.92
Pteris cretica	Pteridaceae			0.50	0.23	0.28	0.56
Thelypteris nudata	Thelypteridaceae			1.01	0.91	0.42	0.84
Polystichium tsus-simense	Dryopteridaceae			1.26	0.91	0.28	0.42
Microlepia setosa	Dennstaedtiaceae			4.52	3.41	1.55	0.28
Pteris biaurita	Pteridaceae			1.01	2.95	3.94	0.56
Angiopteris evecta	Marattiaceae			7.54	0.91	0.56	0.70
Polystichum semi fertile	Dryopteridaceae			4.02	0.23	0.84	2.52
Asplenium cheilosorum	Aspleniaceae				0.23	0.42	0.56
Monachosorum henryi	Dennstaedtiaceae				0.23	0.28	4.20
Odontosoria chinensis	Lindsaeaceae				0.23	0.56	2.24
Thelypteris erubescens	Thelypteridaceae				1.36	0.70	0.14
Nephrolepis cordifolia	Nephrolepidaceae				1.82	2.53	0.56
Cyathea spinulosa	Cyatheaceae				0.23	0.56	0.14
Microsorum cuspidatum	Polypodiaceae				0.45	4.22	0.14
Asplenium lanciniodes	Aspleniaceae				0.23	2.25	0.56
Dryopteris gamblei	Dryopteridaceae				0.68	0.14	0.56
Dipteris wallichii	Dipteridaceae				0.23	0.56	2.10
Thelypteris lakhimpurensis	Thelypteridaceae				0.23	0.14	1.82
Dicranopteris taiwanensis	Gleicheniaceae				0.68	0.14	0.56
Pteris spinescens	Pteridaceae				0.91	0.56	
Bolbitis appendiculata	Dryopteridaceae				0.23	0.56	
Coniogramme pubescens	Pteridaceae				0.68	2.11	
Diplazium sikkimense	Athyriaceae				0.45	1.83	
Polystichum punctatum	Dryopteridaceae				0.68	0.56	0.28
Angiopteris spp.	Marattiaceae				0.23		1.82
Diplazium javanicum	Athyriaceae				0.23		1.54
Diplazium spp.3	Athyriaceae				0.91	0.28	6.58
Microlepia rhomboidea	Dennstaedtiaceae				0.45	1.83	2.10
Dryopteris spp.	Dryopteridaceae				1.36	1.55	1.40
Dryopteris sparsa	Dryopteridaceae				0.68	6.61	4.48
Polypodiodes amoena	Polypodiaceae				0.68	2.11	1.12
Dryopteris juxtaposita	Dryopteridaceae				0.23	1.41	2.24
Dennstaedtia zeylanica	Dennstaedtiaceae				0.23	4.50	5.04
Diplopterygium giganteum	Gleicheniaceae				0.23	1.13	1.12
Diplazium himalayense	Athyriaceae				0.23	2.25	0.42
Macrothelypteris ornata	Thelypteridaceae				0.68	5.06	
Pteridium Aquilinum	Dennstaedtiaceae				0.00	1.13	
Polypodium glycyrrhiza	Polypodiaceae				9.09	0.42	
Pakau pennigera	Thelypteridaceae				14.09		
Cyathea dregei	Cyatheaceae				8.64		
Aglaomorpha coronans	Polypodiaceae				0.23		
Arthromeris wallichiana	Polypodiaceae				1.36		
Blechnopsis orientalis	Blechnaceae				1.36		

Pteris scabririgens	Pteridaceae						0.45		
Sub total		***81.05***	***48.09***	***84.81***	***88.34***	***49.50***	***92.05***	***91.28***	***90.90***
Climber & Vines species									
Rubia cordifolia	Rubiaceae	3.23	9.57				0.23		
Piper betleoides	Piperaceae	0.40	14.83		0.45		0.45		0.84
Tetrastigma paniculata	Vitaceae	0.81	9.09		0.90		0.45		0.28
Flemingia macrophylla	Fabaceae	0.40	0.24		0.90		0.23		0.28
Piper spp.	Piperaceae	1.21	1.44		0.45		2.27		0.14
Mikania micrantha	Asteraceae	0.40	1.44	0.42	4.48		0.68		0.28
Smilax ferox	Liliaceae	0.40	0.48	0.84	1.35		0.23		0.28
Gynostemma pentaphyllum	Cucurbitaceae	1.21	0.48	0.84	0.45		0.45		0.14
Rubus paniculata	Rosaceae	1.61	0.24	0.42	0.90		0.91	0.84	1.40
Jasminum dispermum	Oleaceae	0.40	0.48	4.22	1.79	0.50	1.14	0.28	0.42
Lycopodium	Lycopodiaceae	1.21	0.48	1.27		3.27	0.23	0.28	0.14
Aristolochia pentaphylla	Aristolochiaceae	0.81	0.24	0.42		2.76	0.23	0.14	0.28
Rhaphidophora spp.	Araceae	1.21	2.39	0.84		11.81	0.45	0.28	0.56
Tetrastigma obtectum	Vitaceae	0.40	0.72	1.69		3.77		0.28	0.70
Tetrastigma rumicispermum	Vitaceae	0.40	0.24	2.11		2.51		0.14	0.14
Stephania japonica	Menispermaceae	1.61	0.48	0.42		8.04		1.41	0.14
Piper longum	Piperaceae	0.81	0.96	0.42		2.01		0.42	0.28
Paederia cruddasiana	Rubiaceae	2.42	1.20	0.84		4.02		0.14	0.14
Smilax perfoliata	Liliaceae		0.24	0.42		9.05		0.28	2.10
Aristolochia macrophylla	Aristolochiaceae		0.24			2.01		0.56	0.14
Tinospora cordifolia	Menispermaceae		0.48			0.75		0.70	0.42
Thunbergia grandiflora	Acanthaceae		0.24					0.14	
Rhaphidophora decursiva	Araceae		3.59					0.14	
Parthenocissus quinquefolia	Vitaceae		0.24					0.28	
Argyreia nervosa	Convolvulaceae		0.72					0.14	
Tetrastigma spp.	Vitaceae		0.24					2.11	
Mikania cordata	Asteraceae		0.96					0.14	
Sub total		***18.95***	***51.91***	***15.19***	***11.66***	***50.50***	***7.95***	***8.72***	***9.10***
Grand total		**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 6: Checkbox indicating presence and absence of different species of canes, bamboos, and other species in gewogs

Species	Family	Chhudom	Gelephu	Samtenling	Shershong	Singye	Taraythang	Umling	Jigmechoeling
Bambusa nutans	Gramineae	☑	☐	☐	☑	☐	☐	☐	☐
Calamus acanthospathus	Arecaceae(Palmae)	☑	☑	☐	☑	☐	☐	☐	☐
Calamus erectus	Arecaceae(Palmae)	☑	☑	☑	☑	☐	☐	☐	☐
Calamus flagellum	Arecaceae(Palmae)	☑	☑	☑	☑	☐	☐	☐	☑
Calamus tenuis	Arecaceae(Palmae)	☑	☑	☑	☐	☐	☐	☐	☑
Caryota urens	Arecaceae(Palmae)	☑	☑	☑	☐	☑	☐	☐	☐
Catunaregam spinosa	Rubiaceae	☑	☑	☑	☐	☑	☐	☐	☑
Cephalostachyum capitatum	Gramineae	☑	☑	☐	☐	☑	☐	☐	☑
Cephalostachyum latifolium	Gramineae	☑	☑	☐	☐	☑	☐	☐	☑
Chimonobambusa callosa	Gramineae	☑	☑	☑	☐	☑	☐	☑	☑
Crotolaria pallida	Leguminosae	☑	☑	☑	☑	☑	☑	☐	☑
Cycas pectinata	Cycadaceae	☑	☑	☑	☑	☑	☑	☐	☑
Dendroclamus hamiltonii	Gramineae	☑	☑	☑	☐	☑	☑	☑	☑
Dendrocnide harveyi	Urticaceae	☑	☑	☐	☑	☑	☐	☐	☑
Dendrocnide sinuata	Urticaceae	☑	☐	☑	☑	☑	☑	☐	☑
Dracaena angustifolia	Cruciferae	☑	☑	☑	☑	☐	☑	☑	☑
Drepanostachyum falcatum	Gramineae	☐	☑	☑	☑	☐	☑	☐	☑
Exbucklandia populnea	Hamamelidaceae	☐	☑	☐	☐	☐	☐	☐	☑
Fagerlindia fasciculata	Rubiaceae	☐	☑	☐	☐	☐	☑	☐	☑
Flemingia macrophylla	Leguminosae	☐	☐	☐	☐	☑	☐	☐	☑
Plectocomia himalayana	Arecaceae(Palmae)	☑	☐	☐	☐	☑	☐	☐	☑
Trachycarpus fortunei	Apocynaceae	☑	☑	☐	☐	☐	☐	☐	☐
Tradescantia fluminensis	Umbelliferae	☑	☑	☐	☐	☐	☐	☐	☐
Vernonia volkameriifolia	Compositae	☑	☑	☑	☐	☐	☑	☐	☑

During the survey, six species from the Aceraceae and Gramineae families were recorded across eight Gewogs. Additionally, one species from the Cycadaceae family was also documented. Furthermore, two species from the Rubiaceae and Urticaceae families, as well as species from other families, were recorded as well.

1.5. Classification of the forest types

Based on Cluster analysis, the entire forest of Sarpang was categorized into 3 types (Figure ??) at the distance threshold of 25% similarity index. PCORD software was employed to classify different forest types. The forest was classified based on the Relative Basal Area of trees of each plot. The cluster analysis grouped homogenous plant communities and site factors. The MONTE CARLO test of significance was performed to determine indicator species in each cluster. The top two indicator species with lowest significant P value were added in the cluster dendrogram.

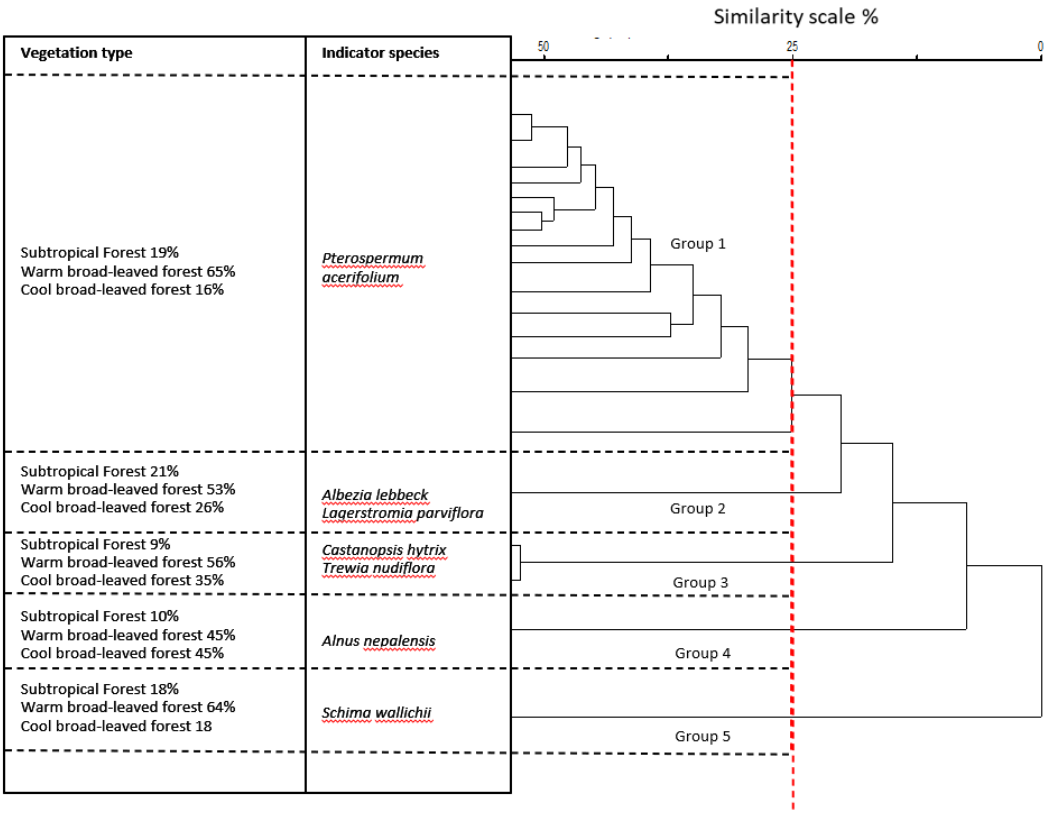


Figure 13:Cluster dendrogram depicting cluster solution with indicator species and forest types. The similarity index scale (%) is arbitrarily marked at 26% marked with dashed lines.

1. **Sub-tropical Forest (Group 1-5)**

These types of forest were between an altitude of 200-1000m asl (-1200m asl) and precipitation of 2500-5000mm (Arun and Dawa 2022). The indicator species recorded was *Pterospermum acerifolium, $p < 0.05$).* Such forests dominate the foothills forming dense jungle on the steep slopes and riverbanks. Some of the characteristic species found in the subtropical forests are *Gmelina arborea, Chukrasia tabularis, Acrocarpus fraxinifolius, Ailanthus grandis, Bombax ceiba, Duabanga grandiflora, Shorea robusta, Tetrameles nudiflora* etc.

2. **Warm Broadleaved Forest (Group 1-5)**

It occurs at a higher altitude with a lower rainfall and contains a mixture of evergreen and deciduous broad-leaved tree species like that of subtropical forest. Warm broad-leaved forest is present between an altitude of 1000 to 2000 masl (-2300 masl) and precipitation of 2300- 4000mm (Arun and Dawa 2022). *Albizia lebbeck, Schima wallichii, Lagestroemia parviflora, Castanopsis hystrix* species was

recorded as indicator species *(p<0.05)*. Many tropical genera, e.g., *Daubanga grandiflora, Pterospermum acerifolium and Tetramles nudiflora*, are absent and more temperate genera appear. Some of the characteristics species found in the this forest type are; *Alangium chinense, Alnus nepalensis, Betula alnoides, Bischofia javanica, Callicarpa arborea, Castanopsis indica, Cordia obliqua, Dendrocalamus hookeri, Dichroa febrifuga, Engelhardia spicata, Entada spp. Helicia nilagirica, Lithocarpus elegans, L. pachyphyllus, Macaranga spp. Maesa spp., Mussaenda roxburghii, Ostodes paniculata, Pouzolzia sanguinea, Rhaphidophora eximea, Schima wallichii, Stereospermum personatum, Trevesia palmata* etc.

3. Cool broadleaved Forest (Group 1-5)

This particular forest type is typically located at higher elevations on the moister side of the mountain. It is characterized by a mixture of broad-leaved tree species, including both deciduous and evergreen varieties, with oak trees being relatively less common. *Alnus nepalenis* has been identified as the predominant indicator species *(p<0.05)*. The cool broad-leaved forest occurs within an elevation range of 2000 to 2900 meters above sea level and experiences an annual precipitation of 2000 to 3000 millimeters (Arun and Dawa, 2022). This forest type exhibits a close ecological connection with Oak Forest. Notable species found in this forest include *Acer campbellii, Betula alnoides, Beilschmiedia sikkimensis, Brassaiopsis spp., Daphniphyllum himalense, Elatostema spp., Exbucklandia populnea, Ilex fragilis, Lecanthus peduncularis, Michelia doltsopa, Michelia velutina, Persea clarkeana, Persea fructifera, Pilea bracteosa, Rubus lineatus, Symplocos spp.,* and others.

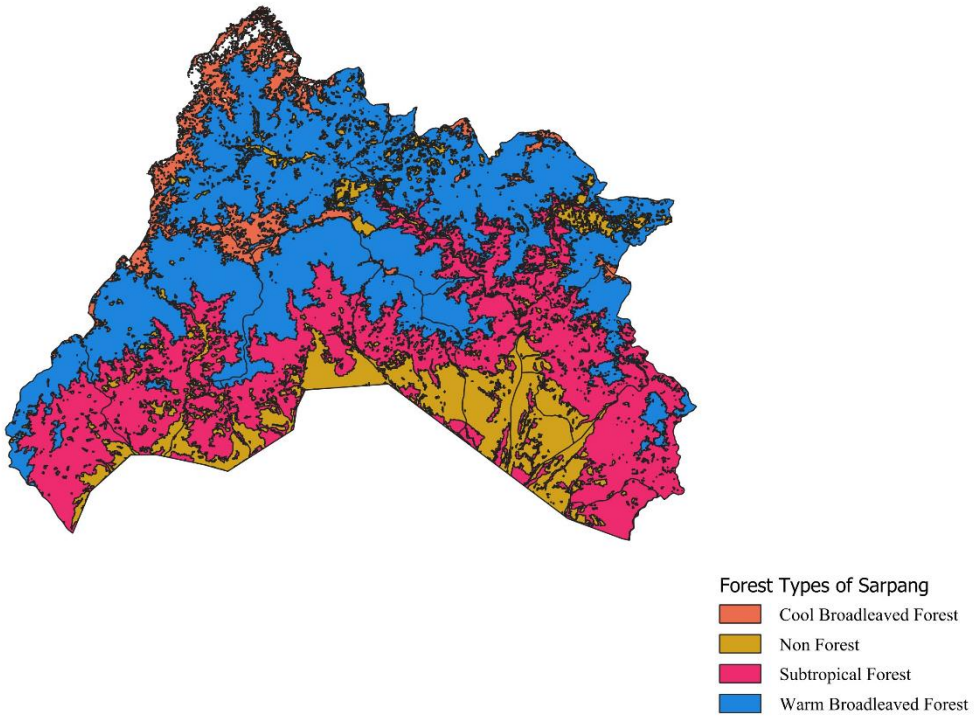


Figure 14: Forest Types of Sarpang

1.6. Influence of environmental variables on vegetation structure and composition

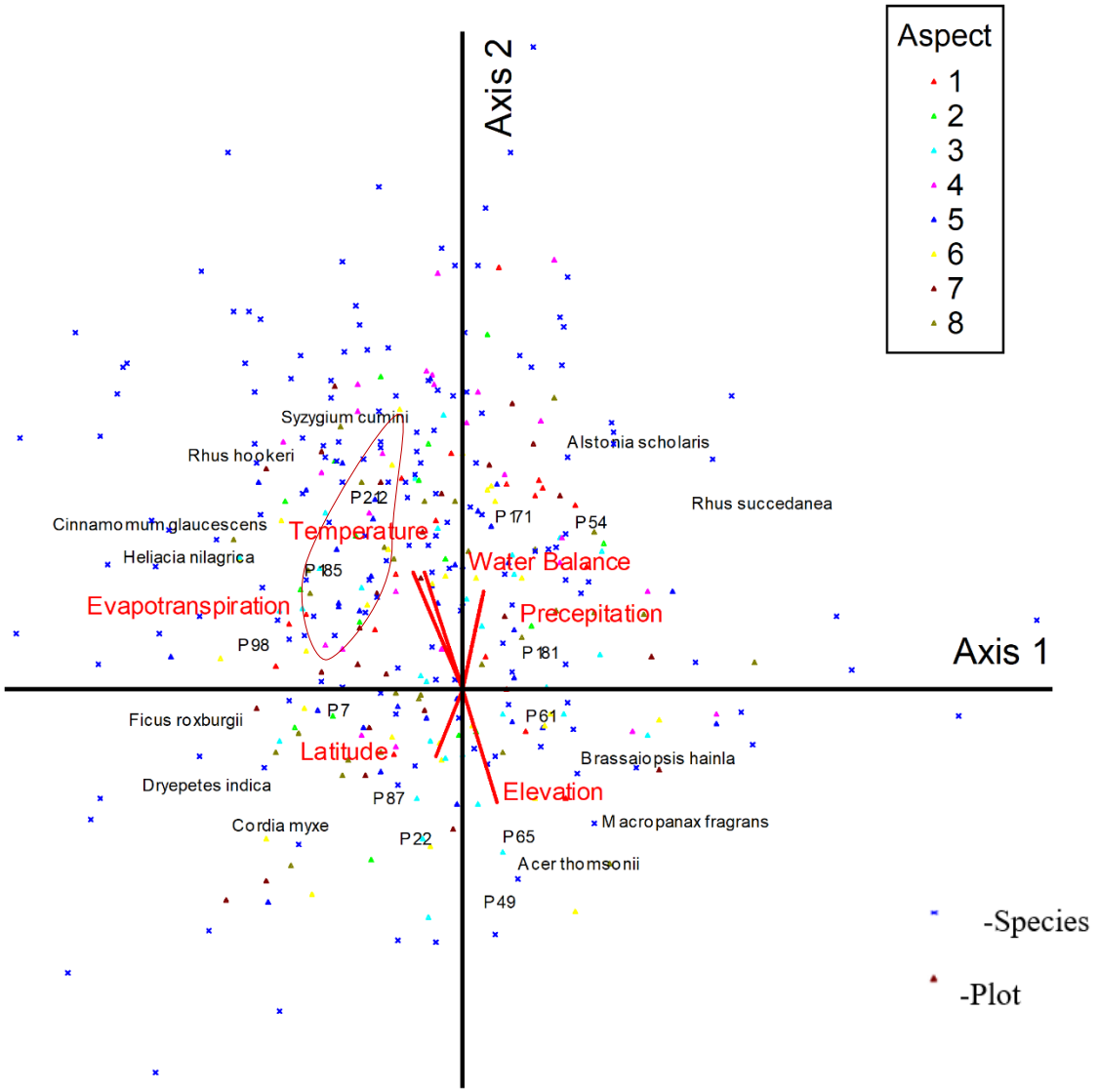


Figure 15: Conical Correspondence Analysis (CCA) graph indicating influence of environmental variables on vegetation structure and composition.

The association between the vegetation structure and environmental characteristics of plots was ascertained using Canonical Correspondence Analysis (CCA) multivariate constrained ordination (Table 7; Fig. 14). Axis 1 is primarily related to latitude, temperature, and evapotranspiration, while Axis 2 is primarily related to elevation, precipitation, and water balance, as shown by the biplots of the CCA ordination (Fig.14).

From the biplot, it can be understood that temperature and evapotranspiration have significant negative correlations with species like *Rhus hookeri, Syzygium cumini, Heliacia nilagrica, and Cinnamomum glaucescens* (r = -0.867 and r = -0.911, respectively). The latitudinal difference has an impact on *Dryeptes indica*, *Ficus roxbhurgii* and *Cordia Myxe* (r=0.374). Precipitation and water balance have an impact on *Rhus succedanea and Alstonia scholaris* (r = 0.385 and 0.411, respectively). Altitudinal variations have an impact on *Acer thomsonii, Macropanax fragans, and*

Brassiopsis hainla (r= -0.014) (Table 8, Fig.10). The clustering of more species with temperature and evaporation shows that these are mostly affected by these two environmental variables rather other variables. There is more clustering of species on temperature and evapotranspiration quadrant indicating these environmental variables have influence of maximum number of species.

Table 7: Correlation between sample scores for an axis derived from the data and the sample scores that are linear combinations of the environmental variables.

Sl. No.	Variable	Axis 1	Axis2	Axis3
1	Elevation	0.853	-0.014	0.364
2	Latitude	0.374	-0.38	0.348
3	Longitude	-0.005	0.054	0.168
4	Slope	0.438	-0.222	-0.087
5	Temperature	-0.867	-0.008	-0.358
6	Precipitation	-0.533	0.385	-0.234
7	Evapotranspiration	-0.911	-0.106	-0.328
8	Water Balance	-0.58	0.411	-0.198
9	Eigenvalue	0.562	0.502	0.291
10	Variance in species data % of IO variance explained	1.5	1.4	0.8
11	Cumulative % explained	1.5	2.9	3.7
12	Pearson Correlation, Spp-Envt*	0.824	0.777	0.704
13	Kendall (Rank) Corr., Spp-Envt	0.455	0.348	0.362

** Correlation between sample scores for an axis derived from the data and the sample scores that are linear combinations of the environmental variables. Set to 0.000 if axis is not canonical. *Correlations are "intraset correlations" of ter Braak (1986)*

1.7.Forest structure features along the altitudinal gradient

Structural traits along the altitudinal gradients were described based on six features (maximum height, maximum diameter at breast height, basal area, stem density, species number and species diversity) and are illustrated in (Table 2). Species richness was accessed in three different vegetation layers (tree & shrub, ground, and epiphyte layers). The higher side diversity index (H') ranges from 2.61 to 3.66 within 8 gewogs (Table 2). The forest stand structural feature is illustrated by DBH class distribution arranged at an interval of 15 cm with 8 classes as shown in Figure?

Within the surveyed area, trees and shrubs were categorized into eight diameter classes, each representing a specific diameter range from 1 to 120 cm DBH (Diameter at Breast Height) as shown in Figure 15. The provided data illustrates the frequency counts for each location within these diameter classes. Notably, there are variations in frequency counts across both the eight gewogs and diameter classes. The maximum count of 352 occurs in the 16-30cm diameter class for Chhudzom Gewog. Overall, this data offers valuable insights into the distribution of diameter classes among the eight gewogs. Similarly, the data provides frequency counts of height classes for trees and shrubs in

the same eight gewogs, categorized into five classes as depicted in Figure 16. The height classes span from 1 to 50 meters, with each class representing a specific range of heights. It is evident that the frequency counts vary among locations and height classes. The highest frequency count of 400 is observed in the 6–10-meter height class in Chhudzom. In general, this data provides valuable insights into the distribution of height classes among the surveyed locations, highlighting variations in tree and shrub heights across different areas.

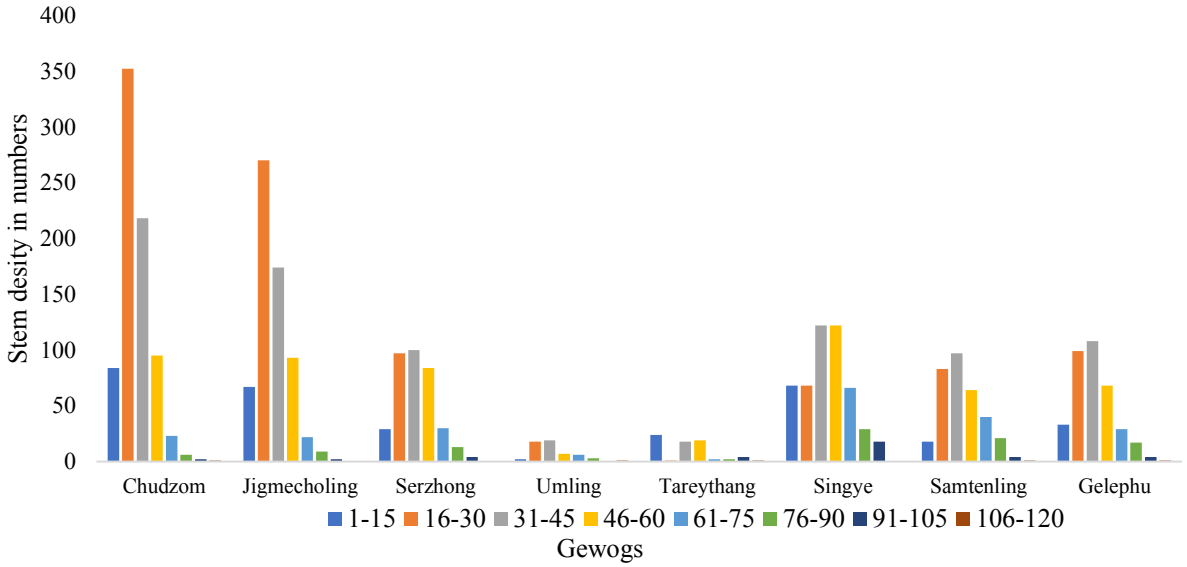


Figure 16:. DBH class distribution of trees inside 8 Gewog illustrating forest structural feature.

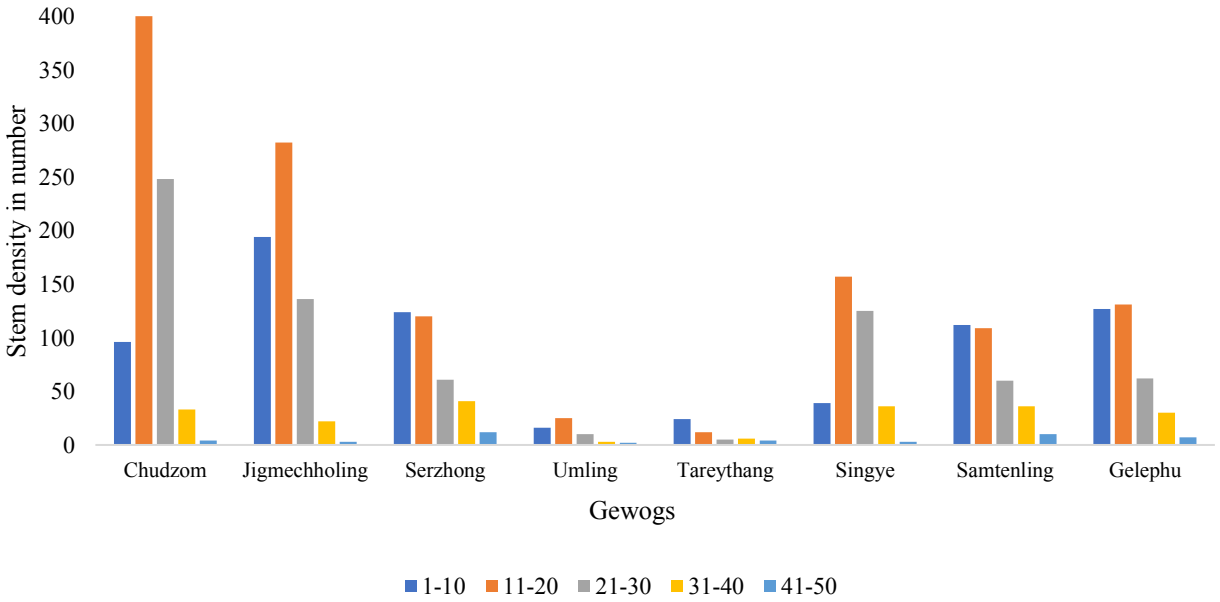


Figure 17:Height class distribution of trees inside 8 Gewog illustrating forest structural feature.

1.8. Species dominance curve

The dominance curve showing the pattern of trees and shrubs ranked by abundance based on RBA% from highest to lowest as shown below. The most dominant species were *Macaranga denticulata, Albizia lebbeck, Alnus nepalensis, Schima Wallichii and Altingia excelsa* and the least dominant species are *Reevesia pubscens, Phyllanthus emblica and Lithocarpus fenestratus*.

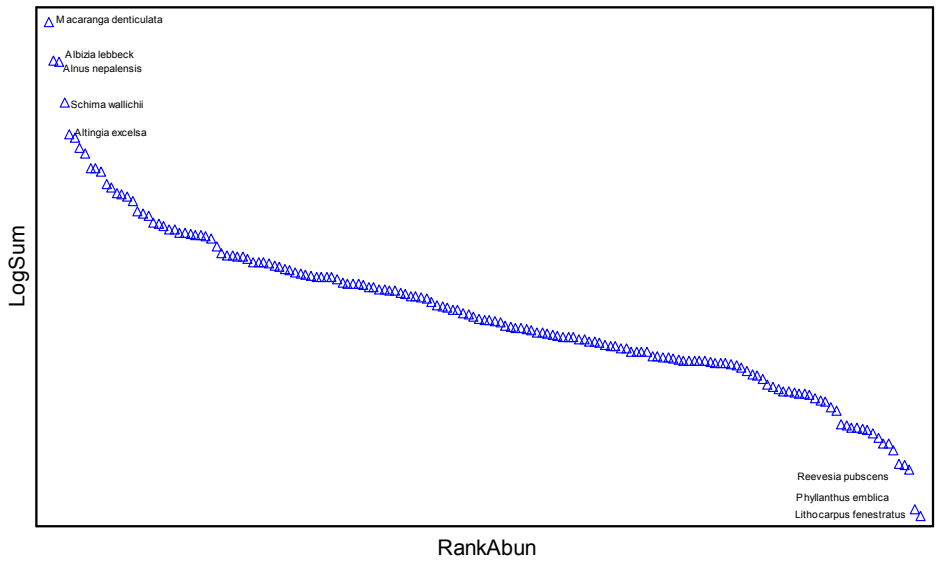


Figure 18:Species dominance curve of tree species.

