



Diversity of bryophytes (mosses) in Fambonglho Wildlife Sanctuary, Sikkim

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ABSTRACT

Bryophytes form an important element of diverse vegetational complexes in the Himalaya. Fambonglho Wildlife Sanctuary is situated in Gangtok (East) district of Sikkim which supports the rich growth of bryophytes both in luxuriance and species diversity. In this article a total of 44 species of mosses collected from different habitat and their associated plants are presented.

Keywords: Associated plants, Bryophytes, Habit, Habitat, Fambonglho, Mosses

INTRODUCTION

Bryophytes are a diverse group of land plants which have large ecological importance. They comprise approximately 25,000 species and they are found in most of ecosystems worldwide (Klavina, 2018). It is estimated that about 18,000 species of mosses, 6,000 species of liverworts and 1000 species of hornworts are reported worldwide (Klavina, 2018). The bryophytes are generally considered as a “key” group in understanding phylogenetic association of the modern plants that dominated the environment. Bryophytes are able to occupy a variety of habitats in the diverse form of growth. They are an integral part of forests ecosystems. In India, 2,850 *taxa* of bryophytes are reported (Singh & Hajra, 1996) where the Himalayan region and the Western Ghats are known as an ideal home of numerous endemic species. Most of the bryophytes are small in size and are widely recognised as the oldest living land plants (Shaw & Renzaglia, 2004). Recent phylogenetic reconstruction of relationships suggests that the hornworts are the basal group to higher land plants where the mosses and liverworts forming a monophyletic sister clade. The growth and sexual reproduction in bryophytes depend on the availability of water and therefore favoured by a humid microclimate. In bryophytes, capacity of regeneration from any fragment of plant body is exceptional (Glime, 2017). Bryophytes play a vital role in the ecosystem with the properties of establishing soil, trapping and holding of moisture, exchange of cations and tolerate desiccation (Glime, 2017). These characters are developed due to their ability to spread branching enormously. Bryophytes also have ecological association with microorganisms, protozoans, nematodes, earthworms, insects, spiders, and many other invertebrates (Gerson, 1982) as well as other plants, and fungi. They provide a favourable substratum and seed bed for the establishment of seedlings to higher plants. Bryophytes provide congenial habitat for fixing nitrogen (Basilier, 1979). Sikkim, one of the north-eastern Himalayan states, is globally known for its rich biological diversity and is a part of Eastern Himalaya, one of the global biodiversity hotspot. The state has six districts with unique biogeographical features having varied altitudinal range and climate which make it a home to diverse of flora and fauna representing from tropical to trans-Himalayan region. Fambonglho Wildlife Sanctuary is located in the Gangtok district lies between

27°18'10" N to 27°22'50" N latitude and 88°27'15" E to 88°35'25" E longitude covering the total area of 51.76 sq. km. and the altitude ranges from 1200 to 2624 m.

METHODOLOGY

Field Work

The collection of bryophyte was done during the month March-May, 2022. The altitude of the surveyed path ranged from 1600 m to 2325 m on the north-eastern part of the sanctuary. They were collected in a paper bags or packets so that they are not dried out. The species which were in loose tufts, mats or are pendant were easily picked up by hand. Extra adhering soil was removed, and care was taken not to cause the colony to fall apart. Some species tightly adhering to their substrate were collected with a small portion of their substrate that kept them together. Likewise, epiphytic species were collected with a shallow strip of the bark. The samples were collected preferably with reproductive body (Gemma, horns, and capsules, etc). These were then preserved in 5% formaldehyde solution for lab work. Guidelines prescribed for Covid19 pandemic by the government (SOP) protocol were strictly followed during the study and precautions were taken maintaining physical distance, wearing face mask, hand gloves and using sanitizer as and when required. Photographs of the studied specimens were taken along with substrates (soil, rock, bricks etc.).

Identification of specimens

Identification of specimen was done in the laboratory of the Department of Botany, Sikkim University based on morphological and anatomical characters. Because of their small size and limited morphology and color diversity it can be a challenge to identify without a microscope. Present identification of the specimens is based on the publications mentioned below.

References used in the identification of Bryophyte specimens
All groups: Tewari and Pant (2002) Dhananjay Kumar Singh, Davendra Singh, Monalisa Dey (2007) Ralph Rope (2016) BSI Checklist, D.K. Singh, S.K. Singh, Devandra Singh (2016) Govinda Pyari, Kumar Shantanu, Prem Lal Uniyal (2011)
Mosses: Jayanta Barukial (2011) Harold E Robinson (1968)

RESULT AND DISCUSSION

In the present paper, 44 species of mosses belonging to 25 families and 35 genera have been recorded from the Fambonglho Wildlife Sanctuary, which are enumerated alphabetically irrespective of their taxonomic positions. It is found that most of the mosses were corticolous (grows on tree trunk/bark), followed by

terricolous (grows on soil) and rupicolous (grows on rocks, cemented walls etc.). The area is very rich in moss diversity along with other division of bryophytes i.e. liverworts and hornworts. Diversity of mosses is high due to limited accessibility to the visitors being far away from human settlement and undisturbed ecological conditions with suitable slope required for the mosses. The most abundant mosses found were *Dicranum undulatum*, *Fissidens javanicus*, *Floribundaria floribunda*, *Haplocladium microphyllum*, *Hedwigia ciliata*, *Homalothecium sericeum*, *Hylocomium splendens*, *Hypnum cupressiforme*, *Leucobryum javense*, *Ptilium crista-castrensis*, *Rhynchostegium megapolinatum*, *Rhynchostegium tenuifolium*, *Struckia argentata* and *Thuidium delicatulum*, however, species of *Mnium hornum*, *Isothecium myosuroides* and *Octoblepharum albidum* were found to be sparsely distributed. Among the 44 species of mosses recorded, 24 genera, namely *Anomodon*, *Brachythecium*, *Campylopus*, *Entodon*, *Floribundaria*, *Haplocladium*, *Hedwigia*, *Homaliodendron*, *Homalothecium*, *Hylocomium*, *Hypnum*, *Isopterygium*, *Isothecium*, *Leucodon*, *Neckera*, *Neckeropsis*, *Octoblepharum*, *Oxystegus*, *Ptilium*, *Racopilum*, *Rhynchostegium*, *Struckia*, *Taxiphyllum*, and *Thuidium* are pleurocarpous and remaining 9 genera namely *Atrichum*, *Bryum*, *Dicranum*, *Distichium*, *Fissidens*, *Leucobryum*, *Mnium*, *Pogonatum*, *Polytrichum*, are acrocarpous.

