Short Research Article

An Overview of Biodiversity in Bhutan

Abstract *- Bhutan is included in the Eastern Himalayan biodiversity hotspot. Because the country's total forest cover surpasses 70%, the exclusive hotspot is a paradise for rich biological diversity. Some of the world's most endangered species can be found in Bhutan's five national parks, four wildlife sanctuaries, one strict nature reserve, and a network of biological corridors, and even outside the Protected Areas. The country's documentation of its rich flora and fauna is in the early stage, and to document the biological diversity in Bhutan, more research work needs to be carried out~~done~~. Bhutan's biodiversity faces a major threat from anthropogenic activities and climate change.*

Keywords - ***agriculture, agro-ecological, biodiversity, fauna, flora***

1. INTRODUCTION

Bhutan is a small landlocked country with a population of 735,553 (NSB, 2018) people and an area of 38,394 km^2 (Gilani et al., 2014). Bhutan is a mountainous country in the eastern Himalayas, with the Himalayan mountain range encompassing the whole country's landmass. It offers a unique collection of extremely varied habitats and considerable biodiversity within a small geographical area, in addition to mountains, steep gorges, river valleys, and flatlands. Bhutan's 38,394 square kilometers make up less than 0.0075 percent of the world's surface, but it is home to a disproportionately diverse range of plants and animals. Over 3.02 % of pteridophytes and 1.47 % of bryophytes are found in the country's forests. Similarly, the country is home to 1.99 % of mammals, 7.75 % of birds, and 4.29 % of the world's butterfly fauna (Table 1). Bhutan's diverse biodiversity is a result of the country's unusual geographic location, as well as variations in altitude and climate. Bhutan's arable land resource is limited due to rough and steep mountain terrain, wide areas of snow and barren rocks, and enormous forestland (Chhogyel & Kumar, 2018). Currently, forests cover 71 % of the country's land area (DoFPS, 2016; Allison, 2017). This forest region, which comprises several types of vegetation, must cover at least 60 % of the national territory in all times to come, as mandated by the constitution of the Kingdom of Bhutan (RGoB, 2008; Burns, 2011). The majority of Bhutan's arable land is in the central valleys and southern foothills, where agriculture is competing with other development activities for a population that is rising at a rate of 1.3 % each year (NSB, 2018). On average, each household has 3.48 acres of arable land, while more than 60 % of all families have less than 3 acres. As a result, the great majority of farmers are small-scale subsistence farmers who produce for their own survival. The majority of these arable lands (up to 70 %) are on steep slopes and are cultivated without soil conservation measures. As a result, these fertile areas are susceptible to various types of land degradation, jeopardizing the livelihoods of around 57 % (Chhogyel & Kumar, 2018) of the people who rely on agriculture.

Bhutan is one of the top ten countries in the world for species diversity (species richness per unit area) and is also one of the top ten worldwide hotspots (Myers et al., 2000). Compared to any other Asian country, it has the highest percentage of land covered by protected areas and the highest proportion of forest cover (Mahat, 1985). Many ecologists conclude that Bhutan is the last best hope for biodiversity protection in the Eastern Himalayas, a region of essential importance to world biodiversity (Tempa et al., 2013; Wilson, 2016). Bhutan stands out among developing countries because it has set aside 51.4 percent of its land area for national parks, wildlife sanctuaries, strict nature reserves, and a network of biological corridors, although it is relying on loans to supplement its financial resources for development (Lham, 2019; Tshewang et al., 2021). Bhutan's incredibly diverse flora is made up of various components: In tropical and sub-tropical evergreen and semi-evergreen forests, Southeast Asian-Malesian components are common. Himalayan-Chinese elements make up the majority of temperate and sub-alpine

Comment [Ma1]: This literature review paper needs a brief methodology and a concrete conclusion. The overall picture of biodiversity in Bhutan is well-captured.

Comment [Ma2]: Please recheck the number of bird species in Bhutan.

Comment [Ma3]: Please check the comments on Table 1.