1.9. Species Area Curve

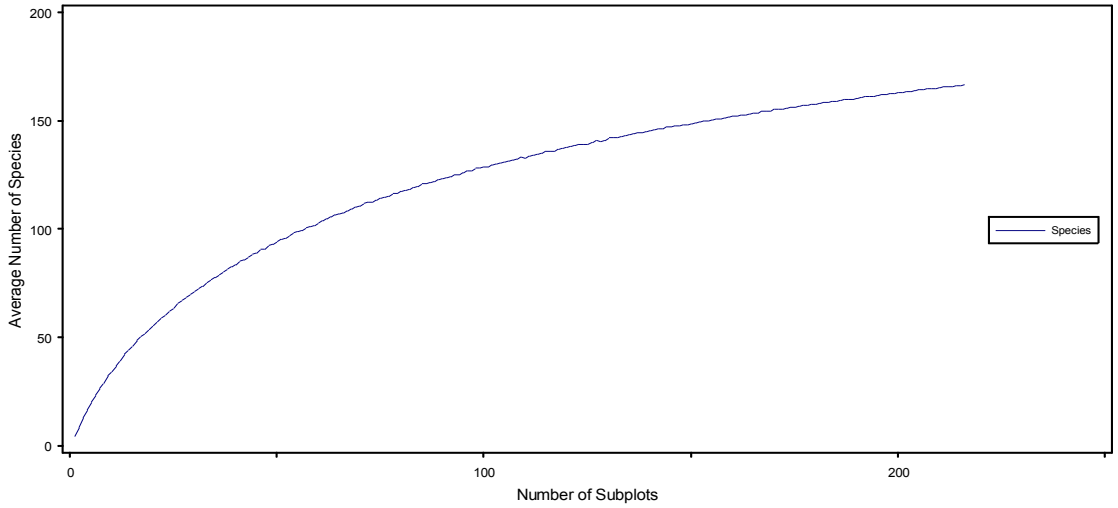


Figure 19:Species Area Curve of tree species.

A species-area curve illustrates the relationship between the habitat's area and the number of species present within that area. It exhibits a pronounced increase in the number of species when the number of surveyed plots ranges from 1 to 100. Beyond this point, there is a more gradual ascent in the number of species between 100 and 200 plots surveyed. However, as the area continues to expand, the curve gradually levels off, indicating that while the number of species initially increases with a larger habitat area, it eventually reaches a stable point. To capture the full diversity of tree species in

Sarpang, it is recommended to survey an area larger than 8 hectares. ($400m^2$ *200=$80,000m^2$, 1 plot =20m*20m= $400m^2$) considering all elevational differences were taken into account.

1.10. Orchids species richness and distribution.

According to the biological diversity checklist published by Tenzin in 2023, Sarpang is home to a rich orchid diversity, with a total of 67 orchid species documented in the region. Among these, three species are classified as critically endangered, while two others are categorized as vulnerable according to the IUCN conservation status (Tenzin, 2023).

These orchid species exhibit a wide altitudinal range, with their presence recorded at elevations ranging from a minimum of 200 meters above sea level (masl) to a maximum of 3800 masl (Choden et al., 2021). This diverse range of elevations underscores the adaptability and ecological significance of these orchids within the Sarpang region (Table 8).

Table 8:List of Orchid species of Sarpang Dzongkhag along with their distribution range (Elevation) and their IUCN conservation status

Sl. No	Scientific name	Families	Elevation Ranges	IUCN conservation status
1	*Paphiopedium fairrieanum*	Orchidaceae	1000-2000masl	CE
2	*Cheirostlis sherriffii*	Orchidaceae	900-1700 masl	CE
3	*Liparis cordifolia*	Orchidaceae	1000-2000masl	*N/A
4	*Liparis bistriata*	Orchidaceae	900-1700 masl	N/A
5	*Liparis cespitosa*	Orchidaceae	300-2100masl	N/A
6	*Liparis viridiflora*	Orchidaceae	270-1600	N/A
7	*Malaxis ophrydis*	Orchidaceae	500-2800 masl	N/A
8	*Oberonia acaulis*	Orchidaceae	1000-1750masl	N/A
9	*Oberonia mucronata*	Orchidaceae	200-1000 masl	N/A
10	*Oberonia pachyrachis*	Orchidaceae	800-1500masl	N/A
11	*Cymbidium aloifolium*	Orchidaceae	350-2000 masl	CE
12	*Cymbidium devonianum*	Orchidaceae	1300-2600masl	V
13	*Cymbidium mastersii*	Orchidaceae	900-2200masl	V
14	*Calanthe biloba*	Orchidaceae	1000-2000 masl	N/A
15	*Calanthe plantaginea*	Orchidaceae	1000-3000masl	N/A
16	*Phaius flavus*	Orchidaceae	500-2500 masl	N/A
17	*Arundina graminifolia*	Orchidaceae	300-2000masl	N/A
18	*Thunia alba*	Orchidaceae	350-2000 masl	N/A
19	*Thunia alba var bracteata*	Orchidaceae	660-1600 masl	N/A
20	*Coelogyne fuscescens Lindley var Fuscecens*	Orchidaceae	750-2000 masl	N/A
21	*Coelogyne flacida Lindley*	Orchidaceae	330-2300 masl	N/A
22	*Coelogyne corymbosa*	Orchidaceae	1500-3800 masl	N/A
23	*Coelogyne nitida*	Orchidaceae	1200-2900 masl	N/A
24	*Coelogyne barbata Griffith*	Orchidaceae	1000-2000 masl	N/A
25	*Coelogyne stricta*	Orchidaceae	1000-2000 masl	N/A
26	*Neogyna gardneriana*	Orchidaceae	1000-2600 masl	N/A
27	*Panisea demissa*	Orchidaceae	1000-3000 masl	N/A
28	*Pholidota articulate Lindley*	Orchidaceae	300-2330 masl	N/A
29	*Pholidota imbricata Hooker*	Orchidaceae	350-1350 masl	N/A

30	*Pholidota pallida Lindley*	Orchidaceae	1000-2300 masl	N/A
31	*Pleione maculate*	Orchidaceae	600-1600 masl	N/A
32	*Agrostopphyllum brevipes*	Orchidaceae	1000-1800 masl	N/A
33	*Eria carinata Lindley*	Orchidaceae	300-1800 masl	N/A
34	*Eria lasiopetala (Wildenow) Ormerod*	Orchidaceae	400-1000 masl	N/A
35	*Eria paniculata Lindley*	Orchidaceae	600-2330 masl	N/A
36	*Eria stricta Lindley*	Orchidaceae	330-1800 masl	N/A
37	*Trichotosia dasyphylla*	Orchidaceae	330-1000 masl	N/A
38	*Dendrobium densiflorum Lindley*	Orchidaceae	350-2000 masl	N/A
39	*Dendrobium jenkinsii Lindely*	Orchidaceae	800-1400 masl	N/A
40	*Dendrobium aphyllum (Roxburgh)*	Orchidaceae	300-1700 masl	N/A
41	*Dendrobium chrysanthum Lindley*	Orchidaceae	1000-2000 masl	N/A
42	*Dendrobium moschatum Swartz*	Orchidaceae	300-1000 masl	N/A
43	*Dendrobium ruckeri Lindley*	Orchidaceae	1200-2000 masl	N/A
44	*Dendrobium transparens Lindley*	Orchidaceae	1300-3000 masl	N/A
45	*Dendrobium cathcartii J.D. Hooker*	Orchidaceae	300-1200 masl	N/A
46	*Epigenium navicularis*	Orchidaceae	1600-1800 masl	N/A
47	*Epigenium rotundatum*	Orchidaceae	1300-3000 masl	N/A
48	*Flickingeria fugax*	Orchidaceae	800-1650 masl	N/A
49	*Bulbophyllum odoratissimum*	Orchidaceae	1000-2300 masl	N/A
50	*Bulbophyllum thomsonii*	Orchidaceae	800-2200 masl	N/A
51	*Bulbophyllum helenae*	Orchidaceae	830-2600 masl	N/A
52	*Ione bicolor*	Orchidaceae	1600-2400 masl	N/A
53	*Acampe papillosa*	Orchidaceae	300-900 masl	N/A
54	*Aerides odoratum*	Orchidaceae	300-900 masl	N/A
55	*Aerides multiflorum*	Orchidaceae	200-650masl	N/A
56	*Ascocentrum ampullaceum*	Orchidaceae	330-1000 masl	N/A
57	*Chiloschista parishii*	Orchidaceae	660-1800 masl	N/A
58	*Esmeralda cathcartii*	Orchidaceae	660-2000 masl	N/A
59	*Gastrochilus calceolaris*	Orchidaceae	1500-2000 masl	N/A
60	*Gastrochilus inconspicuous*	Orchidaceae	200-800 masl	N/A
61	*Pteroceras teres*	Orchidaceae	200-800 masl	N/A
62	*Rhynchostylis retusa*	Orchidaceae	300-800 masl	N/A
63	*Smitinandia mocrantha*	Orchidaceae	500-1500 masl	N/A
64	*Vanda cristata Lindley*	Orchidaceae	800-2000 masl	N/A
65	*Vinda griffithii Lindley*	Orchidaceae	250-1000 masl	N/A
66	*Vinda testacea*	Orchidaceae	780-2000 masl	N/A
67	*Galeola falconeri*	Orchidaceae	800-2000 masl	N/A

1.11. Other Epiphytic Species

Based on a review of the available literature on epiphytic species in Bhutan and the surrounding region, 27 species of epiphytic species are recorded in Sarpang (Bhutan Biodiversity Portal, 2023). The list is solely based climatic conditions and habitat features or forest types on available literature and may be included species which are non-existent. So additional research may need to confirm availability of these species in Sarpang.

Table 9: List of epiphytic species of Sarpang (Rai & Moktan, 2022).

Sl. No.	Species Name	Family	IUCN Conservation Status
1	*Begonia picta*	Begoniaceae	DD
2	*Bromelia pinguin*	Bromeliaceae	NE
3	*Cissus discolor*	Vitaceae	NE
4	*Dischidia nummularia*	Apocynaceae	NE
5	*Hoya linearis*	Apocynaceae	NE
6	*Peperomia pellucida*	Piperaceae	NE
7	*Philodendron hederaceum*	Araceae	NE
8	*Pilea peperomioides*	Urticaceae	NE
9	*Platycerium bifurcatum*	Polypodiaceae	NE
10	*Rhipsalis baccifera*	Cactaceae	NE
11	*Tillandsia usneoides*	Bromeliaceae	LC
12	*Tradescantia zebrina*	Commelinaceae	NE
13	*Aeschynanthus bracteatus*	Gesneriaceae	LC
14	*Aeschynanthus sikkimensis*	Gesneriaceae	DD
15	*Agapetes hookeri*	Ericaceae	LC
16	*Agapetes serpens*	Ericaceae	LC
17	*Cautleya gracilis*	Zingiberaceae	LC
18	*Euonymus theifolia*	Celastraceae	LC
19	*Euonymus vegans*	Celastraceae	DD
20	*Hedera nepalensis*	Araliaceae	NE
21	*Hoya diversifolia*	Asclepiadaceae	LC
22	*Peperomia heyneana*	Peperomiaceae	LC
23	*Peperomia tetraphylla*	Peperomiaceae	LC
24	*Pilea ternifolia*	Urticaceae	LC
25	*Remusetia vivipara*	Araceae	LC
26	*Schefflera bengalensis*	Araliaceae	LC
27	*Vaccinium serratum*	Vacciniaceae	LC

1.12.Bamboo species & distribution

In Sarpang, as of 2023, there is a diverse range of bamboo species with a total count of 17 species, as documented by (Tenzin, 2023). These bamboo varieties flourish throughout the Sarpang dzongkhag, gracing both the foothills and hilltops of the region(Jambay & Dahal, 2023). Within this rich bamboo biodiversity, their conservation statuses vary, with one species classified as "vulnerable" according to the IUCN status, another as "data deficient" (DD), one more listed as "least concern" (LC), one categorized as "almost threatened" (AT), while the rest fall under the "least concern" category, as detailed in Table 10.

Table 10: List of bamboo species in Sarpang according to secondary sources (Jambay & Dahal, 2023.; Tenzin, 2023).

#	Name of species	Common name	Family	Distribution	IUCN conservation status
1	*Bambusa allamii*	Mugi bans (Nep)	Poaceae	Serzhong, Gelephu, Chhuzergang	DD
2	*Bambusa balcooa*	Balcooa (Nep)	Poaceae	Serzhong, Chuzagang,	NE
3	*Bambusa clavata*	Chilli bans (Nep)	Poaceae	Dabgoan, Jigmecholing	V
4	*Bambusa multiplex*	Chinese bamboo	Poaceae	Sarpangtar, Samtenling	NE
5	*Bambusa nutans*	Mal bans (Nep), Pakshing(Dzo)	Poaceae	All 12 gewogs	NE

6	*Bambusa tulda*	NA	Poaceae	Sarpang	NE
7	*Dendrocalamus hamiltronii*	Choya bans (Nep)	Poaceae	Singye, Sarpang, Gelephu	LC
8	*Dendrocalamus sikkimensis*	Balu bans (Nep), Demchar (Shar)	Poaceae	Chudzom	NE
9	*Melocanna baccifera*	NA	Poaceae	Jigmeling, Dekidling	NE
10	*Cephalostachyum capitatum*	Philim Bans (Nep)	Poaceae	Chudzom, Gakidling	NE
11	*Cephalostachyum latifolium*	Philim bans (Nep)	Poaceae	Gakidling (Darachu area)	NE
12	*Pseudostachyum polymorphum*	NA	Poaceae	Darachu, Sarpang	NE
13	*Arundinaria racemose*	NA	Poaceae	Pangkhey, Chhudzom	NE
14	*Drepanostachyum intermedium*	Phalsho(Shar)	Poaceae	Tsangchu, Jigmecholing	NE
15	*Neomicrocalamus andropogonifolius*	Ringshu (Shar)	Poaceae	Galeychu, Dholkhola, Khatley	NE
16	*Chiminobambusa callosa*	Rashi (Shar)	Poaceae	Darachu Jigmecholing	NE
17	*Bambusa valgaris*	Yellow bamboo (common name)	Poaceae	Gelephu	AT

1.13.Grasses

Grasses, a diverse and widespread group of flowering plants in the Poaceae family, are foundational components of terrestrial ecosystems and have profound ecological and economic significance. They provide essential forage for herbivores, support biodiversity by forming the basis of food webs, and help stabilize soil(Tomaškin & Tomaškinová, 2012). Grasses are crucial for agriculture, serving as staple crops for human consumption and as livestock feed. They also play roles in carbon cycling and climate regulation by sequestering carbon dioxide and influencing local climate patterns(*About Grass*, n.d.).

Table 11: List of grass species in Sarpang according to secondary sources(Lægaard, 2001; Roder, 2002).

Sl.no.	Family	Species	Sl.no.	Family	Species
1	Andropogoneae	*Andropogon annulatus*	42	Andropogoneae	*Miscanthus japonicus*
2	Andropogoneae	*Andropogon ascinodis*	43	Andropogoneae	*Miscanthus nepalensis*
3	Andropogoneae	*Andropogon brevifolius*	44	Andropogoneae	*Miscanthus sinensis*
4	Andropogoneae	*Andropogon caricosus*	45	Andropogoneae	*Saccharum officinarum*
5	Andropogoneae	*Andropogon chinensis*	46	Bambusoideae	*Bambusa arundinacea*
6	Andropogoneae	*Andropogon citratus*	47	Bambusoideae	*Bambusa balcooa*
7	Andropogoneae	*Andropogon compressus*	48	Bambusoideae	*Bambusa nutans*
8	Andropogoneae	*Andropogon contortus*	49	Bambusoideae	*Bambusa polymorpha*
9	Andropogoneae	*Andropogon hallii*	50	Bambusoideae	*Dendrocalamus hamiltonii*
10	Andropogoneae	*Andropogon micay*	51	Bambusoideae	*Melocanna baccifera*
11	Andropogoneae	*Andropogon nardus*	52	Bambusoideae	*Neomicrocalamus prainii*
12	Andropogoneae	*Andropogon pertusus*	53	Bambusoideae	*Pseudostachyum polymorphum*
13	Andropogoneae	*Andropogon pseudopaniculatus*	54	Panicoideae	*Aristida adscensionis*
14	Andropogoneae	*Andropogon pumilus*	55	Panicoideae	*Aristida cyanantha*
18	Andropogoneae	*Andropogon reflexus*	56	Panicoideae	*Aristida depressa*
19	Andropogoneae	*Andropogon sorghum*	57	Panicoideae	*Aristida funiculata*
20	Andropogoneae	*Arthraxon hispidus*	58	Panicoideae	*Aristida setacea*
21	Andropogoneae	*Arthraxon lancifolius*	59	Panicoideae	*Arundinella bengalensis*
22	Andropogoneae	*Arthraxon prionodes*	60	Panicoideae	*Arundinella nepalensis*
23	Andropogoneae	*Arthraxon quartinianus*	61	Panicoideae	*Arundinella setosa*
24	Andropogoneae	*Arthraxon serrulatus*	62	Panicoideae	*Brachiaria decumbens*

25	Andropogoneae	*Arthraxon submuticus*	63	Panicoideae	*Brachiaria distachya*
26	Andropogoneae	*Chrysopogon aciculatus*	64	Panicoideae	*Brachiaria mutica*
27	Andropogoneae	*Chrysopogon gryllus*	65	Panicoideae	*Brachiaria reptans*
28	Andropogoneae	*Chrysopogon montanus*	66	Panicoideae	*Cenchrus ciliaris*
29	Andropogoneae	*Chrysopogon zizanioides*	67	Panicoideae	*Cenchrus echinatus*
30	Andropogoneae	*Cymbopogon citratus*	68	Panicoideae	*Cenchrus pennisetiformis*
31	Andropogoneae	*Cymbopogon distans*	69	Panicoideae	*Chrysopogon aciculatus*
32	Andropogoneae	*Cymbopogon martinii*	70	Panicoideae	*Chrysopogon gryllus*
33	Andropogoneae	*Cymbopogon nardus*	71	Panicoideae	*Cynodon dactylon*
34	Andropogoneae	*Cymbopogon pendulus*	72	Panicoideae	*Digitaria adscendens*
35	Andropogoneae	*Heteropogon contortus*	73	Panicoideae	*Digitaria sanguinalis*
36	Andropogoneae	*Imperata cylindrica*	74	Panicoideae	*Echinochloa colona*
37	Panicoideae	*Isachne albens*	75	Panicoideae	*Echinochloa crus-galli*
38	Panicoideae	*Isachne elegans*	76	Panicoideae	*Eragrostis ciliaris*
39	Panicoideae	*Isachne globosa*	77	Panicoideae	*Eragrostis tenella*
40	Panicoideae	*Leersia hexandra*	78	Panicoideae	*Eulalia leptostachya*
41	Panicoideae	*Oplismenus compositus*	79	Panicoideae	*Heteropogon contortus*

1.14. Lichen species richness

Based on existing literature on lichen species diversity and distribution in Bhutan(Aptroot1 & Feijen2, 2002.), Nepal(Bahadur Baniya, 2022), Sikkim(Sinha & Ram, 2009.), and Arunachal Pradesh(Yang et al., 2021), a compilation of 43 lichen species has been identified as potential inhabitants of Sarpang (Table 12). This selection is based on shared climatic conditions and habitat characteristics.

Table 12:List of Lichen species that could occur in Sarpang based on existing literature

SL. no.	Species Name	Family	IUCN Conservation Status
1	*Alectoria nigricans*	Alectoriaceae	LC
2	*Anaptychia speciosa*	Parmeliaceae	LC
3	*Anzia colpodes*	Parmeliaceae	LC
4	*Arthonia leucopallaea*	Arthoniaceae	LC
5	*Arthothelium ruanum*	Arthotheliaceae	LC
6	*Bryoria capillaris*	Parmeliaceae	LC
7	*Caloplaca thallincola*	Teloschistaceae	LC
8	*Candelaria concolor*	Candelariaceae	LC
9	*Candelariella vitellina*	Candelariaceae	LC
10	*Cetraria islandica*	Parmeliaceae	LC
11	*Cladonia foliacea*	Cladoniaceae	LC
12	*Cladonia furcata*	Cladoniaceae	LC
13	*Cladonia pyxidata*	Cladoniaceae	LC
14	*Cladonia rangiferina*	Cladoniaceae	LC
15	*Collema coccophorum*	Collemataceae	LC
16	*Collema nigrescens*	Collemataceae	LC
17	*Cornicularia divergens*	Ramalinaceae	LC
18	*Dermatocarpon miniatum*	Verrucariaceae	LC
19	*Evernia prunastri*	Parmeliaceae	LC
20	*Flavoparmelia caperata*	Parmeliaceae	LC

21	*Flavoparmelia soredians*	Parmeliaceae	LC
22	*Hypotrachyna revoluta*	Parmeliaceae	LC
23	*Hypogymnia physodes*	Parmeliaceae	LC
24	*Lasallia papulosa*	Parmeliaceae	LC
25	*Leptogium pulmonarium*	Collemataceae	LC
26	*Lobaria pulmonaria*	Lobariaceae	LC
27	*Nephroma arcticum*	Nephromaceae	LC
28	*Nephroma helveticum*	Nephromaceae	LC
29	*Ochrolechia parella*	Parmeliaceae	LC
30	*Parmelia sulcata*	Parmeliaceae	LC
31	*Peltigera aphthosa*	Peltigeraceae	LC
32	*Peltigera canina*	Peltigeraceae	LC
33	*Pertusaria pertusa*	Pertusariaceae	LC
34	*Physcia aipolia*	Physciaceae	LC
35	*Physcia stellaris*	Physciaceae	LC
36	*Platismatia glauca*	Parmeliaceae	LC
37	*Pseudevernia furfuracea*	Parmeliaceae	LC
38	*Ramalina dilacerata*	Ramalinaceae	LC
39	*Ramalina farinacea*	Ramalinaceae	LC
40	*Ramalina pollinaria*	Ramalinaceae	LC
41	*Rhizocarpon geographicum*	Rhizocarpaceae	LC
42	*Sticta limbata*	Lobariaceae	LC
43	*Usnea florida*	Parmeliaceae	LC

1.14.Bryophytes

Bryophytes are non-vascular plants comprising mosses, liverworts, and hornworts, characterized by their small size, lack of true roots, and importance in ecosystems for soil stability and moisture retention. They play a vital role in early terrestrial plant evolution(By & Neupane, 2023). Bryophytes consist of three main groups i.e., Mosses, Liverworts, Hornworts. The tables presented below provide a compilation of mosses, liverworts, and hornworts that have the potential to thrive in Sarpang. This list has been curated based on available literature from Bhutan, Nepal, Sikkim, and adjacent regions.

Mosses (Phylum Bryophyta)

Mosses are small, non-vascular plants belonging to the phylum Bryophyta. They thrive in damp environments, lack true roots, and contribute to ecosystem health by providing habitat, retaining moisture, and aiding soil stabilization. There are 283 species of mosses belonging to 47 families in Bhutan (Thomas & Long, 2017). However, based ecological conditions of Sarpang dzongkhag, 49 species of mosses are recorded (Table13). The species listed in table 13 may be more likely to occur in Sarpang, listed based on existing literatures. More research is needed to determine the full extent of mosses diversity in Sarpang.

Table 13:Mosses species list of Sarpang.

Sl.no.	Species Name	Family
1	*Acanthorrhynchium subserratum*	Bryaceae
2	*Acroporium cuspidatum*	Bryaceae
3	*Amblystegium serpens*	Amblystegiaceae

4	*Andreaea rupestris*	Andreaeaceae
5	*Aneura pinguis*	Aneuraceae
6	*Atrichum undulatum*	Polytrichaceae
7	*Barbula unguiculata*	Pottiaceae
8	*Bryum argenteum*	Bryaceae
9	*Campylopus introflexus*	Dicranaceae
10	*Ceratodon purpureus*	Dicranaceae
11	*Climacium dendroides*	Climaciaceae
12	*Conocephalum conicum*	Conocephalaceae
13	*Dicranella heteromalla*	Dicranellaceae
14	*Didymodon tophaceus*	Pottiaceae
15	*Distichium capillaceum*	Ditrichaceae
16	*Encalypta vulgaris*	Encalyptaceae
17	*Entodon schreberi*	Entodontaceae
18	*Eurhynchium riparioides*	Brachytheciaceae
19	*Fissidens taxifolius*	Fissidentaceae
20	*Funaria hygrometrica*	Funariaceae
21	*Grimmia apocarpa*	Grimmiaceae
22	*Hedwigia ciliata*	Hedwigiaceae
23	*Hylocomium splendens*	Hylocomiaceae
24	*Hypnum cupressiforme*	Hypnaceae
25	*Isopterygium tenerum*	Hypnaceae
26	*Leucobryum glaucum*	Leucobryaceae
27	*Marchantia polymorpha*	Marchantiaceae
28	*Metzgeria furcata*	Metzgeriaceae
29	*Mnium hornum*	Mniaceae
30	*Orthotrichum lyellii*	Orthotrichaceae
31	*Philonotis fontana*	Bartramiaceae
32	*Physcomitrella patens*	Funariaceae
33	*Plagiochila asplenioides*	Plagiochilaceae
34	*Pleurozium schreberi*	Hylocomiaceae
35	*Pogonatum contortum*	Polytrichaceae
36	*Pohlia nutans*	Bryaceae
37	*Polytrichum commune*	Polytrichaceae
38	*Pseudocrossidium revolutum*	Pottiaceae
39	*Racomitrium lanuginosum*	Grimmiaceae
40	*Rhytidiadelphus squarrosus*	Hylocomiaceae
41	*Schistidium apocarpum*	Grimmiaceae
42	*Sphagnum palustre*	Sphagnaceae
43	*Taxiphyllum taxirameum*	Hypnaceae
44	*Thuidium tamariscinum*	Thuidiaceae
45	*Tortula ruralis*	Pottiaceae
46	*Trichostomum brachydontium*	Pottiaceae
47	*Ulota crispa*	Orthotrichaceae
48	*Weissia controversa*	Pottiaceae
49	*Zygodon viridissimus*	Orthotrichaceae

Liverworts (Phylum Marchantiophyta)

Liverworts, scientifically known as Phylum Marchantiophyta, are a type of non-vascular, bryophytic plants that belong to the division Marchantiophyta. As per a list of liverworts published in GBIF by (Gyeltshen C & Prasad K, 2022). , there are 96 species of liverworts in Bhutan. Based on different forest ecosystems and climatic variations, a total of 64 species of liverworts that occur in Sarpang (Table 14).

Table 14:List of liverworts that could potentially occur in Sarpang based on review of available literature(Gyeltshen C & Prasad K, 2022; Paudel & Joshi, n.d.)

Sl. no.	Species name	Family
1	*Asterella blumei*	Aytoniaceae
2	*Asterella limbata*	Aytoniaceae
3	*Asterella musciformis*	Aytoniaceae
4	*Asterella wallichiana*	Aytoniaceae
5	*Bazzania assamica*	Lepidoziaceae
6	*Bazzania bhutanica*	Lepidoziaceae
7	*Bazzania japonica*	Lepidoziaceae
8	*Bazzania levieri*	Lepidoziaceae
9	*Bazzania madagascariensis*	Lepidoziaceae
10	*Bazzania nepalensis*	Lepidoziaceae
11	*Bazzania pellucida*	Lepidoziaceae
12	*Bazzania subpellucida*	Lepidoziaceae
13	*Bazzania tridens*	Lepidoziaceae
14	*Blepharostoma trichophyllum*	Jungermanniaceae
15	*Cephalozia connivens*	Cephaloziaceae
16	*Cephalozia pleniceps*	Cephaloziaceae
17	*Cololejeunea dozyana*	Lejeuneaceae
18	*Cololejeunea herzogii*	Lejeuneaceae
19	*Cololejeunea inflata*	Lejeuneaceae
20	*Cololejeunea nepalensis*	Lejeuneaceae
21	*Cololejeunea subinflata*	Lejeuneaceae
22	*Cololejeunea subtumida*	Lejeuneaceae
23	*Colura calyptrifolia*	Calypogeiaceae
24	*Colura gemmascens*	Calypogeiaceae
25	*Colura tenuis*	Calypogeiaceae
26	*Dicranolejeunea nepalensis*	Lejeuneaceae
27	*Diplophyllum albicans*	Scapaniaceae
28	*Diplophyllum obtusifolium*	Scapaniaceae
29	*Diplophyllum taxifolium*	Scapaniaceae
30	*Drepanolejeunea sikkimensis*	Lejeuneaceae
31	*Frullania bhutanica*	Frullaniaceae
32	*Frullania dilatata*	Frullaniaceae
33	*Frullania nepalensis*	Frullaniaceae
34	*Frullania tamarisci*	Frullaniaceae
35	*Gymnocolea inflata*	Gymnocoleaceae
36	*Gymnomitrium corallioides*	Gymnomitriaceae
37	*Gymnomitrium nepalense*	Gymnomitriaceae
38	*Herbertus aduncus*	Herbertaceae

39	*Herbertus reflexus*	Herbertaceae
40	*Jungermannia neesiana*	Jungermanniaceae
41	*Kurzia bhutanica*	Jungermanniaceae
42	*Kurzia rupestris*	Jungermanniaceae
43	*Lejeunea bhutanica*	Lejeuneaceae
44	*Lejeunea cavifolia*	Lejeuneaceae
45	*Lejeunea decurrens*	Lejeuneaceae
46	*Lejeunea nepalensis*	Lejeuneaceae
47	*Lejeunea sandvicensis*	Lejeuneaceae
48	*Lepidozia bhutanica*	Lepidoziaceae
49	*Lepidozia delavayi*	Lepidoziaceae
50	*Lepidozia nepalensis*	Lepidoziaceae
51	*Lepidozia reptans*	Lepidoziaceae
52	*Lepidozia subcapitata*	Lepidoziaceae
53	*Lophocolea bidentata*	Lophocoleaceae
54	*Lophocolea bhutanica*	Lophocoleaceae
55	*Lophocolea nepalensis*	Lophocoleaceae
56	*Marchantia nepalensis*	Marchantiaceae
57	*Marchantia polymorpha*	Marchantiaceae
58	*Metzgeria furcata*	Metzgeriaceae
59	*Metzgeria nepalensis*	Metzgeriaceae
60	*Microlejeunea nepalensis*	Lejeuneaceae
61	*Odontoschisma denudatum*	Cephaloziaceae
62	*Odontoschisma elongatum*	Cephaloziaceae
63	*Odontoschisma macounii*	Cephaloziaceae
64	*Odontoschisma nepalense*	Cephaloziaceae

Hornworts (Phylum Anthocerotophyta)

Hornworts are primitive, non-vascular plants in the phylum Anthocerotophyta, recognized by their unique horn-shaped sporophyte structures(Buck et al., 2011). They have a simple structure, play roles in nitrogen fixation, and contribute to soil improvement in some ecosystems(Pradhan & Our, 2007). This list is based on a review of the literature on hornworts in Bhutan and the surrounding region.