For the identification of collected bryophytes the key characters are:

1. Plants medium-sized, in loose mats, dark to light green. Branch leaves imbricate, appressed, or rarely slightly crisped when dry, erect to spreading, broadly oblong-ligulate, slightly spatulate, narrow midrib, base broadly decurrent; margin undulate, sometimes infolded, or sometimes dentate to spinulose at insertion; entire at apex, apex rounded; costa moderately strong, ending before apex; perichaetia on terminal branch. Capsule ovoid, operculum obliquely short-rostrate

.....*Anomodon minor*

2. Large moss form extensive patches, light to dark green and becomes yellowish when matured. Erect stem, leaves toothed when margin, more crowded above and have a creeping root like structure. Reddish brown seta that holds brown capsule

.....*Atrichum undulatum*

3. The plants are reddish-brown to yellowish-green, small to medium in size and in loose or dense tufts. The stems are simple, rarely branched, erect, and foliate. The leaves are involute when dry and when moist are erect-spreading. The leaf shape ranges from ovate to lanceolate. The leaf starts from an abruptly narrow to a broad ovate base to a setaceous apex. The margins are revolute, costa stout, precurrent to shortly excurrent and entire. The setae are yellowish brown to reddish in colour, not twisted, and cylindrical. The capsule are erect, cylindrical; operculum are obliquely long and rostrate

.....*Barbula constricta*

4. Plant whitish-green to yellowish-green, stem regularly or irregularly branched, sympodial branches common, leaves are ovate, margin serrate or sub-entire. Seta is reddish-brown holding the capsule. Axillary hairs present, branched leaves are ovate-lanceolate to narrow triangular

.....*Brachythecium rivulare*
5. Plant yellow-green to golden-brown, stem densely foliate and irregularly branched, leaves are ovate-lanceolate, margin weakly serrulate, perichetia and perigonia on the stem. Pericheatial leaves are gradually acuminate; seta is reddish-brown holding capsule that becomes orange-brownish after it matures

.....*B. plumosum*
6. Plant consists of dense mats of whitish-green leafy stems, branched stems are light green above, reddish in the middle, and brown below; more or less hairless, fibrous rhizoids develop from the stem. Individual leafy stems have a terede thread-like or worm-like appearance. Individual leaves are hairless, ovate and toothless in their margin. Leaf bases clasp to the stem. Capsules are reddish-brown when matured

.....*Bryum argenteum*
7. Plants soft, densely tuft, yellowish-green above, reddish below, rhizomatous, leaves ovate, spirally twisted when dry, crowded at apex and more distant below, margin smooth. Seta long, reddish-brown, capsule erect and become reddish-brown when matured

.....*B. capillare*
8. Plants very small, closely tufted, bright dull green to yellowish-green above, dark brown below and in lower part matted with brown radicles. Stem slender, short, erect, green, becoming reddish to brownish in lower portion. Leaves are crowded closer in the upper portion and distant below, ovate to oblong-lanceolate, margin entire. Seta slender, erect, reddish-brown holding dark red capsule when matured and is cup-shaped

.....*B. coronatum*
9. Plants glossy yellowish green or golden green. Leaves erect when wet, appressed when dry, rarely falcate, narrowly lanceolate, ending in a long and fine. Lamina very short, ending at mid-leaf and, very small; costa very broad

.....*Campylopus gracilis*
10. Plants in dense compact tufts, green to yellowish brown, shiny, rarely somewhat dull. Leaves erect- appressed or sometimes slightly falcate or flexuose, somewhat contorted when dry, the apex often twisted, weakly to strongly undulate, kneeled above, lanceolate to oblong-lanceolate, broadly acute; margin plane, entire proximately, serrulate to serrate in the distal half. Dwarf males are present on the stem rhizoids of female plants; perichaetial leaves acuminate. Seta solitary and yellow to brown; capsule furrowed when dry, yellow to yellowish brown or reddish brown

.....*Dicranum undulatum*
11. Plant look dense silky tuft green in colour. Stem slender, long and sometimes branched, leaves are present in two rows and form a white sheathing base. Pericheatial leaves present, which resemble as ordinary leaves. Seta long and become twisted when dry. Capsule erect, brownish-red when matured and rhizoids develop below the stem

.....*Distichium capillare*
12. Plants dark green, glossy, branches pinnate, flattened; leaves triangular, ovate-lanceolate, leaves are spreading, margin almost smooth, entire. Seta yellowish-brown, capsule erect to horizontal, when matures green capsule turns to dark red in colour

.....*Entodon flavescens*
13. Plant in dense mats, bright green in colour. Leaves are erect to spreading, oblong-lanceolate to oblong-ovate, margin proximally entire, distally serrulate. Perichaetia on stem and branches, inner perichaetial leaves oblong. Seta yellow, capsule long and when it matures it turns to red colour

.....*E. macropodus*
14. The stem and branches of this mat forming calcareous loving moss have shiny leaves and appear somewhat worm-like. Leaves are ovate elliptical, stem and branches are flattened covering with leaves. Leaves press closely with stem when dry, perichaetia mostly on stem