Comment [Ma4]: Yes, Bhutan diverse biodiversity can be attributed to unusual geographic mountain terrain, but it is also because of the country conservation efforts, where country has mandated 60% of its land to remain under forest cover for all times to come. Please add the above points.

vegetation, including wWestern Himalayan, eEastern Himalayan, and pan-Himalayan species. Traditional Tibetan species grow in the northwest of Bhutan, but certain plant species in the alpine zone have Euro-Siberian and Arctic-alpine affinities (Grierson & Long, 1983). Bhutan's high regional biodiversity is attributed in part to the Himalayas' evolutionary history, which resulted from the Deccan Plateau's upward migration into the Eurasian continent during the early Tertiary period (Pandit, 2017). As a result, both Indian and Malesian sources have left a rich legacy of floristic and faunal features (Rodgers & Panwar, 1988). The Indo-Malayan, Indo-Chinese, Sino-Malayan, East Asiatic floras, and many Gondwanan relics can all be found in the eastern Himalayas (Gillison, 2012).

In the alpine zone of Bhutan, more than 300 species are used in Chinese and Tibetan traditional medicine for therapeutic purposes, resulting in almost 200 different traditional medicines (Wangchuk et al., 2011; Thomas, 2017; Yeshi et al., 2017; Chetri, 2019). Many of these drugs have been standardized by the National Institute of Traditional Medicine Services and are now available in traditional medicine clinics around the country. In addition, a variety of herbal items are marketed and exported. The country has made it into the twenty-first century with much of its biodiversity and natural environment intact thanks to the wise leadership of kings, nature-reverent religious principles, rough terrain, low population pressure, gradual modernization, and environmentally sound development plans (Rinzin, 2006; Brooks, 2013; Lepeley, 2017; Yangka et al., 2018). However, recent modifications in the road and hydroelectric infrastructure highlight the urgent need for a more comprehensive baseline evaluation of the country's biodiversity (Sears et al., 2017; Haque, n.d.). According to forest surveys conducted by the Ministry of Agriculture and Forests in 2017, 71 % of the country was covered in forests (Amatya et al., 2018).

The vegetation types found in Bhutan are Dry Alpine Scrub (4,000 - 4,600 masl), Juniper / Rhododendron Scrub (3,700 to 4,200 masl), Fir Forest (2,800 - 3,300/3,800 masl), Hemlock Forest (2,800 - 3,100/3,300 masl), Spruce Forest (2,700 - 3,100/3,200 masl), Blue Pine Forest (2,100 - 3,000 masl), Evergreen / Oak Forest (1,800 - 2,000 masl), Cool Broadleaf Forest (2,000 - 2,900 masl), Chir Pine Forest (900 - 1,800 masl), Warm Broadleaf Forest (1,000 - 2,000 masl), and Sub-tropical Forest (200 - 1,000 masl) (DoFPS, 2016).

2. AGRO-ECOLOGICAL ZONES OF BHUTAN

The country is divided into three climate zones: alpine in the northern mountains, temperate in the central valleys and inner hills, and sub-tropical in the southern foothills. Summers in the southern foothills are hot and humid and cool winters. Summers are hot, and winters are cold in the middle valleys and inner hills, although spring and autumn are nice. The alpine highlands are chilly all year, with lengthy, severe winters that make crop cultivation extremely difficult. Climate, geography, and altitude all play a role in determining land use, farming systems, crops grown, opportunities, and obstacles in agriculture. The country is organized into six major agro-ecological zones for agricultural planning, each with its altitudinal range and climatic circumstances (Table 2).

Comment [Ma5]: Please cite.

