Floristic Composition and Species Richness of Bryophytes Along an Elevational Gradient in Annapurna Base Camp Trail, Kaski, Nepal

A Dissertation Submitted for the Partial Fulfillment of the Requirement of a Master's Degree in Botany

By

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Declaration

The dissertation entitled "Floristic Composition and Species Richness of Bryophytes Along an Elevational Gradient in Annapurna Base Camp Trail, Kaski, Nepal" which is being submitted to the Central Department of Botany, Institute of Science and Technology, Tribhuvan University, Nepal for the partial fulfilment of the requirement of Master's Degree in Botany has been carried out by me under the supervision of **Associate Prof. Dr. Giri Prasad Joshi**. This work has not been submitted to any other institution for any academic degree.

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Recommendation

This is to recommend that **Ms. Sushma Tripathi** carry out the dissertation entitled "Floristic Composition and Species Richness of Bryophytes Along an Elevational Gradient in Annapurna Base Camp Trail, Kaski, Nepal" for the partial fulfilment of the requirement of a Master's Degree in Botany under my supervision. To my knowledge, this work has not been submitted to any other institution for any academic degree. She has fulfilled all the requirements laid down by the Central Department of Botany, Institute of Science and Technology, Tribhuvan University, Kirtipur for the submission of the dissertation for the Master's Degree in Botany.

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Abstract

The research aimed to document species composition, richness, and habitat distribution of bryophytes along the Annapurna Base Camp (ABC) trail, spanning elevations from 1,650 meters to 4,130 meters. A systematic random sampling method was employed to collect bryophytes specimens from nine strategically selected stations along the elevational gradient. The survey identified 91 bryophyte species across 39 families and 62 genera, with mosses (58 species) being the most prevalent, thereafter by liverworts (30 species) and hornworts (3 species). The Bryaceae and Aytoniaceae families were the most diverse, each represented by eight species. The study revealed a hump-shaped curve in species richness and diversity, peaking at mid-elevations (around 2500 meters) and declining at both lower and higher elevations. Habitat analysis showed that soil was the most preferred substrate (31%), followed by rocks (28%), trees (22%), soil and rock combinations (15%), and tree and rock combinations (4%). This study recommends extensive bryophyte surveys in underexplored areas in Annapurna Conservation Area with relation to different environmental variables. This study provides valuable insights into the bryophyte diversity along the ABC trail, contributing to the broader understanding of bryophyte ecology and conservation in high-elevation regions.

Keywords: Bryophytes, Species Richness, Distribution, Elevational Gradient, Annapurna Base Camp.

शोध सार

यस अनुसन्धानको उद्देश्य अन्नपूर्ण आधार शिविर पदमार्गमा १,६५० मिटरदेखि ४,१३० मिटरसम्मको उचाईमा काईजातको प्रजातिहरूको सङ्ख्या, Species Richness र वासस्थान वितरणलाई दस्तावेज गर्ने थियो। Systematic Random Sampling विधिको माध्यमबाट उचाइका आधारमा नौ रणनीतिक स्टेशनहरूबाट काईजात नमूनाहरू सङ्कलन गरिएका थिए। सर्वेक्षणले ३९ परिवार, ६२ जाती र ९१ फरक-फरक काईजात प्रजातिहरू पहिचान गरिएको थियो ।अध्ययन अनुसार Moss (५८ प्रजाति) सबैभन्दा बढी पाइएको थियो, त्यसपछि Liverworts (३० प्रजाति) र Hornworts (३ प्रजाति) मात्र पाइएका थिए । Bryaceae र Aytoniaceae परिवार सबैभन्दा विविध थिए प्रत्येकमा आठ प्रजातिहरू रहेका थिए। अध्ययनले Species Richness र वितरण हेर्दा हम्प–आकारको वक्र देखिएको थियो ।जुन मध्य–उचाइमा (लगभग २५०० मिटर) उच्च विन्दुमा पुग्यो र दुबै तल्लो र उप्पल्लो उचाइमा घट्दै गएको पाइयो । Habitat Distribution विश्लेषण गर्दा माटोमा सबैभन्दा बढी (३१%), त्यसपछि चट्टानमा (२८%), रूखमा (२२%), माटो र चट्टान संयोजनमा (१५%), र रूख र चट्टान संयोजनमा (४%) पाइएको थियो। यस अध्ययनले अन्नपूर्ण संरक्षण क्षेत्रमा थप काईजात सम्बन्धि विभिन्न वातावरणीय पक्षहरुको प्रभावलाई समेत समेटेर सर्वेक्षणहरू अध्ययनहरु गर्न सिफारिस गर्दछ। यस अध्ययनले अन्नपूर्ण आधार शिविर पदमार्गमा भएका काईजात विविधतामा बहुमूल्य सूचना प्रदान गर्दछ साथमा, काईजात पारिस्थितिकीय र उच्च–उचाई क्षेत्रहरूमा संरक्षणको फराकिलो बुझाइमा योगदान पुऱ्याउँछ ।

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1. Introduction

1.1 Background

1.1.1 Overview of bryophytes

Bryophytes are a diverse group of non-vascular plants, including mosses, liverworts, and hornworts. They are found in almost all types of ecosystems except the seas. Bryophytes are the next most numerous plant group after angiosperms (Goffinet, 2021), with an estimated 23,000 to 25,000 species worldwide (Asakawa et al., 2013). Among them, mosses are the most common, with about 13,000 species, followed by liverworts, and hornworts. In contrast to vascular plants, bryophytes do not have actual roots, stems, or leaves. They complete their life cycle in two stages: gametophytes and sporophytes. They are commonly referred to as the "amphibians of the plant kingdom," because they develop under amphibious conditions and cannot complete their life cycle without external water (Kenrick & Crane, 1997). Mosses form thick mats in various environments. Liverworts exhibit diverse morphologies in moist, shaded areas, and hornworts are characterized by their elongated, horn-like sporophytes (Hallingbäck & Hodgetts, 2000.).

Efficient spore dispersal mechanisms are crucial for bryophytes. Liverworts use elaters and mosses use peristome teeth to aid in the wind-borne spread of spores. Beyond dispersal, bryophytes exhibit broad ecological tolerance, thriving in moist and shaded environments, and some species adapt even in harsher conditions (Andrew et al., 2003). Bryophytes thrive in both temperate and tropical forests, producing carpets on wet earth, rocks, both living and deceased logs, and even tree trunks and leaf. The amount of precipitation, temperature, latitude, and elevation are the primary microclimatic factors which affect their distribution (Sveinbjornsson & Oechel, 1992). Microenvironmental conditions, including shade, humidity, humus content, and temperature, also play a significant role (Evans et al., 2012). Secondary factors affecting bryophyte communities include the age of the soil and rocks, forest soil composition, moisture content (Mandl et al., 2009), and substrate characteristics like pH and humus status (Alvarenga et al., 2010). This interplay of microclimate, microenvironment, and substrate properties shapes their diversity in different habitats.

Nepal's diverse geography, ranging from lowland tropical forests to highland alpine mountains, provides a unique habitat for bryophytes. The variation in elevation creates a wide range of climatic zones, offering numerous habitats for bryophytes from 62 meters to 6,500 meters from sea level (Pradhan, 2018). Nepal has reported 1,318 species of bryophytes, including 766 mosses, 541 liverworts, and 11 hornworts (Pradhan, 2023) with 10 endemics to Nepal (Joshi et al., 2024). This richness in bryophytes highlights Nepal as a favorable place for these ecologically important plants. Studies in Nepal suggested that many bryophyte species are yet to be discovered.

1.1.2 Ecological significance of bryophytes

Bryophytes demonstrate a wide range of adaptive features and are crucial ecological indicators. They can thrive in various climates, substrates, and habitats, showing their versatility and ecological significance. They also provide major contributions to ecosystem functioning by helping in nutrient cycling, water retention, plant colonization, propagation of seeds, seedling growth, and forest restoration, eventually enabling healthy and thriving communities (Jiang et al., 2015).

Acting as the "living skin" of the Earth, bryophytes reduce surface runoff, increase water-holding capacity by facilitating water infiltration, stabilize the soil surface, and support soil erosion control, watershed conservation, and enhanced soil productivity (Zheng et al., 2009). *Riccia himalayensis, Funaria hygrometrica,* and *Physcomitrium cyathicarpum* are examples of bryophytes that grow in cultivated fields all year. The symbiotic relationships of lichens and bryophytes with cyanobacteria play a significant role in nitrogen fixation (Turetsky, 2003).

Bryophytes contribute desirable habitat for many invertebrates, offering shelter and food even in harsh conditions. For example, *Frullania* and *Herbertus* provides habitat for numerous rotifers, nematodes, invertebrates, and algae in their lobules. Some aquatic mosses are good shelter for snails to lay eggs. Insects absorb juice from the cells of gametophores and sporangia, while spiders, mites, millipedes, centipedes, and ants prefer cover within these mosses. *Dicranum scoparium* serves as an insect repellent, resists rot, and is a food plant for rodents like *Myotis schisticolor*. The protonema, leafy shoots, and immature and mature capsules of *Funaria hygrometrica* and *Brachythecium rutabulum* are used as food for slugs (Chopra & Bhatla, 1990).

Their sensitivity to environmental changes, particularly in moisture levels and chemical composition, makes bryophytes valuable indicators of ecosystem health (Batista et al., 2018). Monitoring bryophyte communities provides scientists with insights into the well-being of the surrounding environment (Marschall, 2017). Mosses can serve as for detecting acid rain because they lack a protective epidermis and cuticle, making them susceptible than vascular plants (Saxena & Harinder, 2004). They play roles in erosion control, serve as environmental indicators, and provide materials for seedbeds, fuel, and even medicine. Many bryophytes are precise indicators of different rock types: *Tortella tortuosa* grows on limestone, *Andreaea* and *Racomitrium* on acidic or granitic rocks, *Sphagnum* species on acid bogs, *Ditrichum* species and *Grimmia atrata* on metalliferous rocks and soil, and *Dicranoweisia cirrata* thrives mainly on the tree barks of polluted areas. *Eurhynchium riparioides* is highly valued for analyzing heavy metal compositions in rivers and is used by aquatic birds to construct quality nests. Bryophytes have applications in pesticides, nitrogen fixation, and moss gardening. They are also useful in waste treatment, construction, clothing, furnishing, and packing materials (Saxena & Harinder, 2004). While some mosses have a cuticle to prevent water loss, the majority of leafy mosses are able to do so by altering the shape of their leaves and curling the branches. For example, *Tortula ruralis* may withstand drought conditions for up to ten months and resume normal function after rehydration in a few hours. *Andreaea rothii* grows on hard acidic mountain rocks and can resume photosynthesis even after a 12-month drought. Bryophytes' remarkable capacity to hold huge amounts of water makes them perfect for use in horticulture for plant cultivation (Ogwu, 2019). Additionally, bryophytes play a role in carbon sequestration, potentially contributing to the fight against global warming and climate change (O'Neill, 2000).

1.1.3 Economic significance of bryophytes

Bryophytes have considerable economic importance due to their unique properties, such as resilience and flexibility, which lead to various applications. Although research into their full potential continues, traditional uses highlight their cultural and therapeutic value (Glime, 2007b). Bryophytes like *Marchantia, Sphagnum*, and *Polytrichum* have been used as herbal remedies and food sources by tribal communities worldwide (Harris, 2008).

Beyond traditional medicine, bryophytes have a rich history of industrial applications. They are used for packing, plugging, and ornamentation. Mosses are particularly popular in home décor, and liverwort like *Marchantia polymorpha* is used in wineries to soak up spills (Chandra et al., 2017). Bryophytes have also been used as fillers in wooden structures and upholstery, and even in crafting toys like dolls and balls (Thomas & Jackson, 1985). In Europe and North America, species like *Neckera complanata* and *Sphagnum* serve as absorbents and insulators in bedding and other products (Drobnik & Stebel, 2014).

Research is increasingly uncovering their medicinal properties. Active compounds extracted from bryophytes show antibacterial, antifungal, cytotoxic, and antitumor activity

(Asakawa et al., 2013). Their potential in genetic engineering and protein manufacturing is also gaining recognition, further underscoring their economic significance (Glime, 2007a).

In Nepal, the use of bryophytes is still not well understood. Despite their high medicinal value, people are unaware of their sustainable uses. Mosses, being soft and absorbent, have traditionally been used as bedding, padding, and packing materials in many cultures. Various species of bryophytes are used for several purposes in Nepal. However, only 70 species are reported to have economic significance, including 15 species of liverworts and 55 species of mosses (Pradhan & Shrestha, 2003).

Because of their susceptibility to environmental changes, bryophytes have been used as indicators in several research monitoring climate change (Gignac, 2001). Despite their obvious vulnerabilities, only a few researches have looked at the effects of climate change on bryophytes, their variety, and ecosystems. Global climate models are increasingly recognizing that huge peatlands, including bryophyte-dominated ecosystems, have a considerable impact on world temperatures and flow of water. In the future, research into bryophyte ecophysiology under changing climatic conditions will be critical for providing new information that will benefit in bryophyte conservation.

1.2 Rationale

Although bryophytes have tremendous ecological and economic importance, they are much less studied compared to higher plants. Despite being the first colonizers of land from aquatic environments, bryophytes remain one of the least studied plant groups globally. Due to their tiny size, many bryophyte species are still unexplored in terms of species composition, richness, and habitat distribution in relation to different environmental variables (Gradstein et al., 1989; Grytnes et al., 2006). This lack of knowledge presents a significant gap, considering their species richness, composition, diversity, and their relation to various environmental factors and habitats. This is particularly concerning because bryophytes exhibit a wider elevational range than vascular plants and are known to be sensitive to environmental changes (Frego, 2007; Gignac, 2001). As a result, they are emerging as valuable indicators of climate change. Understanding bryophytes better could greatly contribute to our knowledge of ecosystem health and the effects of climate change.

Bryophytes in Nepal are little known and understood, with very few studies conducted, and most of these are limited to listing bryophytes from selected regions (Joshi et al., 2024).

Previous research has primarily focused on central and eastern Nepal, leaving vast parts of the country and its mountains unexplored (Pradhan, 2014a). Almost all studies from Nepal recommend extensive research on bryophyte composition and richness across the country, particularly along the elevational gradients of mountains (Grau et al., 2007; Pradhan, 2018, 2023; Sharma et al., 2021). Addressing this research gap is crucial to unlocking the species composition, richness, and diversity of bryophytes. Furthermore, understanding their potential as ecological indicators, their role in ecosystem services (Pradhan, 2023.), and the conservation and management of bryophyte biodiversity in mountain ranges is essential.

The reasons for limited bryophyte research in Nepal are: challenges in identification, a scarcity of researchers and studies, and the high cost of exploration (Spitale, 2016). Since, Nepal is a mountainous country and highly vulnerable to climate change, extensive exploration is crucial to document these species before climate change alters their distribution patterns.

The Annapurna Conservation Area, the largest protected area in Nepal, is recognized as a significant biodiversity hotspot. Despite numerous studies documenting its flora and fauna, research on bryophytes remains insufficient, with no comprehensive documentation of bryoflora available to date. This gap hinders our understanding of the status of bryophytes in the Annapurna Conservation Area, their importance, and their interactions with various environmental variables and habitats. Additionally, it overlooks the conservation interventions within conservation area.

The Annapurna Base Camp (ABC) Trail is a globally renowned trekking destination, attracting over a million trekkers annually from around the world. The trail extends to the Annapurna Base Camp, situated at an elevation of 4,300 meters. This study is focused on this trail, which experiences dramatic elevational changes, ranging from tropical elevations around 1,000 meters to alpine elevations at 4,300 meters. These elevation changes result in diverse climatic zones, creating a variety of habitats-from tropical and subtropical to temperate and alpine-that support bryophyte growth. This route is perfect site for studying bryophyte species composition, richness, and diversity in relation to the elevational gradient.

1.3 Research questions

- ❖ What is the floristic composition of bryophytes along the elevational gradient in study site?
- ❖ What are the different habitats of bryophytes?
- ❖ How an elevational gradient shapes species richness along ABC trail?

1.4 Objectives

1.4.1 General objective

The general objective of the study is to assess the floristic composition and species richness of bryophytes along an elevational gradient in the Annapurna Base Camp (ABC) trail.

1.4.2 Specific objectives:

- ❖ To identify and determine the floristic composition of bryophytes along the elevational gradient of ABC trail.
- ❖ To determine the habitat distribution of bryophytes in the ABC trail.
- ❖ To assess the species richness of bryophytes along the elevational gradient of ABC trail.

1.5 Limitations

- ❖ Samples were collected only from trekking pathways.
- ❖ Sampling was done in a single monsoon season.
- ❖ Only a few strategic locations (stations) and plots were sampled, which may not capture the full diversity in specific time.
- ❖ Identification was manual; molecular techniques could have improved accuracy.
- ❖ Limited sample size.
- ❖ Environmental factors like climatic, edaphic and biotic factors weren't measured.

2. Literature Review

2.1 Classification of bryophytes

The word Bryophyta was introduced and used for the first time by Braun (1864). The taxonomy of bryophytes has evolved significantly, when Schimper (1879) first identified them as a distinct plant group. In the following decade, Eichler classified bryophytes into liverworts and mosses, which were further divided into orders by Engler in 1883. By the mid-twentieth century, the focus shifted towards standardized nomenclature. Rothmaler, in 1951, proposed the classification of Hepaticopsida, Anthoceropsida, and Bryopsida. Caver then concentrated on family-level taxonomy within these orders, while Gangulee classified mosses based on the presence or absence of teeth on their capsules. Schofield expanded these concepts to include subclasses and orders for both liverworts and mosses. Most recently, all known bryophytes are grouped under three divisions. They are: Marchantiophyta, Bryophyta and Anthocerotophyta.