.....*E. seductrix*
15. Plants green, yellowish green to brownish. Leafy stems simple, but usually with innovations from the axils of upper leaves; leaves in 18-38 pairs, densely arranged; middle to upper leaves linear-lanceolate to lanceolate, acuminate at apex, the upper half of leaves usually more or less rugose; base of dorsal laminae often rounded, margins crenulate, vaginant laminae half the leaf length. Seta is orange to red colour; capsule horizontal, symmetric and oblong; when matured it becomes dark red to brown colour. Rhizoids arise below the stem of the plant

.....*Fissidens javanicus*
16. Plants leaves appressed to erecto-patent, linear-lanceolate, acuminate; margin weakly denticulate, the teeth strongest at the apex; costa very faint; stem leaves differ from branch leaves in having entire margins and long. Calyptra cucullate, sparsely hairy, seta blackish brown, long, often curved. Capsule ovate-oblong, operculum long, conical-rostrate

.....*Floribundaria floribunda*
17. Plant medium-sized, stem leaves erect, distinct, and broadly ovate to triangular, margins plane and serrulate. Branched leaves distant, and ovate. Seta slender, brown, capsule turned brown colour when it matures. Rhizoids loosely attached to the substratum

.....*Haplocladium microphyllum*
18. Evergreen moss forms a low cushion of plants. Stems are red to brown, devoid of hair-like rhizoids; they are widely spread or erect. Leaves occur along the stem and moderately denser. Individual leaves are lanceolate-ovate, margins are toothless, they strongly clasp the stem at the base, lower leaf margin are rolled downward, while their middle and upper margins are flat. Leaves are green or yellowish green when wet and greyish when dry. They become attached to the substratum when their stem bases and lower stem develop fibrous rhizoids

.....*Hedwigia ciliata*
19. Plants yellowish-green, robust, mainstem creeping, branched and often with stolons, secondary stem pinnately branched; leaves lanceolate to oblong ligulate, branch leaves ovate, shortly acuminate, toothed at the extreme tip, near the base revolute on one side, longitudinally plicate when dry; perichaetial bracts lanceolate, the lower stems leaves smaller; costa single. Seta long and capsule erect to slightly inclined

.....*Homaliodendron flabellatum*
20. Plants have green or golden green main shoots grow closely appressed to the substrate. They have short, crowded side branches that curve upwards and

inwards when dry, with leaves closely appressed. On wetting, the branches rapidly straighten and the leaves spread outwards. Leaves are 2.5 to 3 mm long, strongly pleated, widest at the base, and taper evenly to pointed tip. The margins are weakly toothed. Capsules long, straight and cylindrical

.....*Homalothecium sericeum*

21. Plant form loose web of shoots. Shoots are glossy green or brown-green. Branching pattern is complex. It is composed of one or more bipinnate branched “step by step” and each step represents a year growth. Leaves of the main branch are doubling costate. Its appearance is fern-like

.....*Hylocomium splendens*

22. Plant light or greyish green, branching irregularly pinnate, shoots are green or tinged with a warm, brownish colour in the older part. Leaves closely imbricate, ovate, oblong-lanceolate, margin smooth and denticulate at tip. Top perichaetial leaves erect and spreading; seta erect, slender, capsule when matured it turns to red to brown in colour

.....*Hypnum cupressiforme*

23. Plants green to golden green form a mat or carpet like intertwined of stem and roots; leaves are oblong, pointed at the tip; seta brownish to red, slender; capsule reddish brown, cylindrical

.....*Isopterygium albescens*

24. Plants in cushions, olive-green to whitish-green. Stems erect or pendant, pinnately branched, leaves 3.5 mm long, ovate-lanceolate with apex twisted. Margins plane but sometimes entire to serrulate below the middle, and serrate above. Perichaetia on main axis, ligulate-lanceolate base, seta long, capsule brown, and operculum conic

.....*Isothecium myosuroides*

25. Creeping stems that often form a large mats or cushions vary in colour from almost white when dry to pale green. Leaves are linear-lanceolate and crowded on the stem, veins broad, gradually narrowed from broadly ovate base; rhizoids fibrous

.....*Leucobryum javense*

26. Plant whitish-green, silky, branches arise from the main stem and from basal portion; leaf spreading, not much changed when dry, gradually narrowed to tip from a wider base; uniform from base to apex. Seta slender, brown in colour, capsule when matured it turns to brown in colour

.....*L. juniperoideum*

27. Plants are large sized, whitish green, in loose tufts. Stems erect, bearing many soft-twisted branches; leaves typically soft-textured, narrowly lanceolate to lanceolate, gradually narrowed to subtubulose apices from broadly elliptic base, acute at apex; rhizoid fibrous

.....*L. sanctum*

28. Plants medium-sized, light to dark green, glossy. Stems short or rarely elongate, curved, rarely straight and rigidly spreading, julaceous, fragile branchlets absent from distal leaf axils. Branch leaves erect-appressed; apex acute to short-acuminate, perichaetia common. Rhizoids fibrous and loosely attached to the substratum

.....*Leucodon julaceus*

29. The young plants are bright green, the older are dark-green, simple, and erect, shoots erect from the base. Lower leaves minute, the upper gradually increase in size, the terminal forming a rosette, all oblong-lance shaped, apex more or less acute with a sharp little point; base growing slightly down the stem; margin with a strong red border, spiny toothed from below the middle, the teeth in a double row; veins vanishing below the apex. Dioecious, and male surrounded by rosette leave

.....*Mnium hornum*

30. Leaves ligulate, symmetric, concave, octoferous, leaf base broader, oval and shortly decurrent; apex rounded; margin faintly crenulated almost the upper part of the leaf; costa single