The northern region's alpine zone is characterized by alpine meadows and is too high to grow any food crops. Livestock farming is the most typical mode of life in the cool temperate zone, with some dryland farming thrown in for good measure. Wheat, potato, buckwheat, mustard, and barley are farmed. Agriculture is frequently conducted in terraced irrigated wetlands and drylands in the warm temperate zone, which has moderately warm temperatures until winter when frost occurs. Rice is the principal crop in wetland agricultural areas, and it is rotated with wheat, potato, seasonal fodder, and a variety of vegetables. The dry subtropical zone is warm, with moderate rainfall, allowing a larger range of crops to be grown. Rice, maize, mustard, barley, a variety of legumes, and various vegetables are all grown. The humid subtropical zone has a higher rainfall and temperature than the dry subtropical zone. Rice is the most common crop grown in terraced irrigated wetland agricultural areas, followed by wheat and mustard. The main revenue crops are citrus (mandarin orange) farms at lower elevations and cardamom at higher elevations. Maize, millet, mustard, many types of legumes, ginger, and vegetables are the most common crops in the sloppy dryland agricultural areas. The agroecological parameters in the wet subtropical zone support intensive subsistence agriculture through various forms of multiple cropping. Summer rice is the principal crop, cycled with wheat and

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maize in the winter, depending on irrigation. Most irrigation supplies are rain-fed, and they dry up throughout the winter months. Although large-scale winter cropping is technically viable, it is rarely done due to water scarcity. Maize and various millets are the principal crops in dryland agricultural areas, and they are rotated with a variety of legumes, mustard, niger, millet, tuber crops, and vegetables (Dukpa & Wangdi, 2021).

3. PROTECTED AREAS AND BIOLOGICAL CORRIDORS

A severe loss of biodiversity habitats worldwide has heightened interest in measures to improve conservation methods (Karst & Nepal, 2019). While reserve selection techniques and algorithms are already well developed, the lack of good habitat networks and baseline data is by far the most significant constraint. This is sometimes exacerbated by widely scattered and disjointed remaining habitat fragments where biota movement is severely restricted, culminating in the irreversible disintegration of sustainable plant and animal populations (Gillison, 2012). In light of this, the Royal Government of Bhutan (RGoB) has chosen a forward-thinking approach to ensure an adequate network of environmental ('biological') corridors that allow the free movement of wild animals between protected areas around the country. Given the likelihood of climate change, such a move is significant. The Forest and Nature Conservation Act of 1995 (RGoB, 1995) and other pertinent legislation give these protected regions legal protection. The goal of these sites is to conserve flora and wildlife in their natural habitats, including wild relatives of crops~~farmed species~~. Over 2.7 million ha of forest land (DoFPS, 2016) and ten protected areas encompassing alpine to dry deciduous ecosystems are well scattered in Bhutan's 20 dzongkhags (districts). The protected areas and biological corridors cover 51.4 % of the country (Tables 3). The protected area management plan includes zoning of the parks to accommodate the rights and needs of local communities for timber and fuelwood. Special laws apply in conservation areas to safeguard the protection of local species vital for conservation. It is largely aided by the character of the RGoB's tough and well-established policies, which originate from a deep and long-standing ethical commitment to safeguarding species and the ecosystem that supports them.

Bhutan's conservation policy is centered on a system of national parks that cover 42.82 percent of the country's land, with an additional 8.61 percent designated as 'biological corridors' or 'wildlife highways' that connect protected areas to facilitate the free passage of animals (Sherpa et al., 2004). The fact that all protected areas have more than 70 % forest cover and are rich in biodiversity, the existence of farming and shifting cultivation in each of them raises some worries about their long-term viability (Wangchuk, 2007).

There is a traditional reliance on a number of these protected locations (Wangchuk, 2007). However, as people migrate from rural places to towns and cities, the manpower available for normal subsistence has decreased. To address these issues, the RGoB has created participatory Integrated Conservation Development Programmes (ICDPs) that provide direct material support, such as a monetary compensation scheme for livestock depredation that has reduced human-wildlife conflicts. There were almost no retaliatory killings of wild animals, especially tigers and snow leopards, by residents due to this. Similarly, the ark administration distributed corrugated galvanized sheets to residents of the protected area, which has reduced tree harvesting. The campaign has saved thousands of trees. The park management gave residents new stoves under the ICDP, which reduced their use by around 30%. The ICDP has significantly impacted the challenges to protected areas and ecological corridors (Gillison, 2012).