Crandall-Stotler et al. (2009) classified Marchantiophyta into three classes Goffinet et al. (2009) classified Bryophyta into five classes and Stotler and Crandall-Stotler (2005) has classified Anthocerotophyta into two classes. Bryophytes are classified into three lineages, which include both thalloid and leafy forms. Thalloid liverworts have a dorsiventral flattened shape, with sporophytes on the dorsal surface and scales and rhizoids on the ventral. Similarly, hornworts are made up of dorsiventrally flattened gametophytes and lengthy, horned sporophytes. Mosses, contrary to liverworts and hornworts, have a vegetative structure similar to that of higher vascular plants. They have a branched, leafy structure that forms both the gametophytic and sporophytic bodies, as well as a long seta and capsule. Mosses have the highest morphological variation among bryophytes, particularly in the capsule and peristome teeth, which control spore dissemination.

2.2 Characteristics of bryophytes

Mosses, liverworts, and hornworts exhibit distinct characteristics across various stages of their life cycles. The protonema of mosses is filamentous and forms many buds, while liverworts and hornworts have a globose protonema forming a single bud. The gametophyte of mosses appears as a leafy shoot, whereas liverworts can have either a leafy shoot or a thallus, which may be simple or contain air chambers. In contrast, hornworts possess a simple thallus. The sporophyte growth in mosses and liverworts is apical, but in hornworts, it grows continuously from a basal meristem. Leaf-like structures in mosses are arranged spirally and are undivided with a midvein, whereas in liverworts, they are arranged in three rows, divided into two lobes without midveins. Hornworts do not have leaf-like structures. Mosses develop branches from stem epidermis, liverworts from leaf initial cells or inner stem cells, and hornworts do not have branches.

Gemmae are common on mosses' leaves, stems, rhizoids, or protonema, while in liverworts, they are found on leaves; hornworts lack gemmae. Mosses have paraphyses associated with antheridia and archegonia, liverworts usually lack them but have mucilaginous filaments, and hornworts do not have paraphyses. In terms of special organelles, mosses either have none or simple, small oil bodies, liverworts have oil bodies, and hornworts contain single plastids with pyrenoids. Water-conducting cells are present in both generations of mosses, in a few thalloid liverworts, and absent in hornworts. Moss rhizoids are brown and multicellular, while those of liverworts and hornworts are hyaline and one-celled.

Gametangial positions in mosses are in apical clusters, in liverworts, they can be apical clusters or on the upper surface of the thallus, and in hornworts, they are sunken in the thallus and scattered. Stomates are present in the sporophyte capsule of mosses, absent in both generations of liverworts, and present in both generations of hornworts. The seta of mosses is photosynthetic and emerges from the gametophyte early in development, whereas in liverworts, it is hyaline and elongates just prior to spore release. Hornworts do not have a seta. Moss capsules are complex with an operculum, theca, and neck, liverwort capsules are undifferentiated, spherical, or elongated, and hornwort capsules are undifferentiated, horn-shaped, and grow continuously from a basal meristem. Moss capsules contain columella as sterile cells, liverworts have spirally thickened elaters, and hornworts have columella and pseudoelaters. Lastly, the calyptra in mosses and liverworts ruptures and persists at the apex of the seta and capsule, influencing the capsule shape, whereas hornworts do not have a calyptra (Gradstein et al., 2001; Stotler & Crandall-Stotler, 2005).

Their sizes vary greatly, from tiny bodies like *Nanomitrium austinii* (less than 1 mm) to large ones like *Fontinalis dalacarlica*, which can reach 166 cm (Takaki, 1984). They are unique among land plants for having dominant and branched gametophytes that exhibit unparalleled morphological diversity compared to tracheophytes (Crum, 2001).

2.3 History of bryophytes exploration in Nepal

The exploration of bryophytes in Nepal began in 1802 with Scottish physician Francis Buchanan-Hamilton. In 1808, W.J. Hooker published "*Musci nepalensis*," documenting 17 moss species from various parts of Nepal. In 1820-21, Wallich collected numerous bryophyte specimens from Kathmandu and its vicinity and published his finding in Wallich's catalogue (Wallich, 1832).

The genus *Bryum* has a well-documented history in Nepal. Mitten's pioneering documentation in 1859 (Mitten, 1859) identified 17 *Bryum* species from Nepal within a broader list of 52 species. Building on this foundation, Noguchi and colleagues documented *Bryum* mosses during the East Himalayan Expeditions, identifying 13 species in Nepal in 1966. Their revised list later included 26 species and four varieties across the region, with 14 species specific to Nepal. Further exploration during the second phase of the expeditions in 1971 yielded three additional species. Gangulee's 1974 research focused on eastern Nepal and added 35 *Bryum* species to the known diversity.

The exploration of Nepal's Bryaceae family extends beyond *Bryum*. Iwatsuki's (1979) work documented 13 species from Central Nepal during the 1976 Kochi Himalaya Expedition. Similarly, the 1977 East Himalayan Expedition by Chiba University added 18 new species to the overall list. Additionally, Hedderson and Harold (1990) discovered a new moss species, *Plagiobryum duthiei* Broth. ex. Hedderson & Harold, in western and central Nepal. These studies highlight the occurrence of bryophytes and potential distribution in different parts of Nepal.

From 1950 to 2000, significant advancements were made in the exploration and documentation of Nepalese bryophytes. Collaborative efforts of various institutions and researchers led to the discovery of numerous new species, enhancing the scientific understanding of bryophytes in Nepal. The Royal Botanical Garden, Edinburgh, conducted a series of expeditions between 1989 and 2001, primarily targeting the eastern and central regions of Nepal, documenting numerous bryophyte species across diverse habitats.

Notable scholars such as Banerji, Grolle, Hattori, Manandhar, Long, and Pradhan played crucial roles in expanding the understanding of Nepalese bryophytes (Grolle, 1964; Long, 1993; Manandhar, 1982; Pradhan, 2020). For instance, Asakawa's research on Asiatic Jungermanniales included many species from Nepal, highlighting the region's rich bryophyte diversity. Long and Grolle's studies of Hepaticae in Bhutan and the Sino-Himalayan region further added to the knowledge base of these plants in the broader Himalayan area.

Pradhan and Shrestha's work were particularly noteworthy. They reported 233 alpine bryophyte species, including 72 species of Hepaticae, in eastern and central Nepal. Pradhan also conducted extensive studies on the lower belt bryoflora, recording 294 species of Hepaticae and Anthocerotae. These studies were pivotal in documenting the diversity and distribution of bryophytes in different ecological zones of Nepal.

Several important discoveries were made during this period, adding new species to the record of Nepalese bryophytes. Pradhan's (2000) study documented bryophytes from various localities, such as Phulchowki Hill, where *Hypnum cupressiforme* was recorded as a new species for Nepal. Similarly, bryophytes from Swayambhu, Kathmandu, were studied, resulting in the addition of three new species: *Trematodon mayebatae, Pseudotaxiphyllum elegans*, and *Neckera besseri*. In Bardia National Park, Pradhan reported *Fissidens asplenioides* as a new species for Nepal.

Further contributions came from collaborative and individual research efforts. Grolle et al. (2003) identified *Gottschelia patoniae* as a new record from the east Himalaya. Long's work (2005, 2006) in subsequent years reported several new species, including 17 in 2005 and 3 in 2006.

Pradhan and Joshi's studies also contributed significantly to the field. In 2006, they reported two new varieties and one new species. In subsequent years, Pradhan and Joshi (2006 and 2007) and Pradhan et al. (2007) each reported new species from different parts of the Terai region. Their continued research resulted in the discovery of additional species, with Pradhan and Joshi (2009) recording another new species and Pradhan (2014a) again reporting 3 new species (Pradhan, 2014b).

More recent studies by Gajurel et al. (2017) and Pradhan (2018) continued this trend of discovery, each reporting new species to Nepal, further enriching the understanding of the country's bryophyte diversity.

2.4 Species richness of bryophytes along an elevational gradient

Several studies have examined the distribution and variety of bryophyte species in relation to elevation (Ah-Peng et al., 2007; Grytnes et al., 2006; Wolf, 1993). These studies have identified four common distribution patterns: (1) monotonic drop, (2) monotonic increase, (3) hump-shaped distribution with high richness at mid-elevation, and (4) multimodality. The hump-shaped pattern is the most commonly reported (Song et al., 2015). The length of an elevational gradient can influence the observed pattern of species richness. On shorter gradients, a monotonic increase is typically seen (Spitale, 2016), whereas longer gradients often show hump-shaped or multimodal patterns (Grau et al., 2007; Sun et al., 2013).

Gradstein et al. (2010) investigated bryophytes in the Colombian Andes, exploring the lush, misty western slope (1000 to 4500 meters) and the arid eastern slope (500 to 4500 meters). Their research revealed a distinct trend: species richness increased with elevation, peaking at higher elevations. Liverworts thrived in the moisture-rich conditions of the western slope, while mosses dominated the drier eastern slope. This highlights the role of environmental factors, particularly moisture availability, in shaping bryophyte diversity along elevational gradients.

Vanderpoorten and Engels (2002) investigated bryophyte distribution in Central Belgium, finding that soil conditions, particularly the presence of loam, sand, pebbles, and forest cover, were the most significant predictors of species distribution.

Grytnes et al. (2006) conducted a study on bryophytes in western Norway, spanning elevations from 310 to 1135 meters above sea level. They found no significant correlation between bryophyte species richness and elevation; instead, moisture conditions played a predominant role in shaping bryophyte communities.

Bruun et al. (2006) studied bryophytes in Northernmost Fennoscandia, spanning elevations from 250 to 1525 meters above sea level. They observed an increasing trend in species richness with increasing elevation for both mosses and liverworts, suggesting that higher elevations harbor greater bryophyte diversity.

Ah-Peng et al. (2007) investigated bryophytes on lava flows in La Réunion, covering elevations from 250 to 850 meters above sea level. They found increasing species richness with elevation, influenced primarily by elevation and the nature of substrates like minerals and vegetation.

Grau et al. (2007) studied bryophytes in the central Himalayas of Nepal, covering elevations from 100 to 5500 meters. They found a hump-shaped relationship between species richness and elevation, with peak diversity at mid-elevations. The highest diversity for liverworts was at approximately 2800 meters, and for mosses around 2500 meters. Their research indicated that Nepalese liverworts did not conform to Rapoport's elevation rule, suggesting other factors influence bryophyte distribution in this region.

Vittoz et al. (2010) investigated bryophytes in Switzerland from the tree-line to the nival band. They observed a decreasing pattern of species richness with increasing elevation, with few bryophyte species strictly limited to the alpine-nival zones.

Sun et al. (2013) studied terrestrial bryophyte diversity and community structure along an elevational gradient from 2001 to 4221 meters on Gongga Mountain in Sichuan, China. They observed a humped relationship between terrestrial bryophyte biomass and thickness with elevation, peaking around 3758 meters. Factors like litter depth, air temperature, and precipitation primarily influenced bryophyte distribution.

Costa and Peralta (2015) investigated bryophytes in Itatiaia National Park, spanning elevations from 600 to 2787 meters. They found non-uniform patterns of species richness and distribution across the elevation gradient, with the highest species richness at mid-elevations (2100 to 2200 meters). They also noted an increase in the number of threatened species with rising elevation.

Spitale (2016) studied bryophytes in Norway, the Italian Alps, and South Tyrol, focusing on elevations between 900 and 1900 meters across three substrates: forest floor, deadwood, and tree trunk. Species richness was lower at lower elevations, with higher richness on deadwood, especially for liverworts. Temperature was the most influential factor affecting overall richness, with functional diversity strongly influenced by temperature, solar radiation, and rainfall.

Ma et al. (2020) investigated bryophyte distribution in northeast China in relation to various soil conditions. Using Redundancy Analysis (RDA), they identified soil sodium and phosphorus content as the primary environmental factors influencing bryophyte distribution patterns.

The study of bryophyte species composition and richness along elevational gradients has unveiled various distribution patterns influenced by both biotic and abiotic factors. While some studies have reported a monotonic increase or decrease in species richness with elevation, others have found hump-shaped or multimodal patterns, with peak richness often occurring at mid-elevations. Key factors influencing these patterns include moisture availability, temperature, substrate type, and anthropogenic impacts. For instance, research in the Colombian Andes and Ecuador has shown a hump-shaped relationship, while studies in Western Norway and Northernmost Fennoscandia have highlighted the significant role of moisture and elevation in shaping bryophyte communities.

However, there remain notable research gaps in our understanding of bryophyte distribution along elevational gradients. Many studies have been geographically limited, and there is a need for more comprehensive research across different regions and under varying climatic conditions. Additionally, the interaction between multiple environmental variables, such as soil composition, forest cover, and human disturbances, requires further exploration. Future research should also aim to integrate long-term monitoring to assess the impact of climate change on bryophyte diversity. Addressing these gaps will provide a deeper understanding of the mechanisms driving bryophyte distribution and help in the conservation of these ecologically significant species.

2.5 Bryophytes studies in Nepal

The recent studies on bryophytes in Nepal have significantly expanded our understanding of their diversity and distribution across different regions and elevations. Pradhan and Joshi's (2009) comprehensive documentation highlighted the rich diversity of liverworts and hornworts, encompassing 43 families and 428 species of Hepaticae, along with 11 species of Anthocerotae. Subsequent studies, such as Pradhan and Heimstad's (2018) work in the Mai Pokhari area and Pradhan's (2014a) research on Chandragiri Mountain Forest, further added new species records and emphasized the influence of habitat conditions on bryophyte diversity.

The exploration of specific regions, such as Phulchoki mountain by Pradhan (2014-2017), Panch Pokhari by Pradhan (2015), and Kailali by Paudel (2019), underscored the role of environmental variables in shaping bryophyte communities. Sharma et al.'s (2021) study in Panchase and Khati et al.'s (2022) investigation along the Chandragiri cable car route provided insights into how slope aspects and human disturbances impact bryophyte richness.

Pradhan's (2023) research in Langtang National Park revealed a hump-shaped relationship between species richness and elevation, with specific elevational ranges fostering optimal conditions for bryophyte growth. This pattern, alongside findings of endemic species' distribution, highlights the complex interplay of elevation, temperature, humidity, and canopy cover in determining bryophyte diversity.

Despite these advances, significant research gaps remain. The ecological mechanisms driving bryophyte richness and distribution along elevational gradients need further investigation. Moreover, most studies have not considered critical indices such as biomass, thickness, and cover of bryophytes, which are essential for understanding their ecological roles and modeling ecosystem responses to climate change. Addressing these gaps through comprehensive, multi-faceted research will enhance our understanding of bryophyte ecology and contribute to conservation efforts in Nepal's diverse ecosystems.

3. Materials and Methods

3.1 Study Area

3.1.1 Location

The study area lies in the Annapurna Conservation Area region, which extends from 83°34' to 84°25 E longitude and 28°15' to 28°50 N latitude, beginning in Kyumi Bus Park (1650m) and ending at Annapurna Base Camp (4130m) on the famous Annapurna Base Camp trail (Figure 1 & 2).