However, it is important to note that hornworts are a relatively understudied group of plants, and new species are being discovered all the time. Therefore, it is possible that there are other species of hornworts that occur in Sarpang that are not included on this list.

Table 15:list of hornwort species that could occur in Sarpang.

Sl.No.	Species Name	Family
1	*Anthoceros agrestis*	Anthocerotaceae
2	*Anthoceros bhardwajii*	Anthocerotaceae
3	*Anthoceros crispulus*	Anthocerotaceae
4	*Anthoceros erectus*	Anthocerotaceae
5	*Anthoceros fimbriatus*	Anthocerotaceae
6	*Anthoceros hedinii*	Anthocerotaceae
7	*Anthoceros himalayensis*	Anthocerotaceae
8	*Anthoceros javanicus*	Anthocerotaceae

9	*Anthoceros laevis*	Anthocerotaceae
10	*Anthoceros macrosporus*	Anthocerotaceae
11	*Anthoceros megastomus*	Anthocerotaceae
12	*Anthoceros mulleri*	Anthocerotaceae
13	*Anthoceros nepalensis*	Anthocerotaceae
14	*Anthoceros pandei*	Anthocerotaceae
15	*Anthoceros punctatus*	Anthocerotaceae
16	*Anthoceros rajasthanensis*	Anthocerotaceae
17	*Anthoceros rostratus*	Anthocerotaceae
18	*Anthoceros satoi*	Anthocerotaceae
19	*Anthoceros scaber*	Anthocerotaceae
20	*Anthoceros squarrosus*	Anthocerotaceae
21	*Anthoceros sublaevis*	Anthocerotaceae
22	*Anthoceros tuberculosus*	Anthocerotaceae
23	*Dendroceros bipinnatus*	Dendrocerotaceae
24	*Dendroceros crispus*	Dendrocerotaceae
25	*Dendroceros javanicus*	Dendrocerotaceae
26	*Dendroceros latus*	Dendrocerotaceae
27	*Dendroceros minor*	Dendrocerotaceae
28	*Dendroceros squamatus*	Dendrocerotaceae
29	*Megaceros aenigmaticus*	Megacerotaceae
30	*Megaceros giganteus*	Megacerotaceae
31	*Megaceros hornworts*	Megacerotaceae

1.15. Various species of fungi/mushrooms in Sarpang.

Fungi and mushrooms are vital for recycling nutrients and supporting plant growth in ecosystems. They also serve as a valuable food source and contribute to medicine and various industrial processes(Mata et al., 2010). There are 690 species of fungi in Bhutan(Gyeltshen & Prasad, 2022). A total of 41 species of fungi species were listed based review of available literature. The species could occur in Sarpang based on ecological conditions.

Table 16: List of Fungi species that could exist in Sarpang

Sl. No.	Scientific Name	Common Name
1	*Agaricus augustus*	Prince mushroom
2	*Agaricus bisporus*	Button mushroom
3	*Albatrellus caeruleoporus*	Blue-pored polypore
4	*Aleuria aurantia*	Orange peel fungus
5	*Amanita caesarea*	Caesar's amanita
6	*Amanita hemibapha*	Gongsey Shamong
7	*Amanita vaginata*	Grisette
8	*Armillaria mellea*	Honey fungus
9	*Auricularia auricula-judae*	Judas's ear
10	*Boletus edulis*	King bolete
11	*Boletus ornatipes*	Ornate-stemmed bolete
12	*Bondarzewia montana*	Mountain mushroom
13	*Calvatia gigantea*	Giant puffball
14	*Cantharellus cibarius*	Golden chanterelle

15	*Catathelasma imperiale*	Emperor's candy cap
16	*Clavariadelphus pistillaris*	Yellow coral fungus
17	*Clitocybe gibba*	Camphor mushroom
18	*Clitopilus prunulus*	Clustered wood blewit
19	*Coprinus comatus*	Shaggy ink cap
20	*Cortinarius caperatus*	Gypsy mushroom
21	*Craterellus cornucopioides*	Black trumpet
22	*Dacrymyces palmatus*	Ice jelly fungus
23	*Fistulina hepatica*	Beefsteak fungus
24	*Flammulina velutipes*	Enoki mushroom
25	*Ganoderma lucidum*	Reishi mushroom
26	*Gomphus clavatus*	Clavate chanterelle
27	*Gomphus floccosus*	Flocculent chanterelle
28	*Helvella crispa*	Elfin's saddle
29	*Hericium erinaceus*	Lion's mane mushroom
30	*Hydnum repandum*	Spiny wood hedgehog
31	*Hygrophoropsis aurantiaca*	Orange waxy cap
32	*Hygrophorus russula*	Russula-like waxy cap
33	*Laccaria amethystina*	Amethyst deceiver
34	*Lyophyllum decastes*	Oyster mushroom
35	*Marasmius oreades*	Fairy ring mushroom
36	*Morchella esculenta*	Yellow morel
37	*Pleurotus ostreatus*	Oyster mushroom
38	*Ramaria botrytis*	Clustered coral fungus
39	*Russula cyanoxantha*	Azure bluet
40	*Russula delica*	Golden chanterelle russula
41	*Russula nigricans*	Blackening russula

1.16.Regeneration status of trees and shrubs

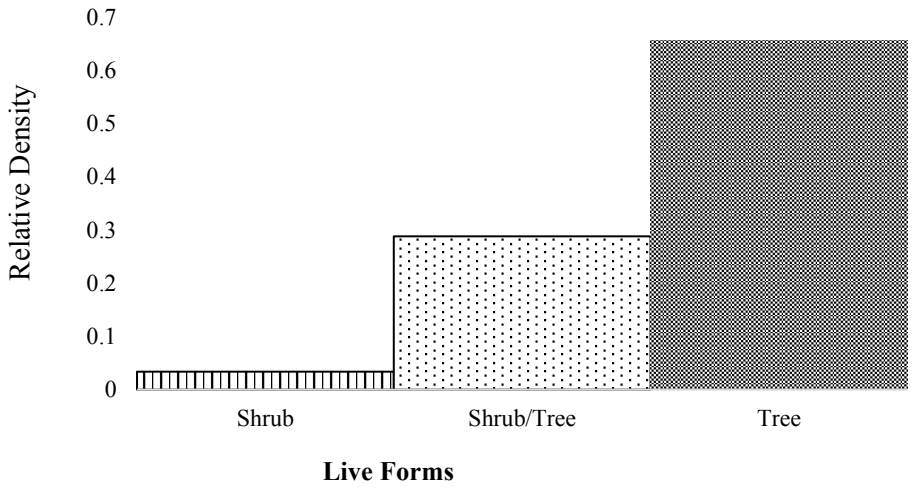


Figure 20: Relative Density of different live forms (Trees, Shrub/tree, Shrubs)

The relative density is highest for trees, followed by small trees/shrubs, and is lowest for shrub species. When considering specific species, the highest relative density is recorded for *Ostodes paniculata* (RD = 0.1288), followed by *Castanopsis spp* (RD = 0.0773), and *Schima wallichi* (RD = 0.0747). Conversely, the lowest relative density is recorded for *Cinnamamon imperssilervium* (RD = 0.0001), as well as for *Sterculia spp,* Chipley Kaula-LN*, Adinanra griffithii, Mesua ferrea, and Syzygium operculatum* (RD = 0.0003).

Importance Value Index (IVI) expresses the overall importance of a species in a community. *Ostodes paniculata, Castanopsis spp & Schima wallichi* exhibited top 3 IVI for tree species (Highlighted with yellow). *Actinodaphane obovata, Tabernaemontana divaricata and Magnifera spp* exhibited top 3 IVI for shrub species (Highlighted with green). *Lindara spp, Phobea lanceolata and Osmanthus suavis* have the highest IVI among the Shrub/tree category (Highlighted with Pink) (Table 7)

Table 16: Regeneration status (RD-Relative Density, RA- Relative Abundance, RF-Relative Frequency and Important Value Index) of regenerating species.

Species	Family	Live forms	Density	RD	Abundance	RA	Frequency	RF		IVI
Acer cambelii	Sapindaceae	Tree		0.0818	0.0079	31.0000	0.0079	3.0000	0.0079	0.0238
Acer pectinatum	Sapindaceae	Tree		0.0053	0.0005	2.0000	0.0005	5.0000	0.0132	0.0142
Acer spp	Sapindaceae	Tree		0.0792	0.0077	30.0000	0.0077	9.0000	0.0237	0.0391
Acer thombsonii	Sapindaceae	Tree		0.0580	0.0056	22.0000	0.0056	4.0000	0.0106	0.0218
Actinodaphane obovata	Lauraceae	Shrub		0.0871	0.0084	33.0000	0.0084	8.0000	0.0211	0.0380
Ailanthus grandis	Cornaceae	Tree		0.0106	0.0010	4.0000	0.0010	9.0000	0.0237	0.0258
Alangium chinensis	Cornaceae	Shrub/Tree		0.0660	0.0064	25.0000	0.0064	4.0000	0.0106	0.0234
Aglia spectabilis	Lauraceae	Tree		0.2691	0.0261	102.0000	0.0261	9.0000	0.0237	0.0760
Albizia lebbeck	Fabaceae	Tree		0.0132	0.0013	5.0000	0.0013	5.0000	0.0132	0.0158
Alastonia microphylla	Apocynaceae	Shrub/Tree		0.0053	0.0005	2.0000	0.0005	4.0000	0.0106	0.0116
Alastonia nepalensis	Apocynaceae	Shrub/Tree		0.0053	0.0005	2.0000	0.0005	5.0000	0.0132	0.0142
Anthocephalus cadamba	Rhamnaceae	Tree		0.0132	0.0013	5.0000	0.0013	9.0000	0.0237	0.0263
Adinanra griffithii	Pentaphylacaceae	Tree		0.0026	0.0003	1.0000	0.0003	7.0000	0.0185	0.0190
Albezia spp	Fabaceae	Shrub/Tree		0.0132	0.0013	5.0000	0.0013	7.0000	0.0185	0.0210
Altingia excelsa	Altingiaceae	Tree		0.0132	0.0013	5.0000	0.0013	9.0000	0.0237	0.0263
Albizia gamblei	Fabaceae	Tree		0.0079	0.0008	3.0000	0.0008	3.0000	0.0079	0.0095
Albiza procera	Fabaceae	Shrub/Tree		0.0053	0.0005	2.0000	0.0005	4.0000	0.0106	0.0116
Albizia lucidor	Fabaceae	Tree		0.0053	0.0005	2.0000	0.0005	9.0000	0.0237	0.0248
Albizia spp	Fabaceae	Tree		0.0264	0.0026	10.0000	0.0026	3.0000	0.0079	0.0130
Alnus nepalensis	Fabaceae	Tree		0.0132	0.0013	5.0000	0.0013	9.0000	0.0237	0.0263
Amaroo wallichii	Rhamnaceae	Tree		0.0185	0.0018	7.0000	0.0018	3.0000	0.0079	0.0115
Aphanamixis polystachya	Meliaceae	Tree		0.0660	0.0064	25.0000	0.0064	3.0000	0.0079	0.0207
Archidendron hendersonii	Fabaceae	Tree		0.0923	0.0090	35.0000	0.0090	7.0000	0.0185	0.0364
Beilschmiedia skimemesis	Lauraceae	Tree		0.0106	0.0010	4.0000	0.0010	5.0000	0.0132	0.0152
Benkara sienensis	Rubiaceae	Tree		0.0528	0.0051	20.0000	0.0051	9.0000	0.0237	0.0340
Betula alnoides	Betulaceae	Tree		0.0158	0.0015	6.0000	0.0015	4.0000	0.0106	0.0136
Betula spp	Betulaceae	Tree		0.1847	0.0179	70.0000	0.0179	7.0000	0.0185	0.0543
Brassaiopsis hainla	Araliaceae	Tree		0.2744	0.0266	104.0000	0.0266	6.0000	0.0158	0.0691
Bridelia retusa	Euphorbiaceae	Tree		0.0792	0.0077	30.0000	0.0077	8.0000	0.0211	0.0365

Celtis tetrandra	Ulmaceae	Tree	0.0106	0.0010	4.0000	0.0010	5.0000	0.0132	0.0152
Castanopsis hystrix	Fagaceae	Tree	0.4908	0.0476	186.0000	0.0476	7.0000	0.0185	0.1137
Castanopsis indica	Fagaceae	Tree	0.0923	0.0090	35.0000	0.0090	9.0000	0.0237	0.0417
Castanopsis spp	Fagaceae	Tree	0.7968	0.0773	302.0000	0.0773	7.0000	0.0185	0.1731
Castanopsis tubuloides	Fagaceae	Tree	0.0317	0.0031	12.0000	0.0031	7.0000	0.0185	0.0246
Celtis australis	Ulmaceae	Shrub/Tree	0.0185	0.0018	7.0000	0.0018	7.0000	0.0185	0.0221
Chellayto oplique	Burseraceae	Shrub/Tree	0.0528	0.0051	20.0000	0.0051	3.0000	0.0079	0.0182
Chipley Kaula-LN	NA	NA	0.0026	0.0003	1.0000	0.0003	9.0000	0.0237	0.0243
Choerospondias axillaris	Anacardiaceae	Tree	0.1900	0.0184	72.0000	0.0184	7.0000	0.0185	0.0553
Cinnamamon imperssilervium	Lauraceae	Tree	0.0013	0.0001	0.5000	0.0001	4.0000	0.0106	0.0108
Cinnamomum bajolgota	Lauraceae	Tree	0.2507	0.0243	95.0000	0.0243	5.0000	0.0132	0.0618
Cinnamomum glaucescens	Lauraceae	Shrub/Tree	0.0053	0.0005	2.0000	0.0005	9.0000	0.0237	0.0248
Cinnamomum spp	Lauraceae	Tree	0.1135	0.0110	43.0000	0.0110	9.0000	0.0237	0.0458
Clerodendron infortinatum	Lamiaceae	Shrub	0.0528	0.0051	20.0000	0.0051	3.0000	0.0079	0.0182
Crateva religiosa	Capparaceae	Tree	0.0660	0.0064	25.0000	0.0064	7.0000	0.0185	0.0313
Cryptocarya amygdalina	Lauraceae	Tree	0.2137	0.0207	81.0000	0.0207	5.0000	0.0132	0.0547
Dendrocnide excelsa	Urticaceae	Shrub/Tree	0.0079	0.0008	3.0000	0.0008	4.0000	0.0106	0.0121
Engelhardia spicata	Juglandaceae	Tree	0.0396	0.0038	15.0000	0.0038	4.0000	0.0106	0.0182
Ficus hispida	Moraceae	Tree	0.0053	0.0005	2.0000	0.0005	5.0000	0.0132	0.0142
Ficus racemosa	Moraceae	Climbing Shrub	0.0053	0.0005	2.0000	0.0005	7.0000	0.0185	0.0195
Ficus roxburgii	Moraceae	Tree	0.0580	0.0056	22.0000	0.0056	7.0000	0.0185	0.0297
Ficus spp	Moraceae	Tree	0.1029	0.0100	39.0000	0.0100	9.0000	0.0237	0.0437
Fraxinus floribunda	Oleaceae	Tree	0.0053	0.0005	2.0000	0.0005	3.0000	0.0079	0.0089
Helicia nilagirica	Proteaceae	Tree	0.0528	0.0051	20.0000	0.0051	8.0000	0.0211	0.0313
Knema spp	Myristicaceae	Shrub/Tree	0.0079	0.0008	3.0000	0.0008	5.0000	0.0132	0.0147
Knema tenuinervia	Myristicaceae	Tree	0.0132	0.0013	5.0000	0.0013	8.0000	0.0211	0.0237
Lagastromea hirsuta	Myristicaceae	Shrub/Tree	0.0053	0.0005	2.0000	0.0005	4.0000	0.0106	0.0116
Lepisanthes senegalensis	Sapindaceae	Shrub	0.0053	0.0005	2.0000	0.0005	3.0000	0.0079	0.0089
Lepisanthes spp	Sapindaceae	Shrub	0.0053	0.0005	2.0000	0.0005	3.0000	0.0079	0.0089
Lindara spp	Fabaceae	Shrub/Tree	0.1847	0.0179	70.0000	0.0179	9.0000	0.0237	0.0596
Lithocarpus elegance	Fagaceae	Tree	0.0053	0.0005	2.0000	0.0005	9.0000	0.0237	0.0248
Lithocarpus spp	Fagaceae	Tree	0.1530	0.0148	58.0000	0.0148	8.0000	0.0211	0.0508
Litsaea polyalthia	Fagaceae	Shrub/Tree	0.0106	0.0010	4.0000	0.0010	9.0000	0.0237	0.0258
Litsea monopetala	Fagaceae	Tree	0.0185	0.0018	7.0000	0.0018	5.0000	0.0132	0.0168
Litsea spp	Lauraceae	Shrub/Tree	0.0844	0.0082	32.0000	0.0082	4.0000	0.0106	0.0269
Lyonia ovalifolia	Ericaceae	Shrub/Tree	0.0317	0.0031	12.0000	0.0031	8.0000	0.0211	0.0273
Macaranga denticulata	Euphorbiaceae	Tree	0.4274	0.0415	162.0000	0.0415	7.0000	0.0185	0.1014
Macaranga indica	Euphorbiaceae	Tree	0.0528	0.0051	20.0000	0.0051	5.0000	0.0132	0.0234
Macaranga spp	Euphorbiaceae	Shrub/Tree	0.0528	0.0051	20.0000	0.0051	9.0000	0.0237	0.0340
Magnifera spp	Anacardiaceae	Shrub	0.0580	0.0056	22.0000	0.0056	7.0000	0.0185	0.0297
Magnolia hoogsonii	Magnoliaceae	Tree	0.0053	0.0005	2.0000	0.0005	5.0000	0.0132	0.0142
Magnolia ptericarpa	Magnoliaceae	Tree	0.0132	0.0013	5.0000	0.0013	6.0000	0.0158	0.0184
Mangefera sylvatica	Anacardiaceae	Tree	0.1451	0.0141	55.0000	0.0141	8.0000	0.0211	0.0493
Merrilliopanax alpinus	Araliaceae	Tree	0.0475	0.0046	18.0000	0.0046	6.0000	0.0158	0.0250
Mesua ferrea	Meliaceae	Tree	0.0026	0.0003	1.0000	0.0003	5.0000	0.0132	0.0137
Michela champaca	Magnoliaceae	Tree	0.1451	0.0141	55.0000	0.0141	7.0000	0.0185	0.0466
Michelia doltsapa	Dryopteridaceae	Tree	0.1636	0.0159	62.0000	0.0159	8.0000	0.0211	0.0529
Mitrephora harai	Annonaceae	Tree	0.0396	0.0038	15.0000	0.0038	9.0000	0.0237	0.0314
Murraya koenigii	Rutaceae	Shrub/Tree	0.0185	0.0018	7.0000	0.0018	5.0000	0.0132	0.0168
Murreya Paniculata	Rutaceae	Shrub/Tree	0.0053	0.0005	2.0000	0.0005	8.0000	0.0211	0.0221

Myrica esculenta	Myricaceae	Tree	0.0079	0.0008	3.0000	0.0008	4.0000	0.0106	0.0121
Myrioneuron nutans	Rubiaceae	Under shrub	0.0185	0.0018	7.0000	0.0018	8.0000	0.0211	0.0247
Mythiya spp	Apocynaceae	Shrub/Tree	0.0106	0.0010	4.0000	0.0010	6.0000	0.0158	0.0179
Neillia thyrsiflora	Rosaceae	Shrub	0.0053	0.0005	2.0000	0.0005	7.0000	0.0185	0.0195
Oroxylum indicum	Bignoniaceae	Tree	0.0237	0.0023	9.0000	0.0023	8.0000	0.0211	0.0257
Osmanthus suavis	Oleaceae	Shrub/Tree	0.0871	0.0084	33.0000	0.0084	9.0000	0.0237	0.0406
Ostodes paniculata	Euphorbiaceae	Tree	1.3272	0.1288	503.0000	0.1288	7.0000	0.0185	0.2760
Pandanus nepalensis	Pandanaceae	Tree	0.0053	0.0005	2.0000	0.0005	8.0000	0.0211	0.0221
Persia spp	Lauraceae	Tree	0.0317	0.0031	12.0000	0.0031	8.0000	0.0211	0.0273
Phobea altenuata	Polygalaceae	Shrub/Tree	0.0106	0.0010	4.0000	0.0010	5.0000	0.0132	0.0152
Phobea lanceolata	Polygalaceae	Shrub/Tree	0.1108	0.0108	42.0000	0.0108	8.0000	0.0211	0.0426
Polyalthia simiarum	Annonaceae	Tree	0.1319	0.0128	50.0000	0.0128	8.0000	0.0211	0.0467
Pstrepermum spp	Malvaceae	Shrub	0.0211	0.0020	8.0000	0.0020	6.0000	0.0158	0.0199
Pterospermum acerifolium	Malvaceae	Tree	0.0158	0.0015	6.0000	0.0015	7.0000	0.0185	0.0215
Pterospermum acerifolium	Malvaceae	Tree	0.1979	0.0192	75.0000	0.0192	5.0000	0.0132	0.0516
Quercus glauca	Fagaceae	Tree	0.0053	0.0005	2.0000	0.0005	7.0000	0.0185	0.0195
Stereospermum tetragonum	Bignoniaceae	Tree	0.0396	0.0038	15.0000	0.0038	6.0000	0.0158	0.0235
Robinia pseudoacacia	Fabaceae	Shrub/Tree	0.0264	0.0026	10.0000	0.0026	6.0000	0.0158	0.0210
Saltix spp	Poaceae	Shrub/Tree	0.0528	0.0051	20.0000	0.0051	4.0000	0.0106	0.0208
Sapium spp	Euphorbiaceae	Shrub/Tree	0.0317	0.0031	12.0000	0.0031	3.0000	0.0079	0.0141
Sarcospema arboreum	Apocynaceae	Shrub/Tree	0.0923	0.0090	35.0000	0.0090	4.0000	0.0106	0.0285
Saurauia nepaulensis	Actinidiaceae	Shrub/Tree	0.0528	0.0051	20.0000	0.0051	9.0000	0.0237	0.0340
Schefflera impressa	Araliaceae	Tree	0.0079	0.0008	3.0000	0.0008	9.0000	0.0237	0.0253
Schefflera spp	Araliaceae	Climbing shrub	0.0660	0.0064	25.0000	0.0064	6.0000	0.0158	0.0286
Schima wallichi	Theaceae	Tree	0.7704	0.0747	292.0000	0.0747	3.0000	0.0079	0.1574
Siltix spp	Poaceae	Shrub/Tree	0.0132	0.0013	5.0000	0.0013	5.0000	0.0132	0.0158
Sloanea decicarpus	Elaeocarpaceae	Tree	0.0079	0.0008	3.0000	0.0008	6.0000	0.0158	0.0174
Sterculia spp	Malvaceae	Shrub/Tree	0.0026	0.0003	1.0000	0.0003	8.0000	0.0211	0.0216
Stereopermum spp	Bignoniaceae	Tree	0.0132	0.0013	5.0000	0.0013	6.0000	0.0158	0.0184
Symplocos spp	Symplocaceae	Shrub/Tree	0.2480	0.0241	94.0000	0.0241	3.0000	0.0079	0.0560
Syzygium operculatum	Myrtaceae	Shrub/Tree	0.0026	0.0003	1.0000	0.0003	4.0000	0.0106	0.0111
Syzygium cumini	Myrtaceae	Tree	0.1715	0.0166	65.0000	0.0166	5.0000	0.0132	0.0465
Syzygium formosum	Myrtaceae	Tree	0.0501	0.0049	19.0000	0.0049	4.0000	0.0106	0.0203
Syzygium spp	Myrtaceae	Tree	0.2348	0.0228	89.0000	0.0228	6.0000	0.0158	0.0614
Tabernaemontana divaricata	Apocynaceae	Shrub	0.0660	0.0064	25.0000	0.0064	8.0000	0.0211	0.0339
Talauma hodgsonii	Magnoliaceae	Tree	0.0053	0.0005	2.0000	0.0005	3.0000	0.0079	0.0089
Terminalia alata	Combretaceae	Tree	0.0106	0.0010	4.0000	0.0010	9.0000	0.0237	0.0258
Terminalia chebula	Combretaceae	Tree	0.0106	0.0010	4.0000	0.0010	7.0000	0.0185	0.0205
Terminalia myocarpa	Combretaceae	Tree	0.0106	0.0010	4.0000	0.0010	8.0000	0.0211	0.0232
Tetradium fraxinifolium	Rutaceae	Tree	0.2137	0.0207	81.0000	0.0207	8.0000	0.0211	0.0626
Toona ciliata	Meliaceae	Tree	0.1135	0.0110	43.0000	0.0110	8.0000	0.0211	0.0431
Trevia spp	Apiaceae	Tree	0.0053	0.0005	2.0000	0.0005	9.0000	0.0237	0.0248
Urea spp	Mycoplasmataceae	Shrub/Tree	0.0132	0.0013	5.0000	0.0013	6.0000	0.0158	0.0184
Zambeosa formosa	Scrophulariaceae	Tree	0.0132	0.0013	5.0000	0.0013	9.0000	0.0237	0.0263
Zanthozylum spp	Rutaceae	Shrub	0.0079	0.0008	3.0000	0.0008	9.0000	0.0237	0.0253
		Total	**10.3074**	**1.0000**	**3906.5000**	**1.0000**	**789.0000**	**2.0818**	**4.0818**

2. Fauna

2.1. Mammal species

Mammal species are integral to ecosystems, offering numerous ecological, cultural, and economic benefits. Their conservation and protection are essential for the well-being of our planet and its inhabitants(T. Wangchuk et al., 2003). In Bhutan, there are 129 species of mammals(NBC, Biodiversity Status Report, 2021). In Sarpang, there have been records of 36 mammal species distributed among 9 different families (Tenzin et al., 2022). There are 5 endangered species, 10 species classified as LC (Least Concern), and 17 species classified as LR (Low Risk)(Tenzin et al., 2021).

Table 17:List of Mammals of Sarpang along with their family and conservation status

Sl. No.	Scientific name	Common/Local name	Family	Conservation status
1	*Paguma larvata*	Himalayan Plam Civet, Bja zig (Dzo)	Viverridae	LC
2	*Catopuna temmincki*	Asiatic Golden Cat	Felideae	LR
3	*Muntiacus mutjak*	Barking Deer, Kasha (Dzo)	Ceruidae	LR
4	*Capriconis sumatraensis*	Himalayan Serow, Jha (Dzo)	Ceruidae	LR
5	*Sus scrofa*	Wild Pig, Rephag (Dzo)	Suidae	LR
6	*Felis bengalensis*	Leopard Cat, Bjazig (Dzo)	Felideae	LR
7	*Cervus unicolor*	Sambar, Shaw (Dzo)	Ceruidae	LR
8	*Felis Marmorata*	Marbled Cat	Felideae	LR
9	*Ursus tibetanus laniger*	Himalayan black Bear, Dhom (Dzo)	Ursidae	E
10	*Panthara tigris*	Tiger, Tag (Dzo)	Felideae	E
11	*Hysterix brachyura*	Himalayan Crestless Purcopine, Bjithru (Dzo)	Hystricidae	LC
12	*Wiverra zibetha*	Large Indian Civet, Bjazig (Dzo)	Viverridae	LR
13	*Herpestes edvardsii*	Common Mangoose, Neuli (Dzo)	Herpestidae	-
14	*Martes foina*	Stone Marten, Shing Sam (Dzo)	Mustelinae	LR
15	*Trachypithecus geei*	Golden Langur, Chakarsergidogchen (Dzo)	Primateae	E
16	*Apodemus syvatics*	Wood Mouse, Jise (Dzo)	Muridae	-
17	*Bos gaurus*	Gaur, Relang (Dzo)	Bovidae	LR
18	*Ratufa bicolor*	Malayan Giant Squirrel	Pteromyidae	-
19	*Macaque assamese*	Assamese macaque, Cha (Dzo)	Primatae	LR
20	*Neofelis nebulosa*	Clouded leopard, Gung (Dzo)	Felideae	LR
21	*Cuon alpinus primaevus*	Wild dog, Phaw (Dzo)	Canideae	E
22	*Panterea pardus*	Common leopard, Zig (Dzo)	Felideae	LR
23	*Elephas maximus*	Asian Elephant, Lamchey (Dzo)	Proboscidae	E
24	*Herpestes urva*	Crab Eating Mongoose	Herpestidae	LC
25	*Macaca mulata*	Rhesus Macaque, Pcha (Dzo), Pra (Kheng)	Primatidae	LR
26	*Viverricula indica*	Small Indian Civet	Viverridae	LR
27	*Lepus nigricollis*	Black Napped Hare	Leporidae	LC
28	*Callosciurus erythraeaus*	Red-Bellied squirrel	Pteromyidae	-
29	*Funambulus pennati*	Five Stripe Palm Squirrel	Pteromyidae	LC
30	*Petaurista petaurista*	Red Giant Flying Squirrel	Pteromyidae	LC
31	*Calllosciurus pygerythrus*	Hoary Bellied Squirrel	Pteromyidae	LC
32	*Aonynx cincerea*	Small Clawed Otter	Mustelidae	LR
33	*Lutra lutra*	Common Otter, Saam (Dzo), Samu (Shar)	Mustelidae	LR
34	*Herpestes javanicus*	Small Asian Mongoose	Herpestidae	LC

35	*Martes flavigula*	Yellow-throated martin	Mustelinae	LC
36	*Atherurus macrourus*	Asiatic brush-tailed porcupine	Hystricidae	LC

When considering an occasion as 30 camera trap days, the barking deer (0.97), Large Indian civet (0.83), Pallas Squirrel (0.83), and tiger (1) exhibit the highest detection rates. Meanwhile, in regard to the occupancy rate, the Golden langur (1), Clouded leopard (1), Barking deer (1), Goral (1), and panther (1) stand out with the highest rates (see Table # and Figure #). The detection is species is higher in camera stations deployed in north-east, south-east, southern parts of Sarpang (Figure#). The richness of species (*number of species detected per deployment)* is higher in south-east, south west and northern parts Of Sarpang (Figure#).

Table 18:Detection and Occupancy rates of mammals based on National Tiger Survey data (2022).