The lack of systematically collected biodiversity baseline data raises concerns about the science behind the designation of protected areas and associated corridor networks. According to Gillison (2012), reserve positions are mostly decided by a limited scientific survey and intuition based on personal experience. In such circumstances, it appears that a structured, systematic approach to gathering baseline data would be beneficial. Much of Bhutan's biological treasure remains undiscovered by scientists. There is no baseline data available to aid scientists in documenting and monitoring changes in flora, wildlife, or forests.

4. FAUNA AND FLORA

Comment [Ma7]: Check comments on the Table 3.

Comment [Ma8]: The “70% forest cover” is repeating many times. Please keep it to around two times.

Comment [Ma9]: This seems controversial. There seems to be some kind of baseline, at least at the basic level. Please rework on this paragraph. May be also mention how this is concluded here.

Bhutan has one of the world's most comprehensive conservation policies. Bhutan is home to some of the world's rarest plants and animals due to its policies and conservation efforts. Bhutan records 11,248 species in all taxa of biodiversity until 2017, of which 136 (1.20 %) are globally threatened (Manita & Nepal, 2021). Out of 11,248 species, 2 (0.02 %) is categorized under Kingdom Protista, 18 (0.16 %) under Kingdom Eubacteria, 55 (0.49 %) under Kingdom Chromista, 690 (6.13 %) under Kingdom Fungi, 5,114 (45.47 %) under Kingdom Animalia, and 5,369 (47.73 %) under Kingdom Plantae (NBC, 2019; Manita & Nepal, 2021).

Comment [Ma10]: If this article is mentioning data until 2017, it looks fine.

Bhutan's biological diversity documentation is still in its infancy. Bhutan recorded 3 fishes (Gurung & Thoni, 2018), 1 dragonfly (Gyeltshen et al., 2017), 4 snails (Gittenberger et al., 2017), 16 plants (Yoshida et al., 2017), 2 aphids, 4 moths, 1 stonefly, and 2 beetles that were all new to science between 2009 and 2017 (NBC, 2019). Bhutan also recorded 566 new species in the same years 2 bryophytes, 5 cicadas,119 moths, 4 butterflies, 14 crabs, 4 beetles, 108 fishes, 101 plants, 44 amphibians and reptiles, 1 true flies, 65 bees and wasps, 59 dragonflies, and damselflies, 35 snails and slugs, and 5 birds (NBC, 2019; Manita & Nepal, 2021). At a rate of 62 species every year (62.88 percent), Bhutan has set a new species record. Many species have yet to be discovered and documented in Bhutan, necessitating extensive research to document the undiscovered species (to science and Bhutan) as well as to understand the number and diversity of species (Rinzin et al., 2009; Nepal, 2020).

Comment [Ma11]: May be this can be removed, since these data are readily already available. However, if authors feels the need to keep, it is also fine.

Bhutan is home to several globally vulnerable species, such as White-bellied Heron *Ardea insignis* Hume, 1878, Rufous-necked Hornbill *Aceros nipalensis* Hodgson, 1829, Black-necked Crane *Grus nigricollis* Przhevalsky, 1876, Himalayan Musk Deer *Moschus leucogaster* Hodgson, 1839, Asian Elephant *Elephas maximus* Linnaeus, 1758, Capped Langur *Trachypithecus pileatus* Blyth, 1843, Golden Langur *Trachypithecus geei* Khajuria, 1956, Bhutan Takin *Budorcas taxicolor whitei* Lydekkar, 1907, Red Panda *Ailurus fulgens* F. Cuvier, 1825, Clouded Leopard *Neofelis nebulosa* Griffith, 1821, Golden Mahseer *Tor putitora* F. Hamilton, 1822, Chinese Pangolin *Manis pentadactyla* Linnaeus, 1758, Snow Leopard *Panthera uncia* Schreber, 1775, and the Bengal Tiger *Panthera tigris tigris* Linnaeus, 1758.