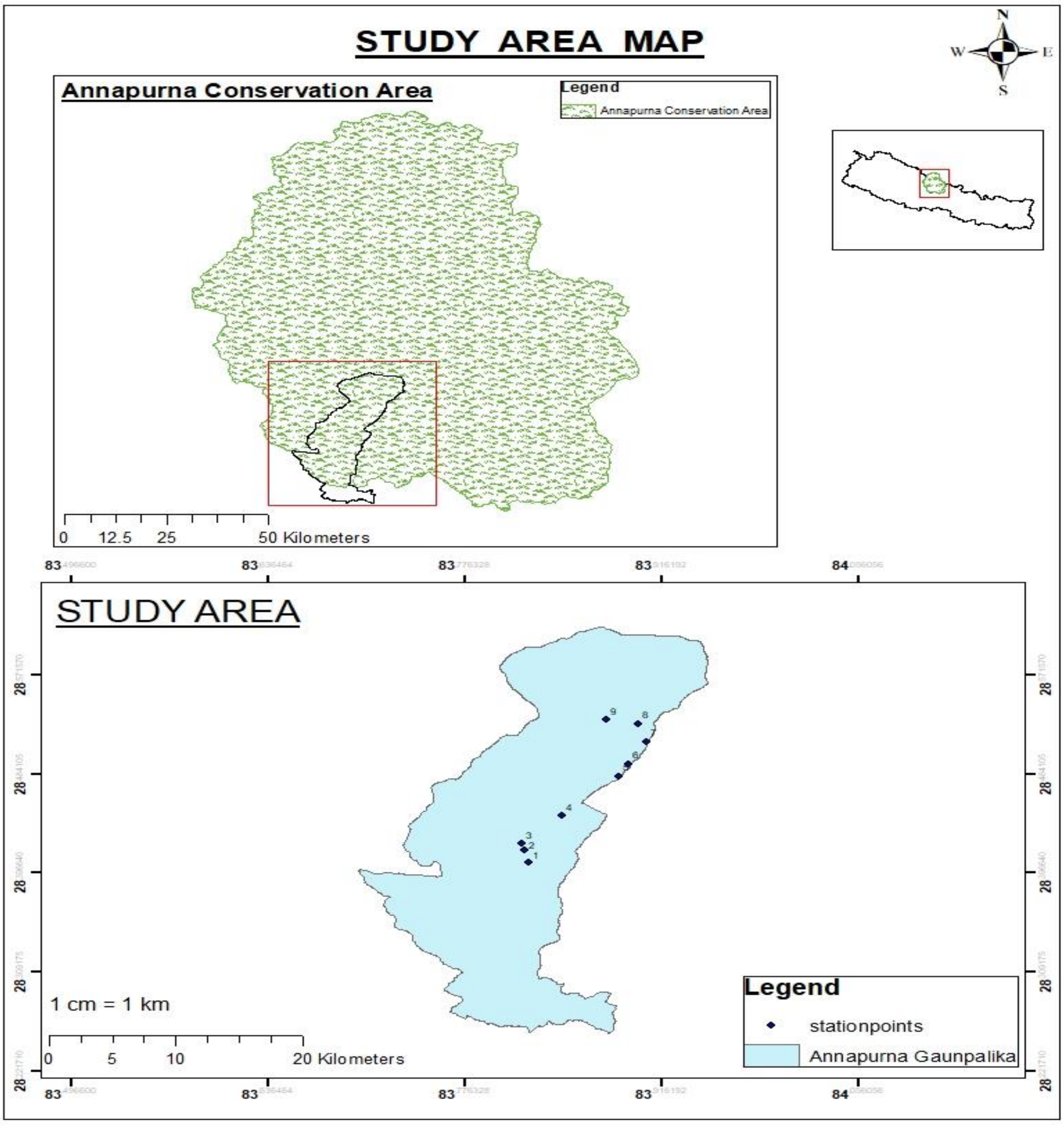

Figure 1: *Figure showing the Study Area*

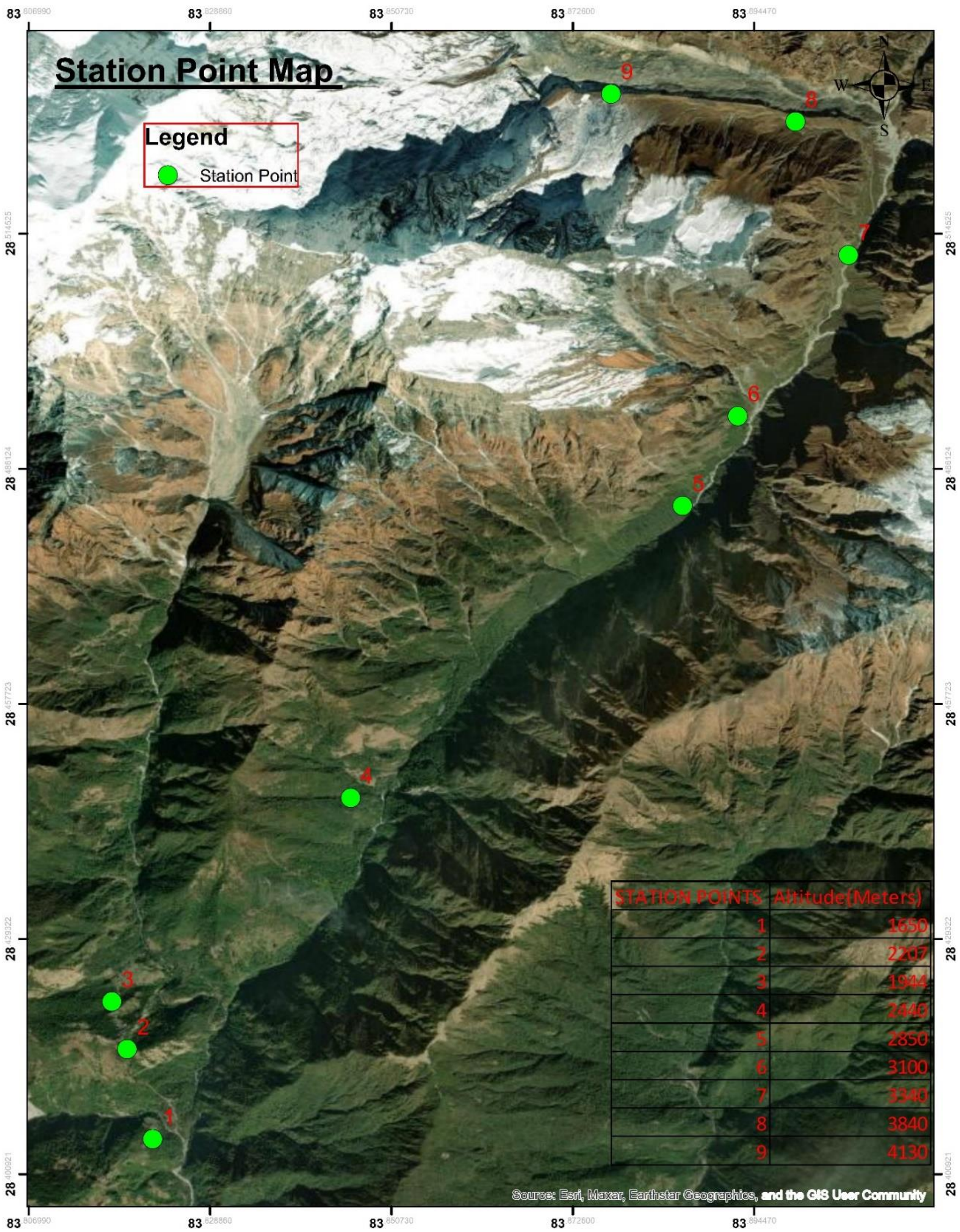

Figure 2: *Study Area showing elevational Stations*

3.1.2 Climate

The region is endowed with sub-tropical to arctic climate. Within this span, the elevation rises from less than 1,000 m to over 4,000 m. The climate varies by elevation and aspect. For every 1,000 meters of height gain, the temperature drops by 6 degrees Celsius. The average daily temperature declines from December to February and reaches its peak between May and July. The seasonal climate is influenced by the southerly monsoon, which occurs between June and September.

The southern Annapurna region receives the most precipitation in the country, with an annual rainfall of 3,000 mm. The northern Annapurna receives 25–500 mm of precipitation per year. The rainfall type is primarily determined by aspect, height, and the presence of a rain shadow effect. The average annual rainfall in the trans-Himalayan region is 193 mm, whereas the cis-Himalayan region receives 2,987 mm.

3.1.3 Vegetation

Vegetation types with their common components found in study area are as follows (Table 1) (Stainton, 1972).

Table 1: *Forest types of Study Area (ABC Trail)*

Climate region	Forests type
Tropical and sub-tropical	▪ Hill Sal forest: ▪ Subtropical Deciduous hill Forest: ▪ Schima-Castanopsis forest ▪ Subtropical Semievergreen hill Forest ▪ Pinus roxburghii forest
Temperate and Alpine Broadleaved	▪ Quercus semicarpifolia forest ▪ Quercus lamellose forest ▪ Lower temperate mixed broadleaved forest ▪ Upper temperate mixed broadleaved forest ▪ Rhododendron forest ▪ Betula utilis forest
Temperate and Alpine Conifers	▪ Abies spectabilis forest ▪ Tsuga dumosa forest

Climate region	Forests type
	▪ Pinus excelsa (P. wallichiana) forest ▪ Picea smithiana forest ▪ Cupressus torulosa forest
Minor temperate and Alpine association	▪ Alnus wood ▪ Populus ciliate wood ▪ Hippophae scrub ▪ Moist alpine scrub ▪ Dry alpine scrub ▪ Juniperus wallichiana forest

(Adopted from Annapurna Conservation Area Management Plan, 2016)

3.2 Data Collection

In October 2023, a bryophyte survey was conducted along an elevational transect spanning from 1,650 m (Kyumi Bus Park) to 4,130 m (ABC). Research and sample collection permits were obtained from the Department of National Parks and Wildlife Conservation authorities to conduct the field studies. Systematic random sampling was employed to gather bryophyte specimens. Nine strategically selected stations, spaced approximately 300 meters (±100 meters) apart, were established to represent different elevations and levels of accessibility (Table 2). At each station, a circular plot with a radius of 50 meters was delineated. The Area-Time Counts Collection method, as adapted from Su et al. (2004), was used to ensure comprehensive coverage composition and species richness of bryophyte. Within each plot, bryophytes were randomly collected over a period of 180 minutes, and the coordinates of each station were recorded using GPS. Additionally, bryophytes were collected along the trail to document the floristic composition.

Table 2: *Sample Collection Stations and their elevation.*

S.N.	Station	Elevation (m a.s.l)	Remarks
1	One	1650	kyumi Bus Park
2	Two	1944	Chumrung
3	Three	2207	Upper Sinuwa
4	Four	2490	Bamboo Forest
5	Five	2850	Dovan Area
6	Six	3100	Hinku Gufa
7	Seven	3340	Vedi Gotha
8	Eight	3740	MBC Area
9	Nine	4130	ABC

3.3 Plant Collection and Identification

1. **Field Collection:** Bryophyte species were initially photographed in their natural habitats to document their appearance and distribution. Specimens were then collected either by peeling them off from the substratum using a pocket knife or by gently removing them by hand. Only sporophyte-bearing specimens were selected for further study.

2. **Specimen Preservation:** Collected specimens were carefully preserved in paper bags and appropriately tagged for identification purposes. A total of 400 specimens were collected for the study.

3. **Cleaning and Drying:** Upon collection, specimens were soaked in water for an hour to facilitate cleaning. Soil and debris were then removed using forceps and a brush. Cleaned specimens were air-dried and transferred to well-labeled paper packets for future reference.

4. **Identification Process:** Specimens were identified using various tools, including a magnifying hand lens (20X), stereomicroscope, and light microscope. The collected bryophytes were identified by consulting books of Gangulee (1969-1980),

Kashyap (1929), Kashyap and Chopra (1932), Pradhan and Shrestha (2021, 2022). Additionally, literatures like British Biological Society (www.britishbryologicalsociety.org.uk), and Flora of North America (FNA, 2024) was also consulted. The author citation of each species was verified using World Flora Online (WFO, 2024).

5. **Classification:** Identified specimens were classified following the classification systems of Stotler and Crandall-Stotler (2005) for hornworts, Crandall-Stotler et al. (2009) for liverworts, and Goffinet et al. (2009) for mosses.

6. **Deposition:** Voucher specimens with collection number (Annex 3 & 4) were deposited at the Tribhuvan University Central Herbarium (TUCH), Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal for future reference and research purposes.

3.4 Data Analysis

The habitat distribution of bryophytes was analyzed across different strata, including soil, rock, tree, a combination of soil and rock, and of rock and tree. Descriptive analysis was performed using MS Excel, and the study area map was prepared with ArcGIS (Version 10.4) and map showing sample plots was prepared from Google Earth program. Data from different elevational stations and plots were used to calculate bryophyte species richness, defined as the number of species recorded in each plot and station.

- ❖ Species Richness = number of species per plot (Ingerpuu and Sarv, 2015).

The species richness at various elevations was then analyzed to understand the distribution patterns along the elevational gradient. A species richness curve was generated using correlation analysis between the number of species and elevation with the R package (Version 4.4.0).

4. Results

4.1 Floristic Composition of Bryophytes in ABC Trail

This study along the elevational gradient of the Annapurna Base Camp (ABC) trail identified 5 classes. These classes were classified into 16 orders. The study further categorized these orders into 39 families. At the family level, 62 genus and 91 species were documented (Figure 3, Annex 3), highlighting the diverse types of bryophytes adapted to different environmental conditions and habitats along the trail.

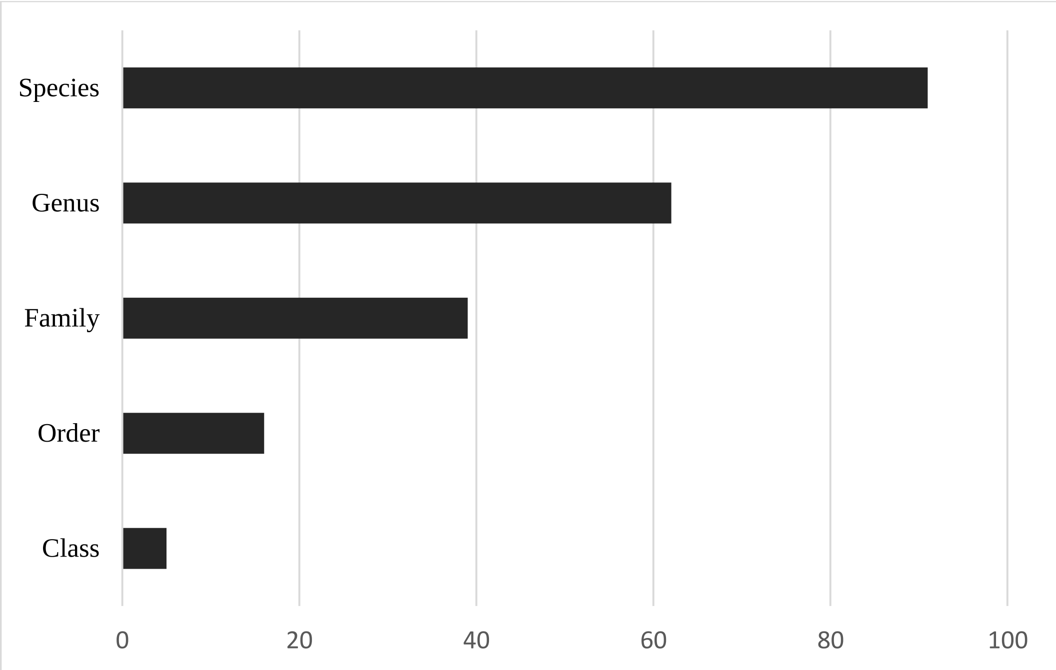

Figure 3: *Floristic Composition of Bryophytes in ABC Trail in distinct Class, Order, Family, Genus and Species.*

4.1.1 Species Composition of Bryophytes with respect to Class and Order

The bryophyte survey along the elevational gradient of the Annapurna Base Camp (ABC) trail identified Bryopsida, the most diverse class, comprising 54 species distributed across 8 orders. Notable orders within this class included Hypnales, which encompassed 16 species, and Bryales, with 14 species. This indicates a significant presence of mosses, particularly those adapted to various microhabitats along the trail. Marchantiopsida was the next most diverse class, represented by 18 species, all within the order Marchantiales. This suggests a robust representation of liverworts, especially those thriving in moist and shaded environments. Jungermaniopsida included 12 species spread across 4 orders. Jungermaniales was the most prominent with 6 species, followed by Porellales with 3 species, Metzgeriales with 2 species, and Pelliales with 1 species. This class highlights the diversity of leafy liverworts in the region. Anthocerotopsida was represented by 3 species, each belonging to a different order: Anthoceratales and Notothyladales, indicating a limited but distinct presence of hornworts (Table 3, Annex 1).

Table 3: *Species Number in different classes and orders.*

Class/Order	ANTHO.	POLYT.	BRYOP.	JUNGE.	MARCH.	GRAND TOTAL
Anthoceratales	2					2
Notothyladales	1					1
Jungermanniales				6		6
Porellales				3		3
Metzgeriales				2		2
Pelliales				1		1
Marchantiales					18	18
Polytrichales		4				4
Encalyptales			1			1
Funariales			1			1
Dicranales			9			9
Pottiales			7			7
Bryales			14			14
Bartamiales			5			5
Hedwigiales			1			1
Hypnales			16			16
Grand Total	3	4	54	12	18	91

ANTHO.: Anthocerotopsida, **POLYT.:** Polytrichopsida, **BRYOP.:** Bryopsida, **JUNGE.:** Jungermaniopsida, **MARCH.:** Marchantiopsida

4.1.2 Species with respect to Family

The bryophyte survey along the elevational gradient of the Annapurna Base Camp (ABC) trail revealed a diverse composition across various taxonomic levels. In total, 39 families were identified. Notably, the Aytoniaceae and Bryaceae families each included 8 species, demonstrating significant diversity within these groups. The Pottiaceae family followed with 7 species, and the Mniaceae family with 6 species. Other families such as Bartramiaceae and Brachytheciaceae each had 5 species, while Marchantiaceae and Polytrichaceae each had 4 species. The Entodontaceae family was represented by 3 species. Several families, including Anthocerataceae, Bruchiaceae, Conocephalaceae, Dicranaceae, Fissidentaceae, Lejeuneaceae, Leucobryaceae, Plagiochilaceae, Pylaisiaceae, Scapaniaceae, and Thuidiaceae, each comprised 2 species. The remaining families were each represented by a single species (Figure 4, Annex 1).