.....*Neckera crenulata*

31. Plants medium-sized, in mats or shelf-forming, green, and glossy. Stem creeping, irregularly pinnate. Secondary stem leaves spreading to squarrose, oblong or oblong-ligulate, asymmetric, undulate to flat; margins entirely proximate, distinctly to slightly serrulate at apex, teeth not recurved; apex broad to rounded-truncate; costa single. Perichaetial leaves linear to ligulate, seta are short in length and capsule oblong-cylindrical

.....*Neckeropsis acutata*

32. Plants whitish green forming tuft matson the trunk of rough bark trees, leaves crowded, erect spreading on a very short stem; leaves ligulate, form an oblong or narrowly obovate, it remains same in normal and dry condition, sheathing base broad, apiculate at tip, minutely serrate, usually form a rosette near tip of the plant, rhizoids fibrous

.....*Octoblepharum albidum*

33. Plant yellowish-green, in loose tufts; stem dark, slender; leaves fragile, spreading, flexuose, elongate, curled when dry, lanceolate, base broad, margin flat, wavy, smooth below, somewhat crenulate with papillate above, tip acute; costa yellowish

.....*Oxystegus cylindricus*

34. Plant lax tufts, stem simple, sometimes branched, with pale basal rhizomatous region. Leaves lanceolate, wider sheathing base, apex sharply acute, margin also sharply toothed almost upto the base of the lamina; seta long; capsule erect, reddish brown, ovate, cylindrical, surface rough

.....*Pogonatum alloides*

35. It forms loose to dense tufts. The wiry plants are large and olive to dark green, becoming brown to age. Stems are typically unbranched, stiff, and erect. Leaves are spirally arranged to the stem, erect spreading to curved and twisted when dry, spreading with recurved tips when wet, the base clasps the stem with a membranous, shiny sheath, oblong-lanceolate or elliptical, yellowish; margins with unicellular teeth from leaf base to apex, the midrib ends above the apex in a short. Seta long, yellowish-reddish brown; capsule long, brown to dark red brown, inclined, box-like appearance

.....*Polytrichum commune*

36. It consists of leafy stems that are more or less erect, although old lower stems are often decumbent on the ground. It forms dense colonies. The stems are light yellowish, brown to dark reddish brown, terete, devoid of hairy-like rhizoids, although some rhizoids are present at the base. Slender leaves are densely distributed along the entire length of the stem. Leaves are widely

spreading when moist, while dry leaves are strongly ascending to erect, individual leaves are linear to linear-lanceolate in shape, entire along their margins. Leaves surface are greyish green or dark green, it become brown-red at its tip; midrib extend to entire leaf except at base. Seta long, less erect, red to reddish brown at maturity; capsule immature are erect, while mature are tilted. It attaches to the substratum with the help of fibrous root present at the base of the stem. Lower stem on the ground also can produce rhizoids, from which clonal plants can develop

.....*Polytrichum juniperinum*
37. Plants grow in beautiful glossy yellow-green mats with stems pinnately branched and arching upwards to look like little plumes. The 2-3 mm leaves are falcate-secund (asymmetric with leaf tips pointing down) to almost bent into a circle. These leaves are plicate with a double costa which is sometimes hard to see with all the leaf folds

.....*Ptilium crista-castrensis*
38. It is a creeping moss that forms dense mats of branching stems. There are two rows of lateral leaves with near parallel sides and two rows of triangular dorsal leaves. The capsule stalk is slender and the calyptra covering is only faintly hairy

.....*Racopilum cuspidigerum var. convolutaceum*
39. Plant forms low patches (smooth mats) in unshaded or lightly shaded but avoid driest places. Branches are irregular, leaves are spreading and pointed

.....*Rhynchostegium megapolinatum*
40. It forms irregularly branching, creeping stems with widely spreading leaves somewhat flattened into one plane. Leaf margins are toothed with a tapering tip and a vein that extends beyond half way but fails before the leaf tip. The seta is smooth and the capsule lid has a long beak

.....*Rhynchostegium tenuifolium*
41. Slender and weak-stemmed moss, moderate-sized, growing in green dense colonies, feather-like, stem leaves triangular, acute to round at apex, branch leaves narrowly ovate-lanceolate, often slightly toothed and inrolled near apex. It generally grows very slowly

.....*Sphagnum cuspidatum*
42. Plant medium-sized, greyish-green, glossy, in low mats. Main stem creeping, terminal branches gradually becoming slender; rhizoids reddish. Leaves erect, ovate-lanceolate, concave, narrowly acuminate, becoming cuspidate. Leaf margin, almost entire; costae short, forked. Inner perichaetial leaves similar to vegetative leaves in shape, but straight. Setae erect, long; capsule erect or curved, ovoid to cylindrical, operculum small and conical

.....*Struckia argentata*
43. Plants in thin to dense mat, dark green to yellowish. Stems complanate-foliate; rarely radiculose ventrally. Leaves wide spreading to squarrose, ovate - or oblong - lanceolate, rarely narrowly ovate, symmetric or nearly so; margins very narrowly recurved almost to apex, serrulate throughout; apex acuminate, not twisted; costa double and short. Seta reddish, capsule reddish and oblong-ovoid

.....*Taxiphyllum taxirameum*
44. Plants form loose mats of compound leaves that are green to yellowish green. The central stems of these are densely covered with narrow scale-like

leaves; larger stem leaves are broadly ovate to triangular in shape. The midribs of these leaves extend nearly to their tips. Primary branches radiate from central stem becoming shorter as they approach the tip. Secondary branches radiate from each primary branch; leaves of both primary and secondary are different in size. Stalk with spore-bearing capsules are produced from the leaves of the plant, cylindrical, operculum present with calyptras

.....*Thuidium delicatulum*

45. The plant forms bright yellow-green fern-like shoots. They are usually tri-pinnately branched and form mats across the area. It grows in woodlands, grassland and in damp places

.....*Thuidium tamariscinum*

It was also observed that most of the mosses wet, moist, and semi-shaded area in association with other mosses. Mosses that were collected were mainly corticolous and were seen to be grown on barks of the angiospermic trees.