Species	Detection	SE	LowCI	UppCI	Occupancy
Asiatic golden cat	0.32	0.12	0.14	0.58	0.5
Assamese macaque	0.48	0.21	0.15	0.82	0.12
Barking deer	0.97	0.02	0.9	0.99	1
Common leopard	0.32	0.17	0.09	0.68	0.25
Crab-eating mongoose	0.38	0.19	0.12	0.75	0.18
Elephant	0.5	0.14	0.26	0.74	0.28
Gaur	0.49	0.11	0.29	0.7	0.4
Golden langur	0.01	0.02	0	0.24	0.98
Goral	0.07	0.03	0.03	0.15	1
Himalayan black bear	0.29	0.1	0.14	0.51	0.75
Himalayan crestless porcupine	0.44	0.16	0.17	0.74	0.21
Himalayan serow	0.5	0.09	0.33	0.66	0.67
Large Indian civet	0.83	0.16	0.35	0.98	0.07
Leopard cat	0.28	0.1	0.13	0.49	0.84
Wild dog	0.28	0.11	0.12	0.52	0.67
Wild pig	0.61	0.07	0.46	0.74	0.7
Yellow-throated martin	0.68	0.07	0.53	0.8	0.64
Clouded leopard	0.08	0.03	0.04	0.16	1
Asiatic brush-tailed porcupine	0.52	0.18	0.21	0.81	0.16
Assamese Macaque	0.48	0.12	0.26	0.7	0.36
Himalayan palm civet	0.63	0.07	0.48	0.76	0.69
Sambar	0.54	0.08	0.38	0.69	0.73
Marbled cat	0.56	0.1	0.37	0.73	0.45
Pallas squirrel	0.83	0.16	0.35	0.98	0.07
Rat	0.69	0.11	0.45	0.86	0.25
Tiger	1	0	0	1	0.03
Black panther	0.02	0.02	0.01	0.09	1
Squirrel	0.01	0.02	0	0.24	0.98

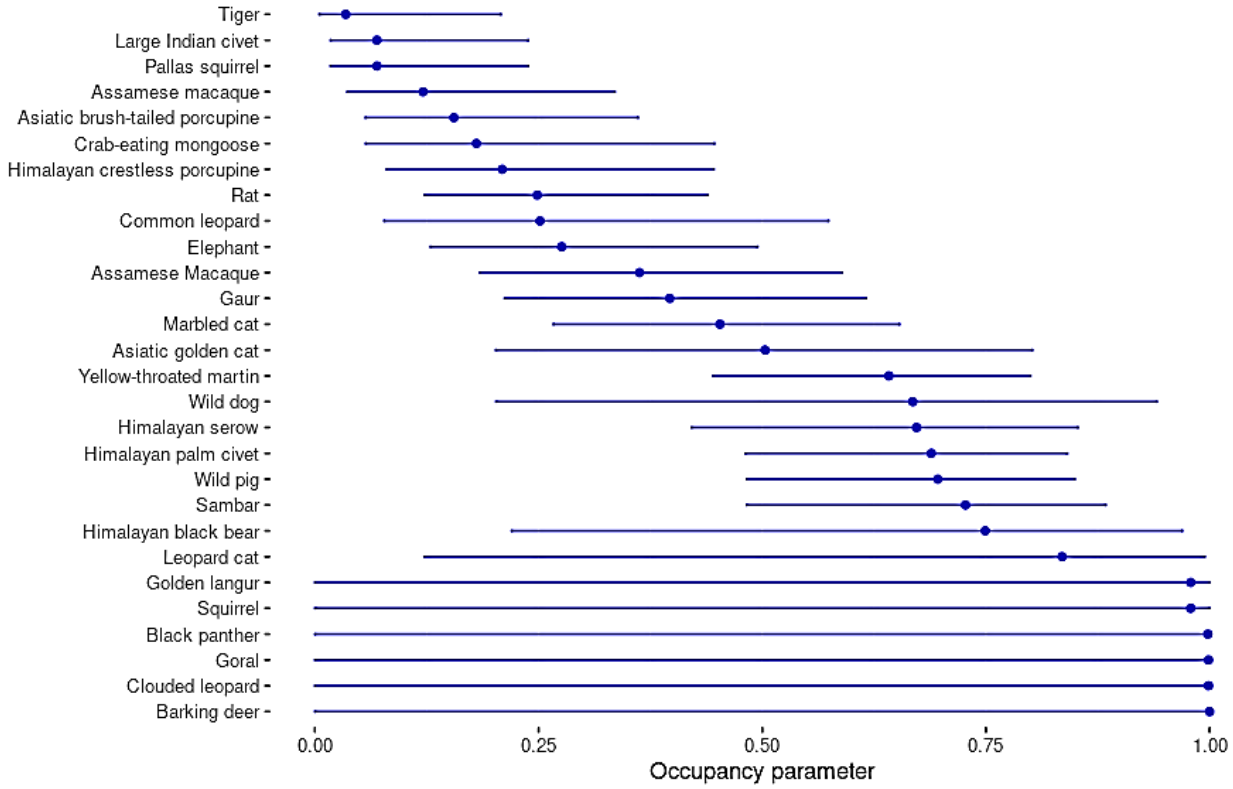


Figure 21:Occupancy Parameter of mammal species based on NTS, 2022.

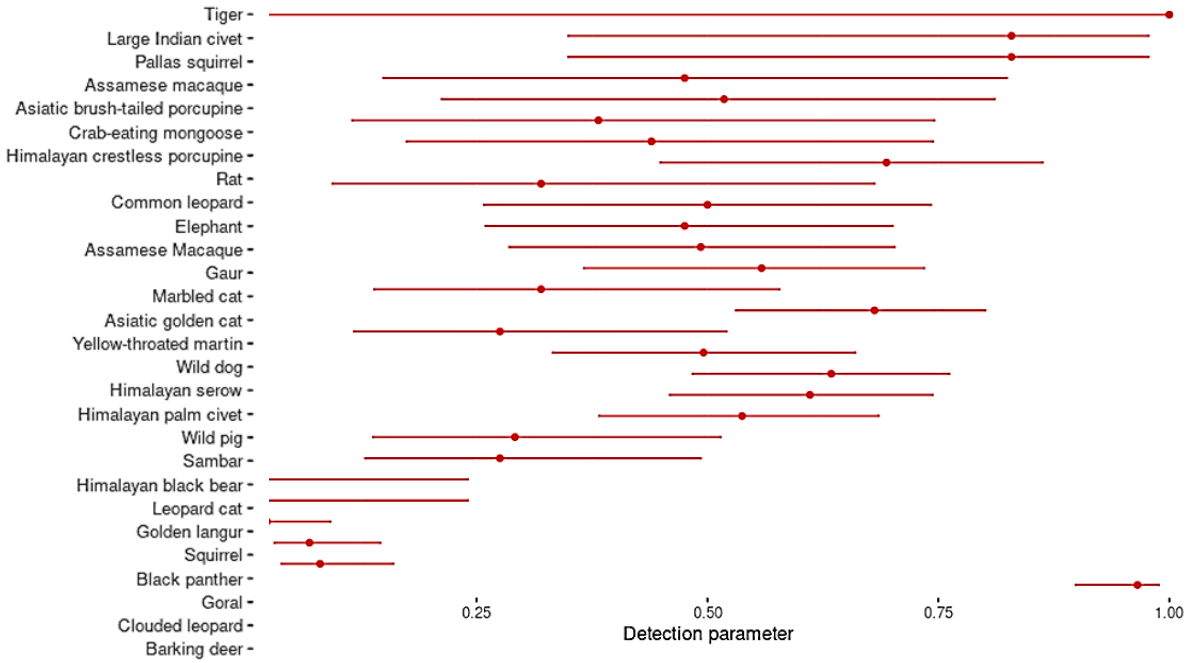


Figure 22: Detection Parameter of mammal species based on NTS, 2022.

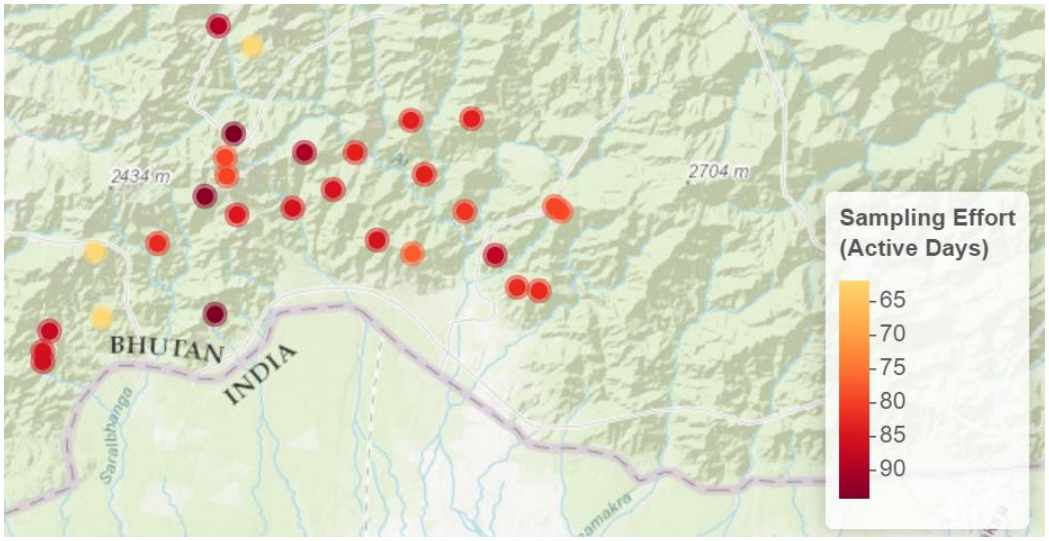


Figure 23: Sampling effort: The total Effort per deployment (camera station) in camera-days.

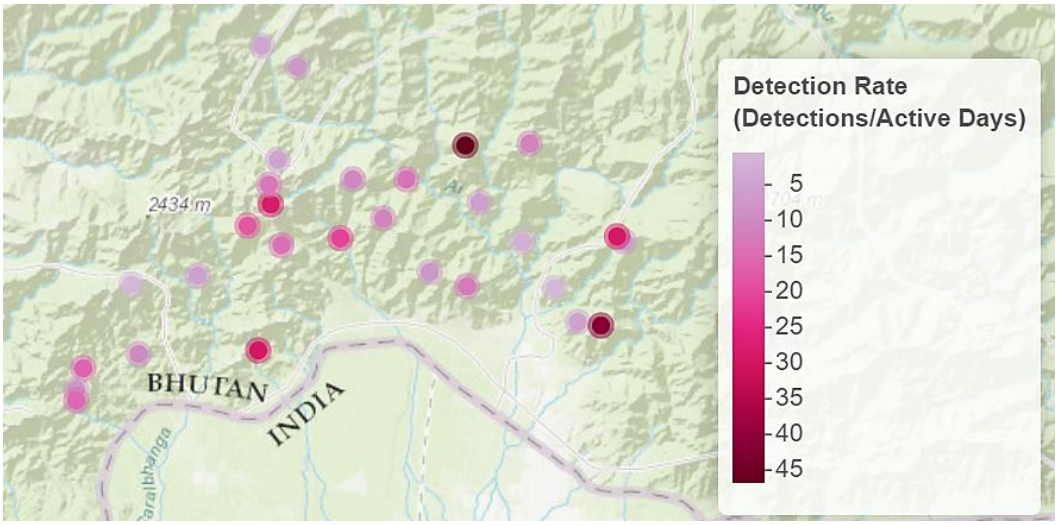


Figure 24:Detection rate: The number of detections per day per deployment (all species).

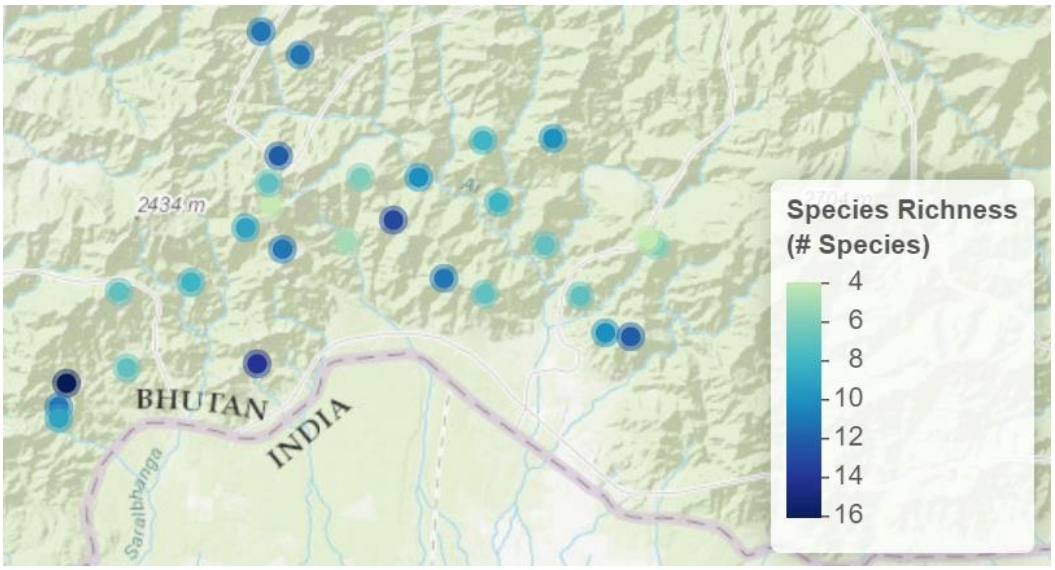


Figure 25:Map 3 - Species Richness: The total number of species detected per deployment

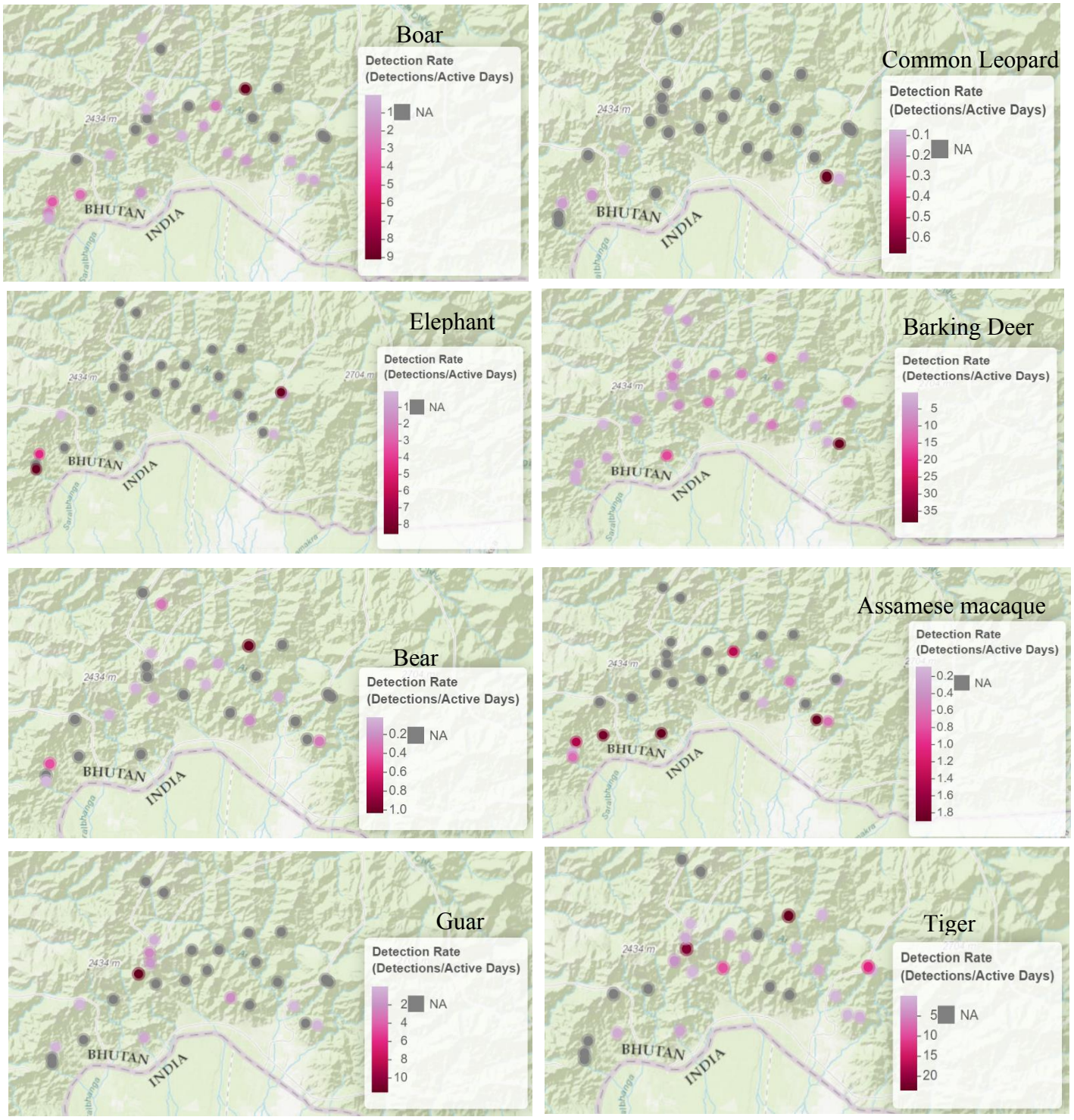
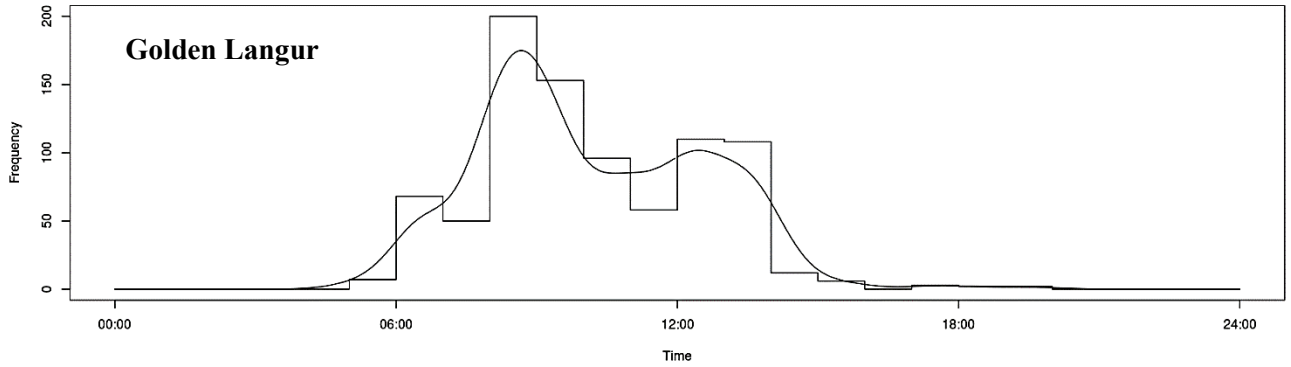
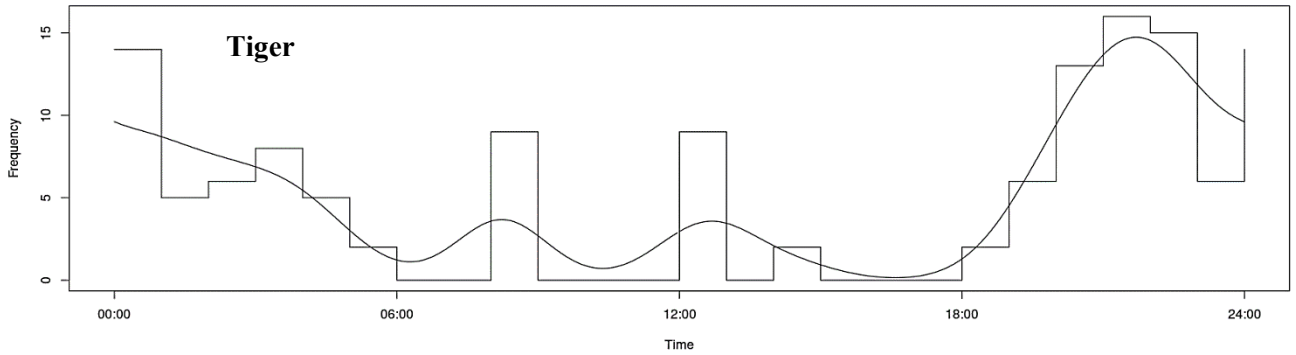


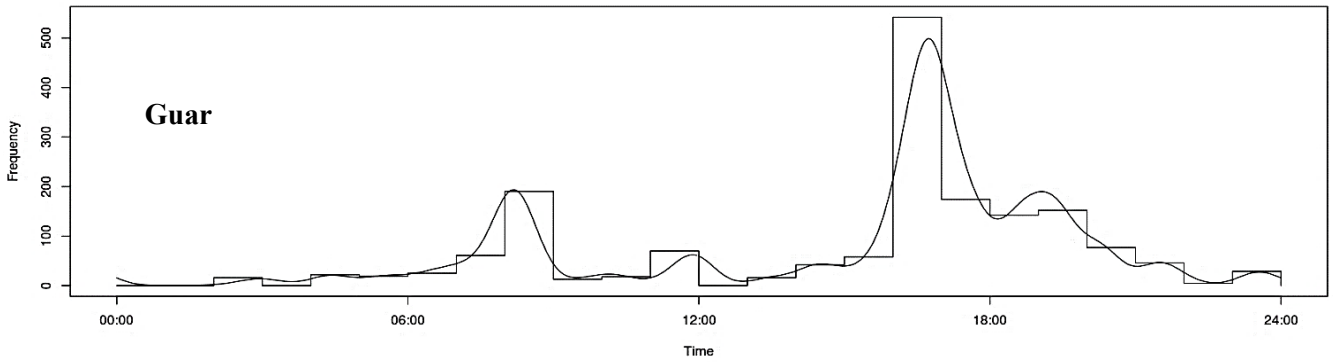
Figure 26:Detection rate: The number of detections per day per deployment (keystone species)

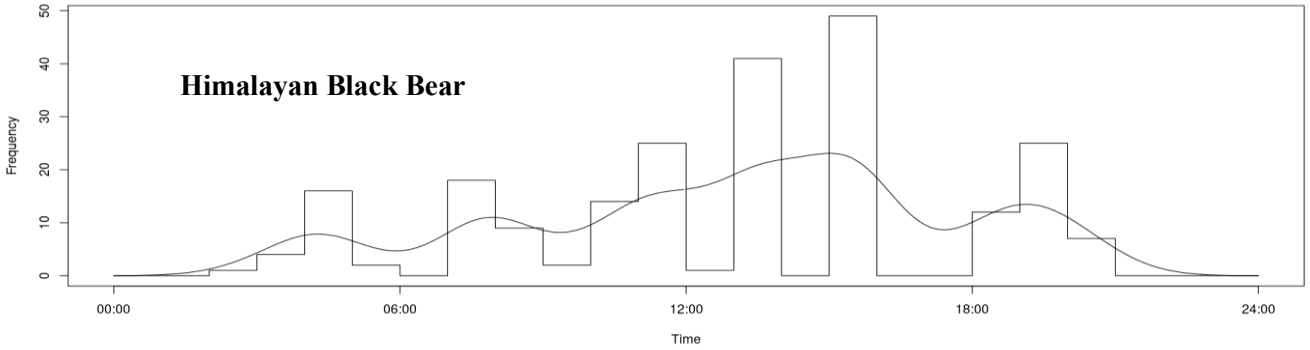
Boar, bear, and tiger are predominantly captured on camera stations in the northern regions of Sarpang, whereas elephants, common leopards, and barking deer are frequently spotted in the southern parts of Sarpang. Gaur, on the other hand, is primarily detected in the mid-latitudes of Sarpang. The barking deer is found in northerns parts, detection rate in southern parts is more predominant than more parts (Figure 25).

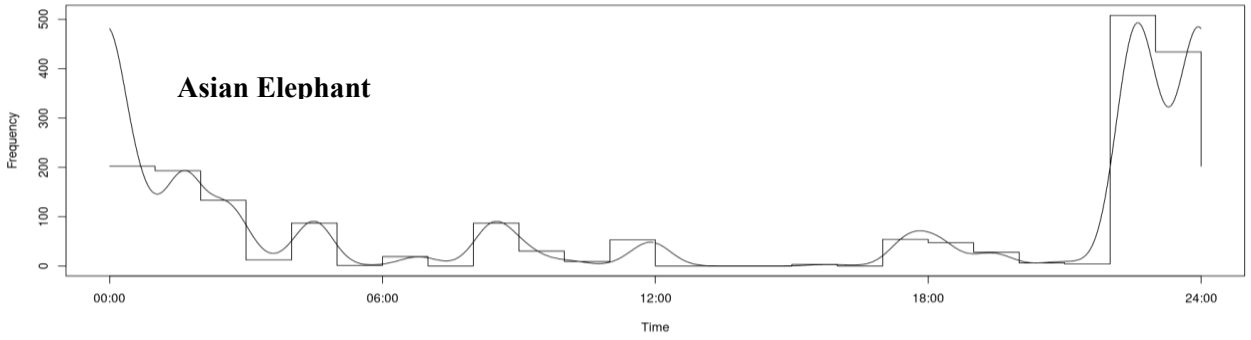
Activity Pattern of Some important Keystone mammal species of Sarpang











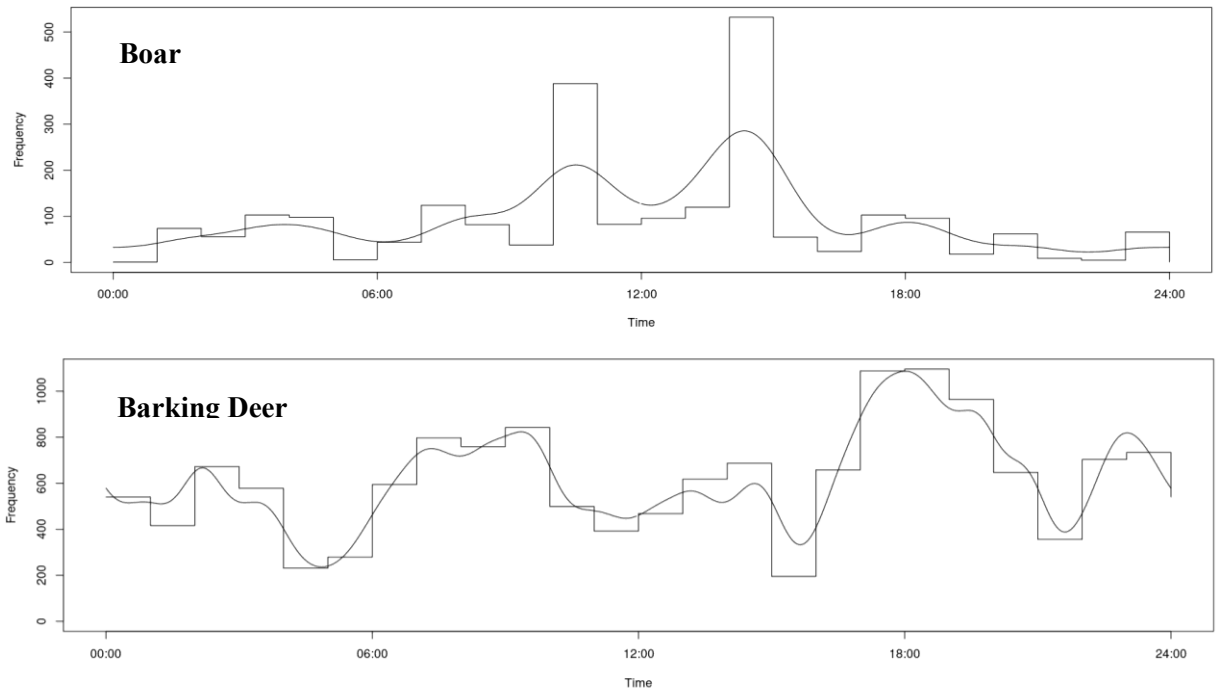


Figure 27: Activity pattern of some keystone mammal species of Sarpang.

The activity patterns of the species were determined from the frequency of the independent photographs captured for each species. The activity patterns are determined for most widely distributed and problematic species like elephant, Boar, Guar, Tiger, bear and Barking deer. These animals frequently come into conflict with local communities. The conflicts often involve livestock depredation, property and crop damage, as well as instances of human casualties and injuries caused by these animals.

The conflicts often involve livestock depredation, property and crop damage, as well as instances of human casualties and injuries caused by these animals. Tigers were found to be primarily nocturnal, with their peak activity occurring between 10 and 11 PM, extending from 6 PM to 6 AM. Similarly, elephants also exhibited nocturnal behavior, being most active between 10 PM and 6 AM, with peak activity around 11 PM and midnight. Golden langurs, on the other hand, were observed to be diurnal, with their activity concentrated between 6 AM and 6 PM. Gaur displayed their highest activity levels around 6 PM. Black bears and boars exhibited peak activity hours in the afternoon. Barking deer, while active throughout the day, showed the highest activity levels around 6 PM (Figure 26).

The information presented above will prove invaluable to planners involved in mitigating human-wildlife conflicts, forestry officials, and farmers alike. It offers critical insights into the specific times when conflict-prone animals are most active, aiding in the development of effective mitigation strategies.

2.2. Small mammals

Small mammals, a diverse and ecologically significant group characterized by their diminutive size, encompass rodents, shrews, moles, and a variety of other species(Lidicker, 2011). These diminutive creatures play crucial roles in ecosystem dynamics, including seed dispersal, predation, and soil aeration(Small Mammals SG., 2023.; van Kolfschoten, 2013). Serving as prey for larger mammals and birds, small mammals are indispensable in maintaining biodiversity(Small Mammals SG., 2023.). Their significance extends to the realm of medical research, particularly with rodents like mice and rats, which serve as common model organisms in laboratory studies.

Table 19:List of small mammals that could occur in Sarpang(Kuenzang Dorji - Small Mammals in Small Country: Diversity and Conservation of Small Mammals in High Altitude Wetland of Phobjikha, Wangdiprodrang, Western Bhutan - The Rufford Foundation, 2023.; Norbu et al., 2019; T. Wangchuk et al., 2004).

Sl.no.	Family	Species
1	Asian golden cat	*Catopuma temminckii*
2	Asian gray shrew	*Crocidura attenuata*
3	Assam macaque	*Macaca assamensis*
4	Bengal spiny rat	*Rattus rattus*
5	Black giant squirrel	*Ratufa bicolor*
6	Chinese bamboo rat	*Rhizomys sinensis*
7	Common shrew	*Sorex araneus*
8	Dusky-footed wood rat	*Rattus nitidus*
9	Eastern house mouse	*Mus musculus*
10	Himalayan field vole	*Microtus sikkimensis*
11	Himalayan marmot	*Marmota himalayana*
12	Indian crested porcupine	*Hystrix indica*
13	Indian gerbil	*Tatera indica*
14	Indian giant flying squirrel	*Petaurista philippensis*
15	Indian mole shrew	*Anourosorex assamensis*
16	Indian short-tailed mole	*Parascaptor indicus*
17	Large Indian civet	*Viverra zibetha*
18	Lesser bamboo rat	*Rhizomys sumatrensis*
19	Malayan weasel	*Mustela nudipes*
20	Masked palm civet	*Paguma larvata*
21	Northern tree shrew	*Tupaia belangeri*
22	Pygmy shrew	*Sorex minutus*
23	Red-bellied squirrel	*Callosciurus erythraeus*
24	Small Indian civet	*Viverricula indica*
25	Southern short-tailed shrew	*Blarina carolinensis*
26	Yellow-throated marten	*Martes flavigula*

2.3.Avian Species

Birds play a crucial role in maintaining the overall health and balance of the local ecosystem, making their conservation and protection essential for preserving biodiversity and ecological stability in the area(Ali et al.,2010). During the survey, a total of 92 bird species were documented. Interestingly,

this precise number of species aligns perfectly with the data found in the "Biodiversity Checklist" meticulously maintained by Tenzin, 2022. Among these 92 recorded species, three have been classified as "Near Threatened" (NT), while an additional two species have been categorized as "Vulnerable." The majority of the recorded bird species fall into the "Least Concern" Category, emphasizing the robust and relatively stable biodiversity of the region (Table 20).

Table 20:List of avian species recorded during survey from Sarpang.