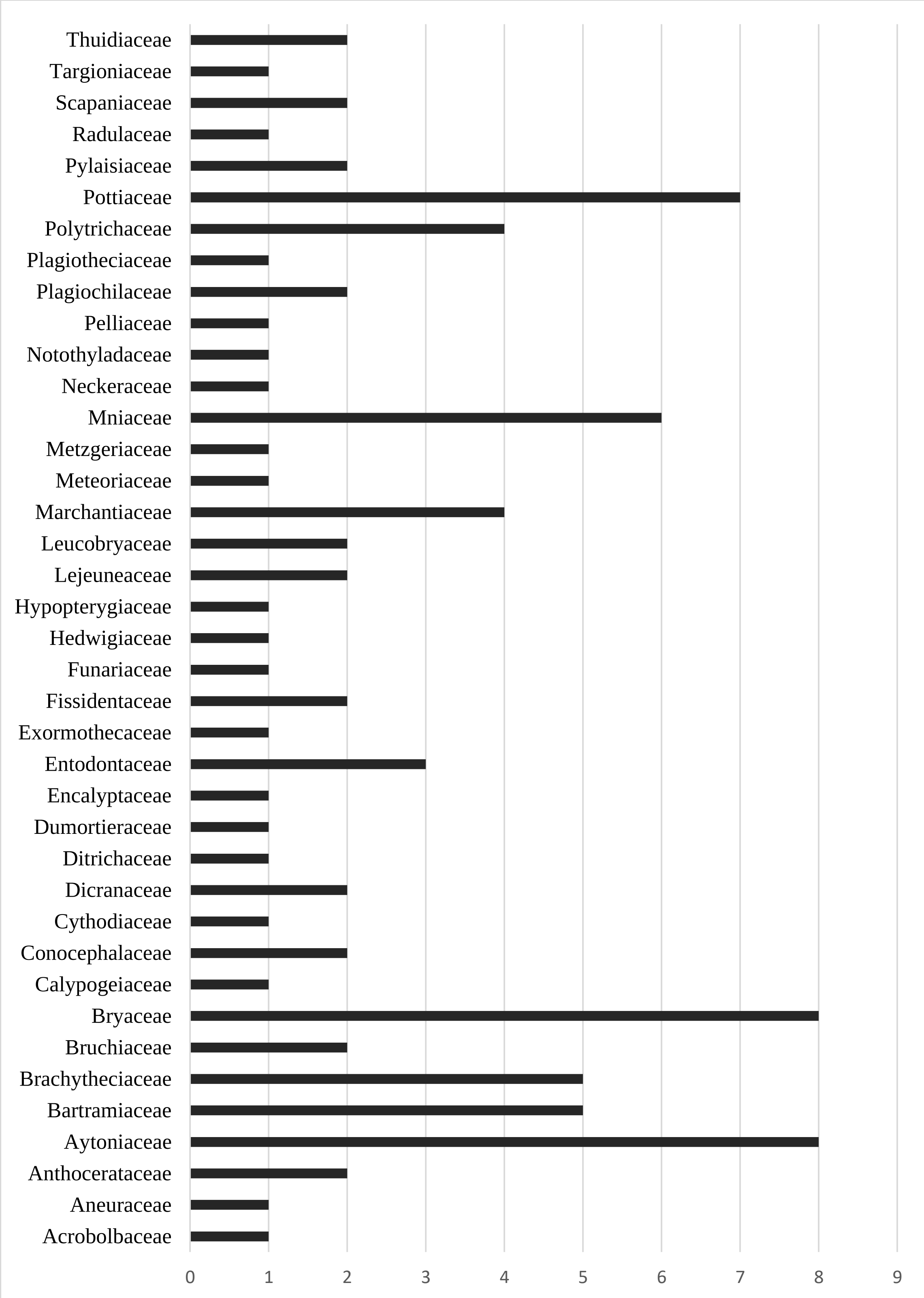

Figure 4: *Species number in different Families in ABC Trail*

4.1.3 Lineages of Bryophytes in ABC Trail

The study identified a total of 91 species of bryophytes along the Annapurna Base Camp (ABC) trail, categorized into three main types: hornworts, liverworts, and mosses. Mosses were the most prevalent, with 58 species documented, indicating their adaptability and widespread presence in the region. Liverworts were the second most common, with 30 species identified, highlighting their significant diversity in the study area. Hornworts were less common, with only 3 species recorded (Figure 5). This distribution underscores the flexibility of mosses and liverworts, enabling them to thrive in various environmental conditions, while the more selective habitat requirements of hornworts limit their distribution along the elevational gradient of the ABC trail.

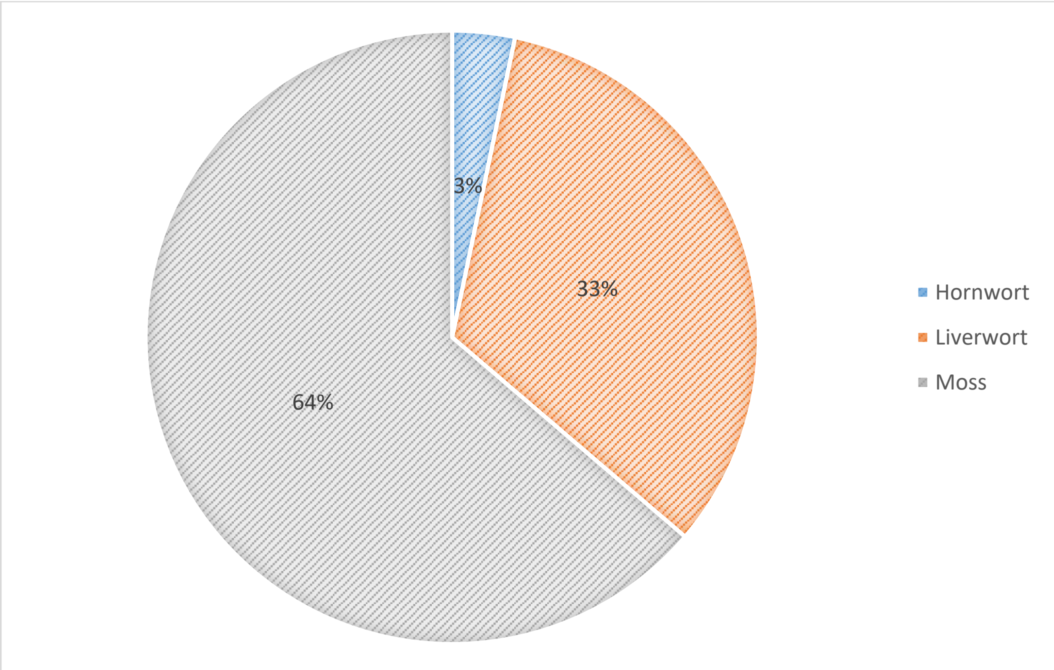

Figure 5: *Percentage of Species in different Bryophytes Division in ABC Trail.*

4.2 Habitat and Distribution of Species

Out of the 91 species identified, 28 species were found exclusively on soil, making it the most common habitat. Rocks were the second most prevalent habitat, supporting 25 species. Trees provided a habitat for 20 species, highlighting the importance of arboreal environments for bryophytes. 14 species were located on a combination of soil and rocks, while 4 species were found on both rocks and trees (Figure 6, Annex 1).

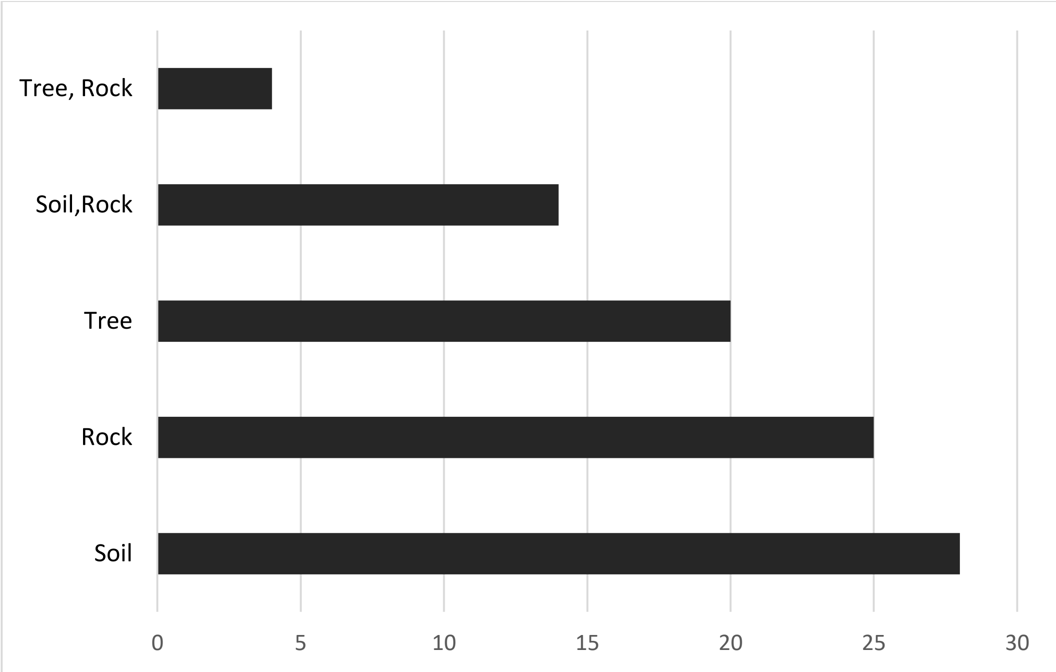

Figure 6: *Bryophyte Distribution in Different Habitat Substratum*

4.3 Species Richness of Bryophytes at different stations along an elevational gradient

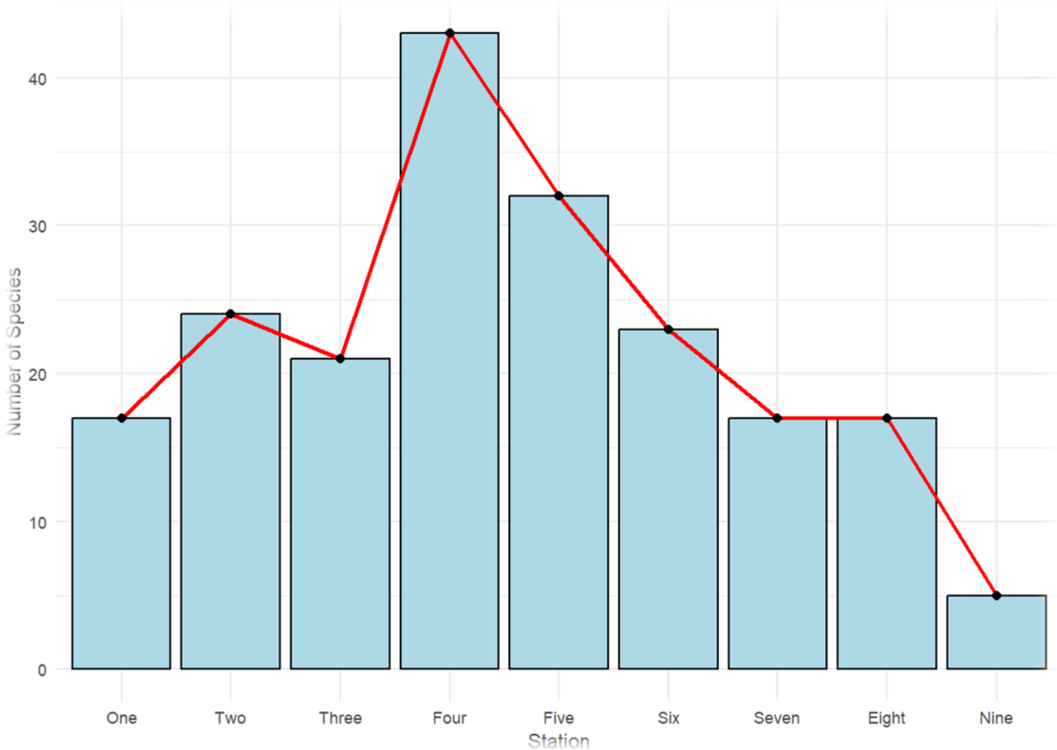

Figure 7: *Number of Species in Different Stations*

The survey of bryophyte species richness along the elevational gradient of the Annapurna Base Camp (ABC) trail revealed significant variation across different elevations, exhibiting a clear unimodal hump-shaped pattern. At Station One (1650 meters), 17 species were identified, with an increase to 24 species at Station Two (1944 meters). Station Three (2207 meters) recorded 21 species, while the highest species richness was observed at Station Four (2490 meters) with 43 species. Following this peak, Station Five (2850 meters) documented 32 species. As the elevation increased further, species richness declined, with Station Six (3100 meters) recording 23 species, and Stations Seven (3340 meters) and Eight (3740 meters) each having 17 species (Figure 7, Annex 2 & 3). The lowest richness was found at Station Nine (4130 meters) with only 4 species.

The relationship between altitude and the number of bryophyte species shows a clear negative correlation (r = -0.504), suggesting that as altitude increases, the number of bryophyte species tends to decrease.This pattern indicates a mid-elevation peak in bryophyte diversity, with richness decreasing at both lower and higher elevations. Specifically, species richness starts at approximately 20 species below 2000 meters, peaks around 40 species near the 2500-meter mark, and then declines to below 5 species at elevations around 4000 meters (Figure 8). This integrated analysis underscores the highest bryophyte diversity at mid-elevations along the ABC trail, aligning with the observed decrease in species richness at both lower and higher elevations.

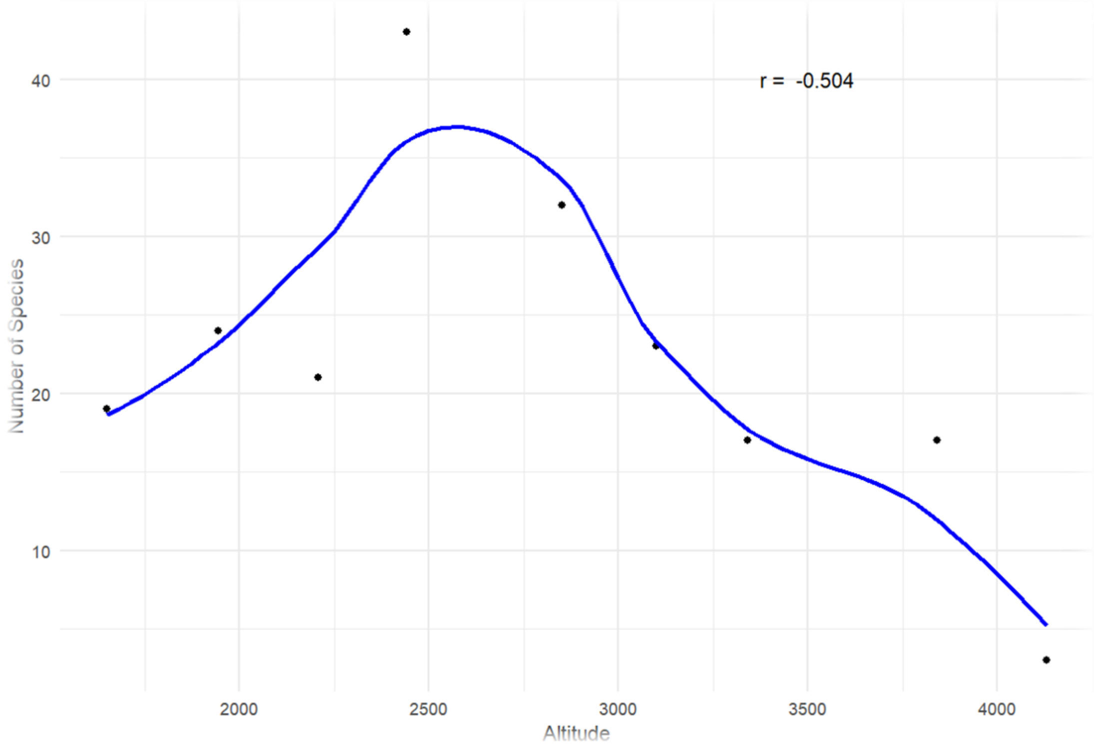

Figure 8: *Curve Showing correlation between Species Richness along an Elevational Gradient of ABC Trail.*

5. Discussion

Nepal's unique location at the crossroads of the Palearctic and Indo-Malayan regions, combined with its dramatic elevation changes, creates varied climatic zones and exceptional biodiversity. This very topography plays a key role in supporting the remarkable species richness and diversity of bryophytes (mosses, liverworts, and hornworts). The highly varied geography, climate, and flora found along the elevational gradient of the Annapurna Base Camp (ABC) trail suggest a high level of biodiversity in the study area. However, bryophytes in this region remain largely unexplored. This study, therefore, serves as a valuable first step in documenting the bryophyte diversity of the ABC trail, contributing to a broader understanding of bryophytes within the Annapurna Conservation Area and laying the foundation for future research. This study along the elevational gradient of the Annapurna Base Camp (ABC) trail identified 91 distinct bryophyte species, categorized into 62 genus, 39 families, 16 orders and 5 classes. The most diverse class, Bryopsida, included 54 species across 9 orders. The highest species richness was observed at mid-elevations, around 2500 meters, suggesting optimal conditions for bryophyte diversity at these elevations. In contrast, species richness decreased at both lower and higher elevations, reflecting less favorable conditions for bryophyte growth.

5.1 Floristic Composition of Bryophytes

The distribution pattern of bryophytes emphasizes the dominance of mosses, followed by liverworts and hornworts. The observed diversity and habitat preferences highlight the ecological flexibility of mosses and liverworts, enabling them to thrive in various environmental conditions. In contrast, the more selective habitat requirements of hornworts limit their distribution along the elevational gradient of the ABC trail. This pattern is consistent with the previous studies from Central (Karki & Ghimire, 2019; Pradhan, 2000, 2001, 2015, 2023), Eastern (Noguchi, 1966; Pradhan & Heimstad, 2018), and Western Nepal (Paudel, 2019; Pradhan, 2002) and regional patterns observed in neighboring countries such as China (Jiang et al., 2015; Shen et al., 2018; Song et al., 2021; Sun et al., 2013; Ye et al., 2023), India (Asthana & Gupta, 2021; Dandotiya et al., 2011; Gangulee, 1969; Jena, 2024; Mitten, 1859; Rawat et al., 2021), This consistency aligns with bryophyte distribution patterns observed globally (Asakawa et al., 2013; Essl et al., 2013; Glime, 2007b; Hodgetts et al., 2023; Sanders et al., 2003; Shaw & Renzaglia, 2004; Tusiime et al., 2007).

Among the bryophyte classes, the present study shows a high dominance of Bryopsida, which aligns with findings from previous studies in similar elevations in western Nepal by Paudel (2019). This trend is further supported by studies conducted at higher elevations in various regions of Nepal by Sharma (2018), Karki and Ghimire (2019) as well as studies in India by Alam (2013) and Sharma et al., (2021), indicating a consistent pattern of Bryopsida dominance across these regions.

5.2 Bryophyte habitats along the Annapurna Base Camp trail

The diverse distribution of bryophytes across various substrates along the Annapurna Base Camp (ABC) trail underscores their remarkable ecological versatility. Soil emerged as the most preferred habitat for bryophytes on the ABC trail, with 28 species found exclusively on this subs

trate. The presence of cracks and crevices on rock surfaces offers these plants crucial pockets of moisture and protection from harsh environmental conditions, making rocks another significant habitat, supporting 25 species. Trees play a vital role, supporting 20 species of bryophytes on the bark, trunks, branches, and other parts. There was also some overlap in habitat preferences, with four species found on both rocks and trees, and 14 thriving in a combination of soil and rocks. This study has provided valuable insights into the habitat preferences of bryophytes, emphasizing the importance of preserving the diverse environments they inhabit. Understanding these preferences is crucial for developing effective conservation strategies to protect bryophyte communities amidst human impacts and environmental changes.