List of mosses along with their habitat and associated plants in Fambonglho Wildlife Sanctuary

Sl. No	Name of the plant	Family	Habitat	Distribution	Associated Plants	Reference
1	<i>Anomodon minor</i> (Hedwig) Lindberg	Anomodontaceae	Calcareous rock and bark of tree	Fambonglho	It was seen to be grown alone.	Dandotiya <i>et al</i> , 2011; Ralph Pope, 2016
2	<i>Atrichum undulatum</i> (Hedw.) P. Beauv.	Polytrichaceae	Soil, road side ditches	Fambonglho	Liverworts: <i>Marchantia linearis</i> Lehm. & Lindenb. Moss: <i>Bryum capillare</i> Hedw. <i>Leucobryum sanctum</i> Hampe. <i>Polytrichum juniperinum</i> Hedw. Angiosperm: <i>Houttuynia cordata</i> Thunb.	Ralph Pope, 2016; Dandotiya <i>et al</i> , 2011.
3	<i>Barbula constricta</i> Mitt.	Pottiaceae	Rocks, thin soil over rocks, cliffs in shade or near streams	Fambonglho	It was seen to be grown alone.	Dandotiya <i>et al</i> , 2011.
4	<i>Brachythecium rivulare</i> W.P.Schimper	Brachytheciaceae	Wet soils, Streamsides Damp rock Decaying woods, edge of the road	Fambonglho	Moss: <i>Brachythecium plumosum</i> (Hedw.) Schimp. <i>Neckera crenulata</i> Hedw. <i>Octoblepharum albidum</i> Hedw. <i>Polytrichum commune</i> Hedw.	Ralph Pope, 2016; Barukial Jayanta, 2011
5	<i>Brachythecium plumosum</i> (Hedw.) Schimp.	Brachytheciaceae	Wet soils, Stream sides Damp rock Decaying	Fambonglho	Moss: <i>Brachythecium rivulare</i> W.P.Schimper	Dandotiya <i>et al</i> , 2011

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			woods, edge of the road		Angiosperm: <i>Commelina benghalensis</i> L. <i>Galinsoga parviflora</i> Cav.	
6	<i>Bryum argenteum</i> Hedw.	Bryaceae	Poor soil and rocks, cemented walls and rocks	Fambonglho	It was seen to be grown alone.	Dandotiya <i>et al.</i> , 2011; Savaroglu <i>et al.</i> , 2006; Ralph Pope, 2016.
7	<i>Bryum capillare</i> Hedw.	Bryaceae	Woodland, soil bank, tree, log, walls, roofs and rocks	Fambonglho	Moss: <i>Entodon macropodus</i> (Hedw.) Mull. Hal, <i>Bryum coronatum</i> Schwagr. <i>Leucodon julaceus</i> (Hedw.) Sull.	Barukial 2011; Dandotiya <i>et al.</i> , 2011; Savaroglu <i>et al.</i> , 2006.
8	<i>Bryum coronatum</i> Schwagr.	Bryaceae	Calcareous Soils or wall Rocks	Fambonglho	Moss: <i>Entodon macropodus</i> (Hedw.) Mull. Hal, <i>Bryum capillare</i> Hedw., <i>Leucodon julaceus</i> (Hedw.) Sull.	Barukial 2011; Bansal <i>et al.</i> , 2012; Dandotiya <i>et al.</i> , 2011; Savaroglu <i>et al.</i> , 2006.
9	<i>Campylopus gracilis</i> Jaeger	Dicranaceae	Wet soil, soil covered rocks, wet cliffs in boggy slopes	Fambonglho	<i>Ptilium crista-castrensis</i> (Hedw.) De Not.	Dandotiya <i>et al.</i> , 2011.
10	<i>Dicranum undulatum</i> Brid.	Dicranaceae	Tree trunk, bark, log	Fambonglho	It was seen to be grown alone.	Dandotiya <i>et al.</i> , 2011; Ralph Pope, 2016.
11	<i>Distichium capillare</i> (Hedw.) Bruch & Schimp.	Districhaceae	Moist soil, tree, roadsides, grassland	Fambonglho	Moss: <i>Atrichum undulatum</i> (Hedw.) P. Beauv., <i>Entodon flavescens</i> (Hook.) A. Jaeger	Dandotiya <i>et al.</i> , 2011; Savaroglu <i>et al.</i> , 2006.
12	<i>Entodon flavescens</i> (Hook.) A. Jaeger	Entodontaceae	Rocks, logs	Fambonglho	It was growing alone in the area.	Dandotiya <i>et al.</i> , 2011; Zhu <i>et al.</i> , 2016.
13	<i>Entodon macropodus</i> (Hedw.) Mull. Hal.	Entodontaceae	Rocks, logs, tree, soil	Fambonglho	Moss: <i>Bryum capillare</i> Hedw., <i>Octoblepharum albidum</i> Hedw.	Dandotiya <i>et al.</i> , 2011; Zhu <i>et al.</i> , 2016.
14	<i>Entodon seductrix</i> (Hedw.) Mull. Hal.	Entodontaceae	Rocks, logs, Tree base, barks	Fambonglho	Moss: <i>Octoblepharum albidum</i> Hedw.	Dandotiya <i>et al.</i> , 2011; Ralph 2016; Zhu <i>et al.</i> , 2016.
15	<i>Fissidens javanicus</i> Dozy & Molkenboer.	Fissidentaceae	Moist soil and rocks	Fambonglho	It was growing alone in the area.	Dandotiya <i>et al.</i> , 2011
16	<i>Floribundaria</i>	Meteoriaceae	Tree	Fambonglho	<i>Haplocladium</i>	Dandotiya <i>et al.</i> ,