Sl. No.	Scientific Name	Common Name	Family	Conservation Status
1	*Ibidorhyncha struthersii*	Ibisbill	Ibidorhynchidae	LC
2	*Oriolus traillii*	Maroon Oriole	Orieolidae	LC
3	*Riparia riparia*	Sand Martin	Hirundinidae	LC
4	*Saxicola ferreus*	Grey Bushchat	Muscicapidae	LC
5	*Aceros nepalensis*	Rufous-necked Hornbill	Bucerotidae	V
6	*Acridotheres fuscus*	Jungle Myna	Sturnidae	LC
7	*Acridotheres grandis*	Great Myna	Sturnidae	LC
8	*Acridotheres tristis*	Common Myna	Sturnidae	LC
9	*Actitis hypoleucos*	Common Sandpiper	Scolopacidae	LC
10	*Alaudala raytal*	Sand Lark	Alaudidae	LC
11	*Alcedo atthis*	Common Kingfisher	Alcedinidae	LC
12	*Amaurornis phoenicurus*	White-breasted Waterhen	Raliidae	LC
13	*Anas crecca*	Common Teal	Anatidae	LC
14	*Anas platyrhynchos*	Mallard	Anatidae	LC
15	*Anthracoceros albirostris*	Oriental Pied-Hornbill	Bucerotidae	LC
16	*Anthus hodgsoni*	Olive-backed Pipit	Motacillidae	LC
17	*Anthus richardi*	Richard Pipit	Motacillidae	LC
18	*Anthus rufulus*	Paddyfield Pipit	Motacillidae	LC
19	*Aquila nipalensis*	Steppe Eagle	Accipitridae	LC
20	*Ardeola grayii*	Indian Pond-Heron	Ardeolae	LC
21	*Artamus fuscus*	Ashy Woodswallow	Artamidae	LC
22	*Aviceda leuphotes*	Black Baza	Accipitridae	LC
23	*Bubulcus ibis*	Cattle Egret	Ardeidae	LC
24	*Buceros bicornis*	Great Hornbill	Bucerotidae	NT
25	*Burhinus indicus*	Indian Thick-Knee	Bucerotidae	NT
26	*Burhinus oedicnemus*	Eurasian Thick-knee	Bucerotidae	LC
27	*Buteo refectus*	Himalayan Buzzard	Accipitridae	LC
28	*Butorides striata*	Striated Heron	Ardeolae	LC
29	*Calandrella brachydactlya*	Greater Short-toed Lark	Alaudidae	LC
30	*Caprimulgus macrurus*	Large-tailed Nightjar	Caprimulgidae	LC
31	*Centropus sinensis*	Greater Coucal	Cuculidae	LC
32	*Ceryle rudis*	Pied Kingfisher	Alcedinidae	LC
33	*Charadrius dubius*	Little Ringed Plover	Charadriidae	LC
34	*Charadrius placidus*	Long-billed Plover	Charadriidae	LC
35	*Chelidorhynx hypoxantha*	Yellow-bellied Fairy- Fantail	Rhipiduridae	LC
36	*Chloropsis aurifrons*	Golden-fronted Leafbird	Chloropseidae	LC
37	*Cinclus pallasii*	Brown Dipper	Cinclidae	LC
38	*Columba livia*	Rock Pigeon	Columbidae	LC
39	*Copsychus saularis*	Oriental Magpie-Robin	Muscicapidae	LC
40	*Coracias benghalensis*	Indian Roller	Coraciidae	LC

41	*Coracina macei*	Large Cuckooshrike	Coraciidae	LC
42	*Coracina melaschistos*	Black-winged Cuckooshrike	Cuculidae	LC
43	*Corvus levaillantii*	Eastern Jungle Crow	Corvidae	LC
44	*Cuculus micropterus*	Indian Cuckoo	Cuculidae	LC
45	*Culicicapa ceylonensis*	Gray-headed Canary- Flycatcher	Muscicapidae	LC
46	*Cyornis rubeculoides*	Blue-throated Flycatcher	Muscicapidae	LC
47	*Dendrocitta vagabunda*	Rufous Treepie	Corvidae	LC
48	*Dendrocopos canicapillus*	Gray-capped Woodpecker	Picidae	LC
49	*Dendrocopos macei*	Fulvous-breasted Woodpecker	Picidae	LC
50	*Dicrurus hottentottus*	Hair-crested Drongo	Dicruridae	LC
51	*Dicrurus leucophaeus*	Ashy Drongo	Dicruridae	LC
52	*Dicrurus macrocercus*	Black Drongo	Dicruridae	LC
53	*Dicrurus paradiseus*	Greater Racket-tailed Drongo	Dicruridae	LC
54	*Dicrurus remifer*	Lesser Racket-tailed Drongo	Dicruridae	LC
55	*Dinopium shorii*	Himalayan Flameback	Picidae	LC
56	*Ducula aenea*	Green Imperial-Pigeon	Columbidae	LC
57	*Ducula badia*	Mountain Imperial- Pigeon	Columbidae	LC
58	*Parus monticolus*	Green-backed Tit	Paridae	LC
59	*Passer domesticus*	House Sparrow	Passeridae	LC
60	*Passer montanus*	Eurasian Tree Sparrow	Passeridae	LC
61	*Pavo cristatus*	Indian Peafowl	Phasianidae	LC
62	*Pericrocotus speciosus*	Scarlet Minivet	Campephagidae	LC
63	*Pernis ptilorhynchus*	Oriental Honey Buzzard	Accipitridae	LC
64	*Phaenicophaeus tristis*	Green-billed Malkoha	Cuculidae	LC
65	*Phalacrocorax carbo*	Great Cormorant	Phalacrocoracid ae	LC
66	*Phoenicurus auroreus*	Daurian Redstart	Muscicapidae	LC
67	*Phoenicurus fuliginosus*	Plumbeous Redstart	Muscicapidae	LC
68	*Phoenicurus hodgsoni*	Hodgson's Redstart	Muscicapidae	LC
69	*Rhyticeros undulatus*	Wreathed Hornbill	Bucerotidae	LC
70	*Leptoptilos javanicus*	Lesser Adjuntant Strok	Ciconiidae	V
71	*Hypsipetes leucocephalus*	Black bulbul	Pycnonotidae	LC
72	*Ketupa flavipes*	Tawny Fish Owl	Strigidae	LC
73	*Megalaima asiatica*	Blue-throated Barbet	Ramphastidae	LC
74	*Megalaima australis*	Blue-eared Barbet	Ramphastidae	LC
75	*Megalamia haemacephala*	Coppersmith Barbet	Ramphastidae	LC
76	*Myophonus caeruleus*	Blue Whistling-Thrush	Muscicapidae	LC
77	*Ninox scutulata*	Brown Hawk Owl	Strigidae	LC
78	*Pandion haliaetus*	Osprey	Pandionidae	LC
79	*Psilopogon asiaticus*	Blue-throated Barbet	Megalaimidae	LC
80	*Psittacula alexandri*	Red-breasted Parakeet	Ramphastidae	LC
81	*Psittacula eupatria*	Alexandrine Parakeet	Ramphastidae	LC
82	*Pycnonotus cafer*	Red-vented Bulbul	Pycnonotidae	LC
83	*Psilopogon lineatus*	Lineated Barbet	Megalaimidae	LC
84	*Psilopogon virens*	Great Barbet	Megalaimidae	LC
85	*Pycnonotus flaviventris*	Black-crested Bulbul	Pycnonotidae	LC
86	*Turdoides striata*	Jungle Babbler	Leiothrichidae	LC
87	*Vanellus duvaucelii*	River Lapwing	Charadriidae	NT
88	*Vanellus indicus*	Red-wattled Lapwing	Charadriidae	LC
89	*Upupa epops*	Eurasian Hoppoe	Upupidae	LC

90	*Lophura leucomelanos*	Kalig Pheasant	Phasianidae	LC
91	*Gallus gallus*	Red Junglefowl	Phasianidae	LC
92	*Arboroplila torqueola*	Hill Patriage	Phasianidae	LC

When it comes to the diversity of bird species, nearly 11 gewogs within Sarpang Dzongkhag exhibit remarkably similar levels of diversity. Singye gewog boasts the highest recorded diversity, as measured by Shannon diversity index (H=6.78), while Umling gewog reports the lowest diversity (H=4.98) (Table 21). This minimal disparity in diversity indices suggests a relatively even distribution of birds across the dzongkhag, emphasizing a balanced avian presence throughout the region. When it comes to species frequency, the Black Bulbul is the most commonly recorded species across the region, while the Asian Barred Owlet is the least frequently encountered species.

Table 21:Shannon Diversity of Birds in Different gewogs

Gewogs	Shannon Diversity
Chhudzom	6.38
Chhuzergang	5.51
Dekidling	5.48
Gelephu	5.48
Jigmechoeling	6.43
Samtenling	6.42
Shershong	5.27
Shompangkha	6.10
Singye	6.78
Taraythang	5.18
Umling	4.98

Habitat Preferences

Various bird species exhibit habitat preferences, leading to variations in the recorded numbers across different habitat types. Specifically, within the cool broadleaved forest, 540 birds have been documented, surpassing the totals of 392 in the sub-tropical and 269 in the warm broadleaved forest habitats. These findings substantiate the cool broadleaved forest as the most favored habitat for avian species within the Sarpang region (Figure 27)

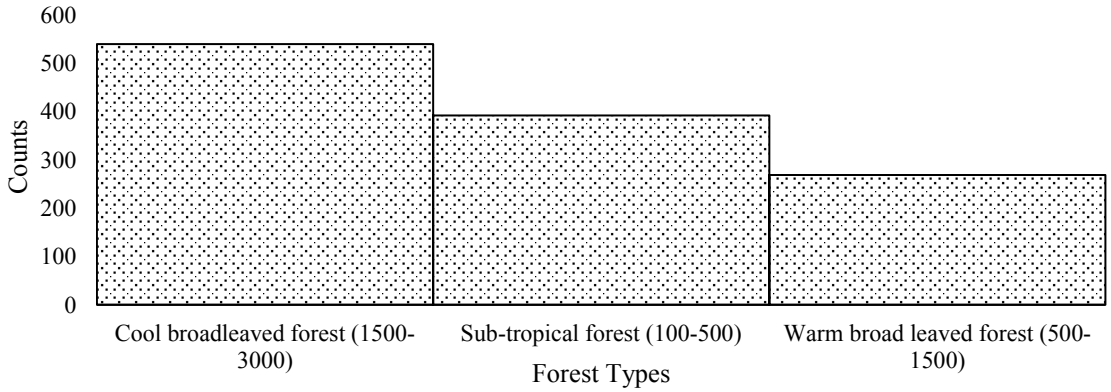


Figure 28:Counts of birds in different forest types of Sarpang.

Behavioral patterns of birds in different weather types

Recorded avian behaviors predominantly revolve around feeding, resting, and various activities influenced by distinct meteorological conditions, encompassing cloudy, foggy, and sunny scenarios. Specifically, during cloudy weather, the preeminent bird activity involves feeding, with 320 individuals engaging in this behavior. Simultaneously, 214 birds adopt a resting posture, while a smaller group of 5 birds allocate their time to preening, and 4 birds are observed participating in courtship behaviors under these meteorological conditions. In foggy weather, the principal activity observed is feeding, with 204 birds participating, accompanied by 182 birds at rest and 6 birds involved in preening. During sunny weather, an equal number of birds, totaling 127, engage in feeding and resting activities, complemented by 7 birds in a resting state and 4 birds dedicated to preening. It is worth noting that the preponderance of avian activities is evident during cloudy and foggy weather conditions, as opposed to sunny conditions (Figure 28).

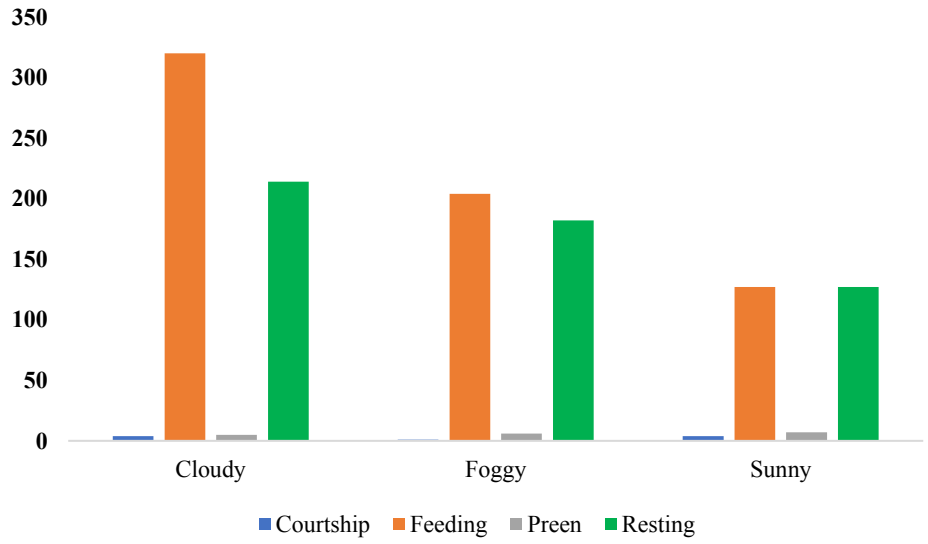


Figure 29:Behavioral patterns of birds in different weather conditions

2.4.Bat (Chiroptera) Species

Bats are vital pollinators and seed dispersers, maintaining plant diversity and ecosystem health. They serve as natural pest controllers, reducing the need for chemical pesticides and benefiting agriculture(Ducummon, n.d.)Bats play a key role in nutrient cycling, and fostering biodiversity, and are essential for the balance of ecosystems(Tshering et al., 2020). Based on a comprehensive review of literature from Bhutan (Dendup, 2020; Tshering et al., 2020) and neighboring regions, Sarpang potentially hosts a diverse bat community comprising 48 species. Among these, 22 species fall under the category of Least Concern (LC), 25 are categorized as Data Deficient (DD), and one species holds the status of Near Threatened (NT) according to the IUCN conservation classification.

Table 22:List of bat species found in Sarpang based on existing literature(Acharya et al., n.d.; Hang & Limboo, n.d.; Tshering et al., 2020)

Sl.no.	Family	Species	IUCN conservation Status
1	*Rhinolophidae*	C. Rhinolophidae (Horseshoe Bats)	DD
2	*Pteropodidae*	Cynopterus horsfieldi	DD
3	*Pteropodidae*	Cynopterus sphinx	LC
4	*Vespertilionidae*	Dycopterus spesdiceus	DD
5	*Pteropodidae*	Enycteris spalaea	DD
6	*Hipposideridae*	Hipposideros armiger	LC
7	*Hipposideridae*	Hipposideros cervinus	DD
8	*Hipposideridae*	Hipposideros cf larvatus	DD
9	*Hipposideridae*	Hipposideros cineraceus	DD
10	*Hipposideridae*	Hipposideros larvatus	NT
11	*Hipposideridae*	Hipposideros pomona	DD
12	*Hipposideridae*	Hipposideros pratti	DD
13	*Hipposideridae*	Hipposideros speoris	DD
14	*Vespertilionidae*	Hypsugo imbricatus	LC
15	*Vespertilionidae*	Insectivorous Bats	DD
16	*Vespertilionidae*	Kerivoula hardwickii	DD
17	*Rhinolophidae*	Megaderma lyara	LC
18	*Miniopteridae*	Miniopterus fuliginosus	LC
19	*Vespertilionidae*	Murina leucogaster	DD
20	*Vespertilionidae*	Murina suilla	DD
21	*Vespertilionidae*	Myotis longipes	LC
22	*Vespertilionidae*	Myotis muricola	LC
23	*Vespertilionidae*	Myotis siligorensis	LC
24	*Vespertilionidae*	Pipistrellus ceylonicus	LC
25	*Vespertilionidae*	Pipistrellus coromandra	LC
26	*Vespertilionidae*	Pipistrellus javanicus	LC
27	*Vespertilionidae*	Pipistrellus pipistrellus	LC
28	*Vespertilionidae*	Pipistrellus tenuis	LC
29	*Rhinolophidae*	Rhinolophus affinis	LC
30	*Rhinolophidae*	Rhinolophus arcuatus	LC
31	*Rhinolophidae*	Rhinolophus ferrumequinum	LC
32	*Rhinolophidae*	Rhinolophus lepidus	DD
33	*Rhinolophidae*	Rhinolophus luctus	DD
34	*Rhinolophidae*	Rhinolophus macrotis	DD
35	*Rhinolophidae*	Rhinolophus pearsoni	DD
36	*Rhinolophidae*	Rhinolophus pearsonii	DD
37	*Rhinolophidae*	Rhinolophus pusillus	DD
38	*Rhinolophidae*	Rhinolophus sinicus	LC
39	*Rhinolophidae*	Rhinolophus sp	DD
40	*Rhinolophidae*	Rhinolophus subbadius	DD
41	*Rhinolophidae*	Rhinolophus yunanensis	DD
42	*Rhinolophidae*	RhinolophusI blambergi	DD
43	*Pteropodidae*	Rousette leschenaultii	LC
44	*Pteropodidae*	Rousettus leschenaultii	LC
45	*Vespertilionidae*	Scotophilus heathi	DD
46	*Vespertilionidae*	Tadarida latouchei	LC
47	*Vespertilionidae*	Tylonycteris pachypus	LC
48	*Vespertilionidae*	Vespertilio murinus	LC

2.5.Herpetofauna

2.5.1. Reptiles

The ecological significance of reptiles lies in their contributions to ecosystem dynamics and health(Miranda, 2017). They help control prey populations, regulate food chains, and maintain ecological balance(Wangyal et al., 2022). Additionally, some reptiles aid in seed dispersal and play a role in shaping plant communities, making them important components of various ecosystems(Wangyal, n.d.). Studying and conserving reptiles is crucial for preserving overall biodiversity and ensuring the stability of ecosystems(Bauer et al., 1992). Tenzin et al., 2022 has documented a total of 34 reptile species inhabiting the Sarpang region.

Table 23:List of reptiles of Sarpang District (Tenzin, 2023.).

Sl. No.	Common name	Scientific name and conservation status	Family
1	*Yellow-speckled wolf snake*	Lycodon jara (Shaw, 1802) LC	Colubridae
2	*Banded krait*	Bungarus fasciatus (Schneider, 1801) LC	Elapidae
3	*Bengal monitor lizard*	Varanus bengalensis (Daudin, 1802) NT	Varanidae
4	*Bengalese kukri snake*	Oligodon dorsalis (Gray & Hardwicke, 1835)	Colubridae
5	*Bronze grass skink*	Mabuya macularia (Blyth, 1853)	Scincidae
6	*Brooke's house gecko*	Hemidactylus brookii (Gray, 1845)	Gekkonidae
7	*Burmese rock python*	Python bivittatus (Kuhl, 1820) VU	Pythonidae
8	*Cantor's black-headed snake*	Sibynophis sagittarius (Cantor, 1839)	Colubridae
9	*Checkered Keelback*	Fowlea piscator (Schneider 1799) LC	Colubridae
10	*Common bronze back*	Dendrelaphis tristis (Daudin, 1803) LC	Colubridae
11	*Common house gecko*	Hemidactylus frenatus (Schlegel, 1836) LC	Gekkonidae
12	*Common mock viper*	Psaminodynastes pulverulentus (F. Boie, 1827)	Colubridae
13	*Common slug snake*	Pareas monticola (Cantor, 1839) LC	Pareidae
14	*Eastern garden lizard*	Calotes versicolor (Daudin, 1802)	Agamidae
15	*Elongated tortoise*	Indotestuda elongata (Blyth, 1853) CR	Testudinoidea
16	*Green pitviper sp.*	Trimeresurus species LC	Viperidae
17	*Indian cobra*	Naja naja (Linnaeus, 1758) LC	Elapidae
18	*Indian forest skink*	Sphenomorphus indicus (Gray, 1853)	Scincidae
19	*Indo-Pacific gecko*	Hemidactylus garnotii (Dumeril & Bibron, 1836) LC	Gekkonidae
20	*Jerdon's forest lizard*	Calotes jerdoni (Gunther, 1870) LC	Agamidae
21	*Khasi Hills bent-toed gecko*	Cyrtodactylus khasiensis (Jerdon, 1870) LC	Gekkonidae
22	*Monocled cobra*	Naja kaouthia (Lesson, 1831) LC	Elapidae
23	*Ornate flying snake*	Chrysopelea ornata (Shaw, 1802)	Colubridae
24	*Radiated rat snake*	Coelognathus radiatus (F. Boie, 1827) LC	Colubridae
25	*Reticulated python*	Malayopython reticulatus (Schneider, 1801) LC	Pythonidae
26	*Russell's viper*	Daboia russelii (Shaw & Nodder, 1797) LC	Viperidae
27	*Striped grass skink*	Eutropis dissimilis (Hallowell, 1857)	Scincidae
28	*Variegated mountain lizard*	Japalura variegata (Gray, 1853) LC	Agamadae
29	*White-lipped pit viper*	Trimeresurus albolabris (Gray, 1842) LC	Viperidae
30	*Saltwater crocodile*	Crocodylus porosus (Laurenti, 1768) LC	Crocodylidae
31	*Gharial*	Gavialis gangeticus (Oppel, 1811) CR	Gavialidae
32	*Zaw's wolf snake*	Lycodon zawi (Slowinski et al., 2001) LC	Colubridae
33	*King cobra*	Ophiophagus hannah (Cantor, 1836) VU	Elapidae
34	*Common Trinket snake*	Coelognathus helena (Daudin, 1803) LC	Colubridae

2.5. 2. Amphibians

Amphibians are crucial ecological indicators, reflecting changes in ecosystem health(Hocking & Babbitt, 2014). They influence nutrient cycling, contribute to food webs, and maintain biodiversity in various ecosystems(USSGS, 2023). Their conservation is essential for preserving ecological balance and global biodiversity(B. K. Koirala et al., 2019). Bhutan has documented a total of 58 amphibian species to date (Wangyal, n.d). Among these, there are a total of 15 amphibian species in Sarpang, with 14 of them categorized as "Least Concern" (LC) according to the IUCN status, while one species is listed as "Near Threatened" (NE) (Tenzin et al., 2022).

Table 24:List of amphibian species in Sarpang along their IUCN conservation status and distribution.

Sl. No.	Scientific name	Common name	Family	Distribution	Conservation status
1	Megophrysparva sp	NA	Megophryidae	Serzhong	LC
2	Bufo melanostictus.	Marble toad	Bufonidae	Moukhola	LC
3	Amolops marinoratus	Marbled sucker frog	Ranidae	Serzhong	LC
4	Euphlyctis cyanophlyctis	Indian Skipping frogs	Ranidae	Sarpang	LC
5	Hoplobatrachus tigerinus	Indian Bull Frog	Ranidae	Sarpang	LC
6	Fejervarya cf limnocharis	Asian Grass Frog	Ranidae	Moukhola	LC
7	Rana (Sylvirana)	Gunther's Amoy Frog,	Ranidae	Moukhola	LC
8	Leptrobrachum bompu	Eastern Spadefoot Toad	Magophryidae	Simkharka	NE
9	Nanorana leibigii	Himalayan Bull frog	Dicroglossidae	Simkharka	LC
10	Amolops assamensis	Assamese cascade frog	Ranidae	Rongkhola, Jigmecholing	LC
11	Hoplobatrachus crassus	Jerdon's bull frogs	Dicroglossidae	Gelephu	LC
12	Duttaphrynus melanostictus	Common Asian toad	Bufonidae	Gelephu town	LC
13	Sylvirana leptoglossa	Assamese forest frog	Ranidae	Ashney, Jigmecholing	LC
14	Rhacophorus maximus	Large tree frog	Rhacophoridae	Assney, Jigmecholing	LC
15	Bufo bufo	European toad	Bufonidae	Gelephu area	LC

However, it's important to note that this list is primarily derived from available literature. Further research is essential to validate the presence of these species and to potentially discover additional ones in the Sarpang region.

3. Aquatic Biodiversity

Importance of Aquatic Biodiversity

Aquatic biodiversity is crucial for maintaining the health and resilience of our planet's ecosystems(Hatler, 2022). It supports the livelihoods of millions of people who depend on fisheries and aquaculture for food and income(Irfan & Alatawi, 2019). Furthermore, it plays a vital role in regulating climate, purifying water, and providing essential services that are fundamental to life on Earth(J. Wang et al., 2021). Bhutan's historical records of freshwater biodiversity were limited, with a significant gap in the documentation of macro-invertebrates until recent years(U. Dorji, n.d.). Fish studies were relatively more extensive, with 91 known species documented in Bhutan by 2013 and the extensive study also led to discovery of a new species leading to increase in fish species recorded.

In contrast, macroinvertebrate studies were concentrated in specific locations. This is concerning as Bhutan's freshwater ecosystems are becoming increasingly fragmented, and the full extent of their impact remains uncertain, emphasizing the need for further research and conservation efforts. Further research and conservation measures are crucial to comprehensively understand and safeguard Bhutan's freshwater biodiversity and its associated ecosystem services.

3.1. Fishes

Fishes play a crucial role in aquatic ecosystems by regulating food webs, contributing to nutrient cycling, and serving as indicators of environmental health(C. T. Perry et al., 2022). Their presence and interactions help maintain the balance and functioning of aquatic environments(Villéger et al., 2017). Bhutan is home to a diverse array of 91 confirmed fish species(Gurung et al., 2013), with 29 of these species identified in the region of Sarpang(Tenzin, 2022).Within this fascinating aquatic ecosystem, there are 16 species classified as Least Concern (LC), 3 species as Data Deficient (DD), 3 species as Endangered (E), 3 species as Near Threatened (NE), one species designated as Near Threatened (NT), and an additional 3 species listed as Vulnerable (V)(Tenzin, 2022).

Table 25: List of fishes of Sarpang based existing literatures

Sl. No.	Species name	Family	Distribution	Conservation Status
1	*Anguilla bengalensis*	Anguillidae	Moakhola	LC
2	*Hypophthalmichthys molitrix*	Cyprinidae	Sarpang fishery	NT
3	*Devario aequipinnatus*	Cyprinidae	Moakhola	V
4	*Ctenopharyngodon idella*	Cyprinidae	Sarpang (Introduced)	E
5	*Cyprinus carpio*	Cyprinidae	Gelephu	V
6	*Tor putitora*	Cyprinidae	Kalikhola	E
7	*Hypophthalmichthys nobilis*	Cyprinidae	Gelephu	DD
8	*Chagunius chagunio*	Cyprinidae	Kalikhola	LC
9	*Cirrhinus mrigala*	Cyprinidae	Sarpang (Introduced)	V
10	*Catla catla*	Cyprinidae	Sarpang (Introduced)	LC
11	*Labeo rohita*	Cyprinidae	Sarpang (Introduced)	NE
12	*Garra annandalei*	Cyprinidae	Sarpang (Introduced	LC
13	*Pseudolaguvia ferule*	Sisoridae	Kalikhola	DD

14	*Pseudolaguvia ribeiroi*	Erethistidae	Takliakhola	LC
15	*Clarias magur*	Clariidae	Sarpang	E
16	*Mastacembelus armatus*	Mastacembelidae	Sarpang	LC
17	*Channa gachua*	Channidae	Sarpang	LC
18	*Myersglanis blythi*	Siroridae	Simkharka	DD
19	*Botia almorhae*	Cobitidae	Takliakhola	LC
20	*Botia lohachata*	Cobitidae	Moukhola	NE
21	*Xenentodon cancila*	Belonidae	Takliakhola	LC
22	*Badis badis*	Chanidae	Takliakhola	LC
23	*Esomus danricus*	Cyprinidae	Moukhola	LC
24	*Barilius barna*	Cyprinidae	Takliakhola	LC
25	*Barilius bendelisis*	Cyprinidae	Taklliakhola	LC
26	*Barilius vagra*	Cyprinidae	Takliakhola	LC
27	*Schizothorax plagiostomus*	Cyprinidae	Simkharka	NE
28	*Barbatula barbatula*	Nemacheillidae	Burkhola	LC
29	*Clupisoma garua*	Aliidae	Gelephu	LC

Assessment of Environmental Variables in Fish Habiat

Table 26:Descriptive statistics for environmental variables of water systems (Habitat)

	Temperature(°C)	**pH**	**Conductivity**(µS/cm).
Min	17.8	8.58	158.4
Max	32.6	13.58	404
Median	19.3	8.77	179.5
Mean	20.78	9.134	228.5

The analysis unveiled a diverse range of temperatures within the water system (Min = 17.80°C, Max = 32.60°C). The median temperature was calculated to be 19.30°C, with a slightly higher mean temperature of 20.78°C. These values indicated an approximate normal distribution of temperature, reflecting a balanced occurrence of both warm and cold temperature measurements in the sampled water. In terms of pH, the recorded values spanned from pH_{Min} = 8.580 to pH_{Max} = 13.580, demonstrating a wide spectrum of alkalinity. The median pH (pH = 8.770) closely approximated the mean (pH = 9.134), suggesting a symmetrical distribution of acidity levels within the water system.

The data on conductivity (µS/cm) exhibited considerable variability, ranging from 158.4 µS/cm to 404.0 µS/cm. The median conductivity, measuring 179.5 µS/cm, served as the central point within the dataset, while the mean conductivity of 228.5 µS/cm indicated a right-skewed distribution. These findings underscored the presence of localized areas with elevated conductivity levels, which may be influenced by specific environmental factors (Table #).

Table 27:Ideal Conditions of water systems for Highest Count of fishes captured.

Sl.no.	**Number**	**Temperature(**°C)	**pH**	**Conductivity**(µS/cm).
1	42	20.7	8.64	234

The significance of this observation becomes evident as it recorded the highest fish abundance among all instances documented. This finding implies that the environmental conditions characterized by a temperature of 20.7°C, a pH of 8.64, and a conductivity level of 234 µS/cm (arbitrary units) were conducive to the heightened presence of fish within the studied ecosystem during this particular observation (Table #).

Table #: Correlations of number of fishes captured with environmental conditions

	Temperature(°C)	pH	Salinity (ppm)
No. of Fish	-0.2	-0.612	-0.63

The analysis revealed negative correlations between each environmental parameter and fish abundance. Specifically, a weak negative relationship was observed between temperature and fish count (r = -0.12). This weak negative correlation between temperature and fish abundance (r = -0.12) suggests that fish populations may be somewhat sensitive to changes in temperature. This highlights the need for monitoring temperature fluctuations and their potential impact on fish populations. In contrast, a strong negative association was identified between pH and fish abundance (r = -0.612). This strong negative association between pH and fish abundance (r = -0.612) indicates that lower pH levels may have a significant adverse effect on fish populations. Acidic or alkaline conditions could potentially limit the presence of certain fish species. Additionally, a strong negative relationship was found between fish count and salinity. This strong negative relationship between fish count and salinity underscores the importance of salinity levels in shaping fish abundance. Higher salinity levels may be associated with reduced fish populations, possibly indicating specific habitat preferences among fish species.

Diversity and Count of Fishes in the Surveyed Area

Table 28:Diversity (Shannon) of Fishes in 4 surveyed gewogs

Gewogs	Shannon Diversity Index(H)
Dekiling	1.47
Gakidling	2.03
Jigmecholing	1.02
Sengye	2.09

Significant variations in species diversity among surveyed areas were observed. Gakidling exhibited the highest diversity index (H = 2.03), signifying a rich and relatively equitable distribution of species within its aquatic ecosystem. In contrast, Jigmecholing registered the lowest diversity index (H = 1.02), implying a less diverse and potentially skewed distribution of species within its aquatic habitat. Dekiling (H = 1.47) and Sengye (H = 2.09) displayed intermediate levels of species diversity. The overall Shannon diversity index for the entire study area was calculated at H = 2.11.

The most abundant family identified was **"Cyprinidae,"** comprising 263 individuals, followed by "**Nemacheilidae**" with 47 individuals. Furthermore, "**Psilorhynchidae**" and "**Sisoridae"** were each represented by 54 individuals. Less frequently encountered families, such as "**Balitoridae," "Badidae," "Bagridae," "Channidae," "Cobitidae," "Mastacembelidae,"** and "*Schilbeidae,"* were observed with 20-37 individuals each. Among these, the most commonly recorded fish species was *Garra annandalei,* with a total count of 35 individuals.