These findings of our study are consistent with those of Pradhan (2014a), who conducted research on the slopes of the Chandragiri hills, where many reported species were found on mountain slopes among other bryofloral species and common weeds. They were detected on rocks, soil, and concrete walls, while epiphytes were found on the barks and twigs of Alnus, Schima, and Castanopsis trees. Similarly, studies conducted in the Phulchoki Mountain Forest, Pradhan (2018) documented a significant presence of bryophytes on tree barks and branches, suggesting that soil provides an ideal foundation for many bryophyte species due to their ability to retain moisture, making them well-suited for terrestrial environments. In these habitats, bryophytes play a crucial role in nutrient cycling and contribute to soil formation (Belnap et al., 2001; Karki & Ghimire, 2019; Zhao et al., 2009; Zheng et al., 2009) . These findings are further supported by Neupane's (2023) study in Palpa, with more than half distributed in terrestrial habitats, followed by species found in both rocks (lithophytes) and terrestrial habitats, epiphytes, and lithophytic habitats (Neupane, 2023). This distribution pattern is consistent with the study in Langtang by Pradhan (2023), where a significant number of species were found across multiple substrate types (Pradhan, 2023).

In this study *Barbula*, and *Bryum* were mainly found in rock substrate. However, Genus such as *Barbula, Bryum, Funaria,* and *Tortula*, which grow on freshly disturbed soil and road cuttings, act as pioneers in these habitats (Frey & Kürschner, 2011; Gradstein et al., 2010; Khati et al., 2022).

The rapid growth of invasive species, unmanaged constructions, and human settlements have a direct impact on the habitat of many bryofloral species (Khati et al., 2022; Pradhan, 2023). During the study it was observed that uncontrolled tourism, invasive species, climate change and unsystematic rural road construction has been the major threat for bryophytes.

5.3 Species richness of bryophytes along an elevational gradient

The diversity and abundance of bryophytes, along mountain slopes are influenced by a multitude of environmental factors. These factors include topography, climate, elevation, edaphic and the types of plants growing in the area. These factors, working together, determine how many different bryophyte species can exist in a particular location, how abundant they are, and the overall composition of the bryophyte community. This study highlights how elevation shapes the bryophyte diversity along the elevation gradient of the Annapurna Base Camp trail.

The relationship between species richness and elevation can vary depending on the length of the elevation gradient. On shorter slopes, there might be a steady increase in the number of bryophyte species as you move uphill (Ah-Peng et al., 2007; Bruun et al., 2006). However, on longer gradients, like the one studied here, a hump-shaped pattern is often observed (Grau et al., 2007; Pradhan, 2023). Peak richness was observed at around 2500 meters, followed by a decrease in the number of species at higher elevations. This aligns with the observations from bryophytes study in central Nepal in Langtang (Pradhan, 2023). This means that species richness increases with elevation up to a certain point, and then it starts to decline at even higher elevations. This hump-shaped pattern has been documented in studies conducted in the Himalayas and Ecuador (Crandall-Stotler & Gradstein, 2017; Grau et al., 2007). These studies suggest that mid-elevations offer the most favorable conditions for bryophyte diversity, likely due to a combination of factors like moderate temperature, good humidity levels, and the presence of a tree canopy for shade and moisture retention. However, the distribution of bryophytes along mountain slopes is not simply determined by elevation. It's a complex interplay of various environmental factors, with elevation acting as a key player (Ma et al., 2020; Marschall, 2017; Vanderpoorten & Engels, 2002). Temperature, humidity, and the availability of suitable habitats like tree cover also play crucial roles in shaping bryophyte diversity across elevational gradients (Asthana & Gupta, 2021; Mandl et al., 2009; Sveinbjornsson & Oechel, 1992; Żołnierz et al., 2022).

6. Conclusion and Recommendation

6.1 Conclusion

This study documented a comprehensive inventory of bryophytes along the elevational gradient of the Annapurna Base Camp (ABC) trail, recording a total of 91 species across 62 genera and 39 families. The findings highlight the dominance of mosses, which constitute 64% (58 species) of the bryophyte diversity, followed by liverworts at 33% (30 species), and hornworts at 3% (3 species). Among the 39 families identified, Bryaceae and Aytoniaceae were the most prevalent, each represented by 8 species, followed by Pottiaceae (7 species), Mniaceae (6 species), Bartramiaceae and Brachytheciaceae (5 species each), and Marchantiaceae and Polytrichaceae (4 species each).

The analysis of habitat preferences along the ABC trail revealed that soil is the most favored substrate, supporting 31% of the bryophyte species, followed closely by rocks (28%), trees (22%), a combination of soil and rock (15%), and a combination of tree and rock (4%). The species richness exhibited a hump-shaped distribution along the elevational gradient, peaking at mid-elevations around 2500 meters.

The study also identified significant threats to bryophyte habitats due to human activities. Unmanaged rural road construction, uncontrolled tourism, and the invasive species pose considerable risks to these delicate plant communities. These findings underscore the urgent need for conservation strategies to mitigate these impacts and safeguard the rich bryophyte diversity along the ABC trail.

6.2 Recommendation

This study recommends the following recommendations:

- Conduct comprehensive bryophyte surveys across different regions of Nepal, particularly in underexplored areas, to establish a detailed database of species.
- Implement long-term studies to monitor changes in bryophyte diversity and distribution, focusing on the impacts of climate change and human activities.
- Collaborate with local authorities to create and enforce conservation policies that protect bryophyte habitats from destructive activities such as unregulated construction and excessive tourism.

- Incorporate molecular studies to improve the accuracy of bryophyte identification, particularly for taxa that are difficult to distinguish based on morphological features alone.
- Conduct further field studies in high-elevation regions to discover and document additional bryophyte species, enhancing the understanding of bryophyte diversity in these areas.

We can ensure the long-term conservation of bryophyte diversity not only along the Annapurna Base Camp trail but also in entire Annapurna Conservation Area, safeguarding these unique plant communities for future generations while balancing the needs of local communities and sustainable tourism.

7. References

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Annex 1: Taxonomic Hierarchy and Habitats of Bryophytes in ABC Trail.

SN	Class	Order	Family	Species Name	Habitat
1	Anthocerotopsida	Anthoceratales	Anthocerataceae	*Anthoceros punctatus* L.	Soil
2	Anthocerotopsida	Anthoceratales	Anthocerataceae	*Anthoceros* sp.	Soil
3	Anthocerotopsida	Notothyladales	Notothyladaceae	*Phaeoceros* sp.	Soil, Rock
4	Jungermaniopsida	Jungermanniales	Scapaniaceae	*Scapania ciliata* Sande Lac.	Tree
5	Jungermaniopsida	Jungermanniales	Scapaniaceae	*Scapania* sp.	Tree
6	Jungermaniopsida	Jungermanniales	Acrobolbaceae	*Acrobolbus ciliatus* (Mitt.) Schiffn.	Soil
7	Jungermaniopsida	Jungermanniales	Calypogeiaceae	*Calypogeia neesiana* (C. Massal. & Carestia) Mull. Frib.	Tree
8	Jungermaniopsida	Jungermanniales	Plagiochilaceae	*Plagiochila chinensis* Steph.	Rock, Soil
9	Jungermaniopsida	Jungermanniales	Plagiochilaceae	*Plagiochila spinulosa* (Dicks.) Dumort.	Tree
10	Jungermaniopsida	Porellales	Lejeuneaceae	*Lejeunea cavifolia* (Ehrh.) Lindb.	Tree

11	Jungermaniopsida	Porellales	Lejeuneaceae	*Spruceanthus semirepandus* (Ness) Verd.	Rock
12	Jungermaniopsida	Porellales	Radulaceae	*Radula complanata* (L.) Dumort.	Rock
13	Jungermaniopsida	Metzgeriales	Aneuraceae	*Aneura pinguis* (L.) Dumort.	Tree
14	Jungermaniopsida	Metzgeriales	Metzgeriaceae	*Metzgeria conjugata* Lindb.	Tree
15	Jungermaniopsida	Pelliales	Pelliaceae	*Pellia epiphylla* (L.) Corda	Tree
16	Marchantiopsida	Marchantiales	Aytoniaceae	*Asterella blumeana* (Nees) Kachroo	Soil
17	Marchantiopsida	Marchantiales	Aytoniaceae	*Asterella khasyana* (Griff.) Grolle	Soil, Rock
18	Marchantiopsida	Marchantiales	Aytoniaceae	*Asterella wallichiana* (Lem. & Lindenb)	Soil, Rock
19	Marchantiopsida	Marchantiales	Aytoniaceae	*Asterellopsis grollei* (D.G. Long) R.L. Zhu & You L. Xiang	Soil
20	Marchantiopsida	Marchantiales	Aytoniaceae	*Mannia* sp.	Soil

21	Marchantiopsida	Marchantiales	Aytoniaceae	*Plagiochasma appendicultum* Lehm. & Lindb.	Rock
22	Marchantiopsida	Marchantiales	Aytoniaceae	*Plagiochasma cordatum* Lehm. & Lindb.	Rock, Soil
23	Marchantiopsida	Marchantiales	Aytoniaceae	*Reboulia hemisphaerica* (L.) Raddi	Rock
24	Marchantiopsida	Marchantiales	Conocephalaceae	*Conocephalum conicum* (L.) Dumort.	Soil, Rock
25	Marchantiopsida	Marchantiales	Conocephalaceae	*Conocephalum salebrosum* Szweyk.	Soil
26	Marchantiopsida	Marchantiales	Cythodiaceae	*Cyathodium cavernarum Kunze*	Soil
27	Marchantiopsida	Marchantiales	Dumortieraceae	*Dumortiera hirsute* (Sw.) Nees	Soil
28	Marchantiopsida	Marchantiales	Exormothecaceae	*Exormotheca* sp.	Soil
29	Marchantiopsida	Marchantiales	Marchantiaceae	*Marchantia linearis* Lehm. & Lindb.	Soil
30	Marchantiopsida	Marchantiales	Marchantiaceae	*Marchantia paleacea* Bertol.	Soil

31	Marchantiopsida	Marchantiales	Marchantiaceae	*Marchantia polymorpha* L.	Soil, Rock
32	Marchantiopsida	Marchantiales	Marchantiaceae	*Marchantia polymorpha* subsp. Ruderalis Bischl. & Boissel. -Dub.	Soil
33	Marchantiopsida	Marchantiales	Targioniaceae	*Targionia hypophylla* L.	Soil, Rock
34	Polytrichopsida	Polytrichales	Polytrichaceae	*Atrichum undulatum (Hedw.) P. Beauv*	Rock
35	Polytrichopsida	Polytrichales	Polytrichaceae	*Pogonatum neesii (Müll. Hal.) Dozy*	Soil
36	Polytrichopsida	Polytrichales	Polytrichaceae	*Pogonatum* sp.	Rock
37	Polytrichopsida	Polytrichales	Polytrichaceae	*Pogonatum urnigerum (Hedw.) P. Beauv*	Rock
38	Bryopsida	Encalyptales	Encalyptaceae	*Encalypta alpina* Sm.	Rock
39	Bryopsida	Funariales	Funariaceae	*Funaria hygrometric*a Hedw.	Rock, Soil
40	Bryopsida	Dicranales	Fissidentaceae	*Fissidens bryoides* Hedw.	Soil

41	Bryopsida	Dicranales	Fissidentaceae	*Fissedens* sp.	Rock
42	Bryopsida	Dicranales	Bruchiaceae	*Trematodon kurzii* Hampe ex Gangulee	Rock
43	Bryopsida	Dicranales	Bruchiaceae	*Trematodon longicollis Michx.*	Soil, Rock
44	Bryopsida	Dicranales	Ditrichaceae	*Ditrichium* sp.	Soil
45	Bryopsida	Dicranales	Dicranaceae	*Dicranella amplexans* (Mitt.) A. Jaeger	Rock, Soil
46	Bryopsida	Dicranales	Dicranaceae	*Dicranum scoparium* Hedw.	Soil
47	Bryopsida	Dicranales	Leucobryaceae	*Campylopus* sp.	Soil
48	Bryopsida	Dicranales	Leucobryaceae	*Dicranodontium denudatum* (Brid.) E. Britton	Tree
49	Bryopsida	Pottiales	Pottiaceae	*Anoectangium aestivum* (Hedw.) Mitt.,	Rock
50	Bryopsida	Pottiales	Pottiaceae	*Barbula constricta* Mitt.	Rock
51	Bryopsida	Pottiales	Pottiaceae	*Chionoloma recurvofolium* (Taylor) M. Alonso, M. J.	Rock

				Cano &. Ja. Zimenez	
52	Bryopsida	Pottiales	Pottiaceae	*Didymodon constrictus* (Mitt.) K. Saito	Rock
53	Bryopsida	Pottiales	Pottiaceae	*Hydrogonium* arcuatum (Griff.) wjk & Margad.	Soil
54	Bryopsida	Pottiales	Pottiaceae	*Hyophila acutifolia* K. Saito	Rock
55	Bryopsida	Pottiales	Pottiaceae	*Hyophila involuta* (Hook)A. Jaeger	Rock
56	Bryopsida	Bryales	Bryaceae	*Anomobryum julaceum* (Schrad. ex G. Gaertn., B. Mey. & Scherb.)	Soil
57	Bryopsida	Bryales	Bryaceae	*Bryum Argenteum* Hedw.	Soil
58	Bryopsida	Bryales	Bryaceae	*Gemmabryum coronatum* (Schwägr.) J.R. Spence & H.P Ramsay	Rock, Soil

59	Bryopsida	Bryales	Bryaceae	*Gemmabryum dichotomum* (Hedw.) J.R. Spence & H.P Ramsay	Rock
60	Bryopsida	Bryales	Bryaceae	*Gemmabryum subapiculatum* (Hampe) J.R. Spence & H.P. Ramsay	Rock
61	Bryopsida	Bryales	Bryaceae	*Imbribryum clavatum* (Schump.) J.R. Spence & H.P Ramsay	Rock
62	Bryopsida	Bryales	Bryaceae	*Ptychostomum pallens (Sw.) J.R. Spence*	Soil
63	Bryopsida	Bryales	Bryaceae	*Rhodobryum roseum* (Hedw.) Limpr.	Soil
64	Bryopsida	Bryales	Mniaceae	*Mnium marginatum* (Dicks. P. Beauv.)	Soil
65	Bryopsida	Bryales	Mniaceae	*Mnium thomsonii* Schimp.	Tree
66	Bryopsida	Bryales	Mniaceae	*Orthomnion cuspidatum* (Hedw.) T.J.	Soil

				Kop. & Yu Sun	
67	Bryopsida	Bryales	Mniaceae	*Pohlia elongata* Hedw.	Rock
68	Bryopsida	Bryales	Mniaceae	*Pohlia nutans* (Hedw.) Lindb.	Rock
69	Bryopsida	Bryales	Mniaceae	*Pohlia flexuosa* Harv.	Soil
70	Bryopsida	Bartamiales	Bartramiaceae	*Bartramia ithyphylla* subsp. patens (Brid.) Fransén	Soil, Rock
71	Bryopsida	Bartamiales	Bartramiaceae	*Philonotis asperifolia* Mitt.	Soil
72	Bryopsida	Bartamiales	Bartramiaceae	*Philonotis fontana* (Hedw.) Brid.	Rock, Soil
73	Bryopsida	Bartamiales	Bartramiaceae	*Philonotis hastata* (Duby) Wijk & Margad.	Rock
74	Bryopsida	Bartamiales	Bartramiaceae	*Philonotis* sp.	Soil
75	Bryopsida	Hedwigiales	Hedwigiaceae	*Hedwigia* sp.	Rock
76	Bryopsida	Hypnales	Thuidiaceae	*Thuidium delicatulum* (Hedw.) Schimp.	Tree

77	Bryopsida	Hypnales	Thuidiaceae	*Thuidium tamariscinum* (Hedw.) Schimp.	Tree
78	Bryopsida	Hypnales	Brachytheciaceae	*Brachythecium albicans* (Hedw.) Schimp.	Rock, Tree
79	Bryopsida	Hypnales	Brachytheciaceae	*Brachythecium plumosum* (Hedw.) Schimp.	Tree
80	Bryopsida	Hypnales	Brachytheciaceae	*Brachythecium rutabulum* (Hedw.) Schimp.	Rock, Tree
81	Bryopsida	Hypnales	Brachytheciaceae	*Brachythecium salebrosum* (Hoffm. Ex F. Weber & D. Mohr) Schimp	Rock
82	Bryopsida	Hypnales	Brachytheciaceae	*Eurhynchium striatum* (Schreb. Ex Hedw.) Schimp.	Tree
83	Bryopsida	Hypnales	Meteoriaceae	*Trachypodopsis serrulata* (P. Beauv.) M.Fleisch	Tree

84	Bryopsida	Hypnales	Pylaisiaceae	*Calliergonella curvifolia* (Hedw.) B.H. Allen	Tree, Rock
85	Bryopsida	Hypnales	Pylaisiaceae	*Ptilium crista-castrensis* (Hedw.) De Not.	Tree
86	Bryopsida	Hypnales	Plagiotheciaceae	*Plagiothecium denticulatum* (Hedw.) Schimp.	Tree
87	Bryopsida	Hypnales	Entodontaceae	*Entodon nepalensis* Mizush.	Tree
88	Bryopsida	Hypnales	Entodontaceae	*Entodon prorepens* (Mitt.) A. Jaeger	Tree, Rock
89	Bryopsida	Hypnales	Entodontaceae	*Entodon sedutrix* (Hedw.) Müll. Hal.	Tree
90	Bryopsida	Hypnales	Neckeraceae	*Neckeropsis* sp.	Tree
91	Bryopsida	Hypnales	Hypopterygiaceae	*Cythophorum* sp.	Rock

Annex 2: Stations and Elevation of Bryophytes collected from ABC Trail.