	<i>floribunda</i> (Dozy & Molk) M. Fleisch.	ae			<i>microphyllum</i> (Hedw.) Broth.	2011
17	<i>Haplocladium microphyllum</i> (Hedw.) Broth.	Thuidiaceae	Tree trunk, bark, log	Fambonglho	<i>Floribundaria floribunda</i> (Dozy & Molk) M. Fleisch.	Dandotiya <i>et al.</i> , 2011 Ralph Pope, 2016
18	<i>Hedwigia ciliata</i> (Hedw.) P.Beauv.	Hedwigiaceae	Tree trunk, rock	Fambonglho	Moss: <i>Octoblepharum Albidum</i> Hedw., <i>Neckera crenulata</i> Hedw.	Dandotiya <i>et al.</i> , 2011 Efrain, De L., 2022
19	<i>Homaliodendron flabellatum</i> Fleischer	Neckeraceae	On rocky patches near stream, bark and branches of trees	Fambonglho	<i>Ptilium cristata-</i> <i>castrensis</i> (Hedw.) De Not.	Dandotiya <i>et al.</i> , 2011
20	<i>Homalothecium sericeum</i> W.P. Schimper	Brachytheciaceae	Rocks, logs, tree, soil	Fambonglho	It was seen to be grown alone.	Dandotiya <i>et al.</i> , 2011
21	<i>Hylocomium splendens</i> (Hedw.) Schimp.	Hylocomiaceae	Rocks, logs, tree, soil	Fambonglho	<i>Isopterygium albescens</i> (Hook.) A. Jaeger	Dandotiya <i>et al.</i> , 2011 Ralph 2016
22	<i>Hypnum cupressiforme</i> Hedw.	Hypnaceae	Tree trunk, rocks, logs	Fambonglho	It was seen to be grown alone.	Barukial Jayanta, 2011; Ralph 2016; Tewari and Pant, 1994.
23	<i>Isopterygium albescens</i> (Hook.) A. Jaeger	Hypnaceae	Rocks, logs, tree, soil	Fambonglho	<i>Hylocomium splendens</i> (Hedw.) Schimp., <i>Rhynchostegium megapolinatum</i> W.P. Schimper	Dandotiya <i>et al.</i> , 2011
24	<i>Isothecium myosuroides</i> Brid	Lembophyllaceae	Tree trunk, bark, log	Fambonglho	It was grown alone.	Dandotiya <i>et al.</i> , 2011.
25	<i>Leucobryum javense</i> (Brid.) Mitten.	Leucobryaceae	Soil, rocks, tree trunks	Fambonglho	Moss: <i>Octoblepharum albidum</i> Hedw. Fern: <i>Selaginella kraussiana</i> (Kunze) A. Braun. Angiosperms: <i>Dioscorea bulbifera</i> L.	Dandotiya <i>et al.</i> , 2011; Laha, R <i>et al.</i> , 2013; Tewari & Pant, 1994.
26	<i>Leucobryum juniperoideum</i> (Brid.) Mull. Hal.	Leucobryaceae	Tree, rocks	Fambonglho	Moss: <i>Octoblepharum albidum</i> Hedw.	Dandotiya <i>et al.</i> , 2011; Tewari & Pant, 1994.
27	<i>Leucobryum sanctum</i> (Nees. ex Schwagr.) Hampe	Leucobryaceae	Soil, rock, tree	Fambonglho	Moss: <i>Octoblepharum albidum</i> Hedw., <i>Entodon macropodus</i> (Hedw.) Mull. Hal.	Dandotiya <i>et al.</i> , 2011; Tewari and Pant, 1994.
28	<i>Leucodon julaceus</i>	Leucodoneae	Bark, logs, rarely on	Fambonglho	Moss: <i>Octoblepharum</i>	Dandotiya <i>et al.</i> , 2011;

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	(Hedw.) Sull.		rocks		<i>albidum</i> Hedw.	Stech <i>et al.</i> , 2011.
29	<i>Mnium hornum</i> Hedw.	Mniaceae	Roots and tree trunks, rocks	Fambonglho	Moss: <i>Hedwigia ciliata</i> (Hedw.) P.Beauv.	Dandotiya <i>et al.</i> , 2011; Ralph Pope, 2016.
30	<i>Neckera crenulata</i> Harvey.	Neckeraceae	Tree barks	Fambonglho	Moss: <i>Hedwigia ciliata</i> (Hedw.) P.Beauv., <i>Brachythecium rivulare</i> W.P.Schimper.	Dandotiya <i>et al.</i> , 2011.
31	<i>Octoblepharum albidum</i> Hedw.	Octoblepharaceae	Tree	Fambonglho	Moss: <i>Brachythecium rivulare</i> W.P.Schimper, <i>Leucodon julaceus</i> (Hedw.) Sull., <i>Leucobryum sanctum</i> (Nees. ex Schwagr.) Hampe., <i>Haplocladium microphyllum</i> (Hedw.) Broth., <i>Hedwigia ciliata</i> (Hedw.) P.Beauv., <i>Entodon macropodus</i> (Hedw.) Mull. Hal.	Barukial, 2011; Dandotiya <i>et al.</i> , 2011; Silva-Maciel <i>et al.</i> , 2013.
32	<i>Oxystegus cylindricus</i> (Brid.) Hilp.	Pottiaceae	Rocky patches	Fambonglho	It was growing alone	Dandotiya <i>et al.</i> , 2011.
33	<i>Pogonatum alloides</i> (Hedw.) P. Beauv.	Polytrichaceae	Sandy wet soil, rocks	Fambonglho	Angiosperm: <i>Ageratum conyzoides</i> L., <i>Persicaria nepalensis</i> (Meisn.) H.Gross.	Barukial Jayanta, 2011; Ralph 2016.
34	<i>Polytrichum commune</i> Hedw.	Polytrichaceae	Soil over rock, marshy places	Fambonglho	Liverworts: <i>Doumortiera hirsuta</i> (Sw.) Nees, <i>Marchantia polymorpha</i> L. <i>Marchantia linearis</i> Lehm. & Lindenb, <i>Plagiochasma appendiculatum</i> Lehm. & Lindenb, Angiosperm: <i>Cynodon dactylon</i> (L.) Pers.	Dandotiya <i>et al.</i> , 2011; Ralph 2016; Popov, 2018.
35	<i>Polytrichum juniperinum</i> Hedw.	Polytrichaceae	Soil over rock, marshy places	Fambonglho	It was growing alone	Dandotiya <i>et al.</i> , 2011; Ralph 2016; Popov, 2018.
36	<i>Ptilium crista-castrensis</i> (Hedw.) De Not.	Pylaisiaceae	Soil over rock, marshy places	Fambonglho	<i>Thuidium tamariscinum</i> W.P.Schimper, <i>Racopilum cuspidigerum</i> var	Dandotiya <i>et al.</i> , 2011; Ralph Pope, 2016.