3.2. Aquatic Macro-invertebrates

Aquatic macroinvertebrates are organisms such as insects, crustaceans, and mollusks that lack a backbone and are of substantial size, residing in freshwater environments(Wangmo et al., 2022). In freshwater ecosystems, the significance of aquatic macroinvertebrates is noteworthy for multiple compelling reasons(Orozco-González & Ocasio-Torres, 2023). Firstly, these organisms function as highly responsive bioindicators, facilitating the evaluation of aquatic ecosystem health Secondly, they hold a pivotal role in aquatic food chains, with their brief adult phase serving as a crucial food source for a diverse array of aquatic organisms(Jackson & Füreder, 2006). Lastly, their pivotal ecological functions encompass nutrient cycling and the decomposition of organic matter, thereby underpinning the holistic operational dynamics and equilibrium of aquatic ecosystems(Dorji, 2020).

3.3. Mayflies (Ephemeroptera)

Mayflies, members of the order Ephemeroptera, are distinguished by their distinct life cycle, featuring aquatic nymph and ephemeral adult stages(Brittain, 1982). Their appearance is characterized by two pairs of delicate membranous wings and elongated thread-like tails(Jackson & Füreder, 2006). These insects predominantly inhabit freshwater ecosystems, with their nymphs' inhabiting rivers, streams, and lakes(J. Wangchuk & Eby, 2019).

Table 29:List of Mayflies that could exist in freshwater ecosystems of Sarpang, Bhutan.

Sl.no.	Species	Family
1	*Baetis sp.*	**Baetidae**
2	*Centroptiloides sp.*	**Baetidae**
3	*Cloeon sp.*	**Baetidae**
4	*Epeorus sp.*	**Heptageniidae**
5	*Ephemera sp.*	**Ephemeridae**
6	*Ephoron sp.*	**Polymitarcyidae**
7	*Habrophlebia sp.*	**Leptophlebiidae**
8	*Heptagenia sp*	**Heptageniidae**
9	*Hexagenia sp.*	**Ephemeridae**
10	*Isonychia sp*	**Isonychiidae**
11	*Leuctra sp.*	**Leuctridae**
12	*Nemoura sp.*	**Nemouridae**
13	*Oligoneuriella sp.*	**Oligoneuriidae**
14	*Paraleptophlebia sp.*	**Leptophlebiidae**
15	*Potamanthus sp.*	**Potamanthidae**

16	*Rhithrogena sp.*	**Heptageniidae**
17	*Serratella sp*	**Ephemerellidae**
18	*Siphlonurus sp.*	**Siphlonuridae**
19	*Stenonema sp.*	**Heptageniidae**
20	*Traverella sp.*	**Leptophlebiidae**

3.4. Stoneflies-(Plecoptera)

Stoneflies belong to the order Plecoptera and exhibit a hemimetabolous life cycle, which consists of aquatic nymph and winged adult stages(W. B. Perry et al., 1987). They possess membranous wings and caudal filaments and are restricted to freshwater habitats such as lotic systems. Stonefly nymphs are adapted to high-velocity, well-oxygenated waters, where they attach to substrates and macrophytes(Wallace et al., 1970). They serve as bioindicators of water quality and are essential members of aquatic trophic webs. As they reach adulthood, stoneflies undergo a metamorphosis into ephemeral, alate forms that are primarily concerned with mating, ovipositing near water sources. This ensures the continuity of the cycle as their progeny emerge and initiate their aquatic nymphal phase(de Figueroa & López-Rodríguez, 2019). There are 38 species of stoneflies recorded in Bhutan, 19 of which were described by Zwick (1977) and 1 by Stark & Sivec (2010). 12 species were reported at genus level.

Table 30:List of stoneflies that could exist in freshwater ecosystems of Sarpang, Bhutan(Dorji, 2015.).

Sl.no.	Species Name	Family
1	*Allocapnia sp.*	**Capniidae**
2	*Allocapnia himalayana*	**Capniidae**
3	*Beloneuria sp.*	**Nemouridae**
4	*Capnia sp.*	**Capniidae**
5	*Chloroperla sp.*	**Chloroperlidae**
6	*Diura similis*	**Perlidae**
7	*Ecdyonurus sp.*	**Heptageniidae**
8	*Epeorus sp.*	**Heptageniidae**
9	*Heptagenia sp.*	**Heptageniidae**
10	*Isonychia sp.*	**Isonychiidae**
11	*Leuctra sp.*	**Leuctridae**
12	*Nemoura sp.*	**Nemouridae**
13	*Paragnetina sp.*	**Perlidae**
14	*Perla sp.*	**Perlidae**
15	*Plecoptera sp.*	**Plecoptera**
16	*Protoperla sp.*	**Perlidae**
17	*Pteronarcys sp.*	**Pteronarcyidae**
18	*Rhithrogena sp.*	**Heptageniidae**
19	*Serratella sp.*	**Perlidae**
20	*Taeniopteryx sp.*	**Taeniopterygidae**
21	*Tricorythodes sp.*	**Leptoceridae**

3.5. Water Beetles (Coleoptera)

Water beetles (Coleoptera) are a diverse group of beetles that have adapted to life in aquatic environments(Das & Biswas, 2018). They are found in all types of freshwater habitats, from temporary pools to large lakes and rivers. Water beetles have a variety of body shapes and sizes, but they all share some common features that help them to survive underwater(Chutia & Kardong, 2022).

Water beetles have a waterproof exoskeleton and a number of adaptations that help them to breathe and swim, such as air bubbles trapped in their fur or under their elytra (wing cases) and modified legs(Blon et al., 2023). Water beetles play an important role in aquatic ecosystems as predators of other aquatic insects, larvae, and small fish, and as a food source for birds, fish, and other animals(Centennial Park, 2023).

Table 31:List of water beetles that could exist in freshwater ecosystems of Sarpang, Bhutan(Blon et al., 2023; Ghalley et al., 2021b)

Sl.no.	Species	Family
1	*Amphicyclus sp.*	**Haliplidae**
2	*Anisops sp.*	**Notonectidae**
3	*Aulacocyclus sp.*	**Notonectidae**
4	*Batrachedrus sp.*	**Notonectidae**
5	*Bidessus sp.*	**Dytiscidae**
6	*Canthydrus sp.*	**Dytiscidae**
7	*Cercyon sp.*	**Hydrophilidae**
8	*Copelatus sp.*	**Dytiscidae**
9	*Cybister sp.*	**Dytiscidae**
10	*Cyphon sp.*	**Scirtidae**
11	*Deronectes sp.*	**Dytiscidae**
12	*Dineutus sp.*	**Gyrinidae**
13	*Enochrus sp.*	**Hydrophilidae**
14	*Eretes sp.*	**Notonectidae**
15	*Haliplus sp.*	**Haliplidae**
16	*Hydrophilus sp.*	**Hydrophilidae**
17	*Hygrotus sp.*	**Dytiscidae**
18	*Laccophilus sp.*	**Dytiscidae**
19	*Limnebius sp.*	**Hydraenidae**
20	*Laccotrephes sp.*	**Nepidae**
21	*Laccotrephes robustus*	**Nepidae**
22	*Laccotrephes spinosus*	**Nepidae**
23	*Lethocerus sp.*	**Belostomatidae**
24	*Liodessus sp.*	**Dytiscidae**
25	*Melanodytes sp.*	**Dytiscidae**
26	*Micronecta sp.*	**Corixidae**
27	*Nepa sp.*	**Nepidae**
28	*Nepeotes sp.*	**Nepidae**
29	*Notonecta sp.*	**Notonectidae**
30	*Platambus sp.*	**Dytiscidae**
31	*Porhydrus sp.*	**Dytiscidae**
32	*Rhantus sp.*	**Dytiscidae**

33	*Stictotarsus sp.*	**Dytiscidae**
34	*Troposternum sp.*	**Hydrophilidae**
35	*Uvarus sp.*	**Dytiscidae**

It is important to note that it is the list of freshwater beetle species that could possibly occur in Sarpang based on available literatures from Bhutan, and neighboring countries. More research is needed to determine the full extent of freshwater beetle diversity in Sarpang.

3.6. Caddisflies (Trichoptera)

Caddisflies (Trichoptera) are a large order of aquatic insects with over 17,000 species worldwide. They are known for their larval cases made of silk and various materials, such as leaves, twigs, and sand(Das & Biswas, 2018). Adult caddisflies resemble moths, but they have hairy wings instead of scales. Caddisflies play an important role in aquatic ecosystems as grazers and predators, and they are also a food source for other animals(Devi Upadhyay, 2020). Caddisflies were first recorded in 1972 in Bhutan and 172 species have been recorded so far. Of these, 18 species were reported at genus level. 36 new species were described from Bhutan, of which 27 species by Malicky (2007), 6 species by Schmid (1975), 2 species by Olah (1985), and 1 species by Malicky and Chantaramongkol (2006).

Table 32:List of Caddisflies that could exist in freshwater ecosystems of Sarpang, Bhutan(Chhopel, 2020).

Family	Species
Hydropsychidae	*Hydropsyche sp., Cheumatopsyche sp., Diplectrona sp., Parapsyche sp., Rhyacopsyche sp.*
Polycentropodidae	*Polycentropus sp., Phylocentropus sp., Plectrocnemia sp., Cyrnus sp., Holocentropus sp.*
Rhyacophilidae	*Rhyacophila sp., Glossosoma sp., Agapetus sp., Hydroptila sp., Allotrichia sp.*
Limnephilidae	*Limnephilus sp., Ecclisomyia sp., Anabolia sp., Stenophylax sp., Platyphylax sp.*
Glossosomatidae	*Glossosoma sp., Agapetus sp., Hydroptila sp., Allotrichia sp., Protoptila sp.*
Phryganeidae	*Phryganea sp., Agraylea sp., Oligostomis sp., Neuronia sp., Agrypnia sp.*
Psychomyiidae	*Psychomyia sp., Tinodes sp., Lype sp., Ecnomus sp., Rhyacopsyche sp.*
Ecnomidae	*Ecnomus sp., Plectrocnemia sp., Cyrnus sp., Holocentropus sp., Polycentropus sp.*
Sericostomatidae	*Sericostoma sp., Goera sp., Brachycentrus sp., Leptocerus sp., Hydroptila sp.*
Leptoceridae	*Leptocerus sp., Athripsodes sp., Oecismus sp., Triaenodes sp., Mystacides sp.*
Goeridae	*Goera sp., Leptocerus sp., Athripsodes sp., Oecismus sp., Triaenodes sp.*
Brachycentridae	*Brachycentrus sp., Leptocerus sp., Athripsodes sp., Oecismus sp., Triaenodes sp.*
Hydroptilidae	*Hydroptila sp., Allotrichia sp., Protoptila sp., Neureclipsis sp., Oxyethira sp.*
Philopotamidae	*Philopotamus sp., Wormaldia sp., Dolophilodes sp., Chimarra sp., Tinodes sp.*
Stenopsychidae	*Stenopsyche sp., Ceratopsyche sp., Cheumatopsyche sp., Diplectrona sp., Parapsyche sp.*
Odontoceridae	*Odontocerus sp., Plectrocnemia sp., Cyrnus sp., Holocentropus sp., Polycentropus sp.*
Beraeidae	*Beraea sp., Silo sp., Oligoplectrum sp., Athripsodes sp., Oecismus sp.*
Lepidostomatidae	*Lepidostoma sp., Crunoecia sp., Lasiocephala sp., Psychomyia sp., Tinodes sp.*
Apataniidae	*Apatania sp., Rhyacophila sp., Glossosoma sp., Agapetus sp., Hydroptila sp.*
Calamoceratidae	*Calamoceras sp., Phylocentropus sp., Plectrocnemia sp., Cyrnus sp., Holocentropus sp.*
Uenoidae	*Uenoa sp., Rhyacophila sp., Glossosoma sp., Agapetus sp., Hydroptila sp.*
Helicopsychidae	*Helicopsyche sp., Psychomyia sp., Tinodes sp., Lype sp., Ecnomus sp.*
Setodesidae	*Setodes sp., Athripsodes sp., Oecismus sp., Triaenodes sp., Mystacides sp.*
Xiphocentronidae	*Xiphocentron sp., Leptocerus sp., Athripsodes sp., Oecismus sp., Triaenodes sp.*

3.7. Dragonflies and Damselflies (Odonata)

The insect order Odonata is divided into three suborders - the more delicate weakly flying damselflies (Zygoptera), the more robust dragonflies (Anisoptera) and a relict group of primitive dragonflies (Anisozygoptera)(Bhutan et al., 2023). However, the odonatologists of the recent world commonly use the term "dragonfly" for the members of all the three suborders(V. J. Kalkman et al., 2020). According to Silsby, 2001, eight superfamilies, 29 families, and some 58 sub-families of dragonflies for approximately 600 genera and 6000 named species have so far been described all over the world. There are 114 species from seventeen families under the order Odonata in Bhutan(Mitra, 2006) .

Dragonflies

Dragonflies, belonging to the order Odonata, are ancient insects that have fascinated scientists and nature enthusiasts for generations. This report provides a comprehensive overview of dragonflies, shedding light on their biological characteristics, ecological roles, and the imperative need for conservation.

Table 33:List of dragonflies that could exist in freshwater ecosystems of Sarpang, Bhutan(T. Gyeltshen et al., 2017; V. Kalkman et al., 2021).

Family	Genus	Species
Aeshnidae	Aeshna	*Aeshna cyanea, Aeshna mixta, Aeshna viridis*
Argiolestidae	Argiolestis	*Argiolestis patens, Argiolestis prothoracica, Argiolestis pulchra*
Calopterygidae	Neurobasis	*Neurobasis chinensis, Neurobasis lutescens*
Chlorocyphidae	Chlorocypha	*Chlorocypha cyanea, Chlorocypha elegantula, Chlorocypha laidlawi*
Coenagrionidae	Ceriagrion	*Ceriagrion coromandelianum, Ceriagrion fallax, Ceriagrion tenellum*
Coenagrionidae	Coenagrion	*Coenagrion puella, Coenagrion scitulum, Coenagrion striatum*
Coenagrionidae	Enallagma	*Enallagma parvum, Enallagma sinense*
Coenagrionidae	Ischnura	*Ischnura senegalensis, Ischnura sp.*
Corduliidae	Cordulegaster	*Cordulegaster annulatus, Cordulegaster bidentatus*
Euphaeidae	Dysphaea	*Dysphaea dimidiata, Dysphaea ethela*
Gomphidae	Gomphus	*Gomphus flavatus, Gomphus simillimus*
Gomphidae	Onychogomphus	*Onychogomphus forcipatus, Onychogomphus styx*
Libellulidae	Brachythemis	*Brachythemis contaminata, Brachythemis duivenbodei*
Libellulidae	Crocothemis	*Crocothemis servilia*
Libellulidae	Diplacodes	*Diplacodes nebulosa*
Libellulidae	Neurothemis	*Neurothemis fluctuans, Neurothemis tullia*
Libellulidae	Orthetrum	*Orthetrum pruinosum, Orthetrum sabina*
Libellulidae	Pantala	*Pantala flavescens*
Platycnemididae	Coeliccia	*Coeliccia flavicauda, Coeliccia pyrrhosoma*
Platycnemididae	Platycnemis	*Platycnemis foliacea, Platycnemis pennipes*
Protoneuridae	Protoneura	*Protoneura auripennis, Protoneura capillaris*

Damselflies

Damselflies (Order: Odonata, Suborder: Zygoptera) are ancient insects known for their delicate appearance and vibrant colors(Mitra, 2006). They are characterized by their slender bodies and intricately veined wings, resembling miniature dragonflies. Damselflies are aquatic during their nymph stage, inhabiting freshwater habitats and preying on small invertebrates. Their striking aerial

acrobatics and agile flight make them efficient hunters of flying insects(T. Gyeltshen et al., 2017). Damselflies are essential indicators of water quality, as their presence or absence reflects the health of aquatic ecosystems. These charismatic insects play a vital role in controlling insect populations and are a fascinating subject of study in entomology and ecology(T. Gyeltshen et al., 2017).

Table 34:List of damselflies that could exist in freshwater ecosystems of Sarpang, Bhutan(T. Gyeltshen et al., 2017; Mitra, 2006).

Family	Genus	Species
Calopterygidae	Calopteryx	*C. virgo*
Chlorocyphidae	Libellago	*L. lineata*
Coenagrionidae	Amphicnemis	*A. amabilis, A. erato*
Coenagrionidae	Argia	*A. maldivesica*
Coenagrionidae	Cercion	*C. calamorum, C. hieroglyphicum, C. malayanum, C. sieboldii*
Coenagrionidae	Copera	*C. annulata*
Coenagrionidae	Coenagrion	*C. angulatum, C. dyeri, C. hastulatum, C. puella, C. siamense*
Coenagrionidae	Enallagma	*E. parvulum*
Coenagrionidae	Ischnura	*I. aurora, I. elegans, I. forcipata, I. senegalensis*
Coenagrionidae	Pseudagrion	*P. microcephalum, P. rubriceps*
Platycnemididae	Platycnemis	*P. foliata, P. pennipes*
Platycnemididae	Protoneura	*P. capillaris, P. indica, P. irregularis, P. meghalayaensis, P. tenuissima*

3.8. Aquatic Worms (Oligochaeta)

Aquatic worms, belonging to the class Oligochaeta, are a diverse group of segmented worms primarily found in freshwater environments(Gusakov et al., 2023). They play crucial roles in nutrient cycling and sediment processing within aquatic ecosystems. Characterized by their cylindrical bodies and the presence of setae, these worms help improve soil structure by burrowing through sediment and consuming organic matter(Pinder & Ohtaka, 2004). They are sensitive to environmental changes, making them important indicators of water quality. Aquatic oligochaetes are not only integral components of aquatic food webs but also contribute to the decomposition of organic material, influencing the overall health of freshwater ecosystems(Gusakov et al., 2023).

Table 35:List of aquatic worms that could exist in freshwater ecosystems of Sarpang, Bhutan (Bhutan Biodiversity Portal, 2023).

Sl.no.	Species name	Family
1	*Aelosoma hemprichi*	**Lumbricidae**
2	*Alma ephippigera*	**Tubificidae**
3	*Aelosoma tenebrosum*	**Lumbricidae**
4	*Branchiobdella parasita*	**Branchiobdellidae**
5	*Criodrilus lacuum*	**Tubificidae**
6	*Dero digitata*	**Naididae**
7	*Enchytraeus buchholzi*	**Enchytraeidae**
8	*Limnodrilus hoffmeisteri*	**Tubificidae**
9	*Lumbricus terrestris*	**Lumbricidae**
10	*Nais elinguis*	**Naididae**
11	*Stylaria lacustris*	**Naididae**
12	*Tubifex tubifex*	**Tubificidae**

3.9. Clams and Mussels (Bivalvia)

Mussels

Mussels, belonging to the class Bivalvia, are aquatic mollusks known for their two-part, hinged shells(Le Vay & Egan, 1999). They are filter feeders, actively pumping water through their gills to capture and consume phytoplankton and other suspended particles(De Francesco, 2022). Mussels are ecologically significant as they help improve water quality by filtering and removing excess nutrients, such as nitrogen and phosphorous, from aquatic ecosystems(McMahon & Bogan, 2001). They are often used as bioindicators of water pollution and quality due to their sensitivity to environmental changes. Additionally, mussels are a valuable food source and play a role in cultural and economic contexts, with aquaculture practices established for their sustainable production(Le Vay & Egan, 1999).

Table 36:List of mussels that could exist in freshwater ecosystems of Sarpang, Bhutan.

Sl.no	Species Name	Family
1	*Anodonta anatina*	**Anodontidae**
2	*Anodonta cygnea*	**Anodontidae**
3	*Anodonta woodiana*	**Anodontidae**
4	*Cuneopsis deccanensis*	**Etheriidae**
5	*Enigmonia aenigmatica*	**Unionidae**
6	*Lamellidens corrianus*	**Unionidae**
7	*Lamellidens marginalis*	**Unionidae**
8	*Lamellidens truncatus*	**Unionidae**
9	*Parreysia favidens*	**Unionidae**
10	*Parreysia laevis*	**Unionidae**
11	*Parreysia ornata*	**Unionidae**
12	*Parreysia favidens*	**Unionidae**
13	*Pseudodon omalis*	**Mycetopodidae**
14	*Trapezoideus granosus*	**Unionidae**

Clams

Clams, members of the class Bivalvia, are aquatic mollusks characterized by their two-valved shells. They inhabit various aquatic environments, from freshwater lakes to marine coastlines(McMahon & Bogan, 2001). Clams are filter feeders, actively pumping water through their gills to capture microscopic plankton and organic particles. They serve as essential components of aquatic food webs, providing sustenance for a variety of organisms(De Francesco, 2022; *The Bivalvia*, n.d.). Clams also play a role in sediment stabilization and nutrient cycling in their ecosystems. Additionally, they are economically significant, as they are harvested for human consumption and are cultivated in aquaculture systems, contributing to the global seafood industry(Maine Department of Environmental Protection, 2023; The Bivalvia, 2023).

Table 37:List of clams that could exist in freshwater ecosystems of Sarpang, Bhutan.

Sl.no.	Species	Family
1	*Anodonta woodiana*	**Anodontidae**
2	*Cristaria plicata*	**Unionidae**
3	*Epioblasma torulosa rangiana*	**Unionidae**
4	*Gonidea angulata*	**Margaritidae**
5	*Lamprotula leai*	**Unionidae**
6	*Lymnaea auricularia*	**Lymnaeidae**
7	*Margaritifera margaritifera*	**Margaritidae**
8	*Mytilus edulis*	**Mytilidae**
9	*Ostrea edulis*	**Ostreidae**
10	*Parreysia corrugata*	**Unionidae**
11	*Pisidium amnicum*	**Pisidiidae**
12	*Pisidium casertanum*	**Pisidiidae**
13	*Pisidium henslowanum*	**Pisidiidae**
14	*Pisidium moitessierianum*	**Pisidiidae**
15	*Pisidium nitidum*	**Pisidiidae**
16	*Pisidium subtruncatum*	**Pisidiidae**
17	*Radix auricularia*	**Lymnaeidae**
18	*Sphaerium corneum*	**Sphaeriidae**
19	*Sphaerium lacustre*	**Sphaeriidae**
20	*Sphaerium rivicola*	**Sphaeriidae**
21	*Unio pictorum*	**Unionidae**

3.10. Freshwater Decapods

The order Decapoda consists of shrimps, crayfishes, lobsters, and crabs. Study on the diversity of Decapods is a new field of research in Bhutan. There are about 18 species of Decapods (Pretzmann 1975; Glenn 2006; Dorji 2016; Samdrup 2017). From the total, two species belong to freshwater shrimps (Dorji 2016) while the rest belong to freshwater crabs. *Liotelphusa wuermlii* is the only species in the country described by Pretzmann (1975).

Table 38: List of freshwater decapods that could exist in freshwater ecosystems of Sarpang, Bhutan.

Sl. No	Scientific Name	Family
1	*Acanthopotamon martensi (Wood-Mason, 1875)*	Potamidae
2	*Acanthopotamon fungosum (Alcock, 1909)*	Potamidae
3	*Acanthopotamon panningi (Bott, 1966)*	Potamidae
4	*Alcomon lophocarpus (Kemp, 1913)*	Potamidae
5	*Alcomon superciliosum (Kemp, 1913)*	Potamidae
6	*Barytelphusa cunicularis*	Gecarcinucidae
7	*Barythelphusa lugubris (Wood-Mason, 1871)*	Gecarcinucidae
8	*Himalayapotamon*	Potamidae
9	*Himalayapotamon emphysetum*	Potamidae
10	*Liotelphusa quadrata*	Gecarcinucidae
11	*Liothelphusa laevis (Alcock, 1910)*	Gecarcinucidae
12	*Macrobrachium assamense*	Palaemonidae
13	*Maydelliathelphusa*	Gecarcinucidae
14	*Potamiscus sikkimense (Rathbun, 1905)*	Potamidae

3.11. Diptera

Diptera is the order of insects that includes flies. These insects are characterized by having a single pair of wings and, in most cases, large compound eyes(Courtney & Cranston, 2015). Diptera are highly diverse and can be found in a wide range of habitats worldwide. They are crucial in ecological processes, serving as pollinators, decomposers, and prey for various animals. Flies have diverse feeding habits, with some being herbivorous, others being blood-feeding parasites, and many being scavengers(Los Huertos, 2020). They are significant vectors of diseases in some cases, making them of public health concern. Additionally, they are extensively studied in fields such as entomology and genetics and are valuable for various research purposes. Under the order Diptera, there are 33 species recorded until now as per the works of Lewis (1974), Chaudhuri and Gosh (1985), Datta (1991), De and Gupta (1995), Takaoka and Praya (2008). This also includes five species which were reported at genus level.

Table 39: List of Diptera species that could exist in freshwater ecosystems of Sarpang, Bhutan.

Sl.No.	Species Name	Family	Sl.No.	Species Name	Family
1	*Actinoptera reticulata*	Syrphidae	32	*Dacus feijeni*	Tephritidae
2	*Adapsilia flavopilosa*	Chloropidae	33	*Dacus fletcheri*	Tephritidae
3	*Atherigona orientalis*	Muscidae	34	*Dacus siamensis*	Tephritidae
4	*Bactrocera aethriobasis*	Tephritidae	35	*Delia platura*	Anthomyiidae
5	*Bactrocera correcta*	Tephritidae	36	*Ensina sonchi*	Tephritidae
6	*Bactrocera dorsalis*	Tephritidae	37	*Eristalis parens*	Syrphidae
7	*Bactrocera gombokensis*	Tephritidae	38	*Eupeodes corollae*	Syrphidae
8	*Bactrocera invadens*	Tephritidae	39	*Mimegralla coeruleifrons*	Tephritidae
9	*Bactrocera nigrofemoralis*	Tephritidae	40	*Orseolia oryzae*	Cecidomyiidae
10	*Bactrocera rubigina*	Tephritidae	41	*Simulium chuzargangense*	Simuliidae
11	*Bactrocera tuberculata*	Tephritidae	42	*Simulium bhutanense*	Simuliidae
12	*Bactrocera verbascifoliae*	Tephritidae	43	*Simulium dattai*	Simuliidae
13	*Bactrocera vishnu*	Tephritidae	44	*Simulium nemorivagum*	Simuliidae
14	*Bactrocera zonata*	Tephritidae	45	*Simulium taktsangense*	Simuliidae
15	*Bactrocera diversa*	Tephritidae	46	*Simulium aureohirtum*	Simuliidae
16	*Bactrocera minax*	Tephritidae	47	*Simulium bumthangense*	Simuliidae
17	*Bactrocera assamensis*	Tephritidae	48	*Simulium mongarense*	Simuliidae
18	*Bactrocera atrifacies*	Tephritidae	49	*Simulium thrimshinglaense*	Simuliidae
19	*Bactrocera biguttata*	Tephritidae	50	*Simulium biforaminiferum*	Simuliidae
20	*Bactrocera cucurbitae*	Tephritidae	51	*Simulium demolaense*	Simuliidae
21	*Bactrocera diaphora*	Tephritidae	52	*Simulium dentatum*	Simuliidae
22	*Bactrocera scutellaris*	Tephritidae	53	*Simulium deothangense*	Simuliidae
23	*Bactrocera scutellata*	Tephritidae	54	*Simulium grisescens*	Simuliidae
24	*Bactrocera signata*	Tephritidae	55	*Simulium indicum*	Simuliidae
25	*Bactrocera tau*	Tephritidae	56	*Simulium pradyai*	Simuliidae
26	*Bactrocera yoshimotoi*	Tephritidae	57	*Simulium rangjungense*	Simuliidae
27	*Bactrocera zahadi*	Tephritidae	58	*Simulium striatum*	Simuliidae
28	*Chromatomyia horticola*	Agromyzidae	59	*Syrphus fulvifacies*	Syrphidae
29	*Culex sasai*	Culicidae	60	*Tephritus multiguttulata*	Tephritidae
30	*Dacus longicornis*	Tephritidae	61	*Terellia tribulicola*	Tephritidae
31	*Dacus dorjii*	Tephritidae			

4. Terrestrial macroinvertebrates

4.1. Ants & Termites (Formicidae)

Ants

Ants are social insects that belong to the family Formicidae. They are known for their highly organized colonies, with distinct castes including workers, soldiers, and a queen(Feldhaar, 2014). Ants are found in nearly all terrestrial habitats, and their colonies can range in size from a few individuals to millions. They play essential ecological roles as both predators and scavengers, influencing the populations of other insects and aiding in nutrient recycling(Siedlecki et al., 2023). Some species have mutualistic relationships with plants and other organisms, while others can be agricultural pests. Ants are also studied for their complex social behaviors, communication methods, and their ability to solve problems collectively, making them a subject of interest in fields such as entomology, ecology, and behavior(Menges et al., 2023).

Table: List of ant species that could exist in Sarpang, Bhutan (Dendup et al., 2021).