S. N.	Station	Plants name	Geographic Coordinates
1	One	*Marchantia linearis* Lehm. & Lindb.	1650 m asl. 28°24'18.7"N 83°49'19.5"E
2	One	*Marchantia polymorpha* L.	
3	One	*Marchantia polymorpha* subsp. Ruderalis Bischl. & Boissel. - Dub.	
4	One	*Asterella khasyana* (Griff.) Grolle	
5	One	*Plagiochasma appendicultum* Lehm. & Lindb.	
6	One	*Plagiochasma cordatum* Lehm. & Lindb.	
7	One	*Reboulia hemisphaerica* (L.) Raddi	
8	One	*Targionia hypophylla* L.	
9	One	*Pogonatum neesii* (Müll. Hal.) Dozy	
10	One	*pogonatum urnigerum* (Hedw.) P. Beauv.	
11	One	*Funaria hygrometrica* Hedw.	
12	One	*Hydrogonium arcuatum* (Griff.) wjk & Margad.	
13	One	*Hyophila acutifolia* K. Saito	
14	One	*Hyophila involuta* (Hook). A. Jaeger	
15	One	*Anomobryum julaceum* (Schrad. Ex G. Gaertn., B. Mey. & Scherb.)	
16	One	*Bryum Argenteum* Hedw.	
17	One	*Anthoceros* sp.	
18	Two	*Marchantia paleacea* Bertol.	1944 m asl. 28°25'18.444"
19	Two	*Marchantia polymorpha* L.	

20	Two	*Plagiochasma appendicultum* Lehm. & Lindb.	N 83°49'1.272" E
21	Two	*Conocephalum conicum* (L.) Dumort.	
22	Two	*Cyathodium Cavernarum* Kunze	
23	Two	*Targionia hypophylla* L.	
24	Two	*Lejeunea cavifolia* (Ehrh.) Lindb.	
25	Two	*Atrichum undulatum* (Hedw.) P. Beauv	
26	Two	*Pogonatum neesii* (Müll. Hal.) Dozy	
27	Two	*Funaria hygrometrica* Hedw.	
28	Two	*Trematodon kurzii* Hampe ex Gangulee	
29	Two	*Ditrichium* sp.	
30	Two	*Dicranodontium denudatum* (Brid.) E. Britton	
31	Two	*Anoectangium aestivum* (Hedw.) Mitt.,	
32	Two	*Hyophila involuta* (Hook). A. Jaeger	
33	Two	*Anomobryum julaceum* (Schrad. Ex G. Gaertn., B. Mey. & Scherb.)	
34	Two	*Bryum Argenteum* Hedw.	
35	Two	Bartramia ithyphylla Brid	
36	Two	*Philonotis fontana* (Hedw.) Brid.,	
37	Two	*Thuidium delicatulum* (Hedw.) Schimp.	
38	Two	*Brachythecium salebrosum* (Hoffm. Ex F. Weber & D. Mohr) Schimp	
39	Two	*Ptilium crista-castrensis* (Hedw.) De Not.	
40	Two	*Anthoceros punctatus* L.	
41	Two	*Phaeoceros* sp.	

42	Three	*Marchantia polymorpha* L.	2207 m asl. 28°24'57.8"N 83°49'07.9"E
43	Three	*Asterella wallichiana* (Lem. & Lindenb)	
44	Three	*Plagiochasma appendicultum* Lehm. & Lindb	
45	Three	*Cyathodium Cavernarum* Kunze	
46	Three	*Targionia hypophylla* L.	
47	Three	*Plagiochila chinensis* Steph.	
48	Three	*Plagiochila spinulosa* (Dicks.) Dumort.	
49	Three	*Scapania ciliata* Sande Lac.	
50	Three	*Calypogeia neesiana* (C. Massal. & Carestia) Mull. Frib.	
51	Three	*Atrichum undulatum* (Hedw.) P. Beauv	
52	Three	*Pogonatum neesii* (Müll. Hal.) Dozy	
53	Three	*Funaria hygrometrica* Hedw.	
54	Three	*Anoectangium aestivum* (Hedw.) Mitt.,	
55	Three	*Hyophila involuta* (Hook). A. Jaeger	
56	Three	*Anomobryum julaceum* (Schrad. Ex G. Gaertn., B. Mey. & Scherb.)	
57	Three	*Pohlia flexuosa* Harv.	
58	Three	*Thuidium delicatulum* (Hedw.) Schimp.	
59	Three	*Brachythecium albicans* (Hedw.) Schimp.	
60	Three	*Ptilium crista-castrensis* (Hedw.) De Not.	
61	Three	*Anthoceros punctatus* L.	
62	Three	*Anthoceros* sp.	
63	Four	*Marchantia linearis* Lehm. & Lindb.	2440 m asl.
64	Four	*Marchantia polymorpha* L.	28°26'47"N

65	Four	*Asterella khasyana* (Griff.) Grolle	83°50'45"E
66	Four	*Asterella wallichiana* (Lem. & Lindenb)	
67	Four	*Plagiochasma appendicultum* Lehm. & Lindb.	
68	Four	*Reboulia hemisphaeerica* (L.) Raddi	
69	Four	*Conocephalum conicum* (L.) Dumort.	
70	Four	*Conocephalum salebrosum* Szweyk.	
71	Four	Cyathodium Cavernarum Kunze	
72	Four	*Targionia hypophylla* L.	
73	Four	*Dumortiera hirsute* (Sw.) Nees	
74	Four	*Metzgeria conjugata* Lindb.	
75	Four	*Aneura pinguis* (L.) Dumort.	
76	Four	*Plagiochila chinensis* Steph.	
77	Four	*Plagiochila spinulosa* (Dicks.) Dumort.	
78	Four	*Atrichum undulatum* (Hedw.) P. Beauv	
79	Four	*Pogonatum neesii* (Müll. Hal.) Dozy	
80	Four	*Pogonatum urnigerum* (Hedw.) P. Beauv.	
81	Four	*Fissidens bryoides* Hedw.	
82	Four	*Fissedens* sp.	
83	Four	*Trematodon longicollis* Michx.	
84	Four	*Hyophila involuta* (Hook)A. Jaeger	
85	Four	*Anomobryum julaceum* (Schrad. Ex GGaertn., B. Mey. & Scherb.)	
86	Four	*Bryum Argenteum* Hedw.	
87	Four	*Mnium marginatum* (Dicks. P. Beauv.)	

88	Four	*Mnium thomsonii* Schimp.	
89	Four	*Orthomnion cuspidatum* (Hedw.) T.J. Kop. & Yu Sun	
90	Four	*Pohlia flexuosa* Harv.	
91	Four	*Bartramia ithyphylla* Brid.	
92	Four	*Philonotis fontana* (Hedw.) Brid.,	
93	Four	*Philonotis hastata* (Duby) Wijk & Margad.	
94	Four	*Brachythecium plumosum* (Hedw.) Schimp.	
95	Four	*Brachythecium rutabulum* (Hedw.) Schimp.	
96	Four	*Eurhynchium striatum* (Schreb. Ex Hedw.) Schimp.	
97	Four	*Trachypodopsis serrulata* (P. Beauv.) M.Fleisch	
98	Four	*Calliergonella curvifolia* (Hedw.) B.H. Allen	
99	Four	*Ptilium crista-castrensis* (Hedw.) De Not.	
100	Four	*Entodon prorepens* (Mitt.) A. Jaeger	
101	Four	*Entodon sedutrix* (Hedw.) Müll. Hal.	
102	Four	*Anthoceros* sp.	
103	Four	*Phaeoceros* sp.	
104	Five	*Marchantia paleacea* Bertol.	2850 m asl. 28°28'54"N 83°53'9"E
105	Five	*Marchantia polymorpha* L.	
106	Five	*Asterellopsis grollei* (D.G. Long) R.L. Zhu & You L. Xiang	
107	Five	*Plagiochasma appendicultum* Lehm. & Lindb.	
108	Five	*Plagiochasma cordatum* Lehm. & Lindb	
109	Five	*Conocephalum conicum* (L.) Dumort	
110	Five	*Conocephalum salebrosum* Szweyk.	

111	Five	*Dumortiera hirsute* (Sw.) Nees	
112	Five	Plagiochila chinensis Steph.	
113	Five	Plagiochila spinulosa (Dicks.) Dumort.	
114	Five	*Funaria hygrometrica* Hedw.	
115	Five	*Trematodon kurzii* Hampe ex Gangulee	
116	Five	*Trematodon longicollis* Michx.	
117	Five	*Dicranella amplexans* (Mitt.) A. Jaeger	
118	Five	*Dicranum scoparium* Hedw.	
119	Five	*Anoectangium aestivum* (Hedw.) Mitt.,	
120	Five	*Hyophila involuta* (Hook)A. Jaeger	
121	Five	*Anomobryum julaceum* (Schrad. Ex GGaertn., B. Mey. & Scherb.	
122	Five	*Imbribryum clavatum* (Schump.) J.R. Spence & H.P Ramsay	
123	Five	*Ptychostomum pallens* (Sw.) J.R. Spence	
124	Five	*Mnium marginatum* (Dicks. P. Beauv.)	
125	Five	*Mnium thomsonii* Schimp.	
126	Five	*Pohlia flexuosa* Harv.	
127	Five	*Bartramia ithyphylla* Brid.	
128	Five	*philonotis fontana* (Hedw.) Brid.	
129	Five	*Philonotis hastata* (Duby) Wijk & Margad.	
130	Five	*Brachythecium plumosum* (Hedw.) Schimp.	
131	Five	*Eurhynchium striatum* (Schreb. Ex Hedw.) Schimp.	
132	Five	*Entodon prorepens* (Mitt.) A. Jaeger	

133	Five	*Entodon sedutrix* (Hedw.) Müll. Hal.	
134	Five	*Neckeropsis* sp.	
135	Five	*Cyothophorum* sp.	
136	Six	*Marchantia paleacea* Bertol.	3100 m asl. 28°29'33"N 83°53'33"E
137	Six	*Marchantia polymorpha* L.	
138	Six	*Asterella blumeana* (Nees) Kachroo	
139	Six	*Asterella khasyana* (Griff.) Grolle	
140	Six	*Conocephalum conicum* (L.) Dumort.	
141	Six	*Mannia* sp	
142	Six	*Exormotheca* sp.	
143	Six	*Plagiochila spinulosa* (Dicks.) Dumort.	
144	Six	*Funaria hygrometrica* Hedw.	
145	Six	*Dicranella amplexans* (Mitt.) A. Jaeger	
146	Six	*Dicranum scoparium* Hedw.	
147	Six	*Barbula constricta* Mitt.	
148	Six	*Didymodon constrictus* (Mitt.) K. Saito	
149	Six	*Hyophila involuta* (Hook). A. Jaeger	
150	Six	*Bryum Argenteum* Hedw	
151	Six	*Gemmabryum coronatum* (Schwägr.) J.R. Spence & H.P Ramsay	
152	Six	*Gemmabryum subapiculatum* (Hampe) J.R. Spence & H.P. Ramsay	
153	Six	*Ptychostomum pallens* (Sw.) J.R. Spence	
154	Six	*Pohlia elongata* Hedw.	

155	Six	*Thuidium delicatulum* (Hedw.) Schimp.	
156	Six	*Brachythecium albicans* (Hedw.) Schimp.	
157	Six	*Brachythecium plumosum* (Hedw.) Schimp.	
158	Six	*Brachythecium salebrosum* (Hoffm. Ex F. Weber & D. Mohr) Schimp	
159	Six	*Ptilium crista-castrensis* (Hedw.) De Not.	
160	Seven	*Marchantia polymorpha* L.	3340 m asl. 28°30'43"N 83°54'21"E
161	Seven	*Plagiochasma appendicultum* Lehm. & Lindb.	
162	Seven	*Conocephalum conicum* (L.) Dumort.	
163	Seven	*Conocephalum salebrosum* Szweyk.	
164	Seven	*Exormotheca* sp.	
165	Seven	*Radula complanata* (L.) Dumort.	
166	Seven	*Pogonatum neesii* (Müll. Hal.) Dozy	
167	Seven	*Dicranella amplexans* (Mitt.) A. Jaeger	
168	Seven	*Barbula constricta* Mitt.	
169	Seven	*Chionoloma recurvofolium* (Taylor) M. Alonso, M. J. Cano & . Ja. Zimenez	
170	Seven	*Gemmabryum dichotomum* (Hedw.) J.R. Spence & H.P Ramsay	
171	Seven	*Gemmabryum subapiculatum* (Hampe) J.R. Spence & H.P. Ramsay	
172	Seven	*Rhodobryum roseum* (Hedw.) Limpr.	
173	Seven	*Pohlia elongata* Hedw.	
174	Seven	*Pohlia nutans* (Hedw.) Lindb.	
175	Seven	*Brachythecium plumosum* (Hedw.) Schimp.	

176	Seven	*Entodon nepalensis* Mizush.	
177	Eight	*Marchantia polymorpha* L.	3840 m asl. 28°31'41"N 83°53'58"E
178	Eight	*Exormotheca* sp.	
179	Eight	*Pogonatum urnigerum* (Hedw.) P. Beauv.	
180	Eight	*Pogonatum* sp.	
181	Eight	*Encalypta alpina* Sm.	
182	Eight	*Dicranella amplexans* (Mitt.) A. Jaeger	
183	Eight	*Barbula constricta* Mitt.	
184	Eight	*Bryum Argenteum* Hedw.	
185	Eight	*Gemmabryum coronatum* (Schwägr.) J.R. Spence & H.P Ramsay	
186	Eight	*Gemmabryum dichotomum* (Hedw.) J.R. Spence & H.P Ramsay	
187	Eight	*Imbribryum clavatum* (Schump.) J.R. Spence & H.P Ramsay	
188	Eight	*Pohlia elongata* Hedw.	
189	Eight	*Pohlia nutans* (Hedw.) Lindb.	
190	Eight	*Bartramia ithyphylla* Brid.	
191	Eight	*Thuidium tamariscinum* (Hedw.) Schimp.	
192	Eight	*Calliergonella curvifolia* (Hedw.) B.H. Allen	
193	Nine	*Marchantia polymorpha* L.	4130 m asl. 28°31'41"N 83°52'38"E
194	Nine	*Asterella wallichiana* (Lem. & Lindenb)	
195	Nine	*Funaria hygrometrica* Hedw.	
196	Nine	*Hedwigia* sp.	

Annex 3: Elevational Range and Collection Number of Bryophytes collected from ABC Trail.

S. N.	Species Name	Elevation range	Collection number
1	*Anthoceros punctatus* L.	1944-2207	089ST
2	*Anthoceros* sp.	1650-2490	090ST
3	*Phaeoceros* sp.	1944-2490	091ST
4	*Scapania ciliata* Sande Lac.	2207	026ST
5	*Scapania* sp.	2850	027ST
6	*Acrobolbus ciliatus* (Mitt.) Schiffn.	3300	028ST
7	*Calypogeia neesiana* (C. Massal. & Carestia) Mull. Frib.	2207	029ST
8	*Plagiochila chinensis* Steph.	2207-2850	024ST
9	*Plagiochila spinulosa* (Dicks.) Dumort.	2207-3100	025ST
10	*Lejeunea cavifolia* (Ehrh.) Lindb.	1944	021ST
11	*Spruceanthus semirepandus* (Ness) Verd.	2450	022ST
12	*Radula complanata* (L.) Dumort.	3340	023ST
13	*Aneura pinguis* (L.) Dumort.	2490	020ST
14	*Metzgeria conjugata* Lindb.	2490	019ST
15	*Pellia epiphylla* (L.) Corda	2830	030ST
16	*Asterella blumeana* (Nees) Kachroo	3100	005ST
17	*Asterella khasyana* (Griff.) Grolle	1650-3100	006ST
18	*Asterella wallichiana* (Lem. & Lindenb)	2207-4130	007ST
19	*Asterellopsis grollei* (D.G. Long) R.L. Zhu & You L. Xiang	2850	008ST

20	*Mannia* sp.	3100	020ST
21	*Plagiochasma appendicultum* Lehm. & Lindb.	1650-3340	009ST
22	*Plagiochasma cordatum* Lehm. & Lindb.	1650-2850	010ST
23	*Reboulia hemisphaerica* (L.) Raddi	1650-2490	011ST
24	*Conocephalum conicum* (L.) Dumort.	1944-3340	013ST
25	*Conocephalum salebrosum* Szweyk.	2490-3340	014ST
26	*Cyathodium cavernarum Kunze*	1944-2490	015ST
27	*Dumortiera hirsute* (Sw.) Nees	2490-2850	017ST
28	*Targionia hypophylla* L.	1650-2490	016ST
29	Marchantia linearis Lehm. & Lindb.	1650-2490	001ST
30	*Marchantia paleacea* Bertol.	1944-3100	002ST
31	*Marchantia polymorpha* L.	1650-4130	003ST
32	*Marchantia polymorpha* subsp. Ruderalis Bischl. & Boissel. -Dub.	1650	004ST
33	*Exormotheca* sp.	3340-3740	018ST
34	*Atrichum undulatum (Hedw.) P. Beauv*	1944-2490	031ST
35	*Pogonatum neesii (Müll. Hal.) Dozy*	1650-3340	032ST
36	*Pogonatum* sp.	3740	034ST
37	*Pogonatum urnigerum (Hedw.) P. Beauv*	1650-3740	033ST
38	*Encalypta alpina* Sm.	3740	035ST
39	*Funaria hygrometric*a Hedw.	1650-4130	036ST
40	*Fissidens bryoides* Hedw.	2490	037ST
41	*Fissedens* sp.	2490	038ST
42	*Trematodon kurzii* Hampe ex Gangulee	1944-2850	039ST