Bhutan's avifauna variety is of great international importance. It is a part of the Sino-Himalayan mountain forests, Indo-Burmese forests, Indo-Gangetic grasslands, South Asian dry habitats, and Tibetan plateau wetlands, classified as BirdLife Important Bird Areas (BirdLife International, 2004). Bhutan is important for migratory birds from the south and north in the summer and winter, respectively (e.g., Bhutan is a major wintering area for the black-necked crane *Grus nigricollis*). The highest levels of avian biodiversity may be found in the tropical and subtropical zones, where around 700 species can be found below 2,000 meters and about 50 species between 2,000 and 4,000 meters. In addition, 30 species found in the country have been classified as globally endangered.

Comment [Ma12]: Please cite

5. CLIMATE

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Bhutan's climate is extraordinarily diverse, which may be due to two main factors: the country's significant altitude differences and the effect of the North Indian monsoons. Like most of Asia, Bhutan's climate is as variable as its heights. Bhutan's weather and climate are influenced by its elevation. The weather in the northern sections of the country, where mountains soar to 7,570 meters, is arctic. The temperature is hot and humid in the summer and chilly in the winter as you get closer to India. Rainfall during the monsoon season is typically heavy. Winters are a nice time to visit the lower parts of the country, but the higher elevations are chilly. The climate varies from semi-tropical to alpine depending on altitude (For every 1,000 m height increase, the temperature drops about 7 degrees Celsius). During the monsoon season, the climate of ~~S~~southern Bhutan is tropical, with temperatures ranging from 15 degrees Celsius in winter to 30 degrees Celsius in summer. In addition, the east is warmer than the west. The central section of the country has a subtropical climate with mild winters, while the northern regions of the country have a harsh environment with snowfall two to three times a year. Temperatures in Thimphu

range from -2.5°C in January to 25°C in the summer, with 100 mm of rainfall. The average temperature in the high mountain regions ranges from 0°C in the winter to 10°C in the summer, with an average rainfall of 350 mm. Because of the valley's height, it has relatively beautiful weather all year. Except for the southern parts that border India's plains and the northern border with Tibet, the middle valleys, where most people live, and visitors come, have a pleasant temperate climate with modest seasonal fluctuations.

6. CONCLUSION

Comment [Ma14]: Need come concrete conclusion of what is coming out of this paper other than brining all available information together on Bhutan's biodiversity.

Bhutan's high biodiversity is due to the country's varied geography, ~~and~~ climate and the conservation efforts. ~~Bhutan is a small mountainous country on the eastern Himalayas' southern slopes~~. With a population of 735,553, the country has a total geographical area of 38,394 square kilometers. Only 2.93 percent of the land is cultivated. For 57 percent of the population, agriculture is their primary source of income. Bhutanese farmers are mostly small-scale, with an average farm size of 3 acres and self-sustaining subsistence integrated farming systems. Due to the great fluctuation in altitude, agro-ecology is diverse despite its modest area. From subtropical to alpine, the diversity of flora provides a mosaic of habitats for a wide range of creatures, which are the foundation of the Himalayan ecosystem's interconnectedness. Bhutanese conservation efforts are mostly focused on the preservation of flagship species. The country has a diverse ecosystem preserved by a vast network of protected areas and stringent conservation rules. Bhutan still requires an inter-ecoregional research-based conservation program due to the diversity of habitats and ecosystems and anthropogenic concerns. A program like this will ensure the Himalayan hotspot, of which Bhutan is a part, is preserved for the long future.