Subfamily	Species Name	Subfamily	Species Name
Amblyoponinae	*Stigmatomma kangba (Xu, Z. & Chu, 2012)*	Myrmica	*Leptogenys lucidula Emery, 1895*
Dolichoderinae	*Dolichoderus affinis Emery, 1889*	Myrmica	*Leptogenys peuqueti (Andre, 1887)*
Phildris	*Philidris laevigata (Emery, 1895)*	Myrmica	*Discothyrea stumperi Baroni Urbani, 1977*
Tapinoma	*Tapinoma indicum Forel, 1895*	Myrmica	*Proceratium williamsi Mathew & Tiwari, 2000*
Dorylinae	*Dorylus orientalis Westwood, 1835*	Myrmica	*Tetraponera allaborans (Walker, 1859)*
Ectatomminae	*Gnamptogenys binghamii (Forel,1990)*	Myrmica	*Tetraponera binghami (Forel, 1902)*
Formicinae	*Camponotus barbatus Roger, 1863*	Myrmica	*Tetraponera modesta (Smith, 1860)*
Camponotus	*Camponotus mitis (Smith, 1858)*	Perissomyrmex	*Tetraponera rufonigra (Jerdon, 1851)*
Camponotus	*Camponotus nicobarensis Mayr, 1865*	Pheidole	*Crematogaster dohrni Mayr, 1879*
Camponotus	*Camponotus oblongus (Smith,1858)*	Pheidole	*Lophomyrmex bedoti Emery, 1893*
Camponotus	*Camponotus parius Emery, 1889*	Pheidole	*Lophomyrmex birmanus Emery, 1893*
Camponotus	*Camponotus wasmanni Emery, 1893*	Pheidole	*Lophomyrmex quadrispinosus (Jerdon, 1851)*
Polyrhachis	*Formica candida Smith, 1878*	Strumigenys	*Lordomyrma bhutanensis (Baroni Urbani, 1977)*
Polyrhachis	*Lasius alienoflavus Bingham, 1903*	Strumigenys	*Mayriella transfuga Baroni Urbani, 1977*
Polyrhachis	*Lasius crinitus (Smith, 1858)*	Strumigenys	*Mayriella warchalowskii Boroweic, 2007*
Polyrhachis	*Lasius draco Collingwood, 1982*	Strumigenys	*Meranoplus bicolor Guérin-Méneville, 1844*
Polyrhachis	*Lasius magnus Seifert, 1992*	Strumigenys	*Meranoplus rothneyi Forel, 1902*
Polyrhachis	*Lepisiota sp.*	Strumigenys	*Monomorium floricola (Jerdon, 1851)*
Polyrhachis	*Nylanderia taylori (Forel, 1894)*	Strumigenys	*Myrmica aimonissabaudiae Menozzi, 1939*
Polyrhachis	*Oecophylla smaragdina (Fabricius, 1775)*	Strumigenys	*Myrmica collingwoodi Radchenko & Elmes, 1998*
Polyrhachis	*Polyrhachis bicolor Smith, 1858*	Strumigenys	*Myrmica indica Weber, 1950*
Polyrhachis	*Polyrhachis dives Smith, 1857*	Strumigenys	*Myrmica pachei Forel, 1906*
Pseudolasius	*Polyrhachis hauxwelli Bingham, 1903*	Tetramorium	*Myrmica rugosa Mayr, 1865*
Myrmicinae	*Polyrhachis hippomanes Smith, 1861*	Tetramorium	*Myrmica rupestris Forel, 1902*
Calyptomyrmex	*Polyrhachis illaudata Walker, 1859*	Tetramorium	*Myrmica villosa Radchenko & Elmes, 1999*
Calyptomyrmex	*Polyrhachis laevigata Smith, 1857*	Tetramorium	*Myrmica weberi Elmes & Radchenko, 2009*

Cardiocondyla	*Polyrhachis punctillata Roger, 1863*	Tetramorium	*Perissomyrmex monticola Baroni Urbani & Andrade,1993*
Cardiocondyla	*Polyrhachis rastellata (Latreille, 1802)*	Tetramorium	*Pheidole jucunda Forel, 1885*
Cardiocondyla	*Polyrhachis sculpturata Smith, 1860*	Tetramorium	*Pheidole parva Mayr, 1865*
Cardiocondyla	*Polyrhachis striata Mayr, 1862*	Tetramorium	*Pheidole smythiesii Forel, 1902*
Carebara	*Polyrhachis thompsoni Bingham, 1903*	Tetramorium	*Pheidole woodmasoni Forel, 1885*
Crematogaster	*Pseudolasius familiaris (Smith, 1860)*	Trichomyrmex	*Strumigenys caniophanoides De Andrade, 2007*
Lasius	*Aphaenogaster feae (Emery, 1889)*	Ponerinae	*Strumigenys dohertyi Emery, 1897*
Lasius	*Calyptomyrmex friederikae Kutter, 1976*	Anochetus	*Strumigenys exilirhina Bolton, 2000*
Lasius	*Calyptomyrmex wittmeri Baroni Urbani, 1975*	Anochetus	*Strumigenys kichijo (Terayama et al., 1996)*
Lepisiota	*Cardiocondyla itsukii Seifert et al., 2017*	Brachyponera	*Strumigenys lyroessa (Roger, 1862)*
Nylanderia	*Cardiocondyla kagutsuchi Terayama, 1999*	Diacamma	*Strumigenys membranifera Emery, 1869*
Oecophylla	*Cardiocondyla obscurior Wheeler, 1929*	Ectomomyrmex	*Strumigenys nannosobek (Bolton, 2000)*
Polyrhachis	*Cardiocondyla wroughtonii (Forel, 1890)*	Ectomomyrmex	*Strumigenys nanzanensis Lin & Wu, 1996*
Formica	*Carebara affinis (Jerdon, 1851)*	Ectomomyrmex	*Strumigenys uberyx Bolton, 2000*
Lasius	*Crematogaster aberrans Forel, 1892*	Harpegnathos	*Strumigenys virgila Bolton, 2000*
Crematogaster	*Anochetus madaraszi Mayr, 1897*	Leptogenys	*Tetramorium bicarinatum (Nylander, 1846)*
Lophomyrmex	*Anochetus risii Forel, 1900*	Leptogenys	*Tetramorium christiei Forel, 1902*
Lophomyrmex	*Anochetus validus Bharti & Wachkoo, 2013*	Leptogenys	*Tetramorium difficile Bolton, 1977*
Lophomyrmex	*Brachyponera jerdonii (Forel, 1900)*	Leptogenys	*Tetramorium indicum Forel, 1913*
Lordomyrma	*Diacamma rugosum (Le Guillou, 1842)*	Proceratiinae	*Tetramorium lanuginosum Mayr, 1870*
Mayriella	*Ectomomyrmex astutus (Smith, 1858)*	Proceratium	*Tetramorium nipponense Wheeler, 1928*
Mayriella	*Ectomomyrmex javanus Mayr, 1867*	Pseudomyrmicinae	*Tetramorium smithi Mayr, 1879*
Meranoplus	*Ectomomyrmex leeuwenhoeki (Forel, 1886)*	Tetraponera	*Tetramorium urbanii Bolton, 1977*
Meranoplus	*Harpegnathos venator (Smith, 1858)*	Tetraponera	*Tetramorium wroughtonii (Forel, 1902)*
Monomorium	*Leptogenys assamensis Forel, 1900*	Tetraponera	*Trichomyrmex destructor (Jerdon, 1851)*
Myrmica	*Leptogenys kitteli (Mayr, 1870)*		

Termites

Termites are social insects belonging to the order Isoptera. They are known for their ability to digest cellulose, primarily found in wood and plant material, and play a vital role in breaking down dead and decaying organic matter in ecosystems(Ahmad et al., 2018). Termites live in colonies with various castes, including workers, soldiers, and reproductive individuals, with each caste having specific roles within the colony(Jouquet et al., 2011). While they are ecologically significant as decomposers, some termite species can also cause significant damage to wooden structures, making them pests in urban and agricultural settings(Garg et al., 2023). Termites are the subject of research in fields like entomology, ecology, and pest control, as understanding their behavior and biology is crucial for managing their impact on human structures and the environment(Rao et al., n.d.).

Table 40: List of termite species that could exist in Sarpang, Bhutan.

Sl.no.	Species name	Family
1	Formosan subterranean termite (*Coptotermes formosanus*)	Rhinotermitidae
2	Asian subterranean termite (*Coptotermes gestroi*)	Rhinotermitidae
3	Malayan subterranean termite (*Coptotermes curvignathus*)	Rhinotermitidae
4	Subterranean termite (*Reticulitermes speratus*)	Rhinotermitidae

5	Indian white termite (*Odontotermes obesus*)	Termitidae
6	Asian wood-eating termite (*Microtermes obesi*)	Termitidae
7	Giant termite (*Macrotermes gilvus*)	Termitidae
8	Hairy-legged termite (*Termes macrothorax*)	Termitidae
9	Compass termite (*Amitermes meridionalis*)	Termitidae
10	Fungus-growing termite (*Odontotermes redemanni*)	Termitidae
11	Bamboo termite (*Nasutitermes nigriceps*)	Termitidae
12	Drywood termite (*Cryptotermes tectonae*)	Kalotermitidae
13	Dampwood termite (*Zootermopsis nevadensis*)	Termopsidae

4.2. Bees (Hymenoptera)

Bees, members of the order Hymenoptera, are highly beneficial insects known for their essential role in pollination. They are characterized by their distinct body structure, including a hairy body, specialized pollen-collecting structures, and a stinger in some species(Nidup & Dorji, 2016). Bees are vital to the reproduction of many flowering plants, including numerous agricultural crops, making them key contributors to global food production(K. Tenzin & Katel, 2019). They form highly organized social colonies with divisions of labor, including queens, workers, and drones. Beyond their ecological importance, bees are subjects of extensive research in fields like entomology, ecology, and conservation due to their sensitivity to environmental changes and their role in maintaining biodiversity(P. Dorji et al., n.d.).

Table 41:List of Bee species that could exist in Sarpang, Bhutan(P. Dorji et al., n.d.; Nidup & Dorji, n.d.; K. Tenzin & Katel, 2019).

Sl.no.	Species Name	Family
1	*Apis cerana*	Apidae
2	*Apis florea*	Apidae
3	*Bombus lepidus*	Apidae
4	*Bombus hypnorum*	Apidae
5	*Bombus lucorum*	Apidae
6	*Bombus trifasciatus*	Apidae
7	*Bombus miniatus*	Apidae
8	*Bombus eximius*	Apidae
9	*Bombus festivus*	Apidae
10	*Bombus genalis*	Apidae
11	*Bombus grahami*	Apidae
12	*Bombus nobilis*	Apidae
13	*Bombus kashmirensis*	Apidae
14	*Colletes bhutanicus*	Colletidae
15	*Lepidotrigona arcifera*	Meliponini
16	*Thyreus abdominalis*	Apidae
17	*Thyreus himalayensis*	Apidae
18	*Apis trigona*	Apidae

4.3. Wasps (Hymenoptera)

Wasps, also belonging to the order Hymenoptera, are a diverse group of insects characterized by their slender bodies, narrow waists, and often bright colors(Dorji et al., 2022). They exhibit a wide range

of behaviors and lifestyles, with some species being solitary and others forming social colonies. Many wasps are carnivorous and serve as efficient predators of other insects, helping control pest populations and maintain ecological balance (Dorji et al., 2016). Social wasp species, like yellowjackets and hornets, also contribute to ecosystems by preying on insects and scavenging. Additionally, wasps are important pollinators, aiding in the reproduction of various plants(Dorji, Gyeltshen, et al., 2017). While some species can sting when provoked, they are integral to natural pest control and play crucial ecological roles(Dorji, Klein, et al., 2017).

Table 42:List of wasp species that could exist in Sarpang, Bhutan(Dorji et al., 2022).

Species Name	Family	Species Name	Family
Allorhynchium metallicum	Eumenidae	*Phalerimeris phalerata*	Scoliidae
Antepipona bhutanensis	Eumenidae	*Phimenes flavopictus*	Eumenidae
Antepipona biguttata	Eumenidae	*Rhynchium brunneum*	Eumenidae
Apodynerus troglodytes	Eumenidae	*Rhynchium haemorrhoidale*	Eumenidae
Campsomeriella annulata	Scoliidae	*Ropalidia artifex*	Vespidae
Coeleumenes burmanicus	Eumenidae	*Ropalidia fasciata*	Vespidae
Coeleumenes impavidus	Eumenidae	*Ropalidia hongkongensis*	Vespidae
Delta conoideum	Crabronidae	*Ropalidia jacobsoni*	Vespidae
Delta esuriens	Crabronidae	*Ropalidia marginata*	Vespidae
Eumenes assamensis	Eumenidae	*Ropalidia nigrita*	Vespidae
Eumenes atrophicus	Eumenidae	*Ropalidia stigma*	Vespidae
Eumenes punctatus	Eumenidae	*Scolia rugifrons*	Scoliidae
Labus pusillus	Eumenidae	*Stenodyneriellus guttulatus*	Eumenidae
Megascolia azurea	Scoliidae	*Stenodyneriellus nepalensis*	Eumenidae
Okinawa Mud Wasp	Crabronidae	*Subancistrocerus sichelii*	Eumenidae
Paraleptomenes darugiriensi	Eumenidae	*Symmorphus ambotretus*	Eumenidae
Vespula orbata	Vespidae	*Symmorphus tukvarensis*	Eumenidae
Xylocopa magnifica	Apidae	*Symmorphus violaceipenni*	Eumenidae

4.4. Butterflies (Lepidoptera)

Butterflies, members of the order Lepidoptera, are renowned for their colorful and intricate wing patterns and their delicate appearance(Bibi et al., 2022). They undergo complete metamorphosis, transitioning through egg, larva (caterpillar), pupa (chrysalis), and adult stages. Butterflies play a vital role in ecosystems as pollinators, facilitating the reproduction of a wide variety of flowering plants. Their interactions with flowers contribute to plant diversity and fruit production(Teng & Zhang, 2023). Additionally, they are a source of fascination and study in fields like entomology and ecology, as their behavior, migration patterns, and coevolution with plants provide valuable insights into ecological relationships. Butterflies are also appreciated for their aesthetic beauty and are subjects of conservation efforts due to their sensitivity to environmental changes(Poel & Wangchuk, n.d.).

Butterflies hold ecological significance as essential pollinators, promoting plant diversity and contributing to the reproduction of numerous species. They serve as vital links in food chains, providing sustenance for various organisms, and their populations can indicate the overall health of

ecosystems(Chib et al., 2016). Beyond their ecological role, butterflies offer valuable insights for research and education in fields such as ecology and evolutionary biology, while also enriching cultural and aesthetic aspects of human life with their symbolism and natural beauty(T. P. Koirala et al., 2020).

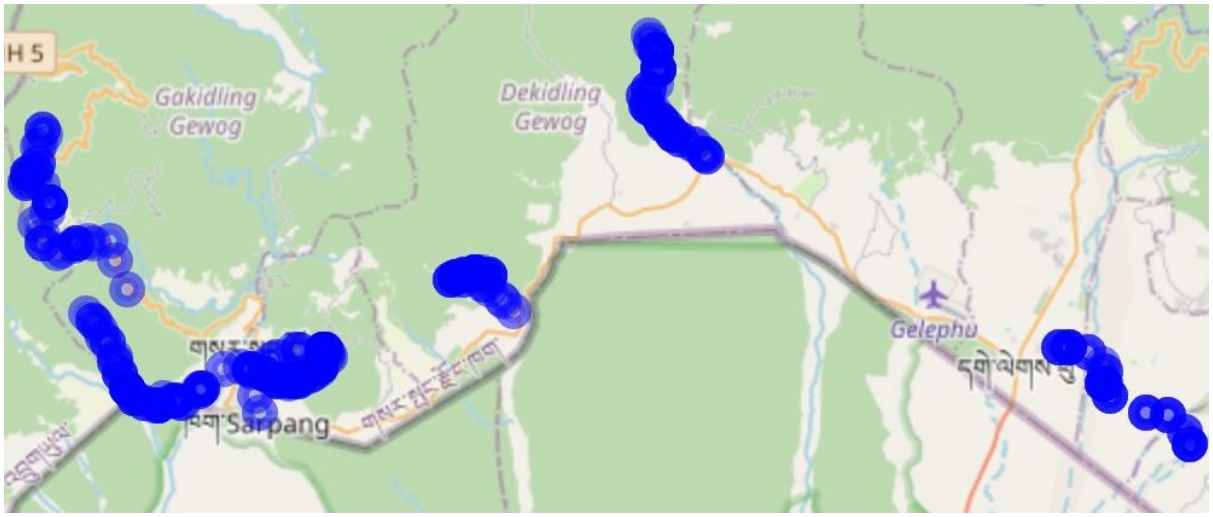


Figure 30:Transect used during survey of butterflies in DFO-Sarpang jurisdiction.

Habitat preferences

The greatest variety of butterfly species is typically found thriving in lush, humid forests, with a notable prevalence of species from the Nymphalidae family. These verdant havens, be they open or moist woodlands, display a comparatively richer tapestry of diversity, boasting a range of 20 to 60 distinct species. In stark contrast, fewer species, numbering between 0 and 20, are encountered in less pristine settings like roadsides, riverbanks, and cultivated fields. This observation serves as a poignant reminder of butterflies' affinity for undisturbed, unaltered forest environments, reinforcing their reluctance to inhabit areas that have been subjected to human intervention or disruption

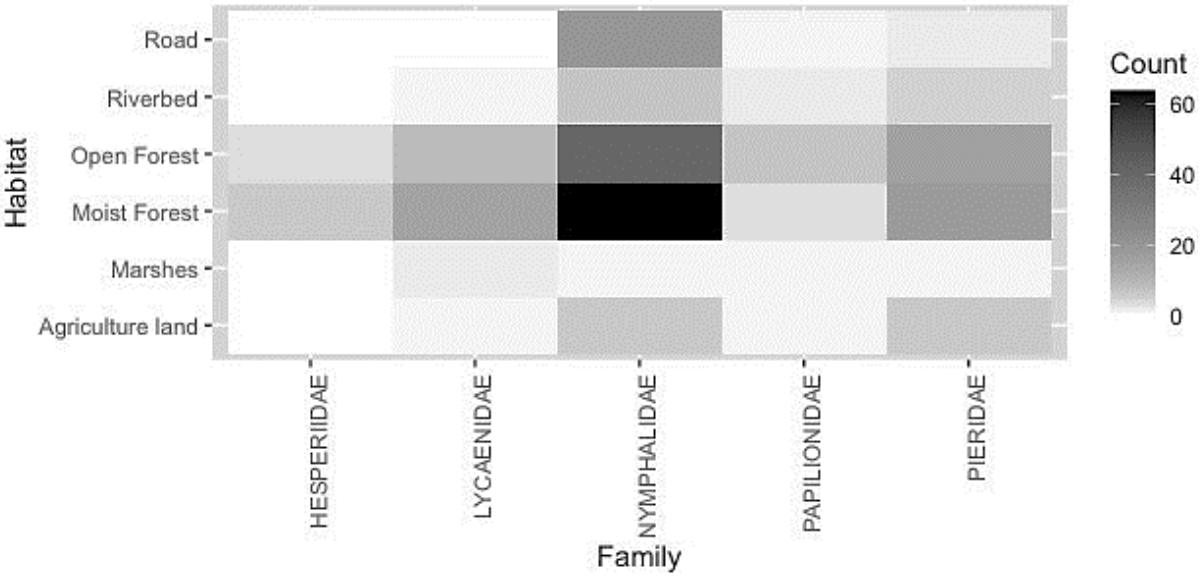


Figure 31:Variation of count butterflies (Family-wise) in different habitats.

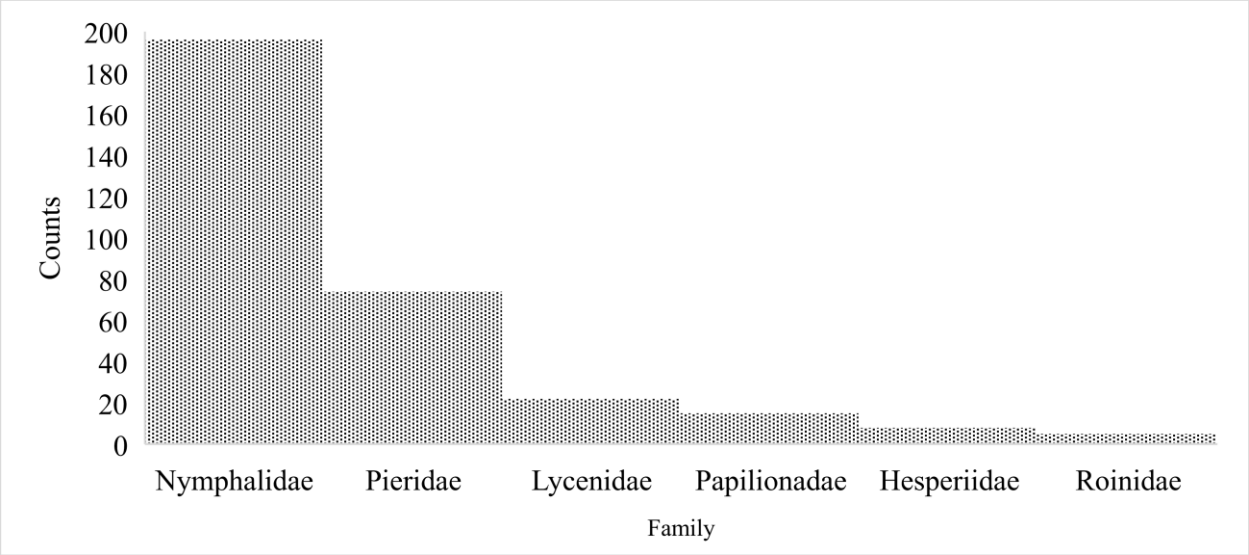


Figure 32:Family-wise count of butterflies in the surveyed area.

A total of 232 numbers of butterflies belonging to 78 species and 6 families were recorded Survey. In the realm of family classification, the Nymphalidae family boasts the highest count with 196 recorded species, while the Roinidae family has the least, with only 5 recorded species. Additionally, there are 74 species recorded in the Lycenidae family, 15 species in the Papilionidae family, 8 species in the Hesperiidae family, and 5 species in the Roinidae family.

Table 43:List of butterflies recorded during the survey.

Sl.No.	Family name	Common name	Scientific name	Conservation status
1	Hesperiidae	Tiger Hopper	*Ochus subvittatus*	NE
2	Hesperiidae	Coon	*Sancus fuligo*	LC
3	Hesperiidae	Orange Tail Awl	*Bibasis sena*	LC
4	Hesperiidae	Restricted Demon	*Notocrypta curvifascia*	LC
5	Hesperiidae	Small Banded Swift	*Pelopidas mathias*	LC
6	Hesperiidae	Common Spotted Flat	*Calaenorrhinus leucocera*	LC
7	Lycenidae	Pale Grass Blue	*Pseudozizeeria maha*	LC
8	Lycenidae	Metallic Cerulean	*Jamides alecto*	LC
9	Lycenidae	Large Hedge Blue	*Celastrina huegelii*	LC
10	Lycenidae	Indian cupid	*Everest lacturnus*	LC
11	Lycenidae	Purple Sapphire	*Heliophorus epicles*	LC
12	Lycenidae	Banded Line Blue	*Prosotas aluta coelestis*	LC
13	Lycenidae	Western centaur oak blue	*Arhopala pseudocentaurus*	LC
14	Lycenidae	Common Tit	*Hypolycaena erylus*	LC
15	Lycenidae	Club Sliver Line	*Spindasis syama*	LC
16	Lycenidae	Yamfly	*Laxura atymnus*	LC
17	Lycenidae	Line blue	*Nacaduba kurava*	LC
18	Lycenidae	Royal chocolate	*Remelana jangala*	LC
19	Lycenidae	Common quaker	*Neopithecops zalmora*	LC
20	Lycenidae	Lesser Grass blue	*Zizina otis*	LC
21	Nymphalidae	Autumn leaf	*Doleschallia bisalides*	LC
22	Nymphalidae	Banded tree brown	*Lethe verma*	LC
23	Nymphalidae	Blue Tiger	*Tirumala limniace*	LC

24	Nymphalidae	Branded tree brown	*Lethe confuse*	LC
25	Nymphalidae	Bright eye Bushbrown	*Mycalesis nicotia*	LC
26	Nymphalidae	Brown King Crow	*Euploea klugii*	LC
27	Nymphalidae	Chestnut tiger	*Parantica sita*	LC
28	Nymphalidae	Chocolate pansy	*Jinonia Iphita*	LC
29	Nymphalidae	Chocolate Tiger	*Parantica melaneus*	LC
30	Nymphalidae	Colour sergeant	*Athyma nefte*	LC
31	Nymphalidae	Common Bushbrown	*Mycalesis perseus*	LC
32	Nymphalidae	Common crow	*Euploea core*	LC
33	Nymphalidae	Common Evening brown	*Melannitis leda*	LC
34	Nymphalidae	Common fivering	*Ypthima baldus*	LC
35	Nymphalidae	Common lascar	*Pantoporia hordina*	LC
36	Nymphalidae	Common Nawab	*Polyura atsamus*	LC
37	Nymphalidae	Common pamfly	*Elymnias hypernestra*	LC
38	Nymphalidae	Common sailer	*Neptis hyla*	LC
39	Nymphalidae	Dark Archduke	*Lexias dirtea*	LC
40	Nymphalidae	Dark Banded Bushbrown	*Mycalesis mineus*	LC
41	Nymphalidae	Glassy Tiger	*Parantica algea*	LC
42	Nymphalidae	Great Eggfly	*Hypolimnas bonila*	LC
43	Nymphalidae	Great Nawab	*Polyura eduamippus*	LC
44	Nymphalidae	Green commondore	*Sumalia daraxa*	LC
45	Nymphalidae	Grey count	*Taneaecia lipidae*	LC
46	Nymphalidae	Indian tortoise shell	*Aglasis cashmeriensis*	LC
47	Nymphalidae	Large Yoeman	*Cirrochroa aoris*	LC
48	Nymphalidae	Lemon pansy	*Junonia lemonias*	LC
49	Nymphalidae	Long brown Bushbrown	*Mycalesis visala*	LC
50	Nymphalidae	Nigger	*Orsotrioena medus*	LC
51	Nymphalidae	Orange oak leaf	*Kallima inachus*	LC
52	Nymphalidae	Peacock Pansy	*Junonia almanac*	LC
53	Nymphalidae	Streaked Baron	*Euthalia alpheda*	LC
54	Nymphalidae	Striped Blue Crow	*Euploea mulciber*	LC
55	Nymphalidae	Striped tiger	*Danaus genutia*	LC
56	Nymphalidae	White Edge Blue Baron	*Euthalia phemius*	LC
57	Nymphalidae	White bar Bush brown	*Mycalesis anaxias*	LC
58	Papilionadae	Common birdwing	*Thoides helena*	LC
59	Papilionadae	Common blue bottle	*Graphium sarpedon*	LC
60	Papilionadae	Common mormon	*Papilio polytes*	LC
61	Papilionadae	Common peacock	*Papilio crino*	LC
62	Papilionadae	Common windmill	*Artophaneura polyeuctes*	LC
63	Papilionadae	Great mormon	*Papilio memnon*	LC
64	Papilionadae	Red Helen	*Papilio helenus*	LC
65	Papilionadae	Spot Swordtail	*Graphium normius*	LC
66	Papilionadae	Yellow Helen	*Papilio nephelus*	LC
67	Pieridae	Chocolate albastross	*Appias lyncida*	LC
68	Pieridae	Common Emigrant	*Catopsilia pomona*	LC
69	Pieridae	Common Grass Yellow	*Euerma hecabe*	LC
70	Pieridae	Common gull	*Cepora nerissa*	LC
71	Pieridae	Great Orange tip	*Hebomonia glaucippe*	LC
72	Pieridae	Indian cabbage white	*Pieris canidia*	LC
73	Pieridae	Large Cabbage White	*Pieris brassicae*	LC

74	Pieridae	Plain Puffin	*Appias indra*	LC
75	Pieridae	Psyche	*Leptosia nina*	LC
76	Pieridae	Red base Jezebel	*Delias pasithoe*	LC
77	Pieridae	Tree Yellow	*Gandaca harina*	LC
78	Pieridae	Yellow orange tip	*Ixias pyrene*	LC
79	Roinidae	Punchenello	*Zemeros flegyas*	LC

4.5. Spiders (Arachnida)

Arachnids, a diverse group within the arthropods, encompass various organisms, including scorpions, ticks, mites, and spiders ((Zehbi & Yousuf, 2023)). Spiders, specifically, are known for their silk-spinning abilities, which they employ for web construction, prey capture, and shelter ((Esyunin et al., 2023)). The majority of spider species are carnivorous, preying on a wide range of invertebrates, including insects(Subedi et al., 2022). This predation has a cascading effect on lower trophic levels, regulating populations of potential pest species and influencing the structure of arthropod communities(Caleb, 2020).

Table 44: List of spiders' species that could exist in Sarpang, Bhutan (Nepal, 2021).

Sl.no.	Species Name	Family
1	*Araneus albotriangulusus*	Araneidae
2	*Argiope aurantia*	Araneidae
3	*Argiope bruennichi*	Araneidae
4	*Argiope bruennichi*	Araneidae
5	*Argiope catenulata*	Araneidae
6	*Argiope lobata*	Araneidae
7	*Argyroneta aquatica*	Argyronetidae
8	*Cheiracanthium inclusum*	Cheiracanthiidae
9	*Clubiona pallidula*	Clubionidae
10	*Coelotes terrestris*	Agelenidae
11	*Cyclosa insulana*	Araneidae
12	*Cyrtophora cicatrosa*	Araneidae
13	*Cyrtophora moluccensis*	Araneidae
14	*Dictyna civica*	Dictynidae
15	*Eriovixia laglaizei*	Araneidae
16	*Gasteracantha cancriformis*	Araneidae
17	*Gasteracantha geminata*	Araneidae
18	*Gasteracantha versicolor*	Araneidae
19	*Heteropoda venatoria*	Sparassidae
20	*Lycosa singoriensis*	Lycosidae
21	*Macromia arachniformis*	Macromiaceae
22	*Nephila clavata*	Araneidae
23	*Nephila maculata*	Araneidae
24	*Neoscona mutabilis*	Araneidae
25	*Nuctenea umbratica*	Araneidae
26	*Oecobius navus*	Oecobiidae
27	*Oxyopes javanus*	Oxyopidae
28	*Parasteatoda tepidariorum*	Theridiidae
29	*Pholcus phalangioides*	Pholcidae
30	*Pisaurina mira*	Pisauridae
31	*Rhene atrata*	Salticidae

32	*Salticus scenicus*	Salticidae
33	*Scytodes thoracica*	Scytodidae
34	*Tegenaria domestica*	Agelenidae
35	*Tetragnatha extensa*	Tetragnathidae
36	*Uloborus plumipes*	Uloboridae
37	Zygiella sp.	Araneidae

4.6. Earthworms (Oligochaeta)

Earthworms, belonging to the Oligochaeta class, are integral components of terrestrial ecosystems. Their ecological significance is rooted in their role as soil engineers, enhancing soil structure and fertility(Iordache et al., 2020). Earthworms burrow through the soil, promoting aeration and water infiltration, while their castings enrich the soil with organic matter(Stojanovic & & Milutiovic, 2013). These actions improve plant growth and contribute to nutrient cycling. With diverse species, earthworms exhibit variations in size, habitat, and behavior(Xiao, 2019). Their capacity to transform soil ecosystems makes them key subjects of ecological research, emphasizing their importance in promoting soil health and sustainable agriculture(Trakić et al., 2016).

Table 45:List of Oligochaeta species that could exist in Sarpang, Bhutan (BBP, 2009).

Sl.no.	**Species Name**	**Family**
1	*Amynthas hilgendorfi*	Megascolecidae
2	*Amynthas medius*	Megascolecidae
3	*Amynthas robustus*	Megascolecidae
4	*Aporetodrilus sp.*	Lumbricidae
5	*Archiculata sp.*	Eudrilidae
6	*Dichogaster bolaui*	Octochaetidae
7	*Dichogaster saliens*	Octochaetidae
8	*Eutyphoeus sp.*	Eudrilidae
9	*Eudrilus eugeniae*	Eudrilidae
10	*Lampito mauritii*	Megascolecidae
11	*Lumbricus terrestris*	Lumbricidae
12	*Metaphire houlleti*	Megascolecidae
13	*Metaphire posthuma*	Megascolecidae
14	*Perionyx excavatus*	Megascolecidae
15	*Pheretima darnleyensis*	Megascolecidae
16	*Pheretima hawayana*	Megascolecidae
17	*Pheretima posthuma*	Megascolecidae
18	*Pontodrilus bermudensis*	Glossoscolecidae
19	*Pontodrilus litoralis*	Glossoscolecidae
20	*Pontoscolex corethrurus*	Glossoscolecidae
21	*Rhinodrilus sp.*	Lumbricidae
22	*Vermicompost worms (Eisenia fetida)*	Lumbricidae

4.7. Millipedes (Diplopoda)

Millipedes, members of the Diplopoda class, constitute a diverse and ecologically significant group of arthropods. With over 12,000 recognized species (Likhitrakarn et al., 2017) they inhabit a variety of terrestrial ecosystems, contributing to nutrient cycling and soil health. Millipedes primarily feed on decaying organic

matter, playing a crucial role in decomposition and nutrient recycling. Their numerous legs, typically two pairs per body segment, are characteristic of this group(Wesener, 2015). Millipedes exhibit fascinating behaviors, including coil-like defense mechanisms and the production of toxic compounds as a deterrent to predators. Further research into their ecology and contributions to ecosystem processes is essential for a comprehensive understanding of their significance ((Golovatch & Wesener, 2016)).

Table 46: List of millipede species that could exist in Sarpang, Bhutan (Golovatch & Martens, 2017).