43	*Trematodon longicollis Michx.*	1944	040ST
44	*Ditrichium* sp.	2850-3740	043ST
45	*Dicranella amplexans* (Mitt.) A. Jaeger	2850-3100	041^{ST}
46	*Dicranum scoparium* Hedw.	1944	042ST
47	*Campylopus* sp.	1944	044ST
48	*Dicranodontium denudatum* (Brid.) E. Britton	1944	045ST
49	*Anoectangium aestivum* (Hedw.) Mitt.,	1944-2850	046ST
50	*Barbula constricta* Mitt.	3100-2850	047ST
51	*Chionoloma recurvofolium* (Taylor) M. Alonso, M. J. Cano &. Ja. Zimenez	3340-3740	048ST
52	*Didymodon constrictus* (Mitt.) K. Saito	3100	049ST
53	*Hydrogonium* arcuatum (Griff.) wjk & Margad.	1650	050ST
54	*Hyophila acutifolia* K. Saito	1650-2490	053ST
55	*Hyophila involuta* (Hook). A. Jaeger	1650-3100	054ST
56	*Anomobryum julaceum* (Schrad. Ex G. Gaertn., B. Mey. & Scherb.)	1650-3740	051^{ST}
57	*Bryum Argenteum* Hedw.	1650-3740	052ST
58	*Gemmabryum coronatum* (Schwägr.) J.R. Spence & H.P Ramsay	3100-3740	057ST
59	*Gemmabryum dichotomum* (Hedw.) J.R. Spence & H.P Ramsay	3340-3740	058ST
60	*Gemmabryum subapiculatum* (Hampe) J.R. Spence & H.P. Ramsay	3100-3340	055ST
61	*Imbribryum clavatum* (Schump.) J.R. Spence & H.P Ramsay	2850-3740	056ST
62	*Ptychostomum pallens (Sw.) J.R. Spence*	2850-3100	061^{ST}

63	*Rhodobryum roseum* (Hedw.) Limpr.	3340	062ST
64	*Mnium thomsonii* Schimp.	2490-2850	060ST
65	*Mnium marginatum* (Dicks. P. Beauv.)	2490-2850	059ST
66	*Orthomnion cuspidatum* (Hedw.) T.J. Kop. & Yu Sun	2490	065ST
67	*Pohlia elongata* Hedw.	2207-2850	066ST
68	*Pohlia flexuosa* Harv.	3340-3740	064ST
69	*Pohlia nutans* (Hedw.) Lindb.	2207-2850	063ST
70	*Bartramia ithyphylla* Brid.	1944-3740	069ST
71	*Philonotis asperifolia* Mitt.	3300	070ST
72	*Philonotis fontana* (Hedw.) Brid.	1944-2851	067ST
73	*Philonotis hastata* (Duby) Wijk & Margad.	2490-2850	068ST
74	*Philonotis* sp.	3880	071ST
75	*Hedwigia* sp.	4130	072ST
76	*Thuidium delicatulum* (Hedw.) Schimp.	1944-3100	073ST
77	*Thuidium tamariscinum* (Hedw.) Schimp.	3740	074ST
78	*Brachythecium albicans* (Hedw.) Schimp.	2207-3100	075ST
79	*Brachythecium plumosum* (Hedw.) Schimp.	2490-3340	076ST
80	*Brachythecium rutabulum* (Hedw.) Schimp.	2490	077ST
81	*Brachythecium salebrosum* (Hoffm. Ex F. Weber & D. Mohr) Schimp	1944-3100	078ST
82	*Eurhynchium striatum* (Schreb. Ex Hedw.) Schimp.	2490-2850	079ST
83	*Trachypodopsis serrulata* (P. Beauv.) M.Fleisch	2490	080ST
84	*Calliergonella curvifolia* (Hedw.) B.H. Allen	2490	081ST

85	*Ptilium crista-castrensis* (Hedw.) De Not.	1944-3100	082ST
86	*Plagiothecium denticulatum* (Hedw.) Schimp.	2490	083ST
87	*Entodon nepalensis* Mizush.	3340	084ST
88	*Entodon prorepens* (Mitt.) A. Jaeger	2490-2850	085ST
89	*Entodon sedutrix* (Hedw.) Müll. Hal.	2490-2850	086ST
90	*Neckeropsis* sp.	2850	087ST
91	*Cythophorum* sp.	2850	088ST

Annex 4: Photo Plates

Plate 1: A) *Anthoceros punctatus* (Tripathi, S., 089ST (TUCH); **B)** *Anthoceros* sp. (Tripathi, S., 090ST (TUCH); **C)** *Phaeoceros* sp. (Tripathi, S., 091ST (TUCH)

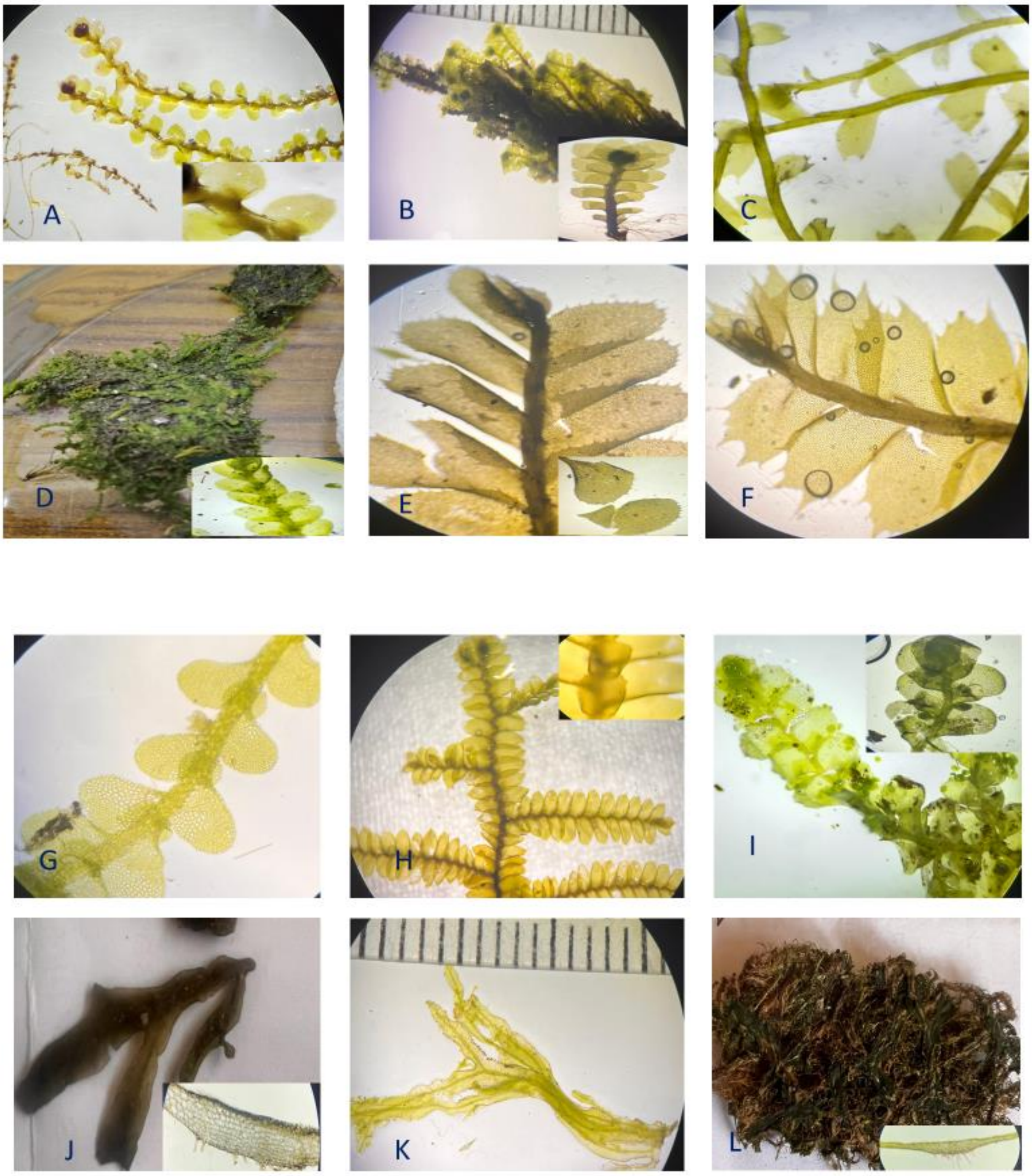

Plate 2: A) *Scapania ciliata* (Tripathi, S.,026ST (TUCH); **B)** *Scapania* sp. (Tripathi, S., 027ST (TUCH); **C)** *Acrobolbus ciliates* (Tripathi, S., 028ST (TUCH); **D)** *Calypogeia neesiana* (Tripathi, S., 029ST (TUCH); **E)** *Plagiochila chinensis* (Tripathi, S., 024ST (TUCH); F) *Plagiochila spinulosa* (Tripathi, S., 025ST (TUCH); **G)** *Lejeunea cavifolia* (Tripathi, S., 021ST (TUCH); **H)** *Spruceanthus semirepandus* (Tripathi, S., 022ST (TUCH); **I)** *Radula complanata* (Tripathi, S., 023ST (TUCH); **J)** *Aneura pinguis* (Tripathi, S., 020ST (TUCH); **K)** *Metzgeria conjugata* (Tripathi, S., 019ST (TUCH;) **L)** *Pellia epiphylla* (Tripathi, S., 030ST (TUCH)

Plate 3: A) *Asterella khasyana* (Tripathi, S., 006ST (TUCH); **B)** *Asterella wallichiana* (Tripathi, S., 007ST (TUCH); **C)** *Asterellopsis grollei* (Tripathi, S., 008ST (TUCH); **D)** *Mannia* sp. (Tripathi, S., 011ST (TUCH); **E)** *Plagiochasma appendicultum* (Tripathi, S., 009ST (TUCH); **F)** *Plagiochasma cordatum* (Tripathi, S., 010ST (TUCH); **G)** *Reboulia hemisphaerica* (Tripathi, S., 012ST (TUCH); **H)** *Conocephalum conicum* (Tripathi, S., 013ST (TUCH); **I)** *Conocephalum salebrosum* (Tripathi, S., 014ST (TUCH); **J)** *Cyathodium cavernarum* (Tripathi, S., 015ST (TUCH); **K)** *Dumortiera hirsuta* (Tripathi, S., 017ST (TUCH); **L)** *Exormotheca* sp. (Tripathi, S., 018ST (TUCH)

Plate 4: A) *Marchantia linearis* (Tripathi, S., 001ST (TUCH); **B)** *Marchantia paleacea* (Tripathi, S., 002ST (TUCH); **C)** *Marchantia polymorpha* (Tripathi, S., 003ST (TUCH); **D)** *Marchantia polymorpha* subsp. (Tripathi, S., 004ST (TUCH); **E)** *Targionia hypophylla* (Tripathi, S., 016ST (TUCH)

Plate 5: A) *Atrichum undulatum* (Tripathi, S., 031ST (TUCH); **B)** *Pogonatum neesii* (Tripathi, S., 032ST (TUCH); **C)** *Pogonatum* sp. (Tripathi, S., 034ST (TUCH); **D)** *Pogonatum urnigerum* (Tripathi, S., 033ST (TUCH); **E)** *Encalypta alpina* (Tripathi, S., 035ST (TUCH); **F)** *Funaria hygrometrica* (Tripathi, S., 036ST (TUCH); **G)** *Fissidens bryoides* (Tripathi, S., 0437ST (TUCH); **H)** *Fissedens* sp. (Tripathi, S., 038ST (TUCH); **I)** *Trematodon kurzii* (Tripathi, S., 039ST (TUCH); **J)** *Trematodon longicollis* (Tripathi, S., 040ST (TUCH); **K)** *Ditrichium* sp. (Tripathi, S., 043ST (TUCH); **L)** *Dicranella amplexans* (Tripathi, S., 041ST (TUCH)

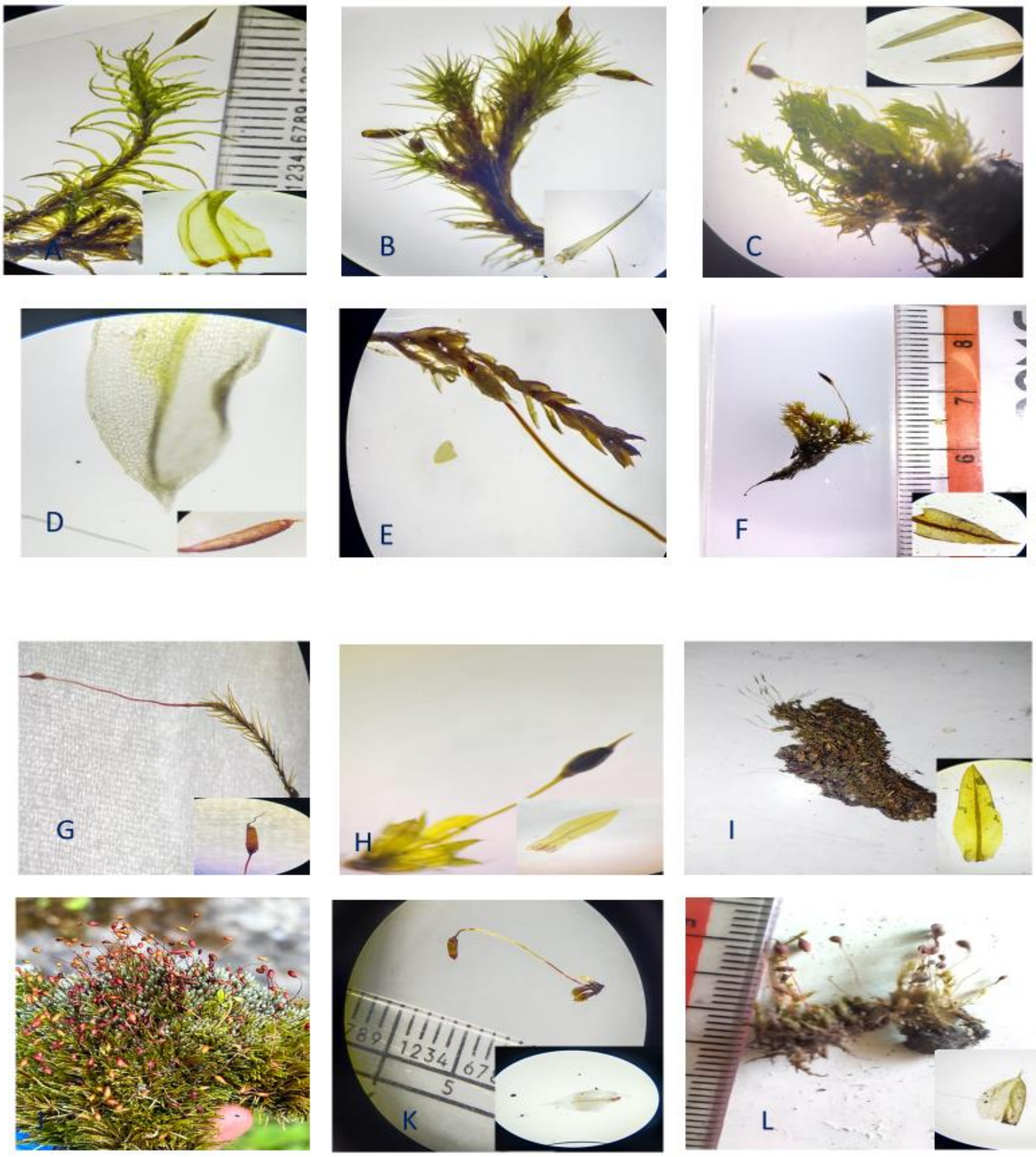

Plate 6: A) *Dicranum scoparium* (Tripathi, S., 042ST (TUCH) **B)** *Dicranodontium denudatum* (Tripathi, S., 045ST (TUCH); **C)** *Anoectangium aestivum* (Tripathi, S., 046ST (TUCH); **D)** *Barbula constricta* (Tripathi, S., 047ST (TUCH); **E)** *Chionoloma recurvofolium* (Tripathi, S., 048ST (TUCH); **F)** *Didymodon constrictus* (Tripathi, S., 049ST (TUCH); **G)** *Hydrogonium arcuatum* (Tripathi, S., 050ST (TUCH); **H)** *Hyophila acutifolia* (Tripathi, S., 051ST (TUCH); *Hyophila involuta* (Tripathi, S., 052ST (TUCH); **J)** *Anomobryum julaceum* (Tripathi, S., 053ST (TUCH); *Bryum Argenteum* (Tripathi, S., 054ST (TUCH); **K)** *Gemmabryum coronatum* (Tripathi, S., 055ST (TUCH); **L)** *Gemmabryum dichotomum* (Tripathi, S., 056ST (TUCH)