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Table 1 *Faunal diversity: number of species in Bhutan as a % of global numbers*

		Bhutan	
Faunal group	**Global numbers**	**No. of species**	**Bhutan/global * 100 (%)**
Spiders	40,462[a]	155[b]	0.38
Moths	160,000[c]	1,115[b]	0.70
Fish	33,230[d]	125[b]	0.38
Butterflies	17,500[c]	750[b]	4.29
Amphibians and Reptiles	11,750[e]	158[b]	1.34
Birds	9,700[f]	752[g]	7.75
Mammals	6,495[h]	129[b,g]	1.99
Pteridophytes	13,600[i]	411[b]	3.02
Bryophytes	25,000[j]	367[b]	1.47

Source: [a]Sharma (2014); [b]NBC (2019); [c]Smithsonian Institution (2007); [d]FishBase (2015); [e]Halliday (2001); [f]Callaghan et al. (2021); [g]Manita & Nepal (2021); [h]Burgin et al. (2018); [i]Sureshkumar et al. (2020); [j]Krosnick & Indoe (n.d.)

Comment [Ma15]: If this table is considering data till 2021, please update the figures with authentic sources. Since most of the figures are until 2017.

Comment [Ma16]: Please use the correct figure, since the paper cited "Manita & Nepal, 2021" has unvalidated figures, mostly modified figures from the "NBC, 2019". For example: the total numbers of species in Table 2. of Manita & Nepal, 2021 is not correct.

Comment [Ma17]: Since this table talks about the 'fauna', pteridophytes and bryophytes are not fauna. This table needs to be revised.

Table 2 *Major Agro-ecological zones of Bhutan*

Comment [Ma18]: Please cite the source(s).

Agro-ecological Zones	Elevation (meter above sea level)	Temperature (degree Celcius)			Rainfall (mm/yr)
		Monthly Min.	Monthly Max.	Annual Mean	
Wet Sub-tropical	150 - 600	11.6	34.6	23.6	2,500 - 5,500
Humid Sub-tropical	600 - 1,200	4.6	33	19.5	1,200 - 2,500
Dry Sub-tropical	1,200 - 1800	3	28.7	17.2	850 - 1,200
Warm Temperate	1,800 - 2,600	0.1	26.3	12.5	850 - 1,200
Cool Temperate	2,600 - 3,600	0.1	22.3	9.9	650 - 850
Alpine	3,600 - 4,600	-0.9	12	5.5	<650

Table 3 *Protected Areas of Bhutan with its total area, percent cover, and the districts it touches*

Comment [Ma19]: Please cite the source(s) since the cited source "Nepal, 2021" does not cite any original sources that have carried out the actual work. It is directly copied from the "Nepal, 2021".

Protected Area	Total Area (sq. km.)	% covered	Dzongkhags
Bumdeling Wildlife Sanctuary	1,521	3.96	Lhuntse, Mongar, Trashiyangtse
Jigme Dorji National Park	4,316	11.24	Gasa, Paro, Punakha, Thimphu, Wangdue Phodrang
Jigme Singye Wangchuck National Park	1,730	4.51	Sarpang, Tsirang, Trongsa, Wangdue Phodrang, Zhemgang
Jomotsangkha Wildlife Sanctuary	334.73	0.87	Samdrup Jongkhar
Phibsoo Wildlife Sanctuary	268.93	0.70	Dagana, Sarpang
Royal Manas National Park	1,057	2.75	Pemagatshel, Sarpang, Zhemgang
Sakteng Wildlife Sanctuary	740.6	1.93	Trashigang, Samdrup Jongkhar
Phrumsengla National Park	905.05	2.36	Bumthang, Lhuntse, Mongar, Zhemgang
Jigme Khesar Strict Nature Reserve	609.51	1.59	Haa, Samtse
Wangchuck Centennial National Park	4,914	12.80	Bumthang, Gasa, Lhuentse, Trongsa, Wangdue Phodrang
Biological Corridors	3,307.14	8.61	Haa, Paro, Thimphu, Punakha, Wangdue Phodrang, Sarpang, Tsirang, Zhemgang, Trongsa, Mongar, Bumthang, Trashigang, Lhuntse, Samdrup Jongkhar
Royal Botanical Park, Lamperi	47	0.12	Punakha

	19,751	51.44	

Source: (Nepal, 2021)