Sl.no.	Species Name	Family
1	*Pleurosoma formosa*	Paradoxosomatidae
2	*P. sinensis*	Paradoxosomatidae
3	*Trigoniulus sp*	Trigoniulidae
4	*T. striatus*	Trigoniulidae
5	*Archispirostreptus sp*	Spirostreptidae
6	*A. multistriatus*	Spirostreptidae
7	*A. striatus*	Spirostreptidae
8	*A. substriatus*	Spirostreptidae
9	*Brachycybe sp.*	Spirostreptidae
10	*B. tuberculata*	Spirostreptidae
11	*Callipus sp*	Spirostreptidae
12	*C. striatus*	Spirostreptidae
13	*C. tuberculatus*	Spirostreptidae
14	*Centrobolus sp*	Spirobolidae
15	*C. striatus*	Spirobolidae
16	*C. tuberculatus*	Spirobolidae
17	*Cylindroiulus sp.*	Julidae
18	*Eurymerodesmus sp.*	Paradoxosomatidae
19	*E. striatus*	Paradoxosomatidae
20	*E. tuberculatus*	Paradoxosomatidae
21	*Acanthogonus sp.*	Cambalidae
22	*Allopyge sp.*	Paradoxosomatidae
23	*Anadenobolus sp.*	Paradoxosomatidae
24	*Anoplodesmus sp.*	Polydesmidae
25	*Aulacobolus sp.*	Paradoxosomatidae
26	*Chordeuma sp.*	Chordeumatidae
27	*C. striatum*	Chordeumatidae
28	*C. tuberculatum*	Chordeumatidae

4.8. Centipedes (Chilopoda)

Centipedes, belonging to the Chilopoda class, constitute a remarkable and diverse group of arthropods. With over 8,000 recognized species, they occupy a range of terrestrial habitats and play essential roles in various ecosystems(Wang et al., 2018). These arthropods are characterized by their elongated bodies, numerous leg pairs, and potent venomous fangs used for subduing prey(Schileyko & Stagl, 2003). Centipedes are primarily carnivorous, preying on a variety of invertebrates, thus contributing to the regulation of arthropod populations(Son et al., 2021). Their ecological significance extends beyond predation, as they participate in nutrient cycling and soil health(Simaiakis & Edgecombe, 2013). Further research into their behavior, physiology, and conservation is imperative to appreciate their full ecological importance.

Table 47:List of centipede species that could exist in Sarpang, Bhutan (Bhutan Biodiversity Portal Data, 2023).

Sl.no.	Species Name	Family
1	*Anacampsotus brunneus*	Scolopendridae
2	*Anacampsotus pygopodus*	Scolopendridae
3	*Arthropleura armata*	Scutigeridae
4	*Cryptops melanocephalus*	Cryptopidae
5	*Epimorpha breviceps*	Scutigeridae
6	*Henicops fulvicornis*	Henicopidae
7	*Lithobius forficatus*	Lithobiidae
8	*Lithobius melanops*	Lithobiidae
9	*Megascolia maculate*	Scolopendridae
10	*Otostigmus scaber*	Scolopendridae
11	*Parascutigera sinensis*	Scutigeridae
12	*Scutigera coleoptrata*	Scutigeridae
13	*Scolopendra hardwickei*	Scolopendridae
14	*Scolopendra subspinipes*	Scolopendridae

4.9. Snails and Slugs (Gastropoda)

Snails and slugs, both classified under the Gastropoda class, are intriguing members of the mollusk phylum(Gittenberger et al., 2017). With over 60,000 species, they are ubiquitous in terrestrial, freshwater, and marine environments, making them ecologically diverse(Gittenberger, Leda, Wangdi, et al., 2017). These gastropods are characterized by their coiled shells (in snails) and lack of a prominent external shell (in slugs)(Gittenberger et al., 2021). They play crucial roles in various ecosystems, contributing to decomposition, nutrient cycling, and serving as important food sources for predators(Wiktor et al., 2009). Snails and slugs also possess remarkable adaptations, such as the secretion of mucus for locomotion and protection, and their hermaphroditic reproductive strategies(Cameron, 2016). Understanding their biology, behavior, and interactions is essential for comprehensive ecological studies and conservation efforts in the face of habitat changes and environmental challenges.

Table 48:List of slug and snail species that could exist in Sarpang, Bhutan(Gittenberger et al., 2017).

Sl.no	Scientific name	Common name	Family
1	*Achatina fulica*	Giant African snail	Achatinidae
2	*Arion subfuscus*	Dusky slug	Arionidae
3	*Bradybaena similaris*	Himalayan land snail	Bradybaenidae
4	*Cepaea hortensis*	Garden snail	Helicidae
5	*Cochlicella acuta*	Keeled snail	Hygromiidae
6	*Deroceras reticulatum*	Gray garden slug	Limacidae
7	*Helix pomatia*	Roman snail	Helicidae
8	*Limax maximus*	Leopard slug	Limacidae
9	*Melanoides tuberculate*	Banded mystery snail	Thiaridae
10	*Oxychilus draparnaudi*	Glossy snail	Oxychilidae
11	*Parmarion martensi*	Black slug	Parmarionidae
12	*Physa acuta*	Pouch snail	Physidae
13	*Planorbis carinatus*	Keeled ram's horn snail	Planorbidae
14	*Pomacea canaliculate*	Golden apple snail	Ampullariidae

15	*Radix Auricularia*	River snail	Lymnaeidae
16	*Succinea putris*	Amber snail	Succineidae
17	*Viviparus bengalensis*	Indian river snail	Viviparidae

4.10. Crickets and Grasshoppers (Orthoptera)

Crickets and grasshoppers, members of the Orthoptera order, represent a diverse and ecologically significant group of insects(Tan & Abdul Wahab, 2018). With over 25,000 recognized species, they inhabit various terrestrial ecosystems, contributing to food webs and nutrient cycling. These insects are characterized by their powerful hind legs adapted for jumping and their distinctive stridulation behavior, which serves important functions in communication and mate attraction(Gorochov, 2019). Crickets are primarily nocturnal, while grasshoppers are diurnal, demonstrating distinct ecological niches. Both groups are herbivores, influencing plant dynamics and participating in predator-prey interactions(Kumar, 2019). Understanding the behavioral, physiological, and ecological intricacies of crickets and grasshoppers is essential for comprehending their roles in ecosystem functioning and for effective pest management strategies.

Table 49:List of cricket species that could exist in Sarpang, Bhutan(Ingrisch, 2002).

Sl.no.	Species Name	Family
1	*Acheta domesticus*	Gryllidae
2	*Gryllomorpha dalmatina*	Gryllidae
3	*Gryllus bimaculatus*	Gryllidae
4	*Gryllus campestris*	Gryllidae
5	*Gryllus pennsylvanicus*	Gryllidae
6	*Loxoblemmus dorsalis*	Gryllidae
7	*Oecanthus pellucens*	Gryllidae
8	*Teleogryllus oceanicus*	Gryllidae
9	*Anaxipha exigua*	Trigonidiidae
10	*Caconemobius tridens*	Trigonidiidae
11	*Nemobius sylvestris*	Trigonidiidae
12	*Paratrigonidium subapterum*	Trigonidiidae
13	*Trigonidium cicindeloides*	Trigonidiidae
14	*Arachnocephalus subsulcatus*	Mogoplistidae
15	*Mogoplistes brunneus*	Mogoplistidae
16	*Myrmecophilus acervorum*	Myrmecophilidae
17	*Tridactylus variegatus*	Tridactylidae
18	*Gryllotalpa gryllotalpa*	Gryllotalpidae

Table 50:List of grasshopper species that could exist in Sarpang, Bhutan(Ingrisch, 2002).

Sl.no.	Species name	Family	Sl.no.	Species name	Family
1	*Acrida cinerea*	Acrididae	21	*Gryllus bimaculatus*	Gryllidae
2	*Acrida gigantea*	Acrididae	22	*Gryllus domesticus*	Gryllidae
3	*Acrida turrita*	Acrididae	23	*Gryllus firmus*	Gryllidae
4	*Acridoderes crassus*	Acrididae	24	*Gryllus testaceus*	Gryllidae
5	*Aiolopus thalassinus*	Acrididae	25	*Gryllodes sigillatus*	Gryllidae
6	*Amiolophus edentulus*	Acrididae	26	*Homorocoryphus nitidulus*	Tettigoniidae
7	*Anabrus simplex*	Tettigoniidae	27	*Locusta migratoria*	Acrididae
8	*Conocephalus longipennis*	Tettigoniidae	28	*Melanoplus femur-rubrum*	Acrididae
9	*Conocephalus maculatus*	Tettigoniidae	29	*Melanoplus sanguinipes*	Acrididae

10	*Conocephalus palustris*	Tettigoniidae	30	*Morphacris fasciata*	Acrididae
11	*Conocephalus rhombeus*	Tettigoniidae	31	*Neorthacris pectoralis*	Acrididae
12	*Conocephalus xanthopterus*	Tettigoniidae	32	*Oxya velox*	Acrididae
13	*Decticus albifrons*	Tettigoniidae	33	*Paracinema tricolor*	Acrididae
14	*Ephippiger ephippiger*	Tettigoniidae	34	*Phlaeoba antennata*	Tettigoniidae
15	*Gampsocleis gratiosa*	Tettigoniidae	35	*Podisma pedestris*	Acrididae
16	*Gampsocleis glabra*	Tettigoniidae	36	*Sphingonotus coerulans*	Acrididae
17	*Gryllus asiaticus*	Gryllidae	37	*Sphingonotus erythropterus*	Acrididae
18	*Gryllus campestris*	Gryllidae	38	*Tetrix subulate*	Tetrigidae
19	*Tettigonia viridissima*	Tettigoniidae	39	*Tettigonia acutipennis*	Tettigoniidae
20	*Xiphidion dorsale*	Tettigoniidae	40	*Tettigonia cantans*	Tettigoniidae

4.11. Woodlice (Isopoda)

Woodlice, members of the Isopoda order, are terrestrial crustaceans that play a vital role in ecosystem decomposition processes(Bragina & Khisametdinova, 2018). Their ability to break down dead organic matter, such as leaf litter and wood, contributes to nutrient cycling and soil enrichment. Woodlice are characterized by their segmented exoskeleton and seven pairs of legs, providing them with a distinctive appearance(Gregory, 2009a). They are well adapted to terrestrial environments, despite their aquatic crustacean ancestry, and exhibit a range of fascinating behaviors, including curling into protective balls when threatened(Gregory, 2009b). This group of organisms serves as a valuable model for studying terrestrial adaptations within crustaceans and their ecological significance in nutrient recycling processes(Wood et al., 2018).

Table 51: List of Isopoda species that could exist in Sarpang, Bhutan(Woodlice and Waterlice Atlas – Field Studies Council, 2023).

Sl.no.	Species name	Family	Sl.no.	Species name	Family
1	*Agabiformosus javanicus*	Porcellionidae	20	*Hyloniscus sp.*	Oniscidae
2	*Agabiformosus siamensis*	Porcellionidae	21	*Indigena sp.*	Philosciidae
3	*Alloniscus birmanicus*	Alloniscidae	22	*Ligidium sp.*	Ligiidae
4	*Alloniscus sp.*	Alloniscidae	23	*Mesoniscus sp.*	Oniscidae
5	*Alloniscus indicus*	Alloniscidae	24	*Monolistra sp.*	Philosciidae
6	*Angaracrisus indicus*	Philosciidae	25	*Niambia sp.*	Philosciidae
7	*Armadillidium vulgare*	Armadillidiidae	26	*Oniscus asellus*	Oniscidae
8	*Armadillidium waltoni*	Armadillidiidae	27	*Oniscus sp.*	Oniscidae
9	*Armadillidium sp.*	Armadillidiidae	28	*Paraphiloscia sp.*	Philosciidae
10	*Burmadrillium sp.*	Armadillidiidae	29	*Philoscia sp.*	Philosciidae
11	*Burmaoniscus sp.*	Alloniscidae	30	*Porcellio scaber*	Porcellionidae
12	*Caecilloisthus sp.*	Philosciidae	31	*Porcellionides pruinosus*	Porcellionidae
13	*Calmanesia sp.*	Philosciidae	32	*Protracheoniscus sp.*	Oniscidae
14	*Cavaticaris sp.*	Philosciidae	33	*Pseudorthometopon sp.*	Philosciidae
15	*Circoniscus sp.*	Alloniscidae	34	*Schizidium sp.*	Philosciidae
16	*Dolichoniscus sp.*	Oniscidae	35	*Synarmadillo sp.*	Armadillidiidae
17	*Euconnus sp.*	Armadillidiidae	36	*Talitrus dorrieni*	Talitridae
18	*Euleptotrichus sp.*	Oniscidae	37	*Trichoniscus sp.*	Oniscidae
19	*Haplophthalmus sp.*	Philosciidae	38	*Troglodilloisthus sp.*	Philosciidae

4.12.Mites and Ticks (Acari)

Mites and ticks, collectively classified under the Acari subclass, represent a diverse and ecologically significant group of arachnids. These minuscule arthropods exhibit remarkable adaptability to various habitats and are involved in essential ecological processes(Navajas et al., 2010). Mites and ticks have evolved a wide range of feeding strategies, including herbivory, predation, and parasitism, making them key players in both terrestrial and aquatic ecosystems(Pešić et al., 2023). Their economic importance extends to agriculture, where they can be pests of crops, and in the medical field as vectors of diseases like Lyme disease and Rocky Mountain spotted fever(Yin et al., 2021). The Acari subclass continues to be a subject of extensive research, shedding light on their evolution, behavior, and interactions with other organisms.

Table 52: List of mite species that could exist in Sarpang, Bhutan(Pešić et al., 2022, 2023).

Sl.No	Family	Species
1	Acaridae	*Dermatophagoides pteronyssinus*
2	Acaridae	*Dermatophagoides farinae*
3	Acaridae	*Tyrophagus putrescentiae*
4	Acaridae	*Glycyphagus domesticus*
5	Acaridae	*Acarus siro*
6	Silvanidae	*Oryzaephilus surinamensis*
7	Anobiidae	*Lasioderma serricorne*
8	Dermestidae	*Trogoderma granarium*
9	Curculionidae	*Sitophilus oryzae*
10	Dermanyssidae	*Dermanyssus gallinae*
11	Macronyssidae	*Ornithonyssus bacoti*
12	Psoroptidae	*Cheyletiella yasguri*
13	Demodecidae	*Demodex canis*
14	Demodecidae	*Demodex felis*
15	Sarcoptidae	*Sarcoptes scabiei*
16	Psoroptidae	*Psoroptes ovis*
17	Psoroptidae	*Chorioptes bovis*
18	Macronyssidae	*Ophionyssus natricis*
19	Varroidae	*Varroa destructor*

Table 53:List of tick species that could exist in Sarpang, Bhutan(Pešić et al., 2022).

Sl.no	Family	Species
1	*Ixodidae*	Haemaphysalis hystricis
2	*Ixodidae*	Haemaphysalis bispinosa
3	*Ixodidae*	Haemaphysalis campanulata
4	*Ixodidae*	Boophilus microplus
5	*Ixodidae*	Rhipicephalus sanguineus
6	*Ixodidae*	Amblyomma variegatum
7	*Argasidae*	Ornithodoros savignyi
8	*Argasidae*	Argas persicus
9	*Argasidae*	Otobius megnini

4.13. Beetles (Coleoptera)

Beetles, members of the Coleoptera order, constitute the most diverse group of insects, with over 350,000 described species and likely many more awaiting discovery(Baier et al., 2019). They are characterized by their hardened forewings, called elytra, which protect their delicate hindwings and contribute to their remarkable success in a wide range of ecological niches(Beaver & Smith, 2022). Coleopterans play crucial roles in ecosystems as decomposers, herbivores, and predators, influencing nutrient cycling and pest control(Lazarev, 2019). Their economic significance spans agriculture, forestry, and biodiversity conservation. Additionally, beetles serve as valuable models in studies of evolution, behavior, and speciation, offering insights into the broader understanding of insect diversity and adaptation(Dorji et al., 2022).

Table 54: List of Beetle (terrestrial and aquatic) species that could exist in Sarpang, Bhutan(Blon et al., 2023; C. Dorji, 2017; Ghalley et al., 2021a).

Sl.no.	Species Name	Family
1	*Agrilus planipennis*	Buprestidae
2	*Anomala alboguttata*	Scarabaeidae
3	*Blatta orientalis*	Blattidae
4	*Calosoma auropunctatum*	Carabidae
5	*Carabus granulatus*	Carabidae
6	*Cicindela hybrida*	Cicindelidae
7	*Chrysochroa fulgidissima*	Buprestidae
8	*Clivina fossor*	Carabidae
9	*Copris indicus*	Scarabaeidae
10	*Cyclommatus metallifer*	Lucanidae
11	*Dynastes hercules*	Scarabaeidae
12	*Euchroma gigantea*	Buprestidae
13	*Geotrupes stercorarius*	Scarabaeidae
14	*Goliathus goliathus*	Scarabaeidae
15	*Gymnopleurus mopsus*	Scarabaeidae
16	*Holotrichia consanguinea*	Scarabaeidae
17	*Hoplia coerulea*	Scarabaeidae
18	*Hylotrupes bajulus*	Cerambycidae
19	*Lachnosterna congrua*	Scarabaeidae
20	*Lamprosoma cuprea*	Buprestidae
21	*Lethocerus indicus*	Belostomatidae
22	*Longitarsus longipennis*	Chrysomelidae
23	*Mantis religiosa*	Mantidae
24	*Melolontha melolontha*	Scarabaeidae
25	*Morpho didius*	Nymphalidae
26	*Mylabris pustulata*	Meloidae
27	*Neoclytus acuminatus*	Cerambycidae
28	*Onthophagus taurus*	Scarabaeidae
29	*Oryctes rhinoceros*	Dynastidae
30	*Oxyrhachis tarandus*	Cerambycidae
31	*Phyllophaga tristis*	Scarabaeidae
32	*Platydema ruficolle*	Tenebrionidae
33	*Polyphylla fullo*	Scarabaeidae
34	*Popillia japonica*	Scarabaeidae

35	*Protaetia cuprea*	Scarabaeidae
36	*Psacothea hilaris*	Cerambycidae
37	*Rhynchites bacchus*	Curculionidae
38	*Sagra femorata*	Chrysomelidae
39	*Scarabaeus sacer*	Scarabaeidae
40	*Scolia flavifrons*	Scoliidae
41	*Sphenomorphus quadriplagiatus*	Cerambycidae
42	*Tenebrio molitor*	Tenebrionidae
43	*Tricoprius orientalis*	Scarabaeidae
44	*Xylotrupes gideon*	Dynastidae

4.14. True Bugs (Hemiptera)

True bugs, classified under the Hemiptera order, encompass a diverse group of insects known for their piercing-sucking mouthparts and distinctive forewings that create a characteristic 'X' shape at rest(R. T. Schuh & Weirauch, 2020). Hemipterans are ecologically significant as both herbivores and predators, and they contribute to essential ecosystem processes(Tawaszakowsk & Pasinska, 2017). Some species are agricultural pests, while others play crucial roles in controlling insect populations(Javahery, 1994). The Hemiptera order includes well-known insects like aphids, cicadas, and water striders, each with unique adaptations and behaviors(Kanturski et al., 2017). Studies on Hemiptera not only shed light on their ecological interactions but also provide insights into the evolution of specialized feeding mechanisms and their economic implications in agriculture and vector-borne diseases.

Table 55: List of Hemiptera species that could exist in Sarpang, Bhutan(Schuh & Slater, 1995).

Sl.no.	Species Name	Family
1	*Acanthoscelides obtectus*	Bruchidae
2	*Adelphocoris lineolatus*	Miridae
3	*Aphis gossypii*	Aphididae
4	*Bemisia tabaci*	Aleyrodidae
5	*Cicadella viridis*	Cicadellidae
6	*Cicadulina bipunctata*	Cicadellidae
7	*Cimex lectularius*	Cimicidae
8	*Dysdercus cingulatus*	Pyrrhocoridae
9	*Eumetasteron flavicornis*	Pentatomidae
10	*Halyomorpha halys*	Pentatomidae
11	*Laodelphax striatellus*	Delphacidae
12	*Leptocorisa acuta*	Alydidae
13	*Lygus lineolaris*	Miridae
14	*Macrodactylus subspinosus*	Scarabaeidae
15	*Mealybugs*	Pseudococcidae
16	*Mealybug destroyers*	Coccinellidae
17	*Melanaphis sacchari*	Aphididae
18	*Myzus persicae*	Aphididae
19	*Nephotettix virescens*	Cicadellidae
20	*Nilaparvata lugens*	Delphacidae
21	*Oncopeltus fasciatus*	Lygaeidae
22	*Orthezia insignis*	Ortheziidae

23	*Planthoppers*	Fulgoromorpha
24	*Pseudococcus comstocki*	Pseudococcidae
25	*Psyllids*	Psyllidae
26	*Rhopalosiphum padi*	Aphididae
27	*Scale insects*	Coccoidea
28	*Sciara militaris*	Sciaridae
29	*Scotinophara lurida*	Cicadellidae
30	*Silverfish*	Lepismatidae
31	*Spider mites*	Tetranychidae
32	*Stink bugs*	Pentatomidae
33	*Thrips*	Thysanoptera
34	*Trialeurodes vaporariorum*	Aleyrodidae
35	*Whiteflies*	Aleyrodidae

4.15. Moths (Lepidoptera)

Moths, belonging to the Lepidoptera order, represent a vast and diverse group of insects characterized by their unique scale-covered wings. With over 160,000 described species, moths are second only to beetles in insect diversity(Benedek et al., 2012). They inhabit a wide range of terrestrial and even some aquatic ecosystems, exhibiting various ecological roles as pollinators, herbivores, and prey for numerous predators(Irungbam et al., 2016). Moths are integral to the pollination of numerous plant species, including many crops, and are crucial in food webs as a food source for birds, bats, and other predators. Additionally, moths have ecological significance as bioindicators for monitoring environmental changes(Groenen & Wangdi, 2019). The Lepidoptera order continues to be a subject of extensive research, illuminating their remarkable diversity, behavior, and coevolution with plants.

Table 56: List of Moth species that could exist in Sarpang, Bhutan(Gielis et al., 2022; Singh, 2020).

Sl.no.	Species Name	Family
1	*Acanthopsyche atra*	Psychidae
2	*Acherontia styx*	Sphingidae
3	*Adrapsa ablalis*	Pyralidae
4	*Aglais urticae*	Nymphalidae
5	*Antheraea assamensis*	Saturniidae
6	*Antherina suraka*	Saturniidae
7	*Argema mittrei*	Saturniidae
8	*Argyrogramma signata*	Noctuidae
9	*Asura conferta*	Arctiidae
10	*Attacus atlas*	Saturniidae
11	*Automeris metzli*	Saturniidae
12	*Calliteara pudibunda*	Lymantriidae
13	*Catocala nupta*	Noctuidae
14	*Cirrhia icterica*	Noctuidae
15	*Cosmotriche lunigera*	Arctiidae
16	*Daphnis nerii*	Sphingidae
17	*Dendrolimus punctatus*	Lasiocampidae
18	*Deilephila elpenor*	Sphingidae
19	*Eumetasteron flavicornis*	Pentatomidae
20	*Euploea core*	Nymphalidae
21	*Graphium sarpedon*	Papilionidae

22	*Helicoverpa armigera*	Noctuidae
23	*Hippotion Celerio*	Sphingidae
24	*Hyles lineata*	Sphingidae
25	*Hyloicus pinastri*	Sphingidae
26	*Imbrasia epimethea*	Saturniidae
27	*Lyssa zampa*	Lasiocampidae
28	*Macroglossum stellatarum*	Sphingidae
29	*Melanitis leda*	Nymphalidae
30	*Neptis hylas*	Nymphalidae
31	*Orgyia antiqua*	Lymantriidae
32	*Papilio polytes*	Papilionidae
33	*Phyllodes imperialis*	Saturniidae
34	*Pieris brassicae*	Pieridae
35	*Polyphemus pedunculus*	Saturniidae
36	*Samia Cynthia*	Saturniidae
37	*Saturnia pyri*	Saturniidae
38	*Spodoptera litura*	Noctuidae
39	*Syngrapha interrogationis*	Noctuidae
40	*Thaumetopoea pityocampa*	Thaumetopoeidae
41	*Trogonoptera brookiana*	Papilionidae
42	*Vanessa cardui*	Nymphalidae
43	*Vespamantoida sinica*	Brahmaeaidae
44	*Xylophanes tersa*	Sphingidae

4.16. Earwigs (Dermaptera)

Earwigs, members of the Dermaptera order, represent a relatively small but fascinating group of insects known for their distinctive forceps-like cerci at the end of their abdomen(Kočárek, 2006). Despite their somewhat menacing appearance, earwigs are largely omnivorous, feeding on both plant material and smaller invertebrates(Kelly et al., 2018). They play roles in soil aeration and decomposition of organic matter. Earwigs also exhibit maternal care, with females guarding their eggs and nymphs(Stuart et al., 2019). While some species are considered pests in agriculture and horticulture, others contribute to biological pest control by preying on crop-damaging insects(Kamimura et al., 2023). The Dermaptera order remains an area of interest for entomologists exploring the unique behavior and ecological interactions of these intriguing insects.

Table 57: List of Earwigs species that could exist in Sarpang, Bhutan (Srivastava, 2013).

Sl.no.	Species Name	Family
1	*Forficula auricularia*	Forficulidae
2	*Labidura riparia*	Labiduridae
3	*Nala lividipes*	Carcinophoridae
4	*Oreasiolabis forficulata*	Anisolabididae
5	*Pygidicrana burri*	Pygidicranidae

4.17. Leeches (Hirudinea)

Leeches, classified under the Hirudinea subclass, are intriguing aquatic annelids known for their blood-feeding behavior and therapeutic applications(Orevi et al., 2000). They possess specialized adaptations for feeding, including a sucker at each end of their body, allowing them to attach to hosts for blood meals. While leeches have been historically associated with medicinal bloodletting, their anticoagulant saliva contains compounds

with potential applications in modern medicine, such as preventing blood clots and aiding in microsurgery(Fedorova & Kaygorodova, 2016). Leeches also serve ecological roles as decomposers in aquatic ecosystems and as parasitic organisms that impact the health of fish and amphibians(Nesemann & Sharma, 2001). Research on leeches continues to unveil their complex biology and their relevance in medicine and ecology.

Table 58: List of leech's species that could exist in Sarpang, Bhutan(Nesemann & Sharma, 2001; Pathak et al., 2020).

Sl.no.	Species Name	Family
1	*Haemadipsa sylvestris*	Haemadipsidae
2	*Hirudinaria granulosa*	Hirudinidae
3	*Limnatis nilotica*	Glossiphoniidae
4	*Poecilobdella viridis*	Hirudinidae
5	*Whitmania pigra*	Hirudinidae
6	*Haemadipsa hirudinea*	Haemadipsidae
7	*Haemadipsa zeylanica*	Haemadipsidae
8	*Hirudinaria manillensis*	Hirudinidae
9	*Limnatis granulosa*	Glossiphoniidae
10	*Poecilobdella javanica*	Hirudinidae
11	*Whitmania laevis*	Hirudinidae

5. Other Microorganisms and invertebrates

Micro-invertebrates, a diverse and often overlooked group of tiny invertebrate animals, play crucial roles in various ecosystems and scientific research. These minute organisms, typically less than 1 millimeter in size, encompass a wide array of taxa, including mites, nematodes, rotifers, and tardigrades. Despite their small size, micro-invertebrates are integral to nutrient cycling and soil health. They are used as bioindicators to assess environmental conditions and are studied in fields such as soil ecology, aquatic ecology, and microbiology. Their importance in understanding ecosystem dynamics, decomposition processes, and responses to environmental change cannot be overstated, making them a focal point of scientific investigations into the intricacies of life at a microscopic scale.

Table 59: List of micro-invertebrates that could exist in Sarpang, Bhutan.

Species Name	Family
Rotifer	Brachionidae, Philodinidae, Trichocercidae
Tardigrade	Macrobiotidae, Milnesiidae, Hypsibiidae
Nematode	Dorylaimidae, Criconematidae, Heteroderidae
Copepod	Calanoida, Cyclopoida, Harpacticoida
Cladoceran	Daphniidae, Chydoridae, Moinidae
Ostracod	Cyprididae, Darwinulidae, Cytheridae
Microcrustacean	Anostraca, Conchostraca, Branchiopoda
Springtail	Sminthuridae, Entomobryidae, Isotomidae
Protozoa	Ciliophora, Flagellata, Amoebozoa

6. Species of other kingdoms that could occur in Sarpang.

1. Chromista: This kingdom includes algae and other protists that have chloroplasts with four membranes. Some examples of chromistans that could occur in Sarpang are:

1. Diatoms
2. Brown algae (e.g., fucus and sargassum)
3. Golden algae (e.g., chrysophytes and prymnesiophytes)
4. Dinoflagellates
5. Euglenoids

2. Fungi: Fungi are a group of eukaryotic organisms that decompose organic matter. They are essential for nutrient cycling in ecosystems. Some examples of fungi that could occur in Sarpang are:

1. Mushrooms
2. Yeasts (e.g., Saccharomyces and Candida)
3. Molds (e.g., Aspergillus and Penicillium)
4. Lichens (e.g., Parmelia and Usnea)
5. Rusts and smuts (e.g., Puccinia and Ustilago)

3. Protista: This kingdom includes a wide range of eukaryotic organisms that do not fit neatly into other kingdoms. Some examples of protists that could occur in Sarpang area:

1. Amoebas (e.g., Entamoeba and Chaos)
2. Flagellates (e.g., Euglena and Trypanosoma)
3. Ciliates (e.g., Paramecium and Tetrahymena)
4. Foraminifera
5. Radiolaria

4. Archaebacteria: Archaebacteria are a group of primitive bacteria that are adapted to extreme environments. Some examples of archaebacteria that could occur in Sarpang are:

1. Methanogens (e.g., Methanobrevibacter and Methanobacterium)
2. Halophiles (e.g., Halobacterium and Haloarchaea)
3. Thermoacidophiles (e.g., Sulfolobus and Thermoplasma)
4. Thermophiles (e.g., Aquifex and Thermus)
5. Psychrophiles (e.g., Psychrobacter and Deinococcus)

5.Eubacteria: Eubacteria are the most common type of bacteria. They play a variety of roles in ecosystems, including decomposition, nitrogen fixation, and photosynthesis. Some examples of eubacteria that could occur in Sarpang are:

1. Escherichia coli
2. Bacillus subtilis
3. Lactobacillus acidophilus
4. Streptococcus pyogenes
5. Staphylococcus aureus

It is important to note that this is just a small sample of the many different species of microorganisms that could occur in Bhutan. There are many other species that have not yet been identified or studied.

Conclusion

The forest was classified into three distinct forest types based on indicator species analysis: sub-tropical forest, warm broadleaved forest and cool broadleaved forest. Each forest type plays a vital role in sustaining the delicate balance of the ecosystem and providing resources for both human communities and wildlife.

The upper mountaintops, adorned with an ethereal beauty, serve as pristine havens for spiritual seekers and cattle grazers. The serenity of these high altitudes, coupled with the untouched natural splendor, provides an ideal setting for meditation and rejuvenation. Simultaneously, the pastures provide sustenance for grazing animals, ensuring a harmonious coexistence between humans and nature.

The mid-altitude humid mid-slopes, characterized by warm and cool broadleaved forests, offer a rich biodiversity, albeit lower than the upper regions. This forest type fulfills the diverse needs of the local communities, providing timber for construction, fodder for livestock, firewood for cooking, and a vast array of non-timber forest products. The canopy of trees acts as a natural umbrella, regulating temperatures and preventing soil erosion, thus maintaining the integrity of the ecosystem.

The lower foothills and ridges, home to a diverse array of plant and animal species, provide a rich resource base for the communities dwelling along these terrains. The forests yield timber, firewood, and non-timber forest products, while also serving as hunting grounds and medicinal plant repositories. The intricate network of streams and rivers originating from these forests provides essential irrigation for agriculture, ensuring food security for the local population.

The entire forest ecosystem functions as a vital water reservoir, with the upper ridgetops acting as natural catchment areas. The accumulated rainwater gradually percolates through the soil, replenishing springs and streams that provide drinking water for human communities, irrigation for agriculture, and sustenance for wild flora and fauna.

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