					<i>convolutaceum</i> (Schwagr.) Angstrom.	
37	<i>Racopilum</i> <i>cuspidigerum</i> var <i>convolutaceum</i> (Schwagr.) Angstrom.	Racopilacea e	Soil over rock, marshy places	Fambonglho	<i>Leucobryum</i> <i>sanctum</i> (Nees. ex Schwagr.) Hampe, <i>Ptilium</i> <i>crista-</i> <i>castrensis</i> (Hedw.) De Not.	Dandotiya <i>et al.</i> , 2011.
38	<i>Rhynchostegi</i> <i>m</i> <i>megapolinatum</i> W.P.Schimper	Brachytheci aceae	Wet and moist soil, tree, and rocks	Fambonglho	<i>Isopterygium</i> <i>albescens</i> (Hook.) A. Jaeger	Dandotiya <i>et al.</i> , 2011.
39	<i>Rhynchostegi</i> <i>m tenuifolium</i> Reichardt.	Brachytheci aceae	Tree trunk, bark, log	Fambonglho	It was seen to be grown alone	Dandotiya <i>et al.</i> , 2011.
40	<i>Sphagnum</i> <i>cuspidatum</i> Ehrh. ex. Hoffm.	Sphagnacea e	Wet humus, base of tree near bogs	Fambonglho	It was grown alone	Dandotiya <i>et al.</i> , 2011; Ralph 2016.
41	<i>Struckia</i> <i>argentata</i> C. Muller	Plagiothecia ceae	Wet soil, tree barks	Fambonglho	It was grown alone	Dandotiya <i>et al.</i> , 2011.
42	<i>Taxiphyllum</i> <i>taxirameum</i> (Mitt.) M. Fleisch.	Hypnaceae	Tree bark	Fambonglho	It was grown alone	Dandotiya <i>et al.</i> , 2011
43	<i>Thuidium</i> <i>delicatulum</i> (Hedw.) Schimp.	Thuidiacea e	Tree trunk, bark, log	Fambonglho	It was grown alone	Dandotiya <i>et al.</i> , 2011; Ralph Pope, 2016.
44	<i>Thuidium</i> <i>tamariscinum</i> W.P.Schimper.	Thuidiacea e	Wet and moist soil, tree, and barks	Fambonglho	<i>Ptilium</i> <i>crista-</i> <i>castrensis</i> (Hedw.) De Not.	Dandotiya <i>et al.</i> , 2011.

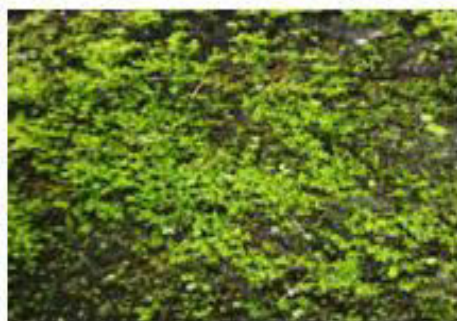
4. Some photo plates of mosses studied in the Fambonglho Wildlife Sanctuary



Anomodon minor (Hedwig) Lindberg



Atrichum undulatum (Hedw.) P. Beauv.



Barbula constricta Mitt.



Brachythecium rivulare W.P.Schimper



Brachythecium plumosum (Hedw.) Schimp.



Bryum argenteum Hedw.



Bryum capillare Hedw.



Bryum coronatum Schwagr.



Campylopus gracilis Jaeger.



Dicranum undulatum Brid.



Distichium capillare (Hedw.) Bruch & Schimp.



Entodon macropodus (Hedw.) Mull. Hal.



Entodon seductrix (Hedw.) Mull. Hal.



Fissidens javanicus Dozy & Molkenboer.



Floribundaria floribunda (Dozy & Molk.) M.



Hylacomium splendens (Hedw.) Schimp.



Leucobryum javense (Brid.) Mitten



Leucobryum juniperoides (Brid.) Mull. Hal.



Leucobryum sanctum (Nees ex. Schwagr.) Hampe



Leucodon julaceus (Hedw.) Sull



Neckera crenulata Harvey.



Octoblepharum albidum Hedw.



Polytrichum commune Hedw.



Pttilium crista-castrensis (Hedw.) De Not.



Racopilum cuspidigerum var *convolutaceum* (Schwagr.) Angstrom



Thuidium delicatulum (Hedw.) Schimp.