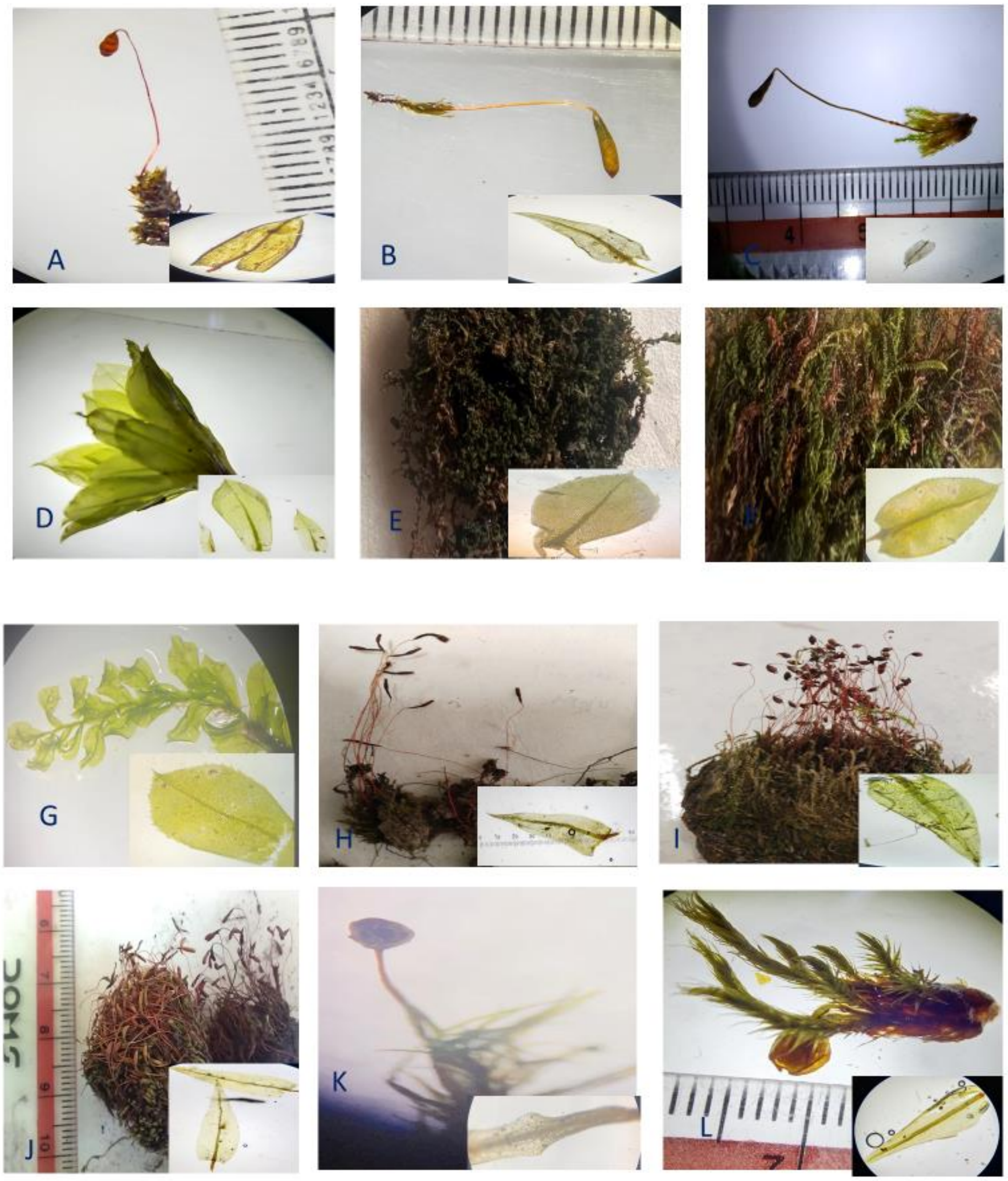

Plate 7: A) *Gemmabryum subapiculatum* (Tripathi, S., 057ST (TUCH); **B)** *Imbribryum clavatum* (Tripathi, S., 058ST (TUCH); **C)** *Ptychostomum pallens* (Tripathi, S., 059ST (TUCH); **D)** *Rhodobryum roseum* (Tripathi, S., 060ST (TUCH); **E)** *Mnium marginatum* (Tripathi, S., 061ST (TUCH); **F)** *Mnium thomsonii* (Tripathi, S., 062ST (TUCH); **G)** *Orthomnion cuspidatum* (Tripathi, S., 063ST (TUCH); **H)** *Pohlia elongata* (Tripathi, S., 064ST (TUCH); **I)** *Pohlia nutans* (Tripathi, S., 065ST (TUCH); **J)** *Pohlia flexuosa* (Tripathi, S., 066ST (TUCH); **K)** *Bartramia ithyphylla* subsp. (Tripathi, S., 067ST (TUCH); **L)** *Philonotis asperifolia* (Tripathi, S., 068ST (TUCH)

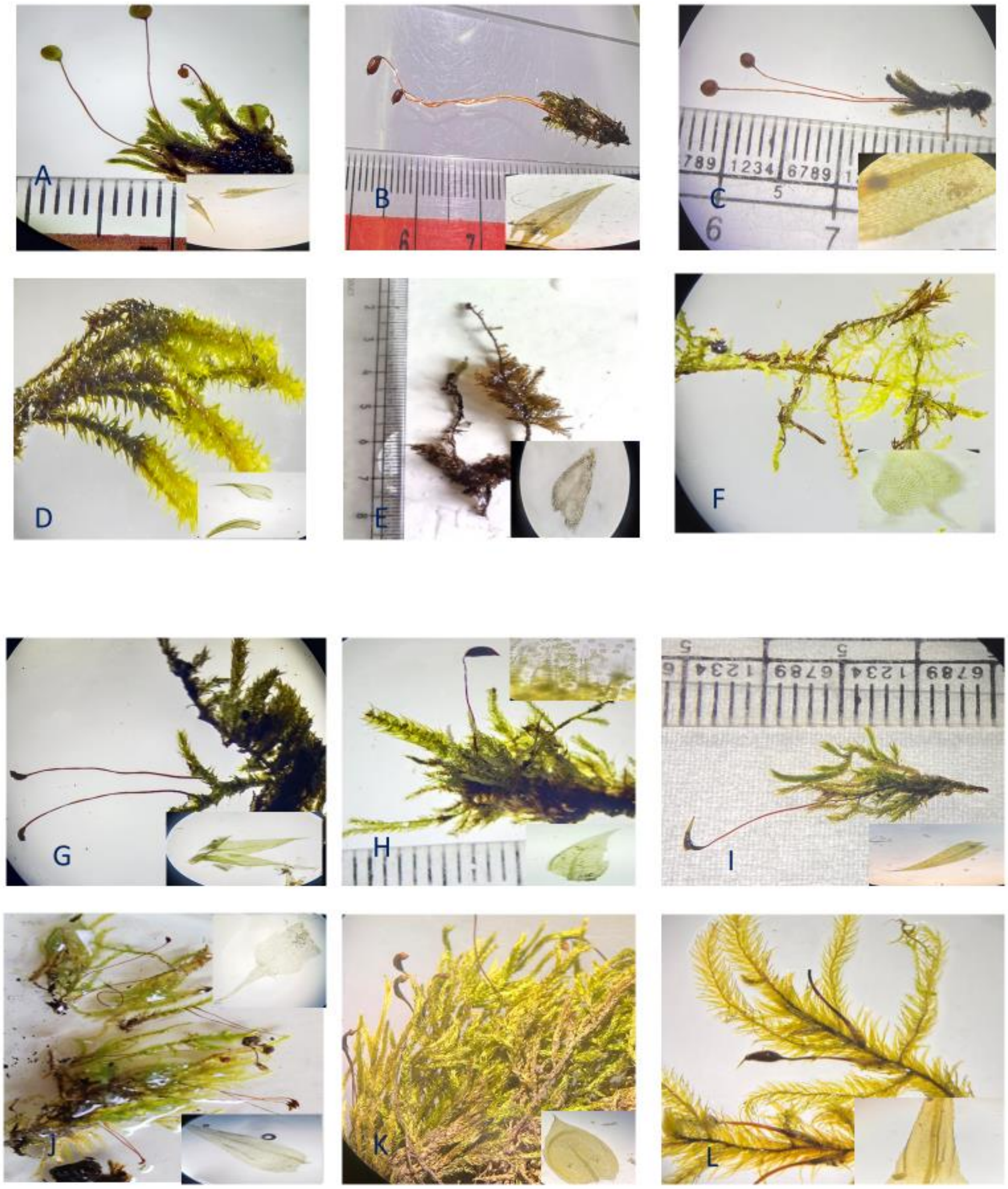

Plate 8: A) *Philonotis fontana* (Tripathi, S., 069ST (TUCH); **B)** *Philonotis hastata* (Tripathi, S., 070ST (TUCH); **C)** *Philonotis* sp. (Tripathi, S., 071ST (TUCH); **D)** *Hedwigia* sp. (Tripathi, S., 072ST (TUCH); **E)** *Thuidium delicatulum* (Tripathi, S., 073ST (TUCH); **F)** *Thuidium tamariscinum* (Tripathi, S., 074ST (TUCH); **G)** *Brachythecium albicans* (Tripathi, S., 075ST (TUCH); **H)** *Brachythecium plumosum* (Tripathi, S., 076ST (TUCH); **I)** *Brachythecium rutabulum* (Tripathi, S., 077ST (TUCH); **J)** *Brachythecium salebrosum* (Tripathi, S., 078ST (TUCH); **K)** *Eurhynchium striatum* (Tripathi, S., 079ST (TUCH); **L)** *Trachypodopsis serrulata* (Tripathi, S., 080ST (TUCH)

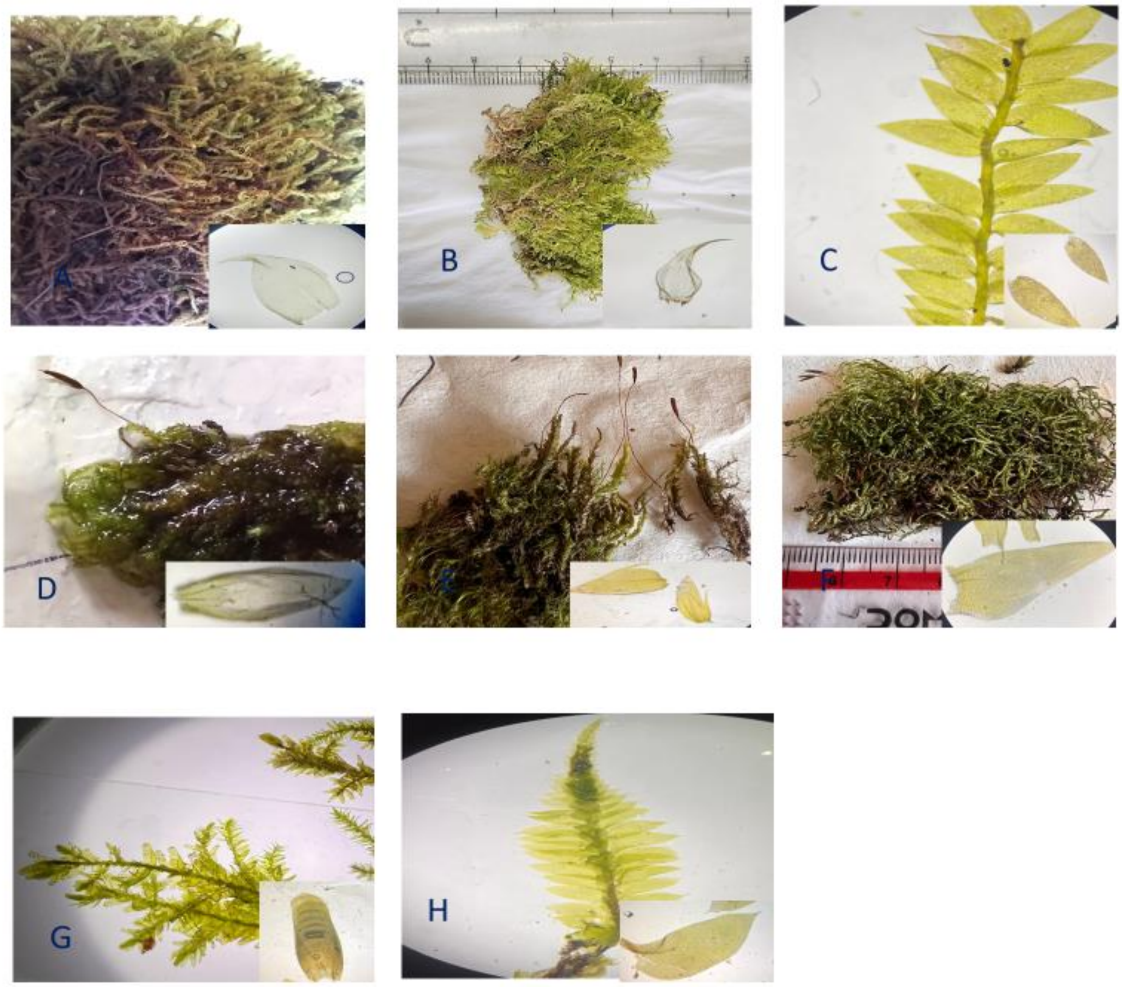

Plate 9: A) *Calliergonella curvifolia* (Tripathi, S., 081ST (TUCH); **B)** *Ptilium crista-castrensis* (Tripathi, S., 082ST (TUCH); **C)** *Plagiothecium denticulatum* (Tripathi, S., 083ST (TUCH); **D)** *Entodon nepalensis* (Tripathi, S., 084ST (TUCH); **E)** *Entodon prorepens* (Tripathi, S., 085ST (TUCH); **F)** *Entodon sedutrix* (Tripathi, S., 086ST (TUCH); **G)** *Neckeropsis* sp. (Tripathi, S., 087ST (TUCH); **H)** *Cythophorum* sp. (Tripathi, S., 088ST (TUCH)

Plate 10: A), **B)** and **C)** Photos during sample collection; **D)** Group photo; **E)** Photo during lab work; **F)** Herbarium Preparation

Annex 5: Research Permission.

नेपाल सरकार

वन तथा वातावरण मन्त्रालय

राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण विभाग

फोन नं. : ४२२०८५०
: ४२२०९१२
: ४२२७९२६
फ्याक्स नं. : ४२२७६७५

पौ.ब. नं. - ८६०
बबरमहल, काठमाडौं
Email : info@dnpwc.gov.np
http//:www.dnpwc.gov.np

पत्र संख्या :- इको,२०८०/८१ (.... शाखा)
चलानी नं. :- ६४२

मिति: २०८०/०६/०५

विषयः <u>अध्ययन-अनुसन्धान अनुमति सम्बन्धमा</u> ।

श्री अन्नपूर्ण संरक्षण क्षेत्र आयोजना प्रधान कार्यालय,
पोखरा कास्की ।

प्रस्तुत विषयमा तहाँ संरक्षण क्षेत्रमा निम्नानुसारको अध्ययन अनुसन्धान अनुमति प्रदान गरिएको व्यहोरा आदेशानुसार अनुरोध छ।

अनुसन्धानकर्ताको नाम	सुष्मा त्रिपाठी		
ठेगाना	माछापुच्छ्रे गा.पा.-०४, कास्की	इमेल : nirvanadhikary@gmail.com	फोन नं: ९८४६२३१७८९
सम्बद्ध संस्था	वनस्पति शास्त्र केन्द्रीय विभाग, त्रि.वि., किर्तिपुर		
अनुसन्धानको प्रकृति	व्यक्तिगत		
पद	अनुसन्धानकर्ता		
अनुसन्धानको तह	स्नातकोत्तर		
अनुसन्धानको शीर्षक	Species Richness and Composition of Bryophytes Along an Elevation Gradient in Annapurna Base Camp Trail		
अनुसन्धान विधि	Sample Collection (bryophytes) and lab analysis	नमूना संकलन	नमूना परिक्षण कहाँ गर्ने
		गर्ने	नेपालमा
अनुसन्धानको अवधि	२०८०/०६/०५ देखि २०८१/०६/०४ सम्म		

शर्त :

१. अनुसन्धानकर्ताले राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन, २०२९ र नियमावली, २०३० तथा मातहतका सबै नियमावलीहरुको पूर्ण पालना गर्नु पर्नेछ ।
२. अनुसन्धानकर्ताले आफ्नो अनुसन्धानको प्रस्ताव सम्बन्धित आयोजना कार्यालयमा समेत पेश गर्नु पर्नेछ ।
३. अध्ययन अनुसन्धान गर्दा सम्बन्धित आयोजना कार्यालयसँग समन्वय गरी गर्नु पर्नेछ ।
४. अनुसन्धानकर्ताले अनुसन्धान समाप्त भएपछि प्राप्त तथ्यांक, एक प्रति कागजी प्रतिवेदन र एक प्रति इलोक्ट्रोनिक प्रतिवेदन यस विभाग र आयोजना कार्यालयमा बुझाउनु पर्नेछ ।
५. अनुसन्धानकर्ताले नतिजाहरु प्रकाशित गर्दा अनुसन्धानमा संलग्न यस विभाग र अन्तरगतका कर्मचारीको योगदानको आधारमा सहलेखकको रुपमा समावेश गराउनु पर्नेछ ।
६. नमूना संकलन गर्दा प्रत्येक प्रजातिको २(दुई) ...टा संख्यामा नबढ्ने गरी हर्बेरियम प्रयोजनका लागि संकलन गर्नु पर्नेछ। संकलित नमूना विदेश लान पाईने छैन।
७. तोकिएका शर्तहरुको पालना नगरेमा विभागले कुनै पनि समयमा अनुमतिपत्र रद्द गर्न सक्नेछ ।
८. बाँकीको हकमा प्रचलित ऐन कानून बमोजिम हुनेछ ।

(प्रकाश शाह)
इकोलोजिष्ट

बोधार्थः
श्री अन्नपूर्ण संरक्षण क्षेत्र सम्पर्क कार्यालय, पोखरा कास्की : जानकारीका लागि अनुरोध छ ।
श्री सुष्मा त्रिपाठी : सम्बन्धित आयोजना कार्यालयसंग समन्वय गरी अध्ययन अनुसन्धान गर्नु हुन ।