CONCLUSION

Sikkim Himalayan region exhibits one of the richest angiosperm diversity in the country and it is equally rich in bryophytes diversity. Among the members in plant kingdom, bryophytes are more sensitive to external environment and they act as an indicator of climate change. However, their occurrence and importance has not been clearly appreciated yet, may be due to limited studies about them. Basic data on mosses presented in this paper will serve as a baseline data which may encourage further studies aiming various aspects including bio-monitoring characteristics, phyto-chemical analysis and their conservation.

ACKNOWLEDGEMENT

Authors are thankful to the Head of the Department of Botany for encouragement and necessary support. Support from DST, India under DST-FIST programme (No. SR/FST/LSI-658/2016 (c)) is acknowledged.

REFERENCE

- Bansal, P. and Nath, V. 2012. A New Record of *Bryum coronatum* Schwaegr. (Bryophyte) in Meghalaya, India *Taiwania* 57(3): 294-299.
- Barukial, J. 2011. A study of moss diversity in Assam Valley Wet Evergreen Forests. *Indian Journal of Fundamental and Applied Science* 1(4): 3-7, ISSN: 2231-6345.
- Basilier, K. 1979. Moss-associated nitrogen fixation in some mire and coniferous forest environments around Uppasala, Sweden. *Lindbergia* 5: 84-88.
- Dandotiya, D., Govindapuri, H., Sumian, S. and Uniyal, L.P. 2011. Checklist of the bryophytes of India. *Archieve for Bryology* 88: 2-82. ISSN: 0945-3466.
- Engler, H.G.A and Prantl, K. 1907. *Haplocladium microphyllum* (Hedwig) Brotherus in Nat, Pflanzenfam. *Atlas of Florida Plants*, Institute for Systematic Botany.
- Gerson, U. 1982. Bryophytes and invertebrates. In: Smith, A.J.E. (eds) *Bryophyte Ecology*. Springer, Dordrecht. DOI: 10.1007/978-94-009-5891-3-9.
- Glime, J. M. 2017. Ecophysiology of development: Fragments. Chapter 5-6. *Bryophyte Ecology*, Vol. 1.
- Hallingback, T. and Tan, C.B. 2010. Past and Present activities and future strategy of bryophytes conservation. *Phytotaxa* 9: 266-274.

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- Harold, E.R. 1968. Notes on bryophytes from the Himalayas and Assam. *Bryologist*, 71 (2). DOI: 10.1639/0007.
- Klavina, L. 2018. Composition of mosses, their metabolites and environmental stress impacts. Gunta Springe, University of Latvia. ISBN: 978-9934-18-321-8.
- Kuusinen, M. and Penttinen, A. 1999. Spatial Pattern of the Threatened Epiphytic Bryophyte *Neckera pennata* at Two Scales in a Fragmented Boreal Forest. *Ecography* 22 (6): 729-735.
- Laha, R. and Lalhriatpuia. 2013. Diversity of Bryophytes in Aizawl District, Mizoram, Northeast India. *International Journal of Science and Research* 4(4): 1654-1655. ISSN: 2319-7064.
- Mao, L.H., Li, Y., Liu, C. and Fang, M.Y. 2017. Prediction of potential distribution of *Haplocladium macrophyllum* in China based on MaxENT model. *Chinese Journal of Ecology* 36 (1): 54-60.
- Pope, R. 2016. *Mosses, Liverworts, and Hornwort: A field guide to common Bryophytes of the Northeast*. Cornell University Press. ISBN: 9781501700781.
- Popov, Y.S. 2018. Distribution pattern of seven *Polytrichum* species in the East European Plain and Eastern Fennoscandia. *Botanica Pacifica. A Journal of Plant Science and Conservation* 7(1): 25-40.
- Robinson, E.H. 2019. Notes on Bryophytes from the Himalaya and Assam. *American Bryological and Lichenological Society* 71(2): 25-40.
- Savaroglu, F., Erkara, P.I., Baycu, C. and Alkan, M. 2006. Spore Morphology of Some Bryaceae Schwagr. Species (Bryaceae). *International Journal of Natural and Engineering Sciences* 1(2): 49-54.
- Shaw, J & Renzaglia, K. 2004. Phylogeny and diversification of bryophytes. *Am J Bot.* 91(10): 1557-81. DOI: 10.3732/ajb.91.10.1557.
- Silva-Maciel, S.M., Coelho, P.L.M., and Porto, C.K. 2013. Reproductive traits in the tropical moss *Octoblepharum albidum* Hedw. Differ between rainforest and coastal sites. *Journal of Bryology* 35(3):206-215.
- Singh, D.K., Singh, S.K., and Singh D. 2016. *Liverworts and Hornworts of India. An Annotated Checklist by Botanical Survey of India*, Ministry of Environment Science, Forests & Climate Change, ISBN: 81-8177-088-9.
- Singh, D.K. & Hajra, P.K. 1996. *Plants of Indian Himalayan Region (An Annotated Checklist and Pictorial guide)*. Botanical Survey of India, Kolkata.
- Stech, M., Werner, O., Mancebo-G., Maria J., Patino, J., Sim-Sim, M., Fontinha, S., Hildebrandt, I., Ros M., R. 2011. Phylogenetic inference in *Leucodon* Schwagr. Subg. *Leucodon* (Leucodontaceae, Bryophyta) in the North Atlantic region. *Taxon* 60(1): 79-88.
- Tewari, D.S. and Pant, G. 2002. *Bryophytes of Kumaon Himalaya*. Bishen Singh, Mahendra Pal Singh, Dehradun. ISBN: 978-8121101189.
- Zhu, Y., Buck, R.W. and Wang, Y. 2016. A revision of *Entodon* (Entodontaceae) in East Asia. School of Life Science. East China Normal University, Shanghai, 20062, China. *The Bryologist* 113(3): 516-589.